Appendix A9.5: Geophysical Survey Report

ANBT25

A9 DUALLING PROGRAMME: PASS OF BIRNAM TO TAY CROSSING

GEOPHYSICAL SURVEY REPORT

commissioned by Transport Scotland

May 2025

HEADLAND ARCHAEOLOGY

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

REGISTERED CIfA ORGANISATION

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This report adheres to the quality standard of ISO 9001:2015

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PROJECT TEAM:

Project Manager **Kirsty Dingwall, Matthew Berry** / Author **Matthew Berry** / Fieldwork **Daniel Wilkinson, Findlay Young** / Graphics **Christian Adams, Dominic Dale-Bates, Lei Ding, Matthew Berry, Tom Watson**

Approved by **Kirsty Dingwall & Matthew Berry** Kirsty Dingwall - MBerry

Headland Archaeology Yorkshire & North
Units 23–25 & 15 | Acorn Business Centre | Balme Road | Cleckheaton BD19 4EZ
t 0127 493 8019
e yorkshireandnorth@headlandarchaeology.com
w www.headlandarchaeology.com

HEADLAND ARCHAEOLOGY an RSK company

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

REGISTERED CIfA ORGANISATION

NON-TECHNICAL SUMMARY

Headland Archaeology (UK) Ltd (the Contractor) was commissioned by Transport Scotland (the Employer) to undertake a geophysical (magnetometer and Ground Penetrating Radar, GPR) survey on five separate parcels of land as part of the A9 Dualling Programme: Pass of Birnam to Tay Crossing (the Proposed Scheme). Jacobs UK are the Consultant for the Proposed Scheme. The required works were undertaken in accordance with a project design agreed with Transport Scotland Historic Environment advisor (TSHEA) and Perth and Kinross Heritage Trust (PKHT). The results of the geophysical survey will be used to inform the cultural heritage inputs into the Environmental Impact Assessment Report (EIAR) for the proposed scheme and may also inform future archaeological strategy, if required.

Magnetometer survey was successfully undertaken across all suitable areas within the four separate survey parcels (P02_1, P02_3–5), an area totalling 6.55 hectares. Approximately 65% coverage was achieved across the proposed sole GPR survey area (P02_2) amounting to 0.14 hectares.

The results of the magnetometer survey suggest that magnetometry was an appropriate prospection method to assess the buried archaeological potential of the survey areas, but three of the four parcels (P02_1, P02_3 and P02_4) have been adversely affected by the presence of large, buried services (SP1–SP3) across them. Most of the anomalies identified by the survey are of agricultural, modern or natural origin however a group of weakly enhanced linear and discrete anomalies of uncertain (U2–U3, L1–L2, MD1 and ME1) and possible archaeological origin (E?1) were identified within the remaining parcel (E?1, U2–U3, L1–L2, MD1 and ME1; P02_5) that lies on slightly higher ground away from the flood plain of the River Tay. It is unclear however whether these anomalies are associated or record an unrelated spread of anomalies of natural/agricultural origin. One curvilinear trend of uncertain origin (U1) in P02_3 and traces of rig and furrow cultivation in two other parcels (P02_4 and P02_5) were the only other findings of note. Based on the results of the magnetometer

survey the archaeological potential of the two parcels (P02_1 and P02_3) most adversely affected by buried services remains uncertain. The archaeological potential of the northernmost parcels either side of the existing A9 are assessed as low to the east (P02_4) but locally moderate across the eastern half of the western parcel (P02_5).

The GPR survey was hindered by obstacles within the survey area but has identified weak traces of linear perpendicular high amplitude trends across multiple depth slices at the western end of the survey area immediately south of Station Road. The anomalies do not align with the direction of survey, Station Road, extant structures or buildings marked on historic mapping associated with historic asset Dunkeld and Birnam Station, Goods Yard (Asset 832) but could identify traces of a since demolished building or infrastructure associated with the yard. Outside of these responses the GPR survey has only recorded one other linear sub-surface high amplitude response that possibly records a buried service, in addition to multiple strong near surface reflectors that identify the location of service and drain covers. No anomalies of note were identified in the location of buildings recorded on historic mapping that were associated with the former railway goods yard.

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LIST OF ILLUSTRATIONS

A9 Dualling Programme:
Pass of Birnam to Tay Crossing
Dunkeld
Perth & Kinross

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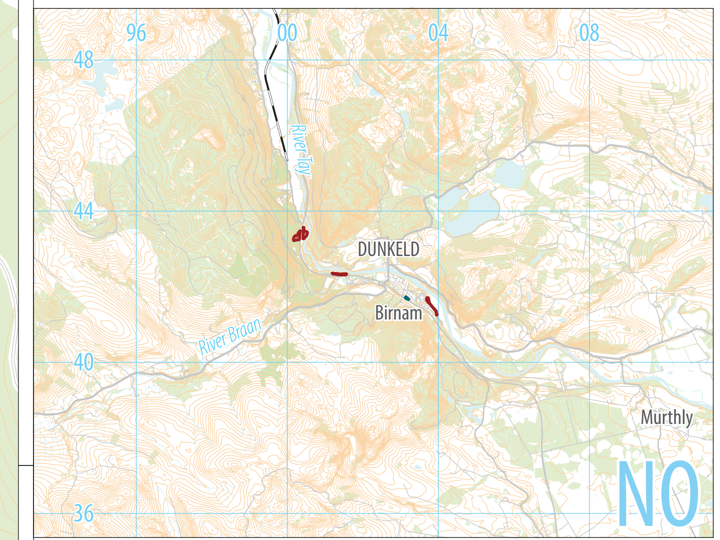

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY

Headland Archaeology Yorkshire & North
Units 23–25 & 15 | Acorn Business Centre | Balme Road | Cleckheaton BD19 4EZ
t 0127 493 8019
e yorkshireandnorth@headlandarchaeology.com
w www.headlandarchaeology.com

N
0 250m
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magnetometer survey area
GPR survey area

ILLUS 1 Site location

A9 DUALLING PROGRAMME: PASS OF BIRNAM TO TAY CROSSING

GEOPHYSICAL SURVEY REPORT

1 INTRODUCTION

Headland Archaeology (UK) Ltd (the Contractor) was commissioned by Transport Scotland (the Employer) to undertake a geophysical (magnetometer and Ground Penetrating Radar, GPR) survey on five separate parcels of land as part of the A9 Dualling Programme: Pass of Birnam to Tay Crossing (the Proposed Scheme). Jacobs UK are the Consultant for the Proposed Scheme. The required works were undertaken in accordance with a project design agreed with Transport Scotland Historic Environment advisor (TSHEA) and Perth and Kinross Heritage Trust (PKHT). The results of the geophysical survey will be used to inform the cultural heritage inputs into the Environmental Impact Assessment Report (EIAR) for the proposed scheme and may also inform future archaeological strategy, if required.

The geophysical survey was undertaken in accordance with the requirements of the Framework Agreement for Archaeology Services Lot 2 - Low Value 'Non-invasive and Invasive investigations' and 'Post Excavation Services' (TS/MP/SER/2020/11) and A9 Dualling Programme: Pass of Birnam to Tay Crossing Project Design for Archaeological Geophysical Survey (Jacobs 2024).

The Project Design was produced to the standards laid down in the European Archaeological Council's guideline publication, EAC Guidelines for the Use of Geophysics in Archaeology (Europae Archaeologia Consilium 2016) and the Chartered Institute for Archaeologists' (CIfA) Standard and Guidance for Archaeological Geophysical Survey (CIfA 2020). The geophysical survey was carried out in line with the same best practice guidelines.

The geophysical survey was carried out during the week commencing March 10th, 2025. The magnetometer survey were carried out between March 10th and March 11th and the GPR survey between March 12th through March 14th.

1.1 SITE LOCATION, TOPOGRAPHY AND LAND-USE

The five survey parcels (P02_1–5) are located close to the existing A9 carriageway to the south and north of Birnam, Perth and Kinross (Illus 1). The four magnetometer parcels take in parts of agricultural fields next to the River Tay, south of Birnam (P02_1, 1.1ha), north-west of Inver (P02_3, 1.04ha) and immediately south of Douglas Fir Wood either side of the existing A9 (P02_4, 1.91ha and P02_5, 2.50ha). The sole GPR survey area (P02_2, 0.22ha) constitutes a small area at Birnam Industrial Estate which includes Station Road, verges adjacent to Station Road and building frontages off Station Road.

More generally to the south-east of the proposed scheme at the Pass of Birnam the terrain is characterised by gently undulating floodplain of Strath Tay with localised areas of higher ground, confined by the River Tay to the north-east and steeply rising ground at the base of Birnam Hill to the south-west. Beyond the narrowest point of the Pass of Birnam, the River Tay floodplain widens before being interrupted by Torr Hill which rises to approximately 90m Ordnance Datum (OD) from the southern bank of the River Tay. Inchewan Burn crosses the floodplain passing between the conjoined settlements of Birnam and Little Dunkeld to join the River Tay. As the River Tay turns west the River Braan meanders across the floodplain to its confluence with the River Tay to the north-east of Inver. Between Inver and the Tay Crossing, Strath Tay narrows again, turning north, with flatter areas of floodplain to the east of the Highland Main Line railway and the existing A9, and steeply rising wooded hills to the south-west and west.

Topographically the land within each of the survey parcels is generally flat except for P02_5 which slopes up to the west away from lower ground adjacent to the existing A9.

ILLUS 2 P02_1, looking south-east

At the time of survey surface conditions across the magnetometer survey parcels were generally very good with short grazing pasture present in P02_3, P02_4 and P02_5 (Illus 4–6), however P02_1 had been lightly cultivated and was much softer under foot (Illus 2). Surface conditions across P02_2 consisted of made ground including uneven grass verges and tarmacadam and gravel road surfaces (Illus 3).

1.2 GEOLOGY AND SOILS

Detailed information on the local geology can be found in Chapter A9 (Geology, Soils and Groundwater) of the A9 Dualling Programme: Pass of Birnam to Tay Crossing DMRB Stage 2 Scheme Assessment Report Volume 1 - Main Report and Appendices Part 3 - Environmental Assessment (Jacobs 2023). A summary is presented below.

The bedrock geology varies across the five survey areas but all consist of different formations of metamorphic geologies. Pelite, slaty metamorphic bedrock of the Birnam Slate and Grit Formation underlies the southern half of P02_1. Semipelite and psammite metamorphic bedrock underlies P02_2 at Birnam. North of Birnam survey parcels P02_3–5 are underlain by metasandstone of the Ben Ledi Grit Formation (BGS 2025). Overlying superficial deposits are recorded predominantly as alluvium across all parcels except for P02_2 and the northwestern limits of P02_5 where glaciofluvial gravel, sand and silt are mapped (BGS 2025).

The local soils comprise humus-iron podzols which may also contain some alluvial soils associated with the River Tay floodplain, terraces and mounds.

The areas identified for GPR survey largely consist of made ground associated with Dunkeld and Birnam Station car park and the Birnam Industrial Estate. Most made ground at the surface comprises tarmacadam and gravel. Below this most of the made ground is associated with embankment fill or re-worked natural ground, that may contain clayey gravelly sand, where the gravel comprises mixed igneous and metamorphic lithologies with anthropogenic materials such as tarmacadam, concrete, brick, glass, tile, plastic, metal, wire, wood, hardcore, roadstone, ceramic, ash or clinker (Jacobs 2023).

2 ARCHAEOLOGICAL BACKGROUND

A summary of the archaeological and historical background of the proposed scheme is provided in the following paragraphs. Further information on the cultural heritage baseline can be found in the A9 Dualling Programme: Pass of Birnam to Tay Crossing DMRB Stage 3 Environmental Impact Assessment Report Appendix A9.2: (Cultural Heritage Baseline Information) and Chapter 14 (Cultural Heritage) of the A9 Dualling Programme: Pass of Birnam to Tay Crossing DMRB Stage 2 Scheme Assessment Report Volume 1 - Main Report and Appendices Part 3 - Environmental Assessment (Jacobs 2023). Known cultural heritage assets are shown on Figure 3 of that document.

ILLUS 3 P02_2, looking ESE

There is limited evidence for prehistoric to medieval activity close to the proposed scheme with areas adjacent to the existing A9 characterised by post-medieval activity and settlement from the 18th and 19th centuries, including the development of transport systems, localised quarrying and Murthly Castle Garden and Designed Landscape (HLT 14).

The Pass of Birnam provides an important entry point into the Highlands from Lowland Perthshire, and as such has seen successive development of the transport networks which pass through it and along Strath Tay, north towards Inverness. The Coupar Angus to Amulree Military Road (site of) (Asset 101) linked the Wade era Dunkeld to Inverness Military Road (Asset 192) and Crieff to Dalnacardoch military road via Strath Braan (Canmore ID 87608). In the 19th century the road network was further enhanced with the development of turnpike (toll) roads and the creation of the Old A9 (Telford).

The opening of Telford's Dunkeld Bridge Over River Tay (Asset 100; Category A Listed Building) in 1808 greatly improved connectivity and saw the development and expansion of Dunkeld as a market town and as a staging post for travellers, including early tourists, to and from the Highlands. It was not until the construction of the Perth and Dunkeld Railway in the mid-1850s, that Birnam began to develop from a small collection of cottages shown on Roy's Military map to a prosperous mid-Victorian Highland resort. The railway, which until its expansion north in 1863 terminated at Birnam, acted as a catalyst to the growth of Birnam which rapidly expanded either side of Perth Road and on Torr Hill. The arrival of the railway at Birnam also enabled the export of raw materials, including timber and agricultural products, via Dunkeld and Birnam Station, Goods Yard (Asset 832).

The settlement of Inver developed around the west ferry crossing at Inver (Asset 99), which served travellers wishing to cross the River Tay prior to 1808, and the mills owned by the Duke of Atholl. The mills were able to take advantage of Inver's position between the River Braan and the River Tay and the readily available source of water this afforded to power several mills, such as the sawmill which processed timber from trees grown on the Atholl Estate. While only elements of the former mills (Asset 73) remain, the water management system associated with the mills at Inver, including weirs in the River Braan (Assets 341 and 843) and the mill lead (Asset 839) survive.

Murthly Castle Garden and Designed Landscape (HLT 14) began to develop in the 18th century as formal gardens, avenues and policy woodland established around Murthly Castle (LB11146; Category A Listed Building). As the designed landscape developed in the 19th century, it expanded north-west beyond Birnam Burn as far as Birnam. The designed landscape to the north-west of Birnam Burn largely comprised policy woodland known for its collections of conifer trees, crossed by formal paths, avenues and the western drive.

ILLUS 4 P02_3, looking north-east

3 AIMS, METHODOLOGY & PRESENTATION

3.1 AIMS AND OBJECTIVES

The specific aims of the geophysical survey were:

› To determine, insofar as is reasonably possible, the presence of archaeological remains within the four separate magnetometer survey areas;

› To determine, insofar as is reasonably possible through the use of GPR survey, the presence of buried archaeological remains associated with Dunkeld and Birnam Station, Goods Yard (Asset 832) within the GPR survey area; and

› The results of the geophysical survey will be used to inform the cultural heritage inputs into the EIAR for the proposed scheme.

The objectives of the geophysical survey were:

› Through magnetometer survey identify, record and interpret archaeological remains within the requested survey areas;

› Through GPR survey identify, map the extent and analyse the nature of individual features that may be present within the survey area that could be associated with Dunkeld and Birnam Station, Goods Yard (Asset 832);

› Prepare an interpretative report on the results of the archaeological geophysical survey; and

› Disseminate the results of the archaeological geophysical survey through the deposition of an ordered archive and report at the National Record of the Historic Environment (NRHE) and a copy of the report with the Perth and Kinross Historic Environment Record.

3.2 METHODOLOGY – MAGNETOMETER SURVEY

Magnetic survey methods rely on the ability of a variety of instruments to measure very small magnetic fields associated with buried archaeological remains. A feature such as a ditch, pit or kiln can act like a small magnet, or series of magnets, that produce distortions (anomalies) in the earth's magnetic field. In mapping these slight variations detailed plans of sites can be obtained, as buried features often produce reasonably characteristic anomaly shapes and strengths (Gaffney & Gater 2003). Further information on soil magnetism and the interpretation of magnetic anomalies is provided in Appendix 1.

Magnetometry is the most widely used geophysical survey technique in archaeology as it can quickly evaluate large areas and, under favourable conditions, identify a wide range of archaeological features including infilled cut features such as large pits, gullies and ditches, hearths, and areas of burning, and kilns and brick structures.

ILLUS 5 P02_4, looking south

It is therefore good at locating settlements of all periods, prehistoric field systems and enclosures, and areas of industrial or modern activity, amongst others. It is less successful in identifying smaller features such as post-holes and small pits (except when using a non-standard sampling interval), unenclosed (prehistoric) settlement sites and graves or burial grounds. However, magnetometry is by far the single most useful technique and was assessed as the best non-intrusive evaluation methodology for this survey

The magnetometer survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals onto a rigid carrying frame. The system was programmed to take readings at a frequency of 10Hz on roaming traverses (swaths) 1m apart. These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R12 Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point.

MLGrad601 and MultiGrad601 (Geomar Software Inc.) software was used to collect and export the data. Anomaly GeoSurvey v1.12.3 (Lichenstone Geoscience) and QGIS v.3.34.6 software was used to process and present the data respectively.

3.3 METHODOLOGY – GPR SURVEY

Ground penetrating radar (GPR) works by discharging a short pulse of energy into the ground with reflections being returned from the interfaces between different materials in the ground. The amplitude of these returns depends on the change in velocity of the radar wave as it crosses these interfaces. A measure of these velocities is given by the dielectric constant of that material. The travel times are recorded for each return on the radargram and an approximate conversion made to depth by calculating or assuming an average dielectric constant. An advantage of a GPR survey is its capability to be used on a variety of ground conditions and supply the user with an estimation of depth.

Drier materials such as sand, gravel and rocks, i.e. materials which are less conductive (or more resistant), will permit the survey of deeper sections than wetter materials such as clays which are more conductive (or less resistant). Penetration can be increased by using longer wavelengths (lower frequencies) but at the expense of resolution. As the antennae emit a "cone" shaped pulse of energy an offset target showing a perpendicular face to the radar wave will be "seen" before the antenna passes over it. A resultant characteristic diffraction pattern is thus built up in the shape of a hyperbola. A classic target generating such a diffraction is a pipe when the antenna is travelling across the line of the pipe. However, if the interface between the target and its surroundings does not result in a marked change in velocity then only a weak hyperbola will be seen, if at all.

This survey utilised a MALÅ GX (Ground Explorer) integrated GPR system manufactured by MALÅ which has the capacity to deploy interchangeable antennae of varying frequencies. A 160MHz and 450MHz antennae were used for this survey and deployed onto a wheeled rough terrain hand drawn cart, connected to a MALÅ GX Controller rugged touchpad.

ILLUS 6 P02_5, looking north

With both 160MHz and 450Mhz antenna GPR readings were taken in real time along parallel traverses spaced 0.25m apart, on a predetermined grid covering the geophysical survey area that was established using a Leica GS18 RTK differential Global Positioning System (dGPS) system. Given the narrow 0.25m line spacing width of the survey specification, internal accuracy within the local grid was maintained with the use of measuring tapes and visual markers. Profiles were collected in the zigzag (bi-directional) method after calibration of the wheel odometer mounted to the antenna. On-site checks over 10m were conducted and found to be accurate at the start of each day.

After initial tests deploying the 160MHz (see Appendix 6) and 450MHz antennae, the 450MHz antenna was chosen for full survey coverage based on the anticipated depth of any likely archaeological targets associated with the former Dunkeld and Birnam Station, Goods Yard (Asset 832) and greater resolution of the data the 450MHz antenna provides across the shallower sub-surface horizons.

The 450MHz GPR system was deployed across the entire survey area (where access allowed) to provide the appropriate depth penetration and resolution to identify archaeological features.

Geolitix processing software was used to process and display the GPR data. Details of the data processes applied are detailed in Appendix 4. Radargrams were assessed and those anomalies thought to be significant noted. Timeslices or plan views showing the variation of reflector amplitude at selected depths were produced and selected examples displayed in the report, as well as significant profile radargrams to illustrate the response to interpreted anomalies.

3.4 DATA PRESENTATION AND TECHNICAL DETAIL

A general site location plan is shown in Illus 1 at a scale of 1:15,000. Illus 2 to Illus 6 inclusive are site condition photographs. Illus 7 shows the location and direction of the site condition photographs at a scale of 1:15,000. Illus 8 and Illus 9 present overviews of the processed greyscale magnetometer data and interpretation of the data, also at 1:15,000. Detailed plans of the geophysical survey data is then presented by area from south to north geographically.

Illus 10 to Illus 17 and Illus 25 to Illus 44 inclusive show the fully and minimally processed (greyscale) data, minimally processed (XY trace plot) data and interpretative plans for the magnetometer survey, by area, at a scale of 1:1,000. The location of the GPR profiles for the complete 450MHz survey are shown in Illus 18. Illus 19 to Illus 24 show the GPR timeslice data, interpretation of selected timeslices and selected radargram profiles.

Technical information on the theory of soil magnetism and the magnetometer interpretive categories are given in Appendix 1. Appendix 2 covers more in-depth GPR theory. Appendix 3 details the geophysical survey location information and Appendix 4 describes the composition and location of the site archive. Data processing details for both magnetometer and GPR surveys are presented in Appendix 5. The timeslice test results of the partial GPR survey deploying the 160MHz antenna are included in Appendix 6. A copy of the OASIS entry (Online Access to the Index of Archaeological Investigations) is reproduced in Appendix 7.

The geophysical survey methodology, report and any recommendations comply with the Project Design for Geophysical Survey (Jacobs 2024), guidelines outlined by Europae Archaeologia Consilium (EAC 2016) and by the Chartered Institute for Archaeologists (CIfA 2020).

All illustrations using Ordnance Survey (OS) base mapping are reproduced with the permission of the controller of His Majesty's Stationery Office (© Crown copyright).

The illustrations in this report have been produced following analysis of the magnetometer data in 'raw' (minimally processed) and processed formats and over a range of different display levels. The GPR timeslices and radargrams selected for interpretation have been chosen to best highlight the anomalies/features recorded by the geophysical survey. All illustrations are presented to display and interpret the data to best effect. The interpretations are based on the experience and knowledge of Headland Archaeology management and reporting staff.

4 RESULTS & DISCUSSION

4.1 MAGNETOMETER SURVEY SITE CONDITIONS AND RESULTS

Magnetometer survey can be recommended over metamorphic bedrock geologies but results can be strongly affected by any igneous intrusions and can be variable depending on overlying superficial deposits, as is the case here, with alluvium covering all areas except for the northwestern fringes of parcel P02_5 which is recorded as glaciofluvial gravel, sand and silt (English Heritage 2008; Table 4).

Excluding areas affected by magnetic disturbance from buried services, the magnetic background of the magnetometer survey data in those survey areas closest to and in the floodplain of the River Tay (P02_1, P02_3 and P02_4) appear relatively homogenous with a greater degree of variability recorded within P02_5 on the slightly higher ground away from the river and where glaciofluvial sand, gravel and silts are mapped.

Against these magnetic backgrounds, anomalies determined of predominantly agricultural, natural and modern origins have been recorded, although a faint curvilinear anomaly and linear trends and clusters of discrete magnetically enhanced anomalies of uncertain and possible archaeological origin have been recorded within P02_3 and P02_5 respectively (discussed below).

However, as mentioned, the magnetic survey data is adversely affected by the presence of substantial buried services within parcels P02_1, P02_3 and to a lesser extent in P02_4. The dominating magnetic response from these can effectively mask any responses from typically much weaker anomalies of possible archaeological origin, if present, and precludes a confident assessment of the archaeological potential of P02_1 and P02_3.

The magnitude, resolution and range of magnetic anomalies identified in areas not affected by magnetic disturbance from buried services, indicates that there was likely sufficient magnetic contrast, for the detection of sub-surface archaeological features, if present, notwithstanding the limitations of magnetometer survey to identify the types, sizes and period of archaeological features as described in Section 3.2. Therefore, the results of the magnetometer survey are determined to provide a reasonably good indication of the archaeological potential of parcels P02_4 and P02_5.

At the time of survey surface conditions across the magnetometer survey parcels were generally very good with short grazing pasture in P02_3, P02_4 and P02_5 (Illus 4–6), however P02_1 had been lightly cultivated and was much softer under foot (Illus 2). Full survey coverage was achieved except for very small areas containing obstacles such as trees, temporary livestock fences, a manure heap and/or bales. No other issues were encountered during the magnetometer survey. Data quality was good with only minimal post-processing required.

Anomalies recorded by the magnetometer survey are discussed according to their interpreted origin.

4.2 ANOMALIES OF FERROUS AND MODERN ORIGIN

Ferrous anomalies, characterised as individual 'spikes', are typically caused by ferrous (magnetic) material, either on the ground surface or in the plough-soil. Little importance is normally given to such anomalies, unless there is any supporting evidence for an archaeological interpretation, as modern ferrous debris is common on most sites, often being introduced into the topsoil during manuring or tipping/infilling. There is no obvious clustering of the 'spike' responses, so these anomalies are likely to be indicative of a random distribution of modern ferrous debris in the plough-soil.

High amplitude, linear, dipolar anomalies recorded in fields P02_1, P02_3 and P02_4 and record the location of buried service pipes (Illus 9 - SP1, SP2 and SP3). SP1 and SP3 extend broadly north to south across P02_1 and P02_4 respectively, while SP2 crosses P02_3 on an east to west alignment. Due to the confines of the geophysical survey parcels and level of magnetic disturbance resulting from the buried services, roughly equating to a 10–15m buffer, it is not possible in some instances to ascertain the exact line of the service.

Further magnetic disturbance recorded around the edges of P02_1 and P02_5 is likely produced by extant fencing and/or magnetic debris gathered at the field boundary (Illus 10–17 and Illus 40–44).

4.3 ANOMALIES OF AGRICULTURAL ORIGIN

Several anomalies of agricultural origin have been identified across the geophysical survey parcels. Most are the result of modern cultivation, with examples of faint linear trends parallel to modern field boundaries visible across fields P02_4 and P02_5 and in the north of P02_1.

Anomalies indicative of historic ploughing (rig and furrow cultivation) have also been identified across fields P02_4 (Illus 33–40) and P02_5 (Illus 41–44). These manifest as slightly more widely spaced parallel, slightly curvilinear trends, aligned in a generally east to west direction.

4.4 ANOMALIES OF GEOLOGICAL ORIGIN

Vaguely curvilinear and discrete anomalies recorded in P02_3 and P02_5 are interpreted as natural in origin. These likely relate to variations in overlying alluvial and glacifluvial superficial deposits present in the upper soil horizons.

4.5 ANOMALIES OF POSSIBLE OR PROBABLE ARCHAEOLOGICAL ORIGIN

A weakly magnetically enhanced, angular linear anomaly, not aligned with present boundaries and/or historic rig and furrow cultivation, is identified in the southeast of P02_5 (Illus 40–44 - E?1). The anomaly could identify an infilled ditch, possibly defining a partial, sub-rectilinear enclosure approximately 35m in diameter. A cluster of discrete magnetically enhanced pit-like anomalies of uncertain origin are recorded within E?1. However these could be of natural origin reflecting the more variable magnetic background to this parcel.

4.6 ANOMALIES OF UNCERTAIN ORIGIN

Linear, curvilinear and amorphous anomalies have been interpreted as of uncertain origin on the basis they cannot be confidently interpreted in any other category. None correspond with any mapped or obvious landscape feature and neither do they share an alignment with the current and former field boundaries or with the direction of recent/historic cultivation.

In the centre-west of P02_3, a weakly defined discontinuous curvilinear anomaly approximately 20m in diameter, has been identified (Illus 29–32 - U1) immediately north of the magnetic disturbance arising from SP2 which crosses the parcel. While the overall appearance of these anomalies may be suggestive of a unified partial curvilinear/circular ditch-like feature, their discontinuity, as well as the overall lack of context due to the small extent of the geophysical survey area and absence of other anomalies of interest, prevent a confident identification and interpretation.

Within P02_5, a group of anomalies of uncertain origin have been recorded in the eastern half of the parcel (Illus 40–44 - U2, U3, L1 and ME1). Weakly enhanced, discontinuous curvilinear anomalies U2 and U3 have been recorded and form partial, sub-circular anomalies approximately 11m and 8m in diameter respectively. These are located at either side of an L-shaped linear ditch-like anomaly aligned north-west to south-east by north-west/south-east (L1). The cluster of discrete pit-like responses at ME1 are recorded at the southern extent of this apparent anomaly.

While it is possible that collectively this group of magnetic anomalies may correspond to archaeological features such as sub-circular enclosures, ditches and pits, it is considered equally plausible that these may correspond to unrelated natural (U2, U3 and ME1) and/or agricultural features (L1).

Approximately 90m west of this group of anomalies, a concentration of very strongly enhanced discrete anomalies is identified (Illus 40–44 - MD1) at the south-west corner of the field. While these anomalies do not correspond with any features recorded on historic maps or on satellite imagery, their magnetic signature strongly suggests an anthropogenic cause, possibly an unmapped extraction site.

4.7 GPR SURVEY SITE CONDITIONS AND RESULTS

The GPR survey area (P02_2) was a mix of grass verges and road surface. At the time of survey vehicles were parked along Station Road and in the parking bays providing access to the buildings fronting onto the geophysical survey area. Trees, signposts, a telegraph pole, large bins and lampposts also restricted data collection along the northern grass verge and western corner of the parcel in particular (Illus 3). Full survey coverage of all suitable areas was achieved with the 450MHz antenna totalling 0.138ha, approximately 65% of the survey parcel. Data quality was generally good however the different ground surface and presumably sub-surface conditions between the grass verges and road surface is evident across the timeslices and remains difficult to process simultaneously. Except for the parked vehicles and other obstacles within the survey area no problems were encountered during the GPR survey.

Generally, the GPR survey has recorded few distinct anomalies that can be confidently identified and interpreted as being of one cause within the depth slice data, though analysis of the radargram profiles (Illus 24) do show multiple discontinuities, with some distinct hyperbolas and discrete high amplitude reflectors and the ‘ringing’ effect of modern near surface features. Extended sections of discontinuous high amplitude reflectors likely arise from the varied nature of the material comprising the made ground now present at the Birnam Industrial Estate.

The GPR survey has identified weak traces of linear perpendicular positive reflection trends, roughly 7m apart, at the western end of the survey area on the grass verge immediately south of Station Road. The anomalies are present to varying degrees across multiple depth slices ranging from approximate depths of 0.75m to 1.25m. The anomalies do not align with the direction of survey, Station Road, extant structures or buildings marked on historic mapping associated with historic asset Dunkeld and Birnam Station, Goods Yard (Asset 832) but could identify traces of a since demolished building or infrastructure associated with the yard.

Elsewhere the GPR survey has only recorded one other linear sub-surface high amplitude response that possibly records a buried service towards the centre of the survey area at a depth of approximately 0.75–1m (Illus 19–20 and Illus 23).

Outside of these responses the GPR survey has recorded multiple strong near surface positive reflectors that have caused a 'ringing' response down through the radargram profiles (Illus 24 Profile 7245) and which identify the location of service and drain covers noted by the field team during the survey.

The remainder of the responses are considered likely to identify variations within the made/re-worked natural ground associated with the Dunkeld and Birnam Station car park and the Birnam Industrial Estate.

5 CONCLUSION

A magnetometer and GPR survey were successfully undertaken across all suitable areas within each of the five survey parcels which amounts to near total coverage for the magnetometer survey and approximately 65% coverage for the GPR survey.

The results of the magnetometer survey have been adversely affected by the presence of large, buried services running the length of parcels P02_1, P02_3 and to a lesser extent P02_4. Due to the dominating magnetic responses from these features, it has not been possible to provide a reliable assessment of the buried archaeological potential in those specific areas, though it is acknowledged that any archaeological deposits, if present, would likely have been destroyed or truncated in the location of the service.

Outside of these areas the results of the geophysical survey suggest that magnetometry is an appropriate prospection method to assess the buried archaeological potential of the survey areas, notwithstanding the limitations of magnetometer survey to identify the types, sizes and period of archaeological features as described herein and across the prevailing geological conditions. The magnitude, resolution and range of magnetic anomalies identified in areas not affected by magnetic disturbance from buried services, indicates that there was likely sufficient magnetic contrast, for the detection of sub-surface archaeological features.

The magnetometer survey has recorded a group of magnetic anomalies largely of uncertain but also of possible archaeological origin west of the existing A9 in the eastern half of P02_5. It is unclear whether these anomalies represent an associated group of features of possible archaeological potential and/or an unrelated spread of anomalies of natural/agricultural origin. The archaeological potential of this area is therefore considered to be locally moderate. The anomalies do not appear to extend east of the existing A9 where the only findings of note are rig and furrow cultivation in P02_4 and the archaeological potential is therefore considered low.

The GPR survey has generally identified few anomalies/features of note. One exception are traces of linear perpendicular high amplitude trends, roughly 7m apart, identified at the western end of the survey area on the grass verge immediately south of Station Road. The anomalies are present to varying degrees across multiple depth slices ranging from approximate depths of 0.75m to 1.25m. The anomalies do not align with the direction of survey, Station Road, extant structures or buildings marked on historic mapping associated with historic asset Dunkeld and Birnam Station, Goods Yard (Asset 832) but could identify traces of a since demolished building or infrastructure associated with the yard.

Other than those responses the GPR survey has only recorded one other linear sub-surface high amplitude response that possibly locate a buried service, in addition to multiple strong near surface reflectors that identify the location of service and drain covers noted by the field team during the survey.

6 REFERENCES

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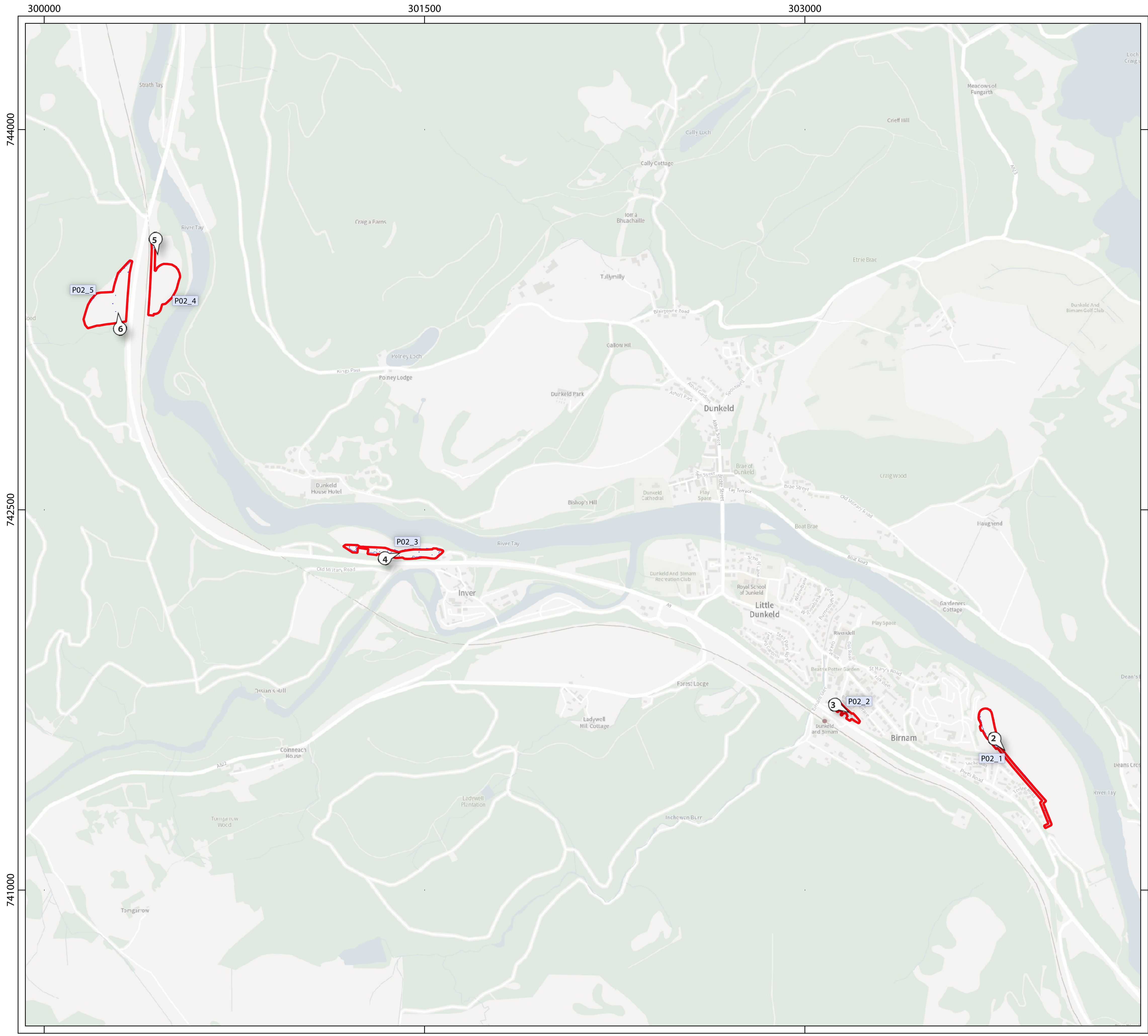
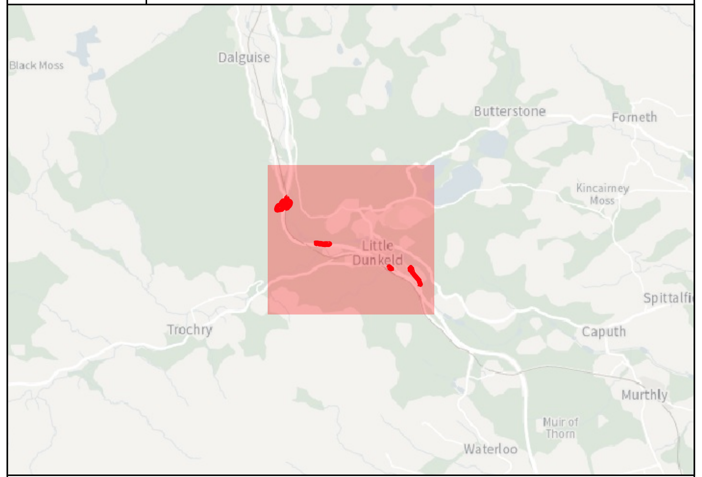
Jacobs (2023b) *A9 Dualling Programme: Pass of Birnam to Tay Crossing DMRB Stage 3 Environmental Impact Assessment Report Appendix A9.2: (Cultural Heritage Baseline Information)* [unpublished client report]

Jacobs (2024) *A9 Dualling Programme: Pass of Birnam to Tay Crossing Project Design for Archaeological Geophysical Survey* [unpublished client report] Ref. A9P02-JAC-EHR-A_ZZZZZ_EG-SP-EN-0001

Natural Environment Research Council (UKRI) 2025 *British Geological Survey* http://www.bgs.ac.uk/ accessed accessed 11th March 2025





Key

Geophysical Survey Area

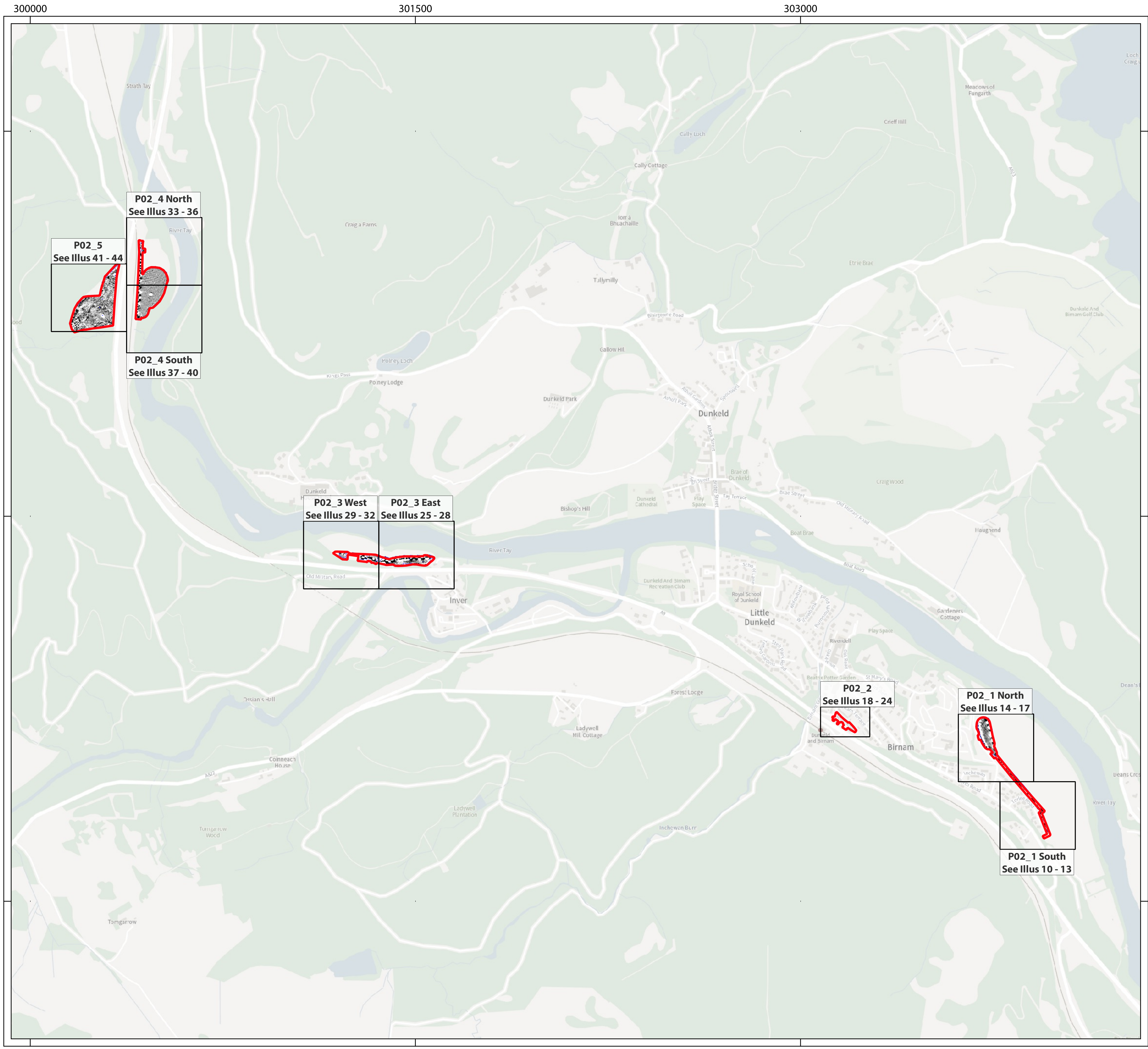
Survey Extent

Location and Direction for Illus 02 to 06

0 300 600 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:15,000 @ A3

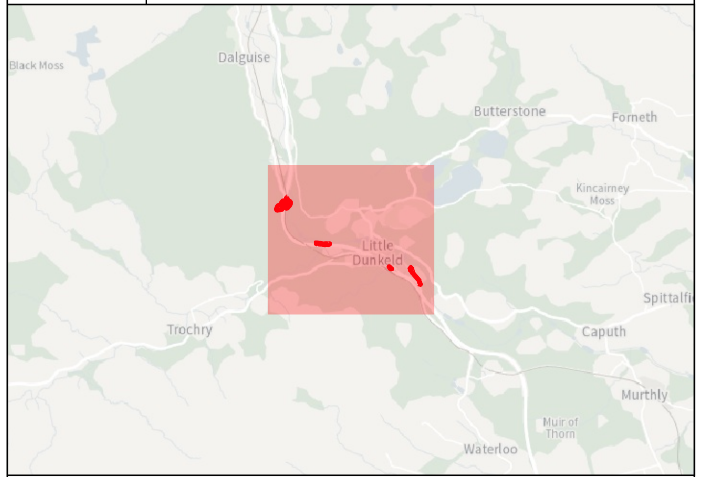
Illus 07 - Survey location showing photograph locations



N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company



Key

- Geophysical Survey Area
- Survey Extent
- Area for Illus 10 to 44

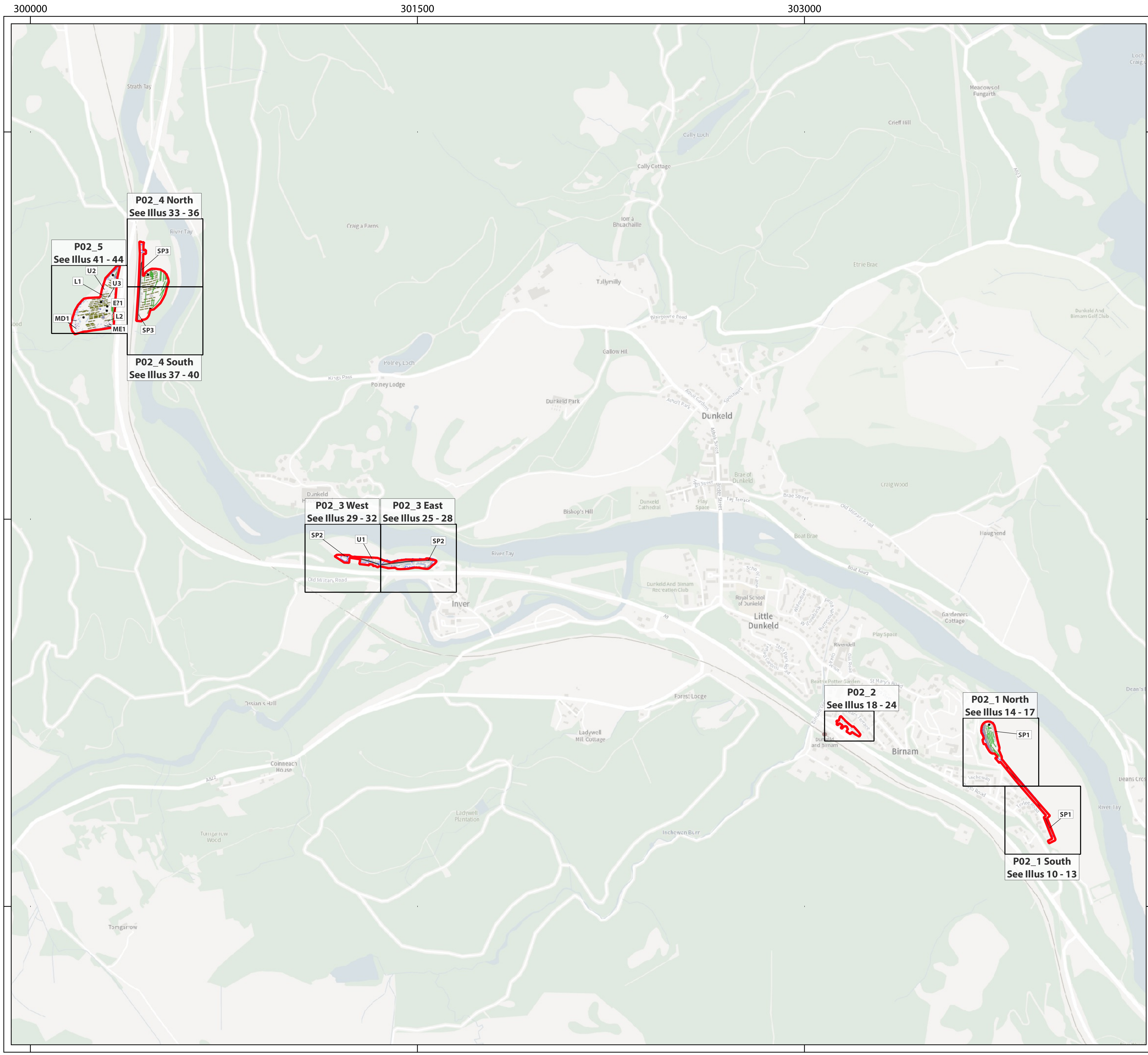
+2nT

-1nT

0 300 600 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:15,000 @ A3

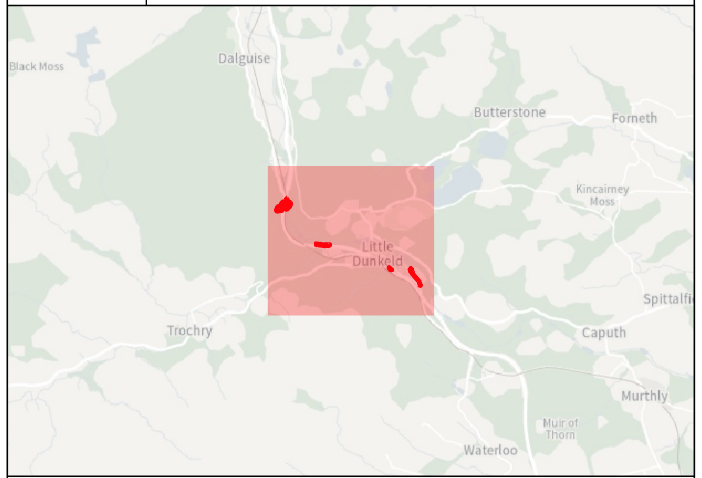
Illus 08 - Overall greyscale plot of processed magnetometer data



N

DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Geophysical Survey Area
- Survey Extent
- Area for Illus 10 to 44
- Ferrous Objects
- Agriculture
- Natural
- Service
- Ridge and Furrow
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural
- Possible Archaeology
- Uncertain

	Abbreviation
E?	Enclosure?
L	Linear
MD	Magnetic Disturbance
ME	Magnetic Enhancement
SP	Service Pipe
U	Uncertain

0 300 600 m

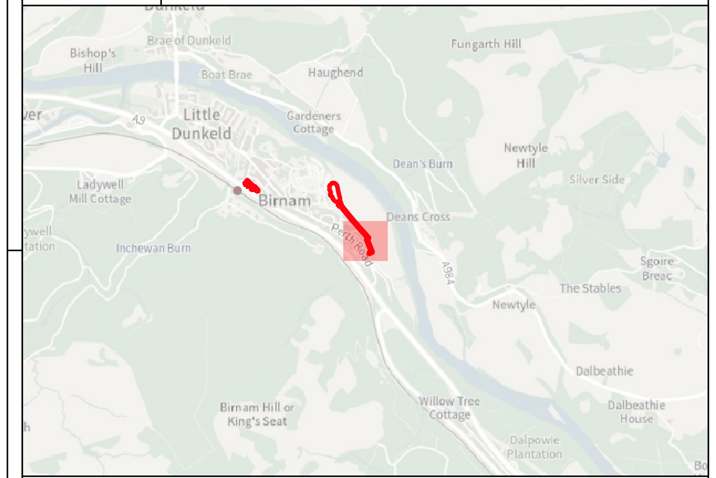
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:15,000 @ A3

Illus 09 - Overall interpretation of magnetometer data

N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company



Key

Survey Extent

+2nT

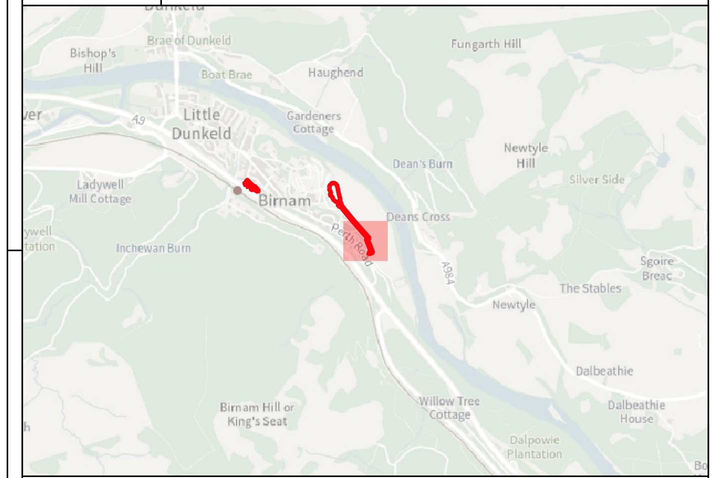
-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 10 Processed greyscale magnetometer data; P02_1 South

N



Key

Survey Extent

+2nT

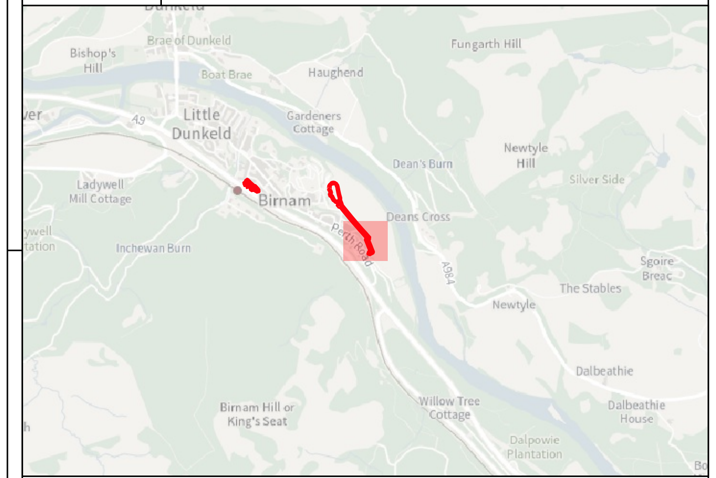
-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 11 Minimally processed greyscale magnetometer data; P02_1 South

N



A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company

Key

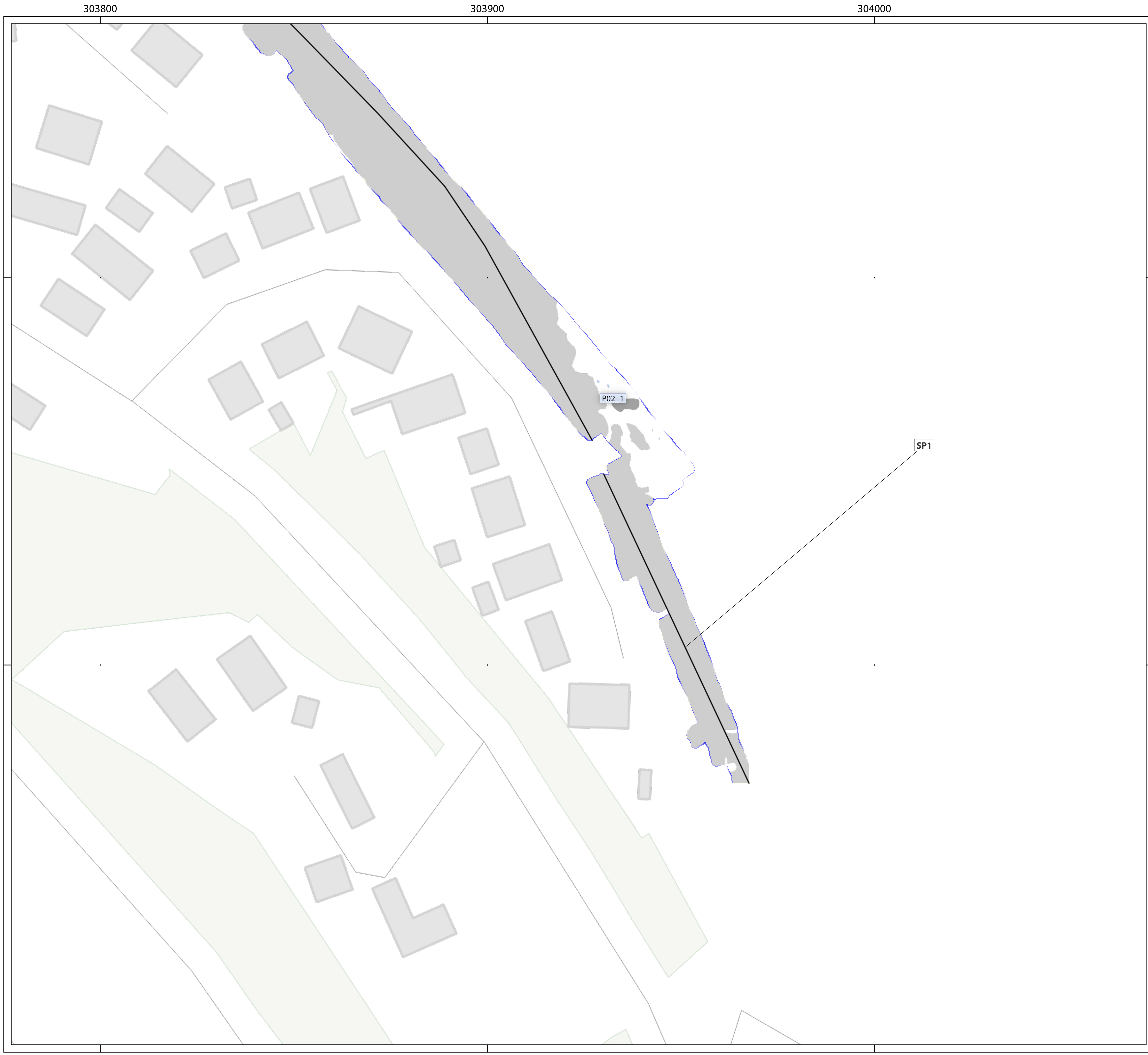
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 12 XY trace plot of minimally processed magnetometer data; P02_1 South



N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

Key

- Survey Extent
- Service
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

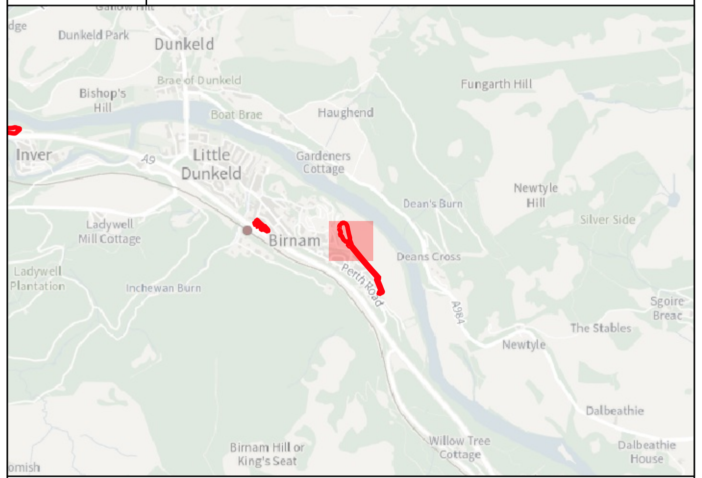
	Abbreviation
SP	Service Pipe

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 13 Interpretation of magnetometer data; P02_1 South

N



Key

Survey Extent

+2nT

-1nT

0 20 40 m

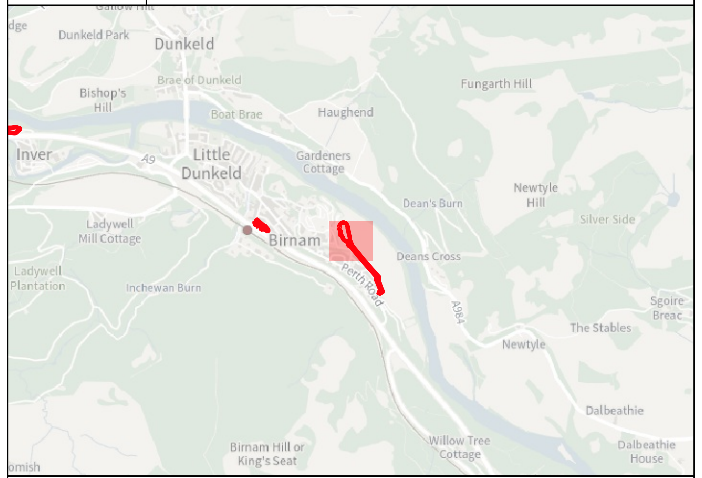
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 14 Processed greyscale magnetometer data; P02_1 North

N

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

Survey Extent

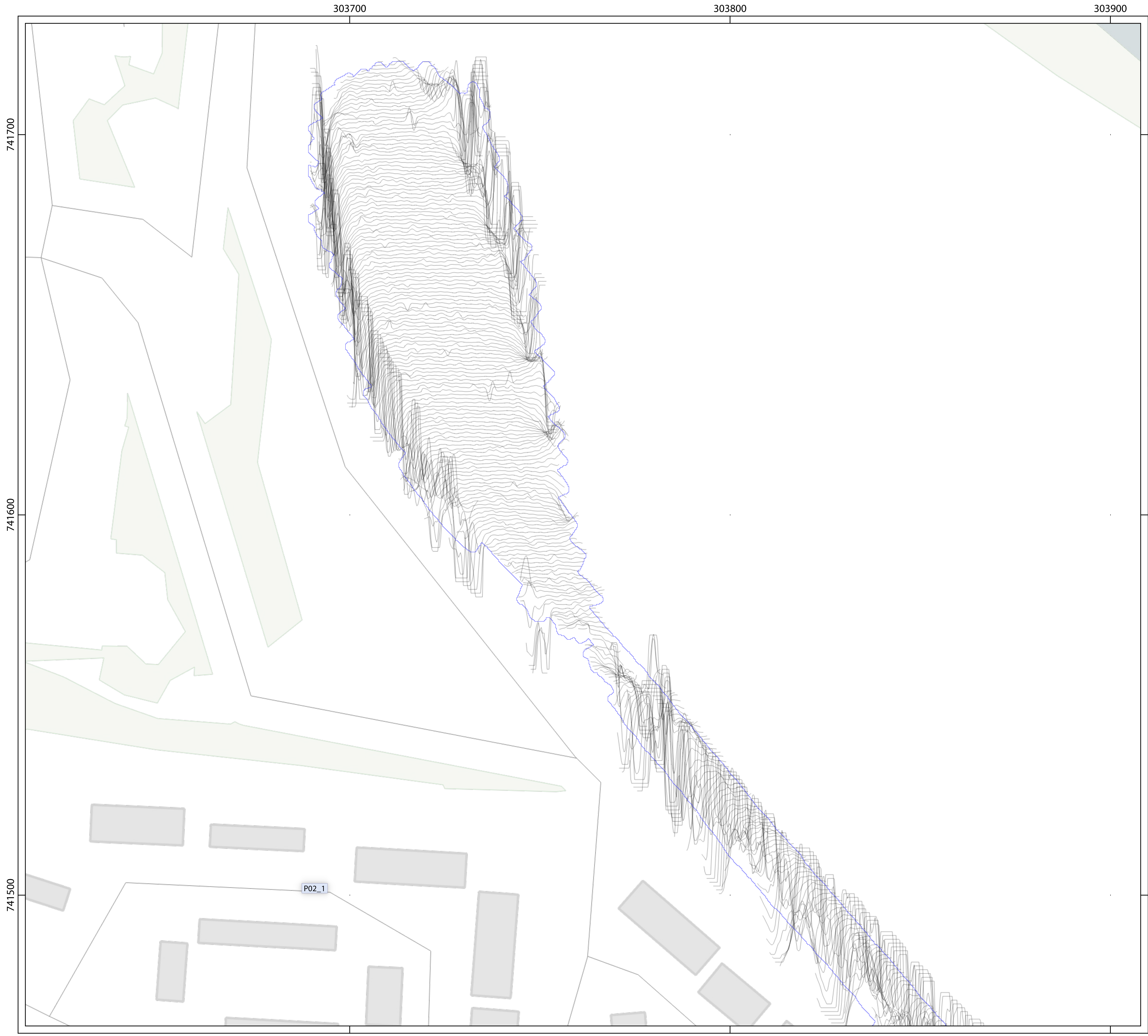
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

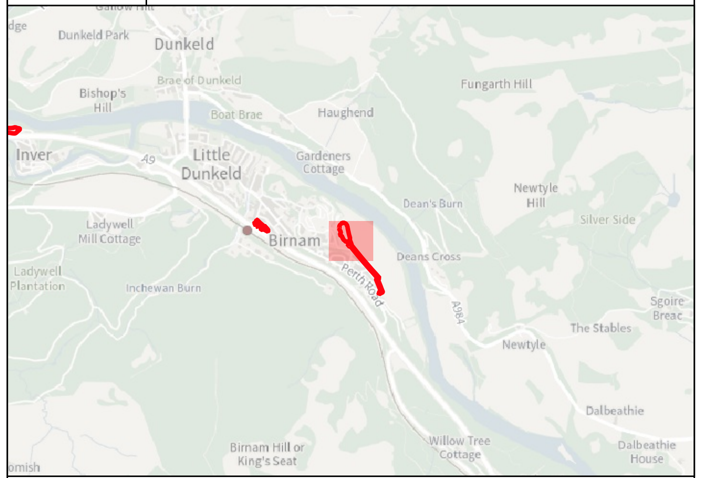
Illus - 15 Minimally processed greyscale magnetometer data; P02_1 North



N

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

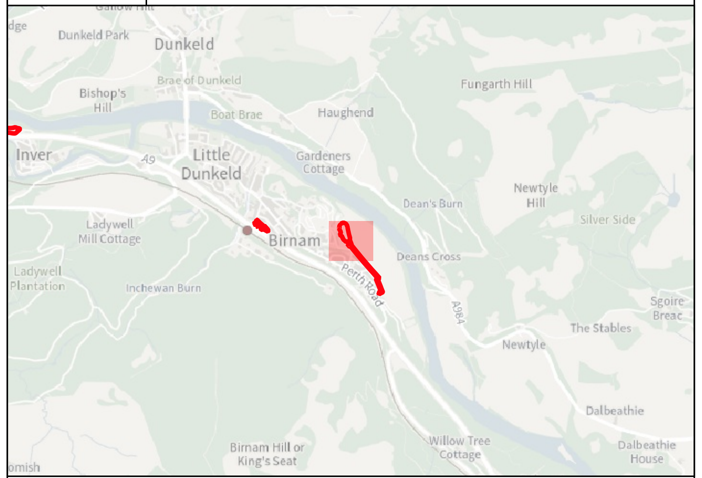
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 16 XY trace plot of minimally processed magnetometer data; P02_1 North



Key

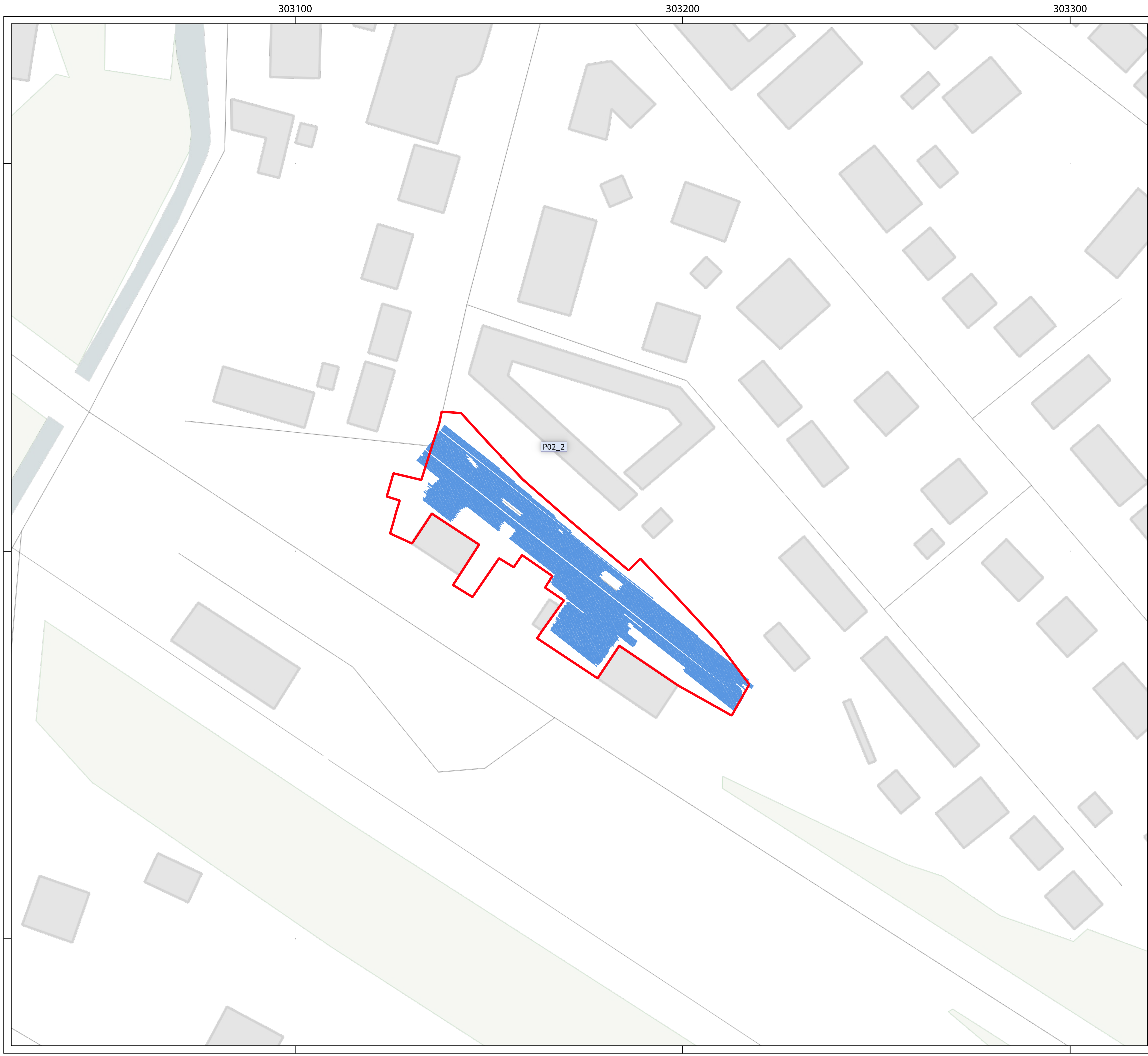
- Survey Extent
- Ferrous Objects
- Agriculture
- Service
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

	Abbreviation
SP	Service Pipe

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 17 Interpretation of magnetometer data; P02_1 North



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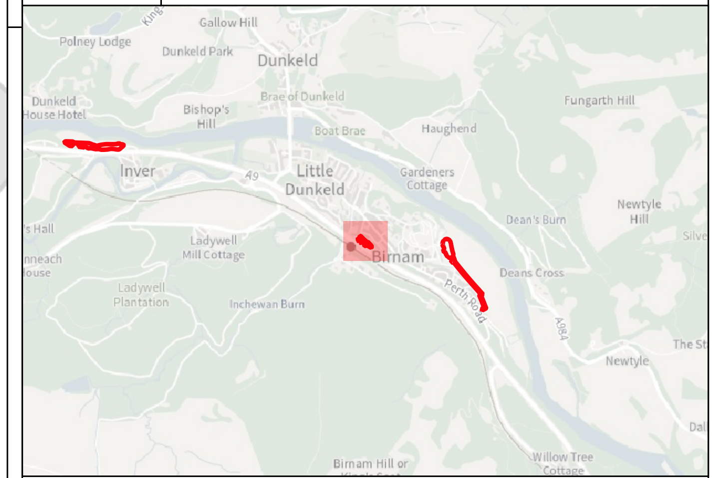
A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Geophysical Survey Area
- Survey Extent
- GPR Profile Locations

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus 18 - GPR Profile Locations

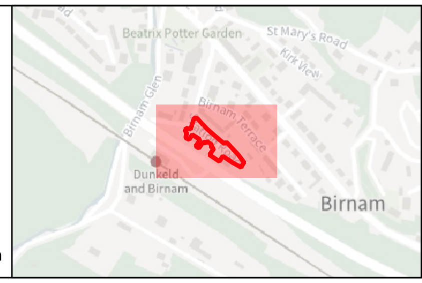
Key

Geophysical Survey Area

High Amplitude

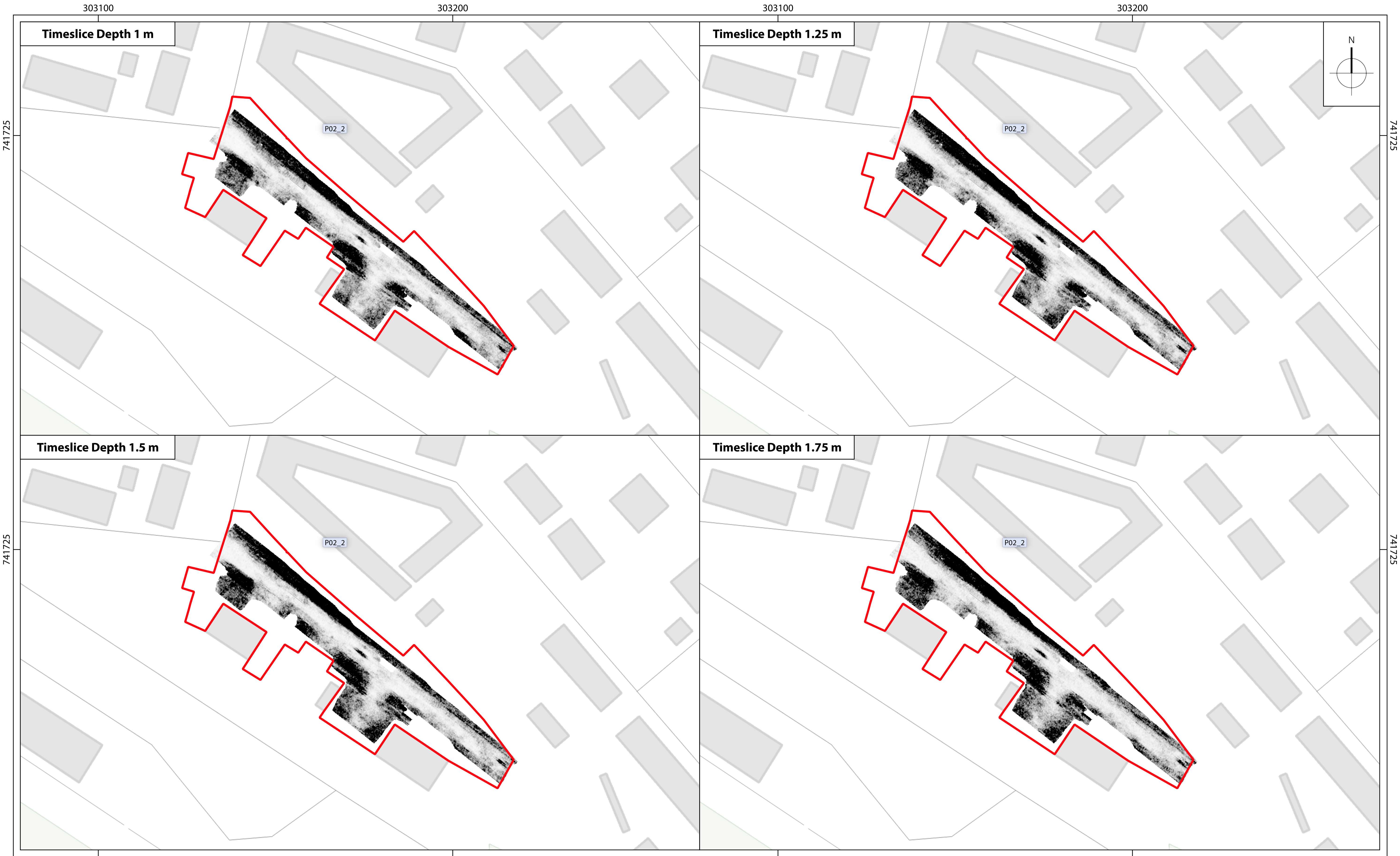
Low Amplitude

0 15 30 m



Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 19 GPR Timeslices 450MHz Antenna; P02_2; Timeslice 0m - 0.75m



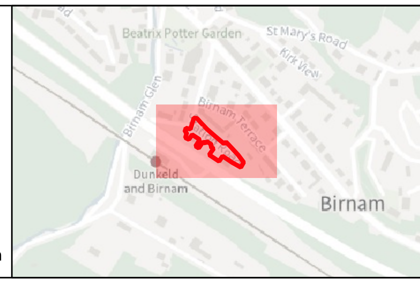
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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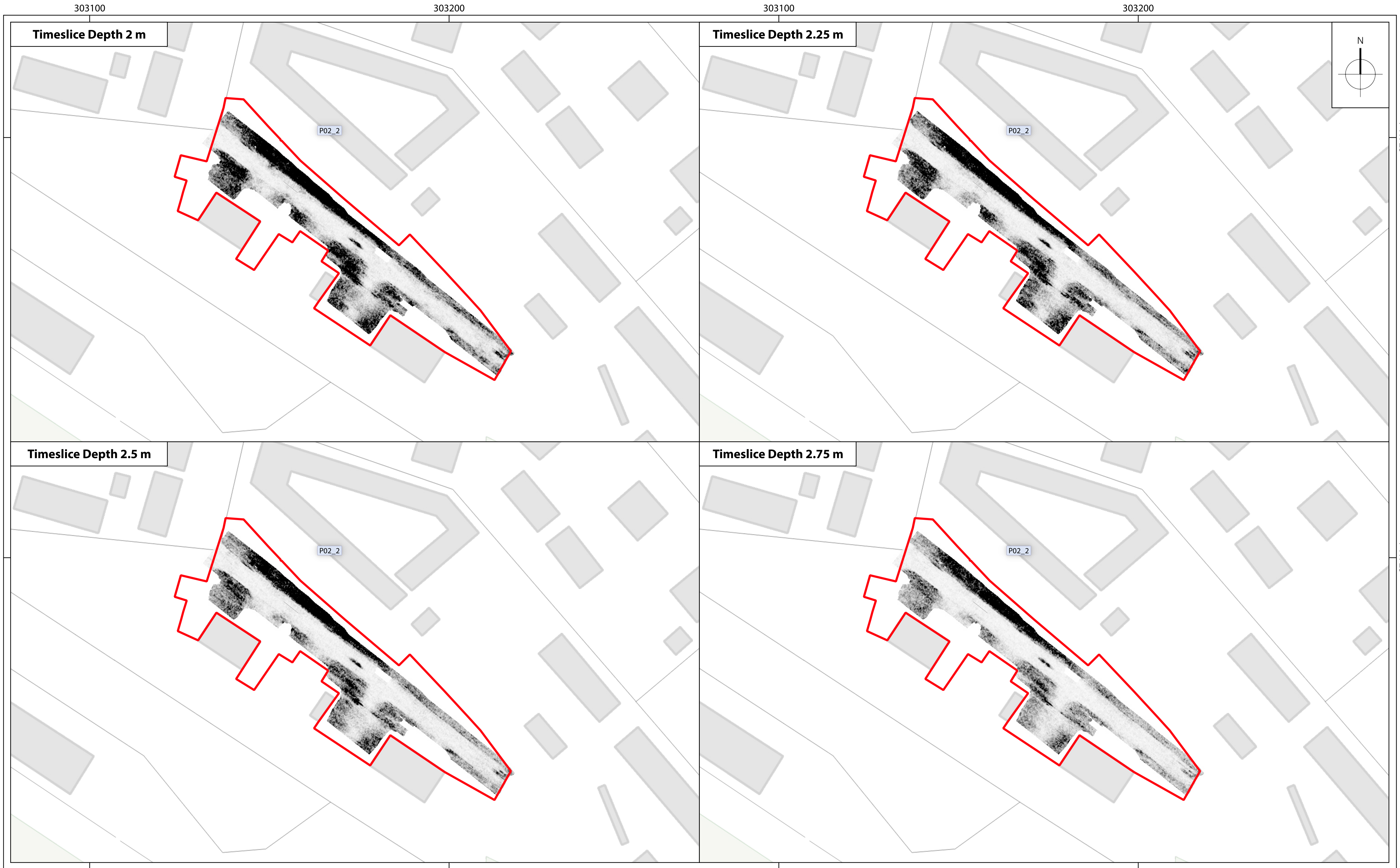
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 20 GPR Timeslices 450MHz Antenna; P02_2; Timeslice 1m - 1.75m



A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company

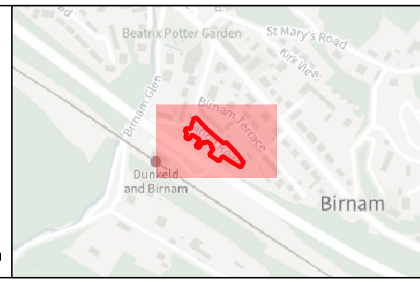
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 21 GPR Timeslices 450MHz Antenna; P02_2; Timeslice 2m - 2.75m

303100 303200 303100 303200

741725 741725 741725 741725

DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

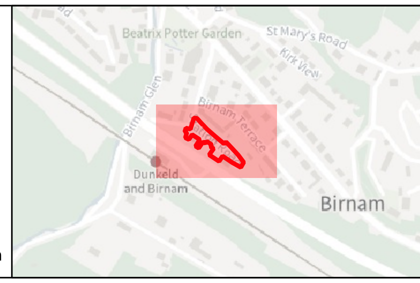
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 22 GPR Timeslices 450MHz Antenna; P02_2; Timeslice 3m - 3.75m

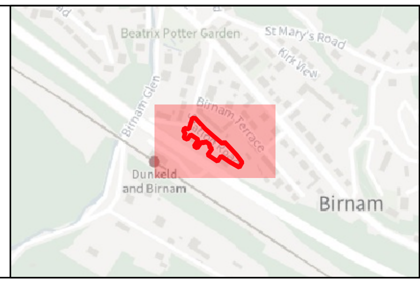
A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company

Key

Geophysical Survey Area
Positive Reflection - Drain/Service
Positive Reflection - Service Cover
Positive Reflection - Uncertain Buried Obstruction/Disturbance
Positive Reflection - Modern Buried Obstruction/Disturbance

0 15 30 m



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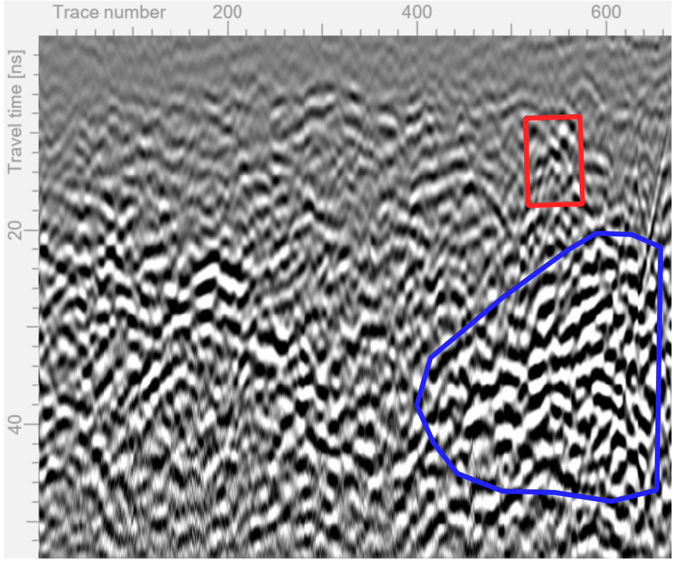
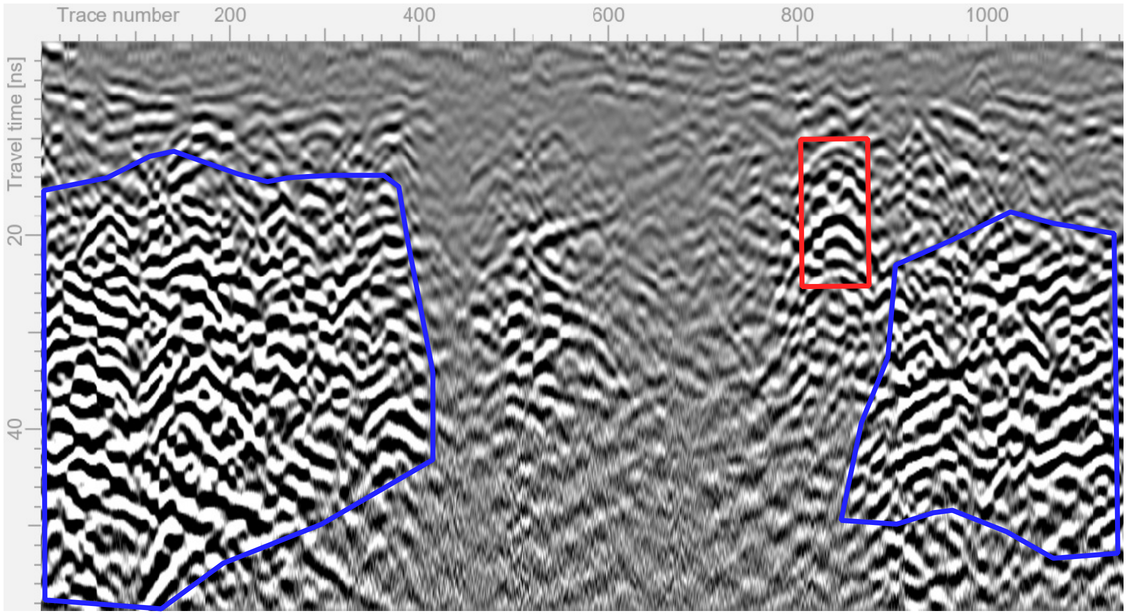
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 23 GPR Interpretation of Selected Timeslices; P02_2

7153



7214



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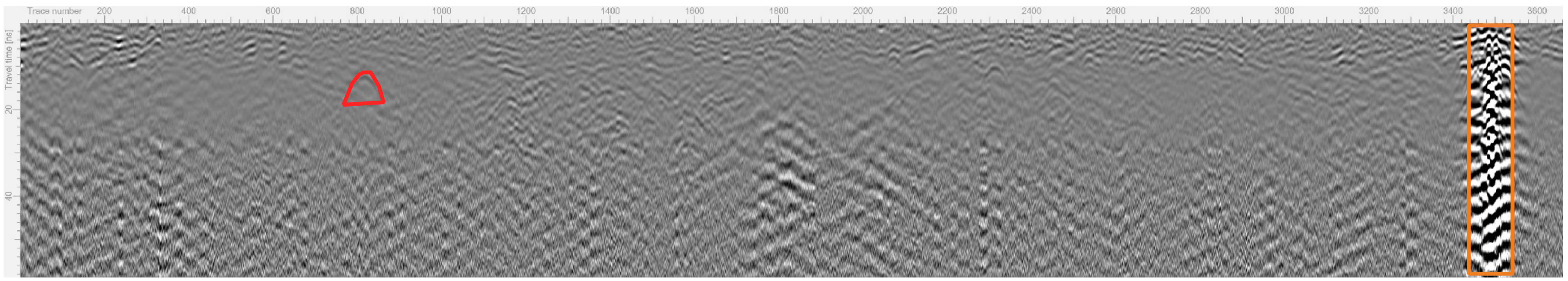
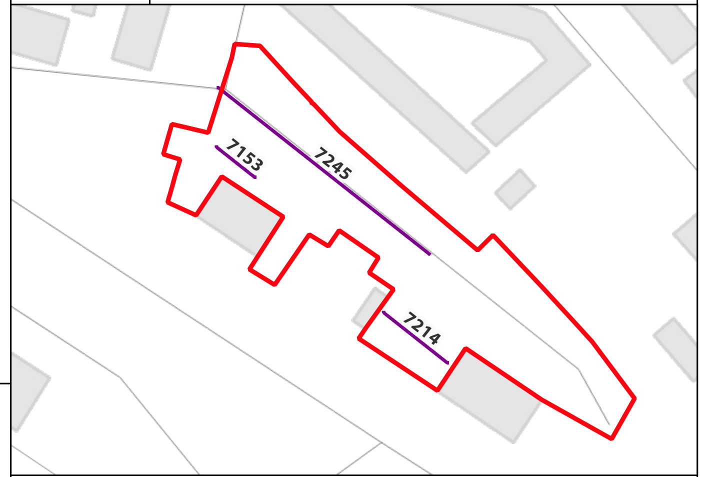


N

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

- High amplitude, discontinuous, disturbed reflectors - Rubble or disturbance
- Ringing - Surface anomaly such as service cover
- Discrete High Amplitude Reflector

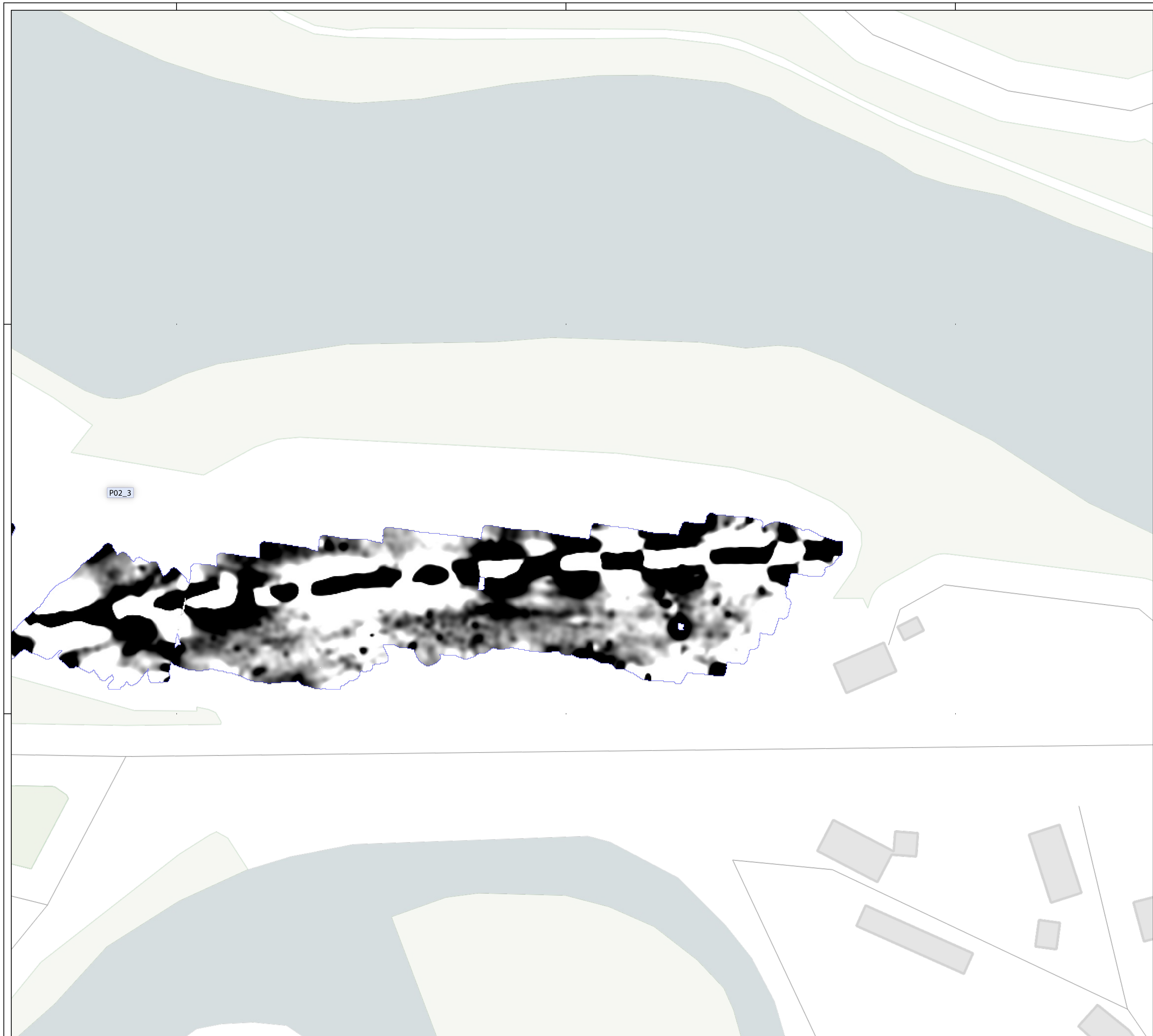
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	@ A3

Illus - 24 Selected radargrams with interpretation

301400 301500 301600

742400

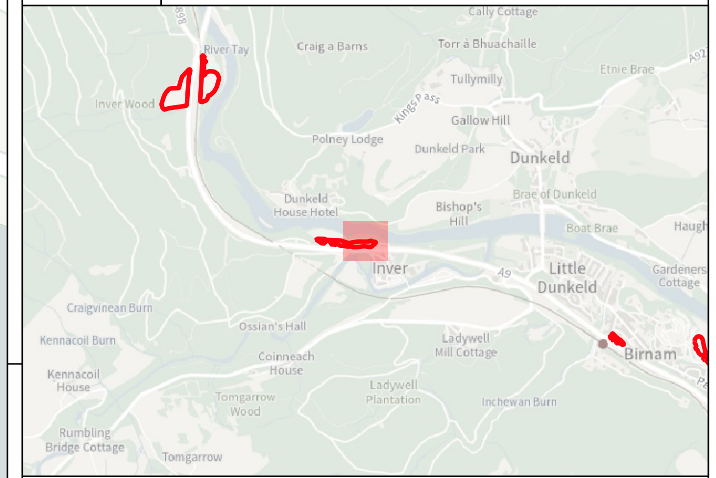
742300



N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company



Key

Survey Extent

+2nT

-1nT

0 20 40 m

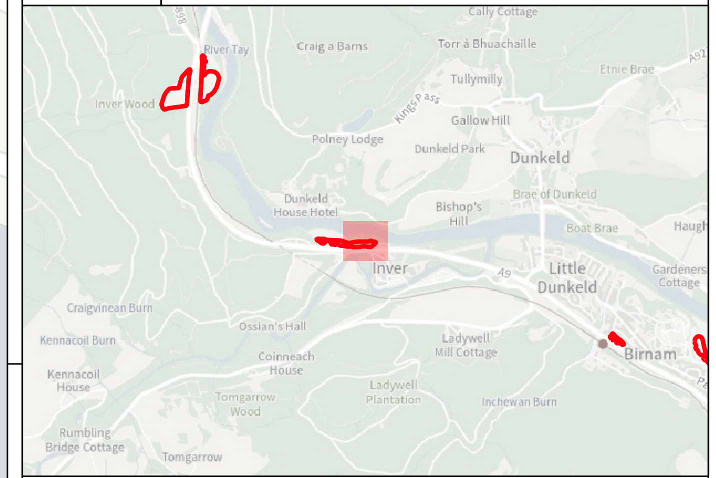
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 25 Processed greyscale magnetometer data; P02_3 East

N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company



Key

Survey Extent

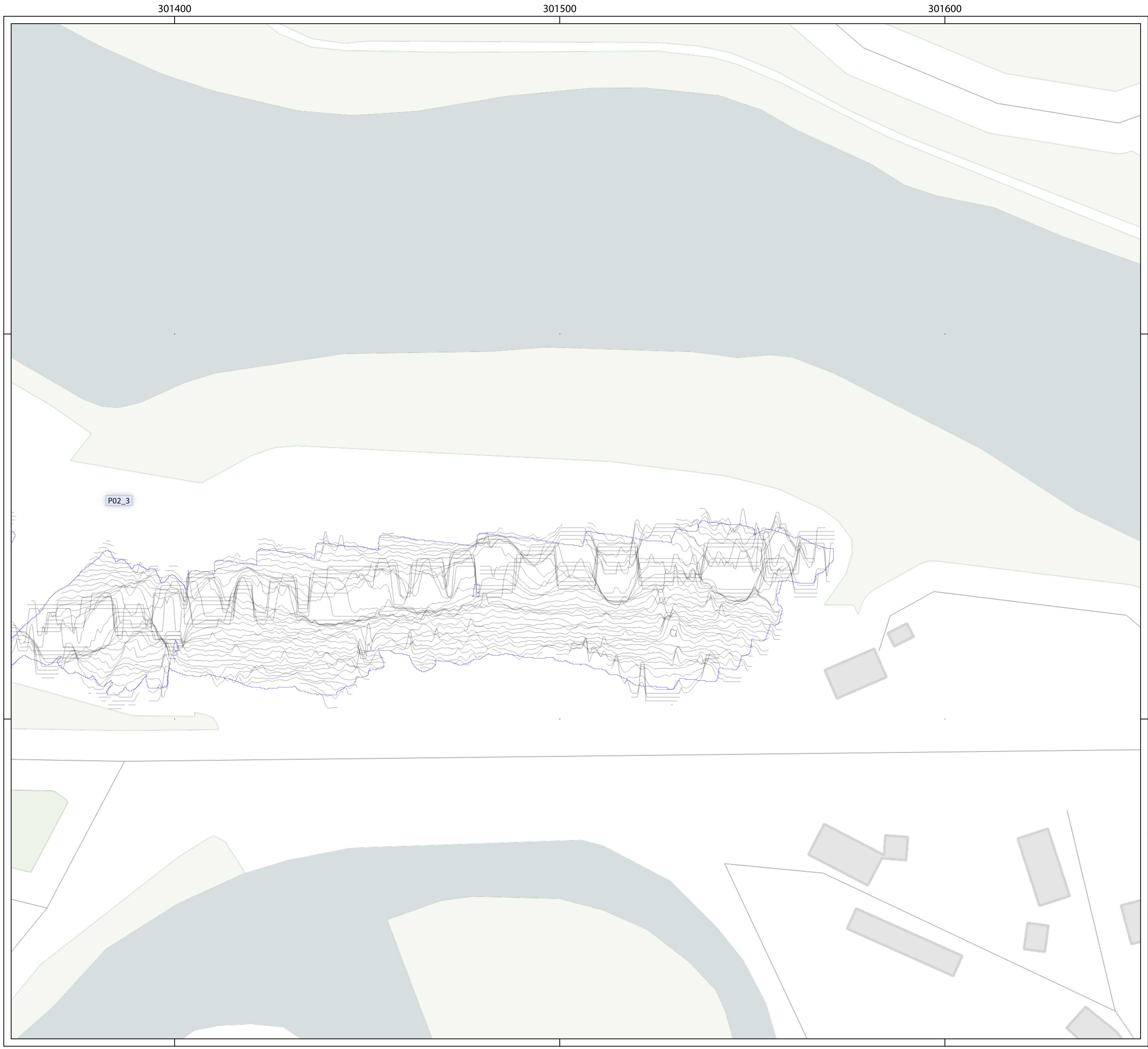
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

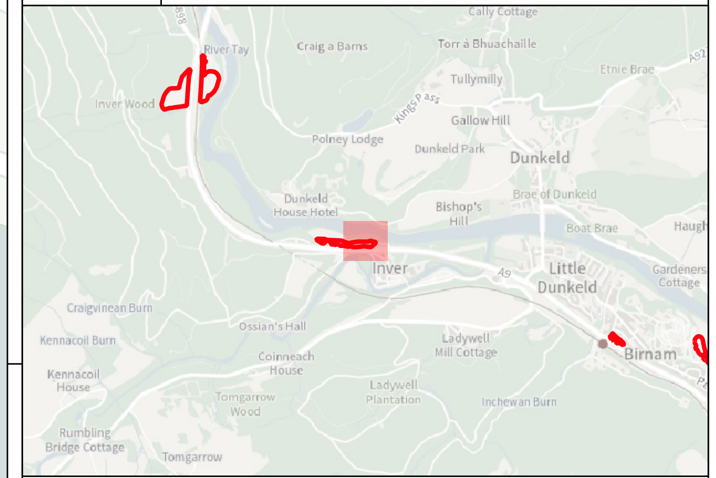
Illus - 26 Minimally processed greyscale magnetometer data; P02_3 East



N

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

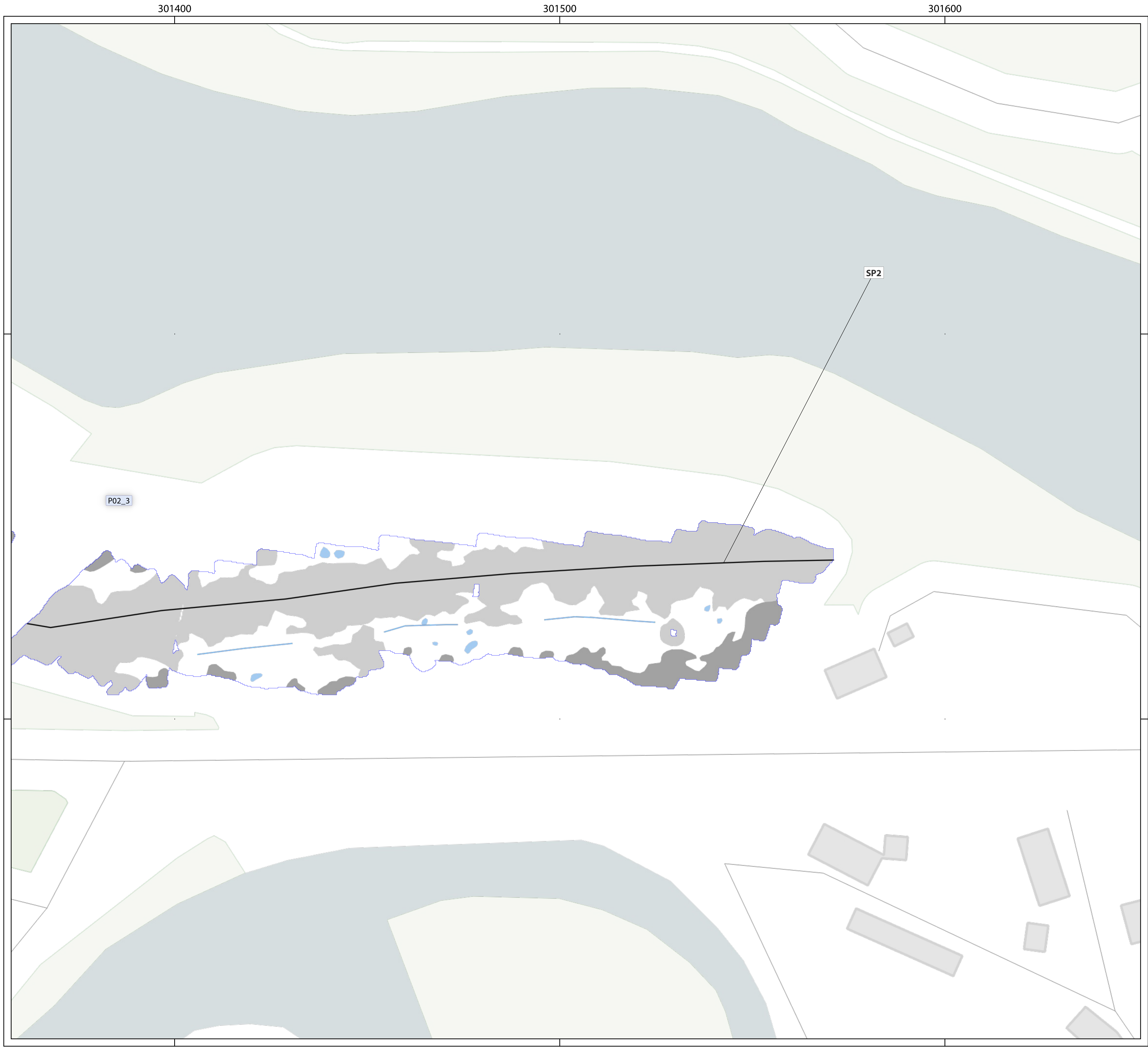
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

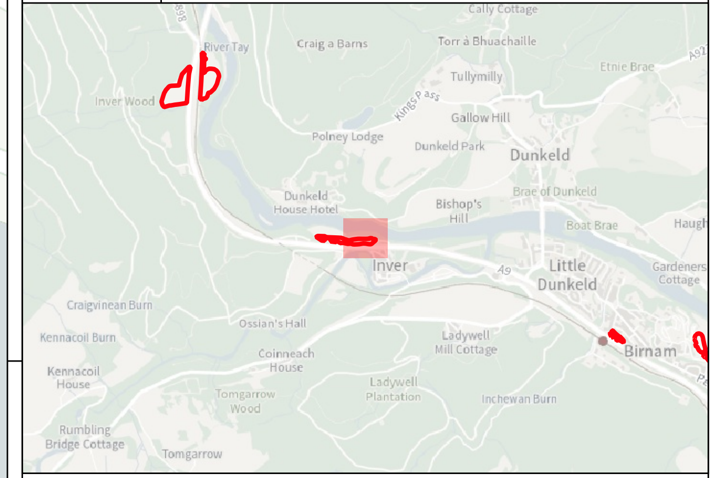
Illus - 27 XY trace plot of minimally processed magnetometer data; P02_3 East



N

DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- Natural
- Service
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

Abbreviation	
SP	Service Pipe

0 20 40 m

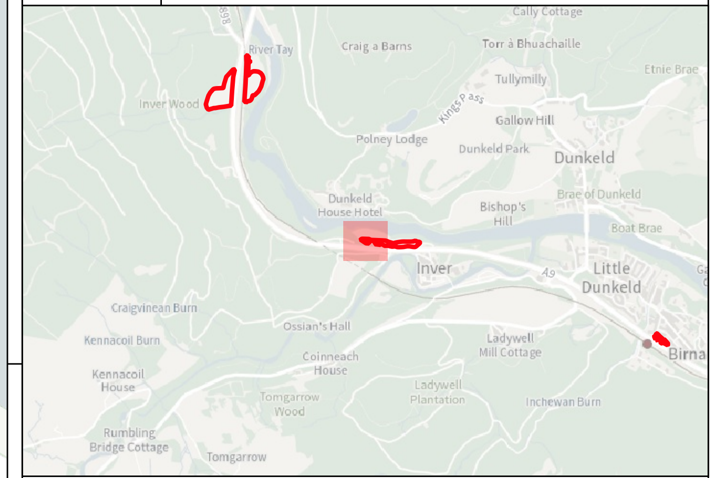
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 28 Interpretation of magnetometer data; P02_3 East

N

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company



Key

Survey Extent

+2nT

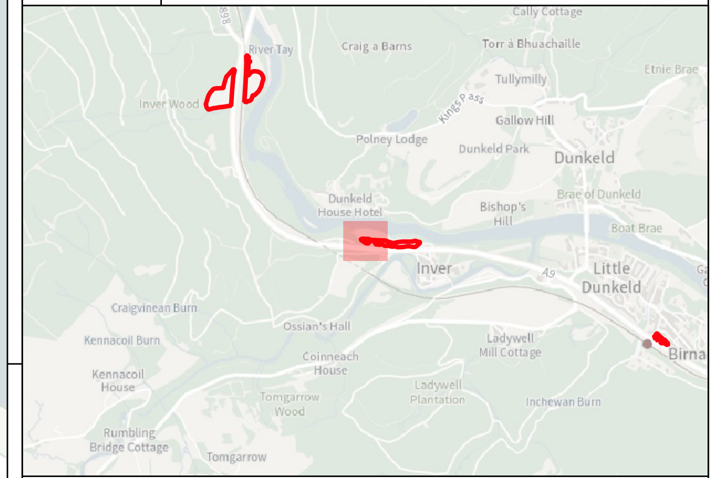
-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 29 Processed greyscale magnetometer data; P02_3 West

N



A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

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Key

Survey Extent

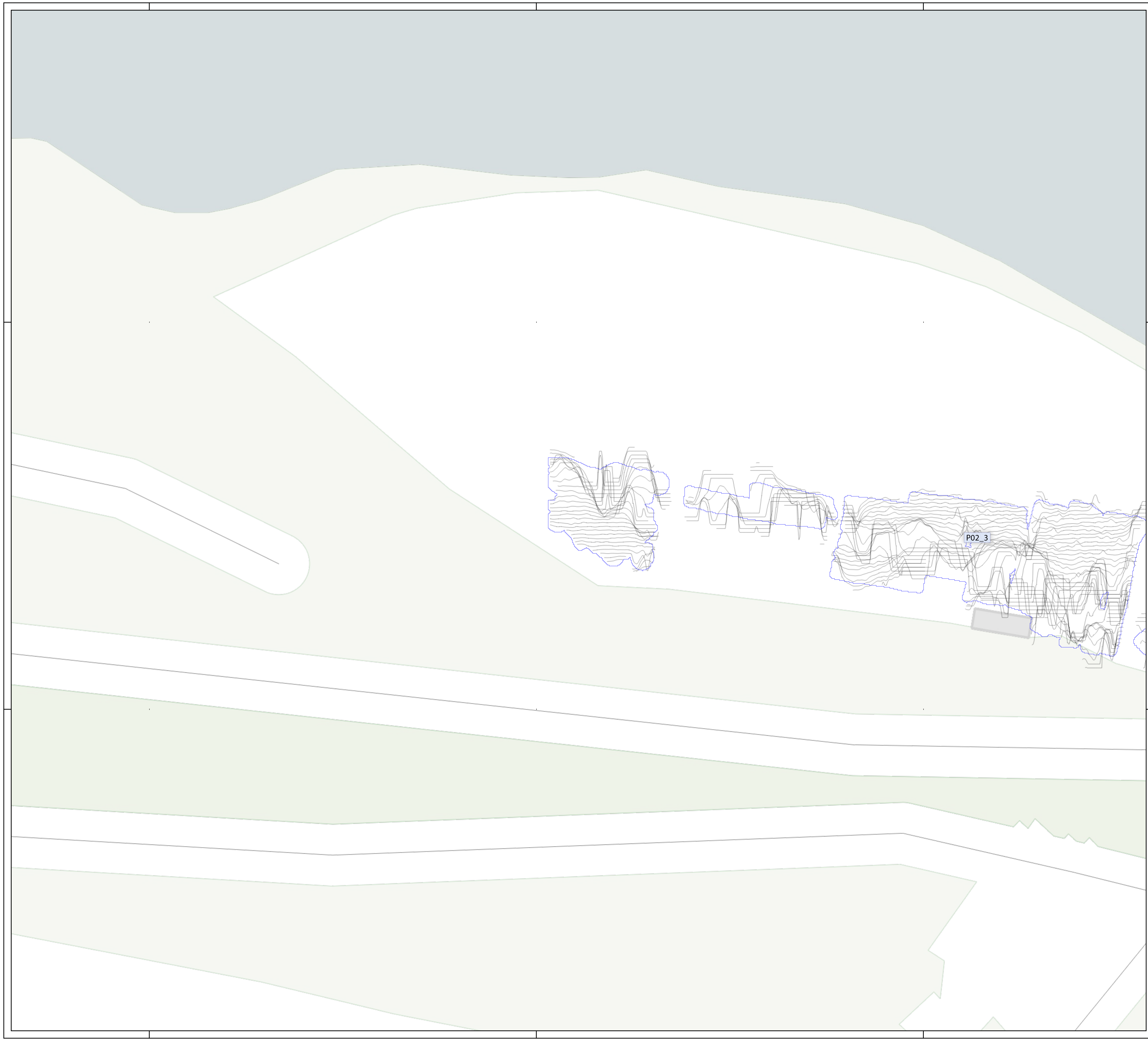
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 30 Minimally processed greyscale magnetometer data; P02_3 West



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A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

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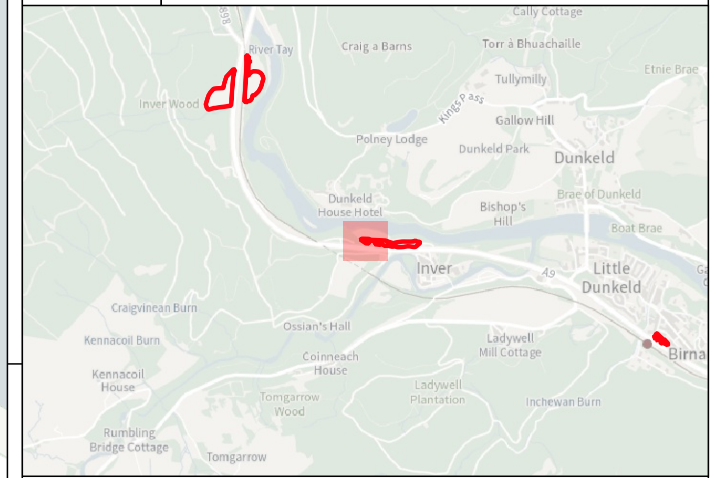


Key

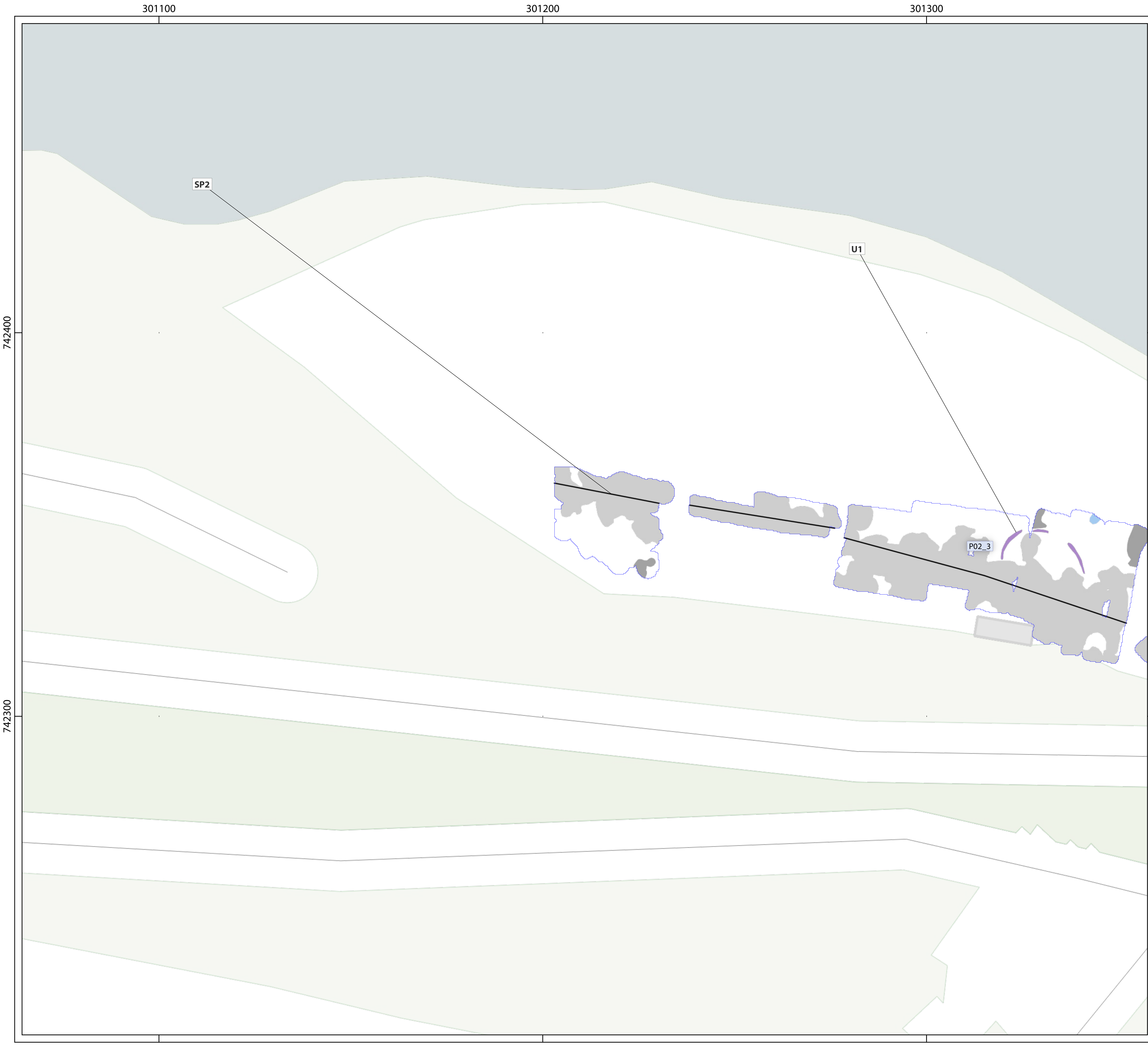
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 31 XY trace plot of minimally processed magnetometer data; P02_3 West



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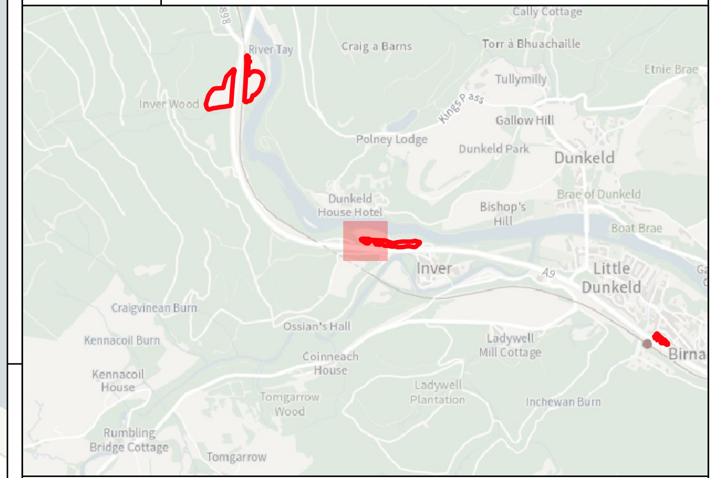


Key

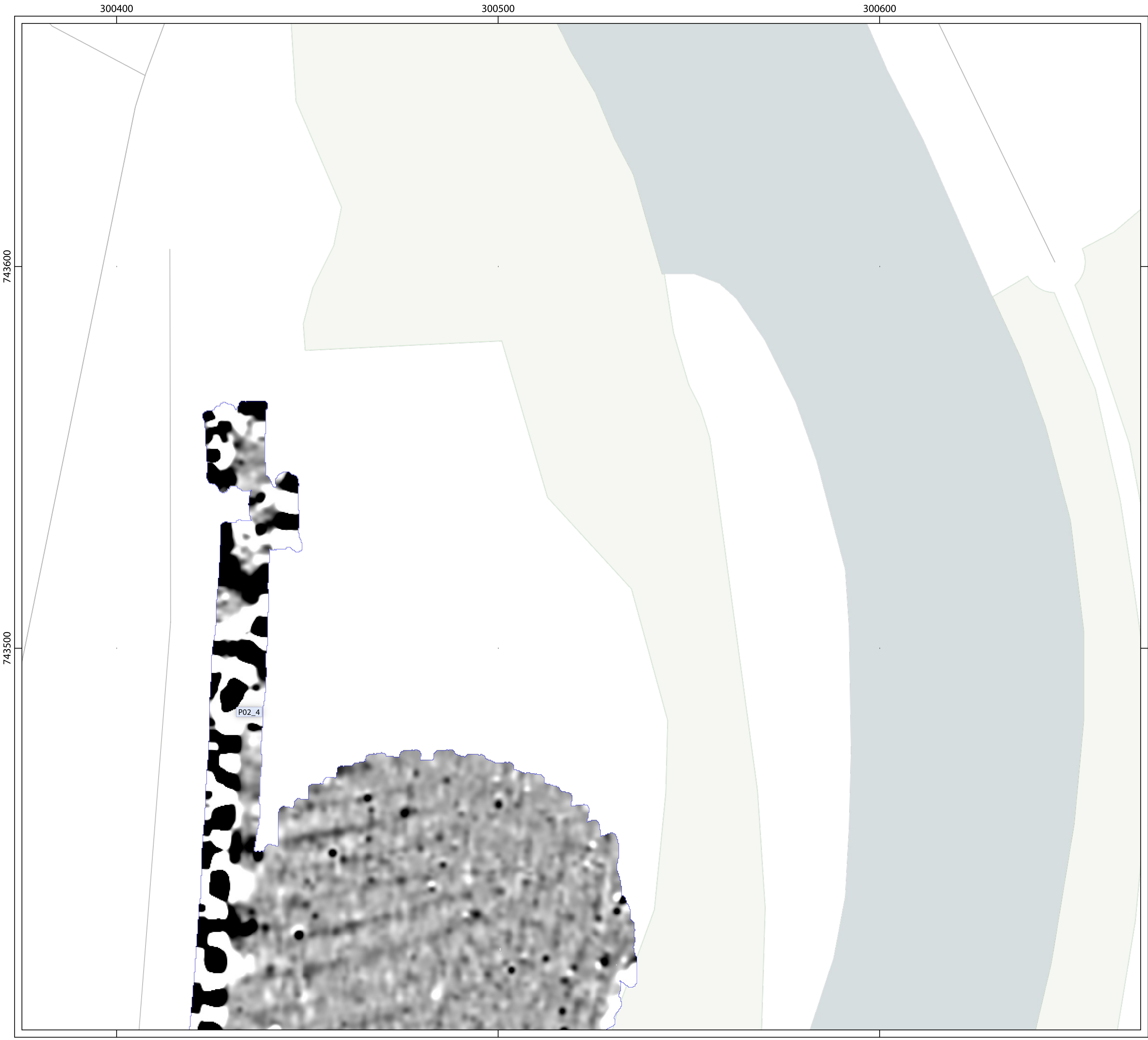
- Survey Extent
- Service
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural
- Uncertain

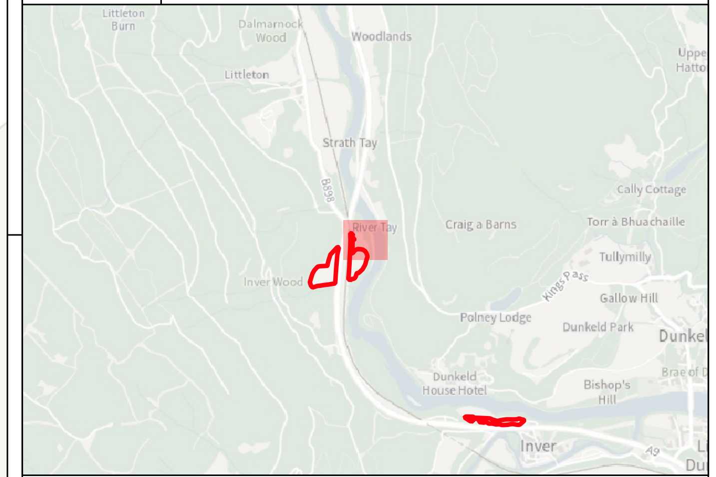
	Abbreviation
SP	Service Pipe
U	Uncertain

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 32 Interpretation of magnetometer data; P02_3 West





Key

Survey Extent

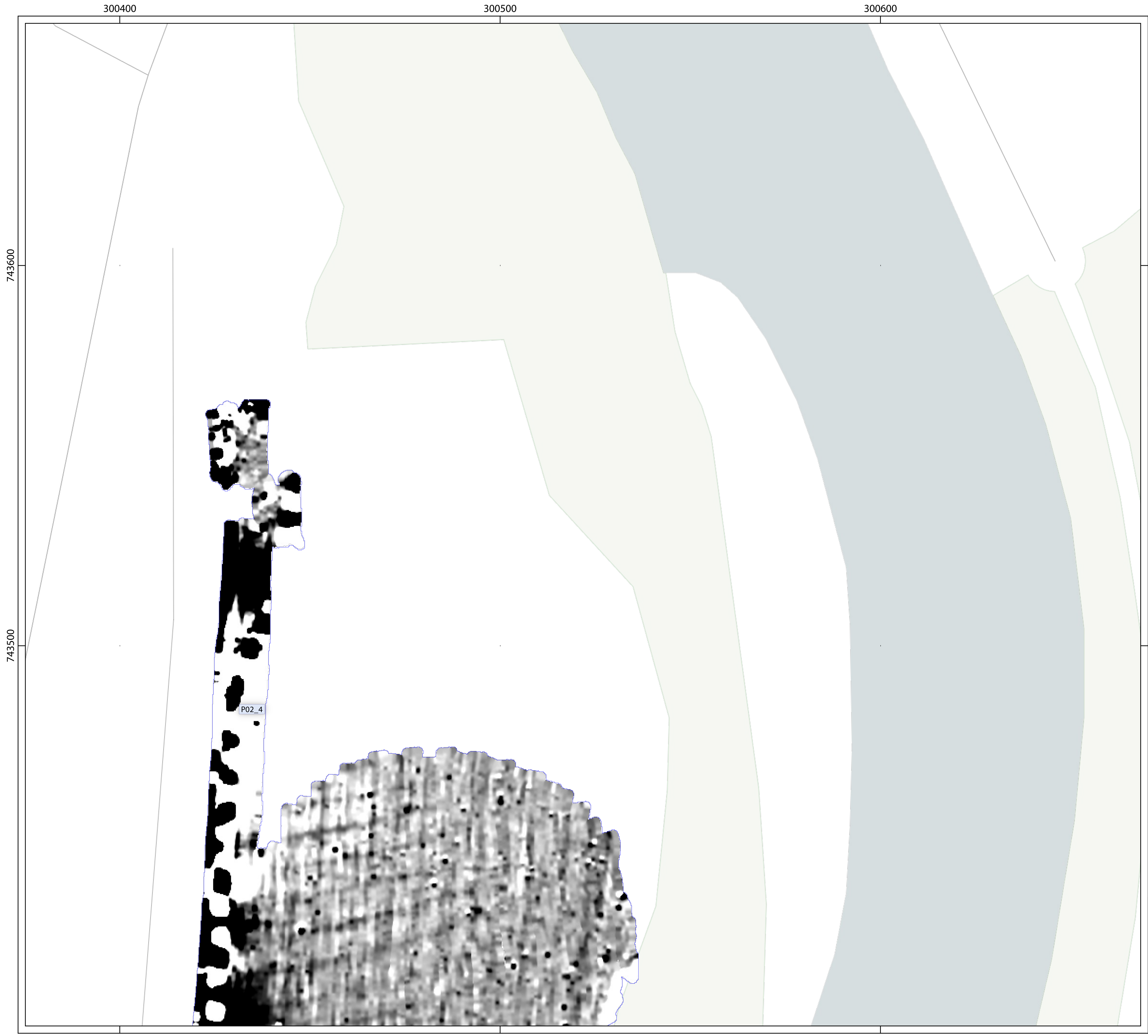
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 33 Processed greyscale magnetometer data; P02_4 North



N

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PASS OF BIRNAM TO TAY CROSSING

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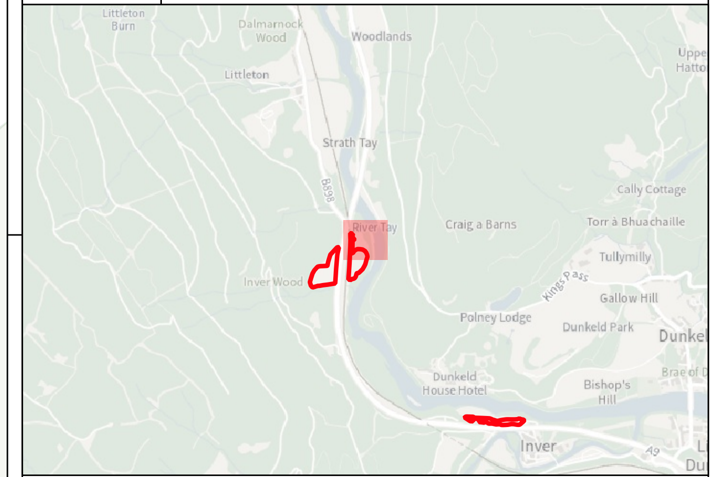


Key

Survey Extent

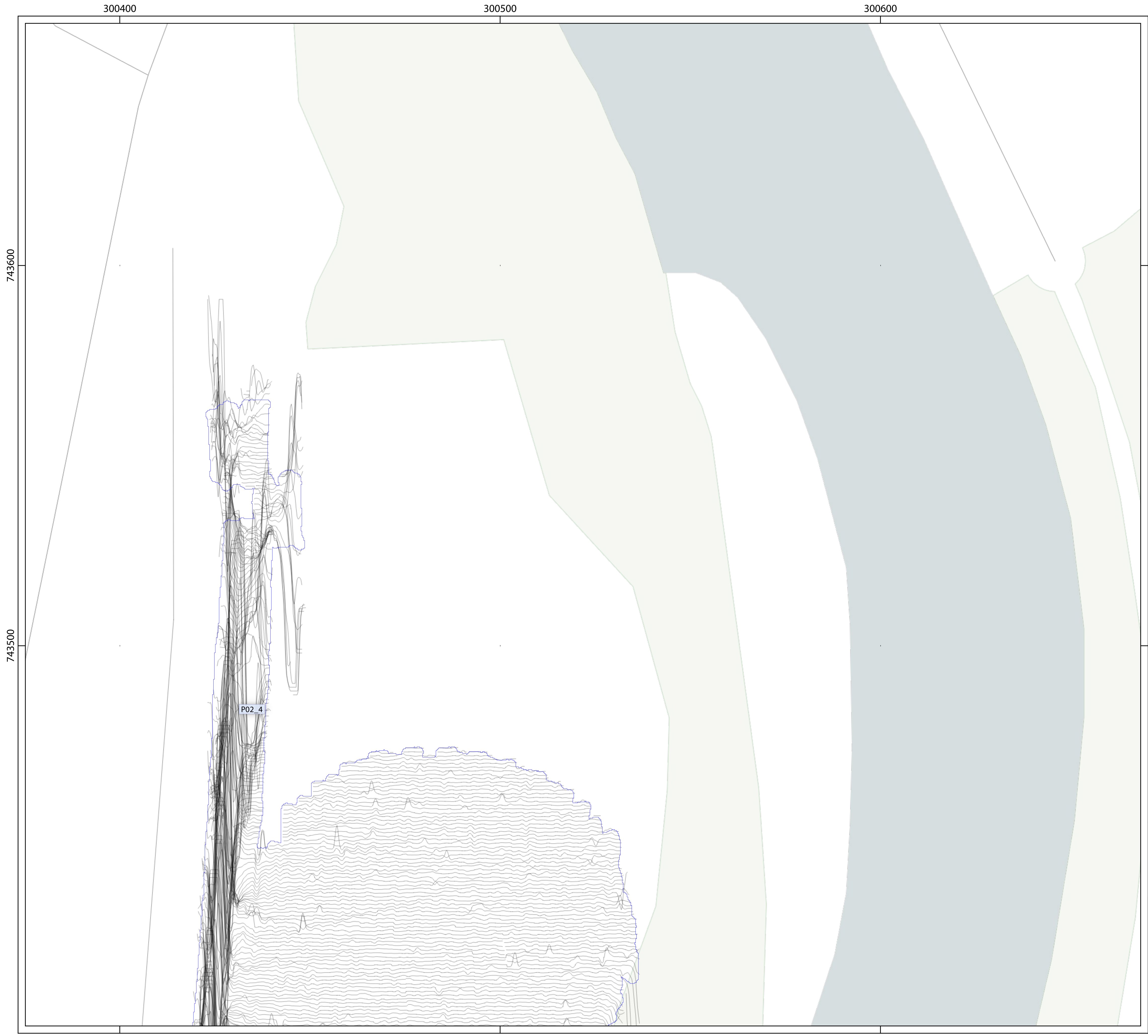
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 34 Minimally processed greyscale magnetometer data; P02_4 North



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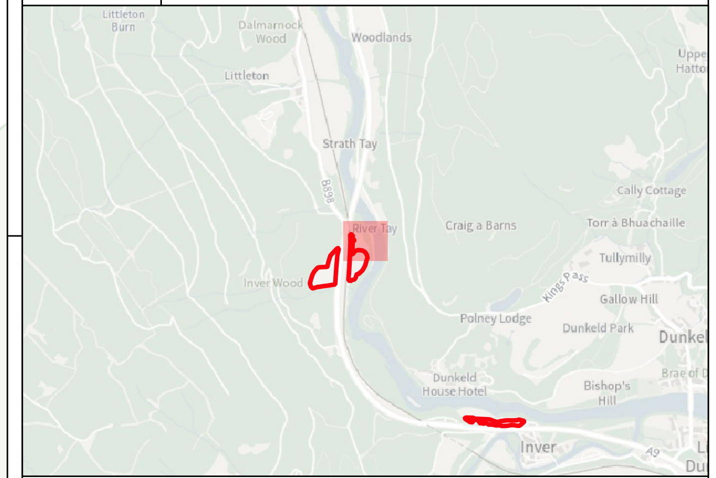


Key

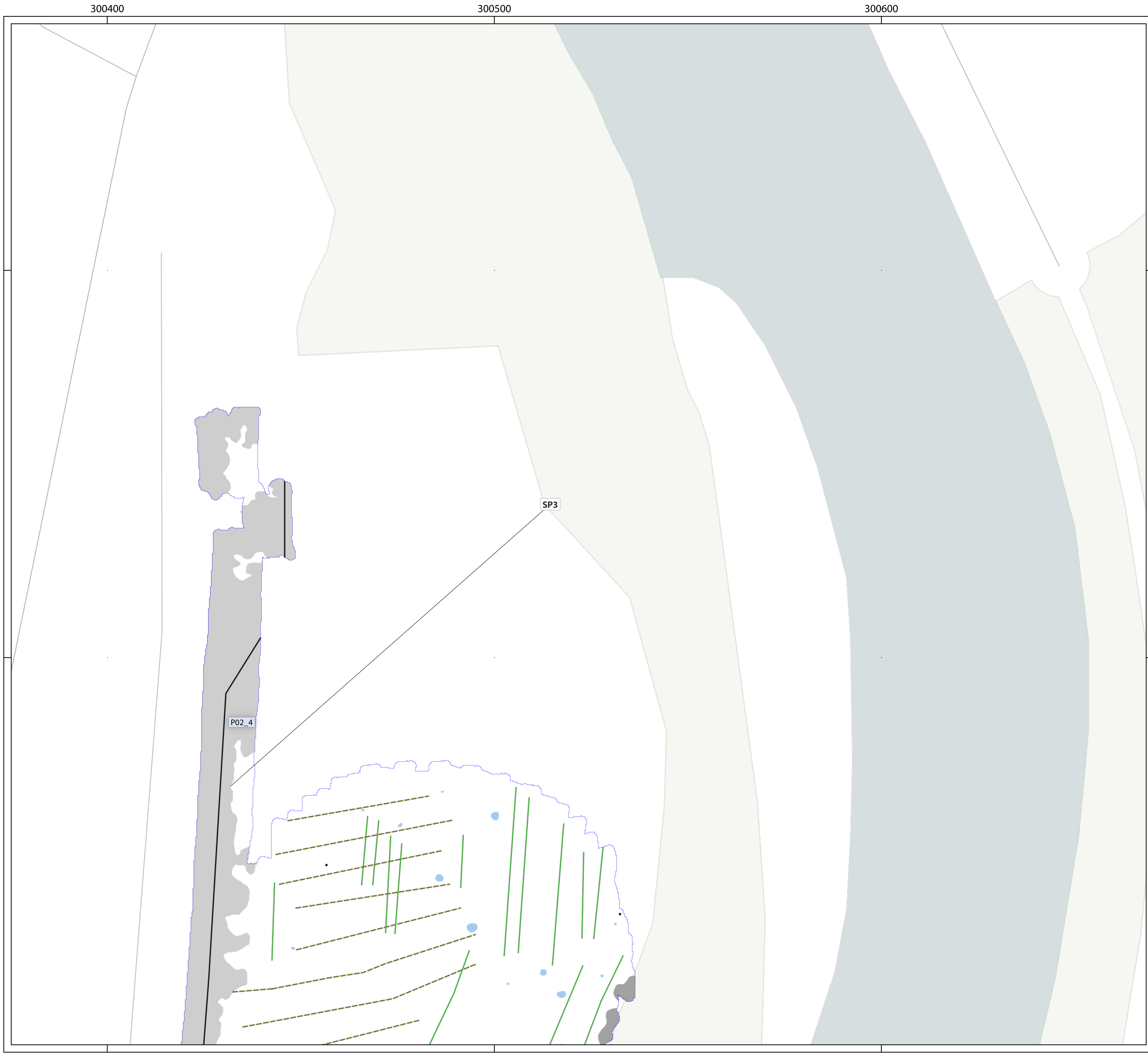
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 35 XY trace plot of minimally processed magnetometer data; P02_4 North



N

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HEADLAND ARCHAEOLOGY
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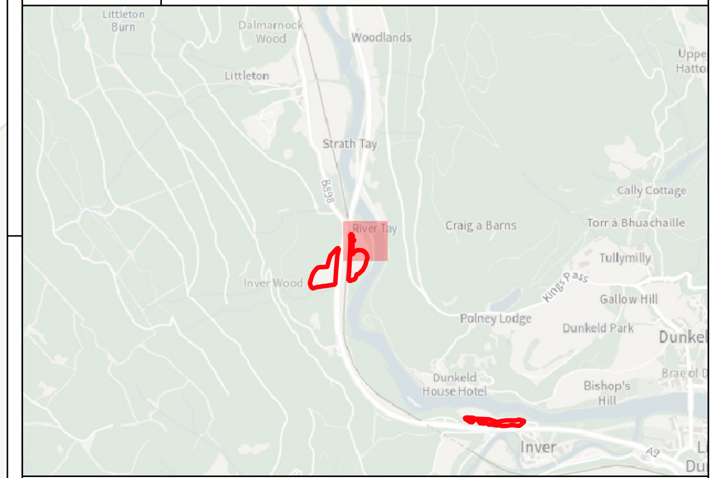


Key

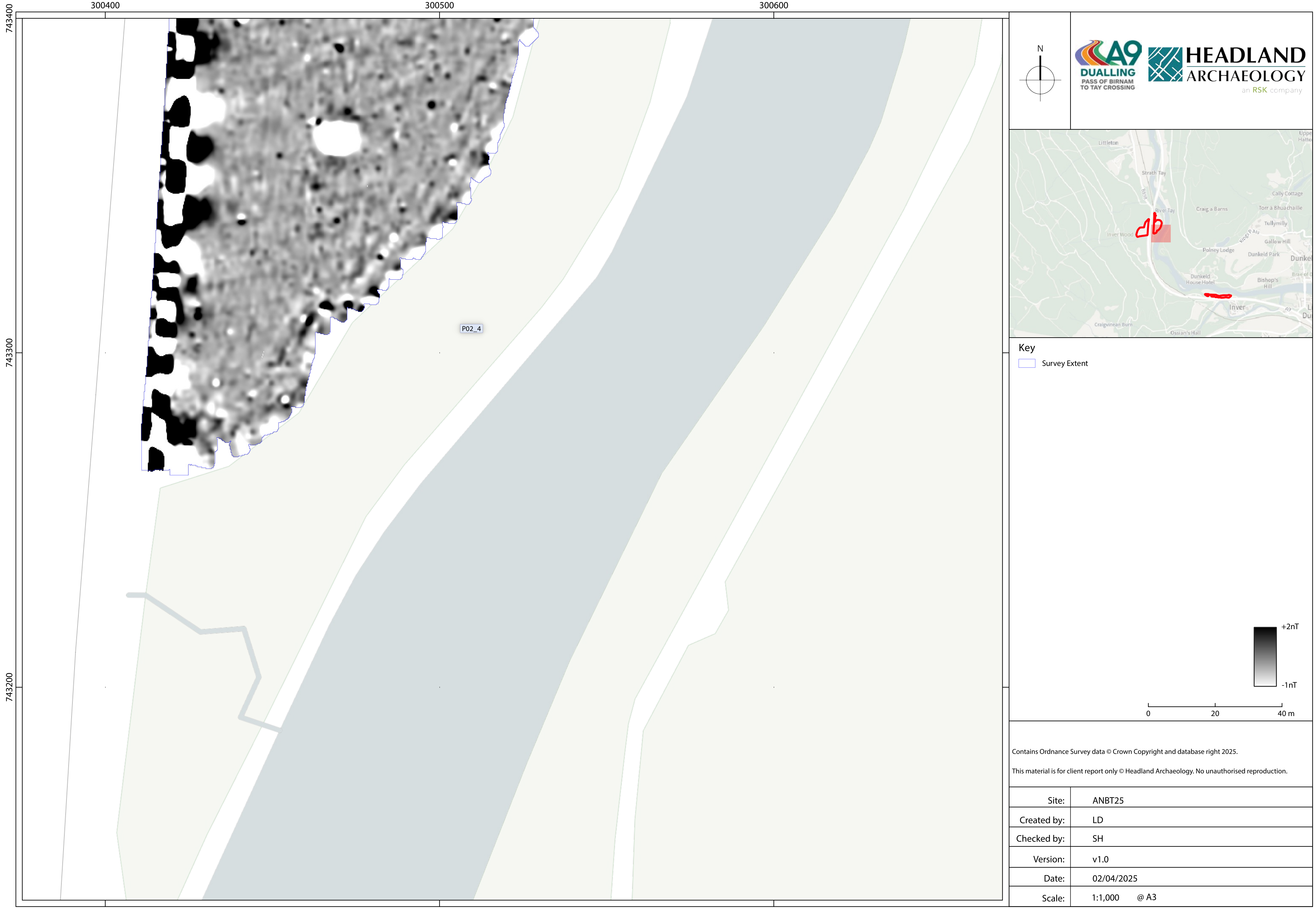
- Survey Extent
- Ferrous Objects
- Agriculture
- Service
- Ridge and Furrow
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

Abbreviation	
SP	Service Pipe

0 20 40 m

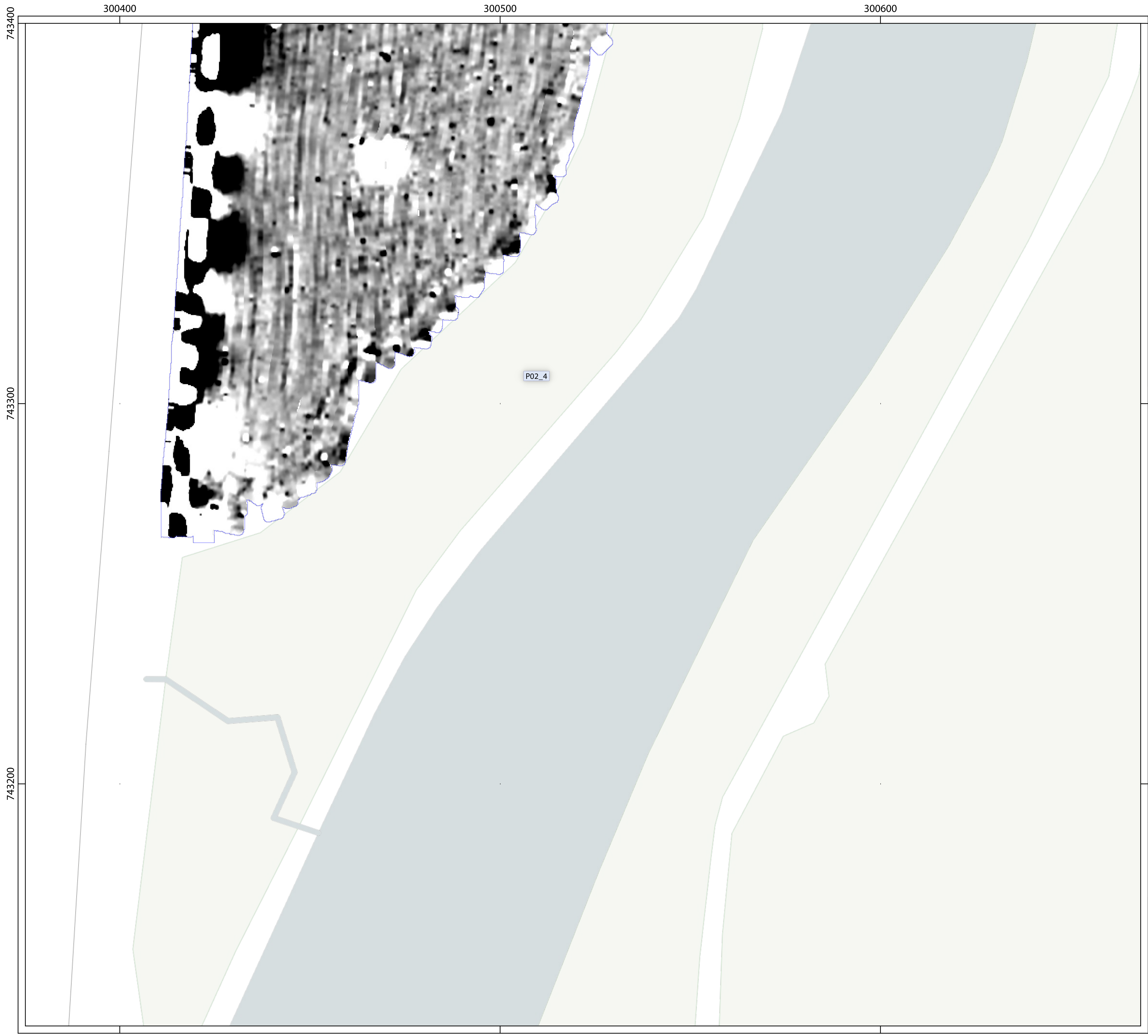
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 36 Interpretation of magnetometer data; P02_4 North



Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 37 Processed greyscale magnetometer data; P02_4 South



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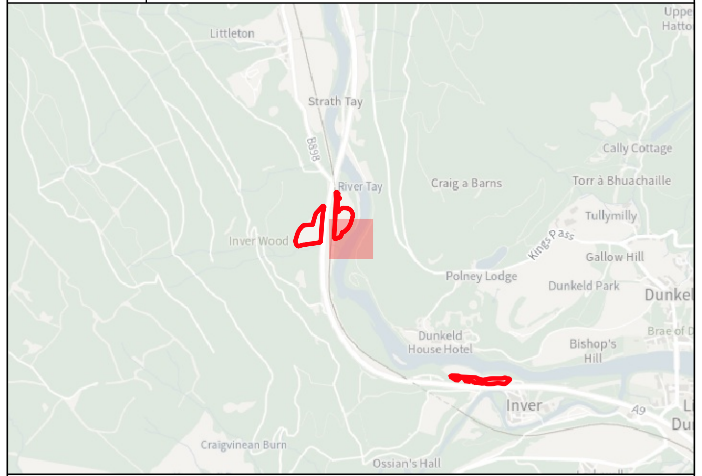


Key

Survey Extent

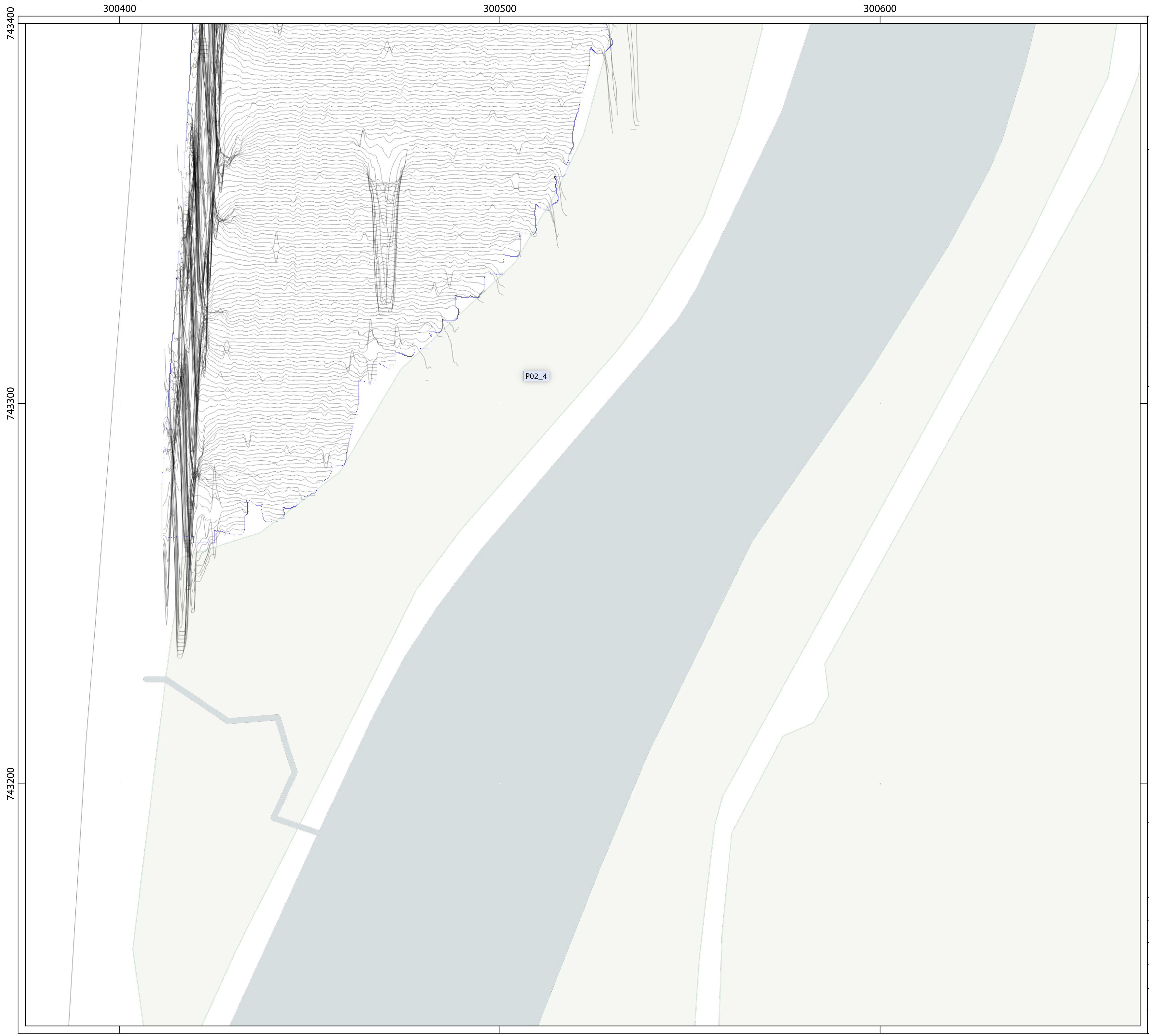
+2nT

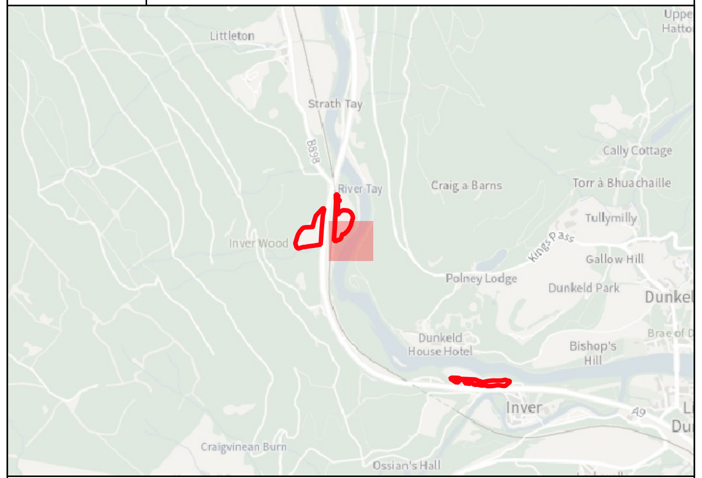
-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 38 Minimally processed greyscale magnetometer data; P02_4 South





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Key

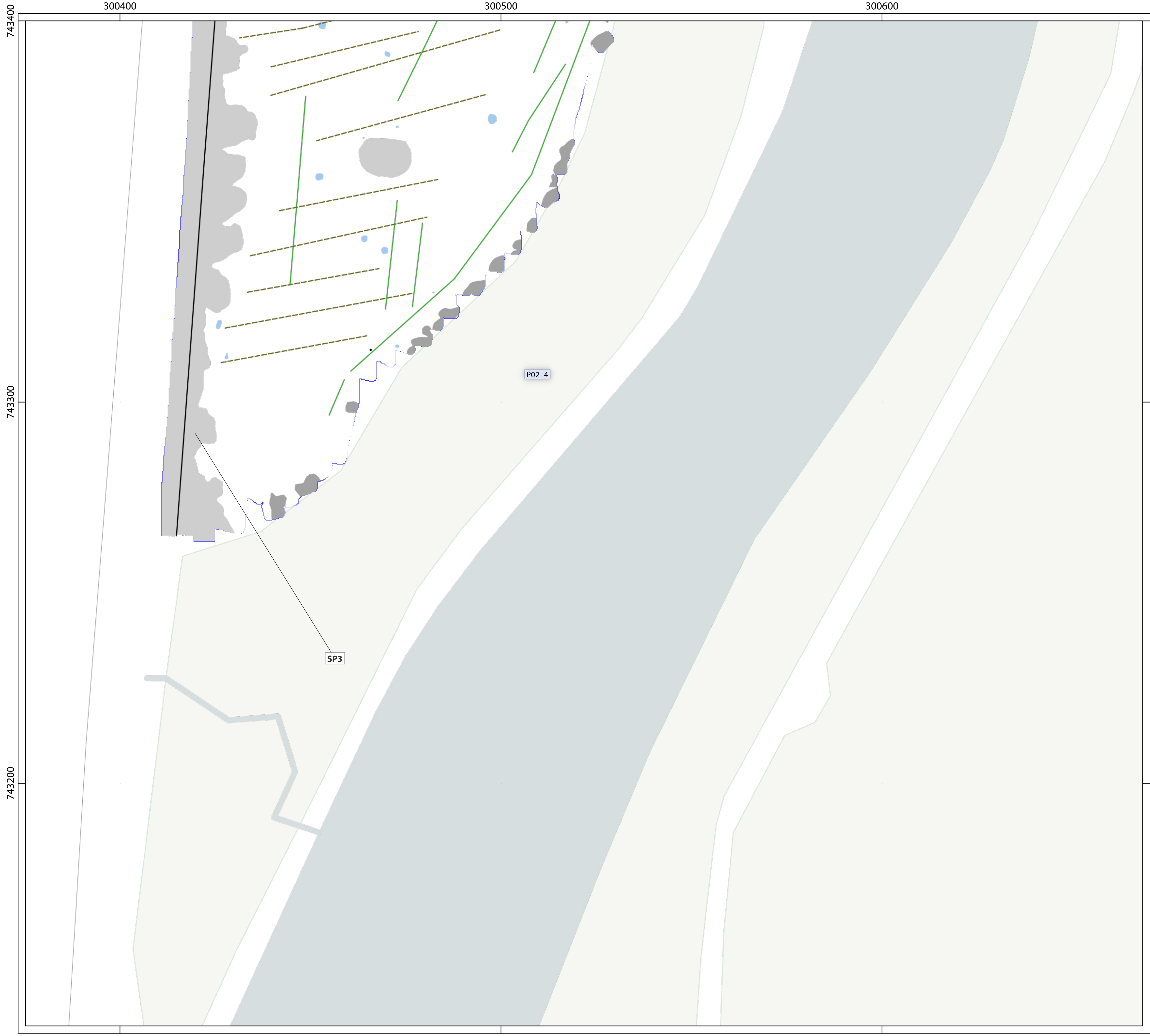
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 39 XY trace plot of minimally processed magnetometer data; P02_4 South



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PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
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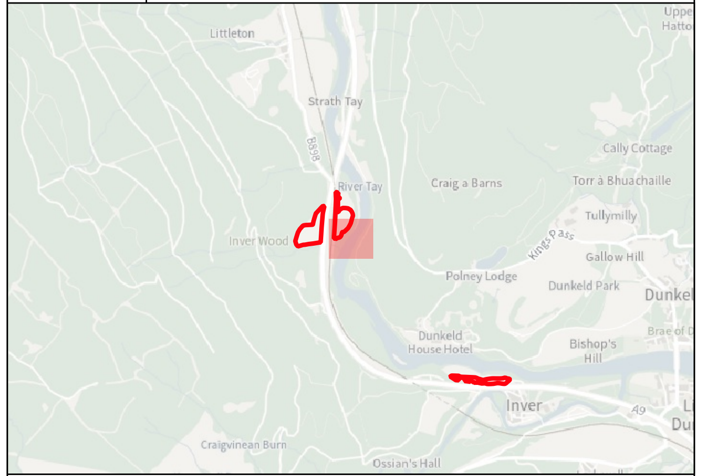


Key

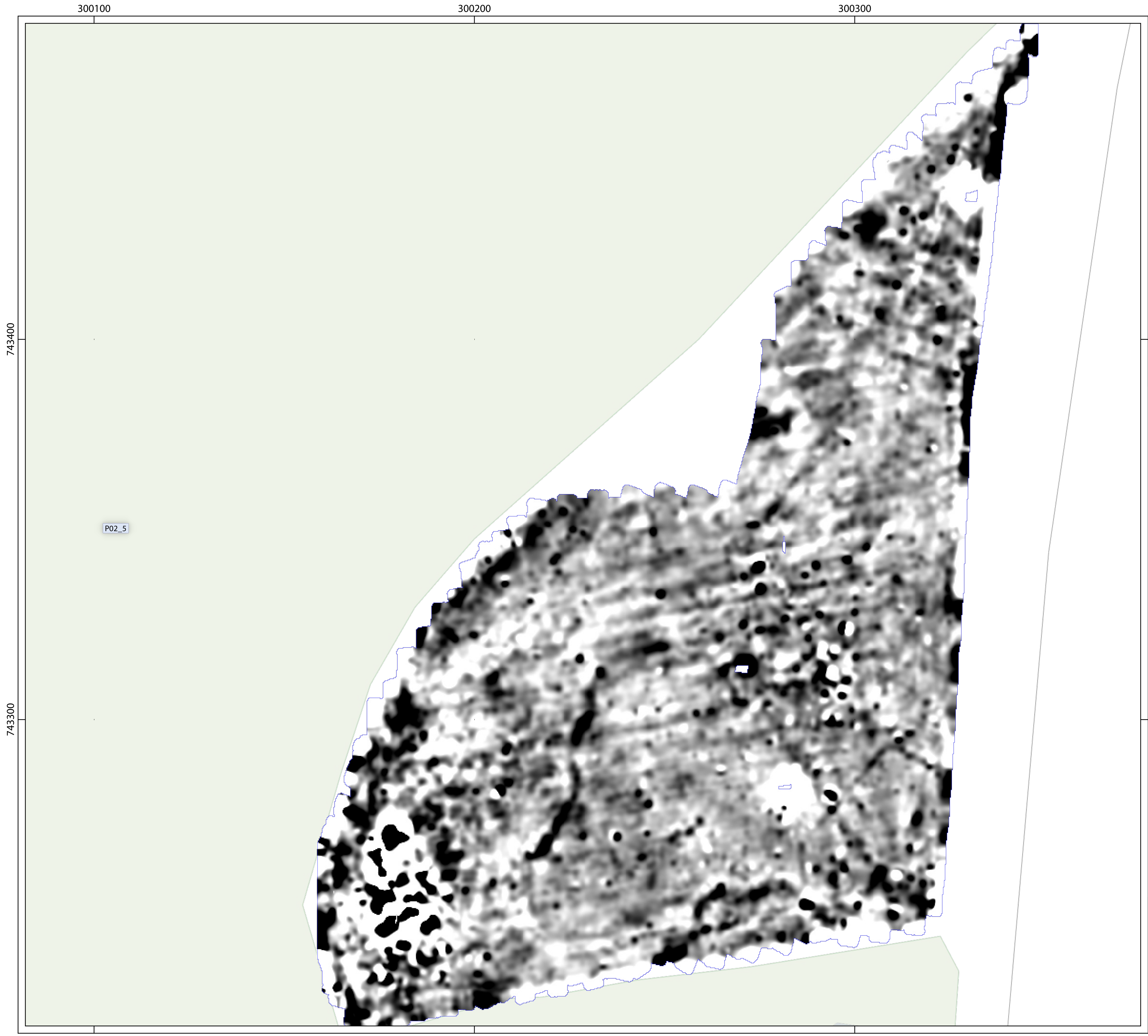
- Survey Extent
- Ferrous Objects
- Agriculture
- Service
- Ridge and Furrow
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

Abbreviation	
SP	Service Pipe

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 40 Interpretation of magnetometer data; P02_4 South



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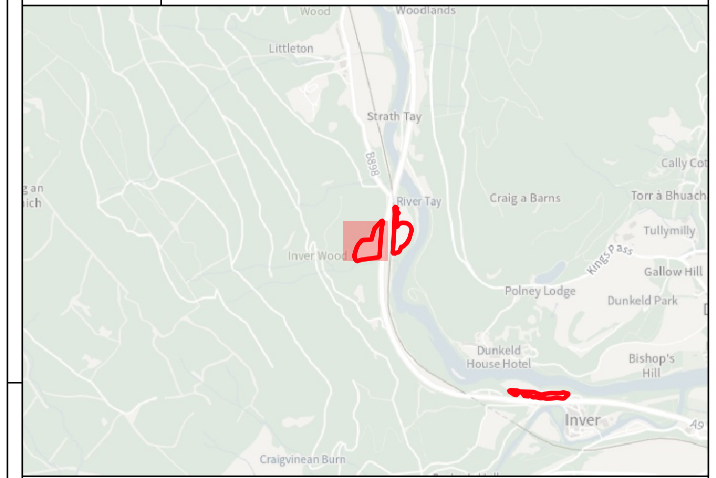


Key

Survey Extent

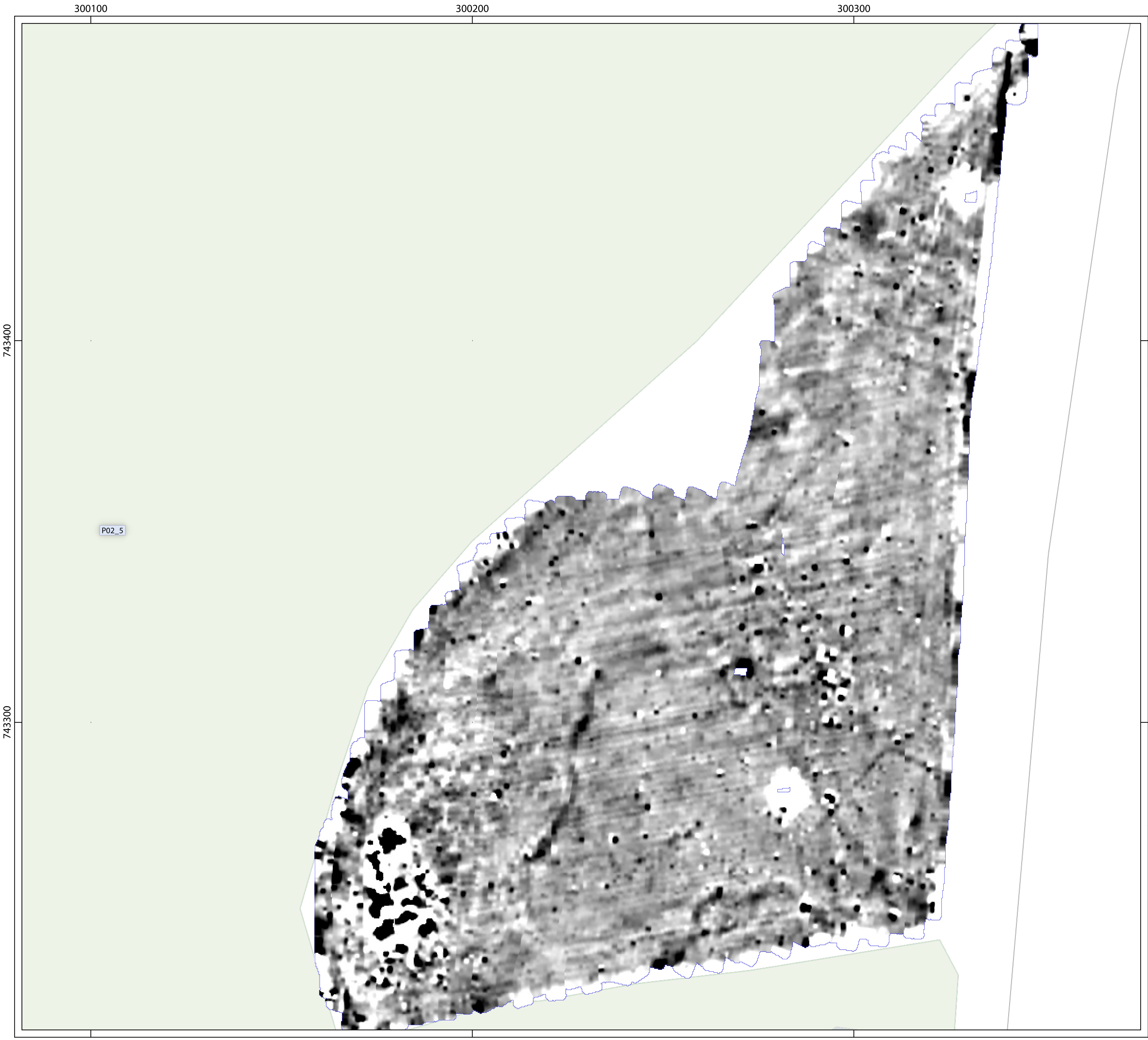
+2nT

-1nT

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 41 Processed greyscale magnetometer data; P02_5



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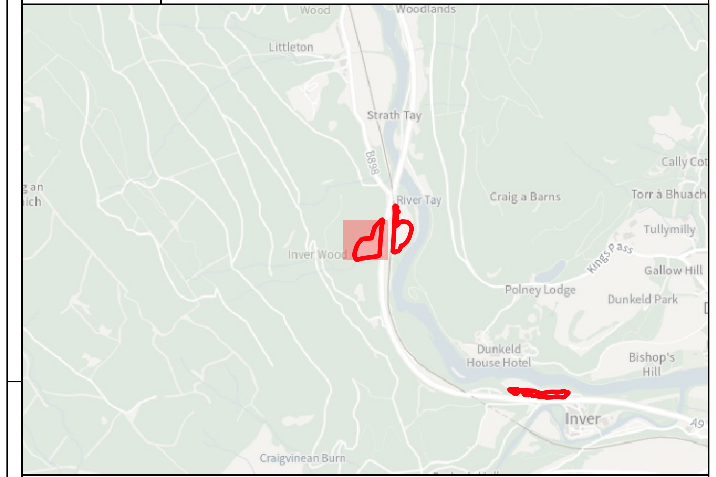

Key

Survey Extent

+2nT

-1nT

0 20 40 m

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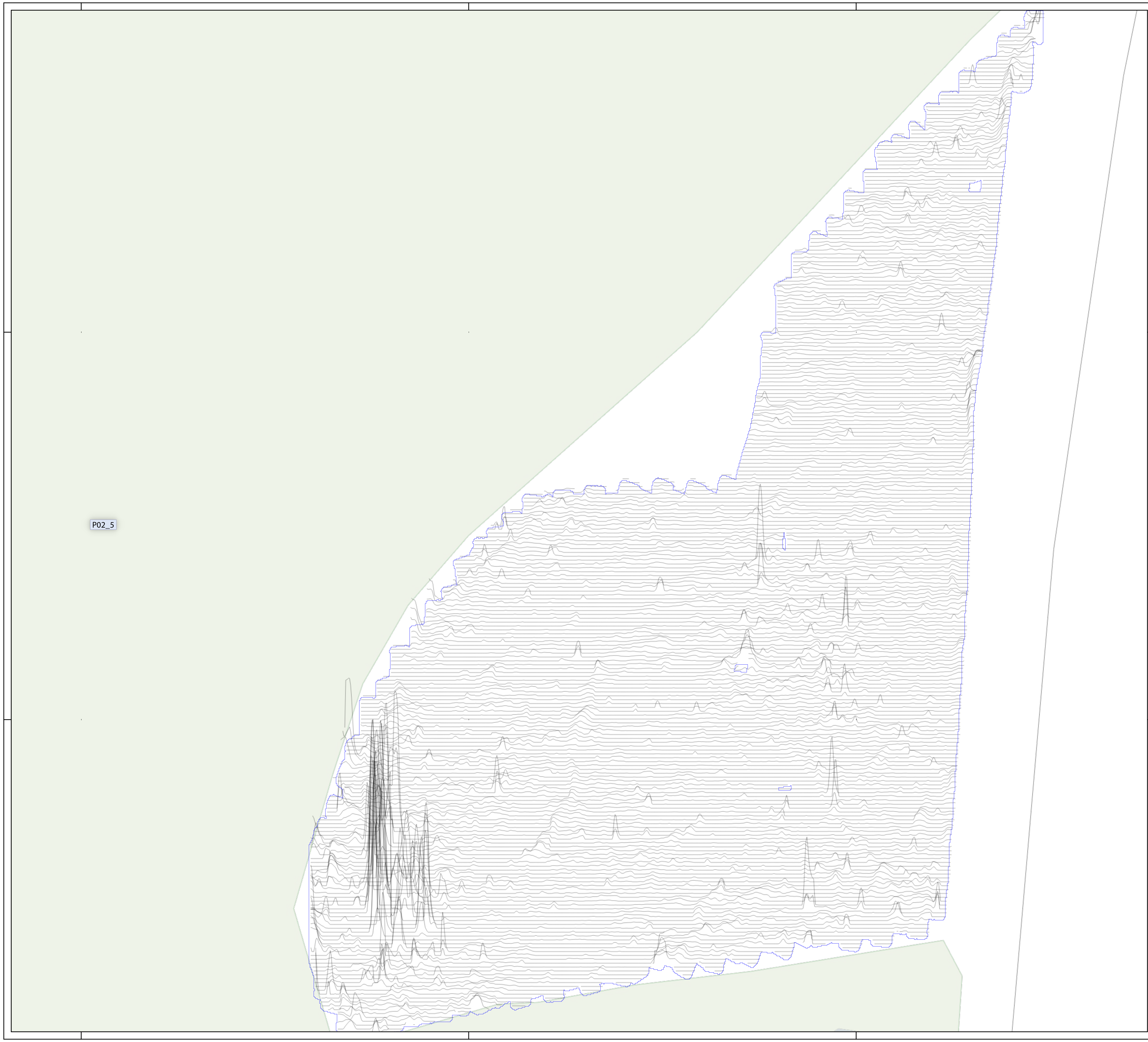
Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 42 Minimally processed greyscale magnetometer data; P02_5

300100 300200 300300

743400 743300



N

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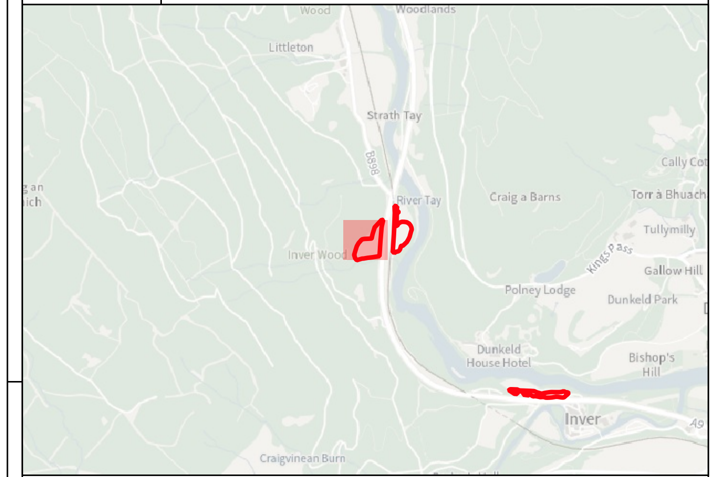


Key

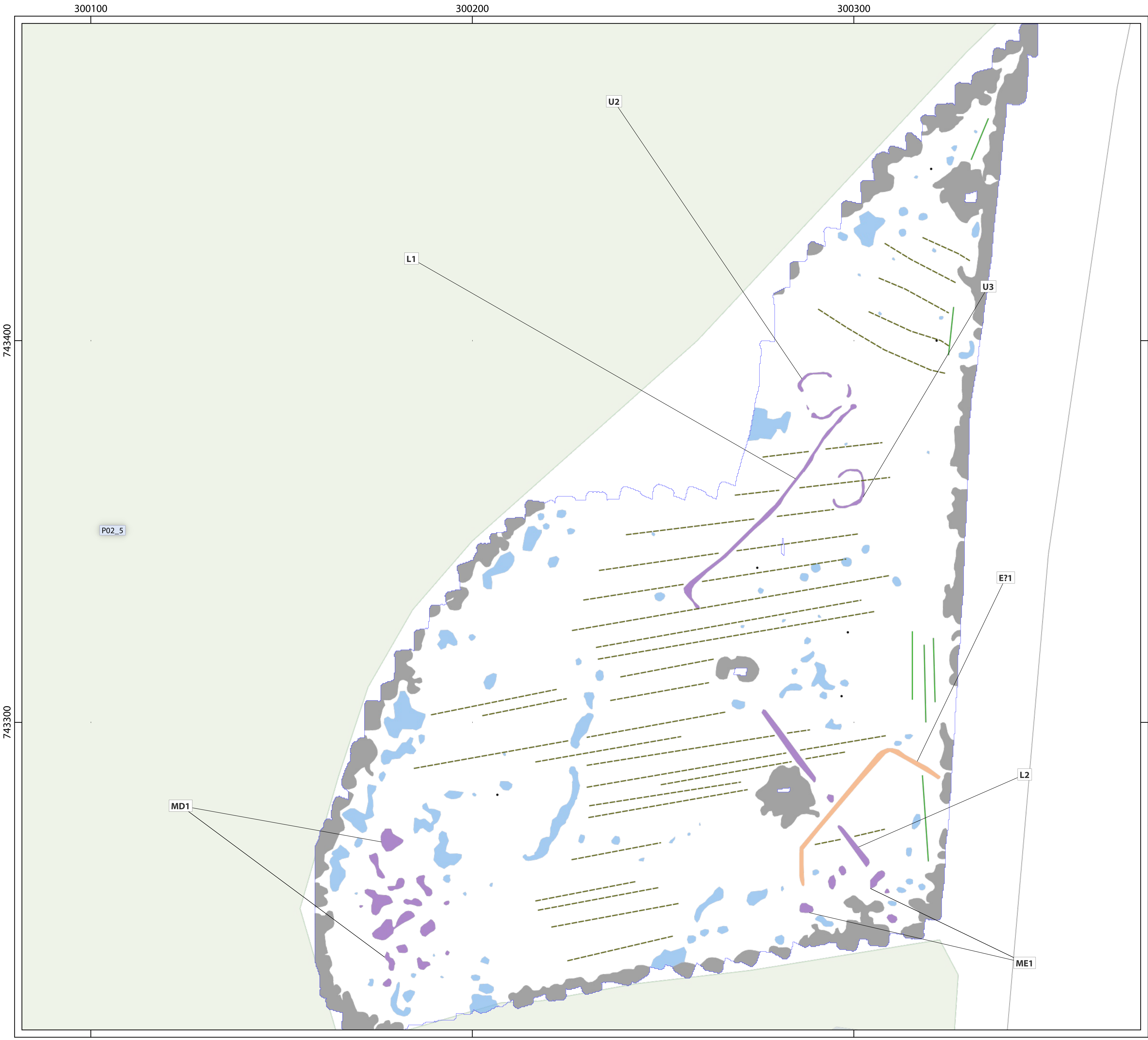
Survey Extent

XY Trace (25nT/cm)

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 43 XY trace plot of minimally processed magnetometer data; P02_5



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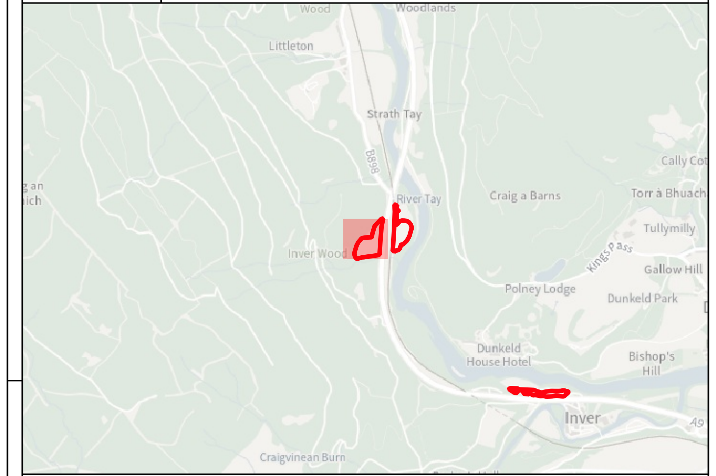
A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- Ferrous Objects
- Agriculture
- Ridge and Furrow
- Magnetic Disturbance (Above Ground)
- Natural
- Possible Archaeology
- Uncertain

	Abbreviation
E?	Enclosure?
L	Linear
MD	Magnetic Disturbance
ME	Magnetic Enhancement
U	Uncertain

0 20 40 m

Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v1.0
Date:	02/04/2025
Scale:	1:1,000 @ A3

Illus - 44 Interpretation of magnetometer data; P02_5

7 APPENDICES

APPENDIX 1 MAGNETOMETER SURVEY

Magnetic susceptibility and soil magnetism

Iron makes up about 6% of the earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haematite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of the topsoil, subsoil, and rock, into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected.

The magnetic susceptibility of a soil can also be enhanced by the application of heat. This effect can lead to the detection of features such as hearths, kilns, or areas of burning.

Types of magnetic anomaly

In most instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However, some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes) These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being introduced into the topsoil during manuring.

Areas of magnetic disturbance These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Lightning-induced remnant magnetisation (LIRM) LIRM anomalies are thought to be caused in the near surface soil horizons by the flow of an electrical current associated with lightning strikes. These observed anomalies have a strong bipolar signal which decreases with distance from the spike point and often appear as linear or radial in shape.

Linear trend This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier rig and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

APPENDIX 2 GPR SURVEY

In GPR survey, electromagnetic waves of frequencies between 50MHz and 2.6GHz are transmitted into the ground. This energy is reflected back to the surface when it encounters significant contrasts in sub-surface dielectric properties.

A radio wave transmitter (Tx) is used to generate a short (<20ns) pulse of radio waves of specific frequency (depending on the antenna selected). These radio waves penetrate into the subsurface. Some of the energy carried by these waves is transmitted to greater and greater distances, while some of the energy is reflected back towards the receiver (Rx) whenever a contrast in electrical properties is encountered. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves.

The receiver measures the variation in strength of the reflected signals with time. The resulting profile is called a 'trace' and is a one-dimensional representation of the subsurface beneath the transmitter and receiver. To build up a two-dimensional section of the subsurface (a radargram), the transmitter and receiver are traversed across the surface at a controlled speed.

In order to present time sections as depth sections, some form of calibration is required through borehole or core information, or through an assessment of the electrical (dielectric) properties of the surveyed materials. It is important to note that such conversions are not always practical.

The higher frequency antennas provide high resolution data over shallow depths (<0.5m) and are mostly employed for near surface structural investigations (e.g., characterising rebar in concrete). The lower frequency antennas can probe to greater depths (up to 30m, depending on subsurface conditions) but exhibit a reduced degree of resolution. These antennas are typically employed in geological/hydrogeological investigations (eg, locating cave systems and sinkholes).

The presence of discrete archaeological features within an otherwise homogeneous ground in the shallow subsurface may constitute a strong contrast in dielectric (electrical) properties, depending upon the diameter and material of the object. Metallic objects constitute the strongest contrast in dielectric properties and generate the strongest (highest amplitude) reflections. Materials such as natural stone, concrete, and brick offer a reduced contrast, and subsequently generate lower amplitude reflections, which it may not be possible to detect, especially in a mixed, artificial sub-surface volume as expected within P02_2. The GPR technique relies on the presence of contrasts that are sufficiently 'sharp' to produce a clear reflection. When surveyed with a standard GPR antenna, reflection events are observed on the recorded radargrams. Based on experience, a 450MHz antenna typically provides reliable reflection data up to 2.0 metres below ground level (mbgl) dependent upon ground conditions.

APPENDIX 3 SURVEY LOCATION INFORMATION

The magnetometer data was collected and is geo-located based on survey grade Real Time Kinetic (RTK) differential Global Positioning System (dGPS). The accuracy of this dGPS equipment is better than 0.01m. The GPS system outputted in NMEA mode in real time, with a visual guide of survey tracks and any survey area boundaries displayed on a tablet device in view of the survey operator to ensure full coverage. Any survey area boundaries are uploaded as a string of co-ordinates or shapefile to the tablet prior to the commencement of survey.

With both 160MHz and 450MHz antenna GPR readings were taken in real time along parallel traverses spaced 0.25m apart, on a predetermined grid covering the geophysical survey area that was established using a Leica GS18 RTK differential Global Positioning System (dGPS) system.

APPENDIX 4 GEOPHYSICAL SURVEY ARCHIVE

The geophysical archive comprises an archive disk containing the raw data in XYZ format, a raster image of each greyscale plot with associate world file, and a PDF of the report.

The project will be archived in-house in accordance with recent good practice guidelines (http://guides.archaeologydataservice.ac.uk/g2gp/Geophysics_3). The data will be stored in an indexed archive and migrated to new formats when necessary.

APPENDIX 5 DATA PROCESSING

Appendix 5.1 Magnetometer data

The gradiometer data has been presented in this report in processed and minimally processed greyscale and XY trace plot format.

Data collected using RTK GPS-based methods cannot be produced without minimal processing of the data. The minimally processed data has been interpolated to project the data onto a regular grid though no filtering has been applied which would normally de-stripe to correct for slight variations in instrument calibration drift, heading errors and any other artificial data.

The XY data has been clipped to remove extreme values and to improve the interpretability of the data.

Appendix 5.2 GPR data

Distance calibration (on-site measurement) Horizontal measurement is undertaken using a wheel odometer mounted to the antenna and is calibrated daily and saved on the GPR console. An on-site check over 10m was conducted and found to be accurate.

Depth calibration A dielectric constant of 6.3 has been assumed by the Geolitix processing software based on reflection profiles across the data set, in order to give the most accurate indication of depth. The calculated depths are expected to be typically ±20% accuracy.Time zero correction To correct the signal to the actual ground surface level.

Background removal To reduce ringing and horizontal reflectors caused by conductive ground.

Manual gain control To compensate for the signal attenuation with depth and enhance the signals from deeper reflectors to aid interpretation. Each profile was enhanced with the same gain parameters.

Frequency filtering High and low pass filters were set at frequencies of 800 MHz and 200 MHz to remove noise from the data, and to isolate "legitimate" signals from reflections of the pulse from the instrument.

Migration 'FK Migration' function to remove the effects of hyperbola tails and pull the data up to the correct true vertical location. Data is migrated using a dielectric constant of 15.

APPENDIX 6 GPR 160MHZ ANTENNA DATA

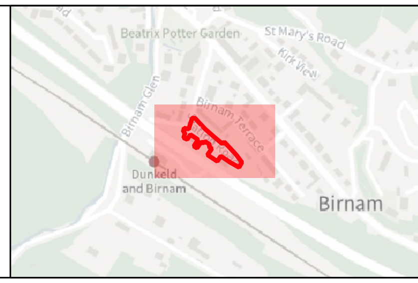
Key

Geophysical Survey Area

High Amplitude

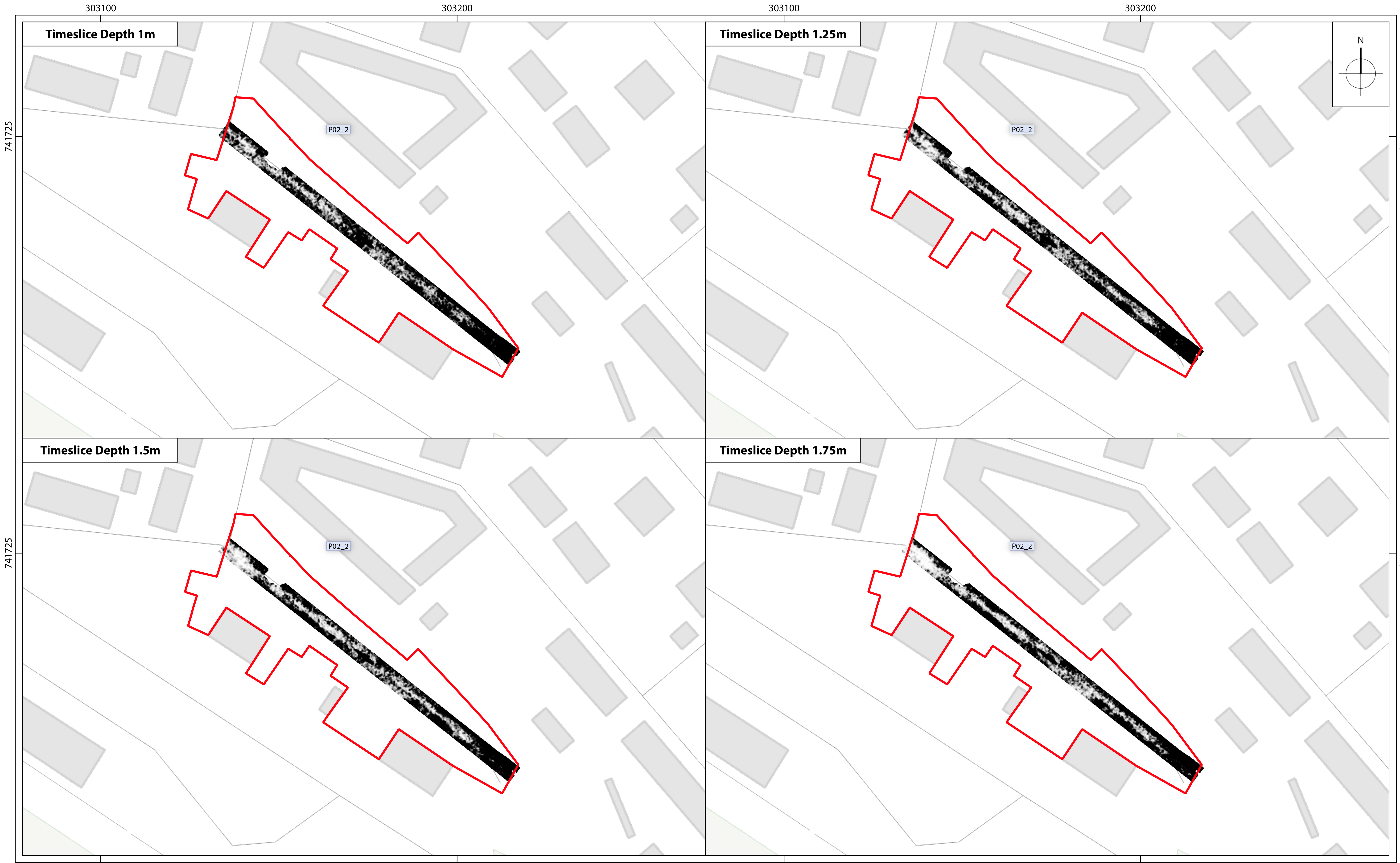
Low Amplitude

0 15 30 m



Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v2.0
Date:	16/04/2025
Scale:	1:1,000 @ A3

Appendix 6 - Illus - 01 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 0m - 0.75m



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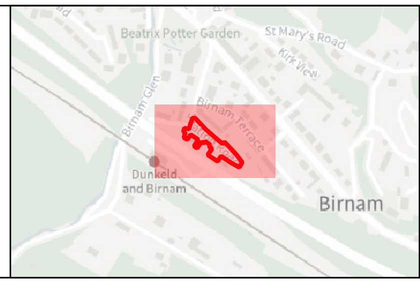
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



Site:	ANBT25
Created by:	LD
Checked by:	SH
Version:	v2.0
Date:	16/04/2025
Scale:	1:1,000 @ A3

Appendix 6 - Illus - 02 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 1m - 1.75m

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company

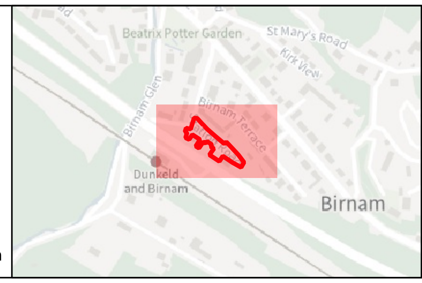
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Checked by:	SH
Version:	v2.0
Date:	16/04/2025
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Appendix 6 - Illus - 03 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 2m - 2.75m

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY
an RSK company

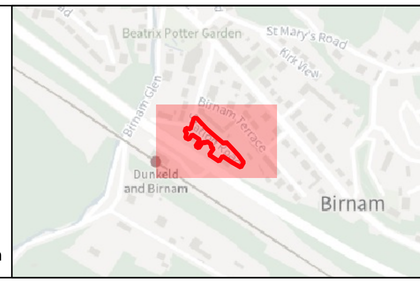
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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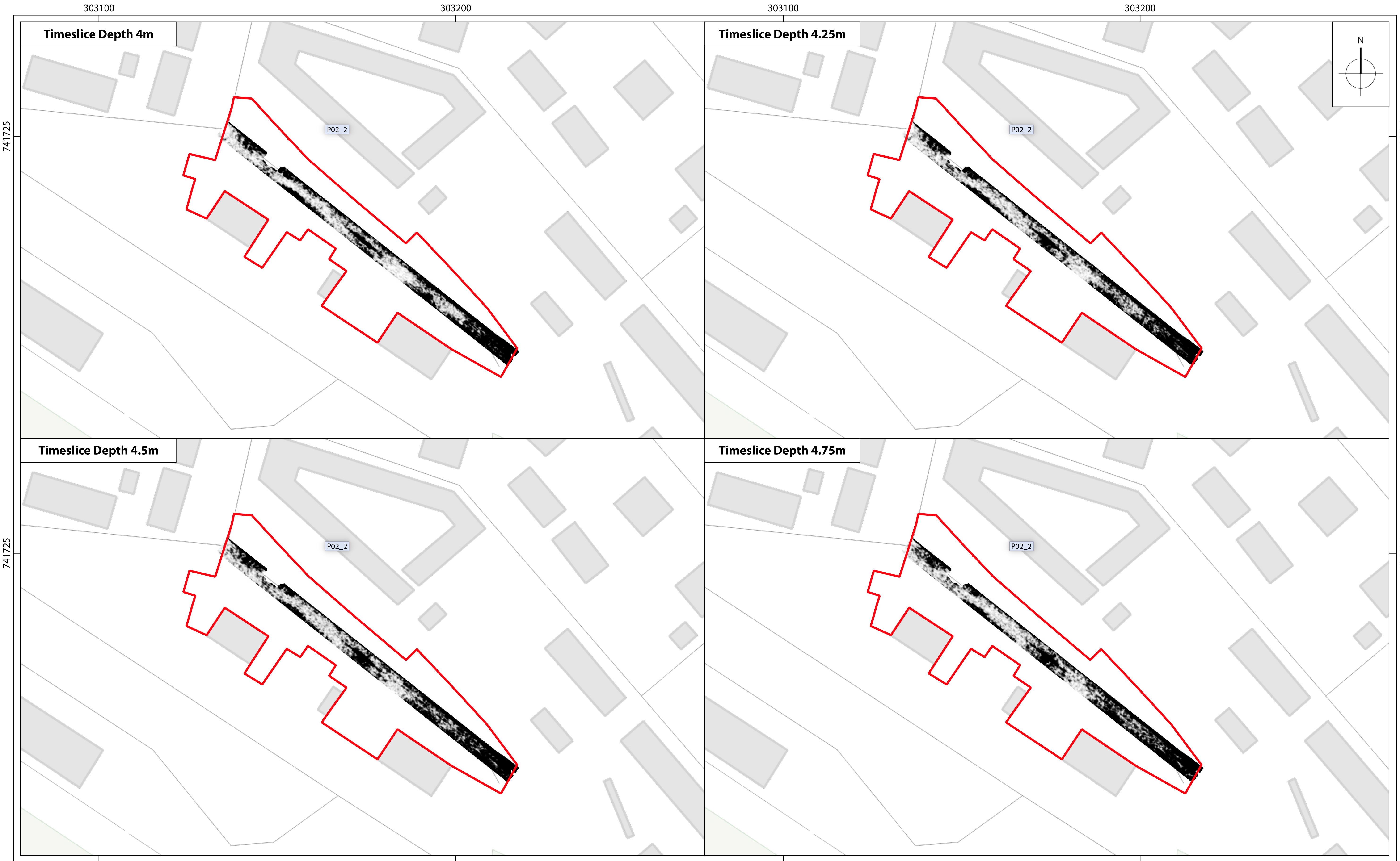
Version:	v2.0
Date:	16/04/2025
Scale:	1:1,000 @ A3

Appendix 6 - Illus - 04 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 3m - 3.75m



A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m

Birnam

Site:	ANBT25
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Appendix 6 - Illus - 05 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 4m - 4.75m

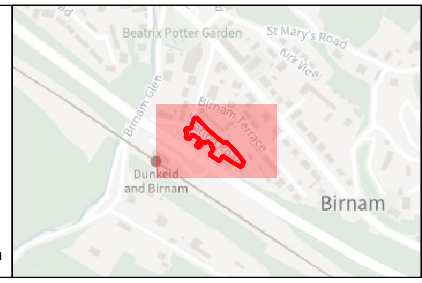
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Appendix 6 - Illus - 06 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 5m - 5.75m

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

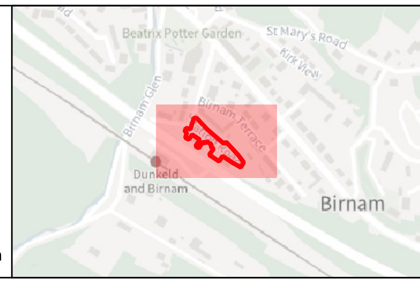
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Appendix 6 - Illus - 07 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 6m - 6.75m

HEADLAND ARCHAEOLOGY
an RSK company

A9 DUALLING
PASS OF BIRNAM TO TAY CROSSING

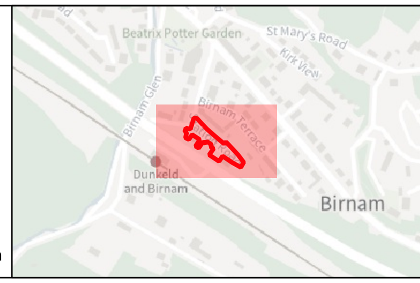
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Appendix 6 - Illus - 08 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 7m - 7.75m

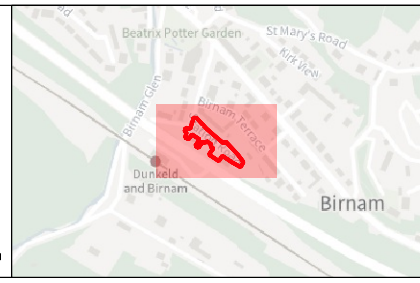
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Appendix 6 - Illus - 09 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 8m - 8.75m

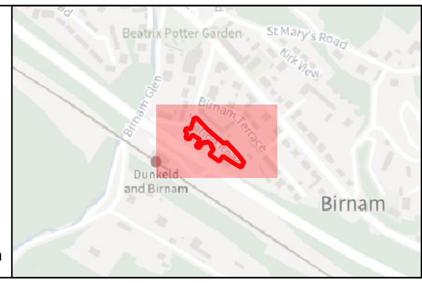
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Checked by:	SH
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Date:	16/04/2025
Scale:	1:1,000 @ A3

Appendix 6 - Illus - 10 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 9m - 9.75m

A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

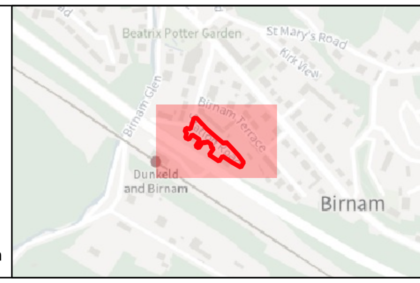
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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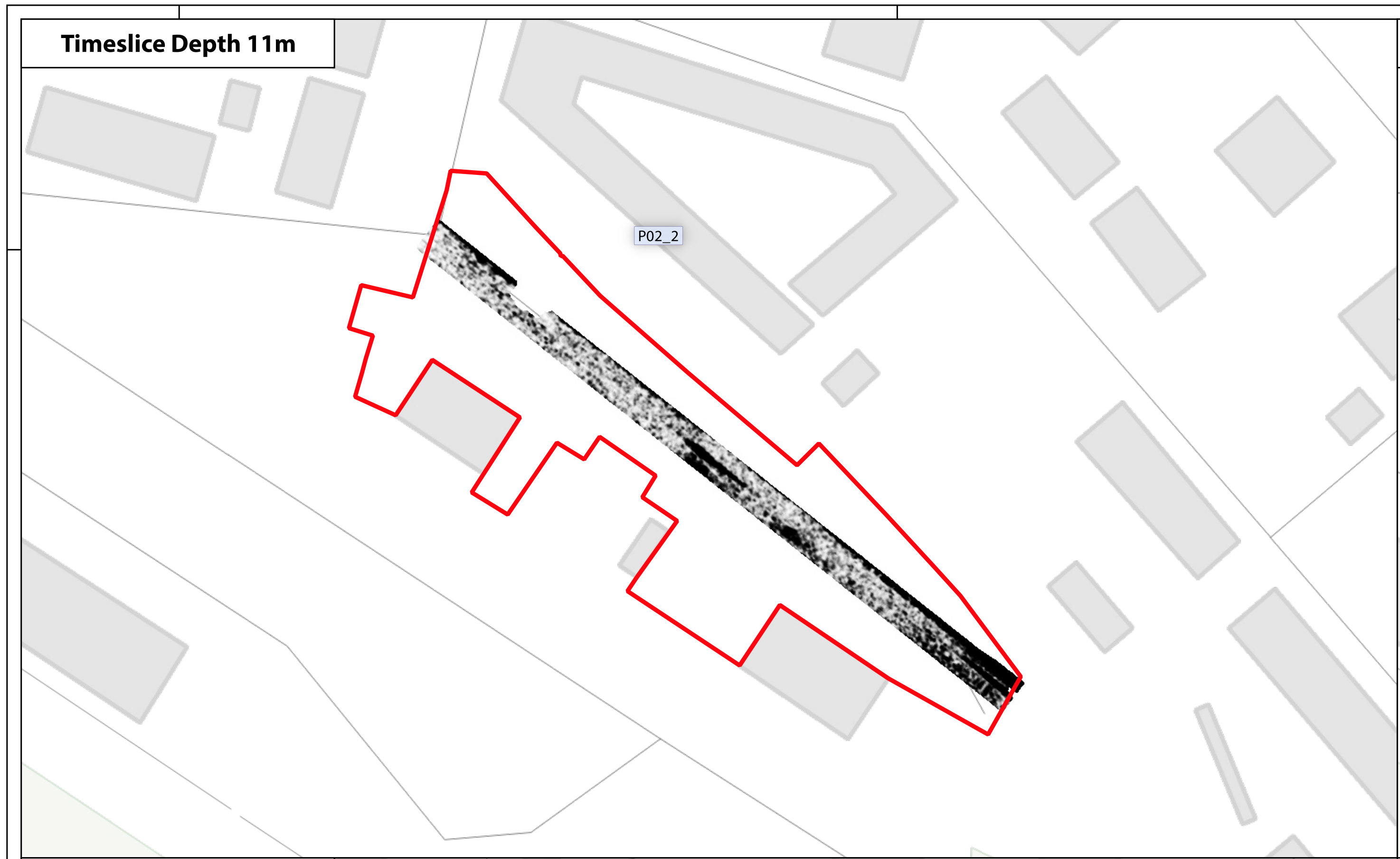
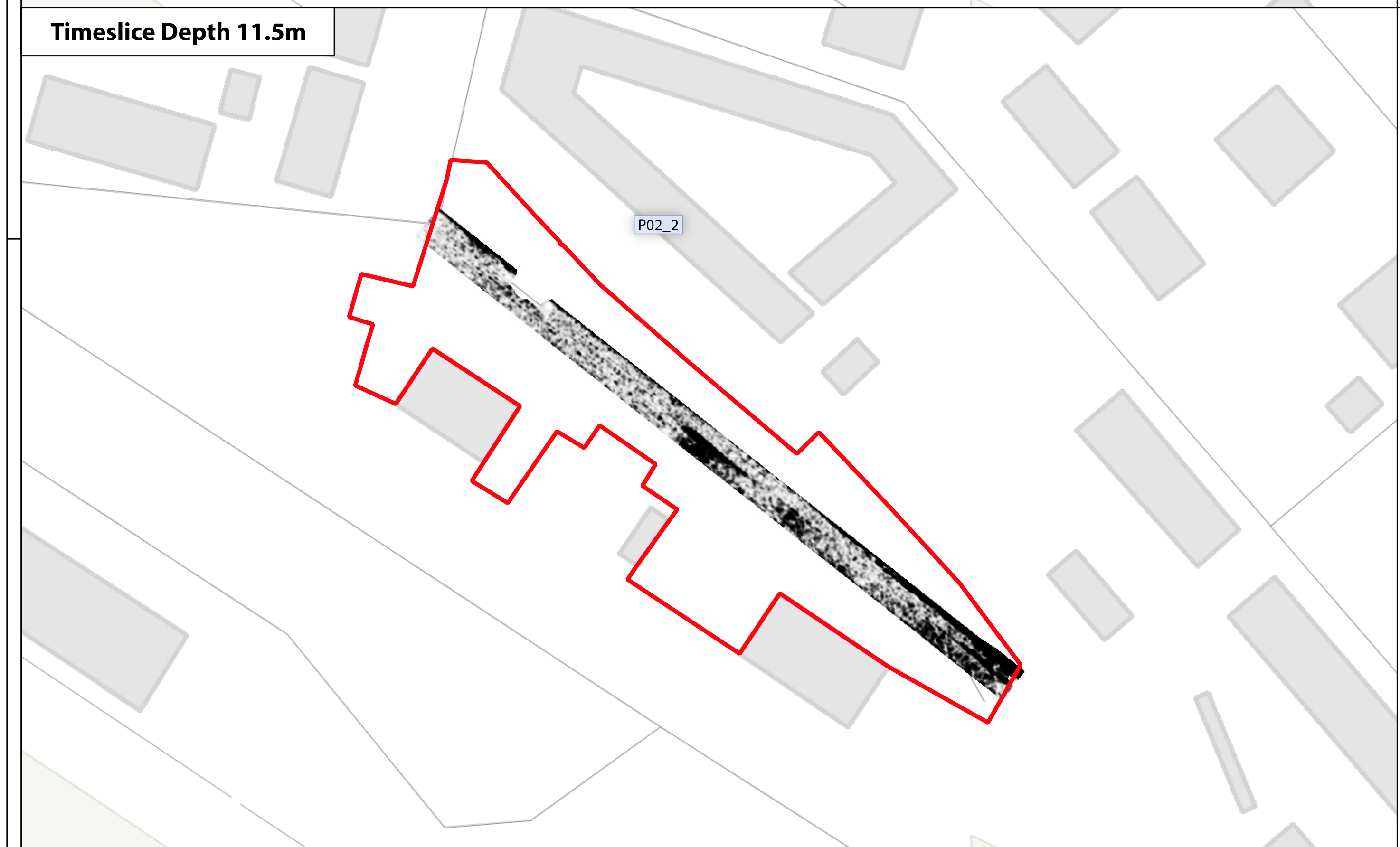
Appendix 6 - Illus - 11 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 10m - 10.75m





A9 DUALLING PASS OF BIRNAM TO TAY CROSSING

HEADLAND ARCHAEOLOGY an RSK company

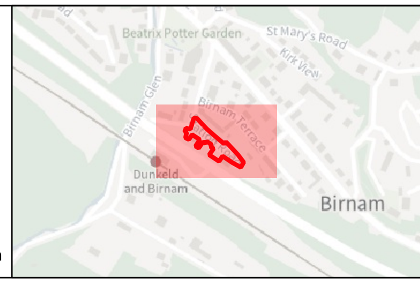
Key

Geophysical Survey Area

High Amplitude

Low Amplitude

0 15 30 m



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Appendix 6 Illus - 12 GPR Timeslices 160MHz Antenna; P02_2; Timeslice 11m - 11.5m

APPENDIX 7 DISCOVERY AND EXCAVATION IN SCOTLAND

OASIS ID (UID): headland1-533174

Project Identifier:	p25-063
Activity type:	Ground Penetrating Radar Survey; Magnetometry Survey; Geophysical Survey; GROUND PENETRATING RADAR SURVEY; MAGNETOMETRY SURVEY
Reason for Investigation:	Planning requirement
Development type	Road
Site name:	A9 Dualling Programme: Pass of Birnam to Tay Crossing
Location:	NO 01397 42332; NO 03169 41696; NO 00463 43394; NO 03787 41552; NO 00260 43317
Admistrative Areas:	Little Dunkeld; Perth & Kinross; Scotland
Historic Environment Record(s) for project:	Perth & Kinross Heritage Trust
National organisation for project:	Historic Environment Scotland
Other national organisations:	Discovery and Excavation in Scotland
Title:	Geophysical Magnetometry and Ground Penetrating Radar Survey at A9 Dualling Programme: Pass of Birnam to Tay Crossing
Description - Methodology:	The magnetometer survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals onto a rigid carrying frame. The system was programmed to take readings at a frequency of 10Hz on roaming traverses (swaths) 1m apart. These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R12 Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point. MLGrad601 and MultiGrad601 (Geomar Software Inc.) software was used to collect and export the data. Anomaly GeoSurvey v1.12.3 (Lichenstone Geoscience) and QGIS v.3.34.6 software was used to process and present the data respectively. With both 160MHz and 450Mhz antenna GPR readings were taken in real time along parallel traverses spaced 0.25m apart, on a predetermined grid covering the geophysical survey area that was established using a Leica GS18 RTK differential Global Positioning System (dGPS) system. Given the narrow 0.25m line spacing width of the survey specification, internal accuracy within the local grid was maintained with the use of measuring tapes and visual markers. Profiles were collected in the zigzag (bi-directional) method after calibration of the wheel odometer mounted to the antenna. On-site checks over 10m were conducted and found to be accurate at the start of each day. Geolitix processing software was used to process and display the GPR data.
Description - outcomes:	Magnetometer survey was successfully undertaken across all suitable areas within the four separate survey parcels (P02_1, P02_3-5), an area totalling 6.55 hectares. Approximately 65% coverage was achieved across the proposed sole GPR survey area (P02_2) amounting to 0.14 hectares. The results of the magnetometer survey suggest that magnetometry was an appropriate prospection method to assess the buried archaeological potential of the survey areas, but three of the four parcels (P02_1, P02_3 and P02_4) have been adversely affected by the presence of large, buried services (SP1-SP3) across them. Most of the anomalies identified by the survey are of agricultural, modern or natural origin however a group of weakly enhanced linear and discrete anomalies of uncertain (U2-U3, L1-L2, MD1 and ME1) and possible archaeological origin (E?1) were identified within the remaining parcel (E?1, U2-U3, L1-L2, MD1 and ME1; P02_5) that lies on slightly higher ground away from the flood plain of the River Tay. It is unclear however whether these anomalies are associated or record an unrelated spread of anomalies of natural/agricultural origin. One curvilinear trend of uncertain origin (U1) in P02_3 and traces of rig and furrow cultivation in two other parcels (P02_4 and P02_5) were the only other findings of note. Based on the results of the magnetometer survey the archaeological potential of the two parcels (P02_1 and P02_3) most adversely affected by buried services remains uncertain. The archaeological potential of the northernmost parcels either side of the existing A9 are assessed as low to the east (P02_4) but locally moderate across the eastern half of the western parcel (P02_5). The GPR survey was hindered by obstacles within the survey area but has identified weak traces of linear perpendicular high amplitude trends across multiple depth slices at the western end of the survey area immediately south of Station Road. The anomalies do not align with the direction of survey, Station Road, extant structures or buildings marked on historic mapping associated with historic asset Dunkeld and Birnam Station, Goods Yard (Asset 832) but could identify traces of a since demolished building or infrastructure associated with the yard. Outside of these responses the GPR survey has only recorded one other linear sub-surface high amplitude response that possibly records a buried service, in addition to multiple strong near surface reflectors that identify the location of service and drain covers. No anomalies of note were identified in the location of buildings recorded on historic mapping that were associated with the former railway goods yard.
Start Date:	10 March 2025
End Date:	14 March 2025
Organisation:	Headland Archaeology (UK) Ltd
Project Manager:	Kirsty Dingwall; Matthew Berry
Expert/Project Officer:	Daniel Wilkinson
Funder:	Transport Scotland

APPENDIX 8 OASIS DATA COLLECTION FORM: SCOTLAND

OASIS ID (UID): headland1-533174

Project Name:	Geophysical Magnetometry and Ground Penetrating Radar Survey at A9 Dualling Programme: Pass of Birnam to Tay Crossing
Activity type:	Ground Penetrating Radar Survey, Magnetometry Survey, Geophysical Survey, GROUND PENETRATING RADAR SURVEY, MAGNETOMETRY SURVEY
Sitecode(s):	ANBT25
Project Identifier(s):	p25-063
Planning Id:	[no data]
Reason for Investigation:	Planning requirement
Organisation Responsible for work:	Headland Archaeology (UK) Ltd
Project Dates:	10-Mar-2025 – 14-Mar-2025
HER:	Perth & Kinross Heritage Trust
HER Identifiers:	[no data]
Project Methodology:	The magnetometer survey was undertaken using four Bartington Grad601 sensors mounted at 1m intervals onto a rigid carrying frame. The system was programmed to take readings at a frequency of 10Hz on roaming traverses (swaths) 1m apart. These readings were stored on an external weatherproof laptop and later downloaded for processing and interpretation. The system was linked to a Trimble R12 Real Time Kinetic (RTK) differential Global Positioning System (dGPS) outputting in NMEA mode to ensure a high positional accuracy for each data point. MLGrad601 and MultiGrad601 (Geomar Software Inc.) software was used to collect and export the data. Anomaly GeoSurvey v1.12.3 (Lichenstone Geoscience) and QGIS v.3.34.6 software was used to process and present the data respectively. With both 160MHz and 450Mhz antenna GPR readings were taken in real time along parallel traverses spaced 0.25m apart, on a predetermined grid covering the geophysical survey area that was established using a Leica GS18 RTK differential Global Positioning System (dGPS) system. Given the narrow 0.25m line spacing width of the survey specification, internal accuracy within the local grid was maintained with the use of measuring tapes and visual markers. Profiles were collected in the zigzag (bi-directional) method after calibration of the wheel odometer mounted to the antenna. On-site checks over 10m were conducted and found to be accurate at the start of each day. Geolitix processing software was used to process and display the GPR data.
Project Results:	Magnetometer survey was successfully undertaken across all suitable areas within the four separate survey parcels (P02_1, P02_3-5), an area totalling 6.55 hectares. Approximately 65% coverage was achieved across the proposed sole GPR survey area (P02_2) amounting to 0.14 hectares. The results of the magnetometer survey suggest that magnetometry was an appropriate prospection method to assess the buried archaeological potential of the survey areas, but three of the four parcels (P02_1, P02_3 and P02_4) have been adversely affected by the presence of large, buried services (SP1-SP3) across them. Most of the anomalies identified by the survey are of agricultural, modern or natural origin however a group of weakly enhanced linear and discrete anomalies of uncertain (U2-U3, L1-L2, MD1 and ME1) and possible archaeological origin (E?1) were identified within the remaining parcel (E?1, U2-U3, L1-L2, MD1 and ME1; P02_5) that lies on slightly higher ground away from the flood plain of the River Tay. It is unclear however whether these anomalies are associated or record an unrelated spread of anomalies of natural/agricultural origin. One curvilinear trend of uncertain origin (U1) in P02_3 and traces of rig and furrow cultivation in two other parcels (P02_4 and P02_5) were the only other findings of note. Based on the results of the magnetometer survey the archaeological potential of the two parcels (P02_1 and P02_3) most adversely affected by buried services remains uncertain. The archaeological potential of the northernmost parcels either side of the existing A9 are assessed as low to the east (P02_4) but locally moderate across the eastern half of the western parcel (P02_5). The GPR survey was hindered by obstacles within the survey area but has identified weak traces of linear perpendicular high amplitude trends across multiple depth slices at the western end of the survey area immediately south of Station Road. The anomalies do not align with the direction of survey, Station Road, extant structures or buildings marked on historic mapping associated with historic asset Dunkeld and Birnam Station, Goods Yard (Asset 832) but could identify traces of a since demolished building or infrastructure associated with the yard. Outside of these responses the GPR survey has only recorded one other linear sub-surface high amplitude response that possibly records a buried service, in addition to multiple strong near surface reflectors that identify the location of service and drain covers. No anomalies of note were identified in the location of buildings recorded on historic mapping that were associated with the former railway goods yard.
Subject/Period:	RIG AND FURROW: Post Medieval; Monument Type Thesaurus (Scotland)

Headland Archaeology Scotland
13 Jane Street
Edinburgh EH6 5HE
t 0131 467 7705
e scotland@headlandarchaeology.com

Headland Archaeology Yorkshire & North
Units 23–25 & 15 | Acorn Business Centre | Balme Road
Cleckheaton BD19 4EZ
t 0127 493 8019
e yorkshireandnorth@headlandarchaeology.com

Headland Archaeology South & East
Building 68C | Wrest Park | Silsoe
Bedfordshire MK45 4HS
t 01525 861 578
e southandeast@headlandarchaeology.com

Headland Archaeology Midlands & West
Unit 1 | Clearview Court | Twyford Rd
Hereford HR2 6JR
t 01432 364 901
e midlandsandwest@headlandarchaeology.com

Headland Archaeology North West
Fourways House | 57 Hilton Street
Manchester M1 2EJ
t 0161 236 2757
e northwest@headlandarchaeology.com

www.headlandarchaeology.com