

# HAVERFORDWEST CASTLE, PEMBROKESHIRE: GEOPHYSICAL SURVEYS



Prepared by Dyfed Archaeological Trust  
For: Pembrokeshire County Council



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**HAVERFORDWEST CASTLE,  
PEMBROKE:SHIRE:  
GEOPHYSICAL SURVEYS**

By

**Philip Poucher**

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**HAVERFORDWEST CASTLE, PEMBROKESHIRE:  
GEOPHYSICAL SURVEYS**

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# **HAVERFORDWEST CASTLE, PEMBROKESHIRE: GEOPHYSICAL SURVEYS**

## **CONTENTS**

	<b>EXECUTIVE SUMMARY/ CRYNODEB GWEITHREDOL</b>	<b>i</b>
<b>1.</b>	<b>INTRODUCTION</b>	<b>1</b>
	<b>1.1 Project Commission</b>	<b>1</b>
	<b>1.2 Scope of the Project</b>	<b>2</b>
	<b>1.3 Report Outline</b>	<b>2</b>
	<b>1.4 Abbreviations</b>	<b>3</b>
	<b>1.5 Illustrations</b>	<b>3</b>
	<b>1.6 Timeline</b>	<b>3</b>
<b>2.</b>	<b>THE SITE</b>	<b>7</b>
	<b>2.1 Site Location and Topography</b>	<b>7</b>
	<b>2.2 Site History</b>	<b>8</b>
<b>3.</b>	<b>METHODOLOGY</b>	<b>12</b>
	<b>3.1 Magnetometry Survey</b>	<b>12</b>
	<b>3.2 Resistivity Survey</b>	<b>13</b>
	<b>3.3 Ground-Penetrating Radar Survey</b>	<b>13</b>
<b>4.</b>	<b>MAGNETOMETRY RESULTS</b>	<b>14</b>
<b>5.</b>	<b>RESISTIVITY RESULTS</b>	<b>20</b>
<b>6.</b>	<b>GROUND PENETRATING RADAR RESULTS</b>	<b>22</b>
<b>7.</b>	<b>ARCHAEOLOGICAL EVALUATION RESULTS</b>	<b>25</b>
<b>8.</b>	<b>DISCUSSION</b>	<b>28</b>
	<b>8.1 General</b>	<b>28</b>
	<b>8.2 Medieval</b>	<b>28</b>
	<b>8.3 18<sup>th</sup> – 20<sup>th</sup> century</b>	<b>29</b>
	<b>8.4 Unknown Features</b>	<b>31</b>
<b>9.</b>	<b>CONCLUSION</b>	<b>37</b>
<b>10.</b>	<b>SOURCES</b>	<b>38</b>
 <b>FIGURES</b>		
<b>Figure 1:</b>	Location map	<b>4</b>
<b>Figure 2:</b>	Detailed plan of survey area	<b>5</b>
<b>Figure 3:</b>	Location plan showing development area and area subjected to geophysical survey	<b>6</b>



<b>Figure 4:</b>	Phased plan of the medieval Inner Ward area	10
<b>Figure 5:</b>	Plan of the mid to late 19 <sup>th</sup> century Gaol in the Inner Ward	11
<b>Figure 6:</b>	Plan of late 19 <sup>th</sup> century Police Station in the Inner Ward	12
<b>Figure 7:</b>	Magnetometry results, grey-scale plot, unprocessed	16
<b>Figure 8:</b>	Magnetometry results, grey-scale plot, clipped to +/-25nT	17
<b>Figure 9:</b>	Magnetometry results, grey-scale plot, low pass filter	18
<b>Figure 10:</b>	Interpretation layer of magnetometry results	19
<b>Figure 11:</b>	Interpretation layer of resistivity results	21
<b>Figure 12:</b>	Interpretation of GPR results	23
<b>Figure 13:</b>	Interpretation of GPR results overlaid on resistivity results	24
<b>Figure 14:</b>	Plan of features identified from all survey techniques	33
<b>Figure 15:</b>	Plan of potential medieval features identified	34
<b>Figure 16:</b>	Plan of potential 18 <sup>th</sup> – 20 <sup>th</sup> century features identified	35
<b>Figure 17:</b>	Plan of undated potential features identified	36

## **PHOTOGRAPHS**

<b>Photos 1-3:</b>	Photographs of the survey area	7
<b>Photos 4-6:</b>	Photographs of the archaeological evaluation 2008	26

## **TABLE**

<b>Table 1:</b>	Archaeological and Historical Timeline for Wales	3
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<b>APPENDICES:</b>	39
--------------------	----

<b>APPENDIX I:</b>	<b>RESISTIVITY SURVEY REPORT – GEOARCH</b>
<b>APPENDIX II:</b>	<b>GROUND PENETRATING RADAR REPORT – SUMO GEOPHYSICS LTD</b>

# HAVERFORDWEST CASTLE, PEMBROKESHIRE: GEOPHYSICAL SURVEY

## EXECUTIVE SUMMARY

*DAT Archaeological Services were commissioned to undertake a series of geophysical surveys in the Inner Ward area of Haverfordwest Castle, Haverfordwest, Pembrokeshire (NGR SM 9535 1573). DAT undertook a magnetometry survey, GeoArch undertook a resistivity survey, and SUMO Geophysics Ltd undertook a ground-penetrating radar survey.*

*The purpose of the surveys was to locate, assess and characterise the archaeological potential of the site to help inform development proposals. This report combines the results of all three surveys.*

*The surveys identified a wide spread of potential archaeological remains at varying depths throughout the site. These remains have been broadly subdivided into features relating to the medieval castle, features relating to its subsequent use as a gaol and police station from the late 18<sup>th</sup> century to the mid-20<sup>th</sup> century, and features of unknown date and character.*

## CRYNODEB GWEITHREDOL

*Comisiynwyd Gwasanaethau Archeolegol YAD i gynnal cyfres o arolygon geoffisegol yn ardal y Ward Fewnol yng Nghastell Hwlfordd, Hwlfordd, Sir Benfro (NGR SM 9535 1573). Cynhaliodd YAD arolwg magnetometreg, cynhaliodd GeoArch arolwg gwrthedd, a chynhaliodd SUMO Geophysics Cyf arolwg radar sy'n treiddio i'r ddaear.*

*Pwrpas yr arolygon oedd lleoli, asesu a nodweddu potensial archeolegol y safle i helpu i lywio cynigion datblygu. Mae'r adroddiad hwn yn cyfuno canlyniadau'r tri arolwg.*

*Nododd yr arolygon ystod eang o weddillion archeolegol posibl ar ddyfnderoedd amrywiol ledled y safle. Mae'r gweddillion hyn wedi'u hisrannu'n fras yn nodweddion sy'n ymwneud â'r castell canoloesol, nodweddion yn ymwneud â'i ddefnydd dilynol fel carchar a gorsaf heddlu o ddiwedd y 18fed ganrif i ganol yr 20fed ganrif, a nodweddion o ddyddiad a chymeriad anhysbys.*

## **HAVERFORDWEST CASTLE, PEMBROKESHIRE: GEOPHYSICAL SURVEYS**

### **1. INTRODUCTION**

#### **1.1 Project Commission**

- 1.1.1 DAT Archaeological Services were commissioned by Pembrokeshire County Council to undertake a series of geophysical surveys of a proposed development site within Haverfordwest Castle, Pembrokeshire. The site comprises part of the internal area of the castle ruins, consisting of the Inner Ward, roughly covering an area of 270m<sup>2</sup>, centred on NGR SM 9535 1573 (Figure 1).
- 1.1.2 Haverfordwest Castle was first established in the early 12<sup>th</sup> century, occupying a prominent position within Haverfordwest on a sandstone promontory overlooking the Cleddau River. The present visible castle remains are largely the result of late 13<sup>th</sup> and early 14<sup>th</sup> century redevelopments. After falling into ruins in the 16<sup>th</sup> and 17<sup>th</sup> centuries, the site was re-used as a gaol by the late 18<sup>th</sup> century, until the late 19<sup>th</sup> century, when it was utilised by the police until the 1960s. A number of former gaol buildings were subsequently demolished, and the site (the Inner Ward area of the medieval castle) was landscaped becoming a lawned area with surviving wall footings protruding through the grass. This area is surrounded to the north, east and south by the high medieval castle walls, and to the west by the former gaol governor's house, now housing the town museum.
- 1.1.3 Pembrokeshire County Council have been working with several partners with the aim of creating a Flagship Heritage attraction at Haverfordwest Castle. Current proposals for the development area include the creation of an outdoor events space and an interpretation of the various phases of development that have taken place within the Inner Ward. In order to inform their development proposals Pembrokeshire County Council have requested a geophysical survey of the area to provide further information of the archaeological potential of the site through the identification of subsurface features that could be indicative of archaeology. The aim of the survey is to locate, assess and characterise the potential archaeology through the combined use of magnetometry, resistivity and ground-penetrating radar. Historic plans and photographs indicate a variety of buildings formerly existed within the survey area. The primary aim of the survey is to establish their locations to enable their integration in subsequent development proposals.
- 1.1.4 Haverfordwest castle is now a Scheduled Monument (PE366), with structural remains also a Grade I listed building (Ref.no.12031). The adjacent former Gaol Governor's House is also Grade II listed (Ref.no.12032), as is the nearby former County Gaol building (Ref.no.12033). Consequently the non-intrusive geophysical survey work required consent from the Welsh Government (Cadw) as part of the Ancient Monuments and Archaeological Areas Act (1979), Section 42(2). A detailed Written Scheme of Investigation was produced for the geophysical surveys, and Cadw granted permission subject to a number of conditions, namely:
- That the surveys and reporting shall be undertaken according to the methodology provided on 10/09/2020 [the Written Scheme of Investigation];

- That there shall be no further ground disturbance, other than that of probe penetration;
- That X-Y trace plots and shaded plots should be included in the report;
- That colour-coded interpretation plans shall include appropriate keys;
- That a digital copy of the survey results shall be submitted to Cadw within 3 months of the work being finished.

1.1.5 The geophysical surveys were carried out in three parts. The magnetometry survey was undertaken using a fluxgate gradiometer, which detects variations in the earth's magnetic field, undertaken directly by DAT Archaeological Services on 30/09/2020. The resistivity survey was undertaken with a Geoscan RM15 resistivity meter, which measures variations in the electrical resistance of sub-surface deposits and features. This was undertaken by GeoArch on 01/10/2020. The ground-penetrating radar was undertaken using a Mala MIRA High Density Array, which transmits pulsed high frequency radio waves into the ground, measuring the reflection strength of the waves to detect sub-surface features. This was undertaken by SUMO Geophysics Ltd on 13/10/20.

1.1.6 Individual reports detailing the results of the resistivity survey and the GPR survey have been produced by GeoArch and SUMO respectively. These are included to the rear of the report as Appendix I and Appendix II. This report illustrates the results of the magnetometry survey, and draws together the results of all three surveys into a single report.

## **1.2. Scope of the Project**

1.2.1 The aim of the project was:

- To identify the presence/absence of any potential archaeological features and deposits through magnetometry, resistivity and ground-penetrating radar surveys;
- To establish the character and extent of any potential archaeological remains within the site area and produce a georeferenced plan in appropriate formats combining the results of the surveys;
- To prepare a report and archive on the results of the geophysical surveys.

## **1.3 Report Outline**

1.3.1 This report provides a summary and discussion of the geophysical surveys and its results and puts those results within their regional and national context.

1.3.2 The results of the magnetometry survey are discussed initially, and then a summary of the results of the resistivity survey and ground penetrating radar (GPR) survey are presented. Both the resistivity and GPR survey were undertaken by separate contractors, and both have produced full comprehensive reports on their findings. The full reports are included as Appendices, both of which include detailed information on their methodology, descriptions of their findings, and interpretations. Also included in this report are the results of a previous archaeological evaluation within the study area, undertaken in 2008, as this is of direct relevance to the interpretation of the geophysical results.

## 1.4 Abbreviations

- 1.4.1 Sites recorded on the regional Historic Environment Record (HER) are identified by their Primary Record Number (PRN) and located by their National Grid Reference (NGR). Sites recorded on the National Monument Record (NMR) held by the Royal Commission on the Ancient and Historical Monuments of Wales (RCAHMW) are identified by their National Primary Record Number (NPRN). Scheduled Monument (SM). Altitude is expressed to Ordnance Datum (OD). References to cartographic and documentary evidence and published sources will be given in brackets throughout the text, with full details listed in the sources section at the rear of the report.

## 1.5 Illustrations

- 1.5.1 Printed map extracts are not necessarily produced to their original scale.

## 1.6 Timeline

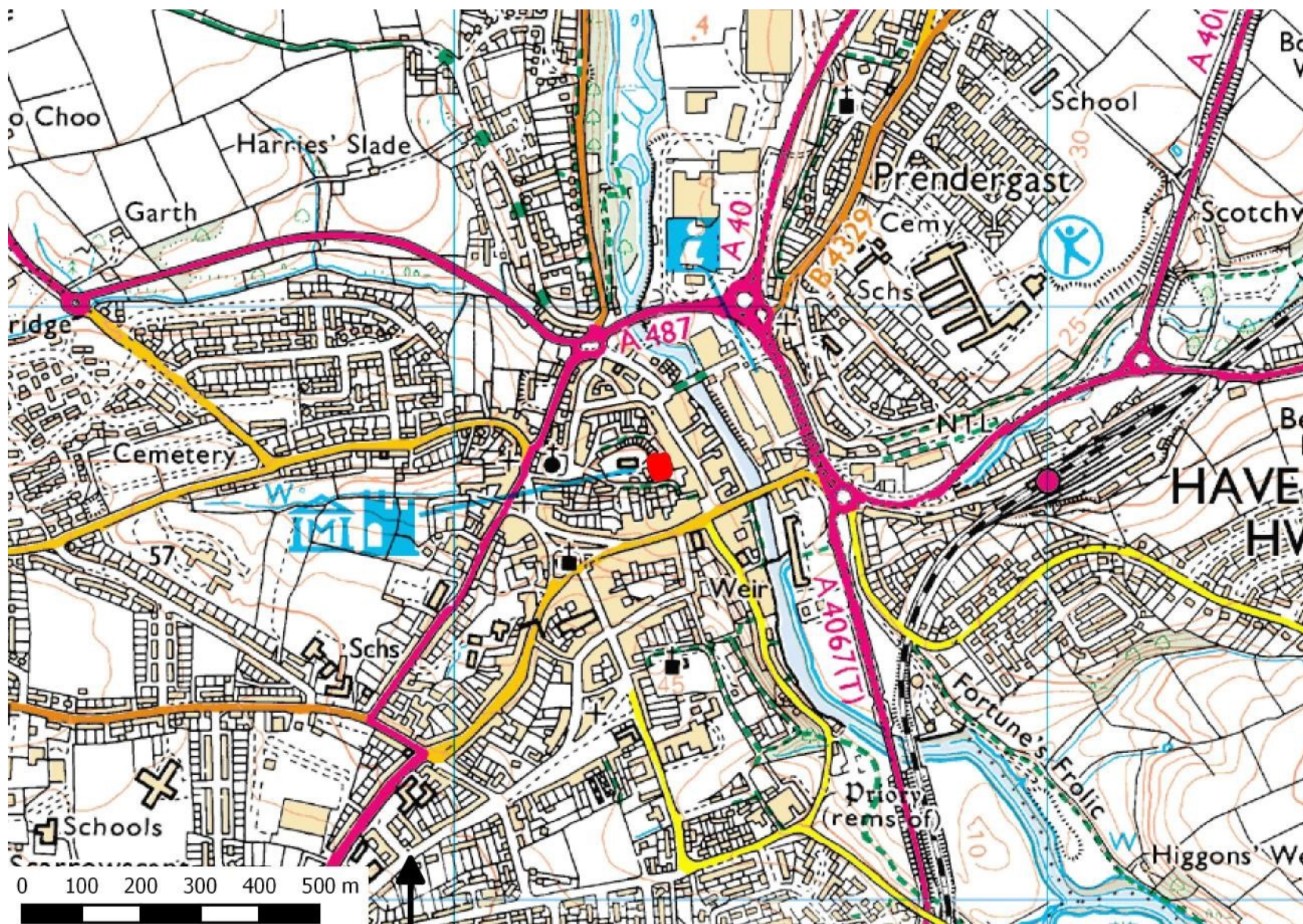
- 1.6.1 The following timeline (Table 1) is used within this report to give date ranges for the various archaeological periods that may be mentioned within the text.

Period	Approximate date	
Palaeolithic –	c.450,000 – 10,000 BC	Prehistoric
Mesolithic –	c. 10,000 – 4400 BC	
Neolithic –	c.4400 – 2300 BC	
Bronze Age –	c.2300 – 700 BC	
Iron Age –	c.700 BC – AD 43	
Roman (Romano-British) Period –	AD 43 – c. AD 410	Historic
Post-Roman / Early Medieval Period –	c. AD 410 – AD 1086	
Medieval Period –	1086 – 1536	
Post-Medieval Period <sup>1</sup> –	1536 – 1750	
Industrial Period –	1750 – 1899	
Modern –	20 <sup>th</sup> century onwards	

**Table 1:** Archaeological and Historical Timeline for Wales

<sup>1</sup> The post-medieval and industrial periods are combined as the post-medieval period on the Regional Historic Environment Record as held by Dyfed Archaeological Trust

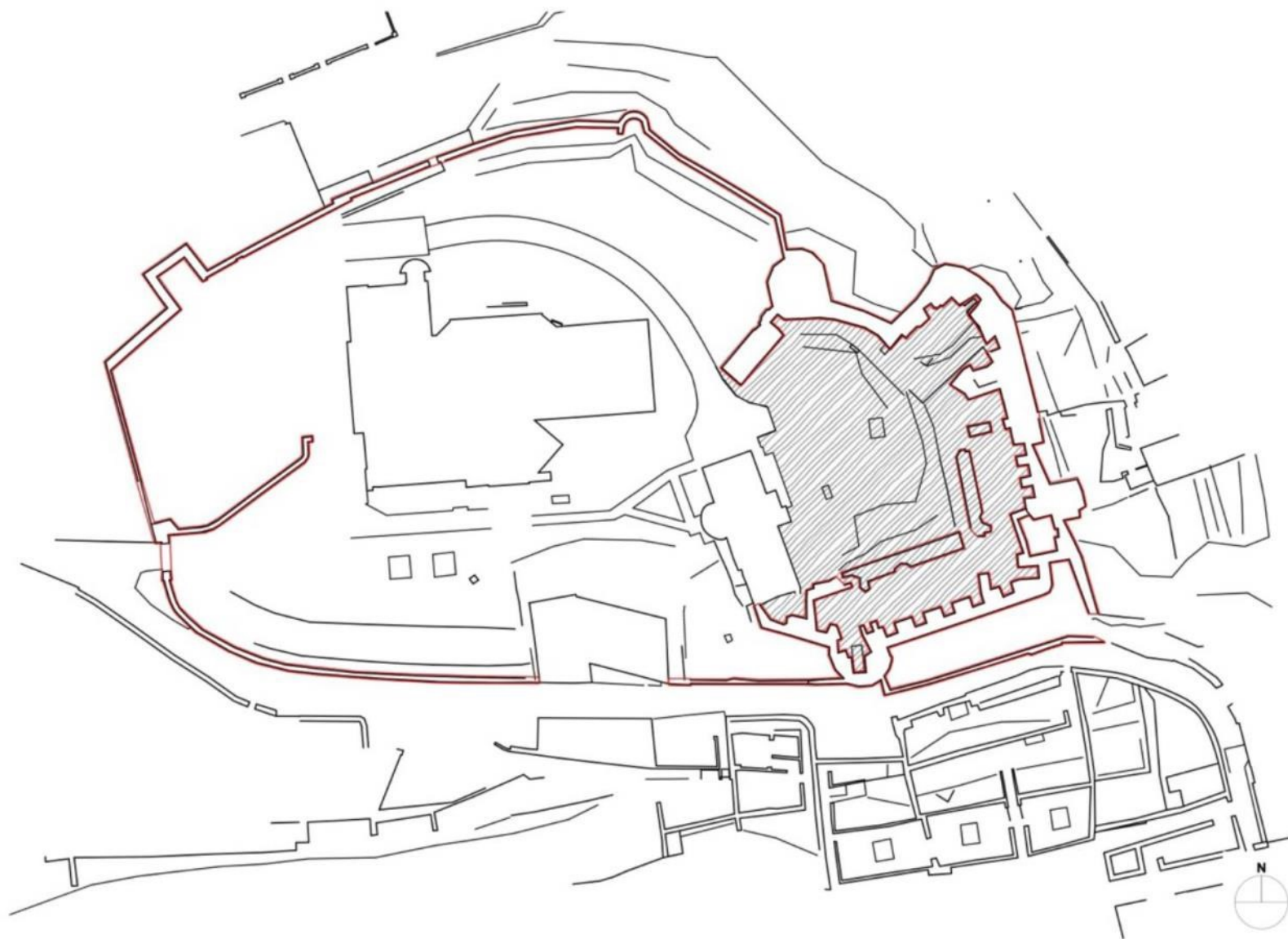




**Figure 1:** Location map of survey area in red.

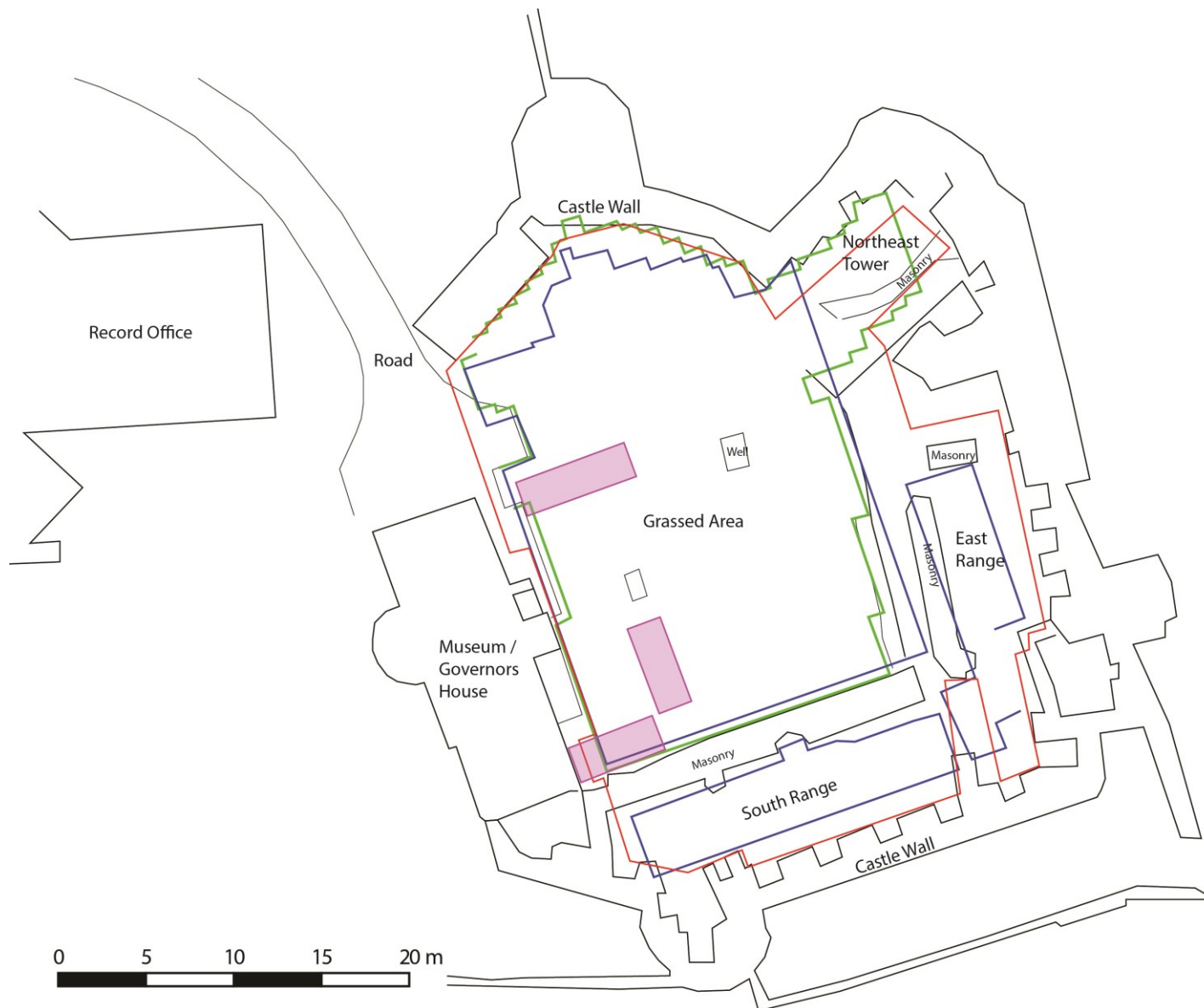
Reproduced from the Ordnance Survey 1:25,000 scale map with the permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright  
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**Figure 2:** Detailed plan of survey area (shaded) within Haverfordwest Castle, plan provided by the client.





**Figure 3:** Location plan showing Inner Ward of the castle and area subjected to geophysical surveys. The extent of the magnetometry survey is outlined in blue, the extent of the resistivity survey is outlined in green, the extent of the GPR survey outlined in red and the location of the evaluation trenches shaded in purple.

## 2. THE SITE

### 2.1 Site Location and Topography

- 2.1.1 The following description of site location and history are taken from research and descriptions carried out by Ludlow (report forthcoming).
- 2.1.2 Haverfordwest Castle (DAT PRN 3320; SAM Pe366) lies at around 23 metres OD at the eastern end of a strong isolated east-west ridge, where it terminates as a steep rocky bluff overlooking the Western Cleddau at its lowest bridging point (Davis 2000, 78; King 1983, 393). The ground falls away on all sides except to the west. A steep slope to the south descends to a watercourse, 'Castle Lake', now culverted beneath the main car park, which separates the castle from the town's High Street. A much shallower slope on the north side descends to the early town. More level ground separates the castle from St Martin's Church to the west.
- 2.1.3 The Inner Ward is a polygonal enclosure of medium size, measuring 40 metres by 40 metres, now with two round towers and two fine ranges of buildings; the whole has been described as 'strong and lofty' (King 1983, 393), but the west side, and all internal walls, have gone. The Town Museum, occupying the former Gaol Governor's House, now forms the west side to the Inner Ward area (Photos 1-3).



**Photo 1:** View southeast across the Inner Ward, with the corner of the museum building on the right.



**Photo 2:** View north, with the outer wall on the East Range on the right, the possible passage wall on the left, and the site of the Northeast Tower to the rear right.



**Photo 3:** View northwest across the Inner Ward, with the East Range wall on the right, the South Range wall on the left, the Museum to the rear left and the Record Office building in the background.

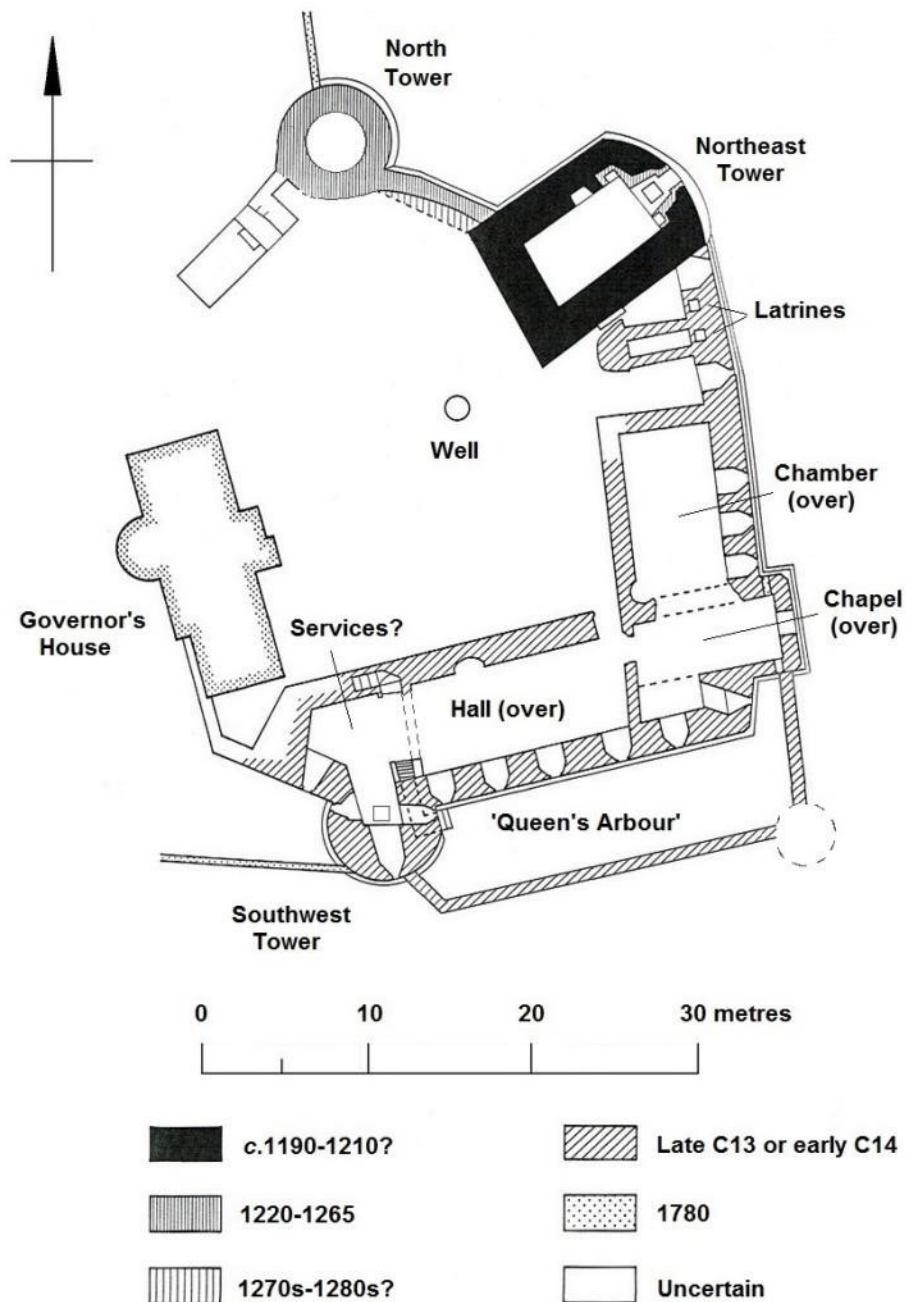
## 2.2 Site History (Figures 4 – 6)

- 2.2.1 Not unusually for a castle, we have no precise dates either for its foundation or its eventual abandonment. Nor can we be entirely sure who was responsible for the bulk of the masonry buildings we see today. However, Haverfordwest Castle was probably founded between 1108 and 1113 by Tancard, a Flemish settler (Davis 2000, 78; James 2002, 432; King 1999, 34; Thorpe 1978, 141-4). From it, the region of Rhos was subdued, and re-organised as the Anglo-Norman lordship of Haverford (Walker 2002b, 161; Rowlands 1981, 144-5, 148). Like most early castles in Wales, it was situated on a navigable waterway to enable supply by sea, and was likely to initially have been a ringwork and bailey.

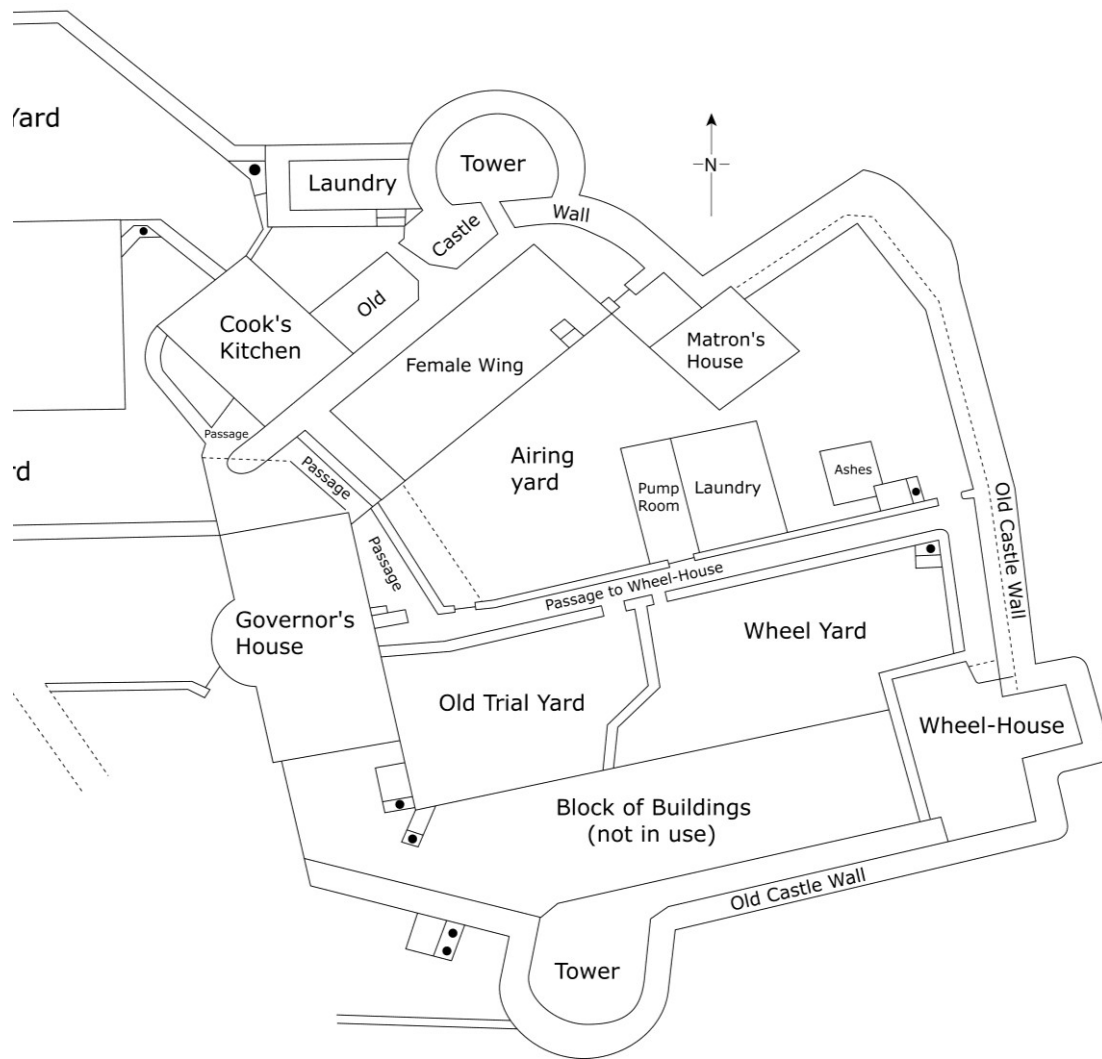
- 2.2.2 Most of the present castle masonry would appear to belong to a period between c.1190 (when the rectangular Northeast Tower of the Inner Ward may have been built) and the early fourteenth century; it is mainly confined to the Inner Ward and includes a palatial ensemble of buildings that are thought to have been built for the Queen of England (Eleanor of Castile) in the late thirteenth century, but may be a little later (completed by Aymer de Valence, Earl of Pembroke). The outer ward defences were probably always slighter than those in the Inner Ward, and may have remained entirely of timber until the early/mid-fourteenth century. The castle changed hands between baronial lords and the Crown on numerous occasions, with many owners being absentee lords, leaving the castle in the hands of deputies and officers. The castle remained however the administrative centre of the lordship throughout the medieval period.
- 2.2.3 Under the Acts of Union of 1536 and 1543 a new county, Pembrokeshire, came into being and Haverfordwest Castle ceased to be the centre of an independent lordship (Charles 1967, 1; Owen 1911, 124 and n. 1) – the first step towards the end of its active life. However, the 1543 Act established Haverfordwest Castle as the main seat of the courts of the Great Sessions for Pembrokeshire (King 1999, 38; Owen 1903, 41, 46; Owen 1918, 203 n.2), prolonging its administrative life a little longer. A survey of 1577 described Haverfordwest Castle as 'utterly decayed' (Owen 1903, 40), but probably in its legal and financial sense rather than with reference to physical decay. The survey is otherwise an invaluable resource which reveals the uses to which the Inner Ward buildings had recently been put (Owen 1903, 40-1): the east range was a chamber-block, a chapel lay at the southeast corner while the Great Hall occupied the south range, with a prison in the Southwest Tower and the 'Queen's Arbour' at its foot. The inner gate was flanked by 'lodges' while a round tower, now gone, lay south of it.
- 2.2.4 Disuse was formalised in 1610 with the permanent removal of its courts, and the establishment of a new County gaol in the town to take its prisoners (Charles 1967, 73, 150, 154; Fenton 1811, 207 n. b; Owen 1903, 41 n. 1). No successful attack is recorded until the mid-seventeenth century Civil War (Davis 2000, 78; Kenyon 2010, 74; King 1981, 10), after which the castle was slighted on Oliver Cromwell's orders. The castle thereafter appears to have remained an empty shell, though still under the control of the County authorities on behalf of the Crown, until 1779.
- 2.2.5 In 1779, the Pembrokeshire authorities established a new County Gaol in the Inner Ward. The medieval South Range was converted to take the prison cells and its inner wall was partly rebuilt. The east range inner wall was also demolished. The Governor's House (now the town museum) overlay the medieval west curtain, which had probably been demolished, at least in part, in 1648. A Debtor's Block was built against the northwest curtain in 1816 (Freeman 1999, 45); features within this wall suggest that the block might similarly have occupied the site of a medieval building. A treadmill was erected in the southeast corner in 1820-1 (Freeman 1999, 48), while the medieval North Tower is said to have been used for executions until 1821 (Phillips 1922, 453 and n. 1). After the Gaol Acts of 1823 and 1865 stipulated the segregation of male and female prisoners (Ireland 2007, 113-14, 116), the Debtor's Block was used as a Female Wing and a Matron's House was built nearby in the late 1860s (Freeman 1999, 46, 50). There were normally between 20 and 40 prisoners, but the figure could rise to 70 or 80 (Freeman 1999, 50).
- 2.2.6 The gaol closed in 1878, The Inner Ward buildings were subsequently occupied by Pembrokeshire Constabulary. The Police remained until 1963 (Ray 1969, 1), when the castle was acquired by Pembrokeshire County Council, in whose hands it remains. The 1820 gaol building in the outer ward was converted to a museum, after 1972 becoming the county record



office. The gaol buildings in the Inner Ward were demolished 1964-7 (Freeman 1999, 51; Ray 1969, 1); the National Monuments Record houses a collection of photographs taken during the work (RCAHM(W) Coflein, NPRN 94235).



**Figure 4:** Phased plan of the Inner Ward area at ground level, showing the projected outline and development of the medieval castle.



**Figure 5:** Plan of the mid to late 19<sup>th</sup> century Gaol, redrawn from a map held in Haverfordwest Record Office.



**Figure 6:** Plan of Haverfordwest County Police Station shortly after its establishment within the Inner Ward, adapted from the Ordnance Survey 1:500 plan of 1889.

### 3. METHODOLOGY

#### 3.1 Magnetometry Survey

- 3.1.1 A fluxgate gradiometer with a DL601 data logger was used to conduct the detailed geophysical survey, which detects variations in the earth's magnetic field. A sample interval of 0.25m (four readings per metre) was used with 1.0m wide traverses across 20m x 20m grids using the parallel traverse method of collecting data. The gradiometers sensitivity was set to detect a magnetic variation in the order of 0.1 nanoTesla.
- 3.1.2 The survey grid was tied into the local Ordnance Survey grid using a Trimble R8s integrated GNSS with TSC3 controller.
- 3.1.3 The data was processed using *Terrasurveyor 3.0.36.1* and is presented at various stages of processing. The presence of high values caused by ferrous objects is clear, and has the potential to hide fine details and obscure archaeological features. As a result the data has been variously



clipped, de-spiked and had a low pass filter applied to remove some of the extreme values to see if finer details show through.

- 3.1.4 The data has been presented in both its unprocessed state, and with various processes applied, as a grey-scale plot, overlaid on local topographical features and an x-y plot. The main magnetic anomalies have been identified, and an interpretation of those results is given.
- 3.1.5 The survey results and interpretation should not be seen as a definitive model of what lies beneath the ground surface, not all buried features will provide a magnetic response that can be identified by the gradiometer. In interpreting those features that are recorded the shape is the principal diagnostic tool, along with a comparison with known features from other surveys. The intensity of the magnetic response could provide further information, a strong response, for example, indicates burning, high ferric content or thermoremnancy in geology. The context may provide additional clues, but the interpretation of many of these features is still mostly subjective.
- 3.1.6 All measurements given will be approximate as accurate measurements are difficult to determine from fluxgate gradiometer surveys. The width and length of the identified features can be affected by its relative depth and magnetic strength.
- 3.1.7 The overgrown hedge boundaries that extended into the development area reduced the area accessible for survey (Figure 3).

### **3.2 Resistivity Survey**

- 3.2.1 The resistivity survey was undertaken by Dr.T.P.Young of GeoArch, using a Geoscan RM15 resistivity meter, operating a 'parallel twin electrode' configuration, employing two pairs (three electrodes) with 0.5m probe spacings placed at 0.5m centres on a PA5 frame, via an MPX15 multiplexer.
- 3.2.2 The full methodology is outlined in Appendix I.

### **3.3 Ground-Penetrating Radar Survey**

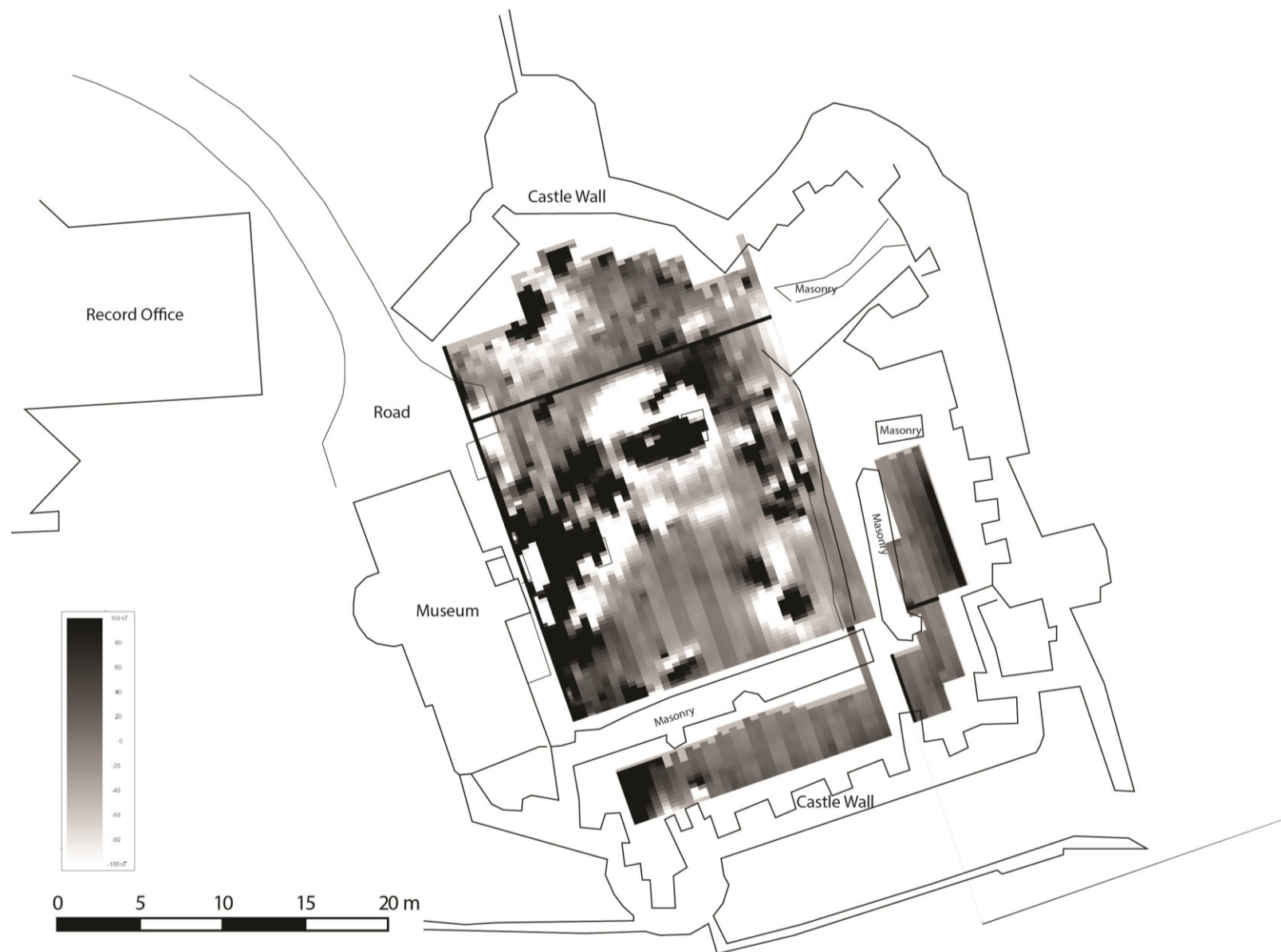
- 3.3.1 The GPR survey was undertaken by SUMO Geophysics Ltd, using a Mala MIRA High Density Array on parallel traverses at 0.08m intervals, using a sample interval of 0.05m.
- 3.3.2 The full methodology is outlined in Appendix II.

#### **4. MAGNETOMETRY RESULTS (Figures 7-10)**

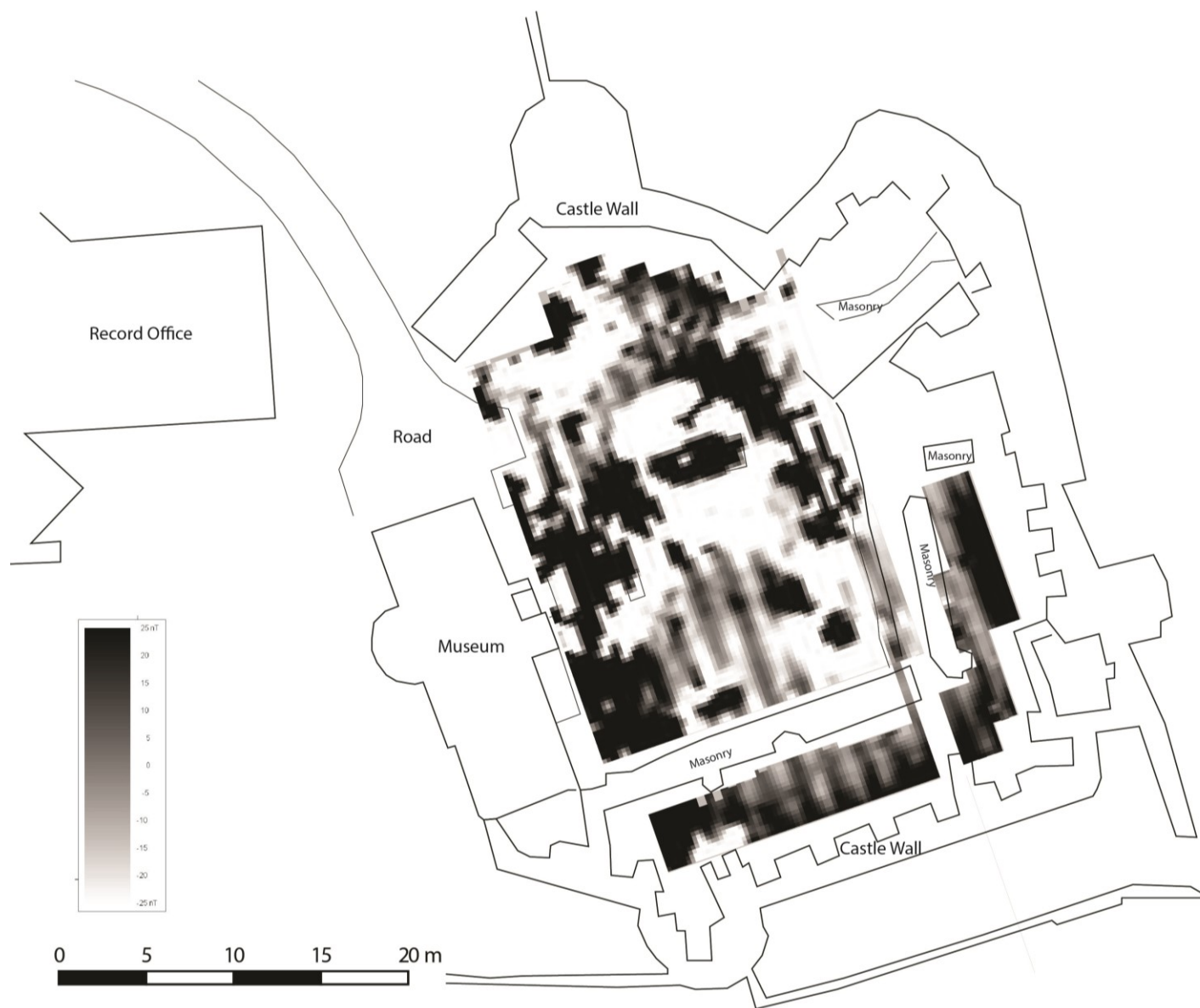
- 4.1 The geophysical survey results are presented as a series of grey-scale plots in Figures 7 – 10. As a result of the very high readings and the comparatively small area surveyed it was not possible to produce a legible x-y trace plot. In total, an area of c.0.7ha was surveyed, which included the majority of the grassed area, the gravelled area along the southern edge representing the interior of South Range, and part of the gravelled area along the eastern side within the East Range. Areas of sloping ground and upstanding masonry meant some area were inaccessible to surveying. The results displayed some very strong magnetic signals, which tends to produce large 'shadows', obscuring readings in their vicinity and tending to make interpretation of individual features in such a relatively small area difficult. However, several features were determined from these results and are shown on Figure 10; with individual reference numbers given in rounded brackets in the following descriptions.
- 4.2 Along the northwest edge of the survey area a strong dipole is visible (1), potentially caused by a large ferrous object or objects, or objects close to the surface. At various stages of processing this appears to be confined to a rectangular area (2) along the northwest wall, corresponding roughly to a former gaol building (the Debtors Block/Female Wing). Immediately to the northeast lies another strong, but potentially smaller, dipole reading (3), potentially also confined to the former building limits.
- 4.3 Against the northeast wall are a series of strong, largely positive readings (4), fronted by areas of potential discrete positive readings. These readings vary quite widely from around -0.5nT (but as much as -35nt) to 25nT (but as high as 90nT). Generally such positive readings can be indicative of cut features, such as ditches, pits and so on, however due to the general high readings across the area and in the background readings, it is difficult to ascertain if these relate to individual features or represent an area of activity. Given the potential for building and demolition debris in this area, such reading may relate to a spread of building material.
- 4.4 In the northeast part of the survey area, approaching the site of the Medieval Northeast Tower, are two relatively large areas of strong readings, one positive (darker responses) and one negative (lighter responses). The negative readings (5) to the northeast appear to correspond roughly with the edge of a medieval tower and site of a later gaol/prison building (Matrons/Sergeants House). The strongest readings are on the very edge of the surveyed area, suggesting the feature they relate to may be just beyond the surveyed area. The positive readings (6) vary from around 75nT to 100nT+, although the results are slightly overshadowed by a stronger feature immediately to the southwest. Such readings may represent a large cut feature, given the context potentially a buried cellar or similar.
- 4.5 In the centre of the site lies the well, covered by a metallic grate. The grate is anticipated to give a strong response in the readings, and this is visible as a strong dipole reading (7) centred on the well. Immediately to the west however is a similar, more extensive response (8), indicating further possible ferrous objects not visible on the ground surface. The reading is also similar to sites of intense heat activity, such as kiln sites, but in this instance may be related more to a large metallic object (see interpretation). The strength of these readings cast large 'shadows', making it difficult to distinguish individual features in this area.
- 4.6 A series of strong dipolar readings lie to the west, the strength of the readings making them difficult to identify individual features, however it is known from the previous evaluation results that lead water piping lies in this area, and this would appear to represent a linear feature (9) heading

northeast to southwest, towards the rear door of the museum building. Further discrete dipolar readings do appear to lie adjacent, however, (10), and a further potential linear feature (11 - potential piping) lie to the south, running in a more east – west direction.

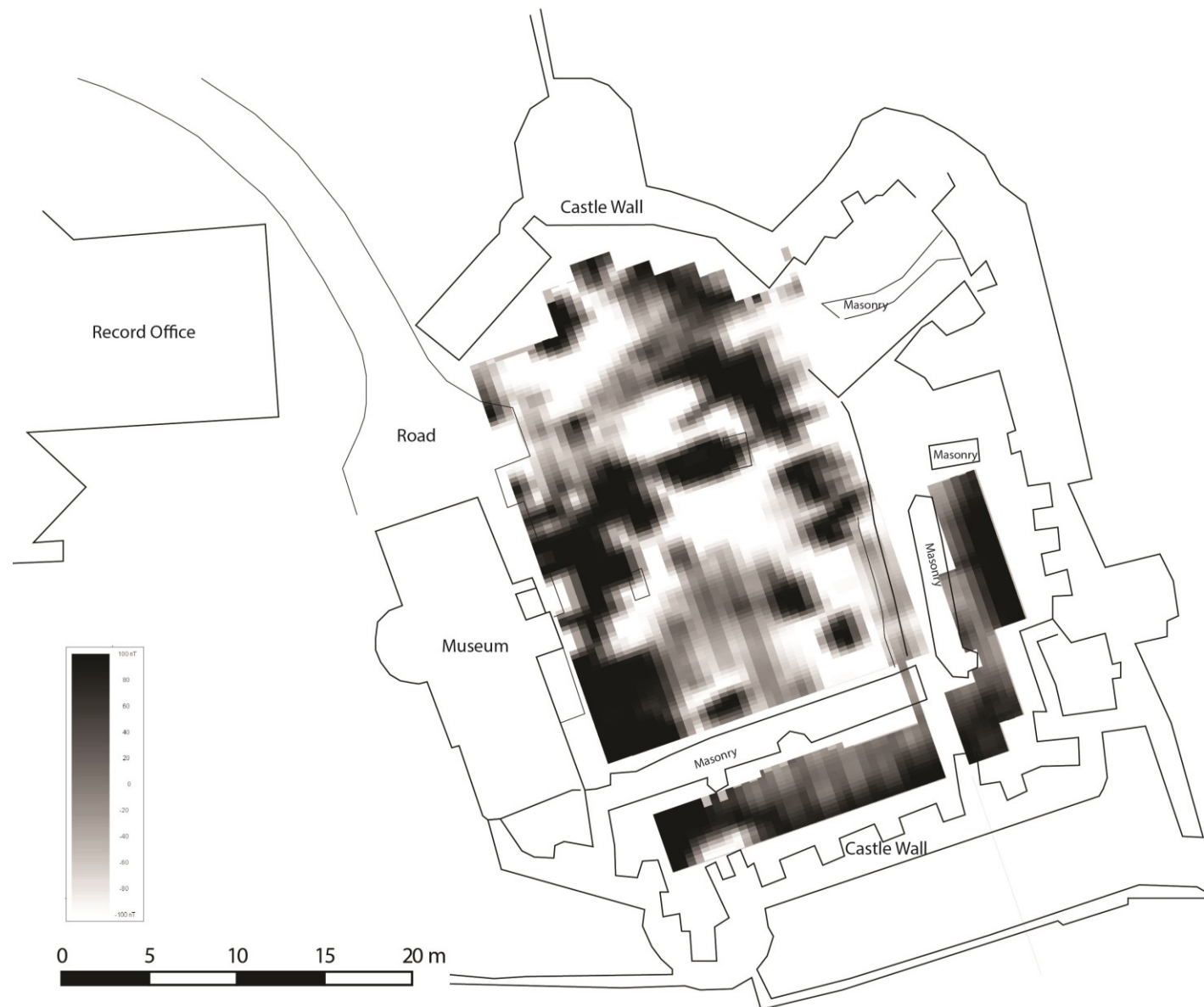
- 4.7 Against the eastern side of the grassed area is an area of strong dipolar readings (12), from -90nT to 100nT+. These readings appear relatively mixed, potentially caused by a concentration of ferrous objects or possibly indicative of an area of concentrated activity and disturbance.
- 4.8 To the south lies three discrete and distinct strong dipolar readings (13). These may be individual objects with a high magnetic content, such as metallic items or highly fired objects, rather than specific features.
- 4.9 There are a series of strong readings against the western side of the area. An area of strong negative readings to the northwest (14) appears to correspond to the modern tarmac surface in this area and is therefore presumably representative of modern disturbance. To the south is a large area of strong dipolar readings (15). This lies in front of the rear door to the museum and therefore appears in part to correspond to metal grills over this rear entrance, but it also lies in an area of potential underground service pipework, and may therefore also represent an area where buried services converge. To the south of this there is an area of generally positive readings (16). This corresponds to an area investigated as part of the 2008 evaluation, and electricity cables were noted along the western edge. It was also suggested a potential area of earlier 20<sup>th</sup> century excavations lay nearby, which could account for these readings. To the east of this a more discrete dipolar feature is noted (17) close to the upstanding wall remains, potentially representing an object with ferrous content.
- 4.10 To the south of the wall along the southern edge of the survey area, within the former South Range, the western side of the area produced some strong positive readings (18). Positive reading are often indicative of cut features, however the strength of these readings suggest it may be related to ferrous objects, potentially extended readings from metallic herras fencing that enclosed the southwest corner of the site. A strong negative reading (19) to the east appears focused on the entranceway into the wall to the south and may therefore be related to modern metallic wall fixtures. A discrete reading lies adjacent (20), the bipolar reading suggesting a buried metallic object.
- 4.11 A large area of strong positive readings (21) were noted in the small area surveyed in the former East Range. These were strongest (up to 98nT) along the eastern edge of the surveyed area, reducing gradually in strength to the west. Wall openings have metallic covers to the east but should be at sufficient distance not to cast such a shadow on these readings, which may therefore be related to buried remains along the eastern edge of the surveyed area.



**Figure 7:** Magnetometry survey results, presented as a grayscale plot with grid lines visible, otherwise unprocessed.



**Figure 8:** Magnetometry survey results, presented as a grayscale plot, clipped to +/-25nT.



**Figure 9:** Magnetometry survey results, presented as a grayscale plot with a low pass filter applied.

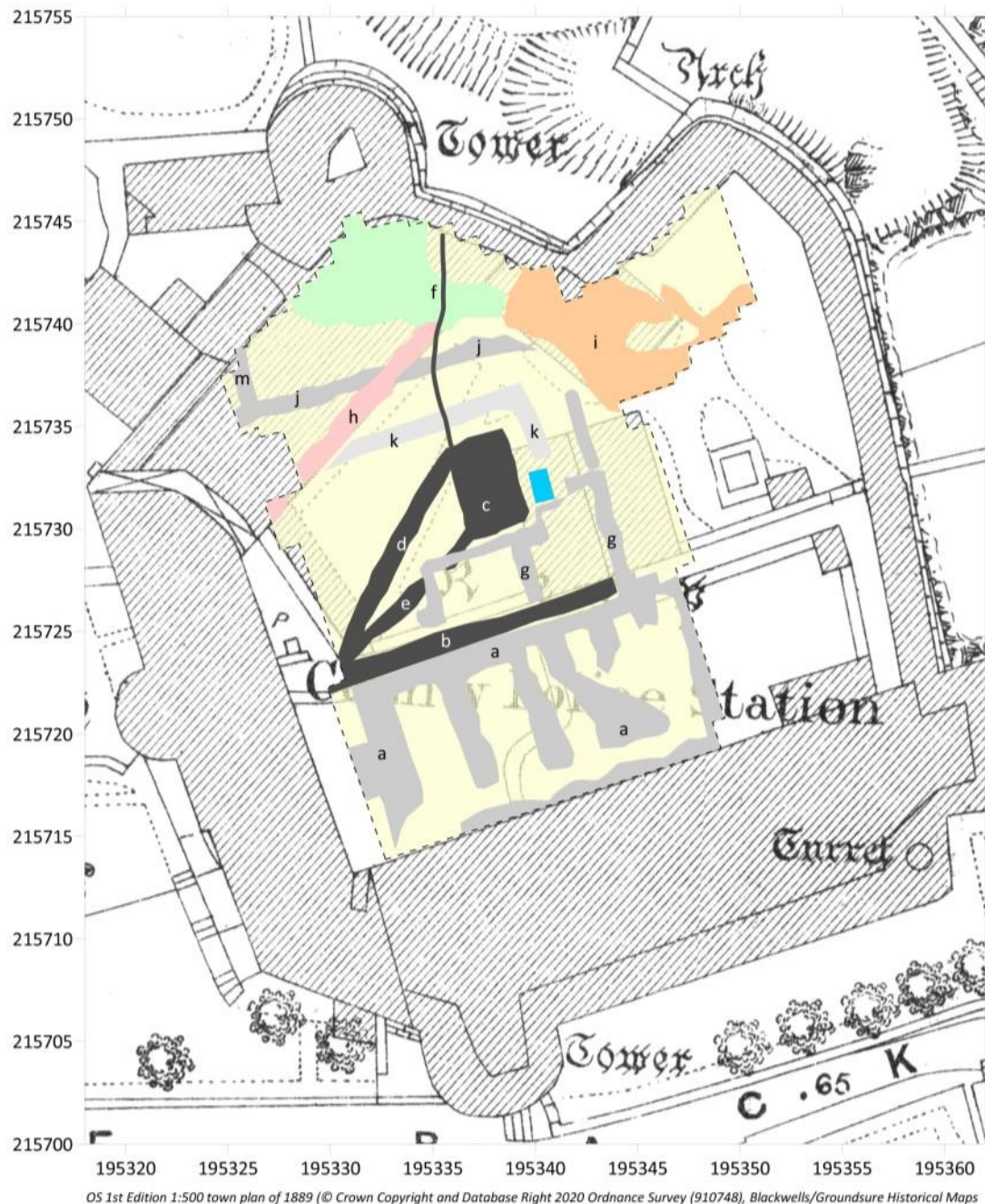


**Figure 10:** Interpretation layer of the magnetometry results. Numbers referred to in Section 4.



## **5. RESISTIVITY RESULTS (Appendix I, Figure 11)**

- 5.1 The resistivity survey was carried out by Dr T.P.Young using a twin probe configuration at 0.5m and 1.0m mobile probe spacing. The full report on the survey results is provided in Appendix I. The following is taken from the Abstract, summarising the results of the resistivity survey, but for the full description of the results and interpretation please refer to Appendix I.
- 5.2 The survey revealed anomalies in locations corresponding to mapped features of the prison, including a linear negative corresponding to the central passageway between the yards, a linear positive feature corresponding to the SE wall of the women's block, and a large positive area anomaly corresponding to the location of the matron's house (although this may potentially owe more to the underlying medieval structure forming part of the early keep).
- 5.3 Also revealed was a large negative anomaly adjacent to the location of the well, 4.6m NS x 3.3m EW, which is provisionally interpreted as a water tank, connected to other parts of the prison by linear negative features suggestive of service trenches.
- 5.4 The southern part of the area (bounded to the north by the central passageway) is characterised by a high-resistivity area with a rather complex internal structure. This appears rather more resistive and more complex than might be expected of the yards that occupied this area in the prison period. The level and strength of these anomalies could possibly be indicative of a medieval cellar or undercroft, but alternatives are also offered.
- 5.5 To the north of the area, several anomalies with raised resistivity traversed the survey area approximately parallel to its baseline. Although an origin for these anomalies within the medieval archaeology cannot be excluded, it is tentatively suggested that these anomalies are more likely to be indicative of structures from the early phase of the prison, between 1779 and 1820, and removed to create space for the 1820 phase.
- 5.6 The survey thus indicates that there is considerable survival of archaeological remains within 1.5m of the surface across the lawn area.



**Figure 11:** Reproduced figure from the resistivity survey (Appendix I - Figure 10), showing interpretation of resistivity data. The full range of resistivity survey results, and a full description of the interpreted features, are included in Appendix I.

- Pale grey tone shows positive resistivity anomalies (a, g, k, j, m) that are aligned in directions probably associated with the earlier prison buildings (c.1779), in turn influenced by the orientation of the medieval structures of the south range.
- Dark grey tone indicates negative resistivity anomalies interpreted as a water tank (c), trenches for water pipes (e and ?d) and paths (b and d).
- Blue rectangle shows the location of the well.
- Pink tone (h) shows a positive resistivity anomaly interpreted as the SE wall of the c.1820 women's block.
- Orange tone (i) shows the very strong positive resistivity anomaly associated with the location of the 'matron's house', itself probably resting on medieval footings.
- Green tone, unlettered, diffuse positive resistivity anomaly, perhaps fallen masonry?

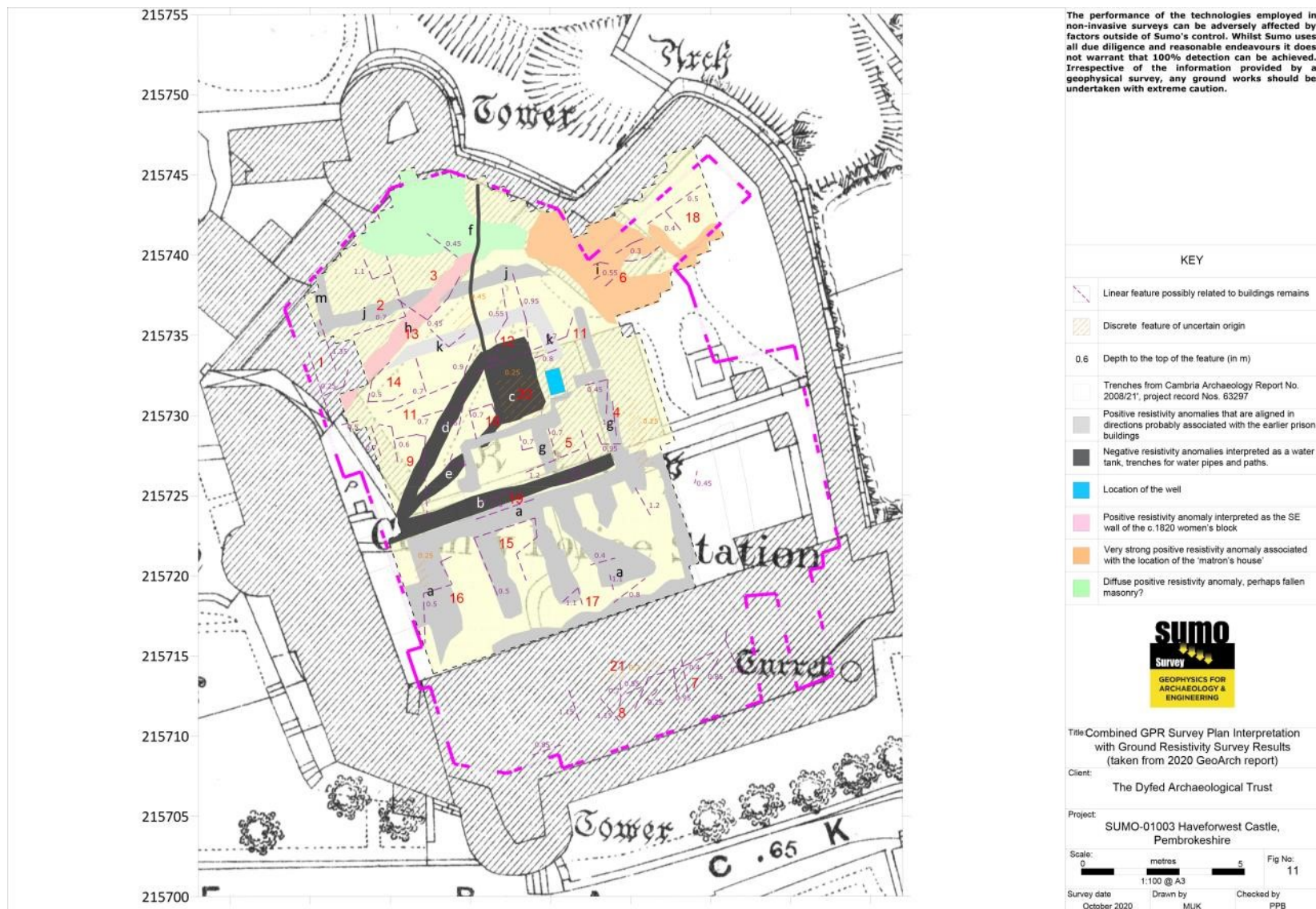
## **6 GROUND PENETRATING RADAR RESULTS (Appendix II, Figures 12 & 13)**

- 6.1 The Ground Penetrating Radar survey was carried out by SUMO Geophysics Ltd. This was undertaken using a Mala MIRA High Density Array, along parallel traverses with 0.08m intervals, using a sample interval of 0.05m. The full report of this survey is included in Appendix II, the results of the resistivity survey, and preliminary findings from the magnetometer survey, were made available during the production of this report. The following is taken from the Executive Summary, but for the full description of the results and interpretation please refer to Appendix II.
- 6.2 Survey results identified two categories of potential archaeological significance, a substantial number of linear features and five discrete features.
- 6.3 Linear features have systematic linear, rectilinear and geometric patterns suggestive of building outlines, walls and other angular structural features. The linear features appear to represent the Inner Ward of the castle as shown on a 1577 plan, as well as later prison buildings shown on an 1889 plan of the castle. Many of the linear features were located inside former prison buildings including the Female Wing, Pump Room, Laundry and Matron's House. Some are suggestive of building outlines and walls and may be associated with internal structures. Others are aligned discordantly and may relate to earlier phases of activity.
- 6.4 Groups of linear features were also found in external areas of the prison including the Airing Yard, Old Trial Yard and Wheel Yard. It is uncertain whether they relate to the earlier or later prison periods or may even predate the prison.
- 6.5 A cluster of linear features detected in the Hall area as shown on the 1577 plan, display trends broadly parallel to the wall orientations, possibly suggesting an association with this period of occupation.
- 6.6 Five discrete features have regular geometric shapes suggestive of a man-made origin. One correlated to a postulated water tank identified by the resistivity survey and another was inside the old Hall. The others are not obviously connected to any of the former buildings and are of uncertain origin.



**Figure 12:** Reproduced figure from the GPR survey (Appendix II - Figure 06), showing interpretation of GPR data. The figure shows the features identified, and the depths at which they were encountered. The full range of GPR survey results, and a full description of the interpreted features, are included in Appendix II.





**Figure 13:** Reproduced figure from the GPR survey (Appendix II - Figure 11), showing interpretation of GPR data combined with the results of the resistivity survey, and overlaid on the 1889 Ordnance Survey map. The full range of GPR survey results, and a full description of the interpreted features, are included in Appendix II.

## **7 ARCHAEOLOGICAL EVALUATION RESULTS (Photos 4 – 6)**

- 7.1 In 2008 an archaeological evaluation (Crane & Wilson 2008) was undertaken by Cambria Archaeology (the trading name of Dyfed Archaeological Trust at the time), which comprised three small trenches, each measuring 5m by 2m, excavated within the Inner Ward area. The locations of the trenches are shown in Figure 3.
- 7.2 Trench 1 (Photo 4) was located towards the southwest corner of the grassed area, against the southeast corner of the museum building. The earliest features revealed within this trench comprised a small, heavily truncated section of mortared stone wall, aligned roughly north – south, at least 0.9m wide and surviving to a height of over 1m. The wall appeared structural, containing remains of a relieving arch. It was considered likely that this represented a fragment of medieval walling. To the east lay another fragment of mortared masonry, bonded with a similar mortar, but also heavily truncated. This was considered to be of similar medieval date, but possibly represented collapsed masonry.
- 7.3 A mortared stone lined drain ran roughly east – west along the southern part of Trench 1, which appeared to be later than the masonry structures, as it truncated both. This was considered to be post-medieval in date, and it was suggested it may have served the latrines in the southwest corner of the old gaol trial yard. A brick and concrete step lay at the western end of the trench, with some concrete footings for a later fence post above, and electricity cables ran north – south along the western end of the trench, close to the rear wall of the museum.
- 7.4 Trench 2 (Photo 5) lay just to the northeast of Trench 1, aligned parallel to the rear wall of the museum. The earliest deposits uncovered were found at the north and south end of the trench, and comprised layers containing a lot of crushed mortar. This was considered to be a post-medieval deposit. A small stone-lined drain was uncovered towards the southern end of the trench, running roughly east – west. This was cut by a large feature, which extended the full length of the trench, the base of which was not revealed. This may have been a result of previous excavations in the area documented in newspaper reports, carried out initially by the gaol governor in 1871, or later excavations in 1914. Remaining deposits appeared to be Victorian in date, including a small pit, potentially related to Victorian landscaping. Modern electricity cables were also uncovered at shallow depths.
- 7.5 Trench 3 (Photo 6) was located to the north, aligned east – west in line with the northern gable wall of the museum. Shale bedrock was encountered at relatively shallow depths (0.25m), overlain by a natural subsoil. The earliest feature appeared to be a shallow posthole, undated but thought likely to be earlier, and potentially therefore medieval. Two lead-water-pipe trenches were uncovered. The earliest, with a partly removed pipe, running roughly east – west before doglegging to the south. This was cut by a later pipe running northeast – southwest. Along the northern side of the trench lay a cavity brick wall, running roughly east – west, and thought to be a relatively recent feature, possibly mid-20<sup>th</sup> century. This wall was cut by the concrete foundations for some modern wooden fence posts.





**Photo 4:** West facing view of Trench 1, with a masonry blocked in the foreground, and wall 111 behind the 1m scale, both considered to be medieval in date.



**Photo 5:** East facing view of Trench 2, the later stone-lined drain visible on the right. 1m scale.





**Photo 6:** West facing view of Trench 3, the lead-pipe trench visible along the centre of the trench, and brick wall to the right.

## **8 DISCUSSION (Figures 14 – 17)**

### **8.1 General (Figure 14)**

- 8.1.1 The results of the various investigations outlined above have indicated a variety of potential archaeological features below the current surface within the Inner Ward area of Haverfordwest Castle. The investigations have been able to provide an indication of the form, character and depth of such features. It is possible to compare many of these identified features to mapped accounts of the site to draw out likely functions and dates for some of these features. As shown in Figure 14, when mapped together these features provide a complicated picture of activity, however, for ease of understanding these have been drawn into three broad categories based on general date ranges. These categories cover broad date ranges, and features highlighted within them may not necessarily have been contemporary.
- 8.1.2 These categories are discussed below but in summary comprise:
- Features associated with the main castle structure, i.e. medieval in date, many of which were re-used and re-purposed well into the 20<sup>th</sup> century.
  - The period of use as a gaol and police headquarters, dating from the late 18<sup>th</sup> century through to the mid-20<sup>th</sup> century.
  - Features of unknown date. Suggestions can be made about some of these features, but a large degree of uncertainty remains. It is clear from the survey results that such features occur at a variety of depths throughout the site.

### **8.2 Medieval (Figure 15)**

- 8.2.1 A phased plan of the potential layout of the medieval Inner Ward area is illustrated in Figure 4. Some medieval remains are still clearly visible, the site is surrounded by high medieval walling largely dating to the 13<sup>th</sup> and early 14<sup>th</sup> centuries, and within the survey area masonry remnants of part of the Northeast Tower, East Range and South Range are exposed. Features of a potential medieval date are illustrated in red on Figure 15. Visible structures are shown in solid red, below-ground features identified from the surveys are shown in pale red, with projected outlines of structure shown as dotted lines.
- 8.2.2 The internal walls of the Northeast Tower were revealed during the demolition and landscaping works of the 1960s (see Coflein NPRN 94235). These outer walls are still partially exposed and visible at ground level (1), allowing the outer limits of the tower to be projected. The southwest wall is not fully visible at ground level, both resistivity results and magnetometry results record some strong readings in this area, which may potentially be associated with a rubble spread, although equally they appear to coincide with the later, post-medieval, Matron's/Sergeant's House (see 8.3). The GPR results identified some possible walling remains (2), indicated by the linear nature of the readings, on a similar alignment to the southeast wall of the tower. These remains were relatively shallow, at a depth of 0.4m to 0.5m, and may represent internal walling within the tower.
- 8.2.3 The East Range comprises two chambers, with a chapel to the south. Upstanding masonry remains mark the outer walls of the chambers (3), and a further low wall (4), which currently acts as a retaining wall to the grassed area, may mark the inner edge of a passageway along the inner face of the East Range. The upstanding masonry allows the wall lines to be projected, although they largely do not appear clearly on the survey results, instead it would appear likely they were truncated by the post-medieval activity. Resistivity results indicated an area of increased resistivity along the western face of this passage/retaining wall (4), which may be an indication of associated tumbled masonry. However, the resistivity survey does suggest a series of linear marks (labelled 'a' on Figure 11) in the southern part of the grassed area, which may be an indication of below-ground cellars, part of a medieval structure across this area. As a possibility there are reasons for and against this

idea. Traditionally the interior area of the ward would be left open, although a brief description from 1577 of a 'greene of lxx [70] foote square having a Well in it' (Owen 1903, 41) may still allow for further medieval buildings in this area, however this same description of the Inner Ward makes no mention of buildings in front of the South Range. Newspaper accounts document excavations in this area, in 1871 and again in 1914, that appear to reveal a deep cellar, occupying a triangular area between masonry walls, the apex of which lay 'just in front of the inner wall of the old prison' (Pembrokeshire County Guardian 10/7/1914). The exact location of these excavations is unclear as no official accounts have been located, it is however variously described as the open area to the rear of the prison governors house (the current museum building), and in the 'quadrangle' immediately to the rear of the building. An area south of the well, and between museum, East Range and South Range would appear most likely. A large cut feature revealed in the archaeological evaluation (Trench 2) was suggested as the result of these excavations, which would coincide with a general area of reduced resistivity. GPR also suggests a linear nature to some features surrounding this area, suggesting a surrounding built structure, which could add weight to the possibility of cellars in this area. However, given the uncertainty surrounding these interpretations this is illustrated in Section 8.4 and Figure 17 below.

- 8.2.4 A fragment of walling (5) uncovered in the evaluation trench (Photo 4) was suggested to be medieval in nature, and does not appear in gaol or police station plans. This walling appears to be on a roughly north – south alignment, and it is possible this mirrors the internal passage along the East Range, suggesting a possible medieval West Range, now lying underneath the museum building. Fragmentary masonry nearby (6) in the same evaluation trench is also thought to be medieval in date. A small post-hole revealed in Trench 3 (10) is also assumed to be an early feature, and therefore potentially medieval in date. This latter feature was revealed at a shallow depth of c.0.25m, cut into underlying bedrock, with the masonry exposed to a depth of c.1m, but continuing in depth.
- 8.2.5 The South Range is marked by upstanding masonry remains along the southern edge of the grassed area (7). Within the South Range the GPR survey identified a number of linear features, and anomalous features. Many of the linear features (8) shared an approximate similarity in alignment with internal cross walls within this range, and may therefore represent internal divisions, at depths of between 0.55m to 1.15m. Photographs of the demolition and consolidation works undertaken in the 1960s (Coflein) indicate some depth to the structure along the South Range, and therefore stratified archaeological deposits and wall divisions may survive in this area.

### **8.3 18<sup>th</sup> – 20<sup>th</sup> century (Figure 16)**

- 8.3.1 In 1779 a County Gaol was established within the Inner Ward area, which led to the re-use of the South Range, the demolition of the East Range, the construction of a new Governors House over the western wall and a Debtors Block built against the northwest curtain wall in 1816. In 1820 the gaol expanded with a new block built in the outer ward (the current Record Office building). In the 1860s the Debtors Block became the Female Wing, and a Matron's House was built nearby. In 1878 the gaol moved to different premises, and the site was taken over by the Pembrokeshire Constabulary, who retained the site until 1963. There are a number of plans of the gaol and subsequent police station available dating to the later 19<sup>th</sup> and early 20<sup>th</sup> century (see Figures 5 & 6 for examples), which allows many of the surveyed features to be ascribed to specific buildings and activities associated with this period of 18<sup>th</sup> to 20<sup>th</sup> century activity. Below-ground features from this period are illustrated in Figure 16 in pale blue, with probable wall lines given a solid edge. Features identified only from later plans of the Police Station (post-1878) are shown as pale green. The projected outlines of buildings identified from historic plans are shown as dotted lines.
- 8.3.2 The Debtors Block/Female Wing lay in a large rectangular building built against the northwest wall of the Inner Ward, which remained as prison cells during the later use

of the site as the police station. The outer wall of this building is visible on all three surveys, although more clearly depicted on the resistivity and GPR results, which suggests intact structural remains buried at a depth of around 0.45m (1). Internal divisions are marked on a plan from the 1920s, and two internal wall divisions (2) are suggested on the GPR results at a similar depth to the outer wall. The magnetometry results record some very high readings (3) from within the building, the strength of the readings suggest some substantial ferrous items are buried in this area. Both resistivity and GPR surveys also indicate several linear features, and spreads of material across this area. Many of these linear features are at different angles suggesting they are not related to the prison/police building, these features are discussed further below (Section 8.4, Figure 17).

- 8.3.3 To the east of the Debtors Block/Female Wing stood the Matron's House, which subsequently expanded to the northwest and became the Sergeant's House when the Gaol became the Police Station, before being used to store armaments in the early 20<sup>th</sup> century. This building was built against and potentially over, the southwest wall of the medieval Northeast Tower, which may account for the lack of obvious surface remains of the tower wall in this area. The GPR survey identifies one linear feature (4) at a depth of approximately 0.55m which appears to align with this building, and may represent an internal wall. Both the resistivity and magnetometry surveys indicate spreads of material (5) in this area that would appear to correspond to the layout of the Matron/Sergeant's House, which suggests possibly spreads of rubble or associated archaeological deposits, and potential obscured flooring and structural remains, relating to this structure.
- 8.3.4 To the south the area was effectively subdivided by an east – west passageway. North of the passageway stood the Airing Yard, with buildings surrounding the location of the well, and further structures against the west side of the yard, and southeast corner of the yard. The structures around the well are divided into two adjoining buildings, a Laundry on the east side, with a Pump Room on the west, enclosing the site of the well (alternatively labelled as the Well House on other plans). The Pump Room/Well House is depicted on all survey results (6). The metal grill covering the well somewhat obscuring any fine detail on the magnetometry results, but resistivity indicating linear structures to the east, west and north, and the GPR results suggesting linear features that may represent the buried walls of the Pump Room/Well House at the north and south ends at depths of around 0.7m to 0.8m. The adjoining Laundry is less well-defined, although resistivity and GPR suggests linear features that may represent an internal wall (7), although there are also likely to be a range of pipework and drains associated with the site. The magnetometry indicates an area of activity roughly coinciding with the plotted outline of the building, with GPR also indicating activity at a depth of approximately 0.25m.
- 8.3.5 Adjoining the Pump Room/Well House to the northwest the resistivity survey identified a rectangular feature (8), fed by services (identified through the evaluation excavation as at least one, possibly two, lead water pipes (9)), which given the location therefore suggested a water tank. The magnetometry results suggest a large metallic item, and the GPR results suggest the southern part of the feature lies only 0.25m below the current ground level. Resistivity also suggested further linear features both to the south and north. Those to the south did not appear on the GPR results, although two square-sided features at a depth of about 0.7m were apparent (10). This may be an arrangement of further services, and potential small structural features associated with this area of laundry activity. A further service trench is suggested on the resistivity results running north (11) from the water tank, potentially feeding the prison block to the north, although as this does not appear on the magnetometry results it may be missing its pipework. Some service trench pipes also appear to correspond to pathways shown on Gaol and Police Station plans, and it is possible the surveys are identifying path surfaces instead of services. GPR results identified two straight-sided features to the north (12), both at around 0.45m to 0.5m below the ground surface. The regular nature would suggest structural features, but they also appear to respect the prison building wall and may therefore be contemporary features.

- 8.3.6 The central passageway that subdivides the area is visible on old photographs as a high boundary wall, with a central passageway, extending from the rear of the museum to the east curtain wall, across the line of the demolished medieval East Range. Remains of this passageway and its boundary walls (13) have been picked up on all surveys. The resistivity notes a marked change to the north and south of this line, the magnetometry suggests an east – west linear roughly in line, and the GPR survey depicts linear features at depths of between 0.5m to 0.7m, up to 1.2m deep in places, which would appear to align with the path and sections of the flanking walling.
- 8.3.7 To the south of the central passageway the resistivity survey in particular produced some intriguing results which have been discussed in the Medieval section above, and a number of features are identified on the GPR and magnetometry surveys, but it is difficult to ascribe particular functions to this period of activity as this was a largely an open area comprising the Old Trial Yard to the west and Wheel Yard to the east, separated by a curving central wall. This wall does not appear clearly on the survey results, but a spike in the magnetometry results (14) does appear to coincide with the southern end of the wall. The archaeological evaluation did however identify a mortared stone-lined drain running along the northern face of the visible masonry walling along the southern edge of this area. The approximate line of this drain may be identifiable on the resistivity results (15). A large cut feature to the north is also identified in the archaeological evaluation trenches (16). It is suggested that this may refer to an excavation carried out in 1871 and re-opened in 1914. The initial excavation was carried out by the gaol governor reportedly investigating an area of collapse, and uncovering the remains of a medieval cellar. The subsequent excavation in 1914 appears to have uncovered the previous excavation, discovering a chamber in a triangular area surrounded by masonry, at considerable depth.
- 8.3.8 Within the former East Range the plans of the Gaol and Police Station indicate a north – south boundary wall between the current north – south medieval masonry wall and the outer curtain wall, with two small buildings adjoining. The magnetometry results in this area identify a general change in readings along the eastern side (17), which may correspond to this boundary wall, although it is assumed that such a wall would have stood at a higher level than the current visible masonry remains which were demolished and built over.

#### **8.4 Unknown Features (Figure 17)**

- 8.4.1 Many features of potential archaeological interest are identified throughout the site that do not clearly align themselves with features visible on mapped evidence of the Medieval Castle, or the post-medieval Gaol and subsequent Police Station. These features are illustrated on Figure 17 in pale brown.
- 8.4.2 A number of linear features (1), and straight-sided potentially structural features, are identified particularly on the resistivity and GPR surveys in the northern part of the survey area. They share a similarity in alignments, suggesting a similarity in date and potentially function. Depths vary, although they tend to appear around the 0.5m to 0.7m range on the GPR survey, with some to the west up to 1.35m deep. They also appear to cross the line of the outer wall of the Debtors Block/Female Wing building to the north, suggesting they are unlikely to be contemporary, and neither do they appear on recorded plans. This may suggest potential medieval features pre-dating the Gaol, and although they do not align with the northern castle wall, they do share an alignment with the South Range. This date, however, is cast into doubt by part of the linear arrangement (2), which appears to correspond to a brick cavity wall identified in the archaeological evaluation trench T3. There appears to be some discrepancy in the depths, this wall appearing at around 0.25m below the current ground level, but the GPR results suggesting remains to the east at a depth of 0.8m. The cavity wall appears a modern feature, potentially short-lived as there appears to be no record of it. If the remaining features are contemporary with this wall, then they must post-date the demolition of the gaol buildings in the 1960s, but the given depths on the GPR survey suggests this is unlikely as relatively, they appear deeper

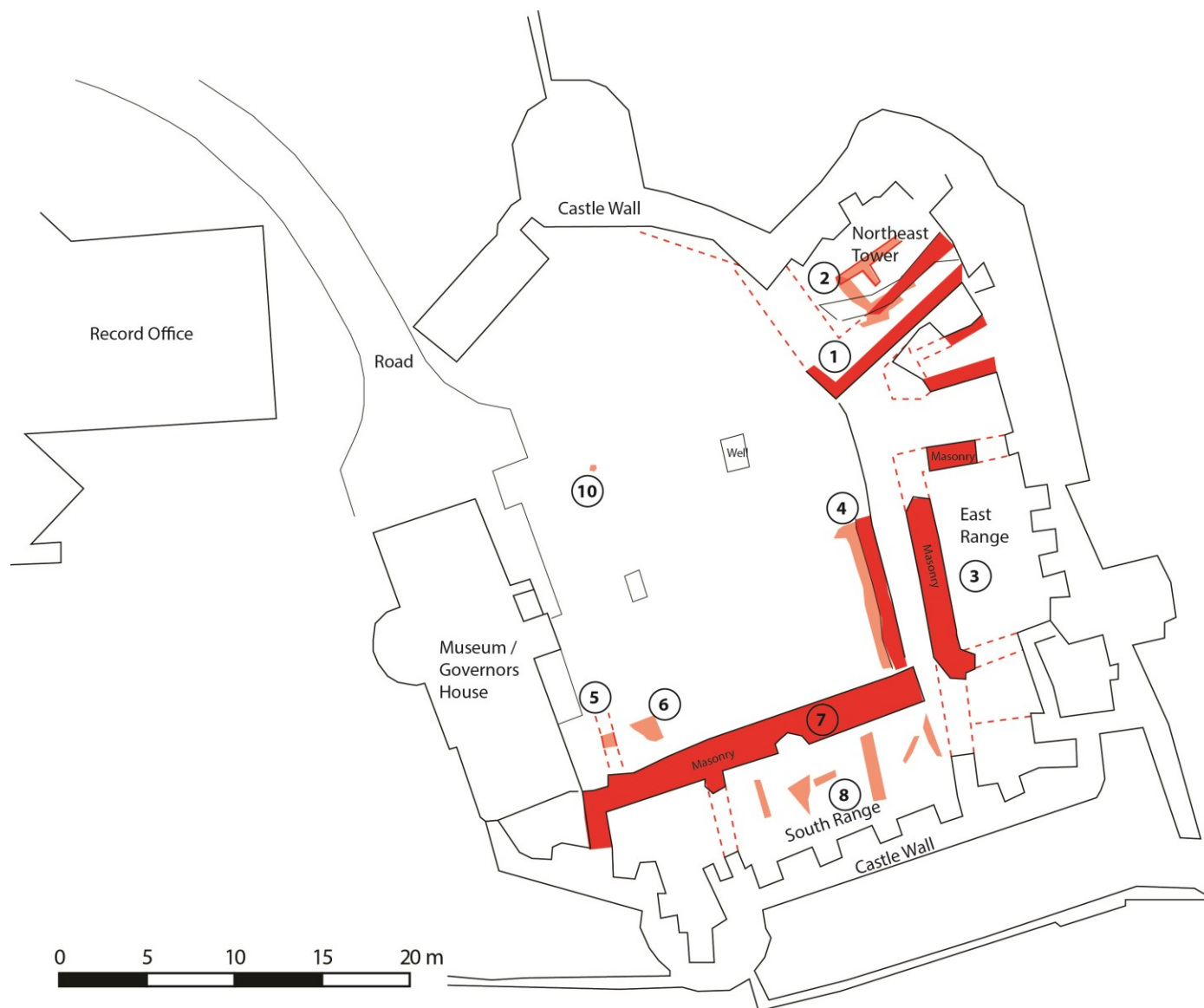
features. In which case, the alignment of the brick wall and these features must be fortuitous. The resistivity survey identified a large diffuse area along the northern edge, potentially an area of rubble (3).

- 8.4.3 To the north (4) and east (5) of the well are areas of strong readings from the magnetometry results, with those to the east seeming to correspond to an area of activity also visible on the GPR survey at a depth of 0.25m. The area to the north (4) may potentially be associated with the Matron's/Sergeant's House and its subsequent demolition, or potentially to a negative feature, such as a rock-cut cellar given the archaeological evaluation suggested bedrock levels were reasonably high in this area. To the east (5) there is the possibility that this area may relate to a rubble spread from the corner East Range wall.
- 8.4.4 Along the western side of the surveyed area are a number of features, depicted on all surveys, likely to represent a mix of activities from differing periods. The magnetometry and resistivity surveys suggests there may be a convergence of services in front of the rear door to the museum (6), which also coincides with part of the central passageway of the Gaol. Immediately south of this the resistivity and magnetometry survey identify a concentration of activity (7), and the GPR survey suggests some straight-sided anomalies. It is possible this may be associated with the construction of the current museum building (originally built as part of the gaol in the late 18<sup>th</sup> century) and the conjectured demolition of the medieval structures along the western side of the Inner Ward. It may also be associated with the excavations in the late 19<sup>th</sup> and early 20<sup>th</sup> century that uncovered a medieval cellar, with some of the straight edges suggested on the GPR results potentially also related to the 2008 evaluation trenches. The evaluation trenches also identified electric cables running north – south close to the rear wall of the museum, and an area of concrete and brick to the south (8).
- 8.4.5 As previously discussed the resistivity survey indicates some intriguing results in the southern half of the grassed area (see Section 8.2.3), to the south of the central passageway. The survey (Appendix I) discusses the possibility that they may represent a medieval structure, and a cellar is also likely in this area, however the possibility remains that they may be associated with features associated with the early Gaol, or indeed material from the demolition and landscaping of the 1960s.
- 8.4.6 In the centre of the grassed area the GPR results record some straight-sided features at a depth of 0.6m to 0.7m. The alignment of the features to the west (9) does not closely accord with features recorded as part of either the medieval castle or the post-medieval gaol and police station. To the east the feature (10) does appear more in line with structures of both periods, but also appears to underlie, or overlie, the line of the central passageway visible on the plans of the Gaol.
- 8.4.7 A number of features (11) are identified within the South Range. Some appear to share an alignment and may therefore be medieval structural features, discussed in section 8.2. Other features are less well-defined, with features to the west having strong magnetic signals, those to the east more visible on the GPR survey. It is possible, given their location within the confines of the South Range, that these also relate to medieval features, however the magnetic features may relate to modern, above-ground objects, whilst the features identified from the GPR lie at relatively shallow depths (0.2m to 0.25m) and may therefore be associated with the demolition and levelling work of the 1960s.





**Figure 14:** Site plan showing features identified from all three survey techniques. Colour coding is explained in subsequent figures.



**Figure 15:** Potential medieval features, see section 8.2, Visible masonry is shown as solid red, below-ground features identified from surveys shown in pale red, with possible walling outlined in solid lines. Projected wall lines (not visible on the surveys) shown as dotted lines.



**Figure 16:** Potential features associated with late 18<sup>th</sup> to mid-20<sup>th</sup> century activity, see section 8.3, Below-ground features identified from surveys shown in pale blue, with possible walling outlined in solid lines. Features only identified from post 1878 plans shown in pale green. Projected wall lines (not visible on the surveys) shown as dotted lines.



**Figure 17:** Potential features of unknown date, see section 8.3.

## **9. CONCLUSION**

- 9.1 The three methods of survey; magnetometry, resistivity and ground-penetrating radar, used within the Inner Ward, produced a range of findings, many of which were complimentary, suggesting a wide spread of potential below ground archaeological remains throughout the survey area.
- 9.2 Comparisons between the survey results, an archaeological evaluation, visible structural remains and historic plans and photographs of the site, has allowed for a detailed series of plans to be produced, mapping the potential archaeological features and deposits, along with informed interpretation of the potential date, character and function of many of these features.
- 9.3 From the medieval period further potential evidence of internal features of the Northeast Tower and the South Range have been identified, with suggested evidence of part of a West Range and a former cellar in the southwest corner of the grassed area.
- 9.4 The surveys have identified many features relating to the re-use of the Inner Ward as a Gaol and Police Station from the late 18<sup>th</sup> to mid-20<sup>th</sup> century. Identified structural remains include a Debtors Block/Female Wing, the Matron's/Sergeant's House, Pump/Well House, Laundry and central passageway, along with associated services and pathways.
- 9.5 Numerous other features have also been identified that could not easily be attributed to known structures or periods of activity, but could relate to archaeological remains from the medieval period through to the later 20<sup>th</sup> century.
- 9.6 The ground-penetrating radar survey, and archaeological evaluation, have also suggested potential depths for archaeological features. This reveals a complex picture across the site, with features identified from just 0.25m below current ground levels, to in excess of 1.0m. High level bedrock has been identified in the northern part of the site, but this appears to drop away in all directions, with significant depths of potential archaeological remains and overlying rubble and made ground deposits then indicated.



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**APPENDICES:**

**APPENDIX I: RESISTIVITY SURVEY REPORT – GEOARCH**

**APPENDIX II: GROUND PENETRATING RADAR REPORT – SUMO  
GEOPHYSICS LTD**

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# GeoArch

Report 2020/16

Ground resistivity survey,  
Haverfordwest Castle, Haverfordwest,  
Pemb [SM 953157]

Dr Tim Young  
22<sup>nd</sup> October 2020

# **Ground resistivity survey, Haverfordwest Castle, Haverfordwest, Pembrokeshire [SM 953157]**

**Dr T.P. Young**

## **Abstract**

*A geophysical survey of the grassed area within the inner ward of Haverfordwest Castle was conducted using ground resistivity, using a twin probe configuration at 0.5m and 1.0m mobile probe spacing.*

*The area proved to be intensely featured, despite the effects of demolition and site clearance, followed by excavation and consolidation following disuse of the police headquarters in 1962. The police headquarters occupied much of a former prison, constructed inside the ruined castle in c.1779 with an additional block added in c.1820.*

*The survey revealed anomalies in locations corresponding to mapped features of the prison, including a linear negative corresponding to the central passageway between yards, a linear positive feature corresponding to the SE wall of the women's block, and a large positive area anomaly corresponding to the location of the matron's house (although this may potentially owe more to the underlying medieval structure forming part of the early keep).*

*Also revealed was a large negative anomaly adjacent to the location of the well, 4.6m NS x 3.3m EW, which is provisionally interpreted as a water tank, connected to other parts of the prison by linear negative features suggestive of service trenches.*

*The southern part of the area (bounded to the north by the central passageway) is characterised by a high-resistivity area with a rather complex internal structure. This appears rather more resistive and more complex than might be expected of the yards that occupied this area in the prison period. The level and strength of these anomalies could possibly be indicative of a medieval cellar or undercroft, but alternative interpretations are also offered.*

*To the north of the area, several anomalies with raised resistivity traversed the survey area approximately parallel to its baseline. Although an origin for these anomalies within the medieval archaeology cannot be excluded, it is tentatively suggested that these anomalies are more likely to be indicative of structures from the early phase of the prison, between 1779 and 1820, and removed to create space for the 1820 phase.*

*The survey thus indicates that there is considerable survival of archaeological remains within 1.5m of the surface across the lawn area.*



## Contents

Abstract .....	1
Methods .....	2
Survey rationale and background .....	2
Historical background .....	2
Ground resistivity .....	2
Use of this report .....	4
Results .....	3
Interpretation .....	3
Discussion .....	4
References .....	4
Figure captions .....	5
Figures .....	6

## Methods

### *Survey rationale and background*

The survey was undertaken.

The survey area is approximately 30m N-S and up to 25m E-W covering an approximately flat grassed area occupying much of the interior of the inner ward of Haverfordwest Castle.

The survey area was defined (Figure 1) by a baseline extending approximately E-W 200mm to the north of the northern side of a medieval ruined wall bounding the cellars along the S side of the ward, starting from a point 2.0m E of the wall of the Museum building (the grid was inherited from the previous magnetometer survey conducted by the Dyfed Archaeological Trust). Reference to the georeferenced version of the 1889 1:500 town plan (Figure 2) suggests that the survey origin was at approximate national grid coordinates [195332.79, 215713.86], with the baseline oriented at 071° to grid north.

The description of the survey in this report refers to x,y site coordinates from this origin on the survey axes as shown in Figure 1.

The survey was conducted in October 2020, under good weather conditions to ClfA (2014) and EH (2008) guidelines.

The survey was commissioned by Fran Murphy, Dyfed Archaeological Trust (DAT), and conducted in coordination with Phil Poucher.

### *Historical background*

As a small component of a larger project, a full supporting historical background has not been constructed for this work. However, to assist with interpretation of the geophysical data the Ordnance Survey 1889 1:500 town plan (see Figures 2, 7-10) has been used. In addition, an undated plan of prison displayed at the site (probably that also illustrated as Shobbrook 2009, Figure 11) provided further information.

A prison was created within the ruined medieval castle in 1779, with new buildings being constructed in 1820. The prison was abandoned in 1878 and the buildings served as a police headquarters (and appear as such on the 1889 town plan). The buildings in the inner ward comprised aspects of the women's prison to the north (cell block, matron's house, well house and laundry, set around a small courtyard), a central passageway, and the treadmill building to the south (over the now exposed medieval cellars). The northern part of these buildings are shown in a photograph:

<https://snorbens.files.wordpress.com/2010/06/6-view-showing-female-wing-airing-yardm-pump-and-laundry.jpg>.

A series of aerial photographs from 1932 (e.g. C6369671) and 1950 (e.g. RCAHWM catalogue number C888867) show survival of the structures in the northern part of the inner ward in good repair, but the southern yards appear empty, overgrown and without their bounding walls, while the southern range of cells appears derelict. A hand-coloured, updated and annotated version of the 1889 town plan supplied by DAT shows in yellow various structures that appear to have been demolished probably between the 1932 and 1950 aerial photographs.

The police station closed in 1962 and the remaining post-medieval structures within the inner ward, with the exception of the 'Prison Governor's house'/inspectors residence' (now the museum) were demolished soon after (they are absent on the 1964 Ordnance Survey 1:10,560 scale map) and consolidation work was subsequently undertaken on the castle by the Ministry of Public Building and Works, with their site hut shown on the 1964 map. Photographs of the works (dated 1968) are present within the Department of the Environment photographic collection held by RCAHWM (catalogue numbers C542521, C542532, C542535, C542533, C542534, C542539, C542541, C542542 and C548838 provide insight into the surveyed area).

### *Ground resistivity*

The ground resistivity survey was undertaken with a Geoscan RM15 resistivity meter, operating a 'parallel twin electrode' configuration, employing two pairs (three electrodes) with 0.5m probe spacings placed at 0.5m centres on a PA5 frame, via an MPX15 multiplexer.

In this configuration, two datasets were acquired:

1. Using the outer probes, a mobile probe spacing of 1.0m give the predicted main component of the response from 1.0-1.4m depth. Data were collected with a 0.5m sample interval on 1.0m instrument traverses (i.e. the raw data has 1.0 x 0.5m node spacing).
2. Using the three probes as two pairs, a mobile probe spacing of 0.5m gives the predicted main component of the response from 0.5-0.7m depth. Data were collected with a 0.5m sample interval on 1.0m instrument traverses (i.e. the raw data has 0.5 x 0.5m node spacing).

The 20m grids were walked in zig-zag mode. Data were downloaded from the instrument and collated using Geoscan Research's *Geoplot* software. Data processing was limited to one pass of the

'despike' function in Geoplot (to remove rogue points of poor ground contact), with radius set to 1 and a threshold of 3 standard deviations, using Gaussian statistics.

Data were then exported from Geoplot and imported to Golden Software's *Surfer*. The data were gridded by kriging to a node-spacing of 0.125m for production of the final, less pixelated, image.

### *Use of this report*

The main technique chosen for the survey, ground resistivity, was chosen because this tool can provide information on cut features and stone constructions in which the substrate and feature do not have markedly different magnetic susceptibilities but differ in texture (leading to different water retention).

Absence of detectable geophysical anomalies cannot be taken as indicative of the absence of archaeological features. All anomalies have been interpreted as far as possible, with contrasting possible interpretations given where appropriate. Geophysical techniques cannot provide an unambiguous evaluation of buried features. Where a higher degree of certainty is required, physical ground-truthing of any geophysical anomalies resolved by the survey will be required.

## Results

There were no technical issues with the set-out or with data acquisition. Conditions were good for both surveys, with short grass and slightly damp ground.

The surveys proved to contain well marked anomalies with a good range of measured resistivity. The survey collected with 1.0m-spaced mobile probes shows most data lying within a range of 28 to 63Ω measured resistance, but with values close to 100Ω in areas closed to exposed masonry in the NE of the area. These data are illustrated on two figures: Figure 3 with a greyscale covering most of this range (Black = 20Ω to white = 80Ω) and Figure 4 with a reduced greyscale range (Black = 28Ω to white = 50Ω) to enhance the visibility of anomalies with the western part of the survey.

The survey collected with 0.5m-spaced mobile probes also shows most data lying within a range of 28 to 100Ω measured resistance. In both surveys the lower values are associated with anomalies in the centre and west of the survey, the highest close to exposed masonry.

## Interpretation

The anomalies will be described below from the south of the area, working towards the north.

The southern part of the area, up to approximately y=9m (extending as far N as the exposed medieval wall on the E margin of the grassed area), is strongly differentiated from the remainder of the surface by being a zone of elevated resistance, with a marked, sharp, northern margin corresponding to the line of the southern wall of the central prison corridor (Figure 10 'a'). Both probe spacings show a somewhat segmental structure to this area.

At 0.5m mobile probe spacing, the strong imaging of the high resistivity feature is interrupted along a slightly sinuous line, NW of which the strength of the anomaly is much reduced. This sinuous line follows the contours of the landscape grass surface, and the change in anomaly strength reflects the increased overburden NW of this line. The originating archaeological feature is thus likely to lie at less than 0.75m, perhaps less than 0.5m, to the SE of this line, but probably at a depth of at least 1m to the NW.

The segmented character of this region into alternating zones of slightly raised and depressed resistivity is intriguing but difficult to interpret. Although an interpretation as a vaulted structure is tempting, there is some suggestion in the 1.0m probe-spaced data that the segmentation is lightly radiating, rather than parallel, which may possibly suggest it does not reflect the original structure here, but rather perhaps disturbance within its remains. The DOE photographs show parallel marks on the ground surface in this region, possibly related to the location of temporary stacks of stone visible in another photograph. These images, however, appear to show these stacks lying on a surface close to the modern level, so the stone stacks are probably unlikely to be the cause of these anomalies. An interpretation of these anomalies as a medieval cellar is possible, but it is equally possible that a yard surface was divided by, for instance, garden beds.

The western end of this region of elevated resistivity is sharply marked and lies parallel to and about 2.9m from the wall of the museum. This is particularly well-marked on the 1.0m probe-spaced data and may indicate a genuine termination of the underlying archaeological source, although the influence of low-resistivity garden soils alongside the house wall must also be considered.

Interestingly, there is no indication of the curved wall dividing the two courtyards (the 'wheel yard' and the 'old trial yard' of the map on display at the site) to the north of the treadmill house (later cell block) on the 19<sup>th</sup> century maps. This might be held as circumstantial evidence that the anomalies in this region are generated by features well below the level of the prison yard. The tentative evidence for depths discussed above might suggest that the originating features are at a level not very different from that of the medieval cellars to the south.

A marked negative linear resistivity anomaly (Figure 10, 'b') running E-W across the site at approximately y = 9m to 10m and approximately 1.1m wide corresponds closely to the mapped location of the central passageway across the prison. The line of the central passageway is well-marked by this negative anomaly, but there are no bounding anomalies suggestive of the lateral walls. The very low resistivity here may simply reflect damp ground between the bounding (but not imaged) walls, but it is possible that other factors may be enhancing the low values recorded, perhaps such possibilities as a clinker-flooring (enhancing ground conductivity) or buried services below the pathway.

To the north of the central passageway, there is a zone from approximately y = 10m to y = 19m with a background resistivity somewhat lower than to the south. For the 1.0m probe-spaced data, the measured background is approximately 45Ω, whereas to the north it is approximately 40Ω.

On the 1.0m probe-spaced data this area is traversed by negative anomalies and the 0.5m probe-spaced data show both negative anomalies and some positive linear anomalies.

The most striking anomaly within this region is a rectangular area, 4.6m NS x 3.3m EW (Figure 10, 'c'), lying immediately to the west and northwest of the modern surround to the well, with its iron grating. Measured resistance falls to  $44\Omega$  with this feature at 0.5m probe-spacing and approximately  $31\Omega$  marginally at 1.0m probe spacing. It is unclear whether the central raised measured resistance at 1.0m probe-spacing is a genuine feature or an artefact of the probe geometry.

Linear negative anomalies extend from the both the NW (Figure 10, 'd') and SW (Figure 10, 'e') corners of the major anomaly towards the western end of the central passageway. Of these, the one from the NW corner is neatly parallel-sided and approximately 1m wide, whereas that from the SW corner is a more irregular anomaly in plan.

At 0.5m probe-spacing narrower and lower-amplitude linear negative anomalies run both W (not shown on Figure 10, but running along the S side of positive anomaly 'k') and slightly irregularly N from the northwest corner (Figure 10, 'f'; potentially a drain).

The interpretation of these anomalies shares the same range of possibilities as that corresponding to the central passageway. The strong rectangular area most likely represents ground water ponded by bounding walls, despite the lack of geophysical evidence for lateral walls (except possibly to the S in the 0.5m probe-spaced data). There is a strong likelihood (given its location adjacent to the well and 'pump house' that this anomaly indicates a subsurface water tank or cistern. If this is so, then the various radiating negative linear anomalies may be candidates for water pipes (or the trenches to hold water pipes).

The 1m-wide anomaly extending SW (Figure 10, 'd') corresponds in plan to the mapped location of a path from the 'matron's house' towards the 'governor's residence'. As with the central passageway, such an anomaly might be produced by, for instance, a cinder path, but equally it is possible that services underlay the path. It is worth noting that the 1889 map indicates 'p', a pump, close to the northern side east door of the 'governor's residence' and this would most likely have required a piped water supply. Given the convergence of the anomalies from the NW and SW corners of the rectangular feature towards this point, it is possible that one (from the SW?) represents a pipe and the other (from the NW) simply represents a path.

The 0.5m probe-spaced data show linear positive anomalies to the S side of the rectangular feature and both datasets show positive anomalies to the E of the well (Figure 10, 'g'). These positive anomalies may be indicative of survival of the footings some of the walls of the 'pump house' and 'laundry', but the rapid eastwards slope of the ground here may also have produced some topographically-induced anomalies. There are also indications of a N-S positive linear anomaly in the 1.0m probe-spaced dataset when imaged with a greyscale to optimise visibility of anomalies in this area (Figures 5 and 8).

To the north of the complex negative anomalies there are a series of dominantly positive anomalies, with overlapping extents.

The most prominent anomaly is a marked narrow positive linear that trends NE-SW (parallel to the surviving stretch of castle wall in the NW of the area) and lies on the mapped line of the SE wall of the 1818 'debtors' prison' later the 'women's prison' (Figure 10, 'h'). The NE and NW walls of this block do not appear to be imaged in the resistivity data and the SW wall would have been outside the survey area.

A second set of anomalies in this area is formed by a diffuse region of elevated resistivity extending SW from the NW-SE trending section of castle wall (shown in green tone on Figure 10). The western limit of this is just W of the passage through the castle wall that formerly led to a yard in the outer bailey. To the E, it merges with the NW corner of the 'matron's house' (later the sergeant's lodgings'). The diffuse nature of the anomaly and its visibility in both datasets, but more clearly so in the 1.0m probe-spaced data, suggests it is dominantly a deeper feature and it may represent a zone of collapsed masonry, and is probably overlain by the prison structures.

The positive anomaly associated with the location of the 'matron's house' is very substantial (Figure 10, 'i'). DOE images C542541 and C548838 show this structure when partially cleared. The photographs show that excavation took place down the outside of the walls (possibly thereby enhancing its potential for geophysical resolution) and also that the deep masonry is suggestive of the medieval footings forming the western section of the early rectangular keep). It seems likely that the later periods of use of this corner of the castle involved new structures placed on ancient footings.

The fourth component of the geophysical featuring in the north of the study area comprises anomalies running E-W and possibly N-S. The clearest anomaly is an E-W positive anomaly, running approximately along the line  $y = 22.5\text{m}$  (Figure 10, 'j'). It is approximately 0.5m wide, much narrower than the putative SE wall of the 'women's prison'. This positive anomaly appears to have narrow zones of reduced resistivity both to north and south. An E-W alignment is also picked out by an E-W zone of reduced resistivity across which the background resistivity drops southwards (on the 0.5m spaced survey it drops from around  $54\Omega$  to  $50\Omega$  and from  $41\Omega$  to  $38\Omega$  on the 1.0m probe-spaced survey. This boundary lies at approximately  $y = 17.5\text{m}$ . The 1.0m probe-spaced data shows a faint indication of a zone of raised resistivity to the north side of the boundary (Figure 10, 'k').

Other possible parallel/orthogonal elements of this group include the positive linear anomaly described above passing close to the mapped wall between the 'pump room'/'well house' and the 'laundry', but possibly extending both further north and south than the extent of that wall (Figure 10, 'g'). There is also a short stretch of N-S positive linear anomaly immediately E of the concrete surface in the NW of the area (Figure 10, 'm'). In addition, there is a possible jump in background values extending W from the S end of the rectangular negative anomaly 'c', and also perhaps the observation of the difference in background value to N and S of the central passageway.

## Discussion

The new data provide some significant lines of evidence.

Firstly, it appears that the water supply provided by the 'well house'/pump room' may have fed a large water tank to its west. This in turn may have been connected with one or more service trenches (pipes), depending upon the interpretation of the more subtle negative linear anomalies.

Secondly, some of the more minor structures of the prison period do not appear to be imaged well by the resistivity survey. These include the walls of the various yards and the walls of the 'pump room'/laundry'. If this lack of imaging is interpreted as a lack of survival, then it would suggest that the demolition and clearance has removed these structures, perhaps in turn implying that those features which have been imaged were originally well below 19<sup>th</sup> century ground level. However, it is also possible that a lack of resistivity contrast is inhibiting imaging of these structures.

A wall (or more likely wall footing) on the mapped line of the SE wall of the debtors'/women's prison appears to survive, although other walls of this structure are not clearly imaged. Elsewhere there is evidence that the paths may survive (or that the paths were underlain by deeper services).

The strong anomalies in the southern part of the survey, together with the evidence for their source being at a considerable depth below the modern surface, may suggest the existence there of a medieval structure. The central passageway of the prison would lie immediately to the north of this hypothetical structure.

The description of the castle in 1577 describes the interior of the inner ward as 'within the circuit of these buildings is an ynner Warde or greene of lxx foote square having a Well in it' (Owen 1903, 41). These dimensions would correspond closely with the present grassed area plus the area occupied by the museum. This suggests that, notwithstanding the suggestion that the anomalies in the area of the yard to the south of the central passageway might suggest a medieval structure, an open area in the centre of the ward may have been an original medieval feature.

This, together with a dissimilar alignment to adjacent known medieval structures, means that a post-medieval origin should probably be sought for the features that generated the anomalies oriented parallel and perpendicular to the survey in the northern part of the survey area. The simplest explanation for this origin can be sought in the controls on that survey orientation – the orientation of the medieval cellar to the south (and its overlying cell block of c.1779) and that of the Governor's House (also of c.1779) to the west. The simplest interpretation of these anomalies is that they too were produced by features also forming a part of the arrangements of the prison of c.1779.

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## Figure Captions

**Figure 1.** Grid setup. Baseline lies 200mm N of cellar wall (in yellow). Surveyed are shown in pale yellow tone. Features mapped by offset from the survey traverses are indicated.

**Figure 2.** Location of the survey area on OS 1<sup>st</sup> Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps). Survey area and measured features shown as in Figure 1.

**Figure 3.** Ground resistivity data as collected, as bitmapped images from *Geoplot*. N to top, total area 40m across.

- (a) 0.5m mobile probe spacing, greyscale: 30Ω (black) to 110Ω (white) measured resistance.
- (b) 1.0m mobile probe spacing, greyscale: 25Ω (black) to 80Ω (white) measured resistance.

**Figure 4.** Ground resistivity data with 1.0m mobile probe spacing, as interpolated image from *Surfer*, greyscale as shown (20Ω (black) to 80Ω (white) measured resistance) covers most of data range.

**Figure 5.** Ground resistivity data with 1.0m mobile probe spacing, as interpolated image from *Surfer*, greyscale as shown (20Ω (black) to 50Ω (white) measured resistance) adjusted to reveal detail within the central part of the grassed area.

**Figure 6.** Ground resistivity data with 0.5m mobile probe spacing, as interpolated image from *Surfer*, greyscale as shown (30Ω (black) to 100Ω (white) measured resistance) covers most of data range.

**Figure 7.** Ground resistivity data (instrument with 1m mobile probe spacing), as Figure 4, but georeferenced on OS 1<sup>st</sup> Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps). Greyscale: (20Ω (black) to 80Ω (white) measured resistance).

**Figure 8.** Ground resistivity data (instrument with 1m mobile probe spacing), as Figure 5, but georeferenced on OS 1<sup>st</sup> Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps). Greyscale: (20Ω (black) to 50Ω (white) measured resistance).

**Figure 9.** Ground resistivity data (instrument with 0.5m mobile probe spacing), as Figure 6, but georeferenced on OS 1<sup>st</sup> Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps). Greyscale: (30Ω (black) to 100Ω (white) measured resistance).

**Figure 10.** Interpretation of data, with anomalies described more fully in text.

- Pale grey tone shows positive resistivity anomalies (a, g, k, j, m) that are aligned in

directions probably associated with the earlier prison buildings (c. 1779), in turn influenced by the orientation of the medieval structures of the south range.

- Dark grey tone indicates negative resistivity anomalies interpreted as a water tank (c), trenches for water pipes (e and ?d) and paths (b and d).
- Blue rectangle shows the location of the well.
- Pink tone (h) shows a positive resistivity anomaly interpreted as the SE wall of the c.1820 women's block.
- Orange tone (i) shows the very strong positive resistivity anomaly associated with the location of the 'matron's house', itself probably resting on medieval footings.
- Green tone, unlettered, diffuse positive resistivity anomaly, perhaps fallen masonry?

Illustrated on OS 1<sup>st</sup> Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps).



Figure 1

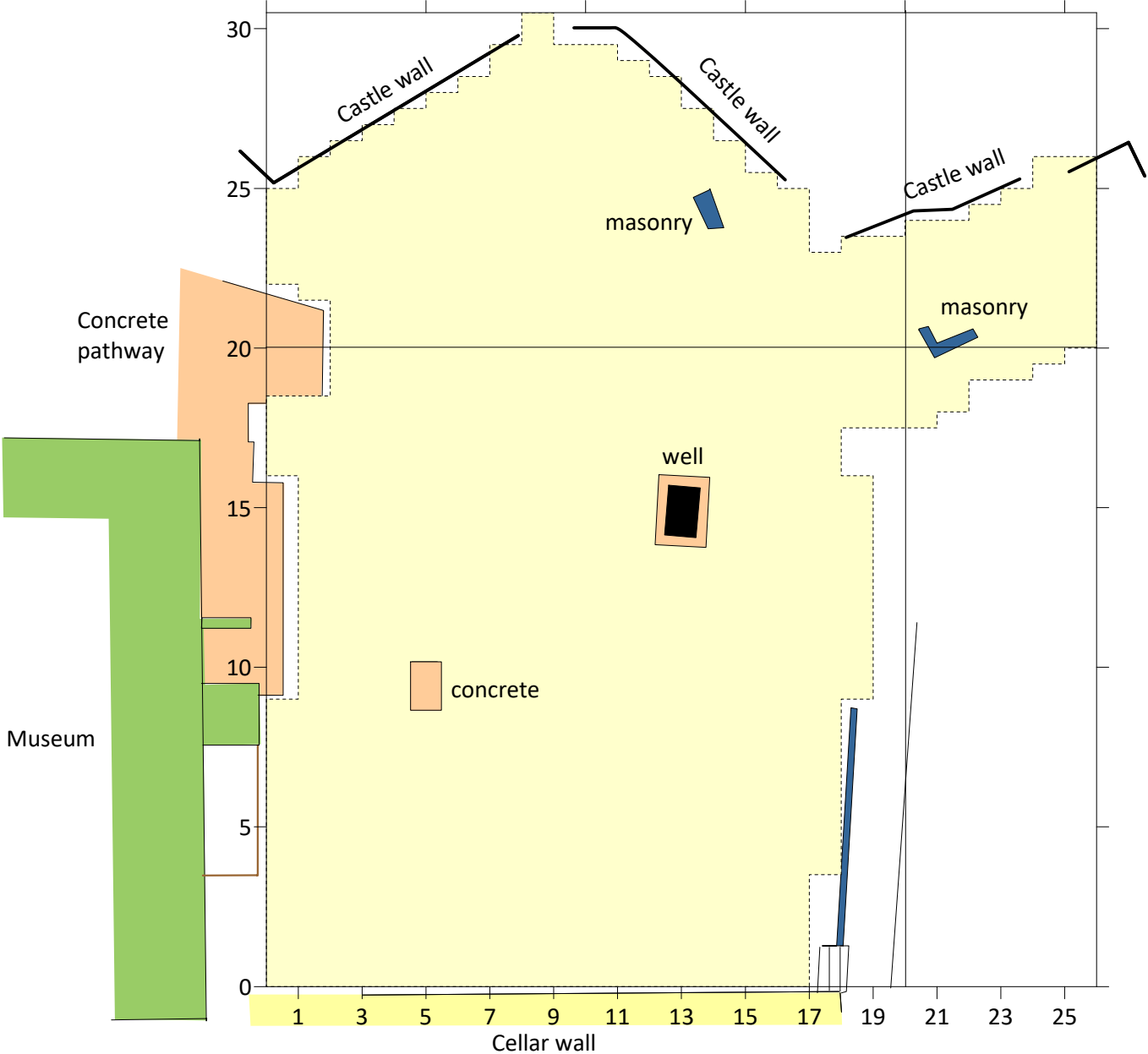
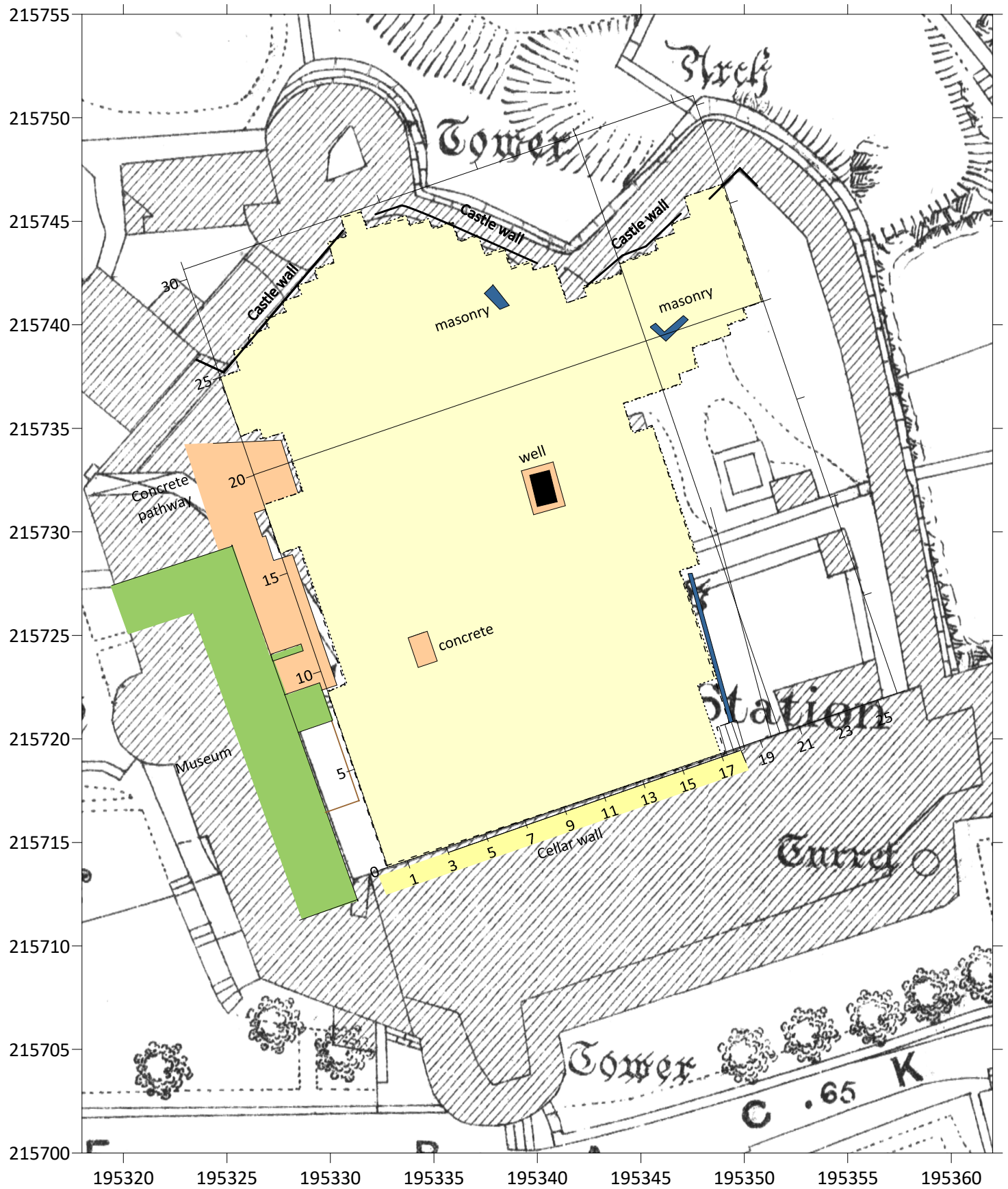


Figure 2



OS 1st Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps

Figure 3

a



b

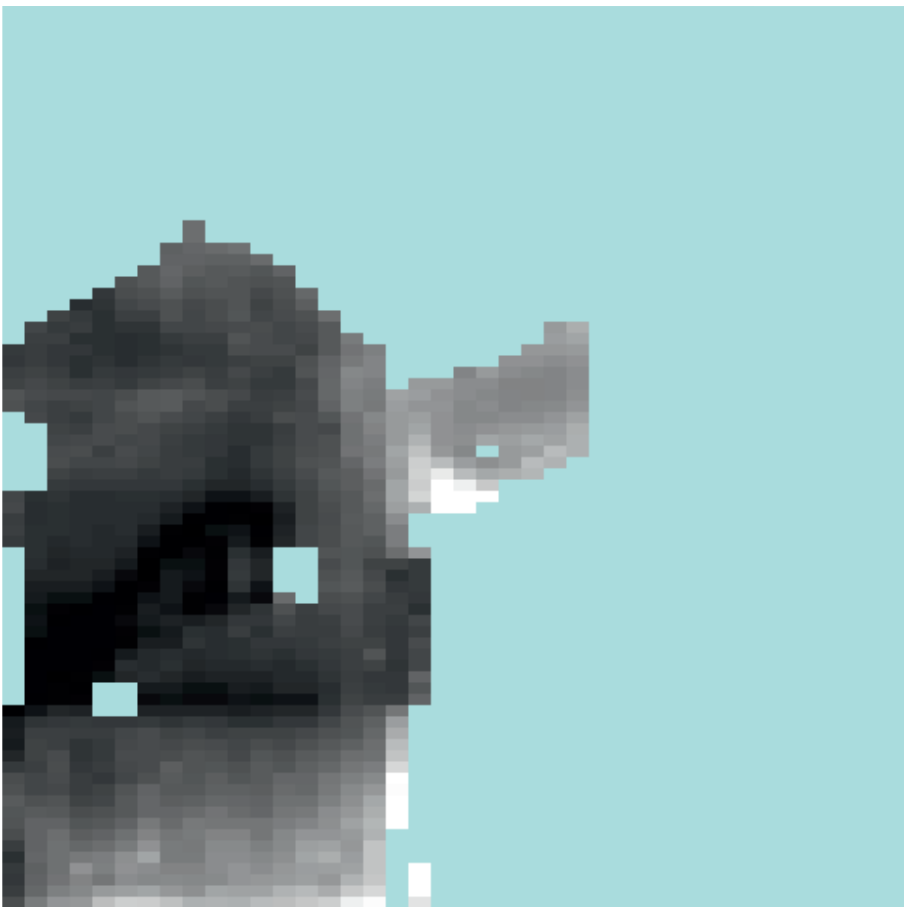


Figure 4

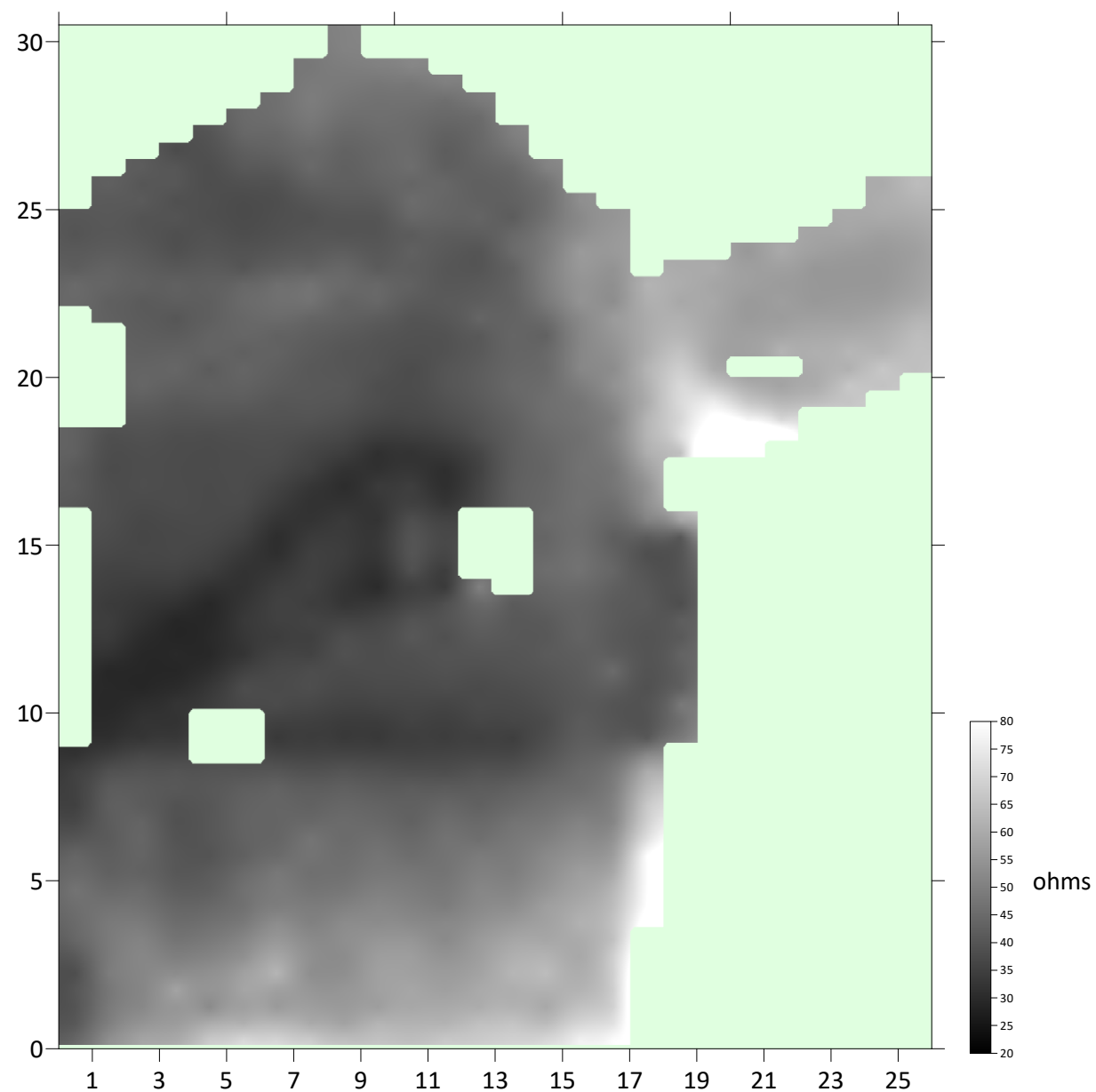


Figure 5

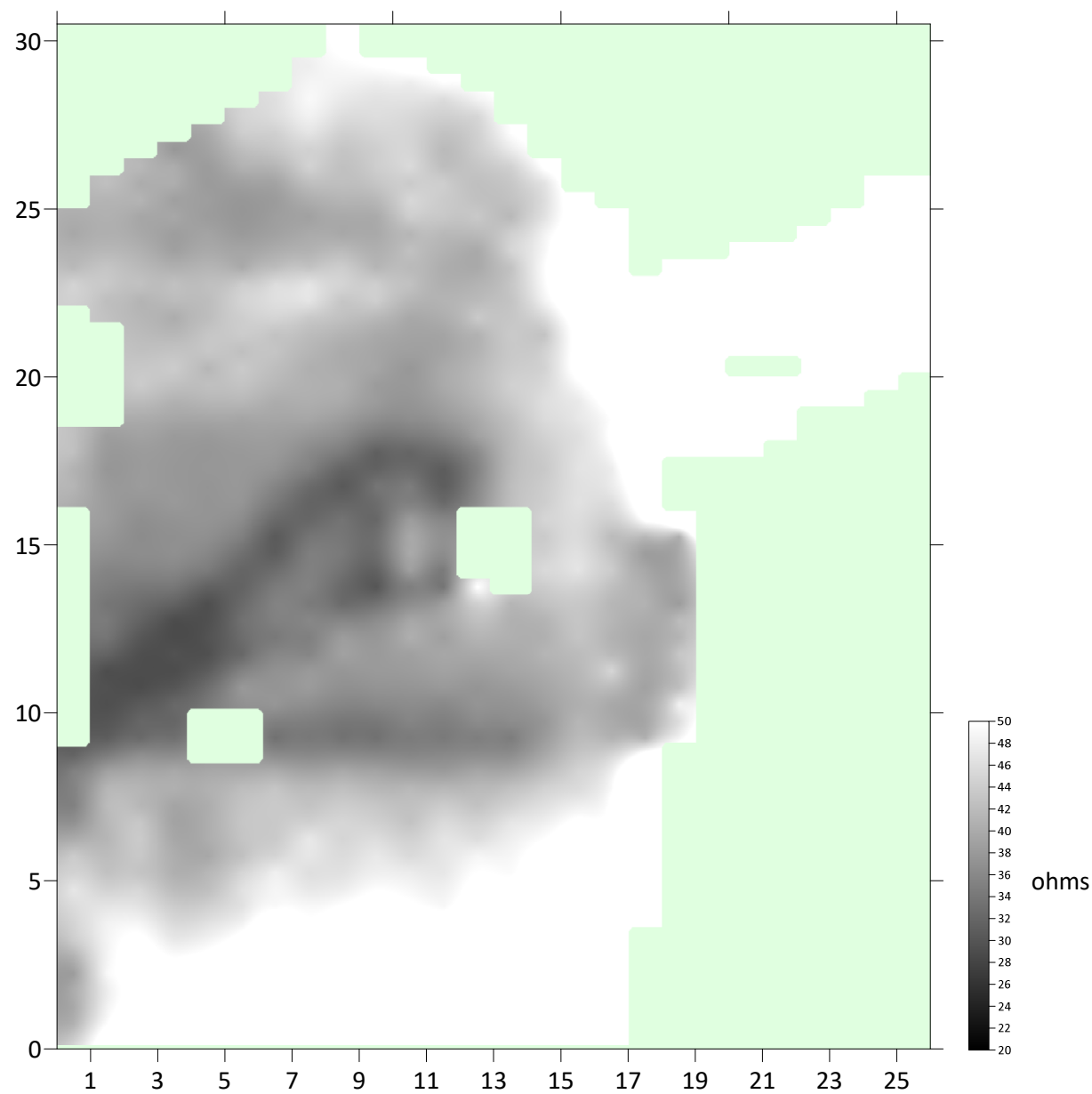




Figure 6

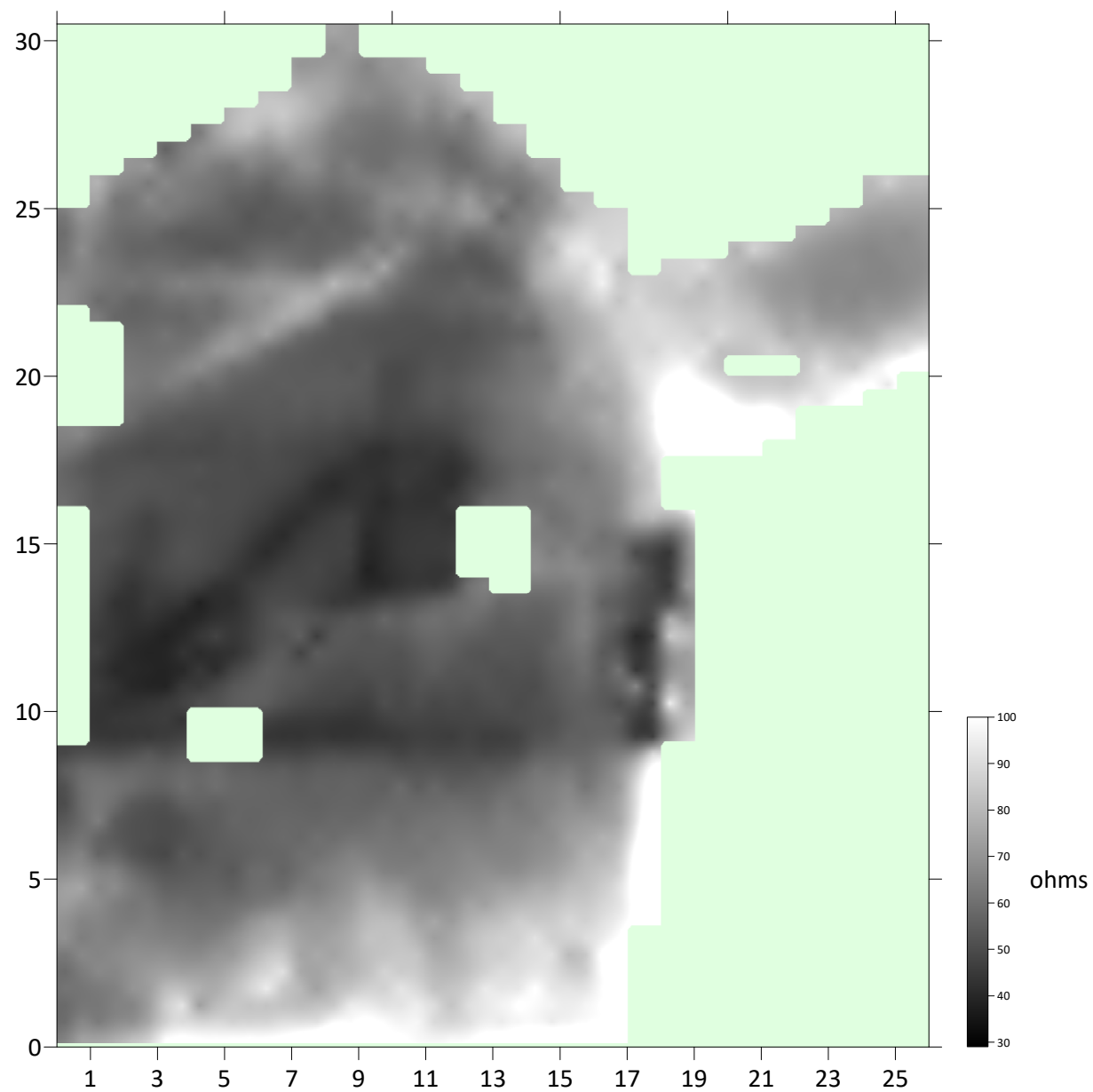


Figure 7

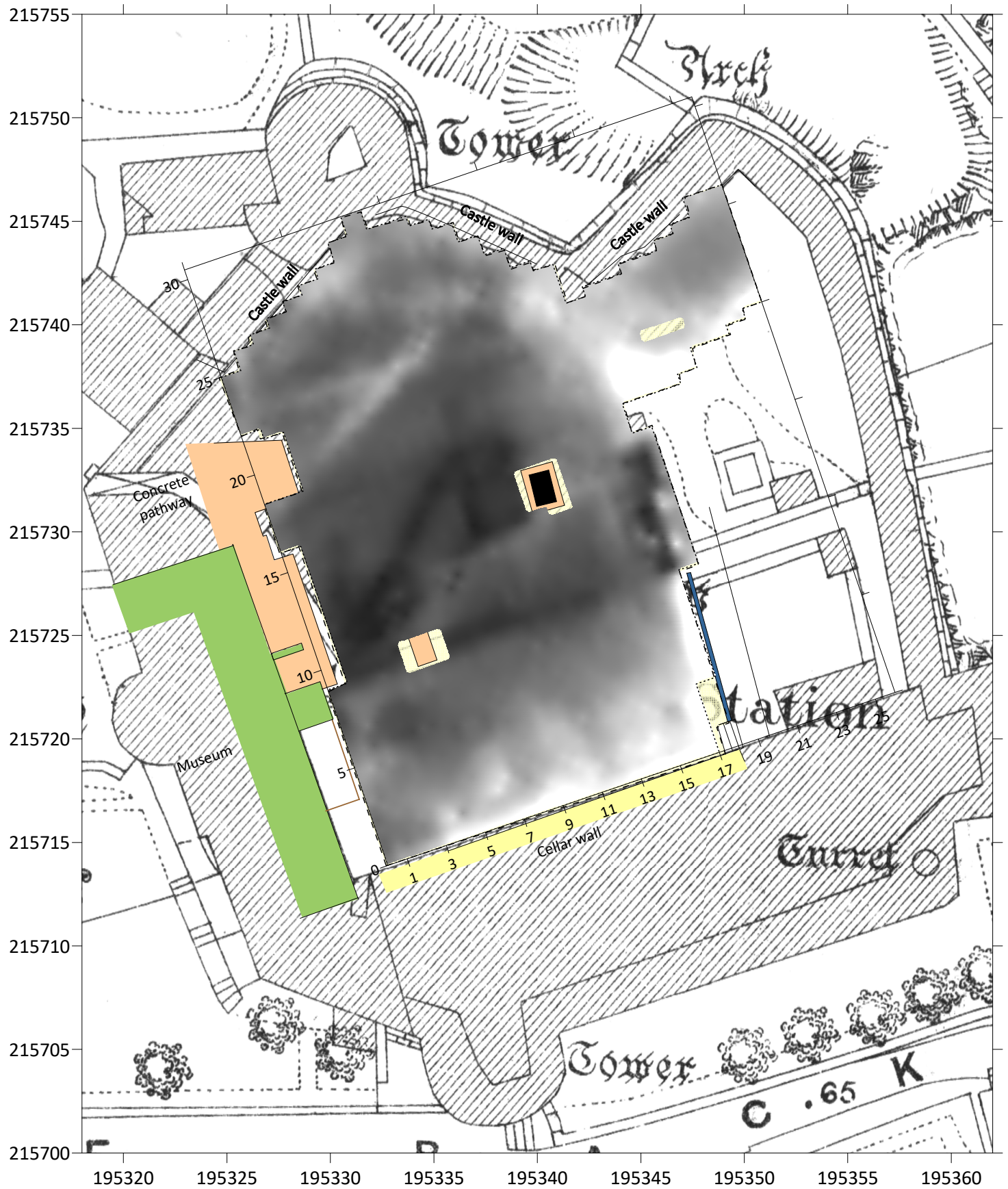
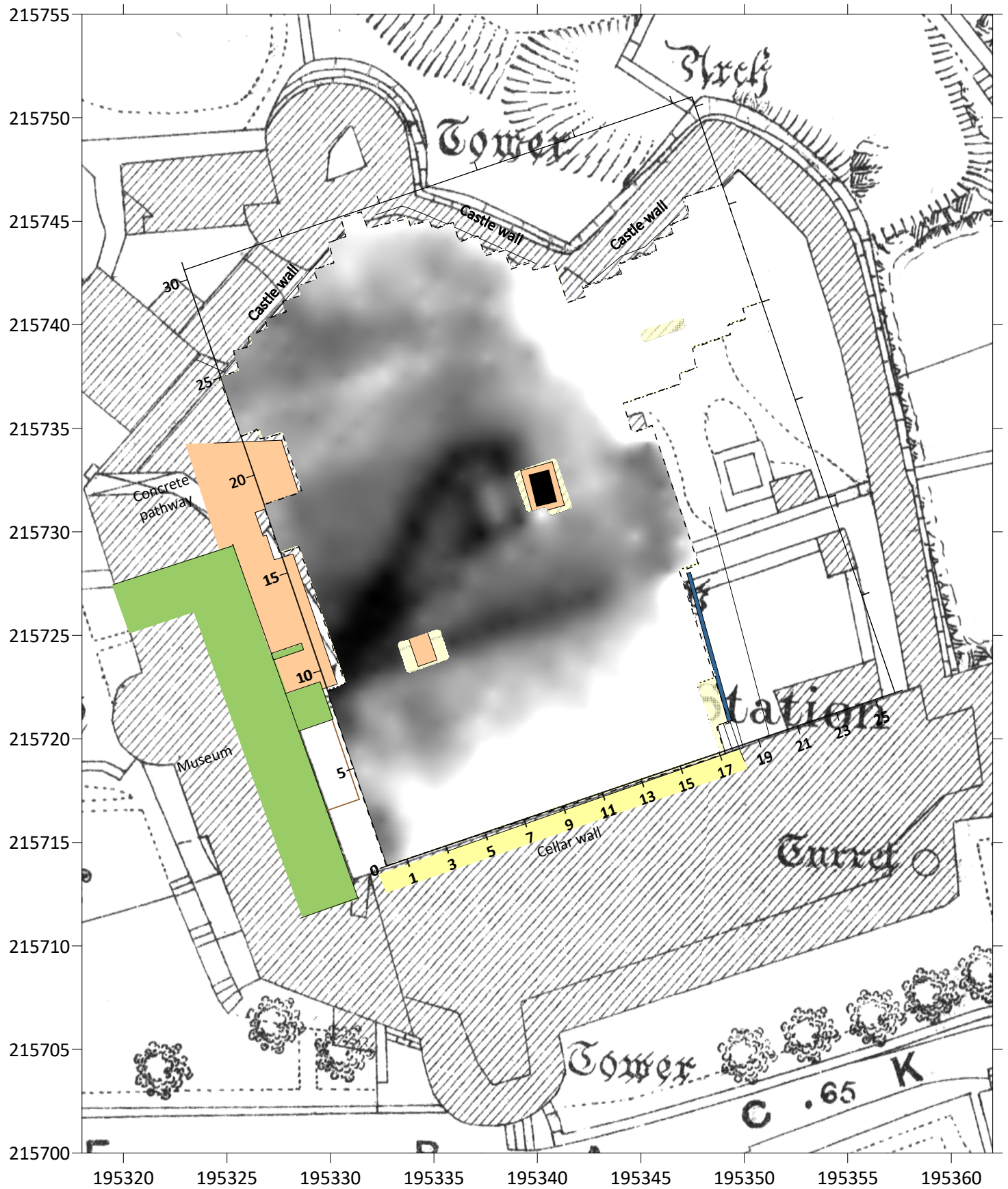


Figure 8



OS 1st Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps



Figure 9

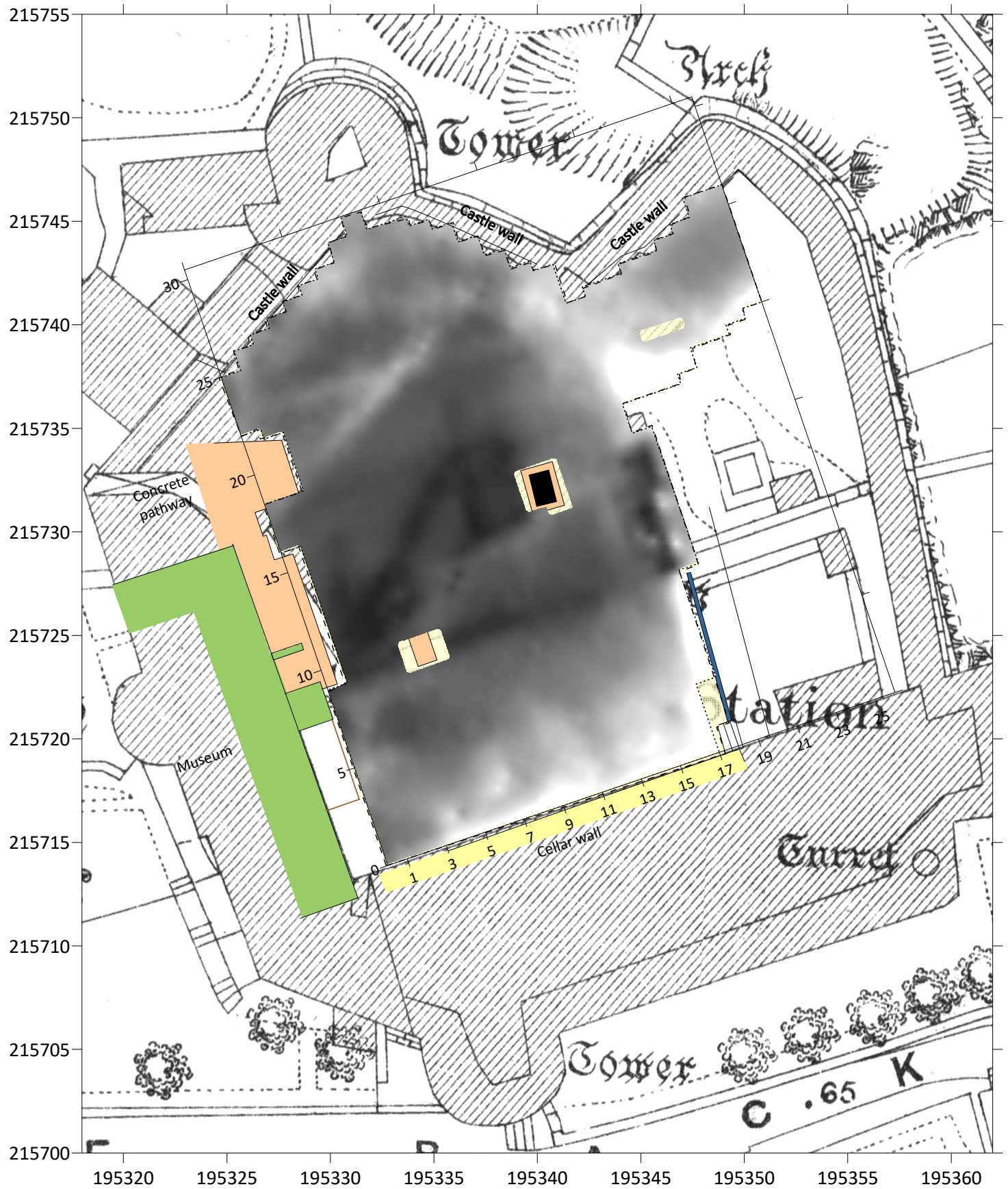
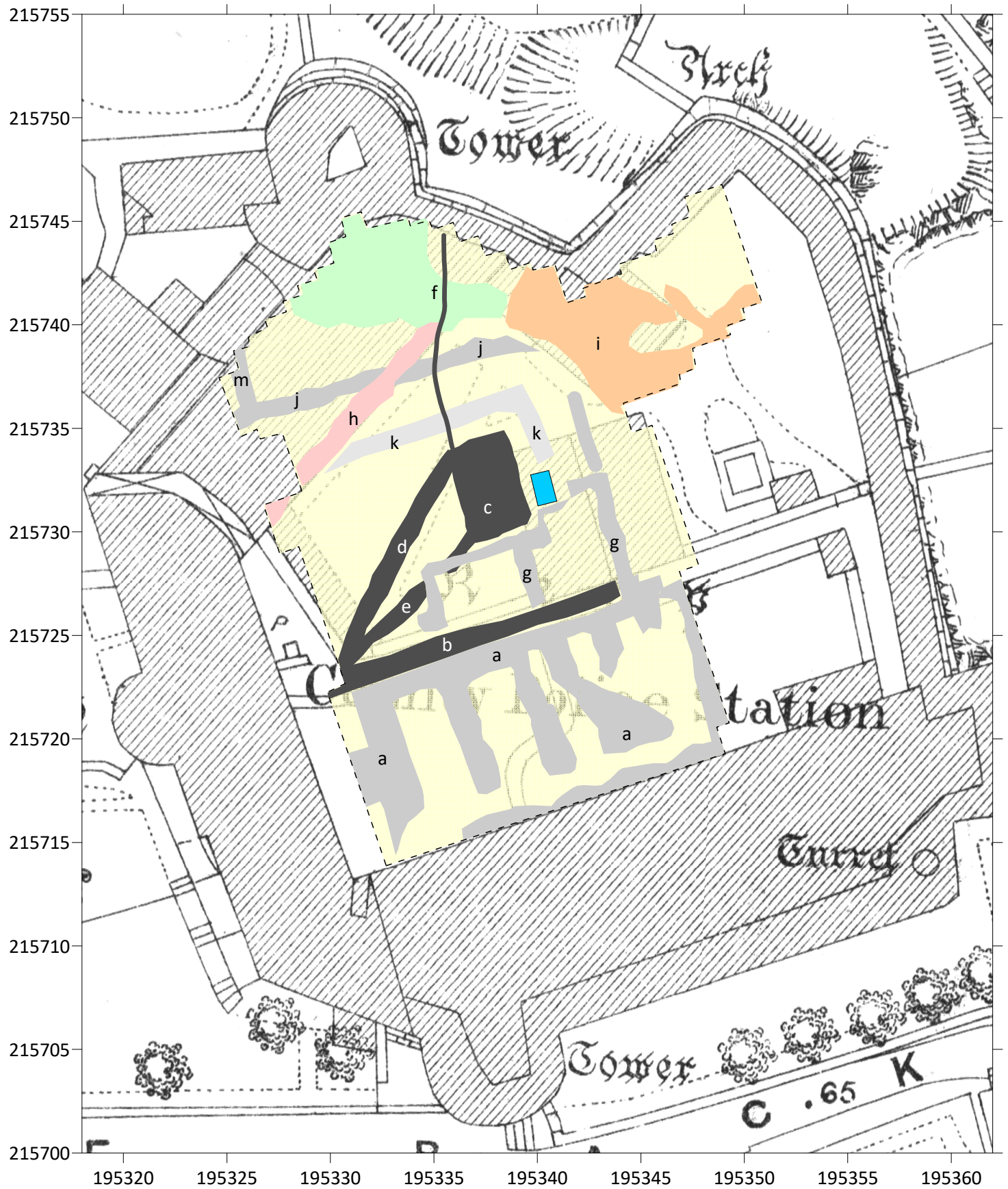


Figure 10



OS 1st Edition 1:500 town plan of 1889 (© Crown Copyright and Database Right 2020 Ordnance Survey (910748), Blackwells/Groundsure Historical Maps



# GeoArch

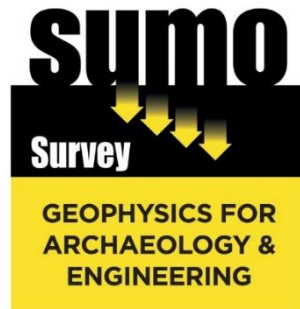


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# **GEOPHYSICAL SURVEY REPORT**

**Haverfordwest Castle, Pembrokeshire**



Client

**The Dyfed Archaeological Trust**

Survey Report

**01003**

Date

**November 2020**



## **Survey Report 01003: Haverfordwest Castle, Pembrokeshire**

<b>Survey date</b>	13th October 2020
<b>Field co-ordinator</b>	Richard Fleming
<b>Report Date</b>	5th November 2020
<b>CAD Illustrations</b>	Magdalena Udyrysz-Kraweć MSc
<b>Data Interpretation</b>	Magdalena Udyrysz-Kraweć MSc Marek R Wajzer BSc PhD FGS
<b>Report Authors</b>	Marek R Wajzer BSc PhD FGS Magdalena Udyrysz-Kraweć MSc
<b>Project Manager</b>	Simon Haddrell BEng AMBCS PCIfA
<b>Report approved</b>	Peter Barker CEng MICE MCIWEM MCIfA FCInstCES

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## TABLE OF CONTENTS

1	LIST OF FIGURES	1
2	SURVEY METHODOLOGY	2
3	EXECUTIVE SUMMARY	2
4	INTRODUCTION	2
5	SURVEY PROCEDURE	3
6	INTERPRETATION OF RESULTS	3
7	DATA APPRAISAL & CONFIDENCE ASSESSMENT	4
8	SUMMARY OF RESULTS	4
9	CONCLUSION	5
10	REFERENCES	6

Appendix      Ground Penetrating Radar Method

### 1. LIST OF FIGURES

Figure 01	1:25000	Site Location Diagram
Figure 02	Various	Location of Survey Area and GPR Profiles
Figure 03	1:250	GPR Survey Mala MIRA Timeslices at 0.2 and 0.4m depth
Figure 04	1:250	GPR Survey Mala MIRA Timeslices at 0.6 and 0.8m depth
Figure 05	1:250	GPR Survey Mala MIRA Timeslices at 1.0 and 1.2m depth
Figure 06	1:100	GPR Survey – Plan Interpretation
Figure 07	1:100	Haverfordwest Castle 1577 Plan
Figure 08	1:100	Combined GPR plan interpretation with 1577 plan and archaeology found in 2008 trenches
Figure 09	1:100	Haverfordwest Castle 1889 Buildings Plan
Figure 10	1:100	Combined GPR Plan Interpretation, 1889 Buildings Plan and 2008 trenches
Figure 11	1:100	Combined GPR Survey Plan Interpretation with Ground Resistivity Survey Results (from 2020 Geo Arch report)
Figure 12	1:100	Plan interpretation of the GPR survey overlain with the grey scale plot of the magnetometer survey (DAT)

## 2. SURVEY METHODOLOGY

Ground Penetrating Radar (GPR) was chosen as an efficient and effective geophysical method for locating the type of archaeological anomalies that might be expected at this site. The GPR method was used in combination with magnetometry and resistivity surveys completed by another firm as part of a wider geophysical study.

GPR	Mala MIRA High Density Array	Traverse Interval 0.08m parallel	Sample Interval 0.05m
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## 3 EXECUTIVE SUMMARY

A GPR geophysical investigation was conducted over the inner ward of Haverfordwest Castle, Pembrokeshire with a Mala MIRA High Density Array Radar to search for evidence of archaeological structures, as part of a wider geophysical survey involving magnetometry and resistivity methods.

Survey results identified two categories of anomalies of potential archaeological significance, a substantial number of linear features and five discrete features.

Linear features have systematic linear, rectilinear and geometric patterns suggestive of building outlines, walls and other angular structural features. The linear features are predominantly in the inner ward of the castle as shown on a 1577 plan, which also includes most of the prison buildings on an 1889 plan of the castle. Many of the linear features were located inside former prison buildings including the Female Wing, Pump Room, Laundry and Matron's House. Some are suggestive building outlines and walls and may be associated with internal structures. Others are aligned discordantly and may relate earlier phases of occupation.

Groups of linear features were also found in external areas of the prison including the Airing Yard, Old Trial Yard and Wheel Yard. It is uncertain whether they relate to the earlier or later prison periods or may even predate the prison.

A cluster of linear features detected in the Hall area on the 1577 plan, display trends broadly parallel to the wall orientations, possibly suggesting an association with this period of occupation.

Five discrete features have regular geometric shapes suggestive of a man-made origin. One correlated to a postulated water tank identified by the resistivity survey and another was inside the old Hall. The others are not obviously connected to any of the former buildings and are of uncertain origin.

## 4 INTRODUCTION

4.1 **SUMO Geophysics Ltd** were commissioned to undertake a geophysical survey of the inner ward of Haverfordwest Castle searching for archaeological structures, to help enhance the site as a flagship heritage attraction.

### 4.2 Site details

<b>NGR / Postcode</b>	SM 9535 1573/ SA61 2EF
<b>Location</b>	The site is located near the intersection of the A4076 Freemans Way and the A40 in Haverfordwest.

<b>HER</b>	Pembrokeshire
<b>District</b>	Haverfordwest Town Council
<b>Topography</b>	Flat topped mounds and paths
<b>Current Land Use</b>	Grassed swards and gravel paths
<b>Geology (BGS 2020)</b>	<u>Solid</u> : Mudstone from the late Ordovician- early Silurian undifferentiated Portfield Formation and Haverford Mudstone Formations. <u>Superficial</u> : None recorded
<b>Soils (CU 2020)</b>	Soilscape 6: freely draining slightly acid loamy soils.
<b>Archaeology (OA 2020)</b>	Haverfordwest Castle is a Scheduled Monument (PE366), with structural remains and also a Grade I listed building (Ref.no.12031). The castle was established in the early 12th century, located on a sandstone promontory overlooking the Cleddau River and its lowest fordable bridging point. Supposedly established by Tankred the Flemming around 1110, the present castle remains are largely the result of major redevelopments in the late 13th century by Queen Eleanor, wife of Edward I. By the 16th century the castle was in ruins and was further slighted in 1648. In 1780 a purpose build gaol was constructed in the castle, which was rebuilt by 1820, and operate with some alterations, not closing until 1878. The buildings were subsequently utilised by the Police until the early 1960s, with a number of the former gaol buildings subsequently demolished. The site became the County Museum for a time before moving to its present location at Scolton Manor. The former Prison Governors House within the castle still hosts the town museum.
<b>Survey Method</b>	Ground penetrating radar (GPR)
<b>Other Studies</b>	The GPR survey was part of a wider geophysical study also carried out in 2020, involving magnetometry by DAT and resistivity survey by GeoArch. At the time of this report, only a plan interpretation of the earth resistance survey was available for correlation (TY 2020) together with the results of a 2008 programme of archaeological excavations by Cambria Archaeology (PC 2008).
<b>Study Area</b>	845 m <sup>2</sup>

#### 4.3 Aims and Objectives

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

## 5 SURVEY PROCEDURE

A survey grid was established over the study area as a reference for the site work. A parallel series of radar profiles was carried out with a Mala MIRA high density array system over accessible parts of the site, at standard 0.08 metre intervals. The positions of the radar profiles are presented in Figure 2. Further information about the GPR method, data acquisition and processing is given in the Appendix.



## **6 INTERPRETATION OF RESULTS**

### **6.1 Introduction**

The GPR survey data is presented in Figures 2 – 5 as a series of timeslices at 0.20 m intervals within the system depth range where results were obtained. The interpreted results are shown in Figure 6. Interpretation of the timeslices identified two categories of reflection targets of potential archaeological significance:

- i) Linear features
- ii) Discrete features

### **6.2 Linear Features**

The features occur as a series of moderate to high amplitude linear anomalies. The linear anomalies are distributed in systematic linear, rectilinear and geometric patterns suggestive of building outlines and other angular structural features, occurring at a depth range between 0.3 – 1.35 metres bgl.

### **6.3 Discrete Features**

Five fairly high amplitude, discrete anomalies were identified in the site. The discrete features have simple, regular, geometric shapes suggestive of a man-made origin, occurring within a shallow depth range of 0.2 – 0.45 metres. Despite the shallow depths, the discrete features may still be of potential archaeological significance due to the location.

## **7 DATA APPRAISAL & CONFIDENCE ASSESSMENT**

The Mala MIRA system was selected as a very satisfactory method for producing high resolution time slices of an archaeological site. A maximum depth penetration of 1.5 metres was achieved over most of the site area. Two categories of anomalies were identified from the data of potential archaeological significance, indicating that the survey has been marginally successful.

Looking at the findings of the Cambria Archaeology excavations, the depths of deposits are expected to range from 0.25m to several metres. The timeslices do not show any discernible horizons that can be interpreted as the top of the natural soils or rock. There is a likelihood of finding surviving structural remains around a backfill of masonry debris, which would explain the limited electrical contrast between the anomalies found and the background reflection levels.

## **8 SUMMARY OF RESULTS**

### **8.1 Introduction**

The survey results are presented as a plan interpretation in Figure 6. Specific anomalies have been given numbered identification labels [1], [2] etc. Figure 7 presents a plan of the Castle circa 1577, which has been superimposed on to the plan interpretation and trench archaeology in Figure 8. An 1889 plan of the Castle showing the former prison buildings is presented in Figure 9, similarly superimposed onto the GPR plan interpretation and trench archaeology in Figure 10. The GPR plan interpretation is overlain on to the results of the

recent earth resistance survey by Geo Arch in Figure 11, and over a greyscale plot from the magnetometer survey in Figure 12.

## 8.2 Significant Anomalies

Two significant categories of anomalies were detected by the GPR Survey - linear features and discrete features, that could be of archaeological significance.

In terms of the 1577 plan of the castle, almost all the linear anomalies except for [7] and [8] (-see below), were detected within the inner ward of the castle. Many of the linear anomalies appear to coincide with former building locations on the 1889 castle plan including the Female Wing [1, 2, 3], Pump Room [5], Laundry [4], Matron's House [6]. Some have shapes suggestive of building outlines and walls [3, 4, 5] that may be associated with internal structures within the former buildings. Other linear anomalies are aligned discordantly, and may relate an earlier phase of occupation in the inner ward.

A cluster of linear features with predominantly NNW/SSE and NE/SW orientations [7, 8] were detected in the area of the Hall shown on the 1577 plan. The same area is shown as buildings not in use on the 1889 map. The binomial orientation of the anomalies broadly parallels the alignment of the walls of the hall, suggesting they could be internal structures from this period.

Groups of linear features were also found in the Airing Yard [9 - 14], Old Trial Yard [15, 16] and Wheel Yard [17] of the 1889 plan. Although these features are inside old prison enclosures, it is uncertain whether they relate to the earlier or later prison periods or even predate the prison.

It is interesting to note that Cambria Archaeology Trench 3 lies within the Airing Yard, where the depth of deposits above natural was only 0.25m. The radar anomalies in this area extend down to 0.7m suggesting these are features cut into the natural.

Several of the linear features in the yards have incomplete rectilinear shapes suggestive of building walls or footings [9, 10, 15, 16, 18]. A number partially intersect the 2008 trenches. The tip of the western half of [9] intersects the unexcavated part of the Trench 1. Two subparallel, linear east-west oriented anomalies [11] align with both the water pipe trench and brick wall on the northern edge of the trench, but do not directly intersect the positions of these excavated features. The western half of [15] has an NNW/SSE orientation and runs down the middle of Trench 2. This anomaly does not correspond to any recorded features in the trench. No anomalies were detected over the position of Trench 1.

A group of linear features inside the old Airing Yard [12] with a subparallel north-south orientation are of uncertain association, perhaps suggestive of landscaping features. A curious, incomplete irregular pentagonal structure was identified in the north-west corner of the Airing Yard [14]. The southern edge of this anomaly intersected trench 3 at the position of two concrete bases.

A group of small linear features in the Wheel Yard [17] show no preferred alignment and are of uncertain origin.

Three ENE/WSW oriented linear structures [19] located in the middle of the survey area appear to be related to the old prison walls transecting this area on the 1889 map.

In addition to the linear features, five discrete features were detected by the GPR survey. A discrete feature in the northern half of the inner ward [20] corresponds to a postulated water tank identified by the resistivity survey, and has a strong corresponding magnetic anomaly. The well to the east in the Pump Room did not produce a clearly discernible anomaly. A discrete feature [21] was also found within the position of the 1577 Hall adjacent to linear anomalies [7] and [8], but cannot be obviously tied to the Hall.

The remaining discrete features do not show any clear correlation to the former building locations and are of uncertain origin.

## 9 CONCLUSIONS

The GPR survey identified two classes of anomalies of potential archaeological significance - linear features and discrete features.

Most of the anomalies were detected in the inner ward of the castle shown on the 1577 plan. The linear features have well defined geometric shapes suggestive of building outlines and walls, detected both inside 1889 prison building locations and in the former yards. Some appear to correlate with the layout of former buildings and yards, whereas others are of more uncertain provenance and may conceivably predate the prison buildings.

A cluster of linear features with a binomial NNW/SSE and NE/SW orientations were detected over the position of the Hall on the 1577 plan. The trends broadly parallel the orientations of the walls and may be related to this period of occupation.

Five discrete features identified by the GPR survey have shapes suggestive of a man-made origin. One correlated to a postulated water tank and another was inside the old Hall. The others are not obviously connected to any former structures and are of uncertain origin.

Relatively few features were found over the positions of the 2008 excavations carried out Cambria Archaeology. Future excavations could be targeted on some of the more prominent anomalies to help determine their provenance.

A future GSSI Dual Frequency (DF) radar survey could be considered as follow-up to the Mala MIRA survey. A DF system survey provides improved depth penetration, further characterisation of individual anomalies and for finding additional features not detected up by the high density radar on multi-phase occupation sites, where simple patterns of archaeological features are not always clearly discernible.

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**Sumo**  
Survey  
GEOPHYSICS FOR  
ARCHAEOLOGY &  
ENGINEERING

### Site Location Diagram

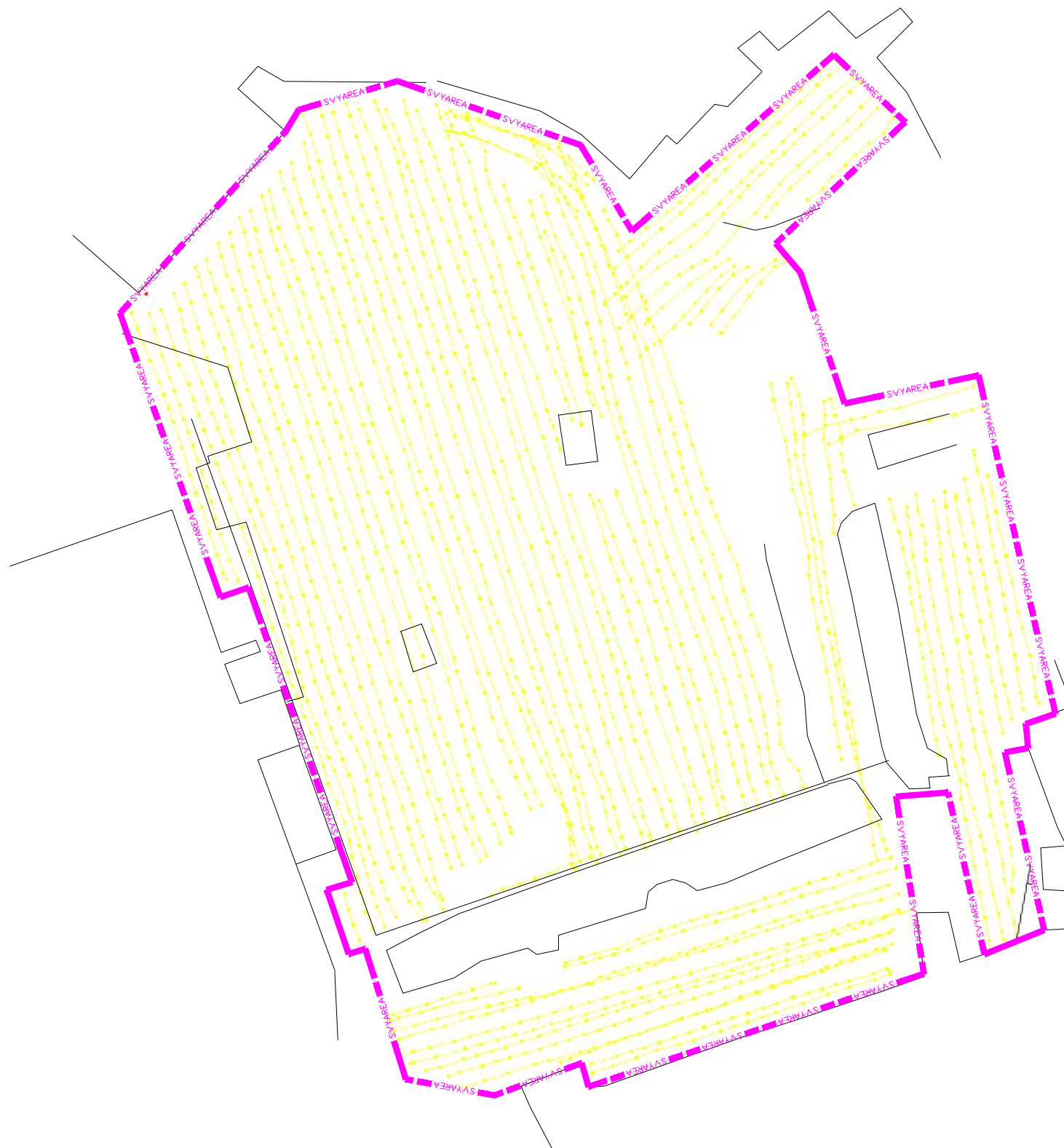
The Dyfed Archaeological Trust

SUMO-01003 Haveforwest Castle,  
Pembrokeshire

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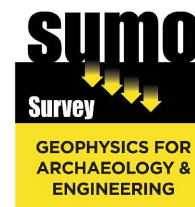
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Survey area



Radar traverse



Title:  
Location of Survey Area and GPR Profiles

Client:  
The Dyfed Archaeological Trust

Project:  
SUMO-01003 Haveforwest Castle,  
Pembrokeshire

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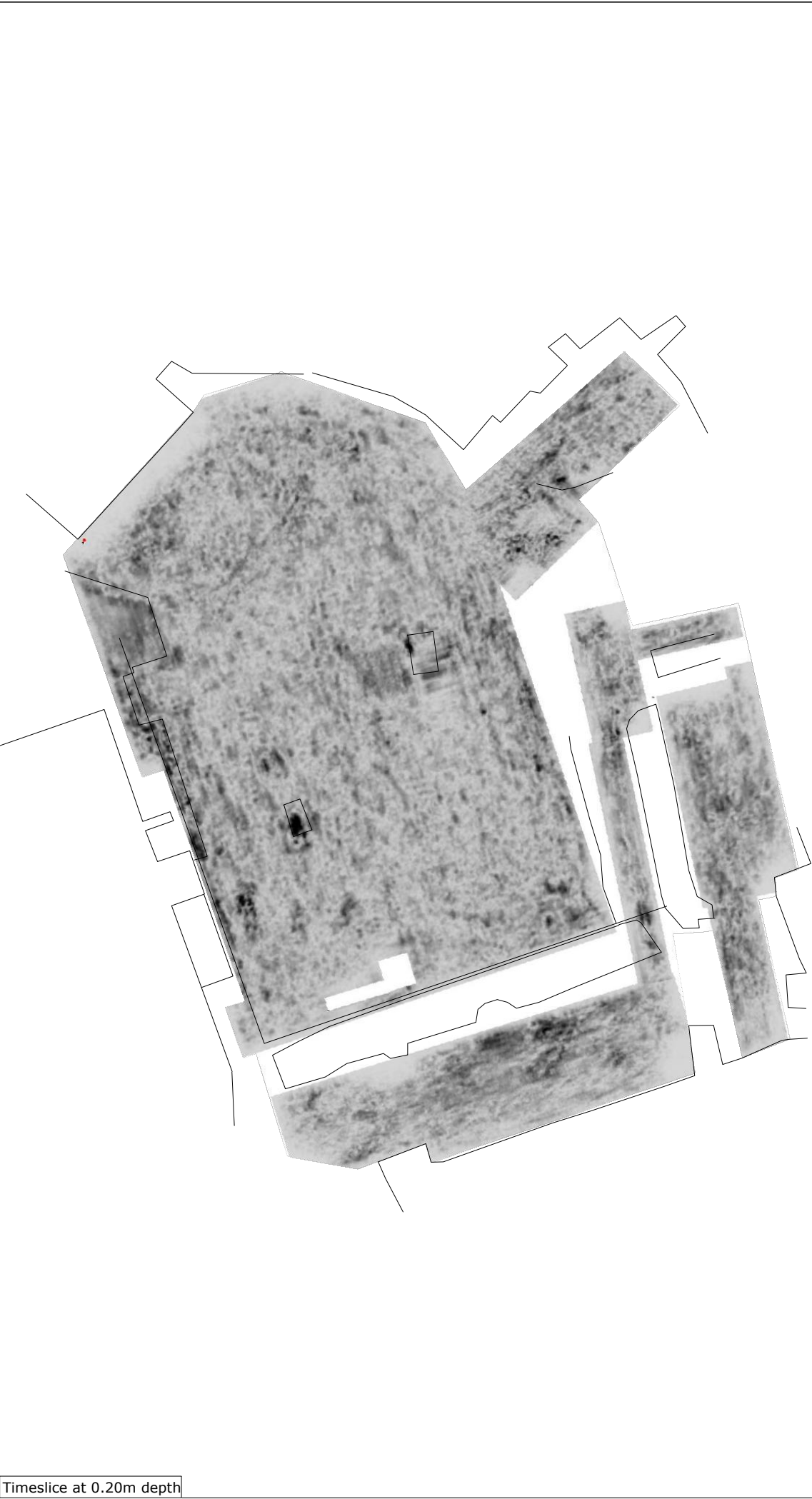
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Survey date  
October 2020

Drawn by  
MUK

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

#### 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

Title: GPR Survey - Timeslices at 0.20m and 0.40m depth

Client: The Dyfed Archaeological Trust

Project: SUMO-01003 Haveforwest Castle, Pembrokeshire

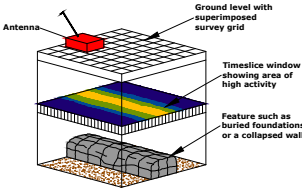
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Survey date: October 2020	Drawn by: MUK	Checked by: PPB
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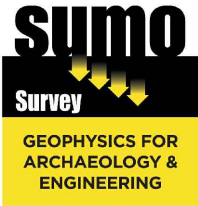
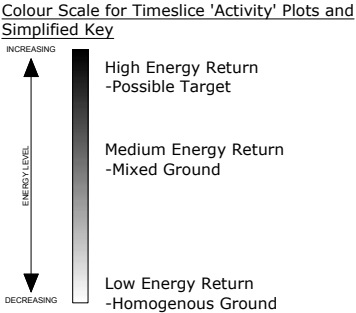
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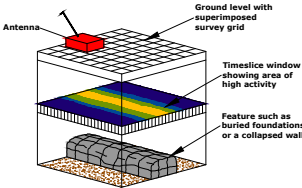
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Client: The Dyfed Archaeological Trust		
Project: SUMO-01003 Haveforwest Castle, Pembrokeshire		
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Survey date: October 2020	Drawn by: MUK	Checked by: PPB





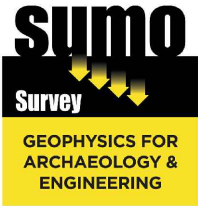
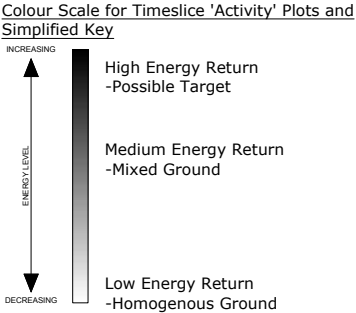
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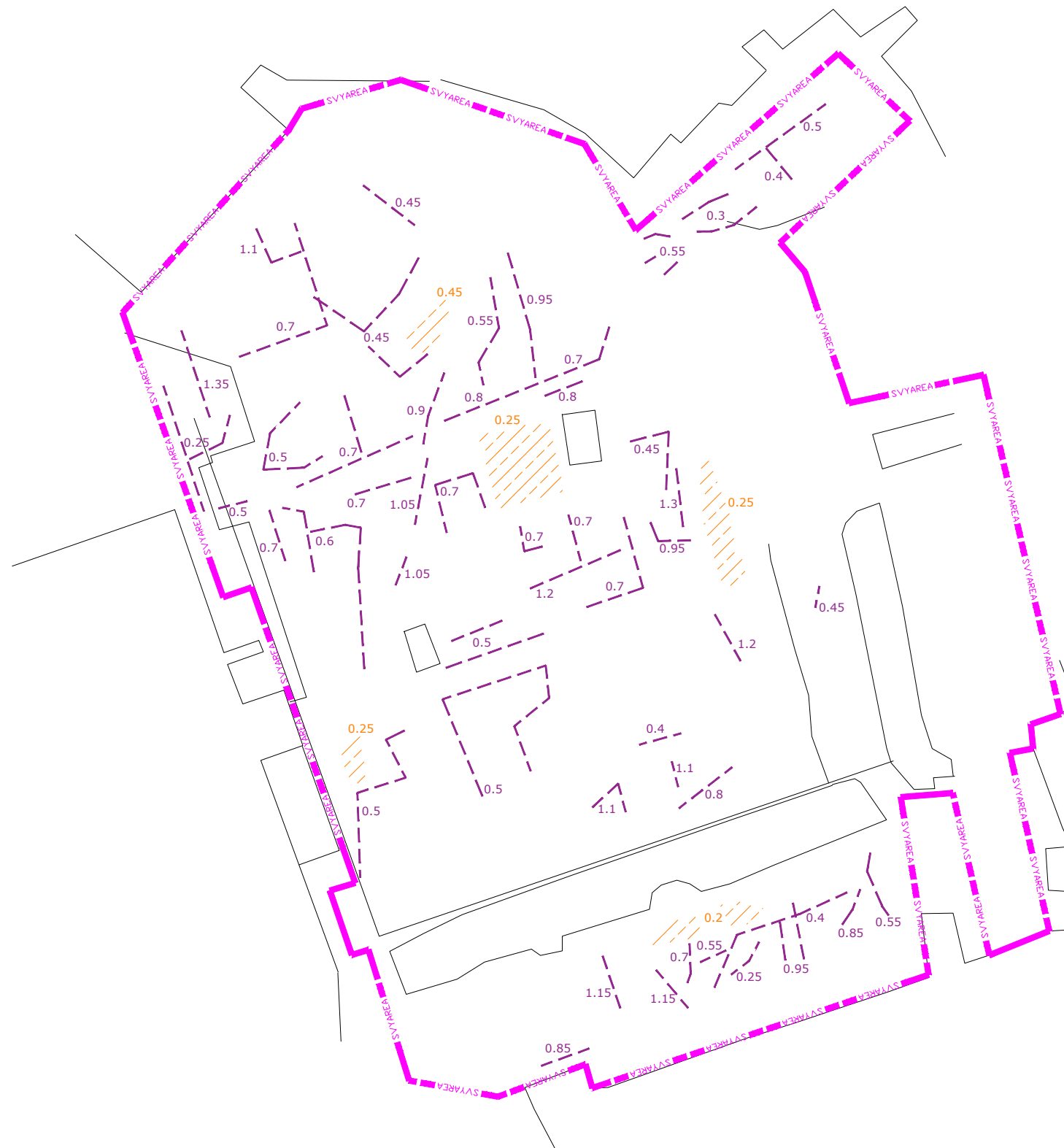


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The weaker reflections in the time slice windows are shown as white and light grey. The stronger reflections are represented by dark grey and black.





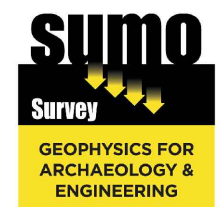
Title: GPR Survey - Timeslices at 1.00m and 1.20m depth		
Client: The Dyfed Archaeological Trust		
Project: SUMO-01003 Haveforwest Castle, Pembrokeshire		
Scale: 0 metres 12.5 1:250 @ A3	Fig No: 05	
Survey date October 2020	Drawn by MUK	Checked by PPB



**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

	Linear feature possibly related to buildings remains
	Discrete feature of uncertain origin
0.6	Depth to the top of the feature (in m)




Title:	GPR Survey - Plan Interpretation
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Client: The Dyfed Archaeological Trust

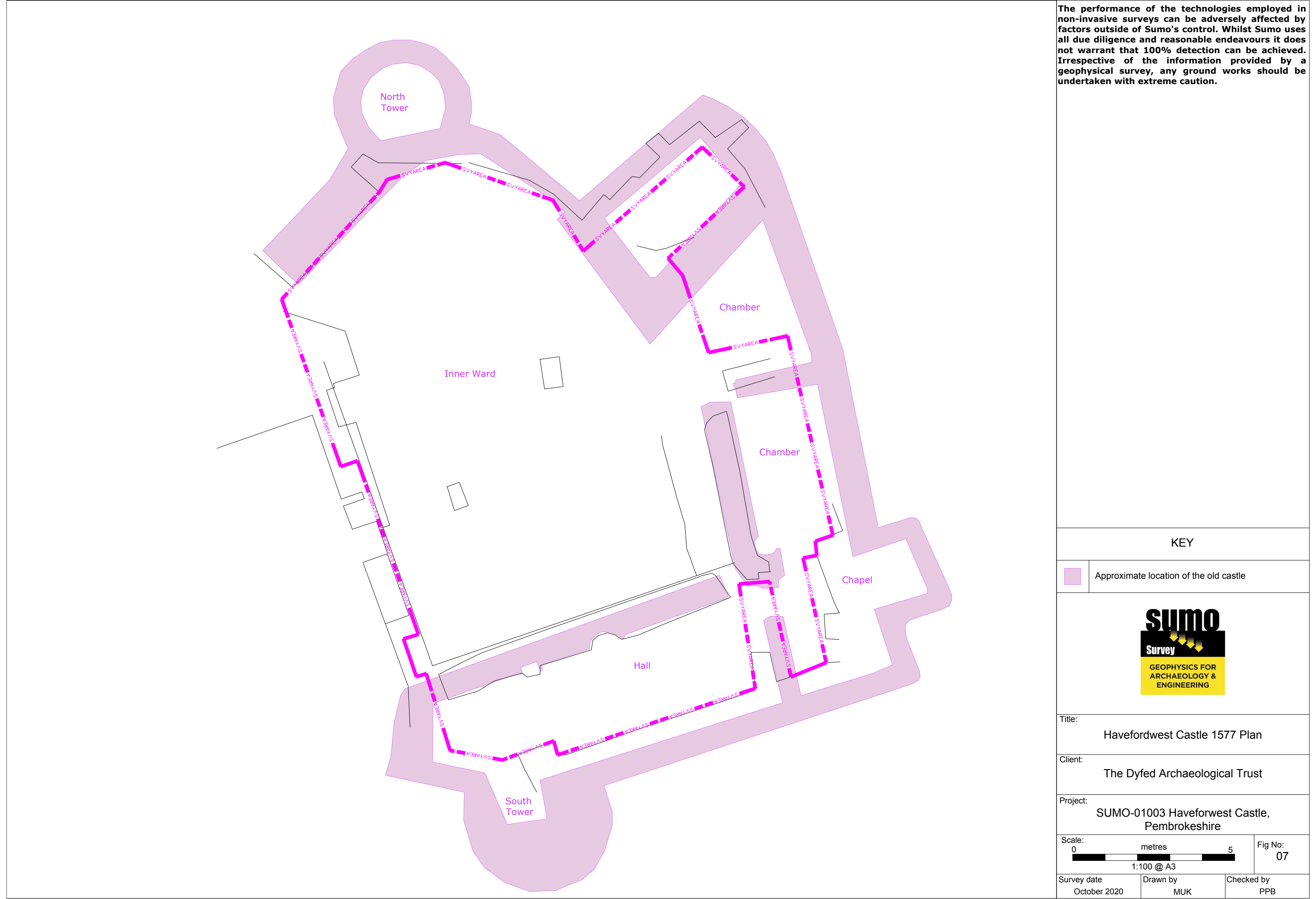
Project:	SUMO-01003 Haveforwest Castle, Pembrokeshire
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Scale: 0 metres 5

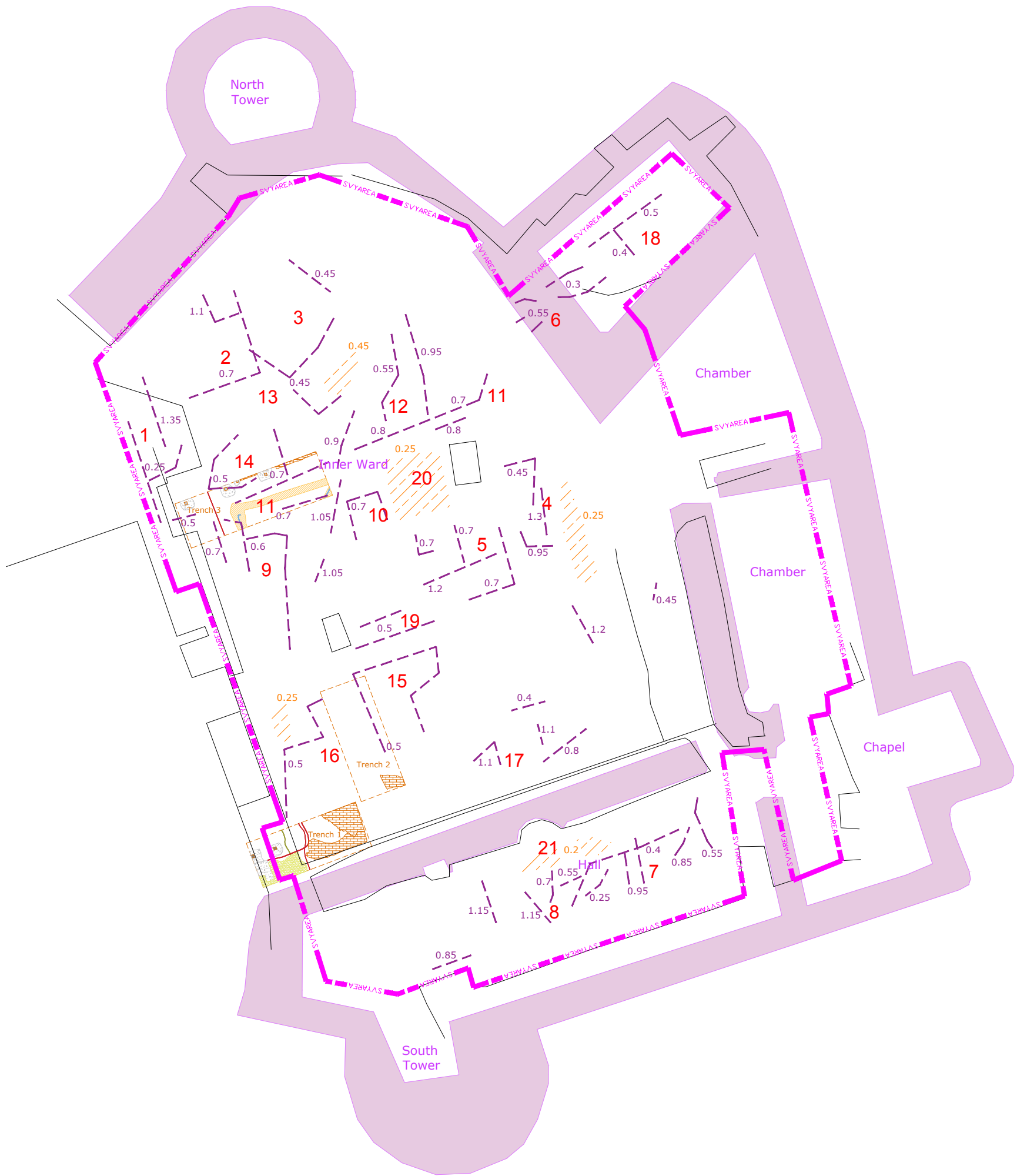


1:100 @ A3

Survey date October 2020	Drawn by MUK	Checked by PPB
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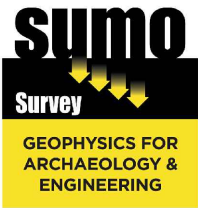


The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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



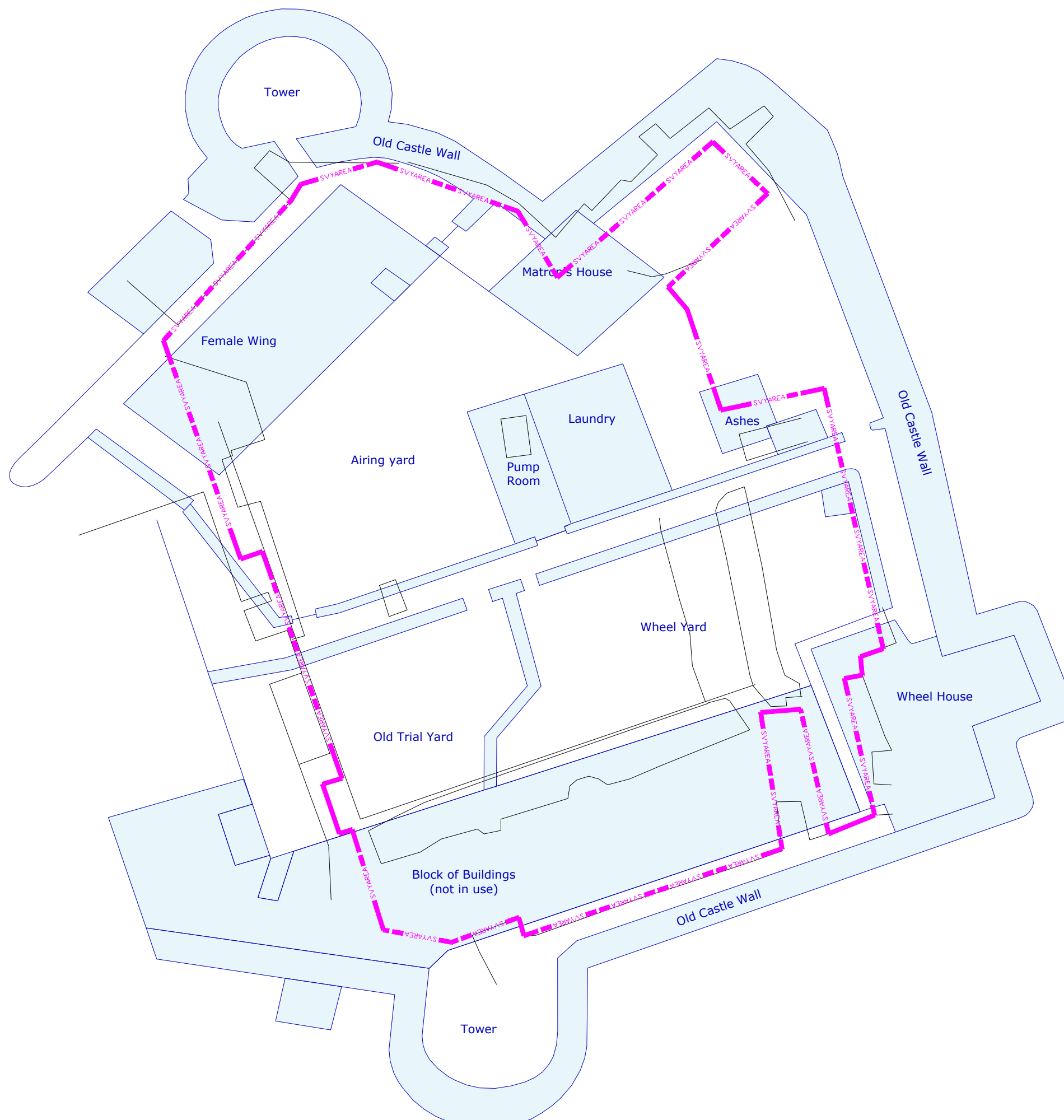
The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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

KEY	
	Linear feature possibly related to buildings remains
	Discrete feature of uncertain origin
0.6	Depth to the top of the feature (in m)
	Approximate location of the old castle
	Trenches from Cambria Archaeology Report No. 2008/21', project record Nos. 63297
	Masonry
	Electric cable
	Lead pipe
	Copper pipe
	Pipe trench
	Fence post
	Concrete
	Gravel




Title: Combined GPR Plan Interpretation with 1577 Plan and Archaeology Found in 2008 Trenches		
Client: The Dyfed Archaeological Trust		
Project: SUMO-01003 Haveforwest Castle, Pembrokeshire		
Scale: 0 metres 5 1:100 @ A3	Fig No: 08	
Survey date October 2020	Drawn by MUK	Checked by PPB

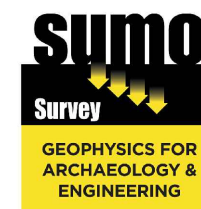




The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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

#### KEY

 Approximate location of 1889 buildings



Title:  
Havefordwest Castle 1889 Buildings Plan

Client:  
The Dyfed Archaeological Trust

Project:  
SUMO-01003 Haveforwest Castle,  
Pembrokeshire

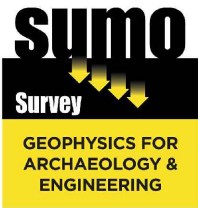
Scale:  
0 metres 5  
1:100 @ A3  
Fig No:  
09

Survey date  
October 2020  
Drawn by  
MUK  
Checked by  
PPB



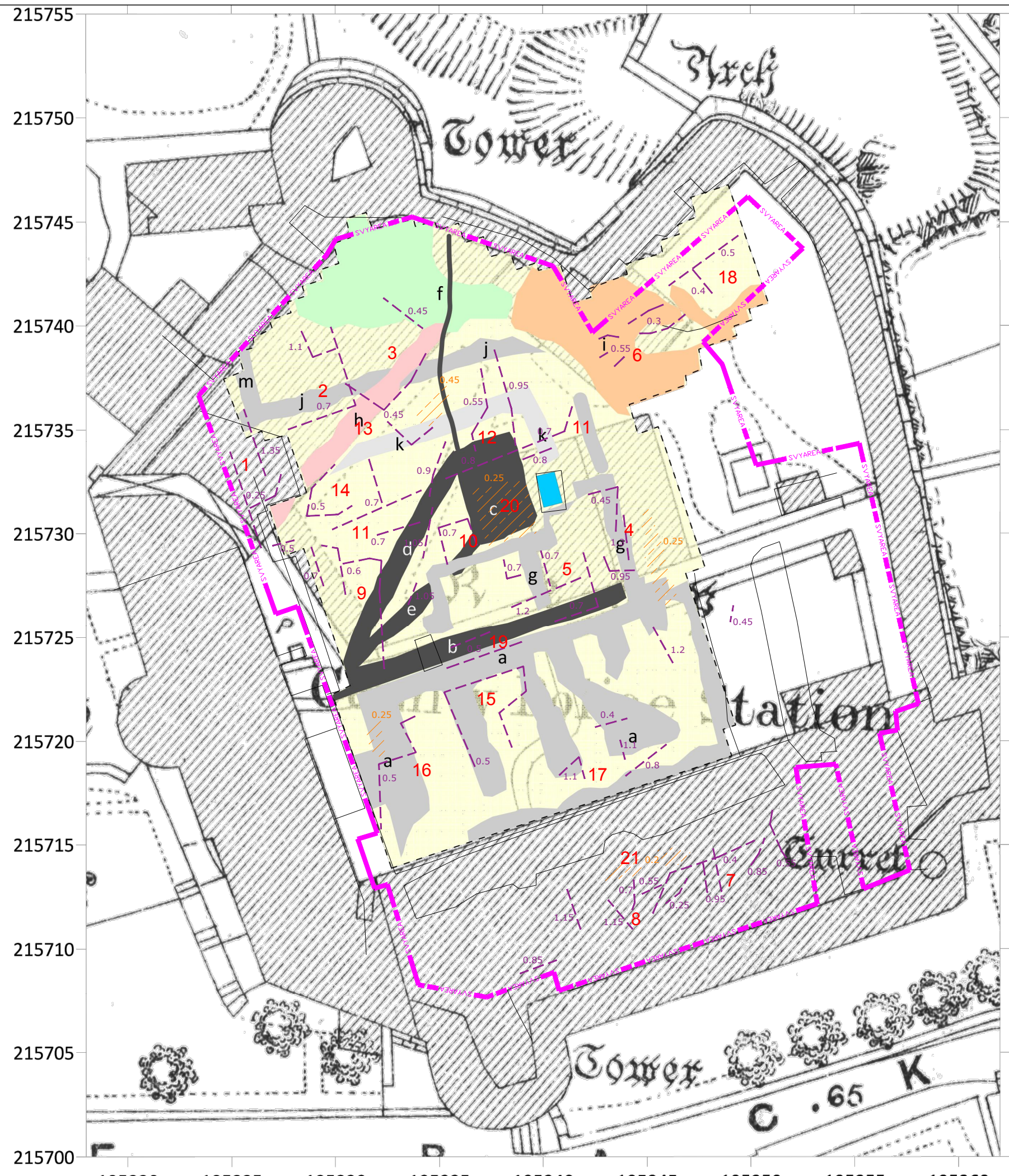
The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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

KEY	
	Linear feature possibly related to buildings remains
	Discrete feature of uncertain origin
0.6	Depth to the top of the feature (in m)
	Approximate location of 1889 buildings
	Trenches from Cambria Archaeology Report No. 2008/21', project record Nos. 63297
	Masonry
	Electric cable
	Lead pipe
	Copper pipe
	Pipe trench
	Fence post
	Concrete
	Gravel



Title: Combined GPR Plan Interpretation, 1889 Building Plan and 2008 Trenches		
Client: The Dyfed Archaeological Trust		
Project: SUMO-01003 Haveforwest Castle, Pembrokeshire		
Scale: 0 metres 5 1:100 @ A3		Fig No: 10
Survey date: October 2020	Drawn by: MUK	Checked by: 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	
	Linear feature possibly related to buildings remains
	Discrete feature of uncertain origin
0.6	Depth to the top of the feature (in m)
	Trenches from Cambria Archaeology Report No. 2008/21', project record Nos. 63297
	Positive resistivity anomalies that are aligned in directions probably associated with the earlier prison buildings
	Negative resistivity anomalies interpreted as a water tank, trenches for water pipes and paths.
	Location of the well
	Positive resistivity anomaly interpreted as the SE wall of the c.1820 women's block
	Very strong positive resistivity anomaly associated with the location of the 'matron's house'
	Diffuse positive resistivity anomaly, perhaps fallen masonry?

**sumo**  
Survey  
GEOPHYSICS FOR  
ARCHAEOLOGY &  
ENGINEERING

Title: Combined GPR Survey Plan Interpretation with Ground Resistivity Survey Results (taken from 2020 GeoArch report)

Client: The Dyfed Archaeological Trust

Project: SUMO-01003 Haveforwest Castle, Pembrokeshire

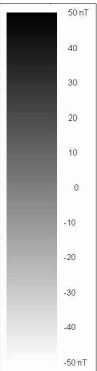
Scale: 0 metres 5  
1:100 @ A3

Fig No: 11

Survey date October 2020	Drawn by MUK	Checked by PPB
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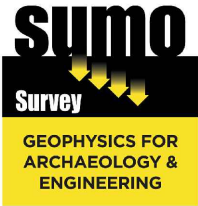


The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical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



KEY

	Linear feature possibly related to buildings remains
	Discrete feature of uncertain origin
0.6	Depth to the top of the feature (in m)



Title: Plan interpretation of the GPR survey overlain with the grey scale plot of the magnetometer survey (DAT)

Client: The Dyfed Archaeological Trust

Project: SUMO-01003 Haveforwest Castle, Pembrokeshire

Scale: 0 metres 5	Fig No: 12
1:100 @ A3	

Survey date: October 2020	Drawn by: MUK	Checked by: PPB
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## **Appendix A - Ground Penetrating Radar (GPR) Method**

### ***Introduction***

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 typical GPR system consists of an antenna unit, together with a signal control and processing unit with built in monitor. The system is powered from a 12V DC battery source. During survey operations, the antenna is moved in parallel traverses over the ground or material under investigation.

A short pulse of electromagnetic energy in the UHF frequency band is emitted into the ground and reflections are returned from the interfaces between different materials in the subsurface. 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 the material under investigation. 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).

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 resolution and depth range of a GPR system is principally dependent on the frequency of the antenna units used. Higher frequency antennas provide the optimum resolution of hidden features, but generally have a limited depth range. Conversely, low frequency antenna units have greater depth range, but lower resolving power.

### ***Survey equipment and configuration***

The Ground Penetrating Impulse Radar used was a Mala MIRA High Density Array Radar with 8 x 400MHz antennae.

#### **Sampling interval**

Individual radar profiles are spaced at standard intervals of 0.08m, with readings 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 ranges between 0.10 - 0.12m/nsec in most UK ground conditions. The MIRA has a variable range setting of up to 60nsec equating to a maximum depth penetration of up to 3.6m, although this figure could vary by  $\pm 20\%$ .

Under ideal circumstances the minimum size of a vertical feature seen by a 400MHz (intermediate frequency) antenna in a damp soil would be 0.05m (i.e. this antenna has a wavelength in damp soil of about 0.25m and the vertical resolution is one quarter of this wavelength).

### 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.

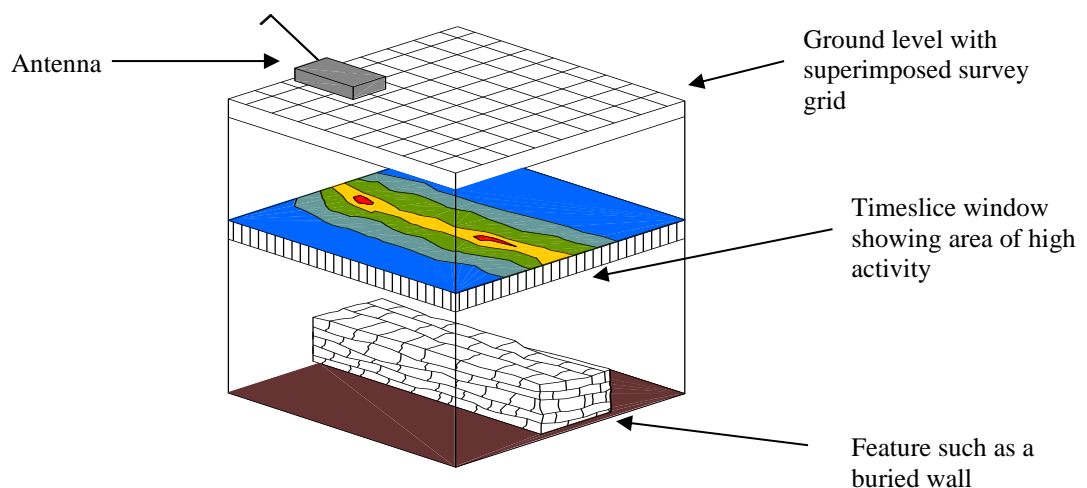
### **Data processing**

Processing is performed using specialist software (Mala Rslicer). There are a wide range of filters available, the application of which will vary depending on the project. The table below shows the typical processes used for this data:

Gain	Amplification to correct for weakening of signal with depth.
DC-Shift	Re-establishes oscillation of the radar pulse around the zero point)
Dewow / Ringdown Removal	Removes low frequency, down-trace instrument noise
Bandpass Filtering	Suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise
Background Removal	Can remove ringing, instrument noise and minimize the near-surface 'coupling' effect
Migration	Collapses hyperbolic tails (also known as 'diffractions') back towards the reflection source
Amplitude Envelope	Simplifies pulses for production of time-slice maps by summing peak values, regardless of polarity, over a given time-window.

### Timeslice plots

The MALA 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 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 calculation have been made to show the equivalent depth into the ground.

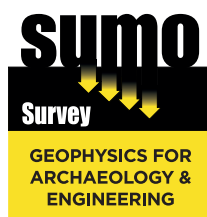
The weaker reflections in the time slice windows are shown as light grey colour. The stronger reflections are represented by colours such black and dark grey.



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.

***Warning***

SUMO use non-invasive survey techniques to detect sub-surface features. However, the performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside SUMO's control, such as ground conditions. Also, it should be understood that the interpretation of ground penetrating radar data are opinions based on inferences from electromagnetic measurements, factors and assumptions, and that such inferences are not infallible. Therefore, because of the uncertainty of variable ground conditions, SUMO does not warrant that 100% detection can be achieved. Irrespective of information provided by a detection survey, any ground works should be undertaken with extreme caution and in accordance with the Health and Safety Executive guidelines HSG47 - Avoiding Danger from Underground Services.



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

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