

GEOPHYSICAL SURVEY REPORT

STRATASCAN™



Project name:
Cranbrook Street, Nottingham

Client:
Scott Lomax

June 2015

Job ref:
J8242

Report author:
Thomas Richardson MSc ACIfA

GEOPHYSICAL SURVEY REPORT

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Cranbrook Street, Nottingham

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Job ref:

J8242

Techniques:

Ground Penetrating Radar

Survey date:

18th-19th May 2015

Site centred at:

SK 577 400

Post code:

NG1 1ER

Field team:

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1 SUMMARY OF RESULTS

A Ground Probing Radar survey was conducted over a 105m x 15m stretch along the carriageway and footway of Cranbrook Street, Nottingham. The survey has not identified any anomalies related to the Norman defensive ditch or any other archaeological features. This is likely due to the depth of these anomalies and the strong response caused by modern urban activity in the area. The anomalies detected are likely to relate to the construction of the footways and carriageway, as well as a number of possible basements and services.

2 INTRODUCTION

2.1 *Background synopsis*

Stratascan were commissioned to undertake a ground penetrating radar survey with the aim of identifying a former boundary ditch, cave systems, and any other potential archaeology. This survey forms part of an archaeological investigation being undertaken by Scott Lomax, funded by English Heritage.

2.2 *Site location*

The site is located on Cranbrook Street, in the centre of Nottingham, Nottinghamshire at OS ref. SK 577 400.

2.3 *Description of site*

The survey covers a 105m x 15m area of carriageway and footway. There were no obstructions to the survey area.

2.4 *Geology and soils*

The underlying geology is Nottingham Castle Sandstone Formation – Sandstone, Pebbly (gravelly) (British Geological Survey website). There is no recorded drift geology (British Geological Survey website).

The overlying soils are not surveyed due to the urban environment of the site (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

2.5 *Site history and archaeological potential*

The following is based on Lomax, S. 2015, *Brief for Ground Penetrating Radar at Cranbrook Street, Nottingham*,

A 1970 excavation at nearby Woolpack Lane, combined with documentary evidence from 1751 suggest a Norman defensive boundary ditch runs along Cranbrook Street. The excavation at Woolpack Lane identified the ditch to have a V shaped profile, and be approximately 6m wide and 3.35m deep. Excavations at Cranbrook House and 1 Hockley (on the corner of Cranbrook Street) have failed to locate the ditch. It is therefore thought that the ditch lies beneath Cranbrook Street itself.

There are also four manmade cave systems, of probable medieval and post-medieval date, recorded beneath properties fronting the survey area. Although these caves are recorded, it is not known whether they encroach into the survey area. There is therefore some potential for known and unknown cave systems in the area (Lomax 2015).

2.6 **Survey objectives**

The objective of the survey was primarily to locate the ditch and cave systems and any potential archaeological features in the survey area prior to development.

2.7 **Survey methods**

This report and all fieldwork have been conducted in accordance with both the English Heritage guidelines outlined in the document: *Geophysical Survey in Archaeological Field Evaluation, 2008* and with the Institute for Archaeologists document *Standard and Guidance for Archaeological Geophysical Survey*.

Due to the urban environment of the site ground penetrating radar (GPR) was selected as the most suitable methodology for this survey. An initial trial was carried out using 200MHz and 400MHz antennae. The antenna which gave the best compromise between the depth of penetration and resolution was selected for the main survey. More information regarding this technique is included in Appendix A.

2.8 **Processing, presentation and interpretation of results**

2.8.1 **Processing**

Manual abstraction

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 in order 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.

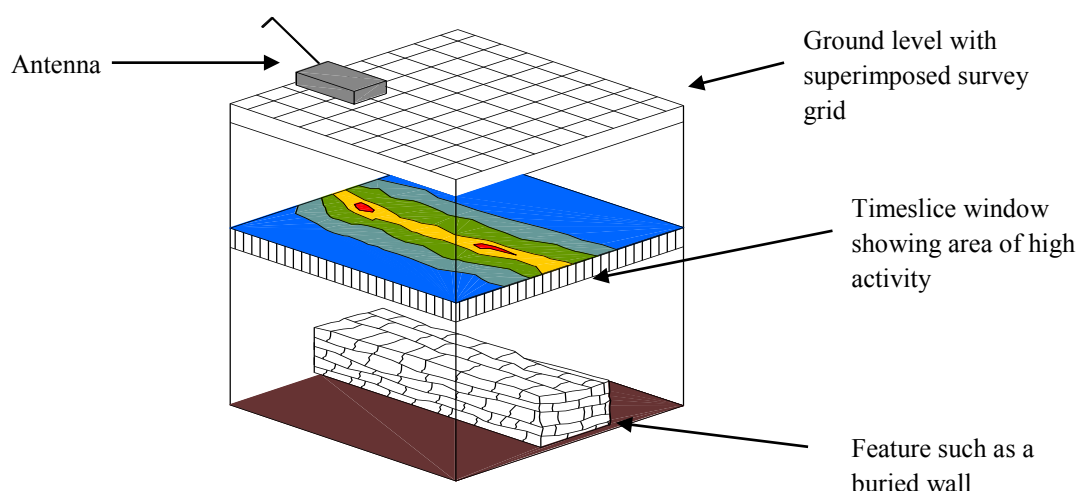
vii. Conductive surface.

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.

viii. 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, red and white.

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.

3 RESULTS

Following the initial trial the 200MHz antenna was selected because it gave greater penetration depth and therefore had more potential to locate deeply stratified urban deposits.

The survey at Cranbrook Street has not identified any anomalies of archaeological origin. A number of discrete and complex anomalies can be seen along the footways between depths of 0.5-1.6m. These anomalies are indicative of buried obstructions and may relate to the construction of the footways or possibly basements extending from the adjacent properties. Two area anomalies, one in the north of the area and one in the south, can be seen in the timeslices of the data. These are indicative of areas of disturbance caused by the construction

of the carriageway. The timeslices of the data also show a linear anomaly running across the centre of the site. This is indicative of a buried service.

4 REVIEW OF DATA

The data at Cranbrook Street generally has a strong background response, particularly in the upper 0.5m, as would be expected given the amount of development in an urban area. Whilst sandstone geologies are generally conducive to radar surveys, the amount of modern activity in the area (construction of the carriage way) can have the effect of attenuating the radar energy and reducing the effective depth of the survey. It is likely that this is the case for this survey, with the effective depth penetration reduced to approximately 2.5m. The reduced depth penetration combined with the strong background response from modern activity makes it unlikely that subtler archaeological anomalies will be detected.

5 CONCLUSION

The survey at Cranbrook Street has not identified any anomalies related to the Norman defensive ditch or any other archaeological features. This is likely due to the depth of these anomalies and the strong response caused by modern urban activity in the area. The anomalies detected are likely to relate to the construction of the footways and possible basements beneath, and the carriageway. Areas of disturbance running along the centre of the street are likely to relate to buried services, whilst a further service has been detected running across Cranbrook Street from the corner of Lennox Street.

6 REFERENCES

British Geological Survey South Sheet, 1977. *Geological Survey Ten Mile Map, South Sheet First Edition (Quaternary)*. Institute of Geological Sciences.

British Geological Survey, 2001. *Geological Survey Ten Mile Map, South Sheet, Fourth Edition (Solid)*. British Geological Society.

British Geological Survey, n.d., *website*:
(<http://www.bgs.ac.uk/opengeoscience/home.html?Accordion1=1#maps>) Geology of Britain viewer.

Lomax, S., 2015. *Brief for Ground Penetrating Radar at Cranbrook Street, Nottingham*

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 6 South East England*.

English Heritage, 2008. *Geophysical Survey in Archaeological Field Evaluation*.

Institute For Archaeologists. *Standard and Guidance for Archaeological Geophysical Survey*.
<http://www.archaeologists.net/sites/default/files/nodefiles/Geophysics2010.pdf>

APPENDIX A – METHODOLOGY & SURVEY EQUIPMENT

Grid locations

The location of the survey traverses has been plotted in Figure 2 together with the referencing information. Traverses were carried out perpendicular to the expected course of the medieval ditch. Traverses were set out using a Trimble GPS system.

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 a Dual Frequency system manufactured by Geophysical Survey Systems Inc. (GSSI).

The radar survey was carried out with a SIR 3000 GPR system utilising a 200MHz antenna. 0.5m parallel traverses were used to record the data.

Sampling interval

Readings were taken at 0.05m intervals with traverse intervals of 0.5m. 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 was determined by hyperbola fitting and calculated to be 0.08m/ns which is marginally slower than 0.11m/ns that is normally found in sandstone. With a range setting of 100nsec this equates to a maximum depth of scan of 4.0m but it must be remembered that this figure could vary by $\pm 10\%$ or more. However looking at the radargrams the reflected signal drops away and the noise level notably increases around 2.0 to 2.5m in depth.

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.

Processing

The radar plots included in this report have been produced from the recorded data using Radan software. Filters were applied to the data to remove background noise.

Horizontal parameters:

Scans/sec	64
Scans/metre	20

Vertical parameters:

Samples/scan	512
Bits/sample	16
Dielectric constant	13.88

Processing history:

a) Range gain applied on site (successive 20ns windows)

Gain 1	-16.00
Gain 2	4.00
Gain 3	48.00
Gain 4	52.00
Gain 5	56.00

b) Position correction (ns) -4.63

c) IIR Filters

Vertical (MHz)

Low Pass	600
High Pass	50

Horizontal (Scans)

Low Pass	3
----------	---

d) Background Removal Full Pass

e) FIR Filters BOXCAR

Vertical (MHz)	Low Pass 410
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f) Migration applied to all data sets

Width	63
Velocity (Top Layer)	0.080

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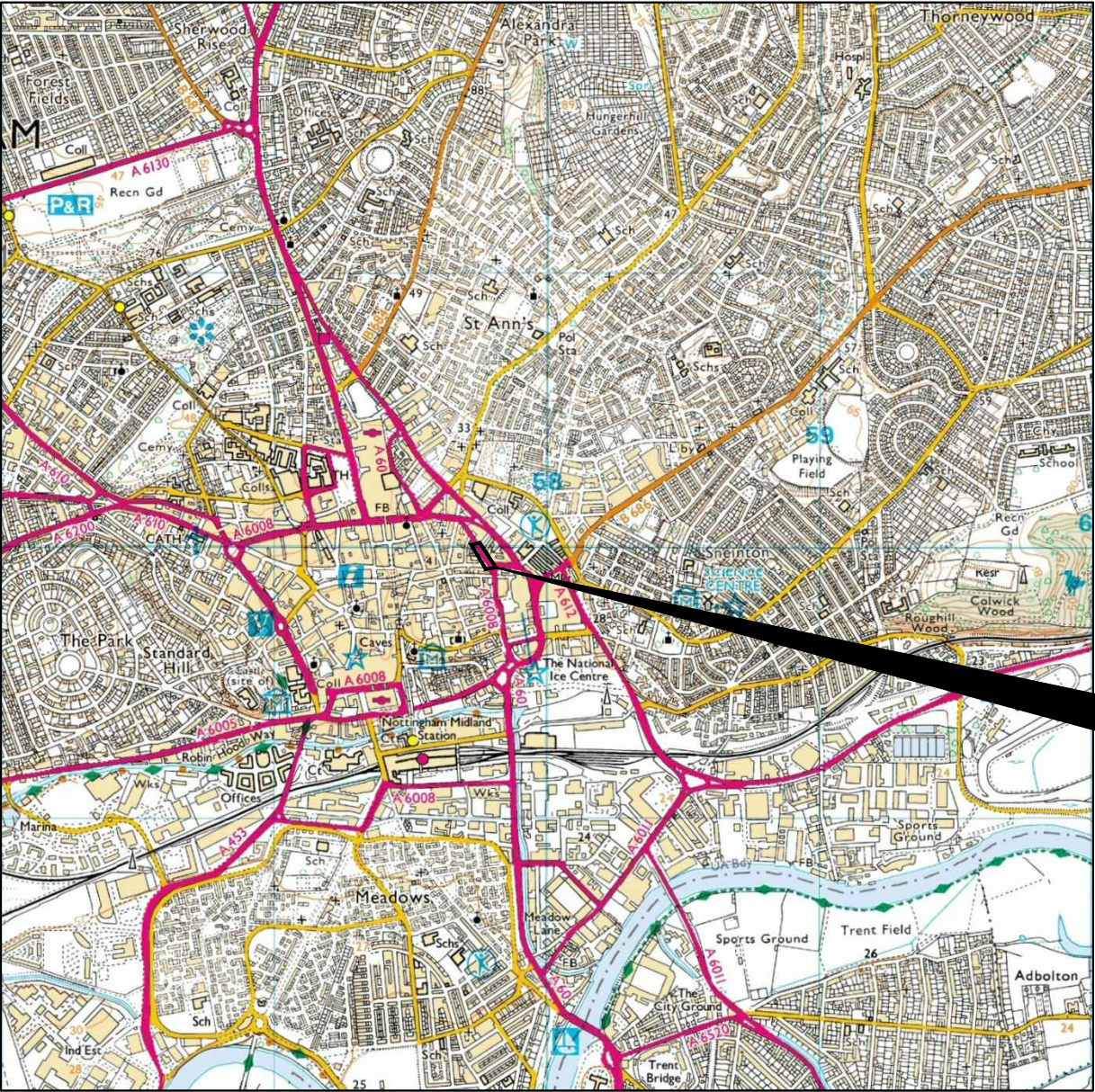
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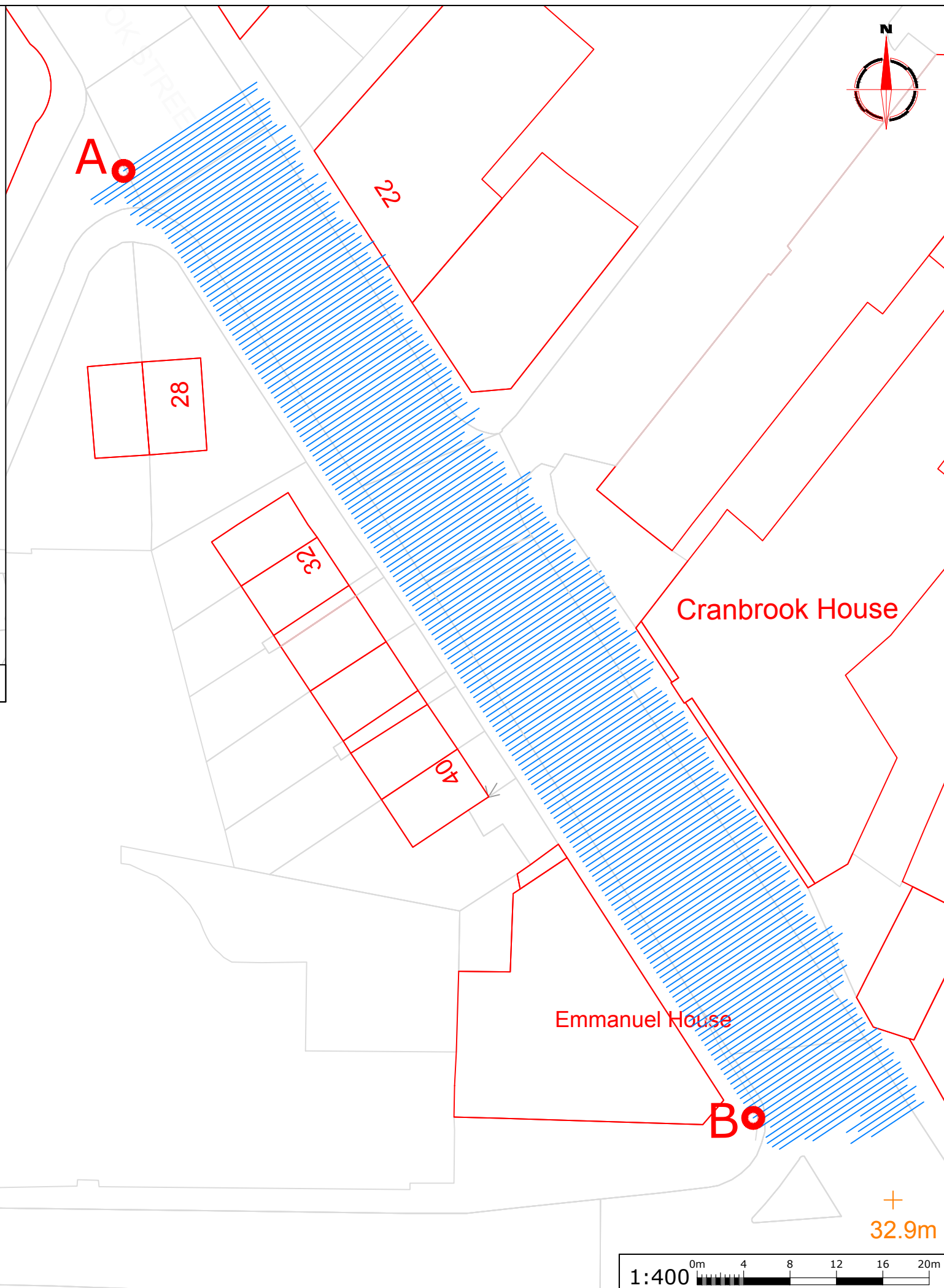
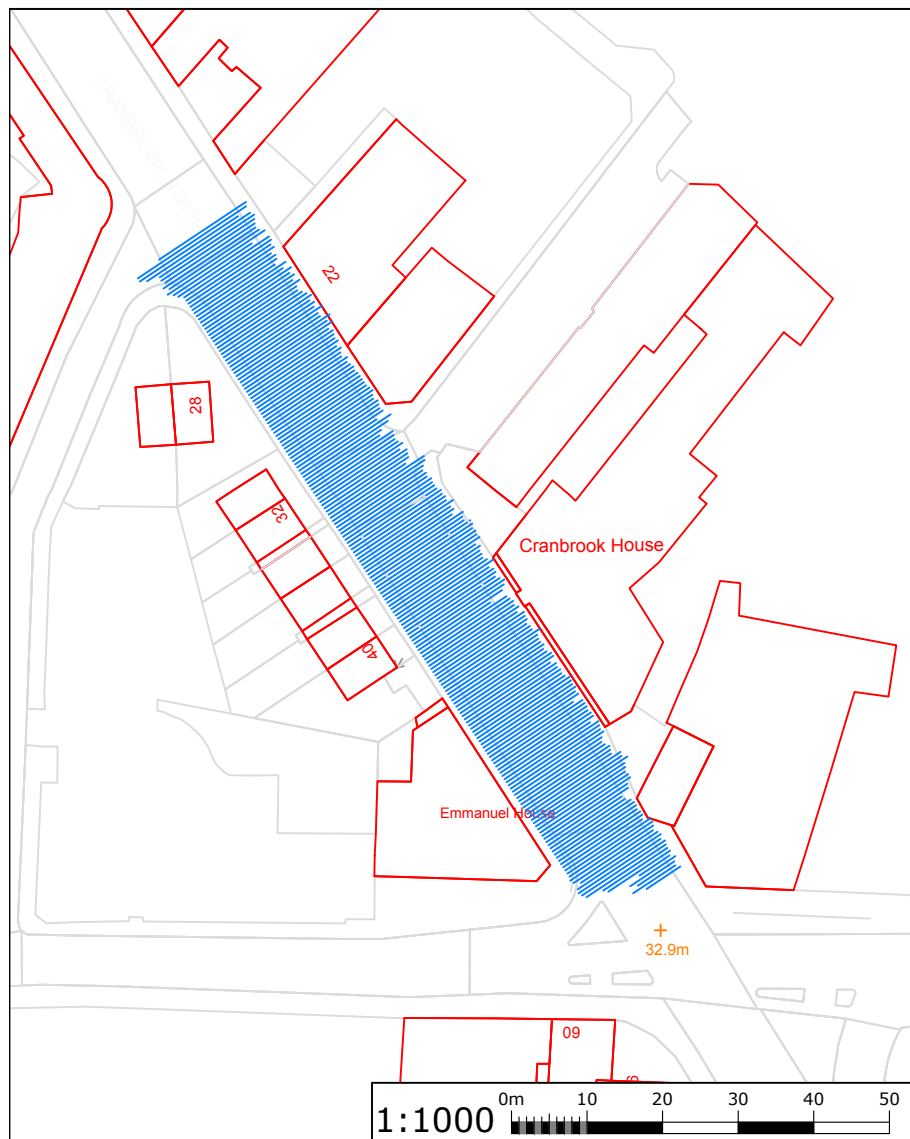
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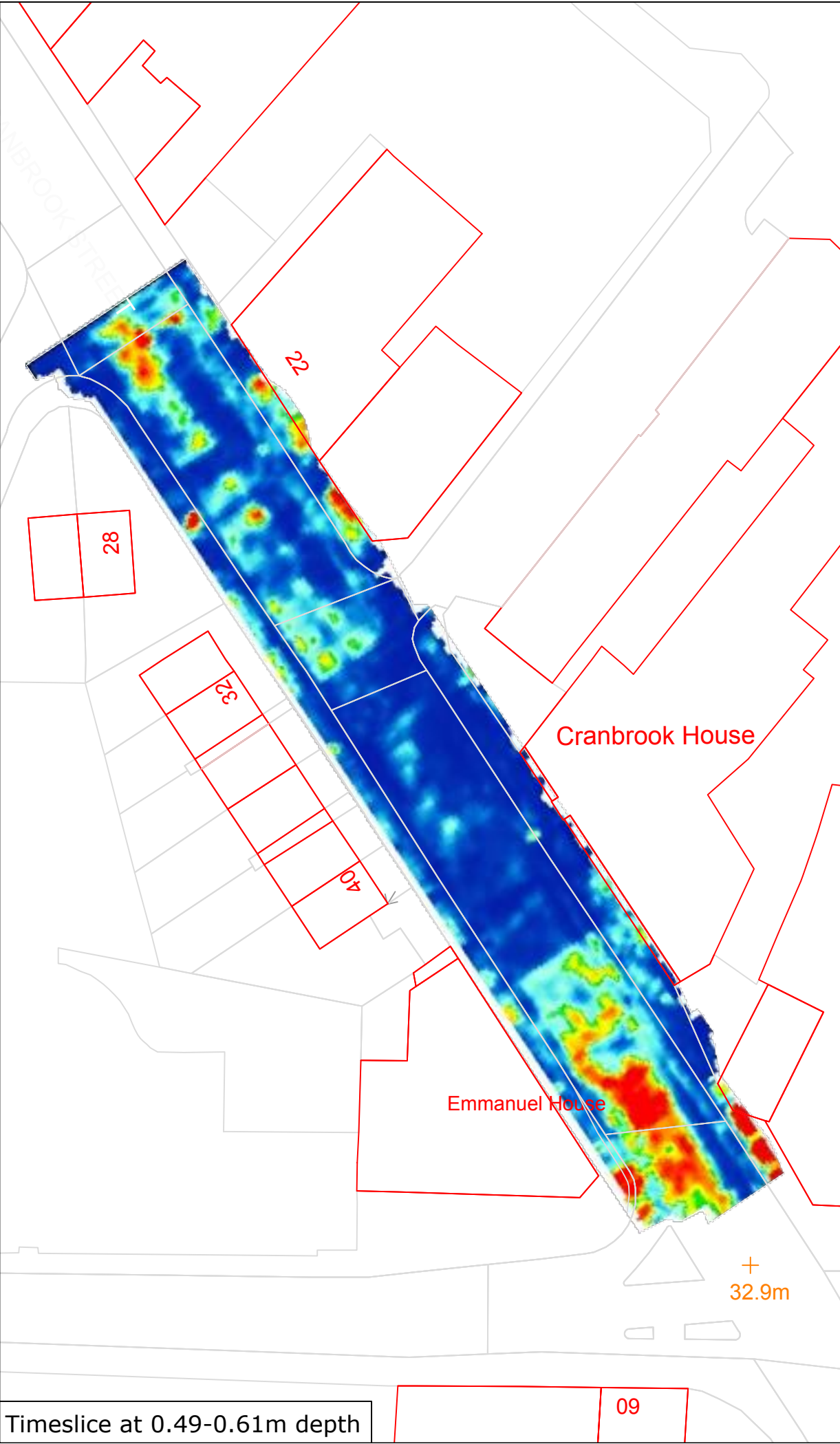
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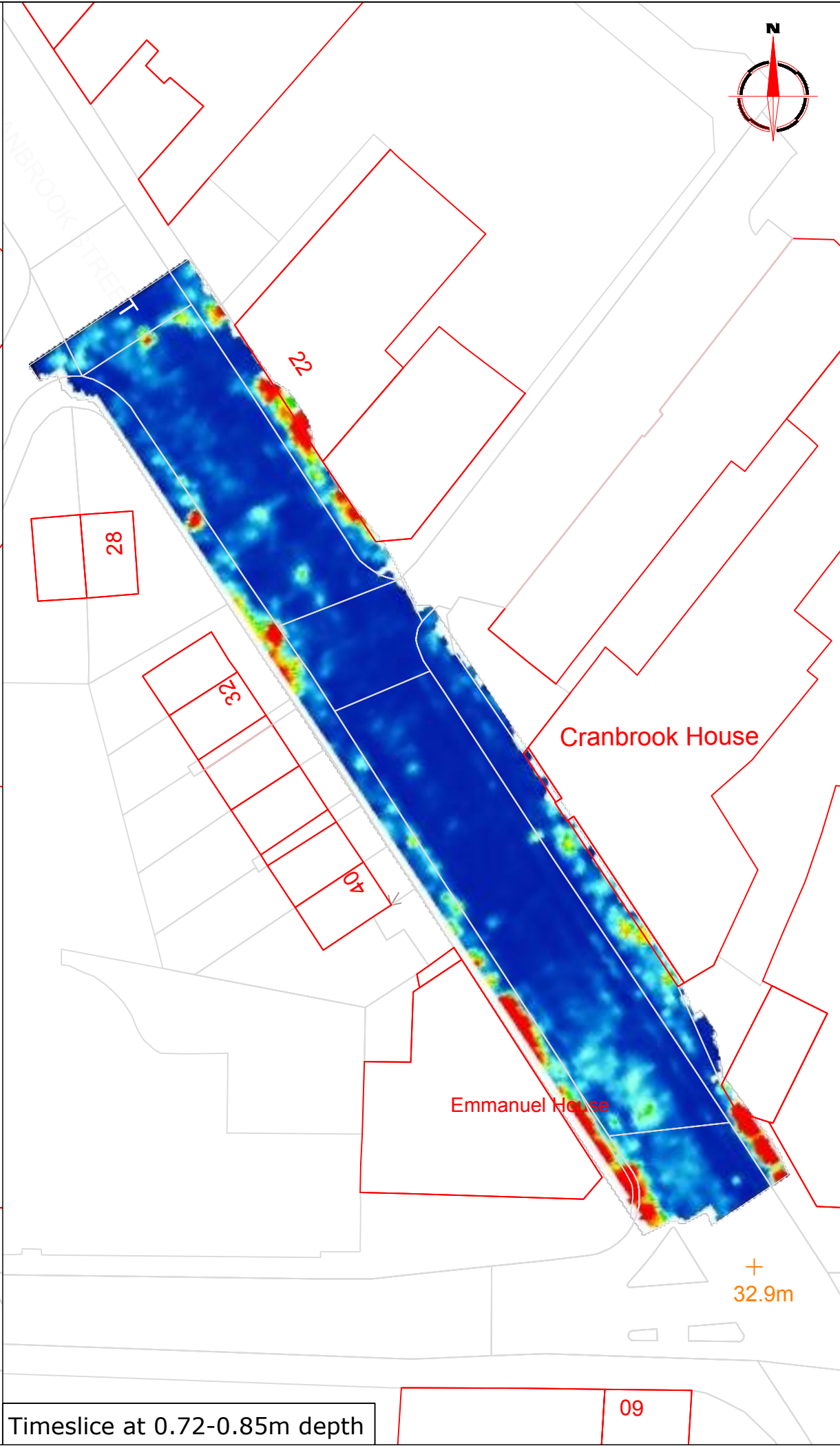
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© Stratascan Ltd - 2015		
Site centred on NGR SK 577 400		
Client SCOTT LOMAX		
Project Title CRANBROOK STREET, NOTTINGHAM		Job No. 8242
Subject LOCATION PLAN OF SURVEY AREA		
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 sumo SUMO GROUP MEMBER		
Scale 1:25000 0m 500 1000m		
Plot A3	Checked by DGE	Issue No. 01
Survey date MAY 15	Drawn by MU	Figure No. 01



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© Stratascan Ltd - 2015		
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B	457777.44, 339948.87	
Client		
SCOTT LOMAX		
Project Title		Job No. 8242
CRANBROOK STREET, NOTTINGHAM		
Subject		
GENERAL SITE PLAN		
 <p>STRATASCAN™</p> <p>GEOPHYSICS FOR ARCHAEOLOGY AND ENGINEERING</p> <p>VINEYARD HOUSE T: 01684 592266 UPTON UPON SEVERN E: info@stratascan.co.uk WR8 0SA www.stratascan.co.uk</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">   </div> <div style="text-align: center;"> <p>SUMO GROUP MEMBER</p>  </div> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div> </div>		
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A3	DGE	01
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MAY 15	MU	02



Timeslice at 0.49-0.61m depth



Timeslice at 0.72-0.85m depth

Amendments

Issue No.	Date	Description
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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 dark colours namely blues. 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 buried foundations or surfaces within the soil matrix.

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

High Energy Return
-Possible Archaeological Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

Client

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CRANBROOK STREET, NOTTINGHAM

Job No.

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Subject

GPR TIMESLICE AT 0.49-0.61m AND 0.72-0.85m DEPTH

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Scale

1:500

0m 5 10 15 20 25m

Plot

A3

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DGE

Issue No.

01

Survey date

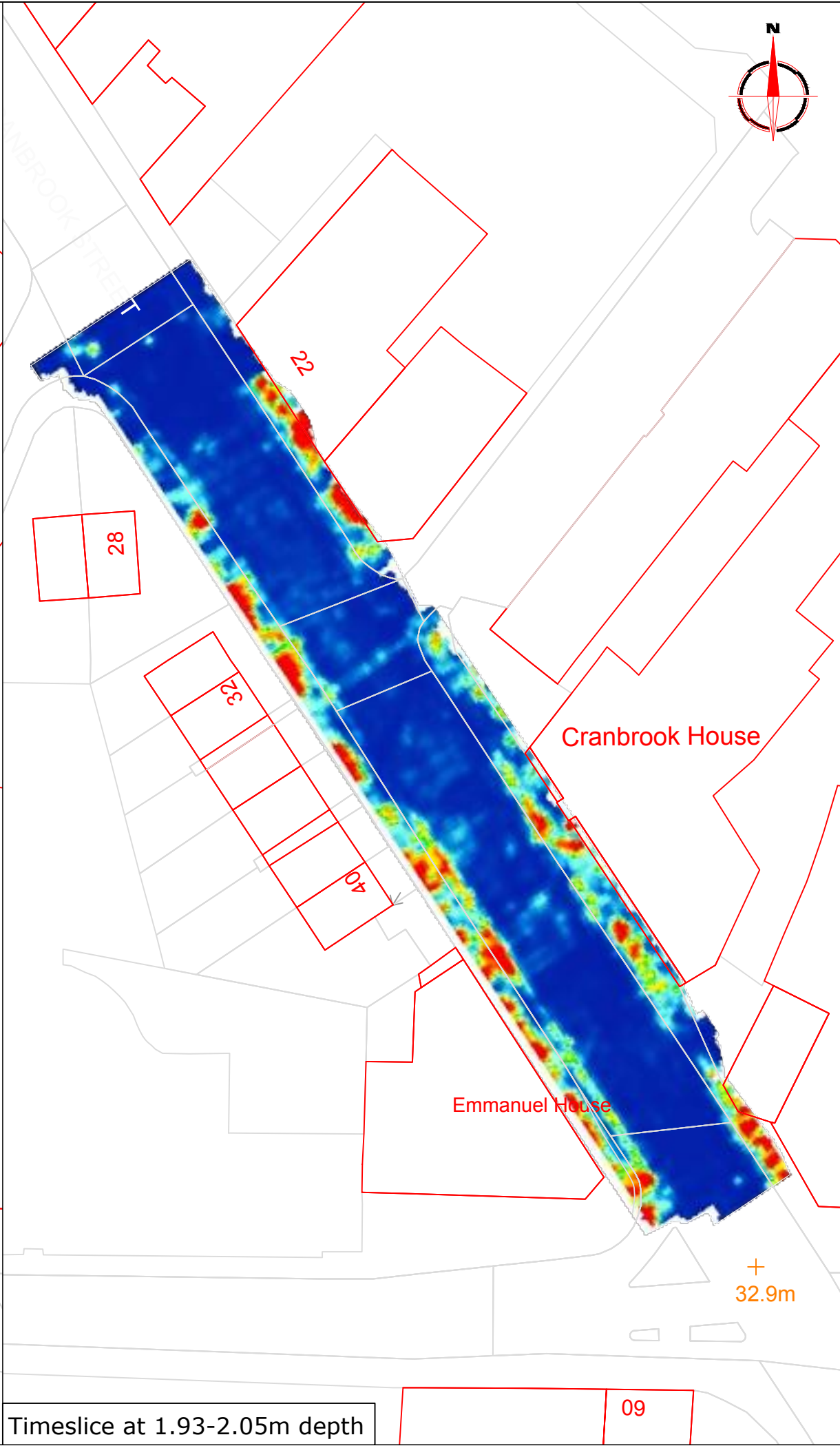
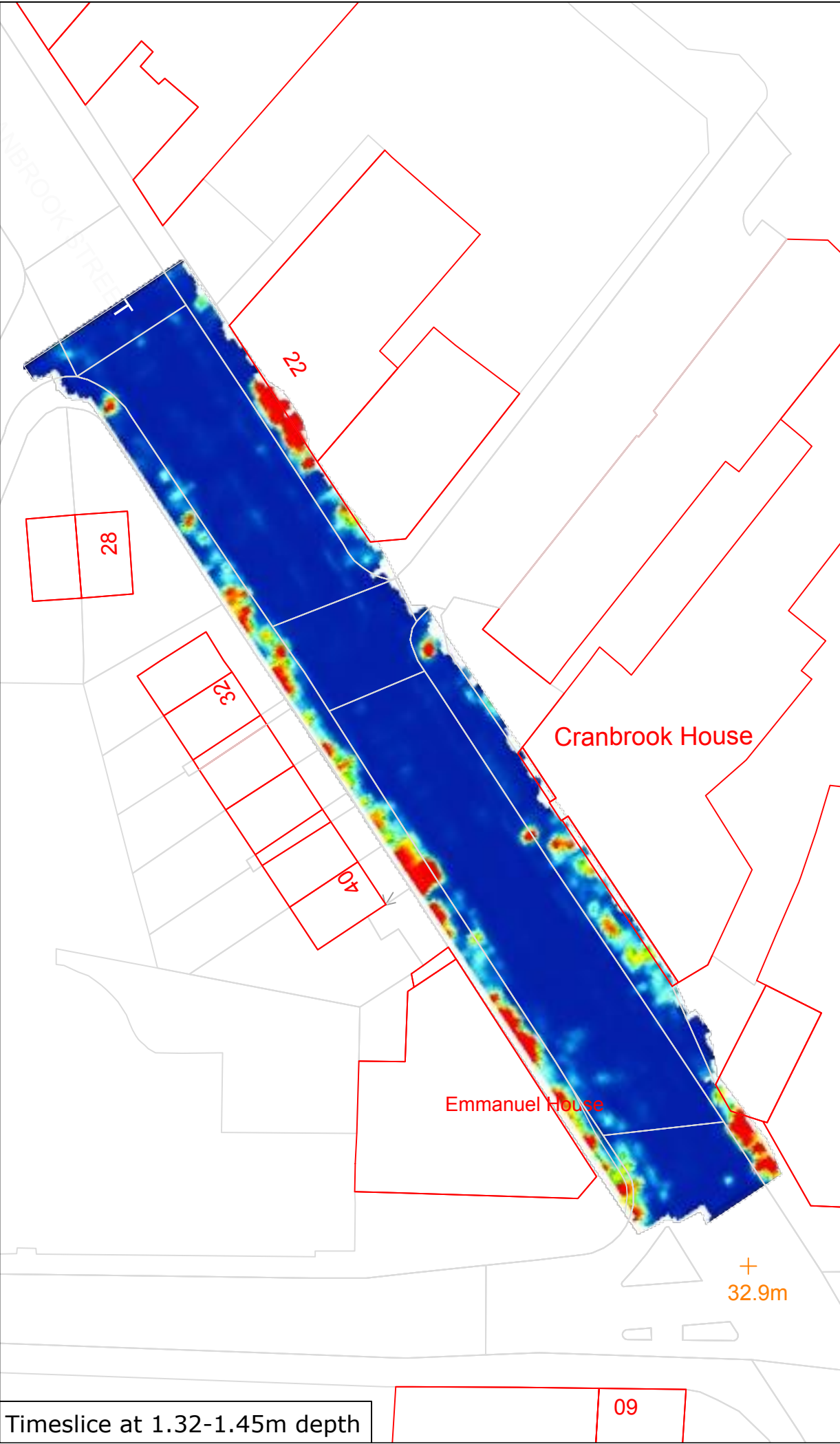
MAY 15

Drawn by

MU

Figure No.

03



Amendments

Issue No.	Date	Description
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TIMESLICE PLOTS

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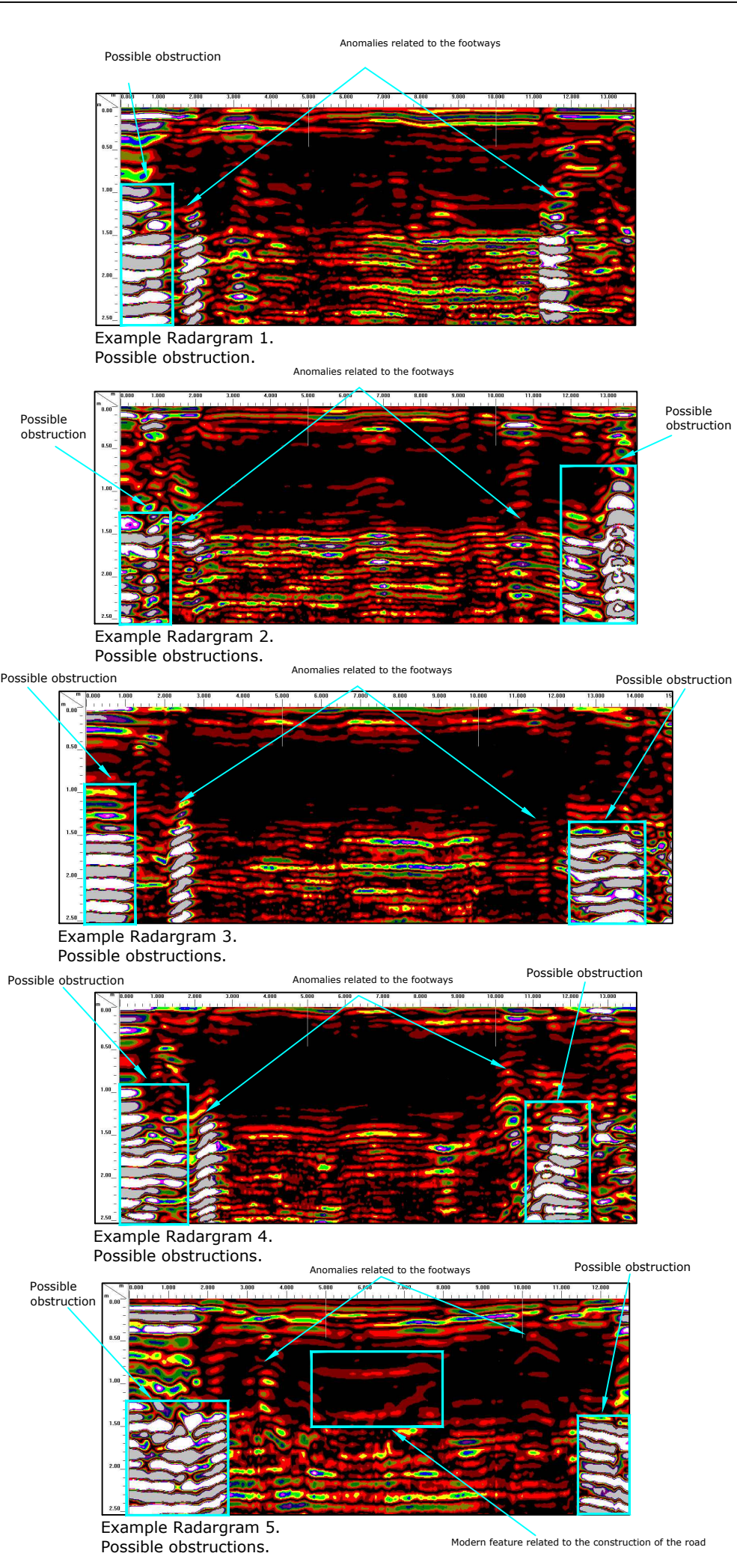
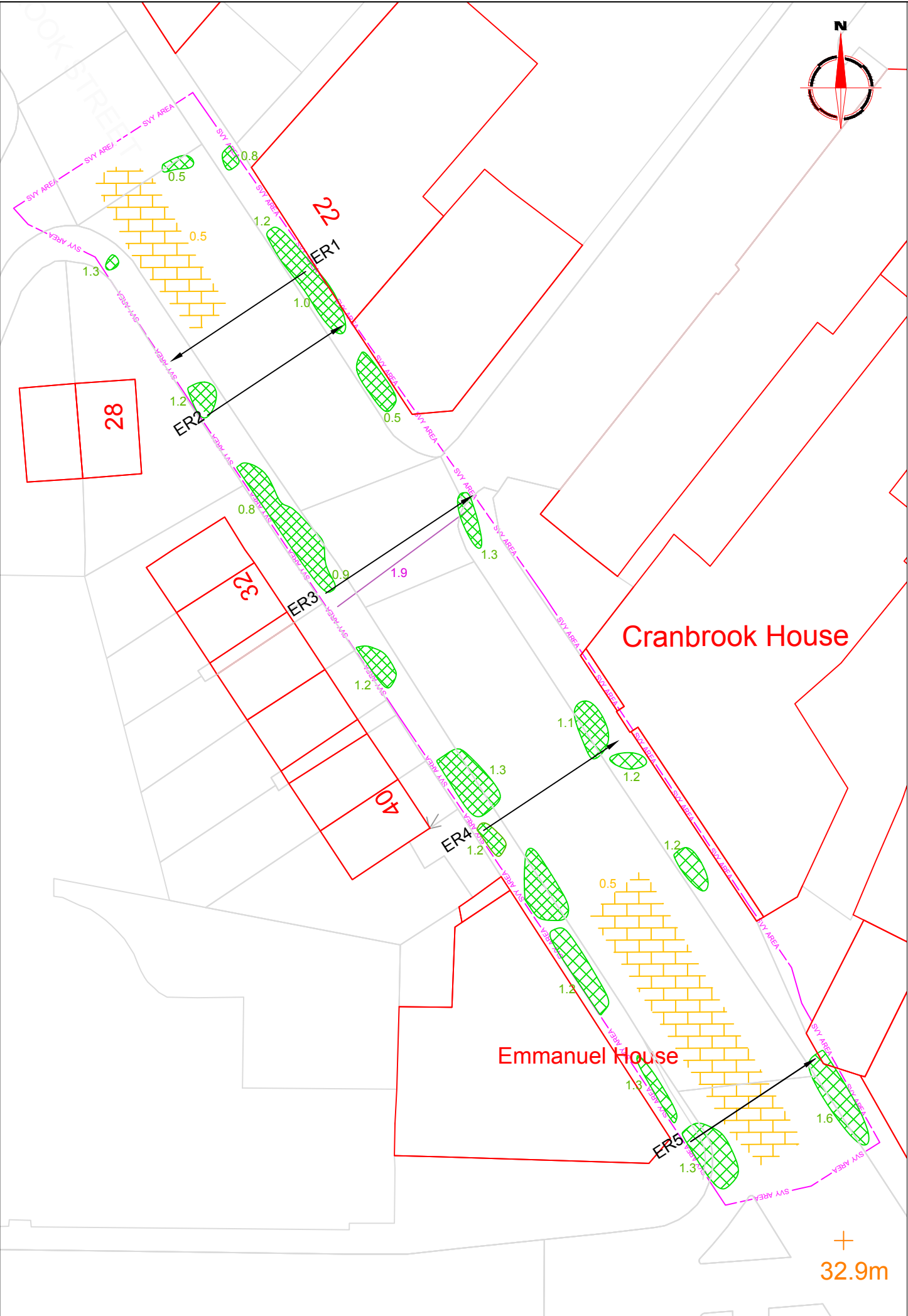
Subject
GPR TIMESLICE AT 1.32-1.45m AND 1.93-2.05m DEPTH

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Scale
1:500
0m 5 10 15 20 25m

Plot A3	Checked by DGE	Issue No. 01
Survey date MAY 15	Drawn by MU	Figure No. 04



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The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of company's control. Whilst the company 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

	Possible obstruction
	Modern feature relating to the construction of the road
	Possible service
0.4	Depth to top of anomaly in metres
	Survey area
	Example radargram

Client

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Project Title

Job No. 8242

CRANBROOK STREET, NOTTINGHAM

Subject

GPR SURVEY - INTERPRETATION WITH EXAMPLE RADARGRAMS

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Scale

1:400

0m 4 8 12 16 20m

Plot	A3	Checked by	DGE	Issue No.	01
Survey date	MAY 15	Drawn by	MU	Figure No.	05