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FRIENDS OF CROOKSTON CASTLE

CROOKSTON CASTLE

GEOPHYSICAL SURVEY REPORT

(c) The Friends of Crookston Castle

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EXECUTIVE SUMMARY

Historic Environment Scotland (HES), Archaeological Survey, undertook geophysical (gradiometer, earth resistance, and ground penetrating radar) survey at Crookston Castle, Glasgow. Fieldwork was conducted between 29th and 31st August 2025.

A block of 2.2ha to the south and east of the castle was surveyed with a Sensys MXPDA gradiometer. Four grids covering 0.22ha in total were surveyed with a Frobisher TAR-3 earth resistance meter, three of which lie within the area enclosed by the castle ditch, with the fourth to the east within the area covered by gradiometry. In addition, three grids totalling 0.19ha were surveyed with a MALÅ GX450MHz HDR ground penetrating radar.

The geophysical surveys produced good quality results in most areas which give a high level of confidence that the methodologies and survey strategy were appropriate to assess the archaeological potential of the survey area. The ground penetrating radar from within the area enclosed by the castle ditch provided disappointing results.

The survey has revealed archaeological features that include structural elements of the castle, and a range of buildings and structures, including a possible well, within the castle keep. Beyond the castle moat an entirely unexpected cluster of later prehistoric roundhouses and a palisaded enclosure have been discovered, a significant addition to the history of this location. These represent a succession of large timber round houses. The identification of ephemeral, possibly timber, building remains to the WSW of the castle moat highlights the potential for settlement of medieval and later date just outside the castle moat. Finally, coal mining of medieval or later date is identified, along with the signatures of demolished 19th and 20th century buildings and infrastructure.

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This document has been prepared following HES' Terrestrial Geophysical Survey Standard Operating Procedures v1.0			
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1.0 INTRODUCTION

Historic Environment Scotland (HES), Archaeological Survey team, conducted multi-method (gradiometer, earth resistance, and ground penetrating radar (GPR)) geophysical survey at Crookston Castle, Glasgow, between 29th and 31st August 2025. This report provides the background to the survey and the methods employed. Results are presented in an National Record of the Historic Environment (NRHE) events record structure comprising an overall Project Event (NRHE Project Event ID: 1218889), with subsidiary NRHE Recording Events describing the different techniques applied:

- NRHE Project Event ID: 1218890 (Gradiometer Survey)
- NRHE Project Event ID: 1218891 (Earth Resistance Survey)
- NRHE Project Event ID: 1218892 (Ground Penetrating Radar Survey)

The archaeological interpretations of the survey data are described in NRHE entries that reference what are regarded as appropriate archaeological site records:

- NRHE Site ID: 44400 Crookston Castle (Chapel, Ringwork, Tower House)
- NRHE Site ID: 386935 Crookston Castle (Mound, Palisaded Enclosure, Roundhouses)
- NHRE Site ID: 386956 Crookston Castle (Enclosure)
- NHRE Site ID: 386957 Crookston Castle (Field Boundaries)
- NHRE Site ID: 386958 Crookston Castle (Roundhouse)
- NHRE Site ID: 386959 Crookston Castle (Buildings, Enclosures)
- NHRE Site ID: 386960 Crookston Castle (Coal Mining Site)

2.0 PROJECT BACKGROUND & AIMS

The Friends of Crookston Castle aim to care for and celebrate Crookston Castle, the only surviving medieval castle in Glasgow. The survey reported on here investigated areas within and adjacent to the castle site though geophysical survey. Engagement with members of the local community was a central aim, by providing experience in using three types of geophysical survey equipment to investigate the area for archaeological features. More generally, the survey contributes to the regional and thematic understanding of Medieval castles and their immediate environs. This survey forms part of a five-year Historic Scotland Foundation (HSF) funded project aimed at developing geophysical survey capability within the Archaeological Survey Team of the Heritage Directorate of HES.

The survey work at Crookston also provides an opportunity to compare the results of modern geophysical survey techniques with earlier excavations and survey. In aiming to enhance archaeological understanding, the survey aimed to seek previously unknown archaeological, or potentially archaeological, anomalies, and to gain further information about previously identified archaeological features. Beyond these general aims, the survey aimed to address the following specific questions:

- *Can the use of gradiometry, ground penetrating radar and Wenner array earth resistance equipment enhance the understanding of the site following the results of the 1999 twin-probe earth resistance survey?*
- *Was there an Iron Age fort on the hilltop?*
- *Can the form of the ringwork (the ditch around the castle) be established?*
- *Can the arrangement of buildings and defences in the barmkin be identified?*
- *Can the Chapel of Croc be identified?*
- *Can any trace of an entrance in the eastern side of the castle's defences be identified?*
- *Can medieval activity be identified in the area to the south of the castle?*
- *Is there any evidence supporting the local rumours of a tunnel linking the castle with Paisley Abbey?*

- *Can traces of Home Guard or US military activity during World War II in the vicinity of Crookston Castle be identified in the geophysical survey data?*
- *Can traces of the 20th century buildings which once stood to the north of Brockburn Road between Towerside Crescent and Crosstobs Road be identified in the geophysical survey data?*

The survey results have been added to the NRHE and are accessible online through trove.scot, HES' digital portal for the historic environment. This information could inform future review of the designated area under the 1979 Ancient Monuments and Archaeological Areas Act. The survey results will also contribute towards answering gaps in the understanding of the castle as set out in the Statement of Significance (HES 2004) for Crookston.

3.0 SITE LOCATION & PREPARATION FOR SURVEY

The survey area (NRHE Event ID: 1218889) is centred on NS 52559 62715 and lies to the north of Brockburn Road, Crookston, Glasgow (Figure 01) on ground that rises from around 18m AOD to about 30m AOD on the higher ground occupied by Crookston Castle (Figure 2; NRHE Site ID: 44400). The prominent remains of the stone-built castle lie within a substantial ditch and bank.

The castle and the ground to the east of the ditch are a scheduled monument (SM90085). The grassed area to the south of the castle is owned by Glasgow City Council, while the rise on which the castle sits is owned by the National Trust for Scotland and is a HES Property in Care (PIC: 119).

The solid geology is Limestone Coal Formation Carboniferous sedimentary, overlain with Till, Devensian – Diamicton Quaternary sedimentary, with a small area of Raised Tidal Flat Deposits, Late Devensian – Gravel, Sand and Silt in the southwest corner of the survey area (BGS 2025). The pedology is characterised as Built-up Land (Scotland's Soils 2025).

Gradiometer survey can be affected by underlying geology, such as the high levels of background magnetism often evident in locations with igneous or metamorphic geologies which can mask subtle changes in the magnetic field associated with archaeological remains. However, the sedimentary bedrock formations recorded at Crookston should have low levels of background magnetism and adverse effects are not anticipated (English Heritage 2008: 15).

Prior to conducting the survey, permission to access the land was obtained from the landowners. As the survey area is a scheduled monument, as per *The Scheduled Monument Consent Procedure (Scotland) Regulations 2015*, a Metal and Mineral Detecting Application was submitted to HES Planning, Consents and Advice Team for consideration. Permission was granted under reference 300079748.

The survey area is not within a Site of Special Scientific Interest, is not protected under the Ramsar Convention, is not within a National or Regional Park, and is not a nature reserve (NatureScot 2025). Reference to the National Biodiversity Network's Atlas for the survey area and a 200m buffer surrounding it, shows the area has no sightings of flora or fauna which require the granting of a licence for this survey to be conducted (NBN 2025).

During the survey, the weather conditions were cool and windy with occasional heavy showers.

A photographic record showing the survey areas showing ground conditions can be found in section 12.

4.0 ARCHAEOLOGICAL BACKGROUND

The scheduled monument description (SM90085) and Trove record (NRHE Site ID: 44400) provides an overview of the remains of Crookston Castle from which the following is derived. First designated in 1920, the medieval castle comprises a stone-built tower enclosed by a substantial ditch and bank. The low hilltop on which it is situated dominates the confluence of the Levern Water and the White Cart. The castle exhibits at least two major phases of construction, perhaps including elements of an earlier fort.

The first phase comprises a massive bank and ditch of an earth-and-timber castle built by Robert Croc in around 1180. The ditch is up to 3.5m deep, with an entrance on its western side. The second phase comprises a stone castle, probably built by Sir John Stewart of Darnley at the beginning of the 15th century. This castle is unique in Scotland and comprised a central oblong block with four square corner towers – though only the northeastern tower survives intact. Crookston continued to be used as a residence until the end of the 16th century.

Geophysical and topographic survey undertaken in 1998 and 1999 (NRHE Recording Event ID: 702551) identified the location of a chapel built by Sir Robert Croc in the late 12th century, lying within the courtyard of the castle. This work also suggested that the 12th-century castle was not of a motte and bailey type as previously suggested but was instead a ringed defence work. The geophysical survey identified a circular enclosure about 20m in diameter defined by a wall trench about 1m across to the east of the castle enclosure.

The earthworks of rig and furrow are apparent on both the north and south sides of the hill, possibly of post-medieval date.

5.0 SURVEY METHODOLOGY

The present survey applied three different geophysical survey techniques (Gradiometer, Earth Resistance and GPR), which are described in Recording Events that detail the spatial framework and technique applied (Section 6). Archaeological interpretations of the survey data are described in the framework of National Record of the Historic Environment (NRHE) entries (Section 7). The survey work was undertaken by volunteers working under the direct supervision of HES staff.

The geophysical survey techniques were conducted in accordance with the Chartered Institute for Archaeologists (CIfA) *Standards and Guidance for archaeological geophysical survey* (CIfA 2016), the European Archaeological Council (EAC) *Guidelines for the use of geophysics in archaeology* (EAC 2016), and the HES *Archaeological geophysical survey, Standard Operating Procedure* (HES 2020). Geophysical survey methods were selected to best deliver the aims detailed in Section 2, following the recommendations outlined in the EAC guidelines (EAC 2016) and the manufacturer's guidelines (Frobisher 2019; MALÅ 2023a, 2023b, 2023c, 2023d; Sensys 2019). All sensors had valid in-date calibration certificates.

A photographic record of the survey area was taken during the work (Section 12; Figure 4).

5.1 GRADIOMETER SURVEY

The gradiometer survey (Figure 4) was conducted across all accessible parts of the open ground the south and east of the castle (NRHE Recording Event ID: 1218890) using a hand propelled Sensys MXPDA system mounted on a Sensys F-type non-magnetic cart, fitted with standard profile wheels. The system used five Sensys FGM650/3 sensors running at 100hz, with sensor bases positioned 0.15m above the ground. Sensors were mounted with 0.50m separation and data was recorded every 0.125m along each traverse, delivering an average density of sixteen readings/m^2. The system was balanced prior to the commencement of the survey, with the calibration position shown in Figure 4.

The survey was conducted by walking parallel traverses in a zig-zag pattern, with traverses aligned east-west and 2.5m apart. Navigation was provided by MONMX, the system's on-board software, which displays the cart position in relation to areas of previously collected data, ensuring that each traverse is evenly spaced. The position of the traverses is recorded as a breadcrumb trail (Figure 4). Positional accuracy was provided by a Leica GS16 GNSS antenna mounted directly on the frame of the cart at a height of 1.50m. This provided a constant stream of data in National Marine Electronics Association (NMEA) format allowing each reading to be accurately georeferenced without the need for a pre-determined grid system.

Data was logged in .prm format using the MONMX v.5.01-03/00 software package on a Panasonic FZ-G1 tablet computer. Following the completion of the survey, the data was exported from the system in both .asc and .uxo formats. The .uxo file was processed and visualised using DW Consulting's Terrasurveyor v4.1.0.1 as described in Appendices 2, 3, and 4, with the .asc file kept for archiving. Interpretations were generated in a Geographic Information System (GIS) environment (ESRI ArcGIS Pro v3.4.4).

Data quality was maintained by avoiding ferrous objects such as fences, gates and inspection covers where possible.

A total of 2.2ha of data were collected employing this method.

5.2 EARTH RESISTANCE SURVEY

The earth resistance survey (Figures 11) was conducted across a grid to the east of the castle ditches (CK03) and three grids within the castle keep (CK04, CK05 and CK06) using an RM Frobisher TAR-3 earth resistance meter (NRHE Recording Event ID: 1218891) The system was configured as a Wenner array using 0.50m probe separation for area CK03 and has a twin-probe array using 0.35m probe separation for areas CK04, CK05 and CK06.

The survey was conducted by walking parallel traverses in a zig-zag pattern 0.50m apart. Readings were recorded every 0.50m along each traverse, delivering an average density of 4 readings/m^2. Navigation was provided by the manual installation of survey grids marked out using red plastic survey pegs and blue nylon rope. The pegs did not have a physical impact on any archaeological deposits as they did not penetrate the ground by more than 0.05m. They were removed on completion of the survey. The location of the grid was recorded using a Leica GS16 GNSS allowing the survey results to be accurately georeferenced.

Each survey grid had its own data file. Data was logged on an SD card installed in the system controller in .xyz format. The files were processed using Snuffler v1.3 as described in Appendices 2, 3, and 4. Interpretations were generated in a GIS environment (ESRI ArcGIS Pro v3.4.4).

A total of 0.22ha of data were collected employing this method.

5.3 GPR SURVEY

The GPR survey was conducted on areas also covered by the earth resistance survey (Figure 13), in grids CK07 (to the east of the castle ditches) and CK08 and CK10 inside the castle keep, using a hand propelled MALÅ Ground Explorer system mounted on a Rough Terrain Cart Mini (NRHE Recording Event ID: 1218892). This system used a single GX450 HDR Antenna using at 450MHz mounted at ground level. Survey planned for CK09 was not undertaken on safety grounds as an overhanding tree had been damaged by high winds during the survey.

The survey was conducted by walking a series of parallel traverses in a zig-zag pattern 0.50m apart. The position of each grid's initial traverse is recorded as a breadcrumb trail (Figure 13). Navigation was provided by the manual installation of a survey grid marked using red plastic survey pegs and blue nylon rope. The markers

did not have a physical impact on archaeological deposits as they did not penetrate the ground by more than 0.05m and were removed on the completion of the survey. Data points were recorded every 0.05m along each traverse, delivering an average density of 20 points/m^2. Positional accuracy was provided by a Leica GS16 GNSS antenna mounted directly on the frame of the cart at a height of 1.50m. This provided a constant stream of data in NMEA format allowing each reading to be accurately georeferenced.

Data was logged using the MALÅ Controller v10.20826 software package on a Samsung Galaxy Tab Active Pro tablet computer. These files were processed and visualised using Mala Vision v1.2505.15 as described in Appendices 2, 3, and 4. Interpretations were generated in a GIS environment (ESRI ArcGIS Pro v3.4.4).

A total of 0.19ha of data were collected employing this method.

6.0 NRHE RECORDING EVENTS

The outcomes of the survey Crookston Castle are structured by a Project Event and subsidiary Recording Events, which are described here. The Project Event (NRHE Event ID: 1218889) provides the overall framework for the range of techniques (Section 5) applied across different parts of the survey area, which are structured around Recording Events described in following Sections. These present the results obtained using the data collection methods detailed in Section 5 and the data processing methods outlined in Appendices 2, 3, and 4.

The figures relating to these results and interpretations can be found in Appendix 7.

6.1 GRADIOMETER SURVEY NRHE RECORDING EVENT ID: 1218890

A total of 2.2ha of the 3.12ha planned for gradiometer survey (NRHE Event ID: 1218890) were surveyable (Figure 4). The 0.92ha discrepancy is mainly accounted for by areas at the north and east of CK01 where the grass was too long to use the gradiometer cart. Area CK01 aimed to investigate the area surrounding the castle, while a planned grid CK02 within the castle ditches was not undertaken because of obstruction of the GNSS signal from overhanging trees. The survey produced good quality gradiometer results.

The gradiometer survey results have been visualised as greyscale plots with fully processed data is displayed at -12/12nT (Figures 5, 6 and 7).

6.2 EARTH RESISTANCE SURVEY NRHE RECORDING EVENT ID: 1218891

Four discrete blocks of earth resistance survey (NRHE Event ID: 1218891) were conducted at Crookston Castle, three within the area defined by the castle's ditches and one to the castle's east (Figure 11). The location of the survey grids was chosen to further investigate specific anomalies found in the 1999 survey. The surveys produced good quality earth resistance data.

The earth resistance results have been visualised as greyscale plots with fully processed data displayed at 182/314.7 ohms (Figure 13).

6.3 GPR SURVEY NRHE RECORDING EVENT ID: 1218892

Three discrete blocks of GPR survey (NRHE Event ID: 1218892) were conducted at Crookston Castle, two within the area defined by the castle's ditches and one to the castle's east (Figure 13). The location of the survey grids

was chosen to further investigate anomalies found in the 1999 survey (NRHE Recording Event ID: 702551). Area CK09 could not be surveyed on 31st August as planned as overhanging trees were damaged by storms on the previous evening. While GPR data in area CK07 was good quality, the data for areas CK08 and CK10 were quite noisy and apparently adversely impacted by the roots of trees growing within the ditches, especially evident in CK08.

The GPR results have been visualised as greyscale plots with fully processed data displayed as a 1.57ns/0.76m timeslice (Figure 13).

7.0 INTERPRETATION

This section presents interpretations of the results obtained using the data collection methods applied (Section 5) and the data processing methods used (Appendices 2, 3, and 4). The results are presented by individual NRHE site ID. All measurements quoted are taken from the centre of the discussed anomalies.

The figures relating to these results and interpretations can be found in Appendix 7.

7.1 NRHE SITE ID: 44400 Crookston Castle

The three areas of geophysical surveys undertaken within the castle keep found a range of features relating to the castle's occupation. These will be described by individual survey grid areas (Figures 11 and 13).

7.1.1 SURVEY AREAS CK04 & CK08

In the area immediately to the southeast of the castle a 25m by 20m area was surveyed using both earth resistance and GPR (CK04 and CK08; Figures 11 and 13), revealing a range of features (Figures 12 and 14).

What may represent the line of a ditch is in the southern corner of the survey grid, evident as a curving band of low resistance data measuring 7.5m long from southwest to northeast and 1.7m wide, broadening at its northern terminus. After a gap of 3.2m a similar, but much broader, band of low resistance data extends for a further 6.3m to the north. The remains of what is probably a wall flanks the southern portion of the ditch on the west, lying roughly parallel with it and evident as a curving band of high resistance 1.75m wide and 7m long. The anomaly corresponds with the outside edge of the mound on which the castle building sits as visible in the LiDAR data (Figure 15). Taken together the anomalies appear to mark the location of a wall flanked by an external ditch on the east. The gap in the ditch may be an entrance to the castle from the west. None of these anomalies are clear in the GPR data (Figure 13).

Immediately to the east of the wall and ditch in the southeastern corner of the survey grid are high resistance linear anomalies that mark the location of the building identified as the Chapel of Croc. These anomalies comprise a roughly L-shaped band of data, together with another forming three sides of a rectangle, the long sides of which runs parallel to the ditch. The position of these anomalies aligns well with the remains of the chapel visible in the ground surface.

There are other low resistance anomalies in the grid, which indicate areas of softer deposits. These include those along the southeastern side, which are difficult to interpret as their full extent is not known. To the west of the causeway through the castle ditch (above) two irregular areas of low resistance are likely to be pit-like features.

Finally, high amplitude readings in the GPR data for grid CK08 (Figure 13) identify what is probably an 18m long drain of unknown antiquity that runs at a right angle to the castle towards the E side of the moat. No corresponding feature is apparent in the earth resistance data.

7.1.2 SURVEY AREA CK05

Located 35m northwest of the extant castle remains, immediately east of the excavated remains of what is believed to be a 'Guard House', a 20m by 10m grid was surveyed using earth resistance (CK05; Figure 11). This revealed what are probably structures and a possible well.

In the southwest corner of the survey grid is an L-shaped very high-resistance anomaly that represents the northeast corner of the Guard House. To the east of the Guard House and running roughly north-south across the survey grid is a low resistance feature likely to be a drain or other negative feature, or features. This dog-legs along the roughly north-south line and varies in breadth along its line. Immediately to the east of the dog-leg is a 1.75m square low resistance anomaly, perhaps a well or sump, with another similar square anomaly 5m to the northeast. The latter anomaly is partly bounded by slightly raised resistance, which could be an area of hardstanding.

Extending in a band from the centre of the southern side of the survey grid towards the centre of the eastern side of the grid are discrete rectangular and sub-rectangular very high and high resistance anomalies, along with one low resistance anomaly. The high resistance anomalies may be structural elements of buildings, with the low resistance anomalies perhaps representing drainage features or sunken elements of buildings. A very high resistance anomaly in the northwest corner of the grid is likely to represent buried stonework.

7.1.3 SURVEY AREA CK06 & CK10

A 25m by 15m grid located immediately to the southwest of the castle keep was surveyed using both earth resistance and GPR (CK06 and CK10 respectively), revealing a range of structural features (Figures 11 and 13).

The most coherent of these features is a gently curving 11.5m long and 0.85m wide band of high resistance that extends from a short line of very high resistance data near the southeastern corner of the grid to the northwest. This curving anomaly follows the outside edge of the oval mound (Figure 12) on which the castle keep sits and suggests that the edge of the mound may incorporate a wall with a distinct break, perhaps an entrance, towards its northwestern end. Appended to the southwestern side of this wall is a square high resistance anomaly measuring 2.5m overall and 1.2m across internally, with a narrow but distinct gap in the west-southwestern side, that may represent a privy. Immediately to the west of the possible privy is an area of low resistance, aligned north to south, that extends towards the moat.

In the GPR data (Figure 14) a clear high amplitude anomaly measuring 3.5m square is clearly evident, corresponding with the expected location of the castle's western tower.

In the west of the grid there are a range of sub-rectangular and irregular very high and high earth resistance anomalies (Figure 12) and some high amplitude GPR responses (Figure 14). These are likely to represent the remains of structures, presumably with some stone components.

Along the northeast edge of the survey grid a linear low resistance anomaly probably represents a wet area where rainwater has accumulated next to the castle wall, possibly in a foundation trench.

7.2 NRHE SITE ID: 386935 Later Prehistoric Settlement, Mound

The remains of five later prehistoric roundhouses and a palisaded enclosure are located in the NW corner of survey grids CK01 CK03 and CK07 lying along a low ridge to the east-southeast of the castle moat (Figures 7, 10, 11, 12, 13, 14 and 17).

Three of the roundhouses are situated in a tight cluster just beyond the castle moat. These all consist of a discontinuous ring of medium magnitude positive anomalies 0.5m across and between 13m and 14m in diameter, representing the wall trenches of timber roundhouses. All three wall trenches either abut or intersect each other, and none can have co-existed, but rather represent three successive houses, with a hint of a fourth evident as a short arc of wall trench. Within the wall trenches there are a rash of medium magnitude sub-circular anomalies ranging between 0.3m and 1.8m in diameter, which may be pits. In two cases, amongst these anomalies there is a distinct circle set 2.5m inside and concentric with the wall trench, likely to be internal post rings for the round houses. The rash of pits in the third roundhouse do not form a coherent pattern, though anomalies that are in the general location expected of a post ring are evident. The fourth roundhouse is similar and lies at the east edge of the area CK01, with about two-thirds of its projected circumference lying within the surveyed area. It comprises a discontinuous arc of medium magnitude positive anomalies 0.4m across, with a projected diameter of 17.5m. Six medium magnitude sub-circular anomalies up to 1.6m in diameter within the area defined by the wall trench do not form a coherent pattern. A little less than half of what may be a fifth roundhouse is evident at the northern edge of the survey grid, and with a projected diameter of 9m is smaller than the other roundhouses.

A sixth roughly circular feature lies immediately to the east of the cluster of three roundhouses, in the gap between these and the fourth roundhouse described above. It is evident as an oval feature in the gradiometer, earth resistance, and ground penetrating radar datasets (Figures 7, 10, 11, 12, 13, 14, and 17), and at 23m northeast to southwest by 21m transversely it may be too large to be a roundhouse and rather represent a palisaded enclosure. The palisade trench is evident in the gradiometer data as a discontinuous ring of medium magnitude positive anomalies, and in the earth resistance data by an almost continuous ring of low resistance valves, although these are weak around its western side. The GPR data shows a similar arrangement with an almost continuous ring of high amplitude readings, which weakens around the west and indicates a flat-bottomed or U-shaped profile ditch up to 0.8m below current ground level. The character of the palisade trench varies subtly across the three datasets, with the gradiometry (Figures 7 and 10) suggesting a break on the southeast, which may be an entrance, a supposition supported by a slight expansion on the terminal of the trench on the south side of the gap. The earth resistance data (Figures 11 and 12) suggests the trench is of variable width, while in the GPR data (Figures 13 and 14) the western arc is slightly flattened, and the ditch varies in width and depth.

To the east-southeast of the centre of the palisaded enclosure is a square feature measuring 6m across and defined by a medium magnitude positive anomaly and a low resistance anomaly about 1.5m across in the gradiometer and earth resistance data respectively. It does not appear as a coherent anomaly in the GPR data. It is not clear what this feature represents, and while it is offset to the east-southeast of the interior of the palisaded enclosure it is more or less symmetrically placed relative to the palisade trench otherwise. Other anomalies within the area enclosed by the palisade trench include medium magnitude positive anomalies and low resistance anomalies which may be small pits or postholes.

A final element of this complex of remains is not evident in the geophysical datasets, but rather as an oval mound evident on the ground and in the LiDAR data that measures about 17m from northwest to southeast by 15m transversely and up to 0.5m in height (Image 3; Figures 3 and 17). The northeast and southwest sides of the mound are slightly flattened. It is situated on the crest of the ridge that extends east-southeast from the castle moat, lying mostly within the southern two-thirds of the area enclosed by the palisade trench described above, extending a little across the trench line on the south. This off-centre position within the footprint of the palisade trench suggests that the mound may not be related to it but may also suggest that the palisade trench

was visible when the mound was constructed. The mound also lies eccentrically to the 6m square feature described above suggesting the two may not be related, with the caveat that neither feature is well understood. Dating the mound is difficult, but reference to the LiDAR data (Figures 3 and 17) indicates that there are two distinct phases of ploughing evident on the ridge, both trending roughly north-northeast to south-southwest. Straight narrow furrows of post-medieval date clearly ride over the mound, while the slight remains of rig cultivation that measures about 8m between furrows appear to either respect the mound, or be overlain by it. While this observation should be treated with caution because later ploughing may have selectively removed relationships, the mound may be of medieval or post-medieval date, lying a top part of the later prehistoric settlement remains by coincidence. One possible interpretation of the mound is of a windmill mound, with another possibility that this is the mound that marked the location of a yew tree associated with Mary Stuart that was cut down in 1816 (NRHE Site ID: 44401).

7.3 NRHE SITE ID: 386946 Enclosure

Immediately to the east of Crookston Castle's (NRHE Site ID: 44400) moat a group of discontinuous linear high magnitude positive anomalies have been identified in the gradiometer data (Figures 7 and 10). These form a rectangle measuring 10m east-northeast to west-southwest by 9m transversely. While this is broadly aligned with the moat and therefore may be related, no direct relationship can be implied so the feature is interpreted as an enclosure of unknown date or function.

7.4 NRHE SITE ID: 386957 Field Boundaries

What may be field boundaries have been identified in the gradiometer data as discontinuous linear medium magnitude positive anomalies (Figures 7 and 10).

These form what appear to be parts of two conjoined enclosures on the lower lying ground to the southeast of the castle moat, bounded on the north and south by roughly east-southeast to west-northwest trending linear anomalies 0.5m wide, with a third linear anomaly lying at right angles and running between the two east-southeast to west-northwest lines. The southern most field boundary has a dog-leg along its length and intersects with a possible roundhouse (NHRE Site ID: 386958) which is described below (Section 7.5).

The boundaries are undated but may form part of the medieval or post-medieval landscape around the castle.

7.5 NRHE SITE ID: 386958 Roundhouse (Possible)

What maybe a later prehistoric roundhouse has been identified in the gradiometer data (Figures 7 and 10) lying at the southern foot of the ridge that extends to the east-southeast of the castle. The feature comprises a discontinuous oval ring about 0.5m across defining an area measuring 7.5m northwest to southeast by 6m transversely. While the certainty of interpretation from the gradiometer data alone is limited, there is a suggestion of an entrance on the east, which may add weight to an interpretation as a later prehistoric roundhouse.

The possible roundhouse intersects a field boundary (NHRE Site ID: 386957), and while the relationship is not known the field boundary is assumed to be later (above).

7.6 NRHE SITE ID: 386959 Medieval Buildings and Enclosures

In the northwest corner of survey grid CK01 possible medieval or post-medieval settlement activity has been identified in the gradiometer data, comprising an enclosure containing three or more rectangular or sub-rectangular buildings (Figures 6 and 9).

The settlement activity is bounded on the south-southwest and east-southeast by two linear arrangements of circular and oval medium magnitude positive anomalies, presumably pits of some sort, measuring up to 1.5m across and spaced about 2m apart. The north-northeast end of the east-southeast side extends towards the castle moat.

To the west of the angle formed by these rows of pits are three clusters of medium magnitude positive anomalies. The first lies close to the line of pits on the east-southeast and comprise roughly linear anomalies arranged perpendicular to one another to form a series of rectangles over an area measuring 15m by 13m. These may define yards or small enclosures and possibly at least one building.

To the west-northwest of these is a sub-rectangular arrangement of oval anomalies that define an area measuring 11m west-northwest to east-northeast by 3.5m transversely which may be a timber post building.

Further medium magnitude positive linear anomalies lie in the northwest corner of the survey grid CK01, forming a rough rectangle 11m northwest to southeast by 5m transversely. This area is confused by magnetic disturbance caused by the remains of a former track (Section 7.8) which complicates its interpretation, but the anomalies may be further yards or enclosures.

7.7 NRHE SITE ID: 386960 Coal Mining Site

A 30m wide band of medium to high magnitude positive anomalies that is clearly evident in the gradiometer data extends across the centre of CK01, running for over 200m roughly from east-southeast to west-northwest. These probably represent traces of shallow coal extraction, possibly bell pits (Figures 5 and 8). Individually the anomalies are roughly circular and range in diameter from 1m to 3m, and follow the base of the ridge on which Crookston Castle (NRHE Site ID: 44400) sits.

The Mining Redemption Authority mapping (MRA 2025) confirms the presence of shallow coal deposits in the area and that there was a mine entry to the southwest of the castle. This activity may date to from the medieval period to the 18th century and may be the origins for local rumours that a tunnel runs from the castle to Paisley Abbey (NRHE Site ID: 43139).

7.8 NON-ARCHAEOLOGICAL AND RECENT FEATURES

The geophysical survey around Crookston Castle has revealed anomalies of non-archaeological or recent origin (Figures 5 and 8).

The southwest of CK01 is dominated by magnetic disturbance caused by a variety of modern factors. These include a sewer pipe running parallel with the southern edge of the survey area represented by a line of dipolar anomalies. To the south of the sewer pipe an area measuring 100m by 20m of very high magnitude ferrous responses (Figure 8) marks the location of three blocks of flats which were demolished in the early 2000's and a row of post-WWII pre-fabricated housing which proceeded them. These are shown on Ordnance Survey mapping for the period (Figure 16; Ordnance Survey Plan NS5262NW/NE 1951).

Historical agricultural practices are represented by linear anomalies aligned north-northeast to south-southwest and northeast to southwest, representing two periods of ploughing that broadly align to field

boundaries recorded on first edition of the Ordnance Survey map (Ordnance Survey Renfrewshire Sheet XII.NE 1898).

Running parallel with the western edge of the survey area and extending towards the castle entrance is a discontinuous band of high magnitude positive and negative anomalies 8m wide. These correspond to Ordnance Survey mapping (Figure 16) that shows a track leading to the castle lying slightly to the east of its modern equivalent.

Bands of magnetic disturbance along the north, south and east edges of the survey area are caused by the modern fencing and may obscure potential features in the data.

Further ferrous spikes scattered across the survey area are likely to be caused by modern ferrous material in the topsoil.

8.0 CONCLUSIONS

The multi-method geophysical survey at Crookston has produced good quality results from earth resistance and gradiometer equipment and generally poor-quality results from GPR survey. Despite disappointing GPR results from within the castle, the survey has successfully contributed to the aims detailed in Section 2.

The survey has revealed a range of archaeological features that include structural elements of the castle, and a range of buildings and structures, perhaps including a well, within the castle keep. Outside the castle moat an entirely unexpected cluster of later prehistoric roundhouses and a palisaded enclosure have been discovered, a significant addition to the history of this location. These represent a succession of large timber round houses. The identification of ephemeral, possibly timber, building remains to the WSW of the castle moat highlights the potential for settlement of medieval and later date just outside the castle moat. Finally, coal mining of medieval or later date is identified, along with the signatures of demolished 19th and 20th century buildings and infrastructure.

In assessing these results against the specific aims listed in section 2, the following observations can be made.

- *Can the use of gradiometry, ground penetrating radar and Wenner array earth resistance equipment enhanced the understanding of the site following the results of the 1999 twin- probe earth resistance survey?* For the area bounded by the castle's ditches the use of the Wenner array at a greater sample interval has added significantly to the clarity of the earth resistance results. However, in the same areas the GPR performed poorly, adding little to understanding of the site and no gradiometer survey was possible here. Outside of the castle ditches the use of GPR and gradiometry added to our understanding of the archaeological deposits.

- *Was there an Iron Age fort on the hilltop?* The results of the survey do not confirm an Iron Age hillfort preceding the castle, a question that may benefit from detailed consideration of the earthworks but probably depends on excavation to resolve. Nevertheless, beyond the castle moat later prehistoric roundhouses and a palisaded enclosure demonstrate that the ridge on which the castle sits has been a focus for Iron Age settlement.

- *Can the form of the ringwork be established?* Establishing the form of the ringwork may benefit from detailed earthwork survey, but the geophysical survey indicates additional complexity to this feature.

- *Can the arrangement of buildings and defences in the barmkin be identified?* The survey has produced some information to suggest a walled enclosures once surrounded the castle building, a feature which is possibly a privy has been identified.

- *Can the Chapel of Croc be identified?* The feature previously interpreted as the Chapel of Croc is evident in the survey data, but no new information has been gathered to add to the interpretation produced from the earlier excavation.

- *Can any trace of an entrance in the eastern side of the castle's defences be identified?* At the location where an entrance has been suggested, some features have been found in the survey data including the suggestion of a second ditch with a possible causeway at its eastern side. There is also a rectangular enclosure just to the east of the moat. While these features do not confirm an eastern entrance, they suggest more activity in this area than previously evidenced.

- *Can any activity associated with the medieval period be identified in the area to the south of the castle?* Possible medieval activity has been found to the southwest of the castle entrance which may be contemporary extra-mural activity.

- Is there any evidence supporting the local rumours of a tunnel linking the castle with Paisley Abbey? No anomalies consistent with a tunnel were found in any of the datasets. However, it is conceivable that the mining activity found in the survey data is the basis for the rumours.

- *Can any traces of either Home Guard or the US military activity in the vicinity of Crookston Castle be identified in the geophysical survey data?* No anomalies which can be positively attributed to either the home guard or US military activity were found in the gradiometer data.

- *Can any traces of the 20th century buildings which once stood to the north of Brockburn Road between Towerside Crescent and Crosstobs Road be identified in the geophysical survey data*? The location of the building which once stood north of Brockburn Road are represented by an area of high levels of magnetic disturbance in the gradiometer data.

In summary, the surveys have met their objectives, providing complementary datasets that support robust interpretations and demonstrate the value of a multi-method approach.

9.0 CAVEATS

Geophysical survey relies upon the detection of anomalous values and patterns in the physical properties of the ground as proxies for anthropogenic activity. It does not directly detect archaeological features. Therefore, the results from these methods of survey are not a direct indicator of the absence or presence of archaeological features.

The ability of geophysical survey to show the potential for archaeological remains is affected by several interrelated factors, including geological and fluvial processes, weather conditions, ground conditions, and the taphonomic processes involved in the archaeological site's formation. Therefore, the survey results may not provide a complete plan of the site's archaeology.

Nonetheless HES have endeavoured to produce interpretations of the data as accurately as possible led by the evidence, while recognising that these interpretations and the conclusions are a subjective assessment of the data.

10.0 ARCHIVE DEPOSITION & DISSEMINATION

A digital copy of this report has been deposited in the HES NRHE and supplied to the local Historic Environment Record (HER). Project and Recording event records in the NRHE summarise the survey methodologies. NRHE Site records have been amended or created with summaries of the results of the surveys. These records are accessible from the hyperlinks embedded in this report or on the Trove.scot website.

In accordance with standard industry practice an Online Access to the Index of Archaeological Investigations (OASIS) record has been generated and submitted to the HER and the Archaeological Data Service (ADS).

As the survey was conducted in Scotland an entry has been generated for inclusion in "Discovery and Excavation in Scotland". This text can be found in Appendix 6.

The digital outputs of the geophysical surveys have been deposited in the NRHE within collection 551 500/1/26/14 in the following formats:

Catalogue Item	Contents
WP009115	• Survey Report as a .pdf file.
GP000331	• Unprocessed earth resistance survey data supplied as .txt files. • Unprocessed gradiometer survey data supplied as .asc files. • Unprocessed GPR data supplied as .coa, .cob, .cor, .mrk, .mrk, .mrkj, .rad, and .rd7 files. • Processed geophysical survey data supplied as georeferenced .tif files.
GV009212	• Geophysical survey polygons showing the survey area extents and including metadata • Geophysical survey interpretation polygons • Geophysical survey interpretation polylines • Geophysical survey interpretation points

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12.0 – IMAGES

Image 1 – View of area CK01 looking northeast (DP626673)

Image 2 - View of area CK01 looking north (DP626674)

Image 3 - View of areas CK01, CK03 and CK07 looking west (DP626675)

Image 4 - View of areas CK04 and CK08 looking south (DP626676)

Image 5 - View of areas CK04 and CK08 looking north (DP626677)

Image 6 - View of areas CK05 and CK09 looking southeast (DP626678)

Image 7 - View of areas CK06 and CK10 looking northeast (DP626679)

Image 8 - View of areas CK06 and CK10 looking south (DP626680)

APPENDIX 1 GLOSSARY OF GEOPHYSICAL ANOMALY TYPES

The following table contains a glossary of the technical terminology used for gradiometer survey anomalies within this report.

	Anomaly Type	Description
Area	Area of Disturbance (Modern)	An area of magnetic disturbance caused by modern activity such as metallic fences, gates, inspection covers, green waste, or modern refuse.
	Enhanced Magnetism (Area of Burning)	An anomaly with a distinct pattern in the XY trace plot which indicates burning has taken place, suggesting the location of a hearth or kiln.
	Enhanced Magnetism (Historic Agriculture)	An anomaly caused by historic agricultural activity such as rig & furrow, or a headland.
	Enhanced Magnetism (Archaeology)	An anomaly of probable archaeological origin; this interpretation will either be based on other supporting evidence or on the form of the anomaly.
	Enhanced Magnetism (Historic Feature)	An anomaly caused by an historic feature. This will appear on a documentary record such as an old map, but the feature is no longer extant on the surface, such as a demolished building, or a former field boundary.
	Enhanced Magnetism (Possible Archaeology)	An anomaly of possible archaeological origin; this interpretation will have no other supporting evidence.
	Enhanced Magnetism (Unclear Origin)	An anomaly for which it is not possible to assign an interpretation.
	Enhanced Magnetism (Utility)	An area of magnetic disturbance caused by the magnetic field of a utility, such as the halo around a gas pipe.
	Geology/Natural	An anomaly interpreted as caused by geological or fluvial processes, such as variations in underlying bedrock, or palaeo-channels.
Trend	Linear Trend (Archaeology)	A linear anomaly of probable archaeological origin; this interpretation will either be based on other supporting evidence or on the form of the anomaly.
	Linear Trend (Drainage)	A linear anomaly caused by modern drainage such as a field drain.
	Linear Trend (Historic Agriculture)	A linear anomaly caused by historic agricultural activity such as rig & furrow, or a headland.
	Linear Trend (Historic Feature)	A linear anomaly caused by a historic feature. This will appear on a documentary record such as an old map, but the feature is no longer visible on the ground, such as an old pathway.
	Linear Trend (Modern Agriculture)	A linear anomaly caused by modern agricultural activity such as ploughing.
	Linear Trend (Possible Archaeology)	A linear anomaly of possible archaeological origin; this interpretation will have no other supporting evidence.
	Linear Trend (Unclear Origin)	A linear anomaly for which it is not possible to assign an interpretation.
	Linear Trend (Utility)	A linear anomaly caused by the presence of a modern utility, such as a gas pipe.
	Geology/Natural	A linear anomaly interpreted as caused by geological or fluvial processes, such as variations in underlying bedrock, or palaeo-channels.
Point	Ferrous Spike	An anomaly caused by a ferrous object in the topsoil which causes a spike in the XY trace plot of the data.

The following table contains a glossary of the technical terminology used for anomalies for earth resistance survey within this report.

	Anomaly Type	Description
Area	Very Low Resistance	An area displaying very low resistance, possibly of anthropogenic origin.
	Low Resistance	An area displaying low resistance, possibly of anthropogenic origin.
	High Resistance	An area displaying low high resistance, possibly of anthropogenic origin.

The following table contains a glossary of the technical terminology used for anomalies for Ground Penetrating Radar survey within this report.

	Anomaly Type	Description
Area	High Amplitude Reflector	An area of high amplitude reflections, possibly of anthropogenic origin.
	Low Amplitude Reflector	An area of low amplitude reflections, possibly of anthropogenic origin.
	Modern Reflector	An area with reflections caused by modern activity such as buried services.

APPENDIX 2 DATA PROCESSING METHODOLOGY

The following section details the data processing method used for these surveys, with the specific processing parameters used for each datafile detailed in Appendix 4. All geophysical survey files are named in line with the Archaeological Geophysical Survey, Standard Operating Procedure (HES 2020).

GRADIOMETER DATA PROCESSING

Following the collection of data using the method detailed in Section 5.1, all datafiles were exported from the Sensys system's MONMX software in both .asc, and .uxo formats. These files were then transferred to the processing computer.

Data processing was conducted using TerraSurveyor v4.1.0.1 (DW Consulting: 2023). The GPS Geoid was set to "WGS-84" and the coordinate system set to "UTM Zone 30" to match the GNSS used during data collection prior to data import. The .uxo files were imported using the pre-defined TerraSurveyor import template appropriate for the Sensys system and converted into .ts4 format composites. The .asc format file was kept for archiving.

The .ts4 file was opened with base settings of 0.25m Intervals and 0.50m track radius and a .grd exported to allow visualisation of the minimally processed data. The data was destriped and clipped. The data was interpolated to values appropriate to the display requirements for the processed results. These processed results were exported in .grd format to allow visualisation of the processed data. The minimally processed data was then clipped to -10/100nT and an XY trace plot generated and exported as a .dxf.

The .grd and .dxf files were imported to the project's ArcGIS Pro geodatabase and converted into the British National Grid coordinate system using the "Project" and "Project Raster" tools, with the input coordinate system set as "ETRS_1989_UTM_Zone_30N", the output coordinate system as "British National Grid", using the "OSGB_1936_To_ETRS_1989_1" geographic transformation, resampled as "Nearest neighbour".

Once the reprojection was complete the data were manually interpreted.

EARTH RESISTANCE DATA PROCESSING

Following the collection of data using the method detailed in Section 5.2, all datafiles were exported from the TAR-3's datalogger by removing the micro-SD card and transferring them to the processing computer using a multi-card reader in .xyz format.

Data processing was conducted using Snuffler 1.3. The .xyz files for each grid were imported using the "Easy XYZ Import into a New File" option and the .xyz format file was kept for archiving.

A new "Map File" was generated to mirror the geometry of the survey grids. The survey grids were then entered into the "Map File" and a "Spawn Main View" process conducted. The data was then exported in .png format to allow visualisation of the minimally processed data. The data was interpolated both horizontally and vertically twice to reduce raster cell size from 0.5m to 0.125m and the resulting data exported in .png format to allow visualisation of the processed data.

The .png files were imported to the project's ArcGIS Pro geodatabase and manually georeferenced to British National Grid coordinate system using the positions obtained using the GNSS.

Once the reprojection was complete the data were manually interpreted.

GROUND PENETRATING RADAR DATA PROCESSING

Following the collection of data using the method detailed in Section 5.4, all datafiles were exported from the MALÅ Controller software in cor .mrkj ,rad and .rd7 formats. These files were then transferred to the processing computer using a USB pen drive.

Data processing was conducted using Mala Vision v1.2505.15. The data files for each traverse were imported into the software's 2D module using the values shown in appendix 4 and a sample radiogram with a clear hyperbole selected to generate the processing workflow. The original data files were kept for archiving purposes.

The sample radiogram was processed using a range of filters to remove low and high frequency noise and trace and time dependant noise. The filters also enhanced the data resolution and emphasise areas where structures were assumed. The filters employed and parameters used are detailed in appendix 4. This processing workflow was recorded and then applied to all other radiograms and suffix of .99 was applied to aid their identification.

Following their workflow processing the resulting files were then imported into the software's 3D module using the parameters details in appendix 4. A series of time slices were produced and exported in .tif format using the "ETRS_1989_UTM_Zone_30N" coordinate system.

The .tif's were imported to the project's ArcGIS Pro geodatabase and converted into the British National Grid coordinate system using the "Project Raster" tool, with the input coordinate system set as "ETRS_1989_UTM_Zone_30N", the output coordinate system as "British National Grid", using the "OSGB_1936_To_ETRS_1989_1" geographic transformation, resampled as "Nearest neighbour".

Once the reprojection was complete the data were manually interpreted.

APPENDIX 3 GEOPHYSICAL SURVEY DATA PROCESSING STEPS

The following table details the processing steps each data file has undergone and the order these processes were applied before the data were transferred to the data visualisation software.

Filename	Process	Values
CRC2024CK01-MAG.ts4	Base Settings	Interval 0.12m, Track Radius 0.32m
	De-stripe	Median / SD 1.5
	Clip	Min -100, Max 100
CRC2024LP03-ER-WR050.svw	Interpolation	0.125m
	Clip	Min 182.1, Max 314.7
CRC2024LP04-ER-TP050.svw	Interpolation	0.125m
	Clip	Min 182.1, Max 314.7
CRC2024LP05-ER-TP050.svw	Interpolation	0.125m
	Clip	Min 182.1, Max 314.7
CRC2024LP06-ER-TP050.svw	Interpolation	0.125m
	Clip	Min 182.1, Max 314.7
CRC2024CK07-GPR	DC Offset	Default Values
	Smart Gain	Default Values
	BG Removal	Window Length (traces) 200
	Bandpass	40 MHz to 680 MHz
	FK Migration	93 m/µs
	Envelope	Default Values
	3D Interpolation	Cell size 0.11m horizontal, 0.19 Thickness
CRC2024CK08-GPR	DC Offset	Default Values
	Smart Gain	Default Values
	BG Removal	Window Length (traces) 200
	Bandpass	37 MHz to 692 MHz
	FK Migration	95 m/µs
	Envelope	Default Values
	3D Interpolation	Cell size 0.11m horizontal, 0.19 Thickness
CRC2024CK10-GPR	DC Offset	Default Values
	Smart Gain	Default Values
	BG Removal	Window Length (traces) 200
	Bandpass	41 MHz to 687 MHz
	FK Migration	93 m/µs
	Envelope	Default Values
	3D Interpolation	Cell size 0.11m horizontal, 0.19 Thickness

APPENDIX 4 GLOSSARY OF GEOPHYSICAL SURVEY DATA PROCESSING TERMS

The following table contains a glossary of the technical terminology used during Sections 4 and 5 of this report.

Process	Definition
3D interpolation	This process is used to generate a series of "Time Slices" from a series of GPR radiograms. This process is used to show identified features in plan.
Bandpass	This process filters a GPR trace by cutting off low frequency and high frequency noise. Depending on the chosen values this acts as a low pass filter and/or a high pass filter.
BG Removal	This process is used to filter GPR trace. It filters by subtracting the average trace value from the trace. This process is used to remove temporally consistent noise from the trace.
Break on Jump	This process calculates the distance between each data point along a traverse and if this distance exceeds the set threshold the traverse will be split into individual traverses. This process is used when there is a large gap in the collected data points caused by GNSS signal drop-out.
Clip	This process removes values outside of the defined upper and lower limits and replaces them with the upper and lower limits. It can be applied as absolute values, or as a standard deviation. The process is used to remove the skewing effect of areas of unusually high or low values in the data.
DC Offset	This process is used to move the start of a GPR trace by a given value. This process is used to remove erroneous data from the upper part of the trace.
De-spike	This process finds data points which are unusually high or low compared with those around it and replaces the values with an average value based on the surrounding points. This process is used to remove the skewing effect of spikes in the data due to ferrous objects in the topsoil.
De-stagger	This process corrects mechanical errors which occur during data collection when a traverse is started too early or too late. It shifts the traverse backwards or forwards to compensate for the error. This process is used when data is collected on steep terrain when it is difficult to keep the cart parallel with the surface.
De-stripe	This process calculates the average (Mean, Mode or Median) of each individual traverse and then deducts this value from the readings along that traverse. This transforms the values into the difference from the average instead of an absolute value. This process is used to remove the striping effect caused by neighbouring traverses being surveyed in opposite directions (heading errors). This process is sometimes referred to as a 'Zero Mean Traverse.'
Discard Overlap	This process is used to remove data points when they have been collected too close to other data points. This process is used to remove the distorting effect caused by traverses overlapping due to operator error.
Envelope	This process turns all data into absolute values.
Fk Migration	This process is used to enhance the resolution of a GPR trace, the trace is stretched up or down to achieve this. The goal of the process is to trace reflections back to their source (Stolt 1978).
High Pass Filter	This process uses either a Gaussian or uniformly weighted window to remove low-frequency noise from the data to highlight the high-frequency trends.
Interpolation	This process is a method of generating new data points based on a range of known data points. This process is used increase the resolution of data visualisations by reducing the raster cell size.
Interval	This process sets the size of the cells in the greyscale image of the data and thus the level of interpolation applied to the data
Low Pass Filter	This process uses either a Gaussian or uniformly weighted window to remove high-frequency trends from the data resulting in a smoothing effect.
Smart Gain	The process applies gain to the y element to a trace using a computer-generated gain curve. This process is used to emphasise area where structures are assumed.
Reduce Points	This process uses an algorithm to reduce the number of data points passed to later processing step. This process is used to reduce processing time for large data sets.
Remove Turns	This process is used to separate a track of data into individual traverses when data collection was not manually stopped by the surveyor at the end of each traverse. A turn is detected by a change in direction of travel and set in degrees. This is commonly used when data is collected using a mechanical towing device.

Straighten	This process corrects sudden changes in direction along a traverse. This process is used to correct errors caused by the GNSS changing between satellite constellations which cause a slight jump in position.
Track Radius	This process sets the size of area around each data point which is included in the interpolated calculation.

APPENDIX 5 DISCOVERY AND EXCAVATION IN SCOTLAND TEXT

The text below has been submitted for inclusion in the 2023 volume of *Discovery and Excavation in Scotland*.

Crookston Castle, Glasgow

Geophysical Survey

Nick Hannon, Hazel Blake & Paul Bethune - HES

Historic Environment Scotland, Archaeological Survey, conducted gradiometer, earth resistance and GPR survey at Crookston Castle Glasgow between 29th August 2025 and 31st August 2025.

The aim of the survey was to investigate areas within and surrounding Crookston Castle and was conducted in partnership with the 'Friends of Crookston Castle' and involved members of the Friends group and local volunteers.

The survey identified anomalies which are consistent with prehistoric settlement immediately to the west of the castle and features consistent with medieval remains within the area bounded by the moat and immediately south of the castle entrance. To the south of the castle traces of post-medieval mining activity were identified as a band of probable bell pits.

The survey produced good quality results which give a high level of confidence that the method and survey strategy were appropriate to assess the archaeological potential of the survey area.

Archive: HES

Funder: The Castle Studies Trust

APPENDIX 6 GEOPHYSICAL SURVEY METADATA

The following table details the metadata entered into the OASIS V form.

Field	Description
Data Collection Organisation	Historic Environment Scotland
Site Name	Crookston Castle
Project ID	CRC2024
OASIS ID	historic14-412624
Report Title	Crookston Castle, Geophysical Survey Report
Report Author	Dr Nick Hannon
Report QC	Dr Dave Cowley
National Grid Reference (centre)	NS 52559 62715
Coordinate System	OSGB1936
Transformation	OSTN15
Geoid	OSGM15
Local Authority	Glasgow
Scheduled Ancient Monument/s	SM90085
Known Archaeology on site	NRHE Site IDs: 44400, 44401, 44373 & 358199
Survey Personnel	Dr Nick Hannon, Dr Hazel Blake & Paul Bethune
Survey Dates	CK01 – 30/08/2025 & 31/08/2025 CK02 – Not Surveyed CK03 – 31/08/2025 CK04 - 30/08/2025 CK05 – 29//08/2025 CK06 - 29//08/2025 CK07 - 29/08/2025 CK08 - 30/08/2025 CK09 – Not Surveyed CK10 – 31/08/2025
Weather Conditions	Cool & overcast, windy, with occasional heavy showers
Land Use	Short Grass
Ground Conditions	Damp
Solid Geology	Limestone Coal Formation Carboniferous (BGS 2025)
Drift Geology	Till, Devensian – Diamicton Quaternary (BGS 2025)
Soil	Built-up Land (Scotland's Soils 2024)
SURVEY TYPE	**GRADIOMETER**
Gradiometer Equipment	Sensys MXPDA
Sensors Type	FGM650/3
Sample Rate (hz)	100
Number of Sensors	5
Sensor Serial Numbers	1519/1520/1521/1522/1523
Sensor Separation (m)	0.50
Reading Interval (m)	0.125
Data Collection Software	MONMX v5.01-03/00
Data Processing Software	TerraSurveyor v4.1.0.1

Data Visualisation Software	ArcGIS Pro v3.4.4
Area Covered	CK01 – 2.2ha CK02 – Not Surveyed
Positional Accuracy	Leica GS16 GNSS +/- 0.02m
SURVEY TYPE	**EARTH RESISTANCE**
Earth Resistance Equipment	RM Frobisher TAR-3
Electrode Configuration	CK03 – Wenner, CK04, CK05, & CK06 Twin-electrode
Electrode Separation	0.50
Electrode Separation Qualifier	Constant Separation
Data Collection Software	On-board hardware
Data Processing Software	Snuffler v1.3
Data Visualisation Software	ArcGIS Pro v3.4.4
Area Covered (ha)	CK03 – 40m x 30m CK04 – 25m x 20m CK05 – 20m x 10m CK06 – 25m x 15m
Positional Accuracy	Leica GS16 GNSS +/- 0.02m
SURVEY TYPE	**GROUND PENETRATING RADAR**
GPR Equipment	MALÅ GX
Antenna	MALÅ GX450MHz HDR
Traverse Separation (m)	0.5
Reading Interval (m)	0.05
Centre Frequency of Antennae	450MHz
Time Window	0ns to 50ns
Average Subsurface Velocity	0.06590362m/ns
Method Of Velocity Estimation	Analysis of Hyperbolic Response
Individual/Parallel Profile	Parallel Profile
Data Collection Software	MALÅ Controller v10.20826
Data Processing Software	Mala Vision v1.2505.15
Data Visualisation Software	ArcGIS Pro v3.4.4
Area Covered (ha)	CK07 – 35m x 30m CK08 – 25m x 20m CK09 – Not Surveyed CK10 – 25m x 15m
Positional Accuracy	Leica GS16 GNSS +/- 0.02m

APPENDIX 7 FIGURES

Legend

- Survey Location
- Glasgow City

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

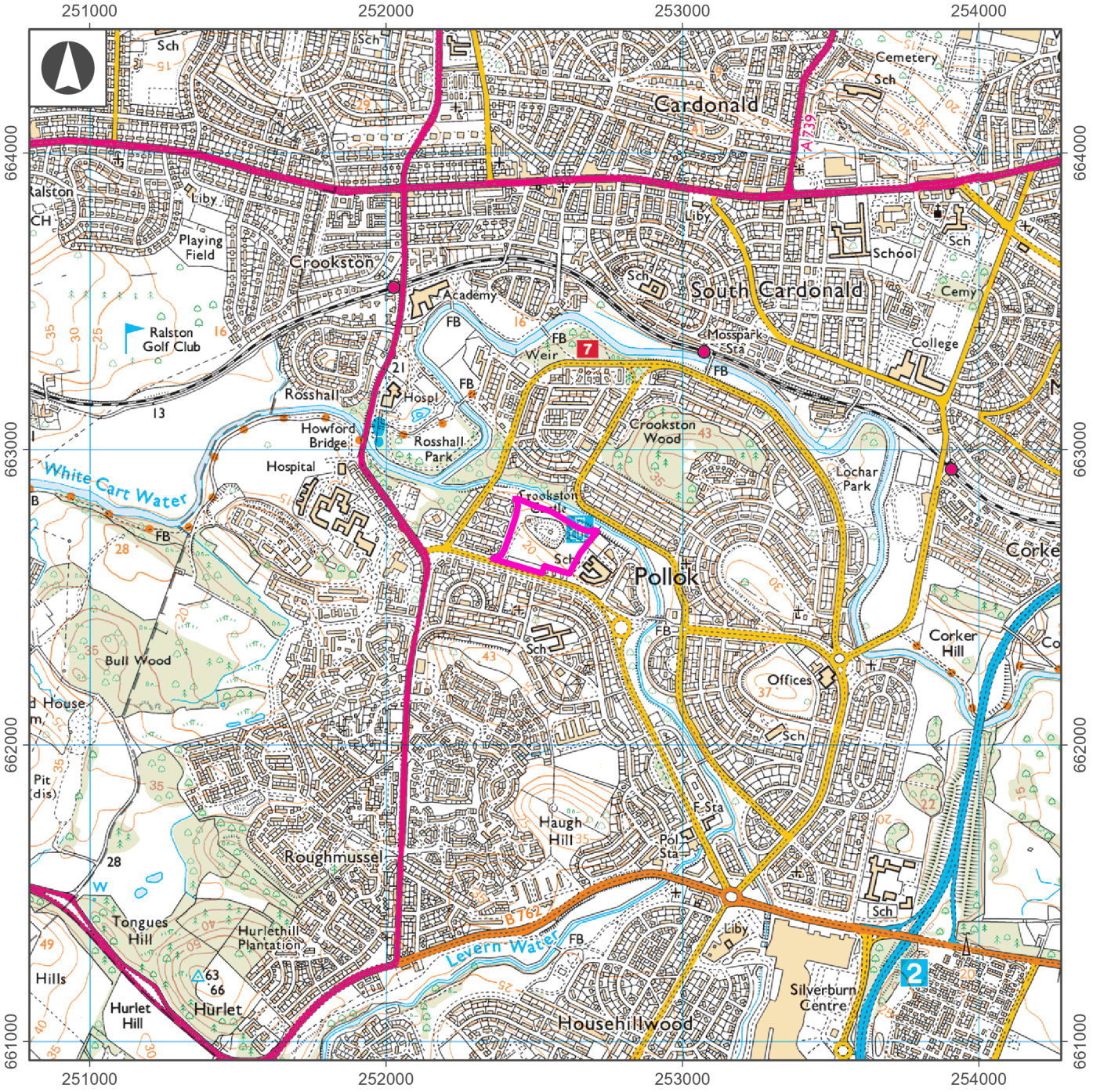
Scale: 1:200,000 @ A4

Datum: OSGB 1936

Kilometres

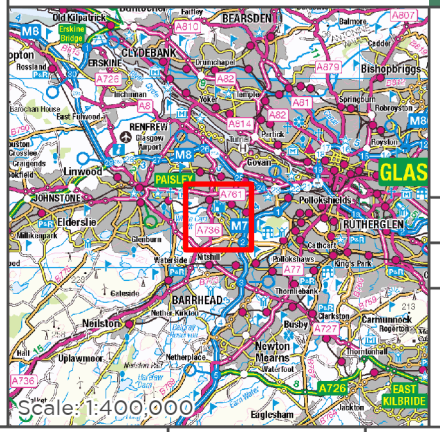
0 2 4 6 8

Figure 01	Survey Location	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	05/11/2025



Legend

Survey Area



FRIENDS OF CROOKSTON CASTLE

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

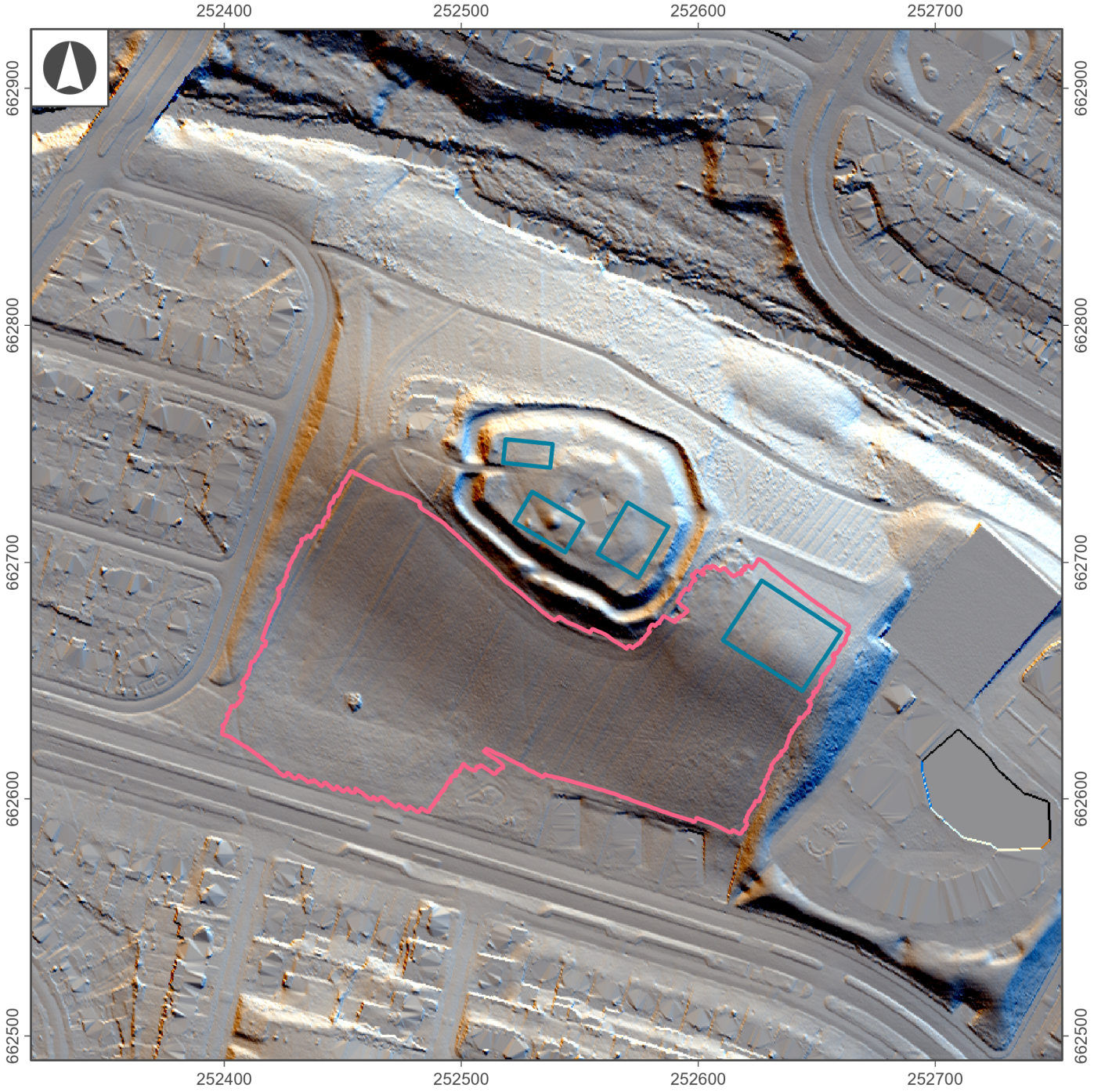
Scale: 1:20,000 @ A4

Datum: OSGB 1936

Metres

0 200 400 600 800

Figure 02	Survey Area	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	05/11/2025



Legend

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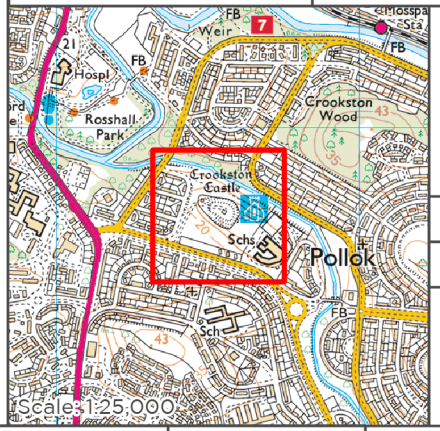
FRIENDS OF CROOKSTON CASTLE

Gradiometer - Survey Outline - 0.50m

Earth Resistance - Survey Outline - Wenner - 0.50m

Resolution (metres)	0.50
Visualisation	Multi Direction Hillshade
Directions	N/A
Altitude (degrees)	25
Azimuth (degrees)	315
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1
Z-Factor	1



HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

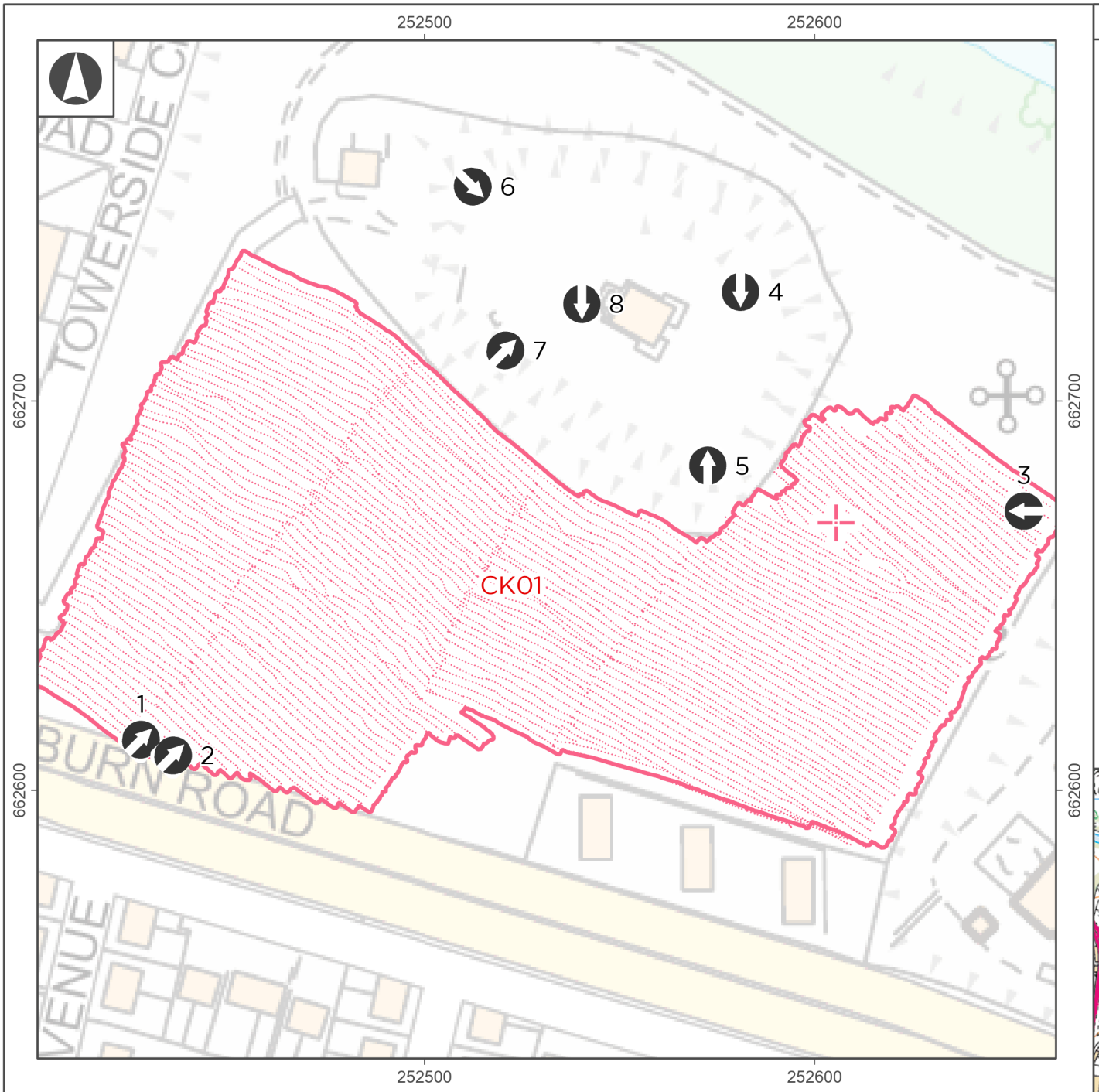
Scale: 1:2,500 @ A4

Datum: OSGB 1936

Metres

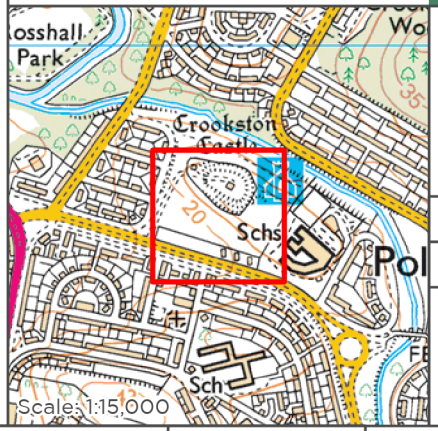
0 25 50 75 100

Figure 03	LiDAR for Scotland Phase IV (2021)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	29/01/2026



Legend

- Gradiometer - Survey Outline - 0.50m
- Gradiometer - Traverse Position
- Gradiometer - Calibration Position
- Photograph Position & Direction



FRIENDS OF CROOKSTON CASTLE

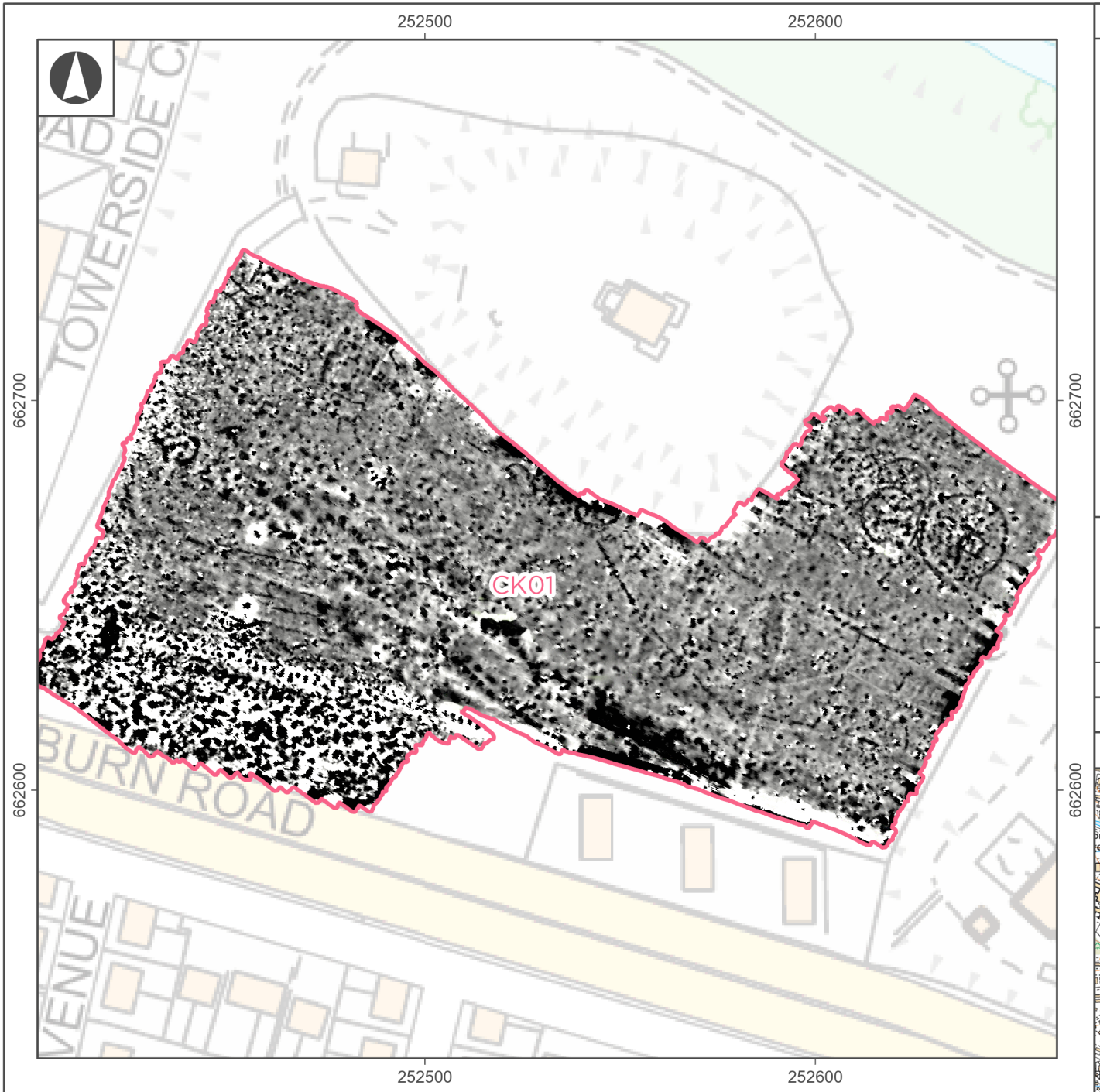
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,500 @ A4

Datum: OSGB 1936

Metres
0 10 20 30 40

Figure 04	Gradiometer Survey GNSS Swaths, Calibration & Photograph Positions	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	05/11/2025



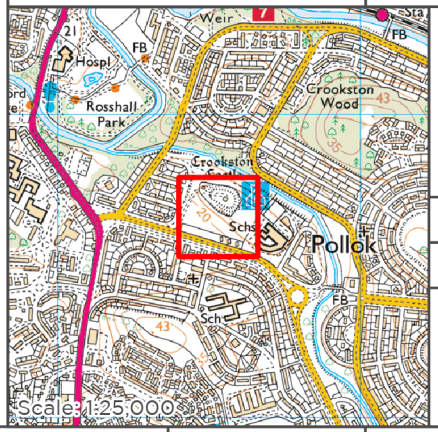
Legend

Gradiometer - Survey Outline - 0.50m

FRIENDS OF CROOKSTON CASTLE

-12 nT 12

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



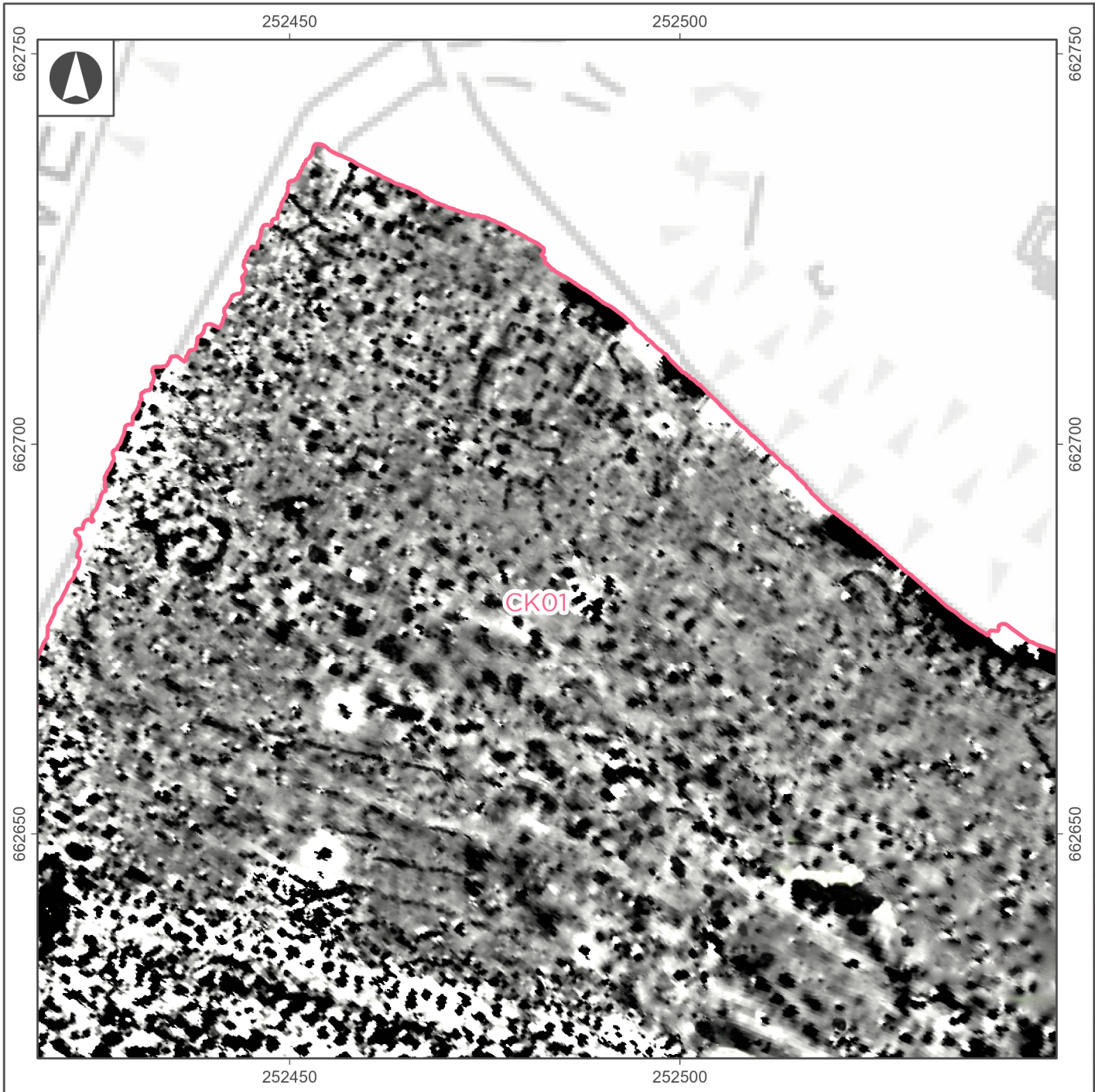
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,500 @ A4

Datum: OSGB 1936

Metres
0 10 20 30 40

Figure 05	Processed Gradiometer Data Greyscale Plot	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



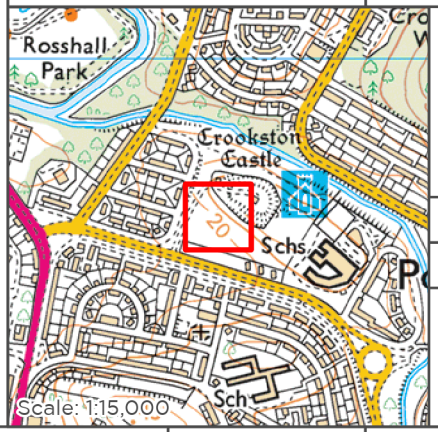
Legend

Gradiometer - Survey Outline - 0.50m

FRIENDS OF CROOKSTON CASTLE

-12 nT 12

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



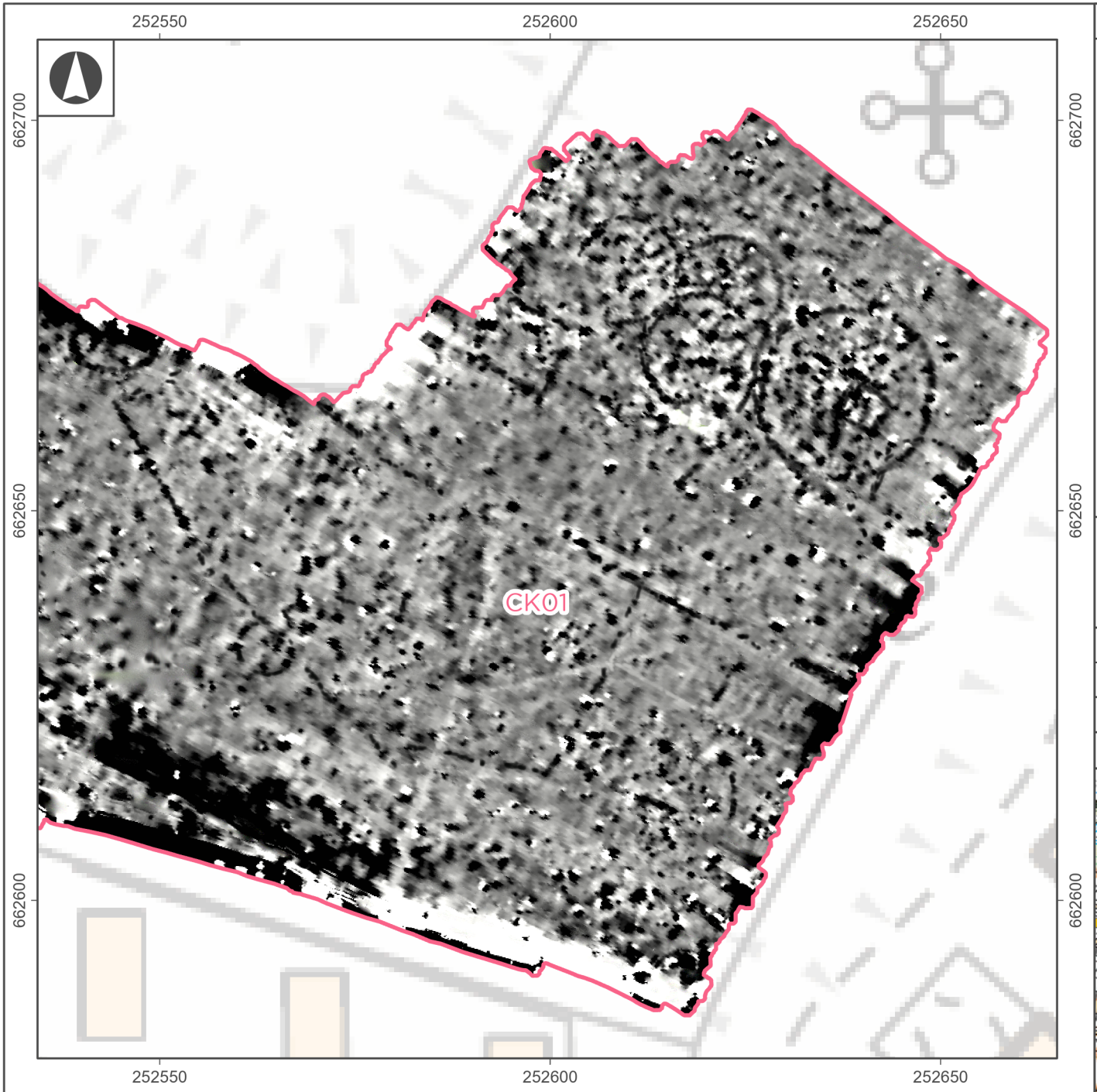
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:750 @ A4

Datum: OSGB 1936

Metres
0 10 20 30

Figure 06	Processed Gradiometer Data Greyscale Plot (West)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



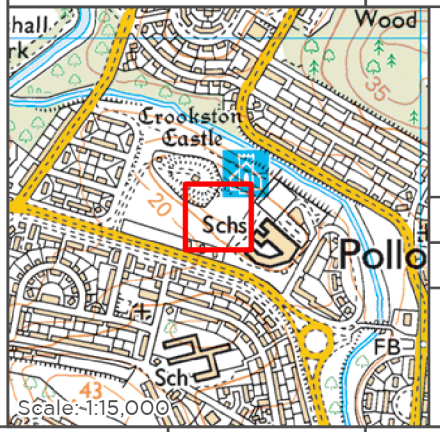
Legend

Gradiometer - Survey Outline - 0.50m

FRIENDS OF CROOKSTON CASTLE

-12 nT 12

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:750 @ A4

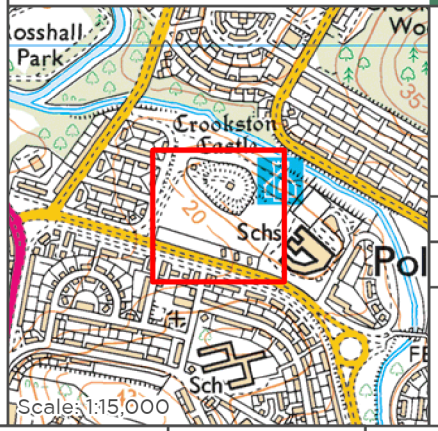
Datum: OSGB 1936

Metres 0 10 20 30

Figure 07	Processed Gradiometer Data Greyscale Plot (East)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026

Legend

- Gradiometer - Survey Outline - 0.50m
- Area of Disturbance - Modern
- Area of Disturbance - Utility
- Enhanced Magnetism - Archaeology
- Enhanced Magnetism - Area of Burning
- Enhanced Magnetism - Possible Archaeology
- Enhanced Magnetism - Mineral Extraction
- Linear Trend - Archaeology
- Linear Trend - Drainage
- Linear Trend - Historic Agriculture
- Linear Trend - Utility
- Ferrous Spike



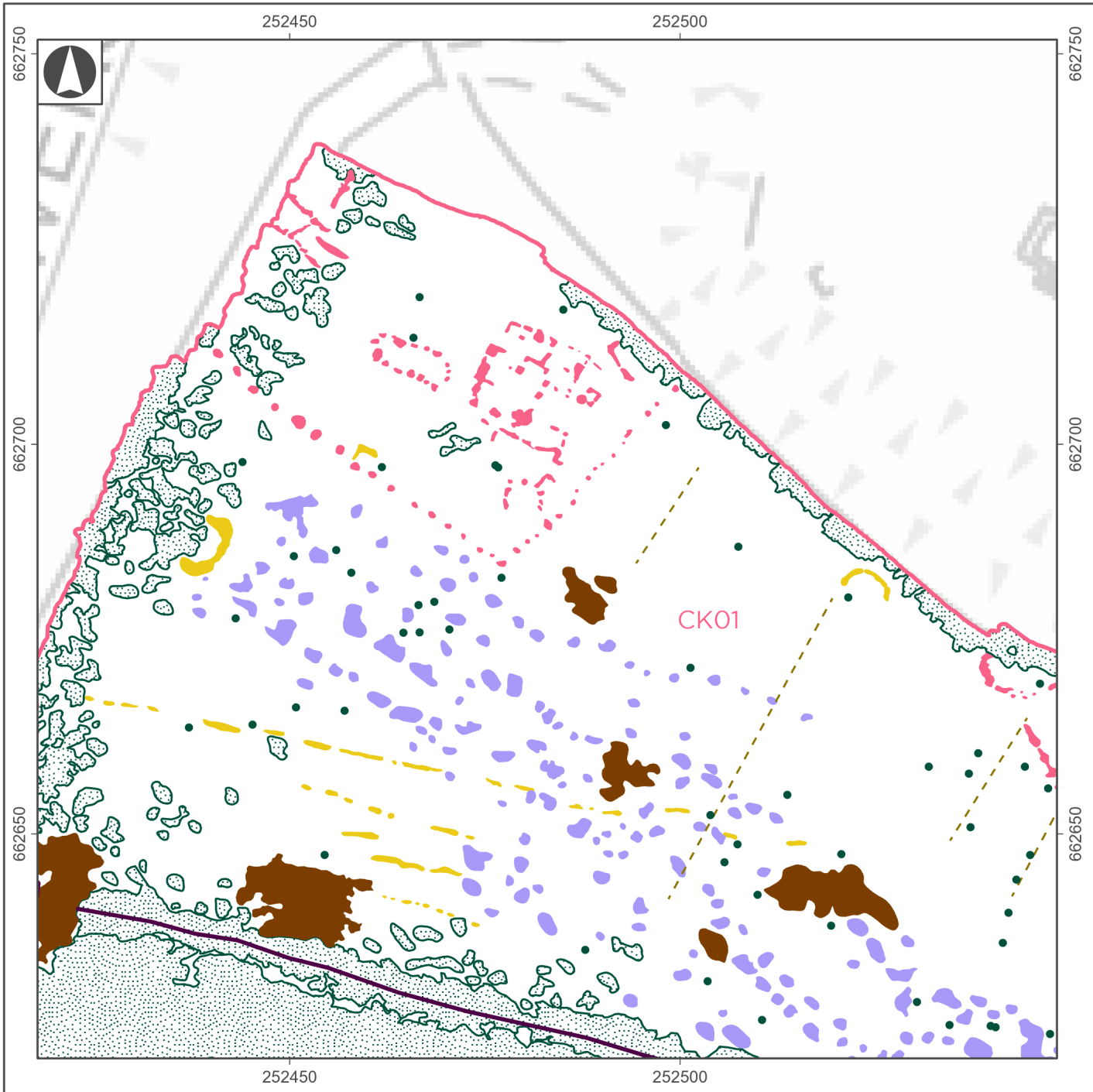
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,500 @ A4

Datum: OSGB 1936

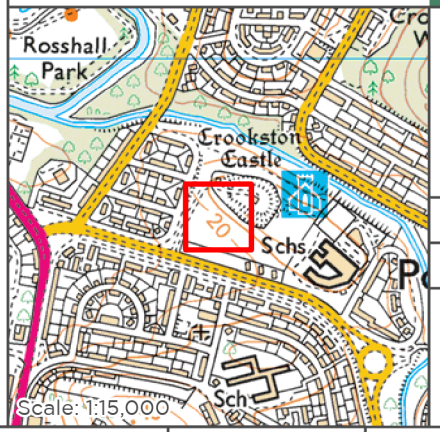
Metres
0 10 20 30 40

Figure 08	Interpretation of Gradiometer Data	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



Legend

- Gradiometer - Survey Outline - 0.50m
- Area of Disturbance - Modern
- Area of Disturbance - Utility
- Enhanced Magnetism - Archaeology
- Enhanced Magnetism - Area of Burning
- Enhanced Magnetism - Possible Archaeology
- Enhanced Magnetism - Mineral Extraction
- Linear Trend - Historic Agriculture
- Linear Trend - Utility
- Ferrous Spike



FRIENDS OF CROOKSTON CASTLE

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

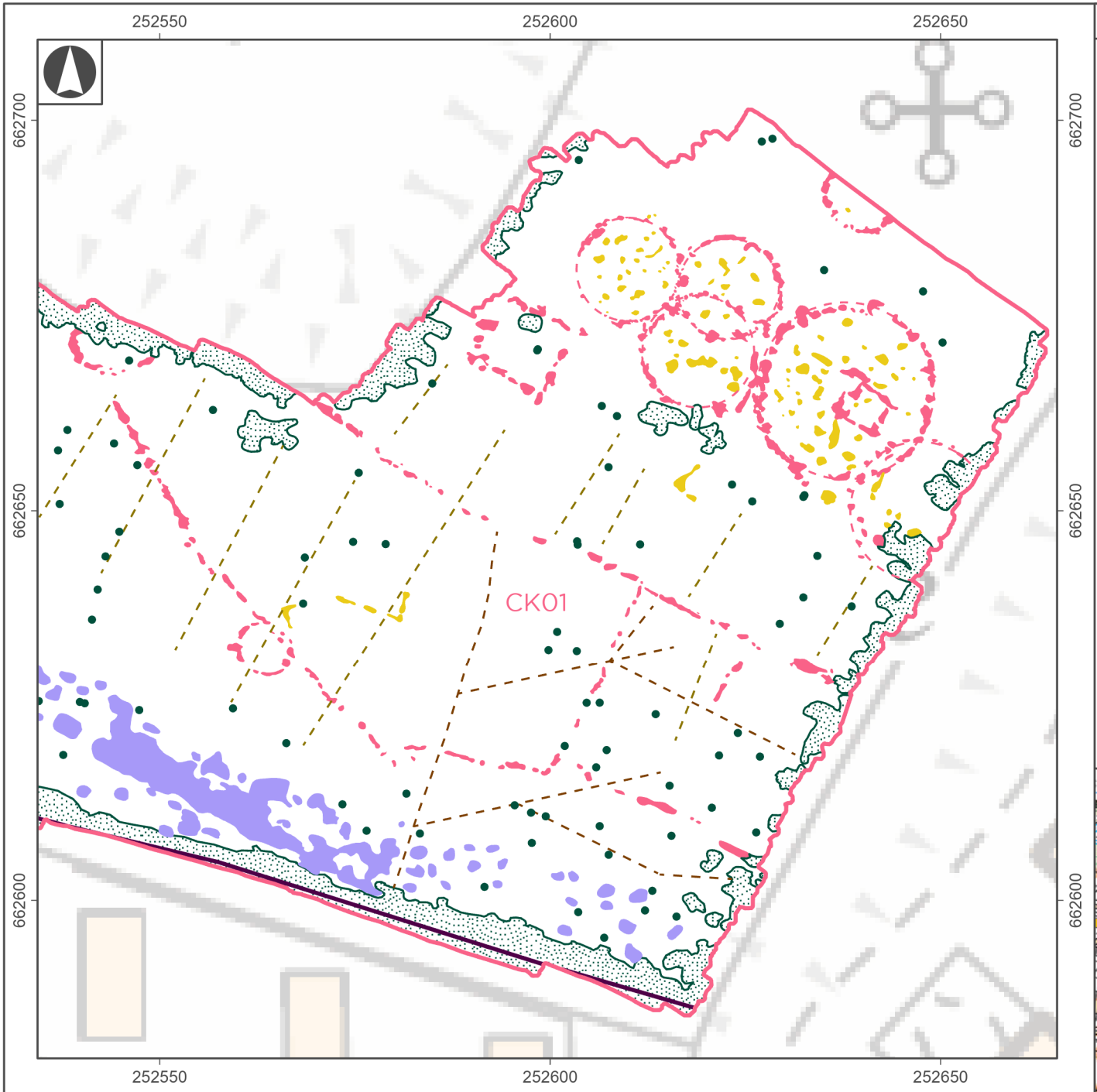
Scale: 1:750 @ A4

Datum: OSGB 1936

Metres

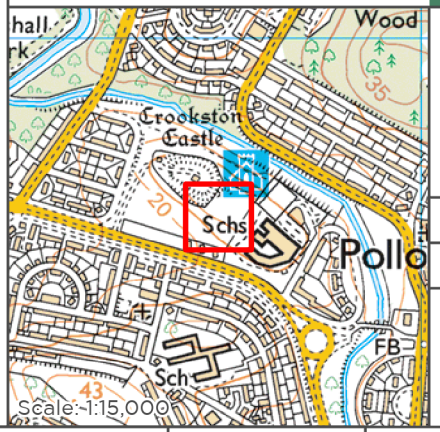
0 10 20 30

Figure 09	Interpretation of Gradiometer Data (West)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



Legend

- Gradiometer - Survey Outline - 0.50m
- Area of Disturbance - Modern
- Enhanced Magnetism - Archaeology
- Enhanced Magnetism - Possible Archaeology
- Enhanced Magnetism - Mineral Extraction
- Linear Trend - Archaeology
- Linear Trend - Drainage
- Linear Trend - Historic Agriculture
- Linear Trend - Utility
- Ferrous Spike



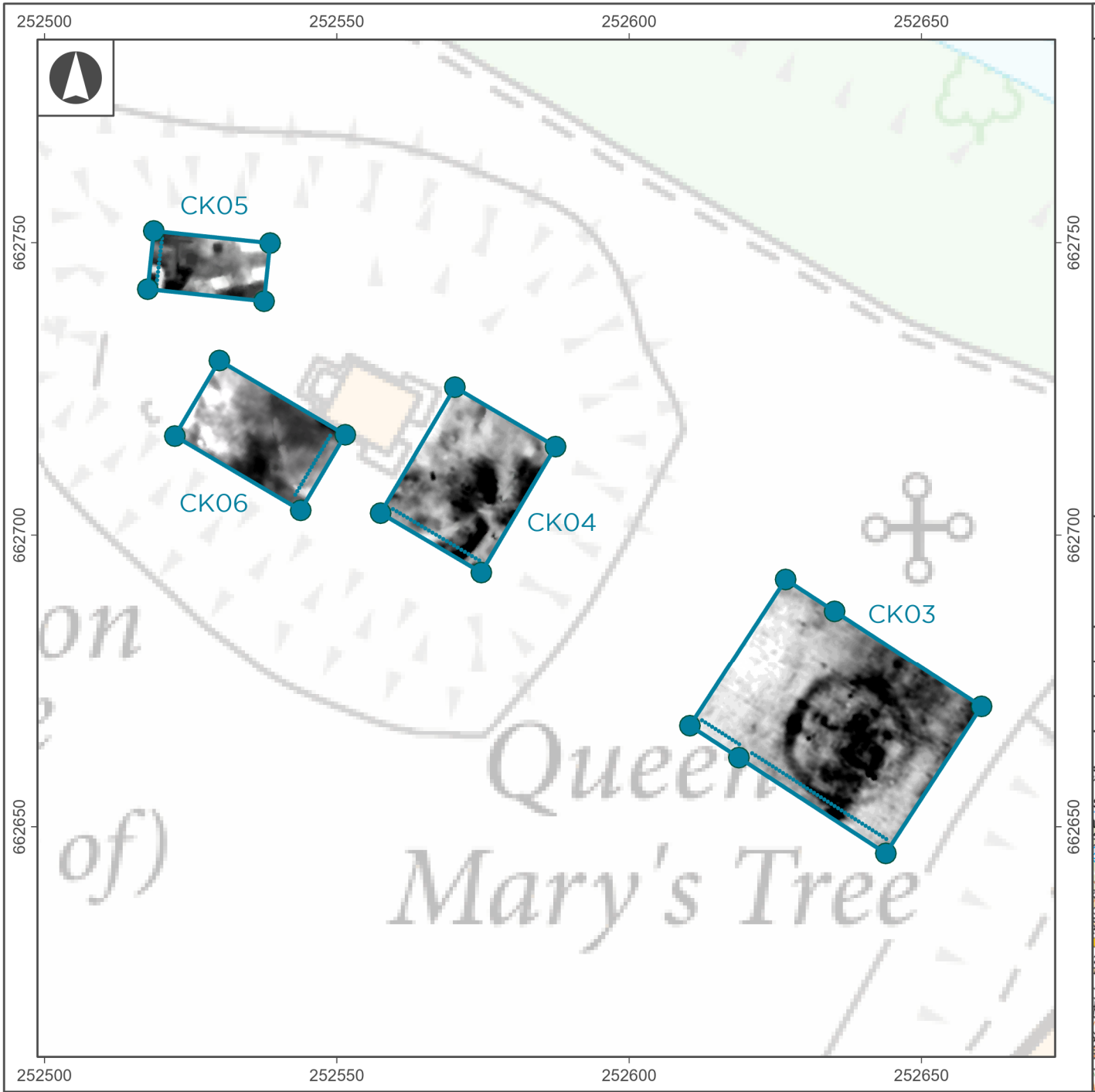
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:750 @ A4

Datum: OSGB 1936

Metres 0 10 20 30

Figure 10	Interpretation of Gradiometer Data (East)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026

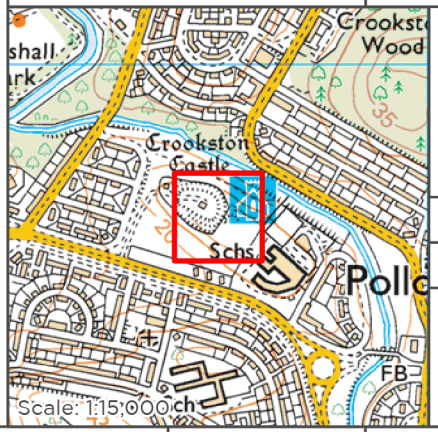


Legend

- Earth Resistance - Survey Outline - Wenner - 0.50m
- Earth Resistance - First Traverse Position
- Earth Resistance - Grid Node

182.1 Ohmns 314.7

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



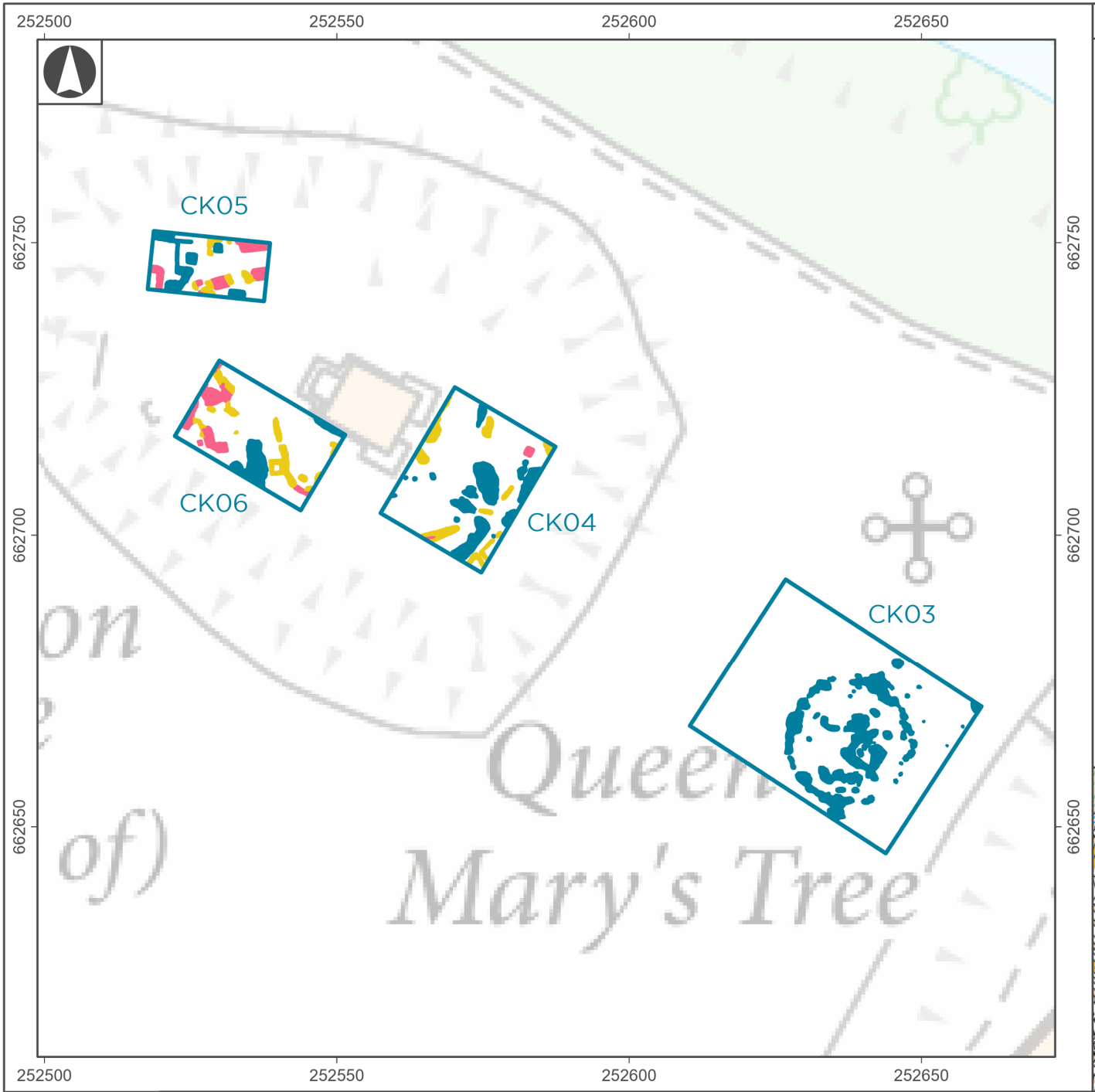
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,000 @ A4

Datum: OSGB 1936

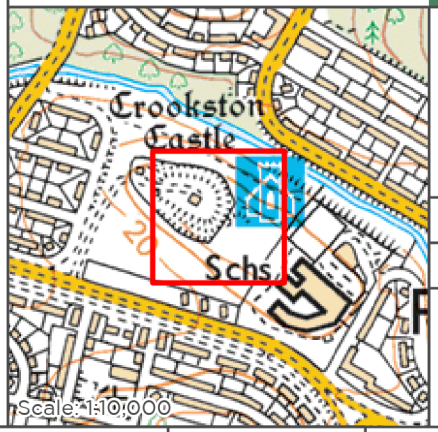
Metres
0 10 20 30 40

Figure 11	Earth Resistance Survey Areas, Traverse Positions and Greyscale Data	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



Legend

- Earth Resistance - Survey Outline - Wenner - 0.50m
- Very High Resistance
- High Resistance
- Low Resistance



FRIENDS OF CROOKSTON CASTLE

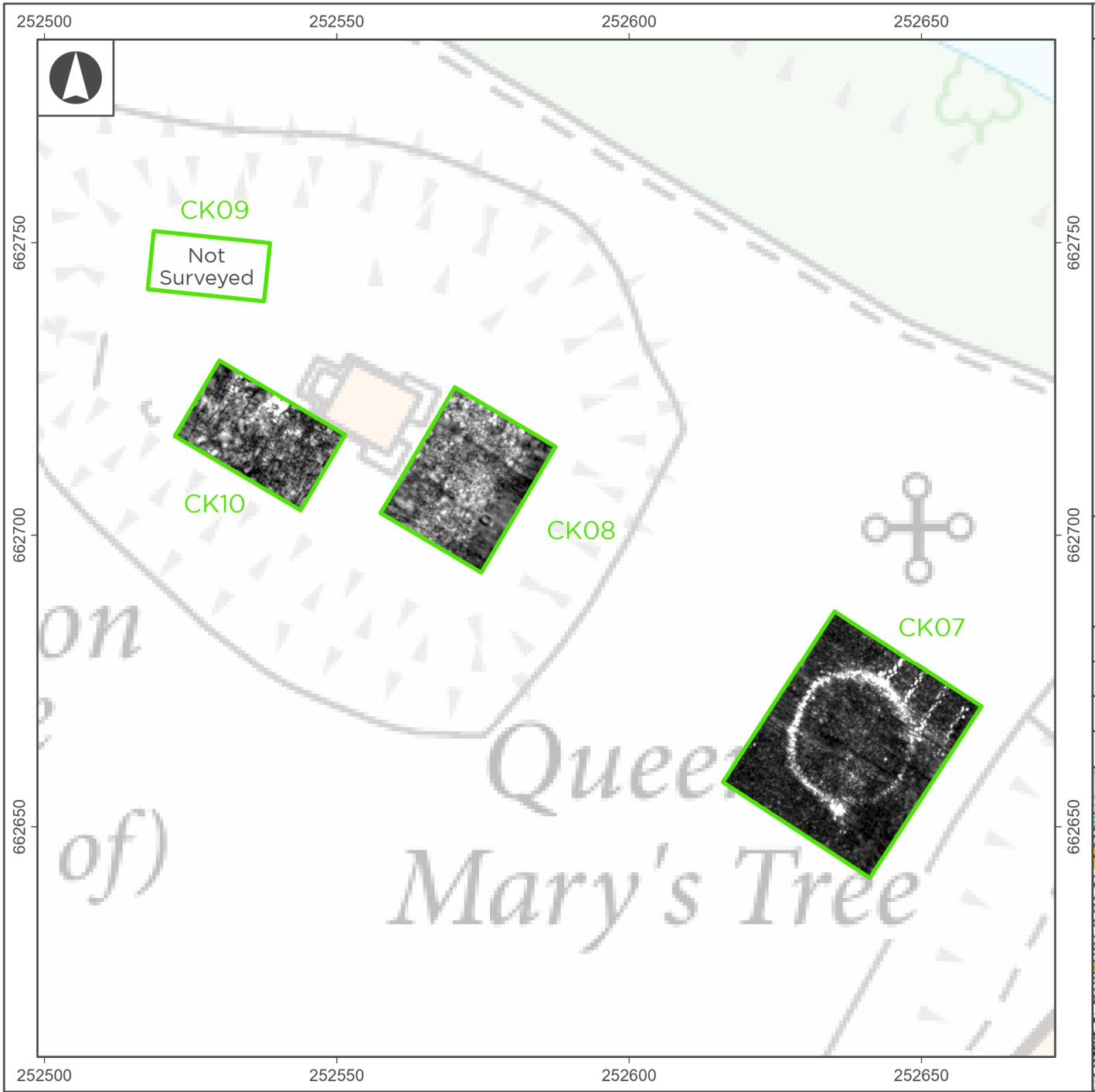
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,000 @ A4

Datum: OSGB 1936

Metres
0 10 20 30 40

Figure 12	Interpretation of Earth Resistance Data	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026

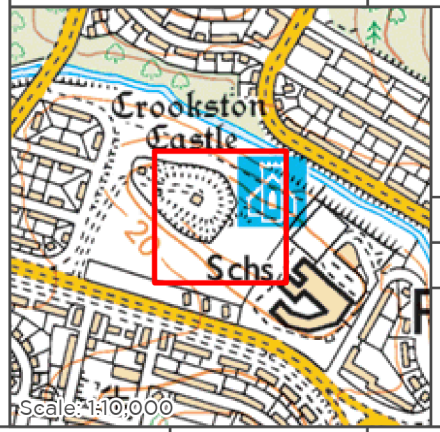


Legend

Ground Penetrating Radar - Survey Outline

Low Amplitude High

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



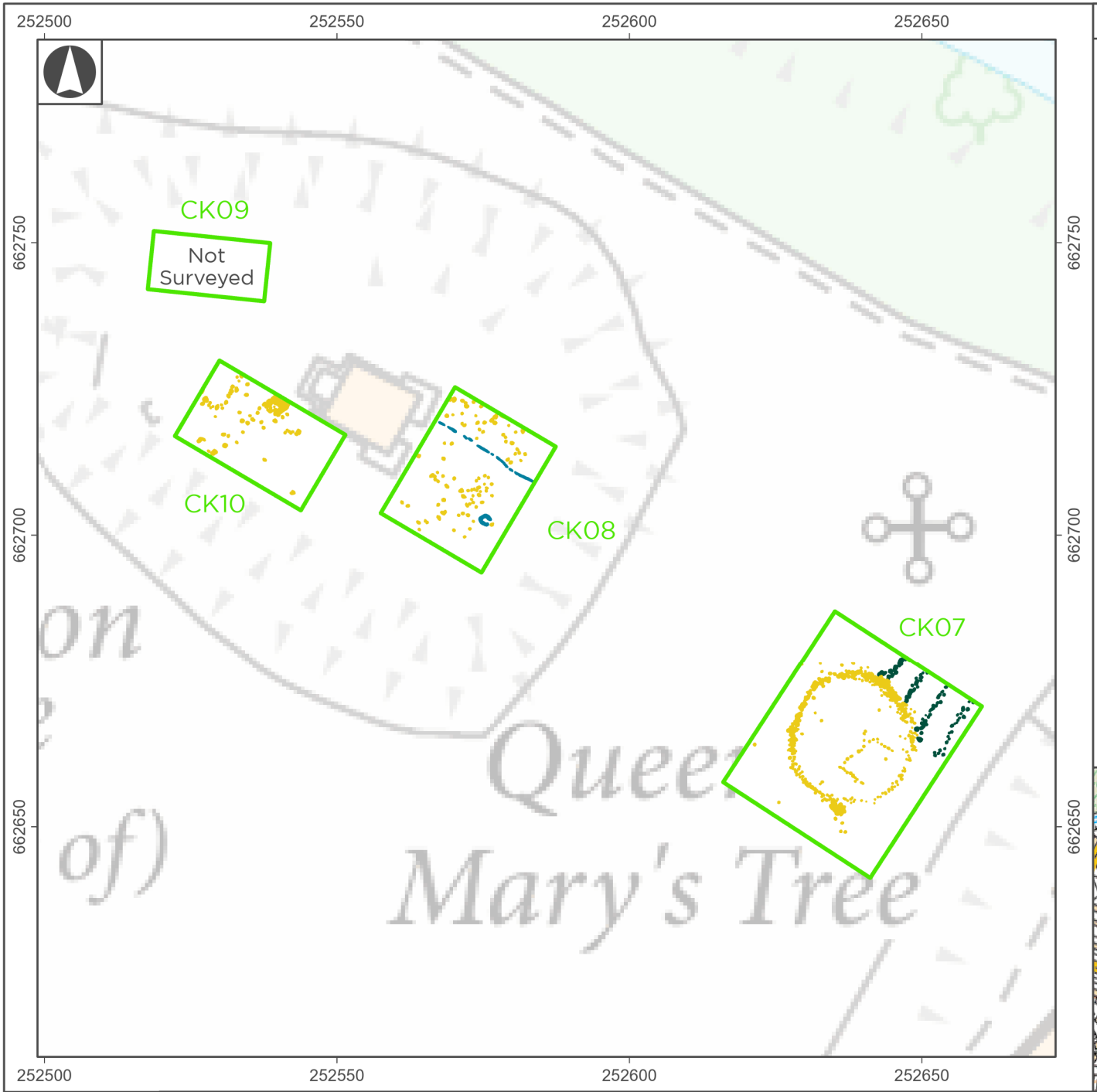
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,000 @ A4

Datum: OSGB 1936

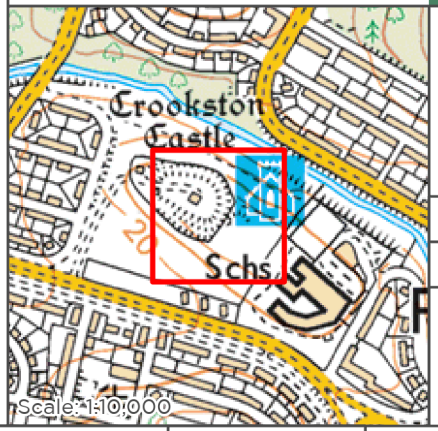
Metres
0 10 20 30

Figure 13	Ground Penetrating Radar Survey Areas, Traverse Positions and Timeslice 117ns Greyscale Plot	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



Legend

- Ground Penetrating Radar - Survey Outline
- High Amplitude Reflector
- Low Amplitude Reflector
- Modern Reflector



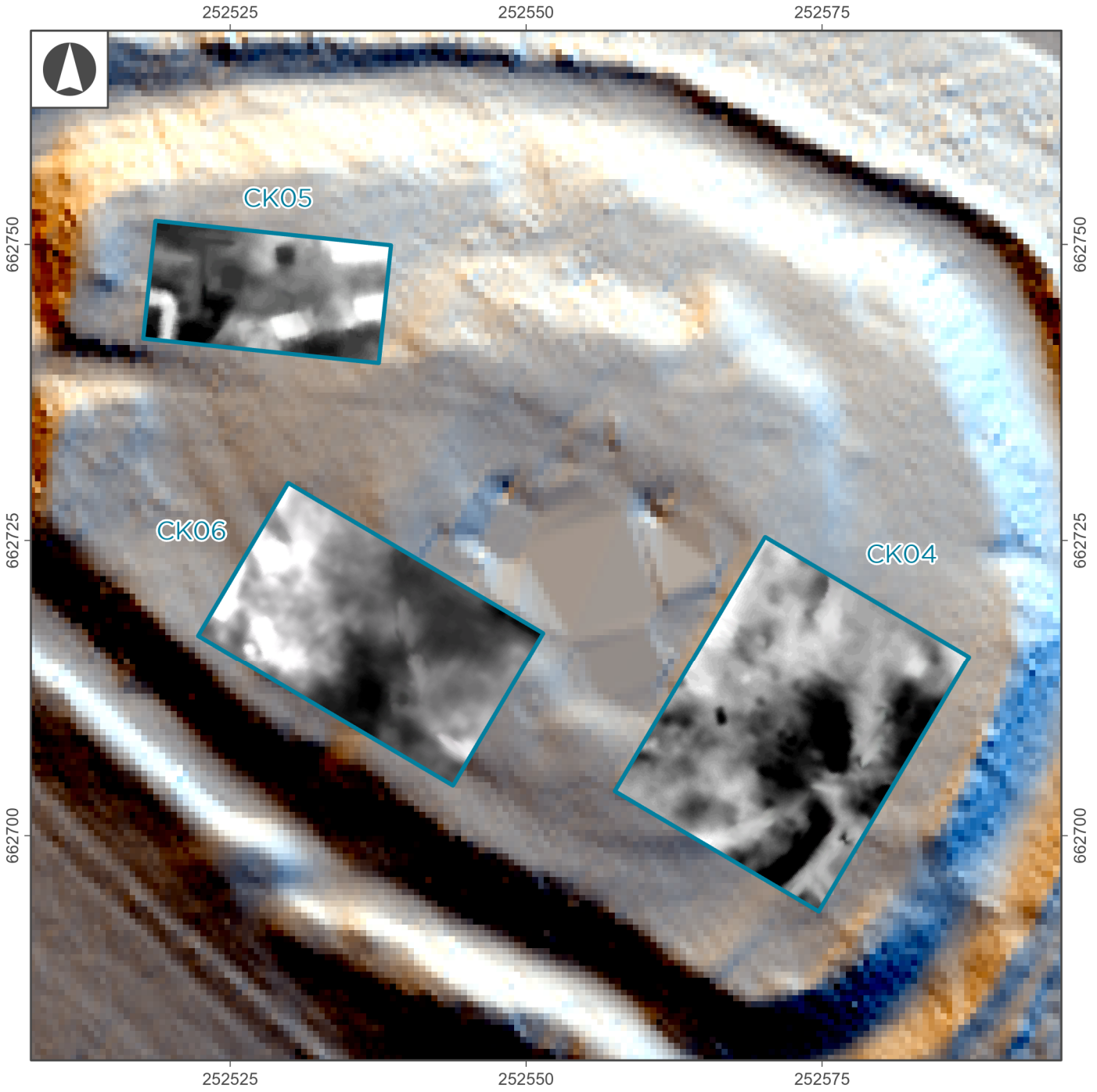
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,000 @ A4

Datum: OSGB 1936

Metres
0 10 20 30

Figure 14	Interpretation of Ground Penetrating Radar Data Timeslice 117ns	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



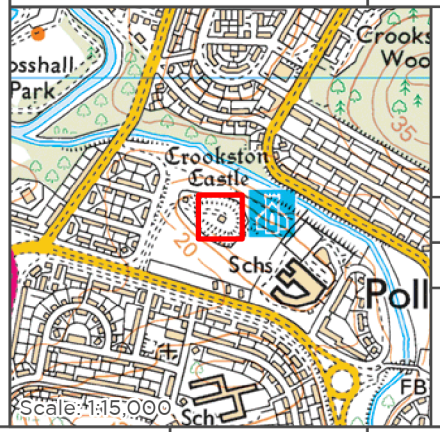
Legend

Earth Resistance - Survey Outline - Wenner - 0.50m

FRIENDS OF CROOKSTON CASTLE

182.1 Ohmns 314.7

Cell size (m)	0.12
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1



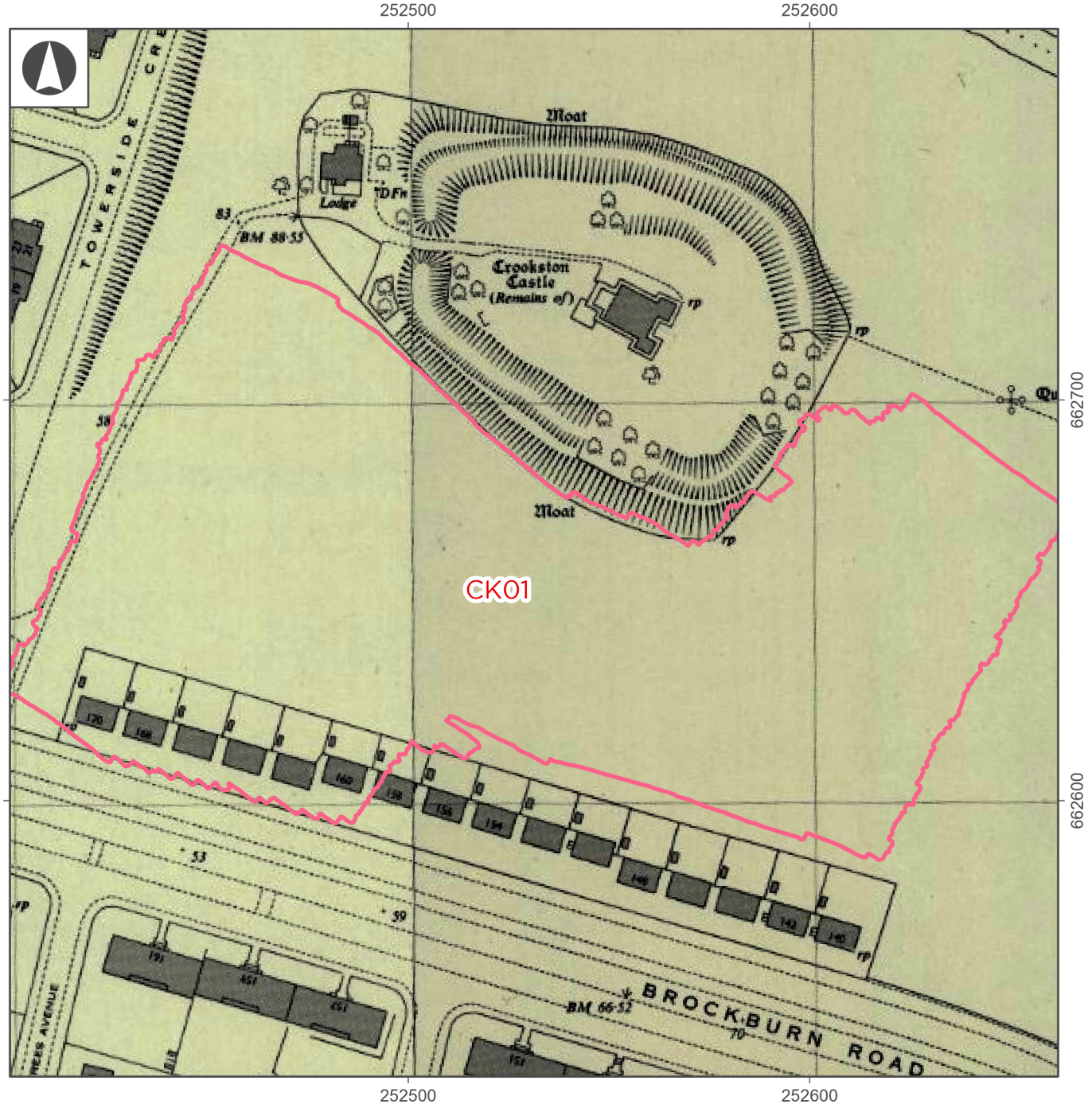
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:500 @ A4

Datum: OSGB 1936

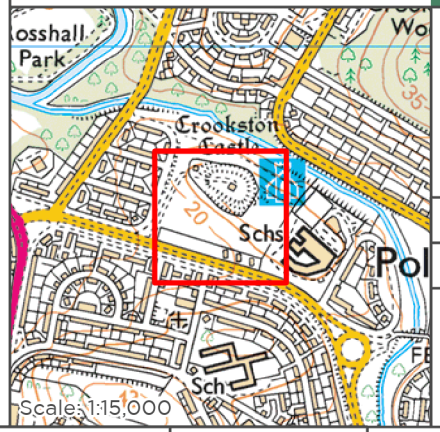
Metres
0 5 10 15 20

Figure 15	Processed Earth Resistance Data Greyscale (West) & LiDAR for Scotland Phase IV (2021)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	29/01/2026



Legend

Gradiometer - Survey Outline - 0.50m



FRIENDS OF CROOKSTON CASTLE

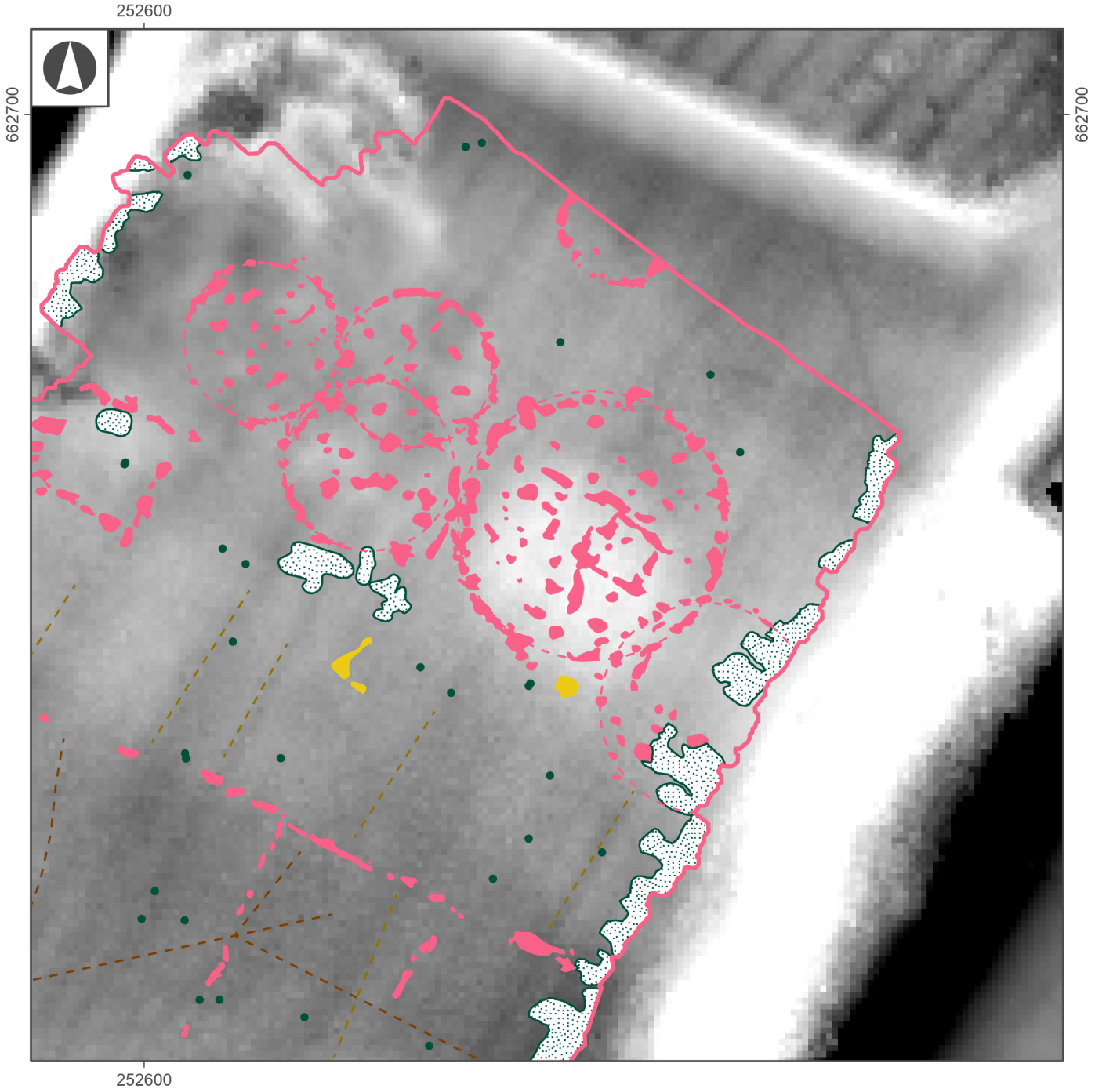
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:1,500 @ A4

Datum: OSGB 1936

Metres
0 10 20 30 40

Figure 16	Gradiometer Survey Area & Ordnance Survey Plan NS5262NW/NE Surveyed 1951, Published 1952	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	27/01/2026



Legend

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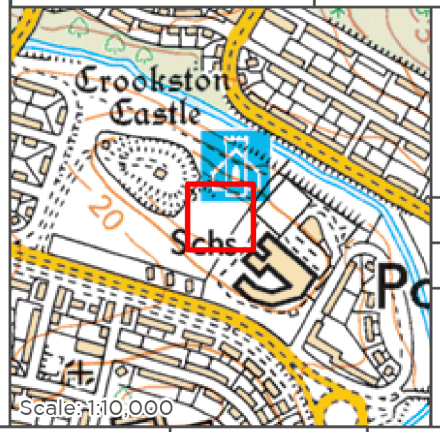
Resolution (metres)	0.50
Visualisation	Simple Local Relief Model
Directions	N/A
Altitude (degrees)	N/A
Azimuth (degrees)	N/A
Stretch	Standard Deviation
Standard Deviations	1
Gamma	1
Z-Factor	1



HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Scale: 1:500 @ A4

Datum: OSGB 1936

Metres
0 5 10 15 20

Figure 17	Interpretation of Processed Gradiometer Data & LiDAR for Scotland Phase IV (2021)	Project Name	Crookston Castle Survey	Prepared By	Nick Hannon
		Event ID	1218889	Prepared On	29/01/2026