GEOPHYSICAL SURVEY REPORT

SUMO Survey

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Colchester Mercury Theatre

Client
Colchester Archaeological Trust

Survey Report
SOR13985

Date
January 2019

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GEOPHYSICAL SURVEY REPORT

Project name:
Colchester Mercury Theatre

SUMO Job reference:
SOR13985

Client:
Colchester Archaeological Trust

Survey date:
21st and 28th November, 14th December 2018

Report date:
24th January 2019

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TABLE OF CONTENTS

LIST OF FIGURES

1 EXECUTIVE SUMMARY

A Ground Penetrating Radar (GPR) survey was conducted around the Mercury Theatre in Colchester, Essex. The site was divided into three sub-areas, which were investigated in separate phases of site work. Area 1 is located to the south of the theatre, Area 2 is north-east of the main building and Area 3 lies to the east of Area 1.

Two GPR systems were utilised for the investigation. A GSSI SIR 3000 was used for Areas 1 and 2 and a GSSI Dual Frequency Radar for Area 3. The objective of the GPR survey was to search for evidence of archaeological remains.

An orthogonal grid of radar profiles was completed over the survey areas spaced at intervals of 1.0 metre for Area 1 and 0.5 metre for Areas 2 and 3, where access allowed. The survey data was interpreted as individual radar profiles with the results presented as plan interpretations.

The GPR survey identified a number of anomalous features potentially corresponding to archaeological structures, disturbed ground with structural fragments and anomalous layering that could be associated with foundations or buried floors.

2 INTRODUCTION

2.1 Background synopsis

SUMO Geophysics Ltd were commissioned to undertake a geophysical survey in three areas to the south and north-east of the Mercury Theatre, prior to the refurbishment and extension of the theatre. This survey forms part of a larger programme of investigations carried out by **Colchester Archaeological Trust.**

2.2 Site details

NGR / Postcode	TL 992 251 / CO1 1PT
Location	The site covers three areas which are located to the south and north-east of the theatre building.
District	Colchester, Essex County
District Ward	Castle, Essex County
Geology	Solid: Thames Group – clay, silt and sand. Superficial: Kesgrave Catchment Subgruop – Sand and Gravel (BGS 2018).
Soils	Unsurveyed (U), mainly urban and industrial areas (SSEW 1983).
Archaeology	The development site is located within the southwestern corner of the early Roman legionary fortress and the later Roman walled town of Colchester. It lies adjacent to the Roman town wall and immediately to the southeast of the Roman Balkerne Gate. The survey area is located within insula 25a of the Roman town. There is evidence of at least one Roman town house with surviving wall foundations within Areas 1 and 3 together with tessellated and mosaic floors. A tessellated floor and foundations were also recorded within Area 2 (WSI 2018).

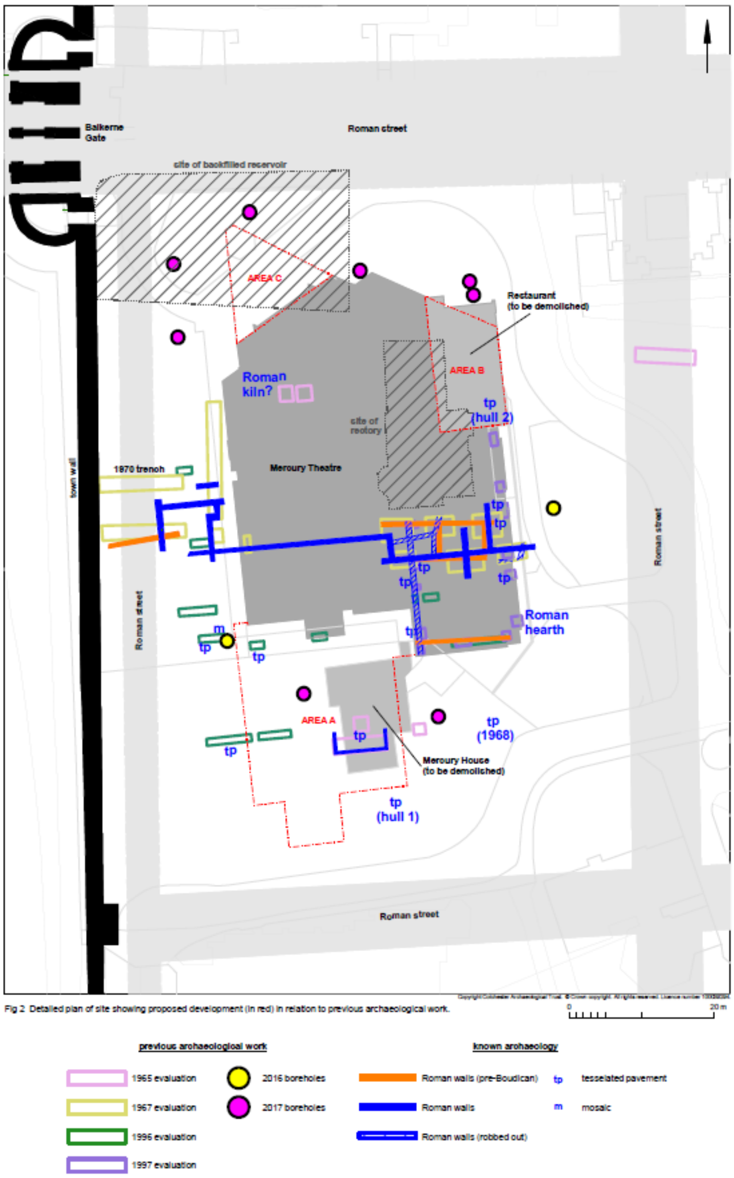


Fig 2 Detailed plan of site showing proposed development (in red) in relation to previous archaeological work.

Survey Method	Ground Penetrating Radar (GPR)
Survey Equipment	Areas 1 and 2 - GSSI SIR3000 in conjunction with a 400MHz antenna. Areas 3 – GSSI Dual Frequency Radar system in conjunction with 300MHz and 800MHz antenna units.
Study Area	530m^2

2.3 Aims and Objectives

The key objective of the GPR survey was to search for evidence of any archaeological remains such as walls, foundations and floors.

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 Method

Ground Penetrating Radar was used as an efficient and effective method of detecting buried voids in urban environments. More information regarding this technique is included in Appendix A. An orthogonal grid of radar profiles spaced at 0.50 and 1.00 metre intervals was completed over the accessible parts of the site areas.

3.3 Data Processing and Interpretation

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.

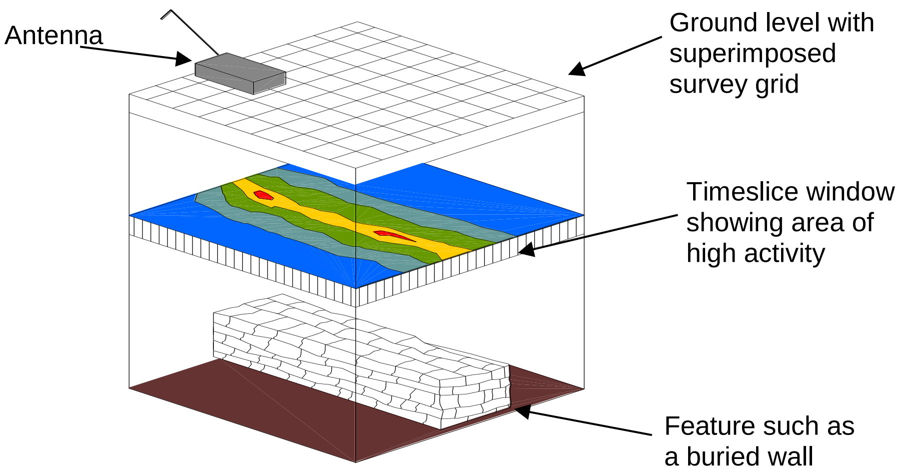
vii. Conductive surface.

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 obscure 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".

viii. 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.

3.5 Presentation of results

The location of the survey area is provided in Figure 2. Plan interpretations of the data are provided in Figures 4 with accompanying example radargrams in Figures 5-7.

4 RESULTS

4.1 Introduction

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 such as structures. 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 the interpretation of each individual radar profile, followed by an areal interpretation of all the profiles. Features identified across several profiles are interpolated in areas where the data is well constrained.

The confidence levels placed on a plan interpretation depend on the spacing of the survey grid. A target such as a buried structure 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 obtain total survey coverage of a site. Consequently, the survey line spacing is selected to provide a good indication of site conditions and allow for available access.

The contrast in electrical properties at the interface between solid material and air produces a large electrical contrast. This generates a high amplitude response that should stand out clearly from the background reflections. In a man-made void if the construction is simple, the air reflection should be reasonably smooth and planar.

The GPR survey identified six significant categories of reflection targets:

i) Possible structure (Roman walls)
ii) Possible structure (unknown origin)
iii) Disturbed ground with structural fragments
iv) Anomalous layering type I (structural?)
v) Anomalous layering type II
vi) Possible service

4.2 Possible structure (Roman walls and unknown origin)

The possible structure reflection category consists of moderate to high amplitude, well defined reflections, with either planar or upwardly convex curved top surfaces, with clearly defined margins usually characterised by edge scattering. Several examples of this reflection category are shown in Radargrams 1-5, 7, 9-10 and 12.

Numerous possible structures have been identified in all three areas, occurring at depths of 0.3 – 1.0 metre bgl. The most significant possible structures occur in Area 1 and Area 3 and correspond to the position of a Roman Wall, suggesting they may represent buried remains of this wall. Other non-specific possible structures have been detected in all three areas. These could be archaeological features or of more recent origin such as modern foundations or blocks of concrete, masonry and brickwork.

4.3 Disturbed Ground with structural fragments

Disturbed ground generally appears as zones of moderate to high amplitude, irregular, broken reflections. In some cases, slightly chaotic internal structure may be evident, resulting from the limited interaction between a number of small, high amplitude reflections. Some examples of disturbed ground are shown in Radargrams 2, 7, 10 and 13.

Disturbed ground has been identified in all three areas occurring at depths of 0.2-1.1 metres but is mainly present in Area 1. The disturbed ground could be associated with fragmented structural remains, or pottery and tile detritus. However, some of the disturbed ground could be more recent, associated with backfilled excavations or discrete compositional variations in made ground.

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4.4 Anomalous layering type I

Anomalous layers occur as well defined, fairly high amplitude, planar sub-horizontal reflections with weak evidence of edge scattering. Some examples of the anomalous layering are presented in Radargrams 6-8 and 11-13.

Five areas of anomalous layering were identified by the GPR survey occurring in Areas 2 and 3 at depths of 0.2 – 0.6 metres. Anomalous layers are associated with distinct compositional layers in the subsurface that may correspond to archaeological remains such as buried tessellated pavements or floors, old surfaces or they could be they may be discrete layers within soil or made ground.

4.5 Anomalous layering type II

The type II anomalous layers are characterised as semi-continuous, high amplitude reflections originating close to ground surface associated with underlying reverberations. An example of these reflections is given in Radargram 13. Any underlying reflections are obscured by the reverberations, so information was obtained on the underlying ground in these areas.

The type II anomalous reflections occur in the southern corner of Area 3. The cause of the reverberations is uncertain but may be associated with a highly reflective near surface material such as ash or clay.

4.6 Possible service

A GPR profile either orthogonal or at a high angle to a length of service typically produces a steeply curved or hyperbolic reflection of moderate amplitude, which should be discernible against background reflections. The service position is located at the apex of the hyperbola. At low angles of intersection between survey lines and service tracks, the resultant planar reflection response is more ambiguous and can be difficult to identify.

One possible service was detected in the west of Area 1 at the depth of 0.5 metres.

5 DATA APPRAISAL & CONFIDENCE ASSESSMENT

5.1 The data across the survey area shows a good contrast between strong complex and discrete responses and that of the background response, suggesting that the underlying ground is conducive to a GPR survey. The maximum depth penetration achieved by the GPR survey was approximately 2.5 metres for GSSI SIR3000 system and 1.5 metres for GSSI Dual Frequency system. Anomalies potentially associated with archaeological features have been detected, indicating that the survey has been effective.

6 CONCLUSION

6.1 The GPR survey identified a number of anomalous features potentially corresponding to archaeological remains in all three areas of the site. The most significant features include possible structures, some of which appear to correlate to an old Roman wall. Other features of interest include disturbed ground with structural fragments and anomalous layering, some of which could be associated with foundations or buried floors.

7 REFERENCES

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SSEW 1983 *Soils of England and Wales. Sheet 4, East England*. Soil Survey of England and Wales, Harpenden.

WSI 2018 *Written Scheme of Investigation for an archaeological excavation at the Mercury Theatre, Balkerne Gate, Colchester, Essex, CO1 1PT.* Colchester Archaeological Trust

Appendix A - Technical Information: Ground Penetrating Radar

Grid locations

The location of the survey traverses has been plotted in Figure 2. Traverses were carried out on 0.5m and 1.0m orthogonal grids.

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.

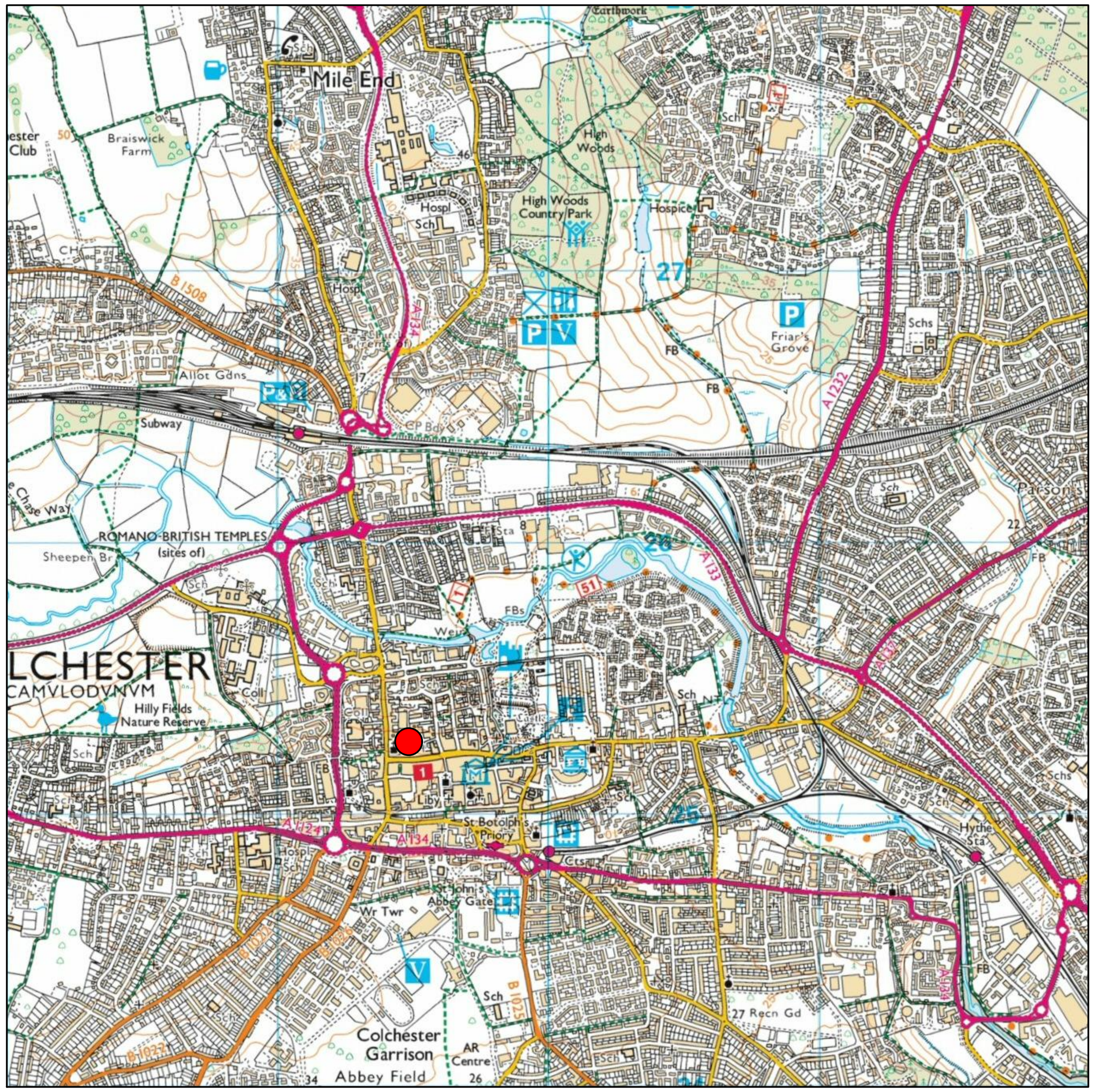
Depth of scan and resolution

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.



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Site Location

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GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Site Location Diagram

Client:
Colchester Archaeological Trust

Project:
SOR13985 - Colchester Mercury Theatre

Scale:
0 metres 1000
1:25000 @ A3

Fig No:
01

Survey date	Drawn by	Checked by
November 2018	MUK	PPB

N

REFERENCING INFORMATION

A-F	Base points

KEY

	Survey area
	Radar traverse

Title: Location of Survey Areas

Client: Colchester Archaeological Trust

Project: SOR13985 - Colchester Mercury Theatre

Scale: 0 metres 15 1:300 @ A3

Fig No: 02

Survey date	Drawn by	Checked by
November 2018	MUK	PPB

Information provided by the client

	Roman walls (pre-Boudican)
	Roman walls
	Roman walls (robbed out)
tp	Tesselated pavement
m	Mosaic

sumo Survey
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Title: Known archaeology

Client: Colchester Archaeological Trust

Project: SOR13985 - Colchester Mercury Theatre

Scale: 0 metres 15
1:300 @ A3

Fig No: 03

Survey date	Drawn by	Checked by
November 2018	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

	Possible structure (Roman walls)
	Possible structure (unknown origin)
	Disturbed ground with structural fragments
	Anomalous layering type I (structural?)
	Anomalous layering type II
	Possible service
0.60	Depth to the top of the feature (in m)

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Plan Interpretation

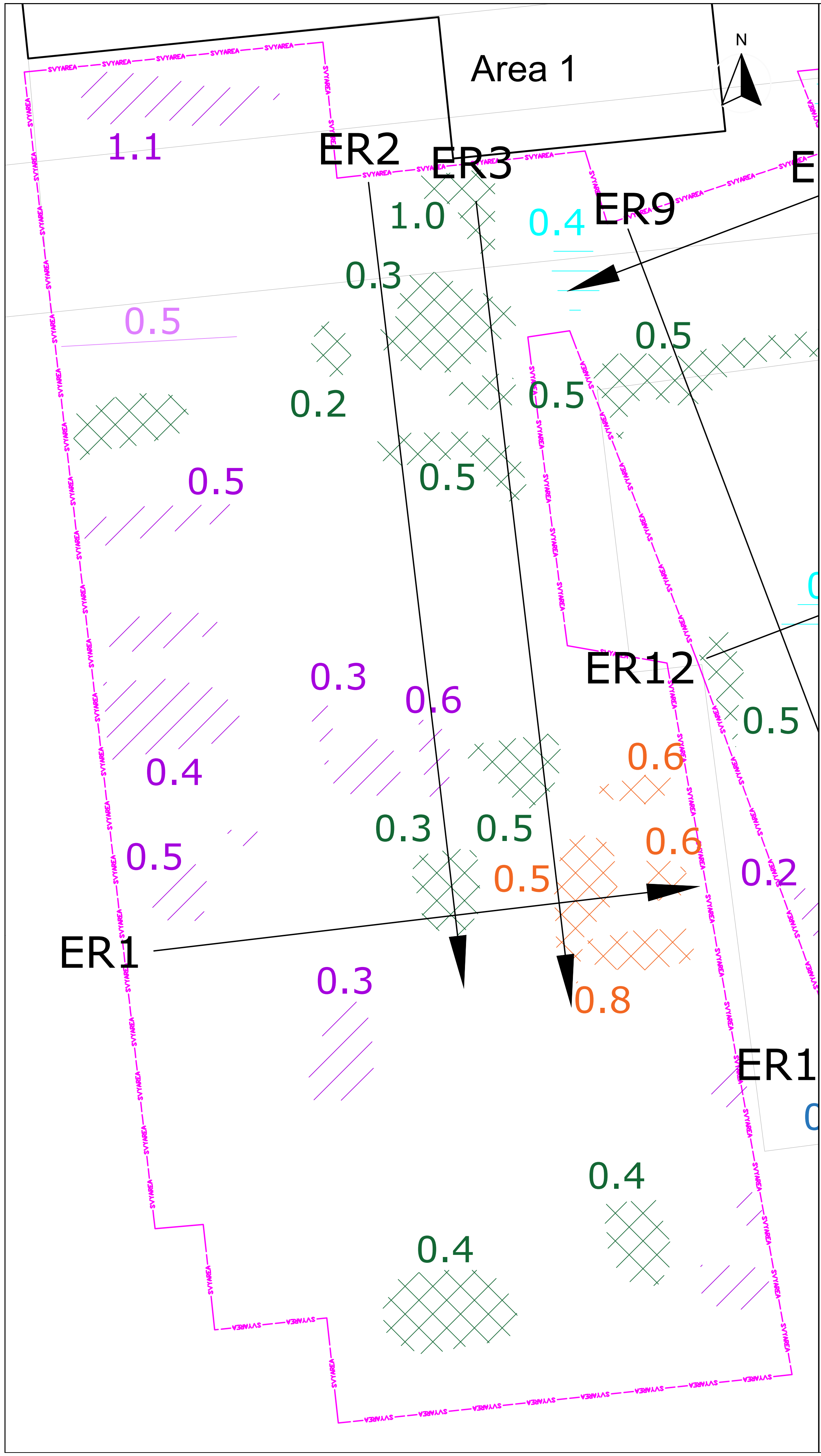
Client:
Colchester Archaeological Trust

Project:
SOR13985 - Colchester Mercury Theatre

Scale:
0 metres 15
1:300 @ A3

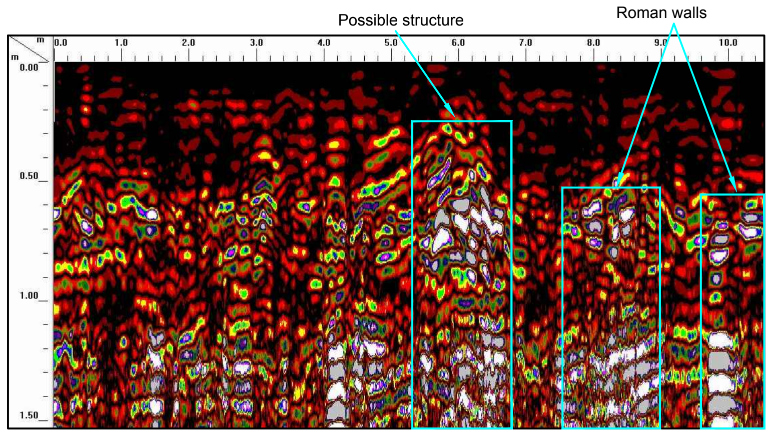
Fig No:
04

Survey date	Drawn by	Checked by
November 2018	MUK, MRW	PPB

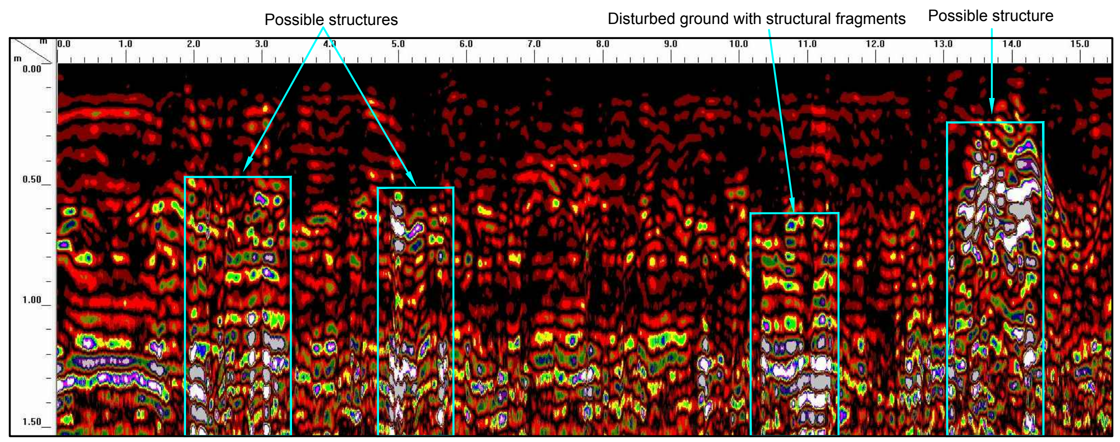


The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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

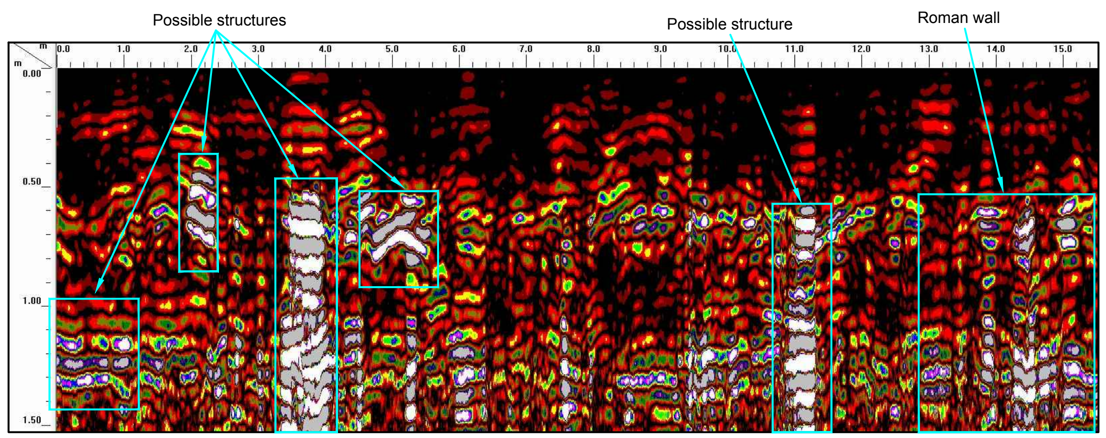
GSSI SIR3000 radar is collected with 400MHz.



Example Radargram 1.
Roman walls and possible structure.



Example Radargram 2.
Possible structures and disturbed ground with structural fragments.



Example Radargram 3.
Roman wall and possible structures.

KEY

	Possible structure (Roman walls)
	Possible structure (unknown origin)
	Disturbed ground with structural fragments
	Anomalous layering type I (structural?)
	Anomalous layering type II
	Possible service
0.60	Depth to the top of the feature (in m)
	Example radargram

Sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey - Interpretation with Example Radargrams - Area 1

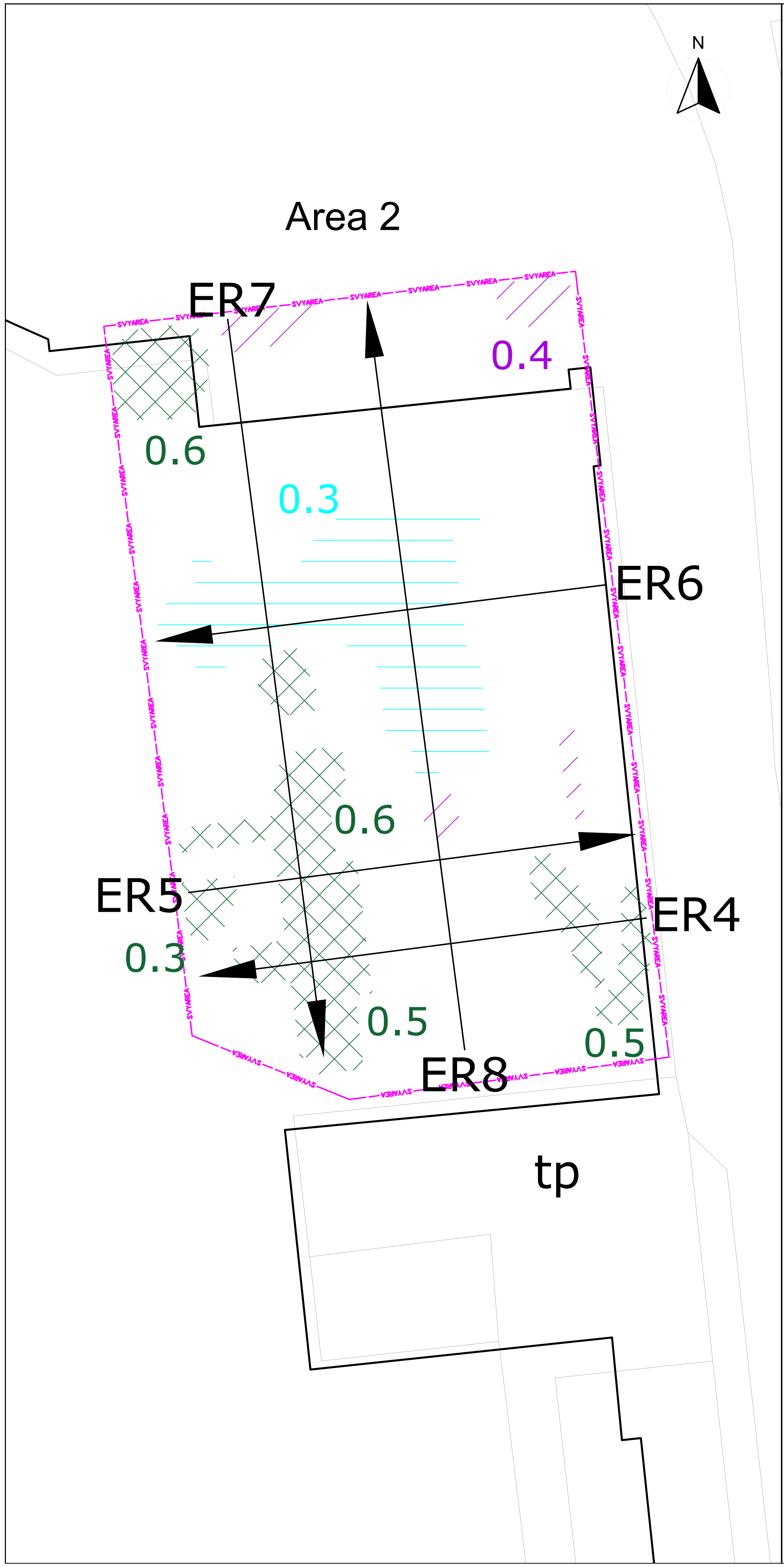
Client:
Colchester Archaeological Trust

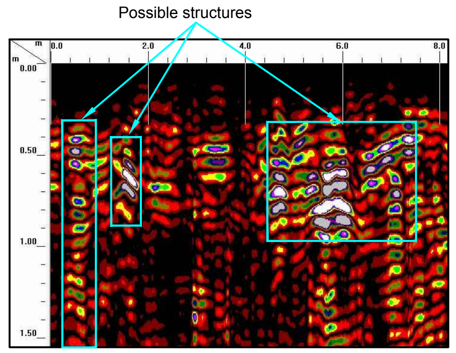
Project:
SOR13985 - Colchester Mercury Theatre

Scale: 0 metres 5
1:100 @ A3

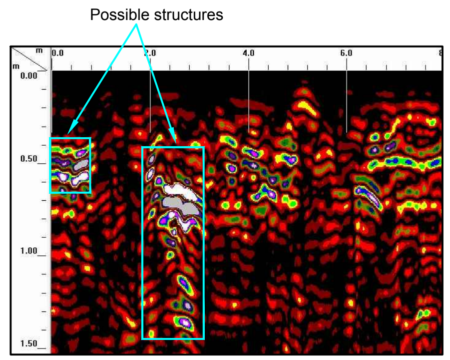
Fig No: 05

Survey date	Drawn by	Checked by
November 2018	MUK	PPB

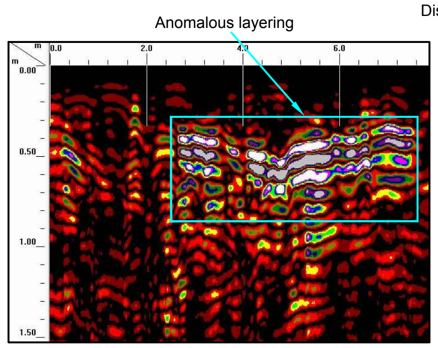




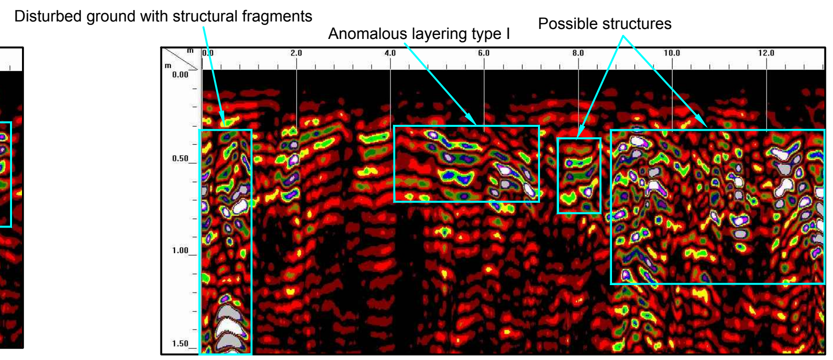
Example Radargram 4.
Possible structures.



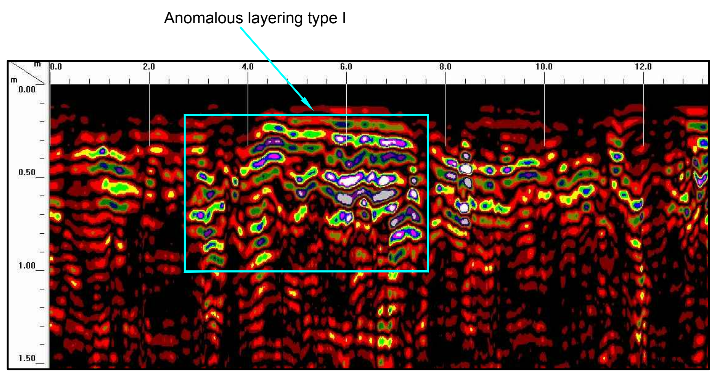
Example Radargram 5.
Possible structures.



Example Radargram 6.
Anomalous layering.



Example Radargram 7.
Disturbed ground with structural fragments, anomalous layering type I and possible structures.



Example Radargram 8.
Anomalous layering type I.

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GSSI SIR3000 radar is collected with 400MHz.

KEY

	Possible structure (Roman walls)
	Possible structure (unknown origin)
	Disturbed ground with structural fragments
	Anomalous layering type I (structural?)
	Anomalous layering type II
	Possible service
0.60	Depth to the top of the feature (in m)
	Example radargram

Sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Interpretation with Example Radargrams - Area 2

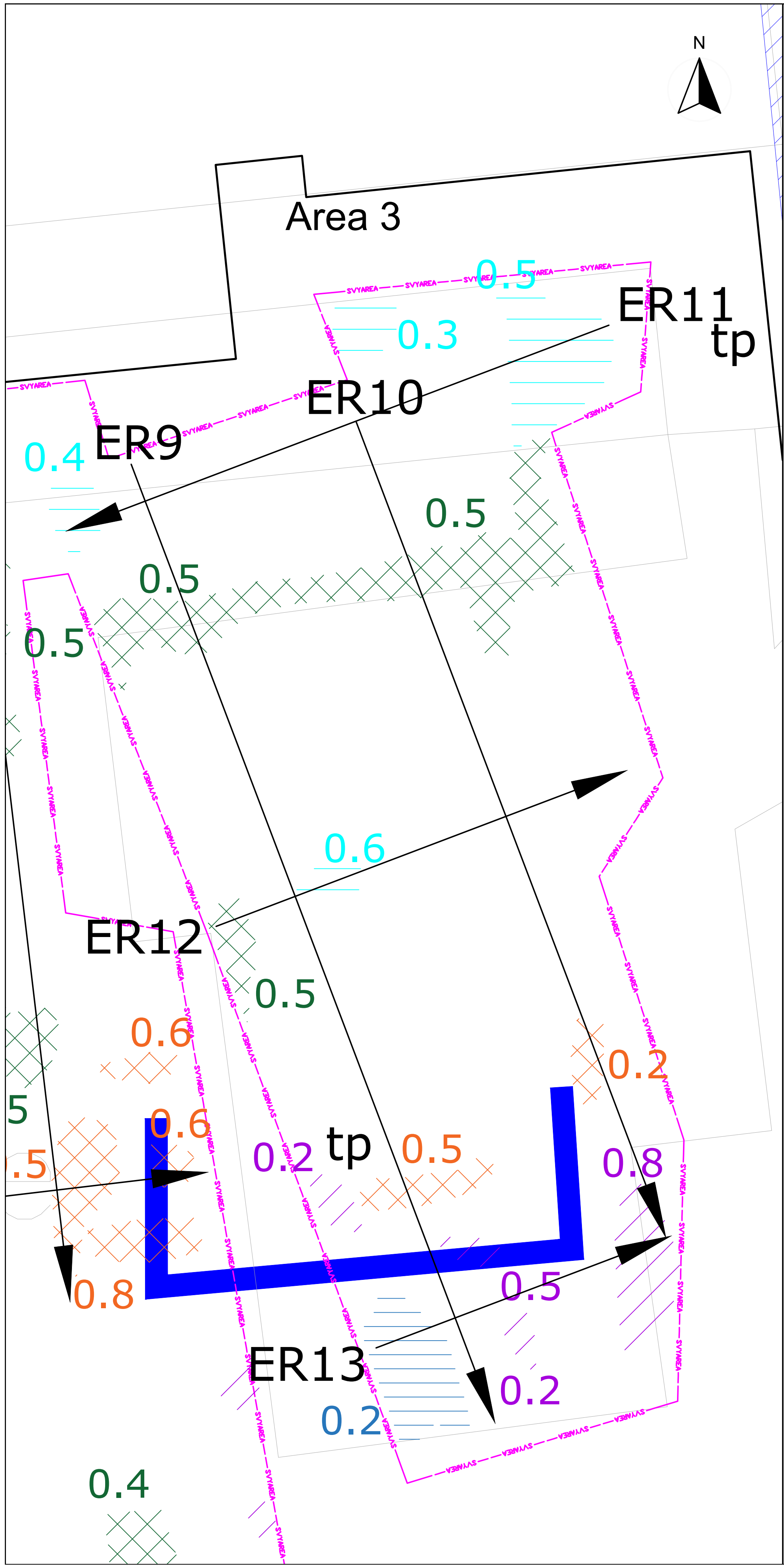
Client: Colchester Archaeological Trust

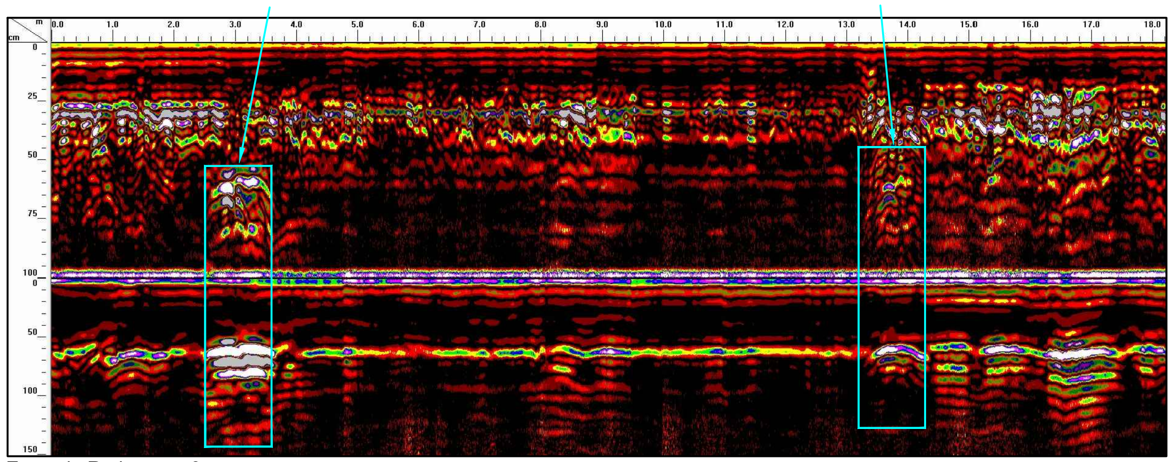
Project: SOR13985 - Colchester Mercury Theatre

Scale: 0 metres 5 — 1:100 @ A3

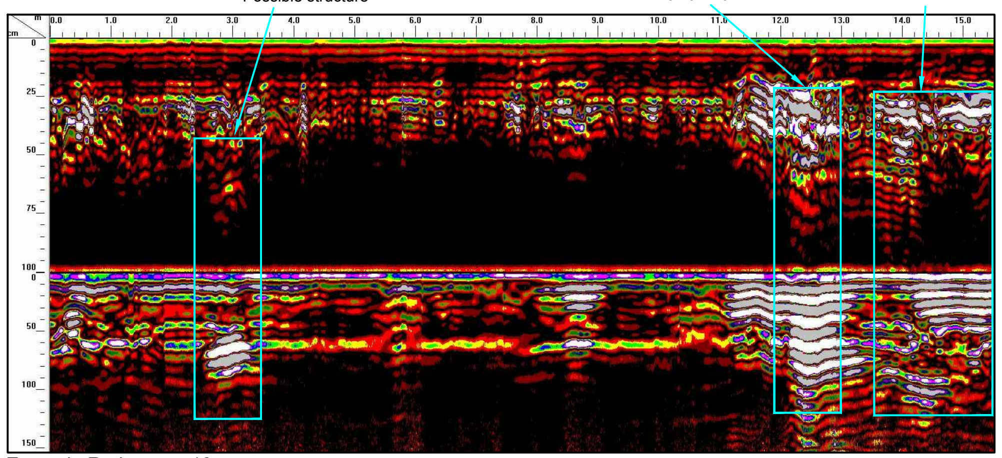
Fig No: 06

Survey date	Drawn by	Checked by
November 2018	MUK	PPB

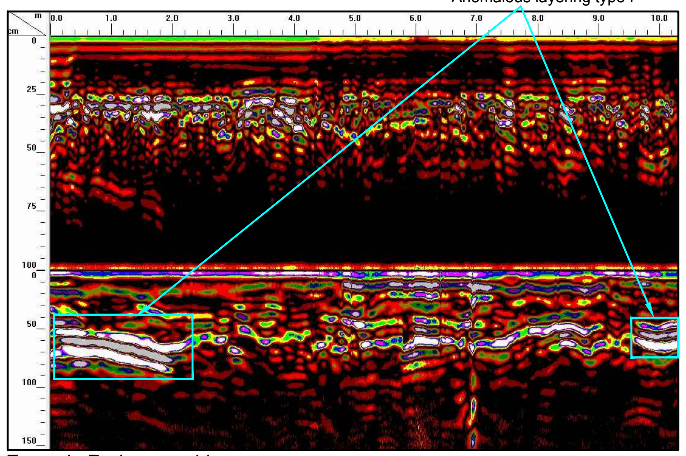




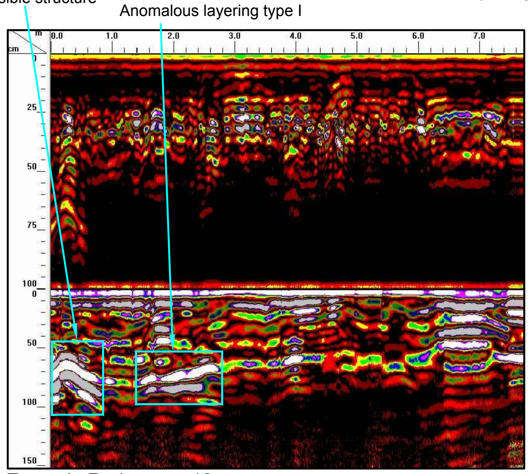
Example Radargram 9.
Roman wall and possible structure.



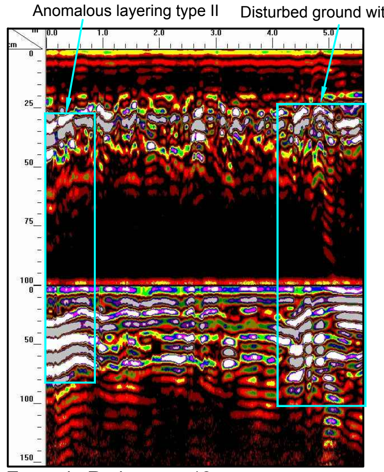
Example Radargram 10.
Roman wall, possible structure and disturbed ground with structural fragments.



Example Radargram 11.
Anomalous layering type I possibly related to structures.



Example Radargram 12.
Possible structure and anomalous layering type I possibly related to structure.



Example Radargram 13.
Anomalous layering type II and disturbed ground with structural fragments.

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.

Dual Fregency GSSI radar is collected with 300MHz and 800MHz antennae simultaneously. The example radargrams show data from both frequencies. The top section shows the high frequency (800MHz) data, while the bottom section shows the low frequency (300MHz) data.

KEY

	Possible structure (Roman walls)
	Possible structure (unknown origin)
	Disturbed ground with structural fragments
	Anomalous layering type I (structural?)
	Anomalous layering type II
	Possible service
0.60	Depth to the top of the feature (in m)
	Example radargram

GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey - Interpretation with Example Radargrams - Area 3

Client: Colchester Archaeological Trust

Project: SOR13985 - Colchester Mercury Theatre

Scale: 0 metres 5
1:100 @ A3

Fig No: 07

Survey date	Drawn by	Checked by
November 2018	MUK, MRW	PPB

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

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