

Proposed New Burial Ground, Annaghdown
Co. Galway
Archaeological Geophysical Survey

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Confidential Report To:

Galway County Council

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Prospect Hill
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Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. MinereX Geophysics Ltd. (MGX) carried out the archaeological geophysical survey at the proposed new burial ground, Annaghdown, Co. Galway. The methods employed were Magnetic Gradiometry, 2D-Resistivity (ERT), Ground Penetrating Radar (GPR) and EM61 Metal Detector. Across areas shown on Map 1.
2. The objectives of the survey were to locate possible unknown archaeological deposits or objects within the area of the proposed new burial ground.
3. The survey was carried out on the 14th and 15th January 2025 under license from the National Monuments Service (25R0004).
4. Maps 2 – 4 show historic maps for the area indicating changes in the field boundaries over time.
5. Map 5 shows the results of the magnetic gradient survey, revealing patterns of agricultural activity, including cultivation patterns and metal remains of human activity. However, there is no indication of archaeological features such as foundations, walls, buildings, or ditches.
6. The 2D-Resistivity line (Figure 1) indicates that the sites geology consists of overburden (till derived from limestone) up to about 2.5m deep, with rock beneath. The resistivity data shows no significant features or artifacts suggestive of archaeology.
7. Map 6 presents GPR survey time slices at a 0.4m depth, revealing diagonal trends from SW to NE that align with the cultivation patterns seen in the magnetic results.
8. Map 7 shows that the EM61 metal detector results for buried metal, mostly corresponding to the magnetic gradient results and likely linked to agricultural activity or other human activity.
9. Map 8 provides a summary interpretation of all geophysical survey findings. Cultivation patterns are shown as orange arrows in a consistent direction, while metal-related anomalies are categorized by hatch colour: **black** (metal fencing along existing field boundaries), **red** (larger buried metal objects visible in both magnetic and EM61 data), **green** (small metal items like nails detected only in the magnetic survey), and **cyan** (non-ferromagnetic metals like aluminium or copper, found only by the metal detector).
10. The survey detected various items but no typical archaeological features like foundations, walls, or man-made geometric shapes. The only visible human-related structures within the data are cultivation patterns and metal remains. The only detected potentially significant archaeological features are cultivation ridges, and they may not have a lasting physical visibility and could be the so-called 'ghost ridges'.

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1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out the archaeological geophysical survey at the proposed new burial ground, Annaghdown, Co. Galway. The methods employed were Magnetic Gradiometry, 2D-Resistivity (ERT), Ground Penetrating Radar (GPR) and EM61 Metal Detector.

The objective was to identify any potential subsurface archaeological features. The survey area was within one agricultural field used for pasture. It has a size of 0.4ha and is indicated on Map 1.

The client is Galway County Council.

A walk-over survey of the area did not reveal any features of archaeological significance surviving above ground and there are no monuments listed on the site.

The survey was carried out on the 14th and 15th January 2025 under license from the National Monuments Service (25R0004).

1.2 Objectives

The objectives of the survey are to locate possible archaeological deposits or objects. These findings will then be considered for the development of the burial ground. Targeted archaeological testing is possible after a geophysical survey.

The main objectives of the geophysical survey are:

- To determine possible archaeological features and deposits
- To identify unknown archaeological objects
- To recommend possible targets for direct archaeological testing

1.3 Location and Site Description

Locations maps are attached. The site is in the townland of Annaghdown. The area is within one field which is used for grazing. There are twenty recorded monuments located within 1km of the site. All of them are to the south with the nearest one being 300m away.

The geology consists of till derived from limestones overburden over the Burren Formation bedrock (described as dark pale grey clean skeletal limestone).

Seven trial pits carried out by Galway County Council prior to the geophysical survey, and most of them did not revealed rock to a depth of around 2 meters (~6.5ft), only Trail Pit 1 found the rock at 1.5m (5ft). Above the rock there is overburden consisting of topsoil, subsoil and a mix of sandy subsoil and broken rock.

1.4 Archaeology

Maps 2 to 4 illustrate three different historical maps of the survey area. On the first historical map (the first edition from 1837), the site is divided into two fields, with the boundary running diagonally through the middle of the area. On the more recent maps, the study area is shown as part of a single field.

An archaeological assessment was conducted for the proposed new burial ground in Annaghdown, County Galway in October 2024 by Through Time Ltd (2024). The site, located in agricultural land, was surveyed with no visible archaeological features identified. Historical Ordnance Survey maps show significant landscape changes since the early 19th century, with rough ground and vegetation areas to the west of the site. The Archaeological Survey of Ireland lists no monuments in the area, with the closest being an ecclesiastical enclosure approximately 300m south. Although a fort is suggested in the vicinity by a publication on the medieval landscape, a walkover survey found no evidence of archaeological monuments.

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps and figures are included to illustrate the results of the survey. More detailed descriptions of geophysical methods and measurements for archaeology can be found in Bonsall J. et al. 2014, Clark 1990, David A. et al. (2008), English Heritage 2008, Schmid A. et al 2015, Gaffney C. et al (2002) and O'Sullivan (2009).

This geophysical survey has been acquired, processed, interpreted and reported in accordance with these guidelines.

Elevations were surveyed on site and are used in the vertical sections (Fig 1).

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data, give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

Four different methods were employed during the survey. The methods employed were Magnetic Gradiometry, 2D-Resistivity (ERT), Ground Penetrating Radar (GPR) and EM61 Metal Detector. 2D-Resistivity surveying was carried out along one line, R1. The electromagnetic method EM61 was carried out over a grid with a spacing of 1m. GPR was carried out with 400MHz antenna and was done on parallel lines with 1m distance. The Magnetic Gradiometry survey was carried out along lines 1m apart with readings every 0.25m along the lines. All those methods have been carried out within the yellow box shown on Map1.

2.2 Magnetic Gradiometry

The Magnetic Gradiometry survey was carried out with a Grad601-2 fluxgate gradiometer over the yellow area indicated on Map 1 along lines 1m apart with readings every 0.25m along the lines. The survey was conducted within 8 grids, 3 of which were 30 by 30 meters and 5 were 20 by 20 meters.

On site, a grid was marked out with the dimensions of the grid programmed in the data logger (DL601). Start and end points for each line was marked every two metres. The operator walked along each line at a constant speed allowing evenly spaced readings. The grid locations were surveyed in using an RTK-GPS.

The Grad601-2 is a single axis, vertical component fluxgate gradiometer comprising a DL601 Data Logger, BC601 battery cassette, and two Grad-01-1000L cylindrical gradiometer sensors mounted on a rigid beam. Each sensor contains two fluxgate magnetometers with one metre vertical separation.

The data processing was using algorithms like despiking and destriping to enhance that data. The results of the magnetometer survey are plotted as PNG format in the projection Irish Transverse Mercator (ITM). The vertical difference of the Z-component (vertical gradient) of the magnetic field is displayed.

The visualisation of the data is done in greyscale images with 256 greyscales from white to black stored in PNG format.

2.3 2D-Resistivity (ERT)

One 2D-Resistivity line was surveyed using 32 electrodes with 3-meter spacing, covering a total length of 93 meters. The readings were taken with a Tigre Resistivity Meter, Imager Cables, stainless steel electrodes and a laptop with ImagerPro acquisition software.

During 2D-Resistivity surveying, data is acquired in the form of linear arrays using a suite of metal electrodes. A current is induced into the ground via a pair of electrodes whilst a potential difference is measured across a second pair of electrodes. This allows for the recording of the apparent resistivity in a

two-dimensional arrangement below the line. The data is inverted after the survey to obtain a model of subsurface resistivities. The generated model resistivity values and their spatial distribution can then be related to typical values for different materials.

The penetration depth of a resistivity set-up increases towards the centre where it reaches an approx. value of $1/6^{\text{th}}$ of the array length.

2.4 Ground Penetrating Radar (GPR)

The GPR survey was carried out along lines 1m apart over 8 grids (3 grids 30x30m, and 5 grids 20x20m) within the yellow box shown on Map 1. The equipment was a SIR3000 system and a 400MHz antenna. The data was collected in the time domain with a trace length of 60nS and stored in the internal 'RADAN' format for later office-based analysis. The distance along the survey line was given by a survey wheel attached to the antenna. The scan spacing was 0.02m and 512 samples were taken at each scan.

All grids were surveyed in with an RTK-GPS system to ITM and with high accuracy (< 0.05m).

The depth penetration of the EM pulse emitted by the Ground Penetrating Radar is predominantly dependent upon the electrical conductivity of the ground beneath the antenna. A clay-rich soil will have a higher conductivity and therefore lower resistivity and allow less penetration than a clean dry sand and gravel or limestone.

The greater the level of absorption of the EM wave energy, the less depth penetration is achieved. Based on a time-depth conversion velocity of 0.1m/ns, which is typical for mixed soils like sandy gravelly clay and silt, the 400MHz antenna achieves penetration of 2m.

2.5 EM61 Metal Detector

The EM61 is a powerful metal detector that can detect objects with a weight of several kilograms or more at a depth of 3m and smaller objects closer to the surface. It uses a TEM (transient electromagnetic) technique. It measures the decaying signal in millivolts over different time windows. It discovers all types of metal both magnetic and not magnetic. The larger the amount of metal in a certain location, the higher the measured anomaly will be.

The survey data was recorded over a regular grid with 1 m line spacing. The data was saved every 20 cm along each survey line leading to a near continuous data field. The distance along lines was recorded with a survey wheel attached to the EM61 cart.

2.6 Site Work

The survey was carried out on the 14th and 15th January 2025 under license from the National Monuments Service (25R0004). The weather conditions were good throughout the acquisition period. Health and safety standards were adhered to at all times. The locations and elevations were surveyed with a Carlson NR3 RTK-GPS to accuracy < 0.05m.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was executed utilizing the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors. The interpretation is based on the individual methods carried out across the area.

3.1 Magnetic Gradiometry

The magnetic gradiometry data was processed as follows: Referencing to the Irish Transverse Mercator (ITM) grid, filtering the raw data and displaying it as a greyscale image in 256 gradations of black and white as $\pm 3\text{nT}$. The magnetic gradient data with the data range of $\pm 3\text{nT}$ is shown in Map 5.

Magnetic gradiometry locates small anomalies that typically indicate archaeological cuts and fills such as former ditches, trenches, pits or postholes. Postholes are very small and can only be found under optimal conditions and in conjunction with other patterns or when they form a larger pattern such as a circular arrangement.

Interpretations follow certain patterns, and linear, circular, curved, ellipsoidal and rectangular shapes are often man-made, while less organised and more random shapes are often caused by geological, hydrogeological, geomorphological or similar natural processes.

Cultivation ridges and furrows or ploughing lines are recognisable in the data, by the repeating pattern of parallel lines in the range of $\pm$ a few nanotesla (nT).

Rapid changes between white and black hues indicate strongly magnetised objects in the soil, which are mostly ferrous magnetic metal pieces (ferritic litter). These anomalies are also called magnetic dipole anomalies and they have negative and positive components that can reach several hundred nT in amplitude. Many of these objects are pieces of iron that are lost in agriculture by machinery or introduced by fertiliser or fencing material.

The magnetic gradient image primarily reveals two types of features. The first are the diagonal lines running in the SW-NE direction which have been interpreted as cultivation patterns, or cultivation ridges.

Cultivation Ridges can be defined as broad-ridge remnants, at intervals of c. 2–4m, forming straight or parallel groups and extending over large areas. On this site, the direction of the cultivation ridges match with an historic field boundary shown on old maps (Map 2).

These cultivation ridges may be visible in excavations or, if they are not show, then they are called 'ghost ridges'. (Jerry O'Sullivan, 2009).

'Ghost ridges' are solely changes in the magnetic field of the ground resulting from agricultural activity, which is common in Ireland, especially in County Galway. An attempt to excavate the ground to uncover these structures would not yield visible results, as they are visible only in magnetic gradient images.

Possible causes of so-called 'ghost ridges' are organic manures, which would have influenced the iron content of the soils, and ashes arising from sod or stubble burning, which would have increased the soil magnetic susceptibility of ashy silt deposits forming in furrow bottoms (Jerry O'Sullivan, 2009). These structures can be interpreted as archaeological since they originate from past human activity.

The second features visible on the magnetic gradient results is related to ferrous magnetic metal pieces (ferritic litter). Most locations corresponding to the results of the EM61 metal detector survey. Ferritic litter is visible in many places and a single dot like black/white pattern is generally a single piece of metal in the ground. Those anomalies are commonly found in fields where agricultural activities have been or are being conducted. These are typically small parts of agricultural equipment.

Some dot-like anomalies appear exactly in the same locations where a trial pit was excavated. This is related to the disturbance of the soil in that area, which creates a slightly different magnetic gradient result. Similarly to the EM61 metal detector survey, strong anomalies are visible near the walls and fences at the field boundary, which are primarily associated with the presence of a fence.

3.2 2D-Resistivity (ERT)

The 2D-Resistivity data was positioned and inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available and for this project the Jacobian Matrix was recalculated for the first three iterations, then a Quasi-Newton approximation was used for subsequent iterations. The dataset was inverted using seven iterations resulting in an RMS error of <3.0%.

Resistivities are characteristic for certain materials. If there is a high content of clay minerals (which are electrically conductive) then the resistivity will be lower than as if there is a high content of clastic grains like sand or gravel. The purer the clay and the lower the sand and gravel content, the lower the resistivity. Water content in overburden layers can influence the resistivities, but generally clay content has a more dominating effect. The resistivity will be also higher than the surrounding soil matrix when there are more stones, rocks and foundations.

For a geological interpretation, the resistivities (<500 Ohmm) indicate overburden (glacial till) to about 2.5m depth. Below this depth the resistivities increase and this indicates the rock of the Burren Formation (described as dark pale grey clean skeletal limestone).

There are no notable features or items in the resistivity data that can be interpreted as archaeological.

3.3 Ground Penetrating Radar (GPR)

The GPR data was processed and analysed in the REFLEXW reflection and transmission data processing software package. The datasets were converted from 'RADAN' format to 16-bit REFLEXW format for digital signal processing.

Test data processing was carried out and the final processing sequence applied to all the 2D lines consisted of horizontal background removal, gain function, bandpass frequency filter, subtrack mean filter, energy decay and xy-filter, shifting the traces to time and ground zero and a depth stretch with a velocity of 0.1m/ns. This is a typical velocity for the ground material found under the site and the depth obtained is an estimate.

The 3D-Model was made by interpolating the processed 2D-Lines to produce a 3D-block.

The 400MHz data was processed as individual 2D-lines and as 3D-blocks, and all data was scrutinised for possible historical, archaeological or other features.

It is important to note that the depths to features shown on the GPR data in the figures are not exact but approximate. This is due to the fact that the conversion velocity of 0.1m/ns assumes a homogeneous subsurface and does not take potential electromagnetic anisotropy into account.

Time slices from the 3D-blocks are shown in Map 6 at a depth of 0.4m.

The GPR results do not reveal any significant archaeological features. The diagonal lines, particularly visible at the south-east corner, align in direction with the lines observed in the magnetic gradient results and are more likely related to historical agricultural activity than to archaeological features.

3.4 EM61 Metal Detector

The EM61 values were positioned and merged into one data file for the survey area. Then they were gridded, blanked and contoured with the SURFER contouring package. The contours are created by gridding and interpolation. The EM61 data for Channel 1 in mV (millivolt) is displayed as a colour contour map (Map 7).

Low readings (blue-green-yellow) generally indicate areas without metal in the subsurface. The values vary somewhat due to background conductivities. High values (red) indicate metal objects. The colour scale has a very limited range and the survey does not indicate a lot of metal under the survey area.

The increased values near the centre of the survey area (orange) suggests a different geological composition of the overburden (higher background conductivities) rather than being related to archaeological features.

High values occur around the north and west edges of the survey area and are attributed to metal items at existing boundary walls and fence.

The very high values marked as red spots (Map 7), indicate the presence of buried metal. Most of these correspond with the locations identified in the magnetic gradiometry results.

4. CONCLUSIONS

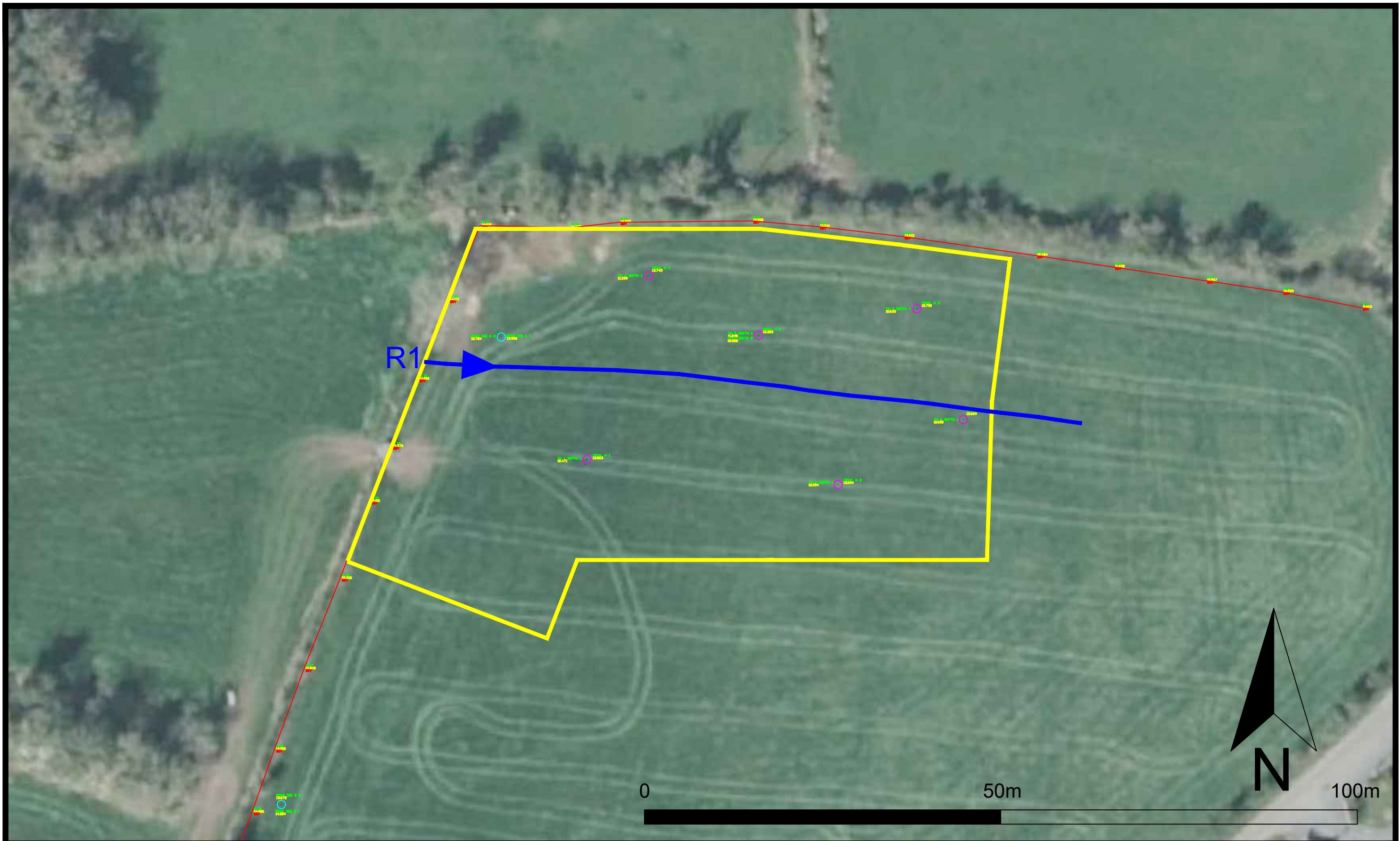
The following conclusions are made:

- Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for the proposed new burial ground, Annaghdown, Co. Galway. The survey consisted of Magnetic Gradiometry, 2D-Resistivity (ERT), Ground Penetrating Radar (GPR) and EM61 Metal Detector. The survey locations are displayed on Map 1.
- The objectives of the survey were to locate possible unknown archaeological deposits or objects within the area of the proposed new burial ground.
- The results of the magnetic gradient survey shown on Map 5 reveal features associated with agricultural activity, such as cultivation patterns and metal remnants of human activity. The results of the magnetic gradient survey do not indicate the presence of archaeological feature or deposits such as foundations, wall remnants, building or ditches.
- The 2D-Resistivity line (Figure 1) shows the geological background across the site consists of overburden (till derived from limestones) to a depth of around 2.5m, underlain by rock. There are no notable features or items in the resistivity data that can be interpreted as archaeological.
- The GPR survey results are shown as time slices from 3D-Blocks in Map 6 at a depth of 0.4m.
- The GPR survey image indicates some diagonal lines, oriented in the same direction as the cultivation patterns visible in the magnetic results.
- The EM61 metal detector (Map 7) indicates the presence of buried metal. Most of this is visible in the magnetic gradient image and these are likely associated with agricultural activity.
- Map 8 contains a summary interpretation of all the features found during the geophysical survey.
- The cultivation patterns are represented by orange arrows oriented in the same direction, and the direction of these cultivation ridges aligns with the historical boundary of the fields running through the survey area, visible on the historical map (Map 2).
- Metal-related anomalies are divided into four types, each represented by a different hatch colour:
 - Black anomalies, are associated with metal present in the fencing associated with the existing field boundaries.
 - Red anomalies correspond to features visible both in the magnetic gradient image and in the EM61 metal detector contour map, indicating larger buried ferritic metal objects.
 - Green anomalies are visible only in the magnetic gradient results and represent small metal objects that were too small to be detected by the EM61 metal detector, such as nails.
 - Cyan anomalies are detected only by the metal detector and are not visible in the magnetic gradient results, indicating non-ferromagnetic metals (such as aluminium or copper).

- While the survey showed a number of items, there are no typical archaeological features like foundations, wall remnants or linear, circular, curved, ellipsoidal and rectangular shapes which are often man-made. The only structures associated with human activity that are visible in the data are cultivation patterns and metal remains which are likely associated with agricultural activity.
- The cultivation ridges identified in the data, may not have a lasting physical visibility and could be the so-called 'ghost ridges' (O'Sullivan 2009).

5. REFERENCES

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10. **Through Time Ltd. 2024.** Archaeological assessment of a proposed new burial ground in Annaghdown, County Galway.



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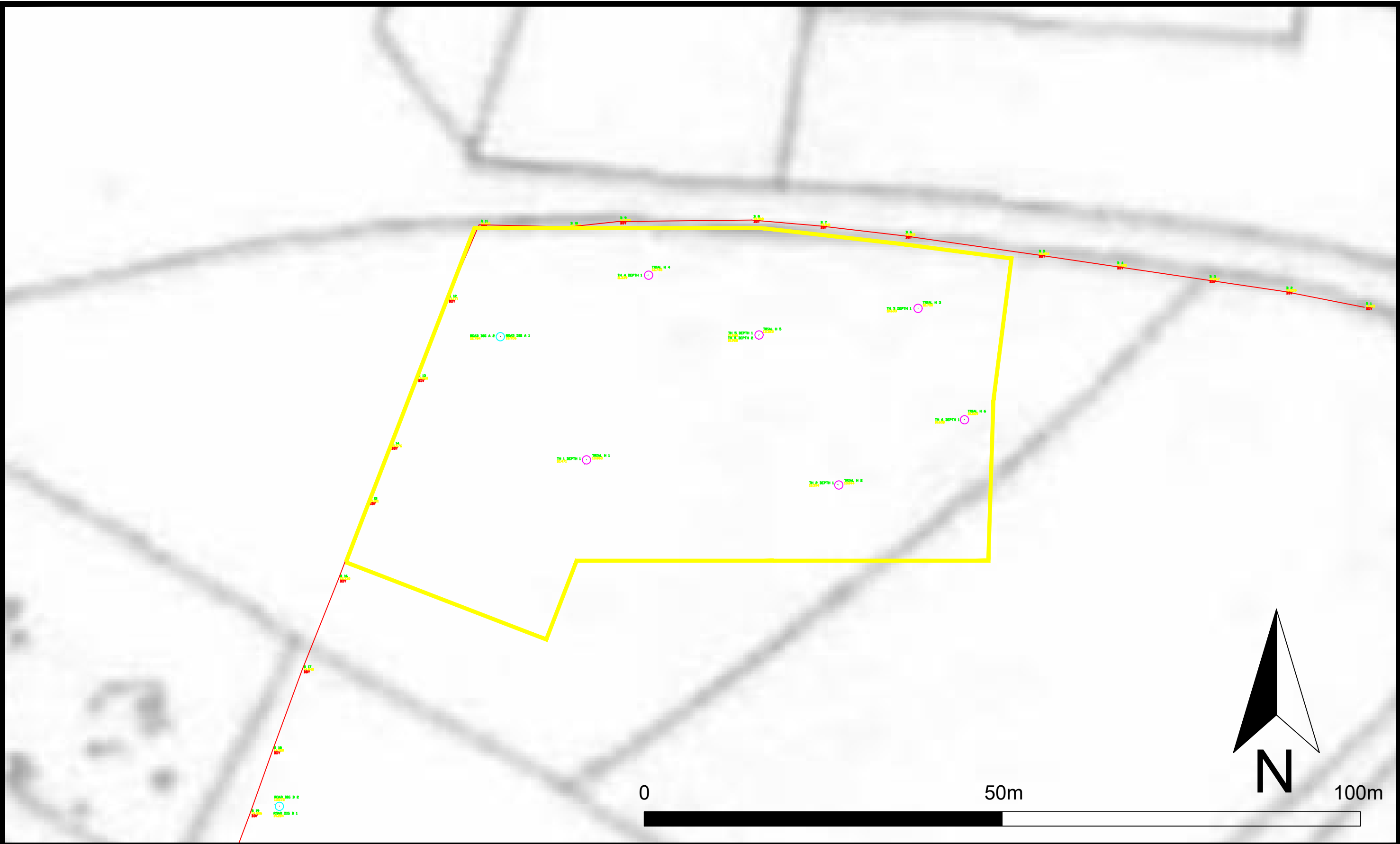
CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 1: Geophysical Survey Location Map

SCALE:	1:500 @ A3
PROJECT:	6836
DRAWN:	JS
DATE:	22/01/2025
MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

Geophysical Survey Locations:

	R1	2D-Resistivity Line
		EM61/Mag/GPR Survey Area
	TRIAL H 4	Trial Pit

Locations are in Irish Transverse Mercator (ITM), Elevations are in mOD (Malin Head)



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CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 2: Extract from 1st edition historical map1837

SCALE:	1:500 @ A3
PROJECT:	6836
DRAWN:	JS
DATE:	22/01/2025
MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

Geophysical Survey Locations:

 EM61/Mag/GPR Survey Area

 TRIAL H 4 Trial Pit

Locations are in Irish Transverse Mercator (ITM), Elevations are in mOD (Malin Head)



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CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 3: Extract from Cassini edition of OS 6-inch map

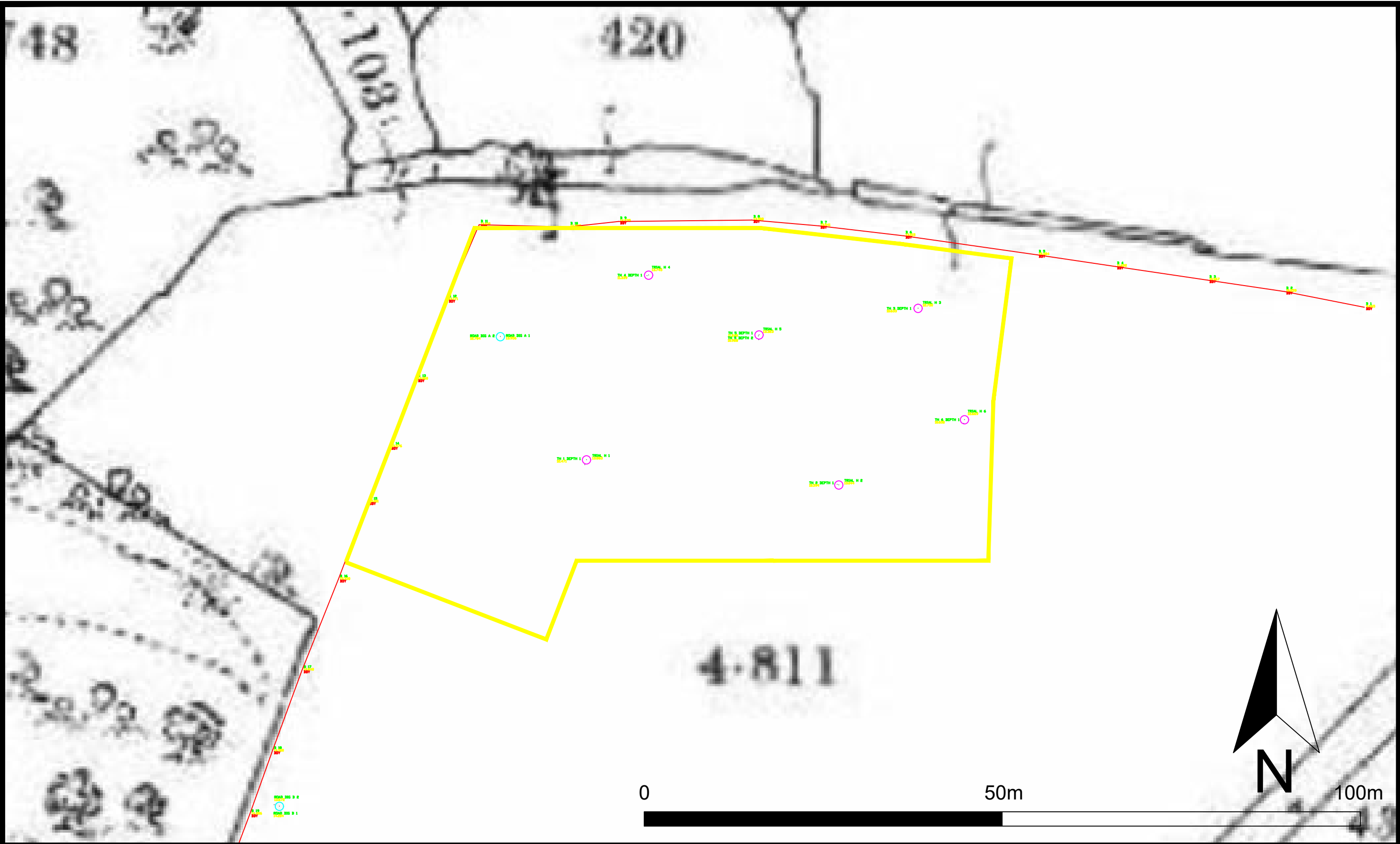
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PROJECT:	6836
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DATE:	22/01/2025
MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

TRIAL H 4

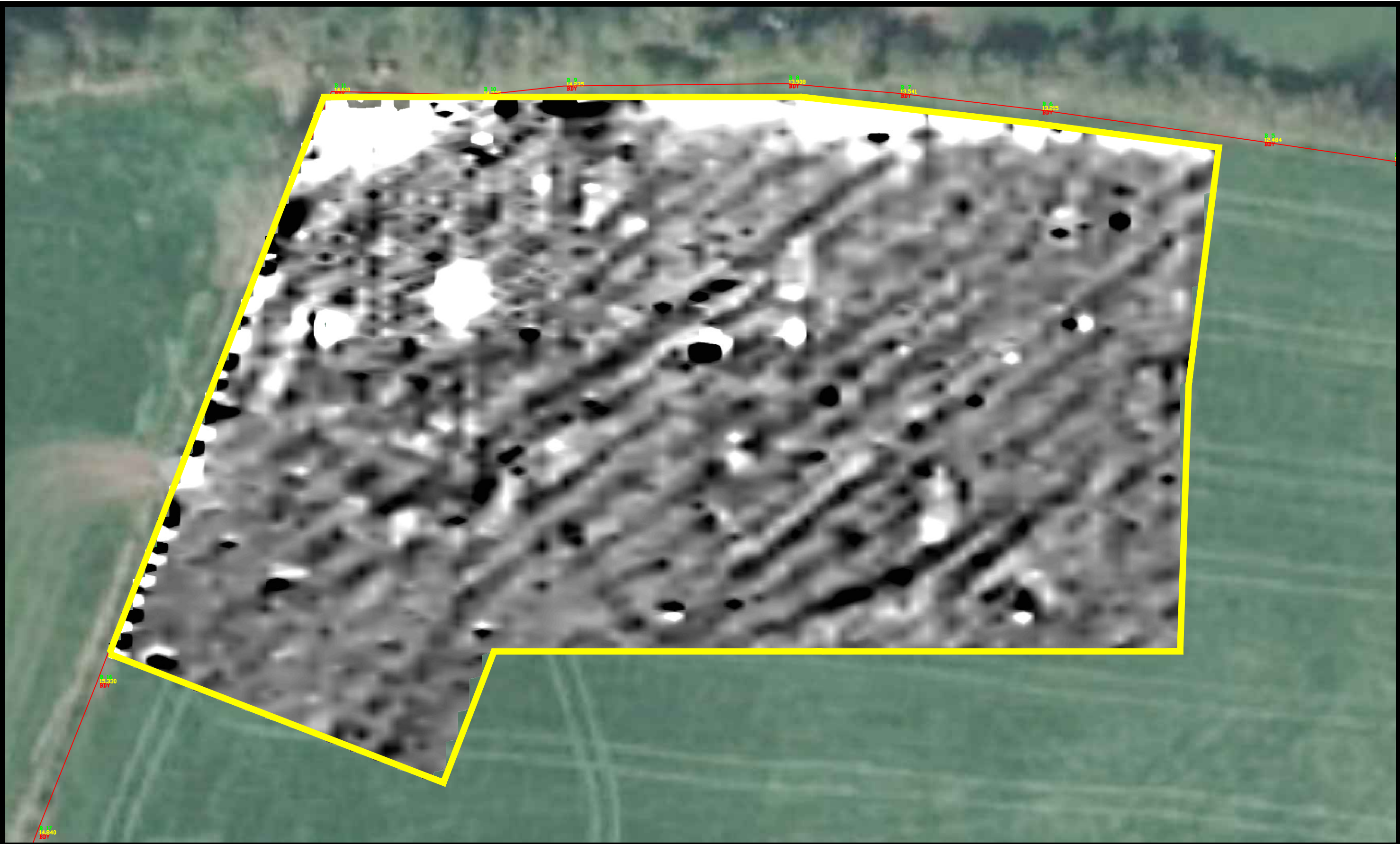
EM61/Mag/GPR Survey Area

Trial Pit

Locations are in Irish Transverse Mercator (ITM), Elevations are in mOD (Malin Head)



Minerex Geophysics Limited Unit F4, Maynooth Business Campus Maynooth, Co. Kildare Tel. (01) 6510030 Email: info@mgx.ie Web: www.mgx.ie	CLIENT	Galway County Council	SCALE:	1:500 @ A3	Geophysical Survey Locations: EM61/Mag/GPR Survey Area TRIAL H 4 Trial Pit Locations are in Irish Transverse Mercator (ITM), Elevations are in mOD (Malin Head)
	PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey	PROJECT:	6836	
	TITLE	Map 4: Extract from historical 25-inch map	DRAWN:	JS	
			DATE:	22/01/2025	
			MGX FILE:	6836f_Drawings.dwg	
			STATUS:	Final	

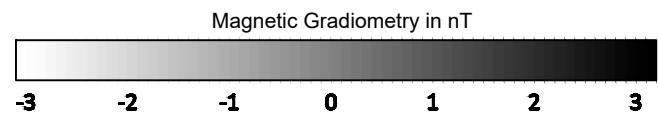


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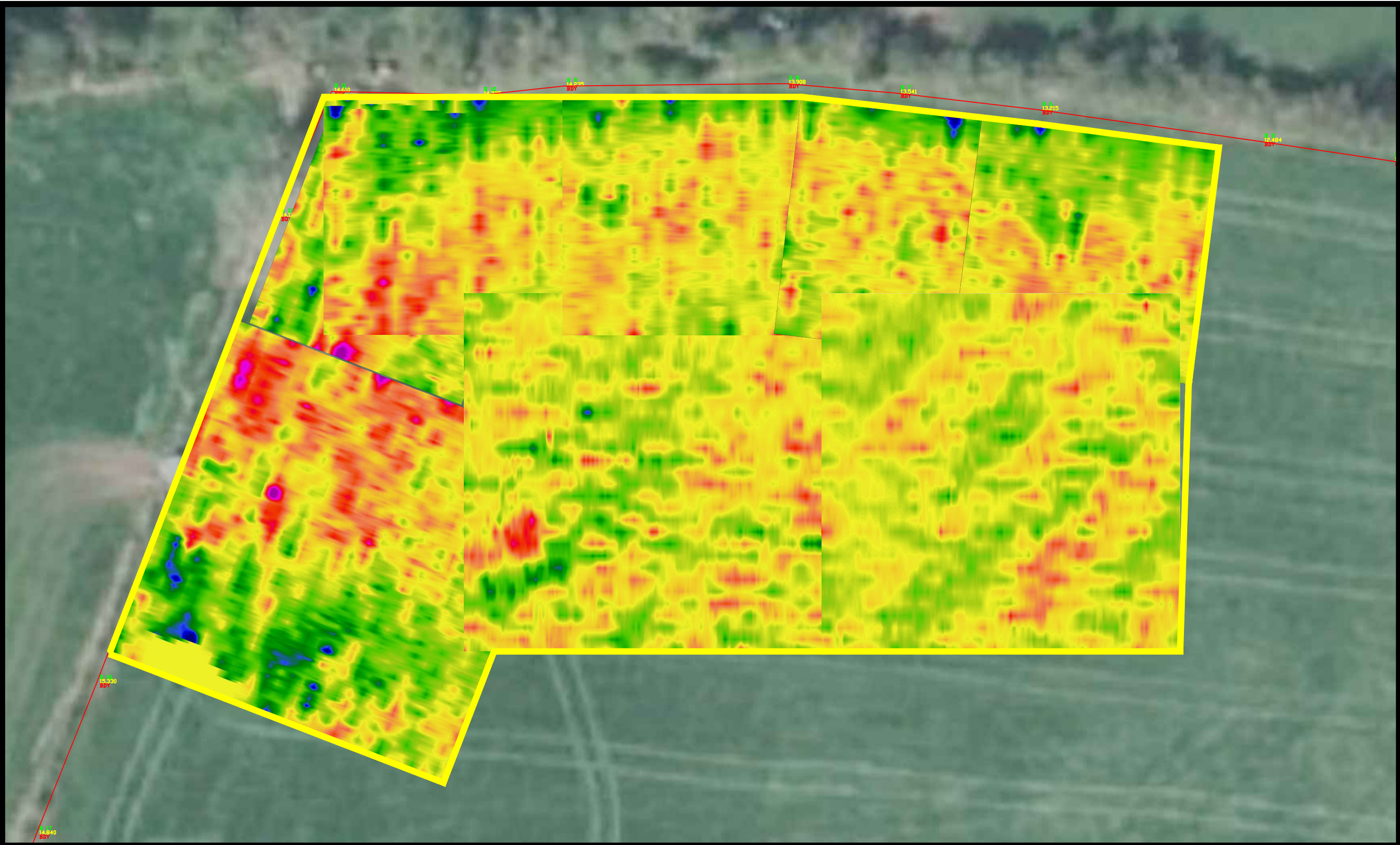
CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 5: Magnetic Gradient Map with +/- 3nT

SCALE:	1:300 @ A3
PROJECT:	6836
DRAWN:	JS
DATE:	22/01/2025
MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

Magnetic Gradiometry Survey Values:



The grey-scale image shows the magnetic gradient between the lower and upper sensor (1m vertical separation) in nT (nanoTesla) with a range of +/- 3 nT. Black (positive) indicates that the magnetic field at the lower sensor (approx. 0.3m above ground) is higher than the magnetic field at the upper sensor (approx. 1.3 above ground).

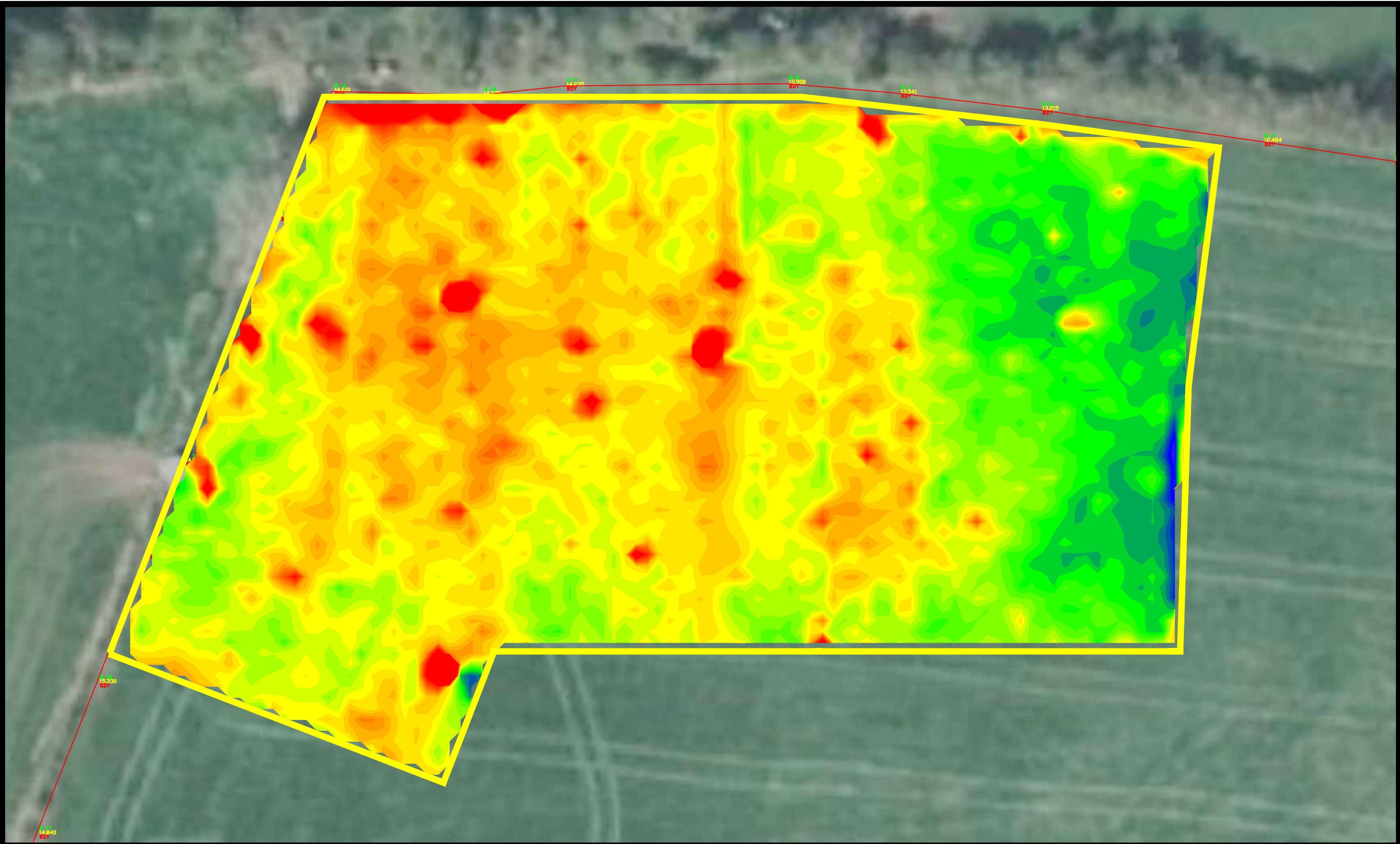


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CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 6: GPR Depth Slice Image at 0.4m

SCALE:	1:300 @ A3
PROJECT:	6836
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MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

The map shows a depth slice of the 400MHz GPR survey at approx. 0.4m depth. The vertical depth is approximate and computed with GPR wave velocity of 0.1 m/ns.

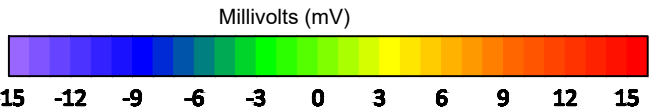


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CLIENT	Galway County Council
PROJECT	Proposed New Burial Ground Archaeological Geophysical Survey
TITLE	Map 7: EM61 Metal Detector Contour Map

SCALE:	1:300 @ A3
PROJECT:	6836
DRAWN:	JS
DATE:	22/01/2025
MGX FILE:	6836f_Drawings.dwg
STATUS:	Final

EM61 Metal Detector Values:



Colour scale images represent responses from the EM61 survey. Blue and green represents little or no response, indicating little or no metal, the change from green/blue to orange across the site indicates a change in background geological conditions while red is a strong response which indicates the presence of metal in the area.

