HUNTER GEOPHYSICS

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GEOPHYSICAL SURVEY REPORT

SITE NAME	Creswick Cemetery
SITE CODE	2011/1
CLIENT	Creswick Cemetery Trust
HERITAGE VICTORIA CODE	3951 CRESWICK CEMETERY
SURVEYORS	David Hunter (project director), Shannon Hunter, James Butler, Matthew Crosbie, Zara Dennis, Michael Lever, Jasmyne Pendragon, Alexander Sly, Alexander Stott, Zachary Spielvogel.
SURVEY DATES	3rd April 2011, 10th April 2011, 30th April 2011, 14th May 2011, 21st May 2011, 22nd May 2011, 11th July 2011, 7th - 11th December 2011, 20th December 2011.
REPORT SUBMISSION DATE	19th March 2012.
REPORT AUTHOR	David Hunter

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Unless otherwise noted, all *coloured* aerial photographs are courtesy of NearMap. Black-and-white aerial photographs are courtesy of the State Library of Victoria.

Statement of indemnity

The results and interpretation of the geophysical surveys described herein should not be considered an absolute representation of the underlying soil or archaeological features, but instead as a hypothesis yet to be verified. Confirmation of geophysical interpretations is only possible through archaeological excavation.

While Hunter Geophysics aims to produce accurate interpretations of geophysical surveys, numerous unforeseeable issues may arise that may limit the accuracy of interpretations. These may include unforeseen soil or geological conditions, the presence of rabbit or other animal burrowing, ploughing, site drainage and interference caused by variations in the atmosphere.

Every effort is made to ensure that these risks are minimized, but Hunter Geophysics does not guarantee that the interpretations of geophysical data provided herein are accurate.

Executive summary

An intensive geophysical survey was undertaken by Hunter Geophysics at the Creswick Cemetery for the purposes of locating unmarked graves. The geophysical investigation has not only determined the location of numerous unmarked graves, but has also detected the remains of a well, garden beds and other soil and archaeological features associated with the sexton’s cottage. The sexton’s cottage, believed to have been demolished circa 1969, has also been relocated through the examination of aerial photographs of the site. Artefacts found on the ground surface immediately south of the area subjected to the geophysical survey are believed to be associated with the sexton’s house: natural soil processes have contributed to the southward movement of these artefacts.

Please note that there are two cemeteries in Creswick: the ‘Old Creswick Cemetery’ on Drummond Street, and the newer ‘Creswick Cemetery’ on the Clunes-Creswick Road; the (newer) Creswick Cemetery is the cemetery that was the subject of the geophysical investigation detailed herein.

Front cover image: memorial monument listing the names of the individuals known to have been buried in compartment six at the Creswick Cemetery, Creswick, Victoria.

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Introduction

Hunter Geophysics were commissioned by the Creswick Cemetery Trust to undertake a geophysical survey of Compartment Six of the Creswick Cemetery, Creswick, Victoria. Heritage Victoria, a part of the Department of Planning and Community Development, was notified of the intention to perform the geophysical survey as per legislative requirements.

Aims

The geophysical survey was requested to determine the location of any unmarked graves within a 50x50-metre area in Compartment Six at the Creswick Cemetery. Cemetery records indicate that 377 individuals were buried in the area to be covered by the geophysical survey.

Geography, topography, geology and climate

The Creswick Cemetery is located to the north of the township of Creswick, along the Creswick-Clunes Road. The southern entrance to the cemetery is located at Map Grid of Australia (MGA) coordinates E755428 N5856236 (zone 54, using the Geodetic Datum of Australia 1994).

The cemetery is situated on a slight rise (a five-metre increase in elevation over the 430 metres from the southern entrance to the northern fence) on a Pliocene basalt bedrock (as per figure 3), resulting in a clay soil matrix.

The geophysical survey occurred across three field seasons:

> 21st and 22nd May, 2011, when initial ground-penetrating radar and magnetic gradiometry data were collected. The fortnight proceeding this survey saw little rainfall, allowing the penetration of radiowaves from the ground-penetrating radar unit to exceed one metre.
>
> 11th July, 2011, when the electrical resistance data were collected. The month proceeding this survey saw heavy rainfall, likely enhancing the results of the electrical resistance survey.
>
> December, 2011, when ground-penetrating radar and magnetic gradiometry data were re-collected. Electromagnetic (ground conductivity) data were also collected during this phase. While rain was absent throughout this period, the soil was likely saturated due to the recent wet season. Radiowaves from the ground-penetrating radar unit did not penetrate more than eighty centimetres into the ground during this field season.

Archaeological background

Historic records show the burial of 377 individuals in compartment six of the New Creswick Cemetery. Records and aerial photographs also indicate the presence of a cottage, previously occupied by cemetery sextons, near the survey area.

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Creswick Cemetery Landscape: A Brief History
Section by PenDragon Heritage (ed. D. Hunter).

The Creswick Cemetery has a long history starting from its first burial, which was that of a two year old named John James Bunyan on 20th December, 1858. There have been over 11,900 burials registered by the cemetery trust since its being gazetted. A memorial was erected in 1909 at the cemetery to commemorate the twenty-two miners that died during the Australasian Mine Disaster of 1882. Nineteen of the twenty-two miners from the Australasian Mine Disaster are buried at the Creswick Cemetery.

Compartment Six of the Creswick Cemetery has experienced changes to its landscape. A cottage was built in 1858, believed to have been in the approximate location of the present day galvanized steel sheds. This cottage was occupied by the various sextons of the Cemetery. The first sexton, Mr Benjamin White, maintained the cemetery until his death, when he was succeeded by his son. In 1886, Robert Wall Jnr. became sexton of the cemetery and was provided an annual wage of £120 and given residence in the cottage. Seven sextons resided in the cottage until 1922. The last official sexton was Mr A Ellis, who resigned in 1956. The sexton's cottage was leased to the public from 1955 until June 1969, and was advertised for demolition or removal in 1969.

Numerous historically significant individuals have been interred at the Creswick Cemetery, including Jane Ingram, Sir Alexander Peacock, William Black Miller, William "Baron" Bell, John O'Neill, Jeremiah Coffey and Peter Harrington. The Chinese migration in to the region during the Gold Rush resulted in numerous Chinese being buried at the Creswick Cemetery (within Compartment Six).

Figure 1: aerial photograph of Creswick, showing the Creswick Cemetery (circled in red to the north) and the Old Creswick Cemetery (circled in red to the south). (N.B.: North is toward the top of the image).

Figure 2: aerial photograph of the Creswick Cemetery, dated 2nd July 2011, shown with a 25-metre MGA grid.

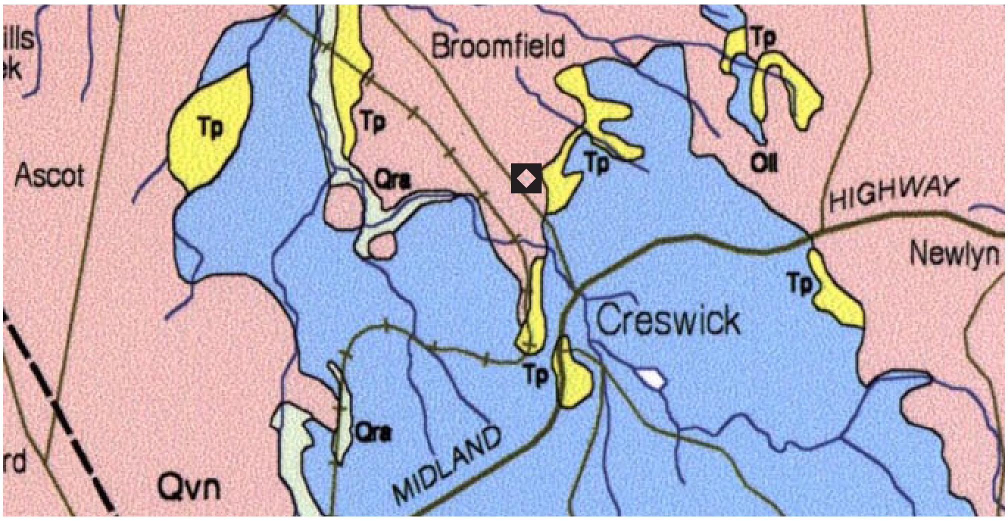
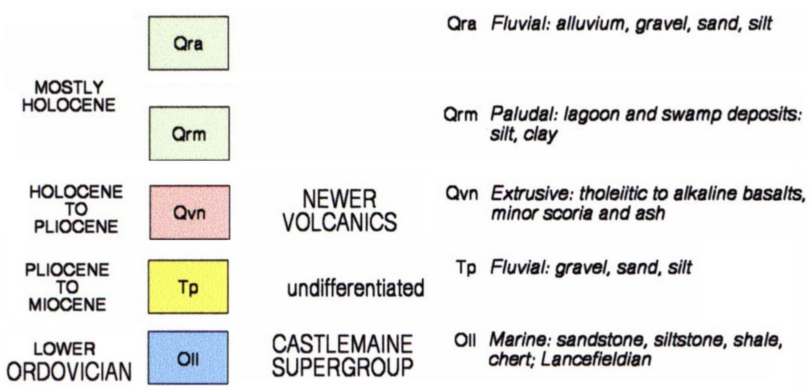


Figure 3 (above and right): an extract of the Ballarat Australia 1:250,000 geological map showing Creswick and surrounding areas. The Creswick Cemetery is shown on the map as a black square to the northwest of Creswick (within the pink Qvn area). Map courtesy of the Geological Survey of Victoria.



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Methodology

Ground-penetrating radar (GPR), electrical resistance, electromagnetic (ground conductivity) and magnetic gradiometer data were collected by Hunter Geophysics across three field seasons. Rectangular survey areas were staked out using a Topcon GR-3 RTK GNSS receiver, and divided into smaller sub-grids around surface obstacles.

Ground-penetrating Radar survey

Data collection

The survey was performed following survey traverses running in alignment with magnetic north and magnetic south. Subsequent traverses were surveyed in alternate directions (i.e., in a ‘zig-zag’ fashion).

Data were recorded using a Sensors and Software Noggin+ SmartCart, with a central transmitting frequency of 250MHz. Traverses were spaced at 25cm intervals, with each GPR trace being recorded at 5cm intervals along each traverse. Each GPR trace was recorded with a time-window of 63 nanoseconds.

Data were collected automatically by a computer using an odometer wheel calibrated at the beginning of the survey. In this manner, GPR traces are recorded autonomously as the surveyor pushes the GPR system along the traverse. The data were stored in an internal data logger and downloaded to a field computer using the Sensors and Software WinPXFER v3 software.

Data processing

The data were pre-processed in the Sensors and Software Ekko_View Deluxe software. This phase involved the reversing of data collected from alternate survey traverses (in order to have each traverse aligned correctly) and the re-sampling of GPR traces to an effective interval of 4.7cm (in order to correct for topographic disturbances, which cause incorrect odometer readings).

The data were then plotted using the Sensors and Software GFP_Edit v4 software, and then transferred to the Sensors and Software Ekko_Mapper v4 software for further processing. This further processing involved subjecting the data to a migration filter (using a velocity of 0.73m/ns) and a background subtraction filter (using three GPR traces as an average for subtraction). Finally, the data were subjected to a bandpass filter, which filtered out any recorded radiowaves with a frequency outside of the range of 200-400MHz. Ekko_Mapper was then used to create horizontal depth-slices from the collected data.

The data were not subjected to topographic corrections as the survey area was relatively flat (and, therefore, corrections were not required).

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Magnetic gradiometry survey

Data collection

The survey was performed following survey traverses running in alignment with magnetic north and magnetic south. Subsequent traverses were surveyed in alternate directions (i.e., in a ‘zig-zag’ fashion).

Data were recorded using a Bartington Grad601-1 single-axis fluxgate magnetic gradiometer. Traverses were spaced at 25cm intervals, with each reading being recorded at 12.5cm intervals along each traverse. The instrument was set to a sensitivity of 0.1nT and was calibrated at MGA coordinates E755536.7 N5856379.35 (zone 54).

Data were collected automatically using an internal sample trigger while the operator walked at a constant pace along each traverse. The data were stored in an internal data logger and downloaded to a field computer using the Snuffler v0.83 software.

Data processing

The data were pre-processed in the Snuffler software in order to correctly position each reading. Further processing of the data involved the use of a Zero Mean Traverse filter and a Zero Mean Grid filter in order to equalize sub-grids. De-staggering of the data was also undertaken prior to interpolation and plotting using a greyscale format. The data were clipped at -12.7nT (black) and 8.7nT (white).

Electrical resistance survey

Data collection

The survey was performed following a survey traverse running in alignment with magnetic north and magnetic south. As this survey was of an experimental nature, only one traverse was surveyed. The northern end of the traverse was located at MGA coordinates E755513.1 N5856408.05 and the southern end of the traverse was located at MGA coordinates E755505.5 N5856369.3.

Data were recorded using a Hunter Geophysics-built twin-probe electrical resistivity system, with a mobile electrode separation of 50cm. Readings were taken at 25cm intervals along the traverse.

Data were recorded manually and entered into a field computer using the Snuffler v0.83 software.

Data processing

The data were converted from ‘raw’ electrical resistivity readings into ‘processed’ electrical resistance readings, interpolated and plotted using a greyscale format. The data were also plotted on a linear graph for viewing purposes using Micrsoft Excel v12.3.2.

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Electromagnetic (ground conductivity) survey

Data collection

The survey was performed following survey traverses running in alignment with magnetic north and magnetic south. Subsequent traverses were surveyed in alternate directions (i.e., in a 'zig-zag' fashion).

Data were recorded using a Geonics EM-38 Mk. I Ground Conductivity Meter (otherwise known as a Geonics EM-38 DLM), in the vertical quadrature-phase mode. Traverses were spaced at 25cm intervals, with each reading being taken every ten centimetres along each traverse. As this survey was of an experimental nature, only forty traverses were surveyed.

Data were collected automatically using an internal sample trigger while the operator walked at a constant pace along each traverse. The data were stored in a field computer using the Geonics EM38xp v1.06 software.

Data processing

The data were pre-processed in the Geonics DAT38W v2.03 software in order to correctly position each reading. The data was then loaded into the Golden Software Surfer v9.11.947 software before being subjected to interpolation and plotting using a colour scale. The data were clipped at 5.05 millisiemens per metre (mS/m) (purple) and 33.5mS/m (red).

Aerial photograph analysis

Aerial photographs were collected from NearMap and the State Library of Victoria and were interpreted as per traditional aerial archaeological techniques. The aerial photographs and interpretations were entered into a Geographic Information System (GIS) environment using Global Mapper v.12 for presentation purposes.

Reporting, mapping and archiving

The geophysical survey and report follow the recommendations outlined in the English Heritage Guidelines (David 1995) and IFA Paper No. 6 (Gaffney et al. 2002) as a minimum standard. Mapping was performed using a Topcon GR-3 real-time kinematic global navigation satellite system (RTK GNSS), providing a precision of less than one centimetre in the horizontal plane, and less than two centimetres in the vertical plane. This is of a higher precision than required by the English Heritage Guidelines) and Aboriginal Affairs Victoria requirements (both of which require a half-metre precision as a minimum).

Geophysical data, figures and text are archived in-house following the recommendations of the Archaeology Data Service (Schmidt 2001).

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Results

Aerial photograph examination

Aerial photographs from NearMap, Google Earth and government were examined for evidence of potential archaeological features. Aerial photographs from Google Earth were of a low resolution and were not suitable for the purposes of archaeological prospection; however, the NearMap- and government-supplied aerial photographs provide evidence of the location of the former sexton's cottage, as well as a drainage gully running southeast from the cottage.

Due to their oblique nature (i.e. the photographs were not taken directly above the survey area, but rather on an angle to the ground), the aerial photographs cannot be accurately georeference ('matched up') with ground features shown in the maps produced by Hunter Geophysics. The aerial photographs are shifted at most sixty centimetres northwest of their correct position.

Please see figures 4 to 12 on the following pages for in-depth results of the aerial photograph examinations.

Figure 4: aerial photograph of the southern half of the Creswick Cemetery, showing structures (in red), the concrete block upon which a horse-drawn scraper is displayed (in teal), the two trees and stump (in green) and the creek (in dark blue).

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Figure 5: aerial photograph of the southern half of the Creswick Cemetery, with an aerial photograph of the site taken in 1977 overlaid above the current aerial photograph.

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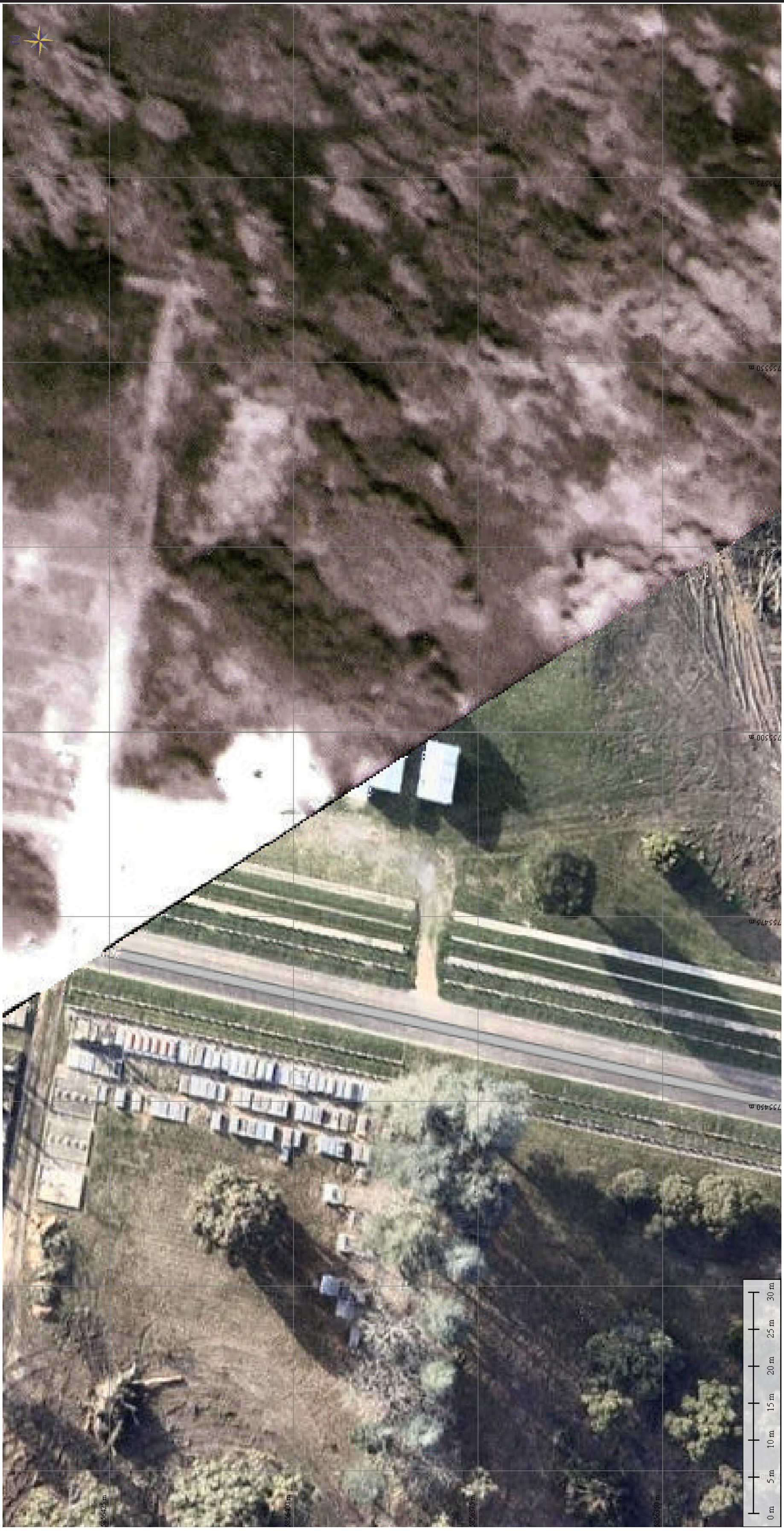

Figure 6: detailed view of the 1977 aerial photograph in the area surrounding the geophysical survey area.

Figure 7: interpretation of the 1977 aerial photograph shows the probable location of the former sexton's cottage.

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Figure 8: the former sexton's cottage. Image courtesy of the Creswick Cemetery Trust.

Figure 9: the former sexton's cottage. Image courtesy of the Creswick Cemetery Trust.

Figure 10: the location of the former sexton's cottage is shown (in yellow) relative to the two galvanized steel sheds present at the site today.

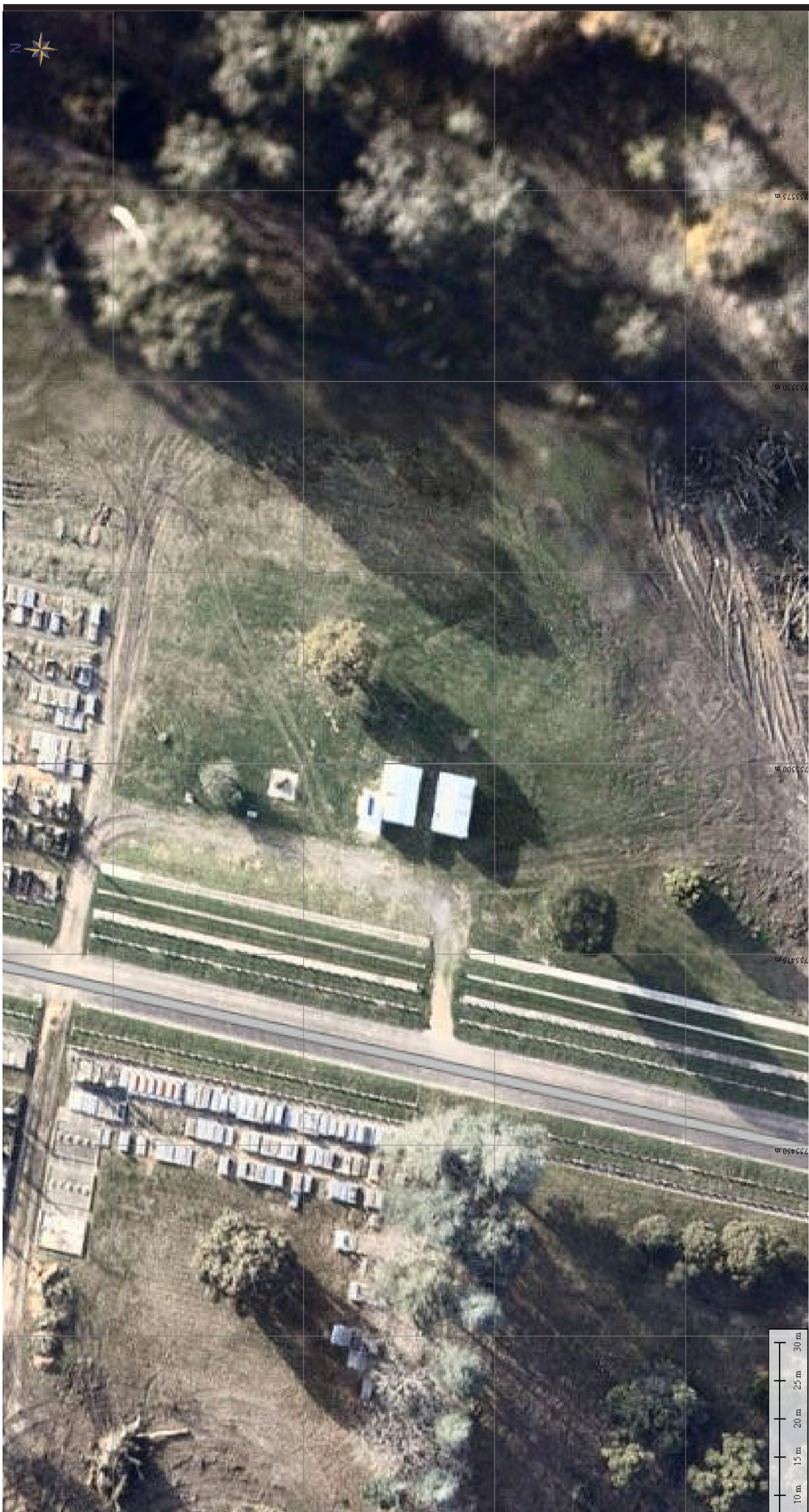

Figure 11: detailed view of the current aerial photograph, showing Compartment Six (to the immediate east of the two galvanized steel sheds).

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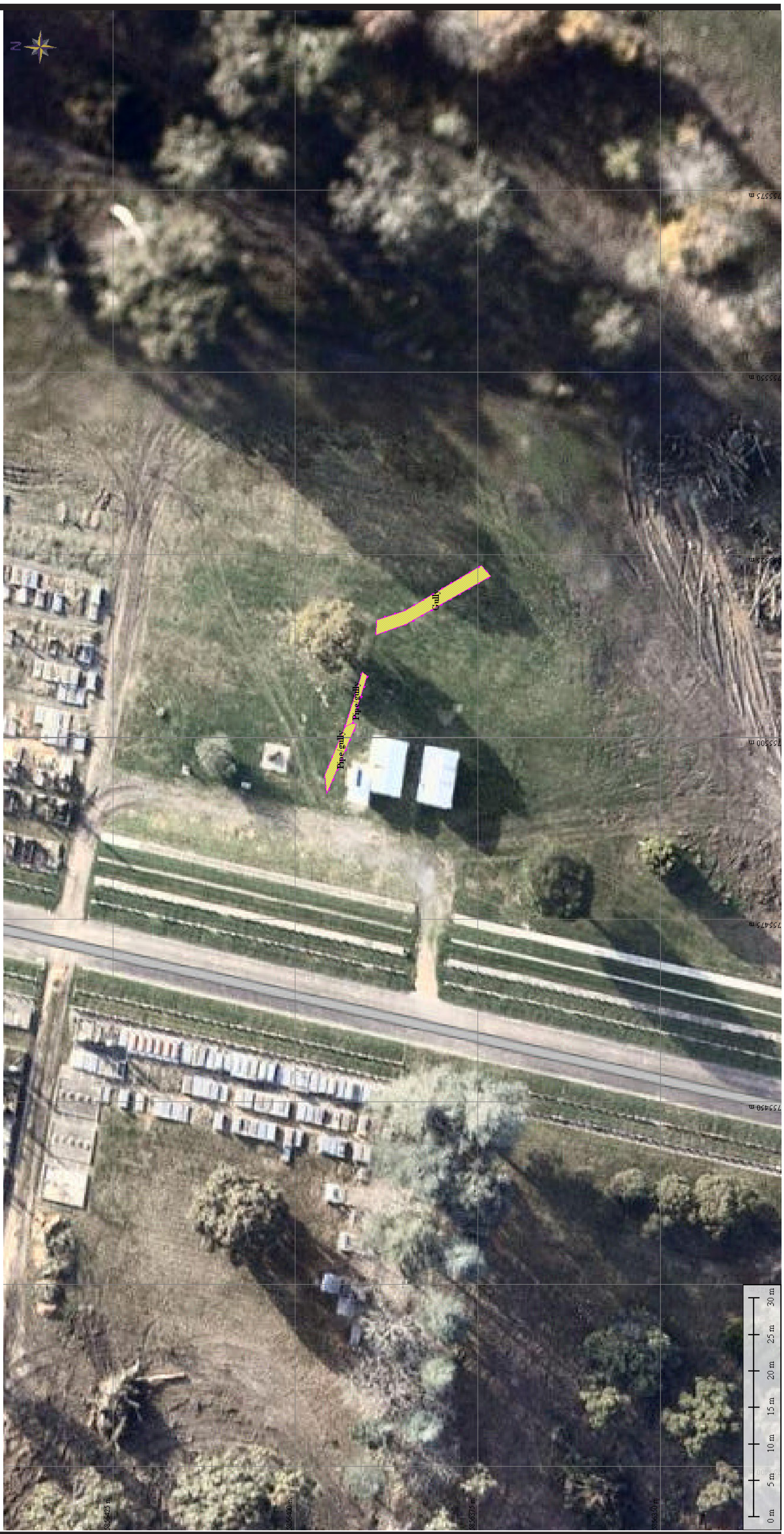

Figure 12: interpretation of the current aerial photograph shows the location of drainage likely associated with the former sexton's cottage.

Note that these drainage features also appear in the ground-penetrating radar results.

Ground-penetrating Radar survey

The ground-penetrating radar survey provided the most detail concerning the underlying archaeological features and the location of unmarked graves within the survey area. Combined with the findings of the aerial photograph examinations and the results of magnetic gradiometry survey, two buried metal pipes have been detected, several rows of unmarked graves - as well as numerous scattered unmarked graves - have been located, along with archaeological features including a drainage ditch/gully believed to be associated with the sexton's cottage. Additionally, other broad areas of uncertain soil disturbance have been located; these areas are consistent with rubbish middens (pits) but this may only be verified through archaeological excavation.

A more detailed discussion on the drainage ditch/gully is on page 37. The following pages show the various depth-slices generated from the collected ground-penetrating radar data, along with interpretation maps.

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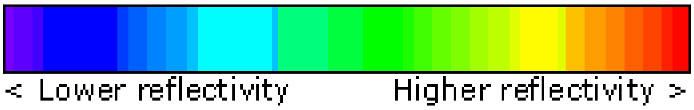

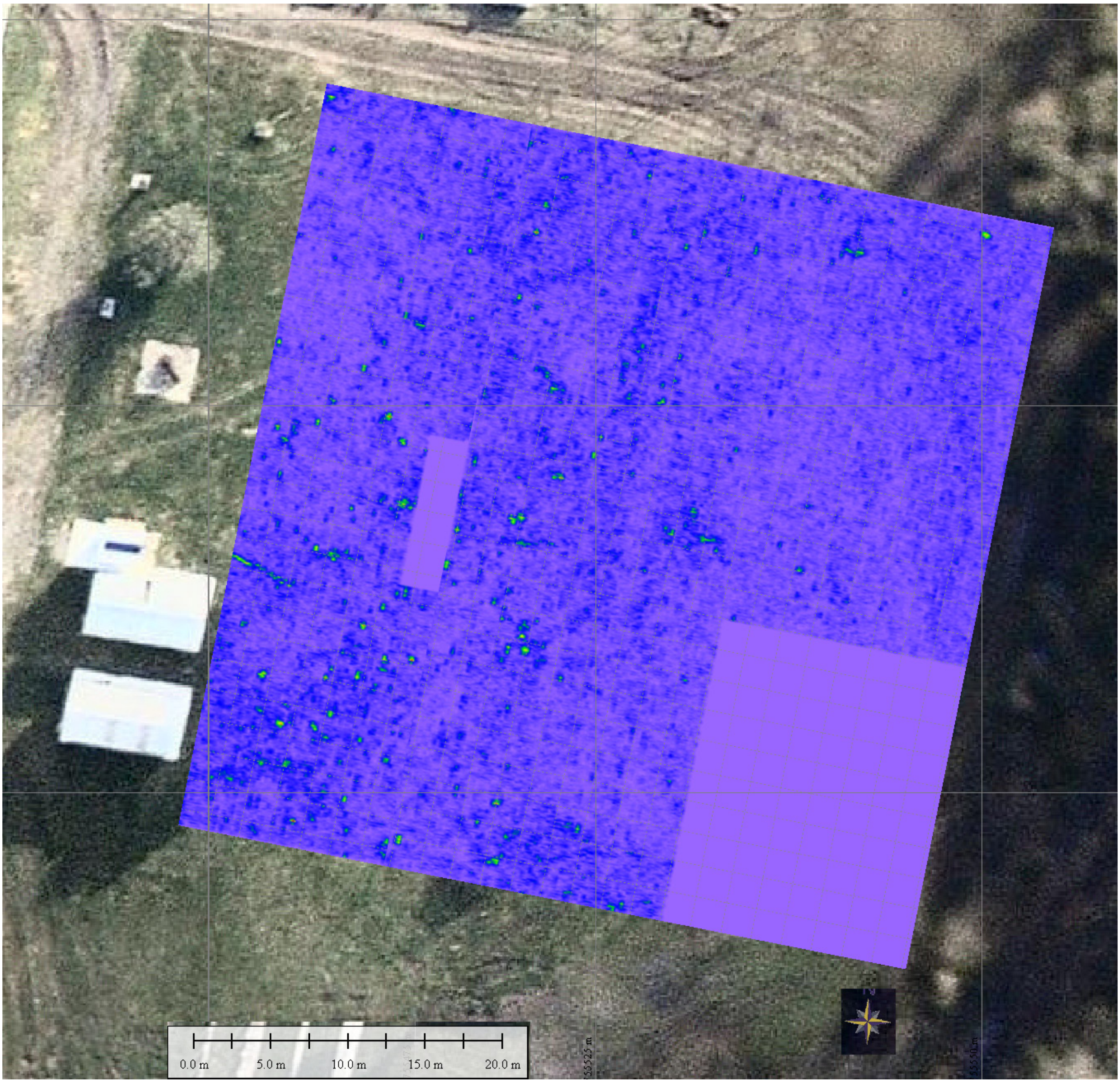

Figure 13: Ground-penetrating Radar (GPR) depth slice, 0-10cm below ground surface.

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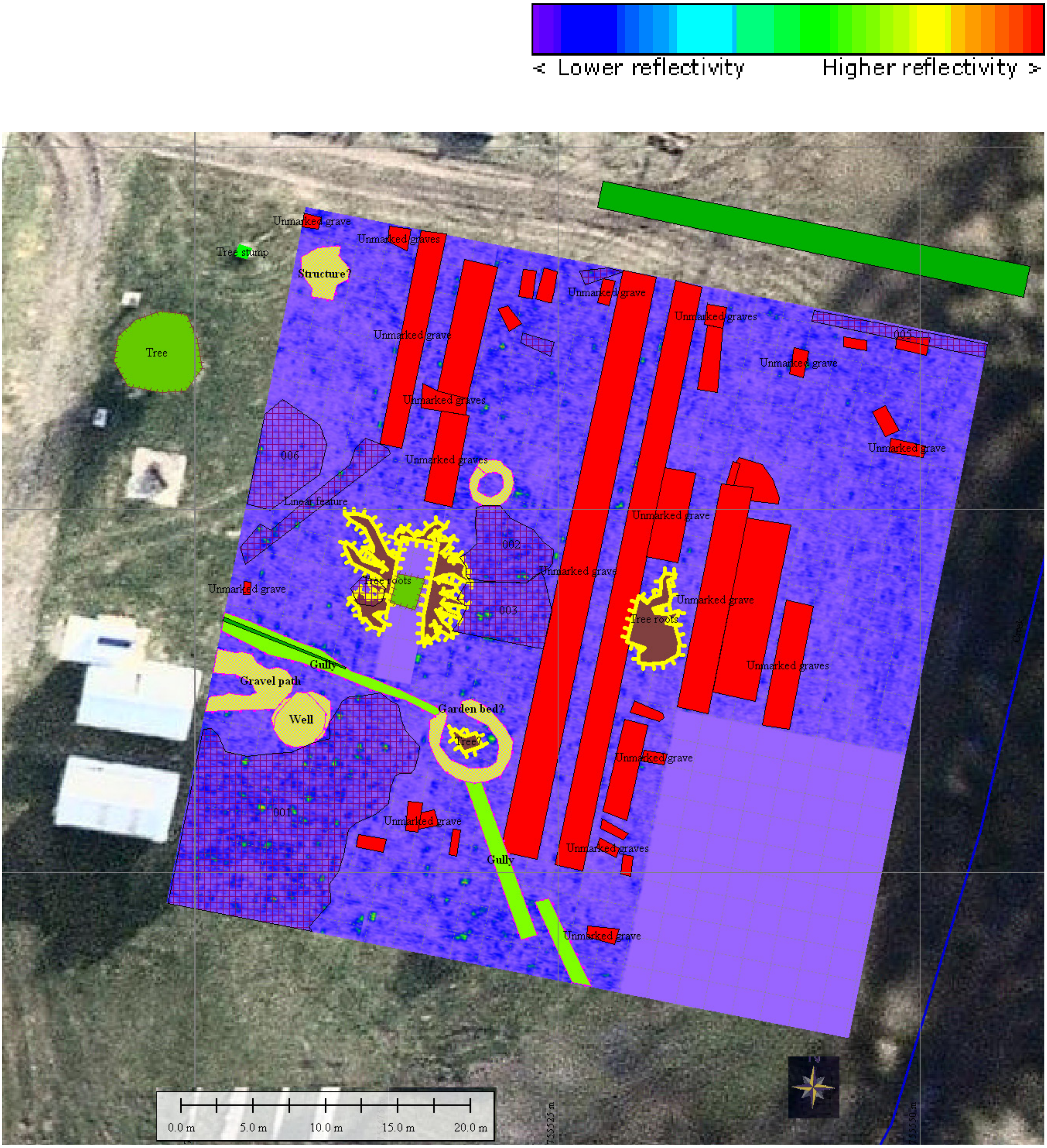

Figure 14: GPR depth slice, 0-10cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

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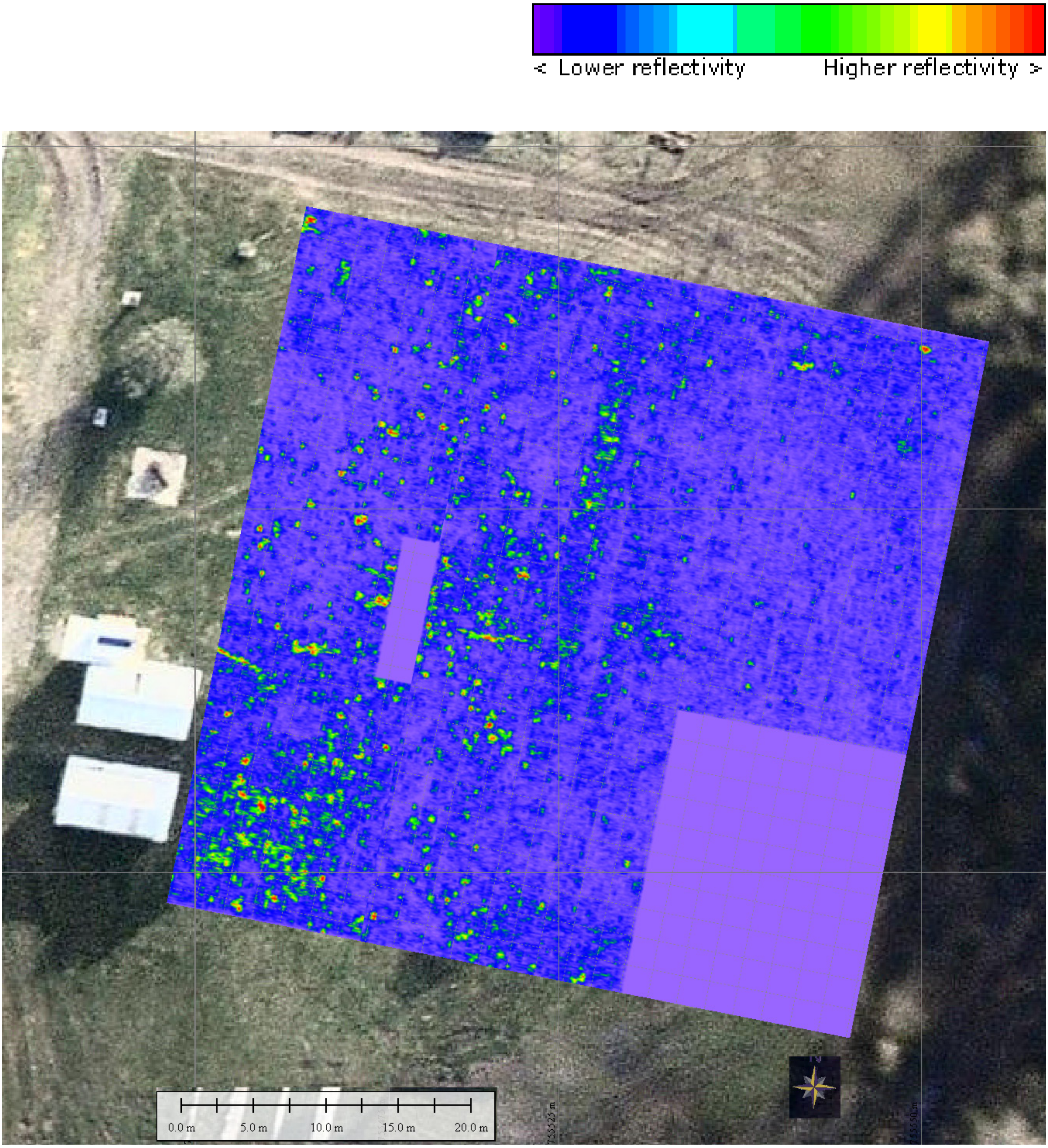

Figure 15: Ground-penetrating Radar (GPR) depth slice, 10-20cm below ground surface.

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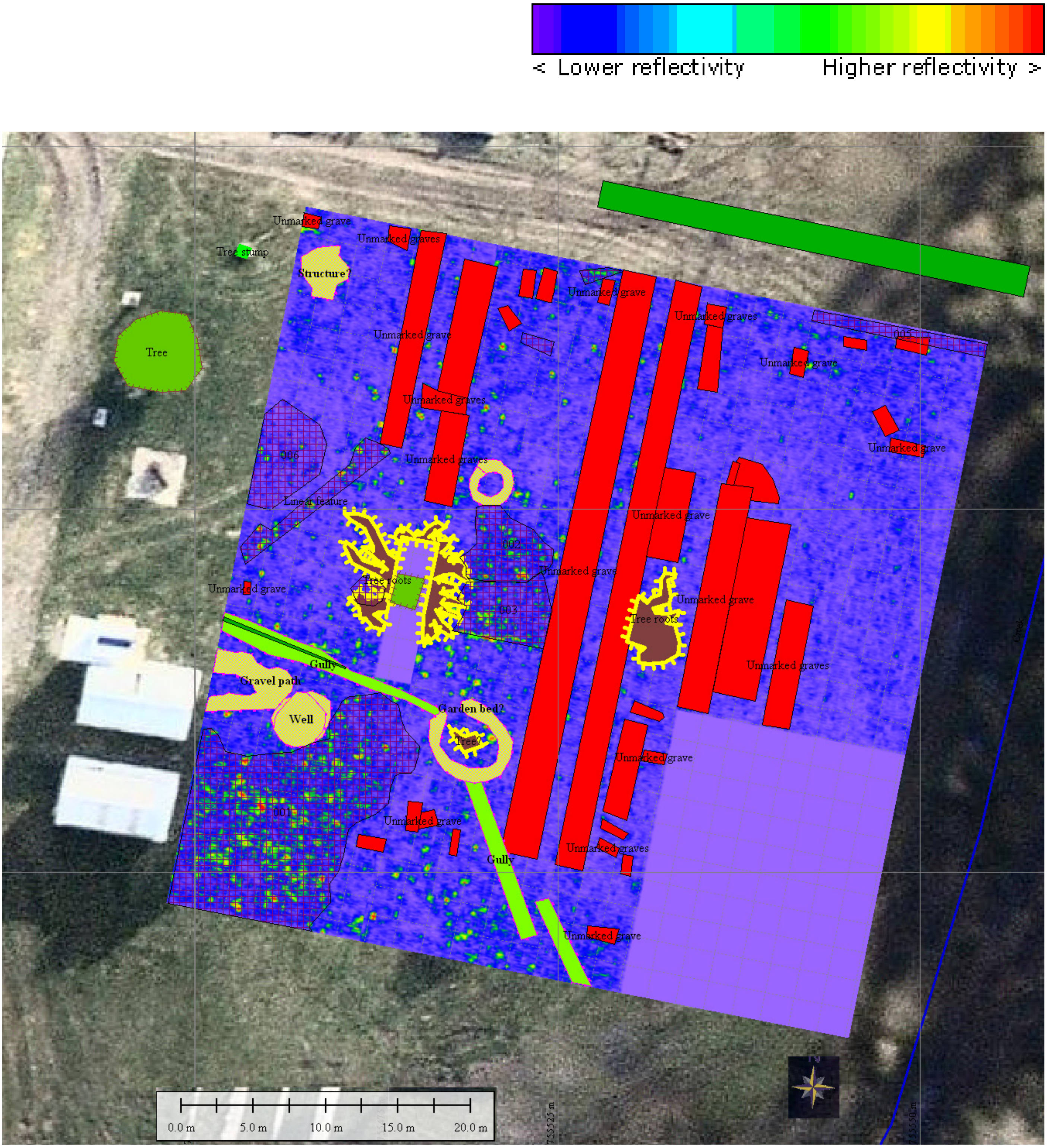

Figure 16: GPR depth slice, 10-20cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

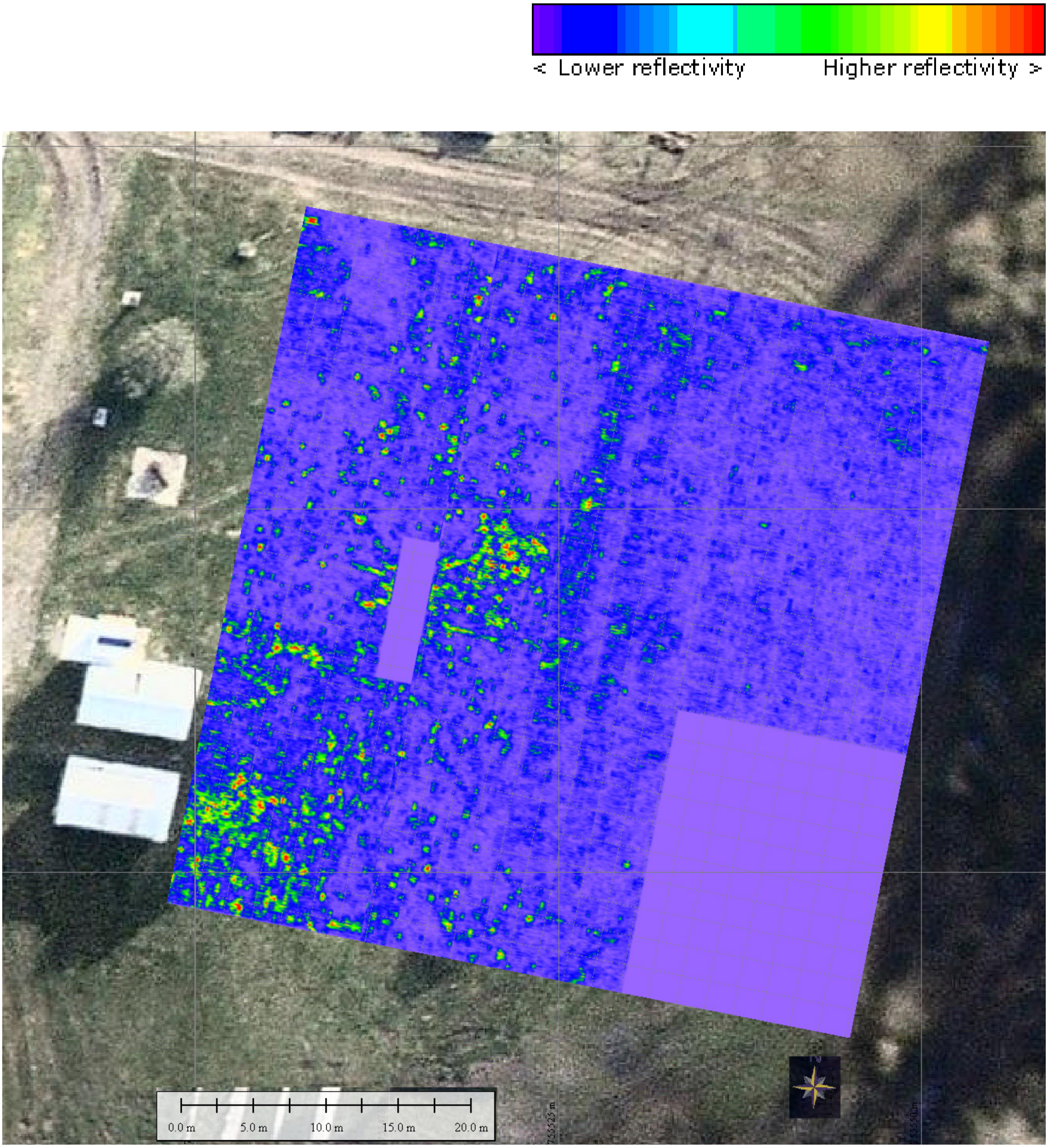

Figure 17: Ground-penetrating Radar (GPR) depth slice, 20-30cm below ground surface.

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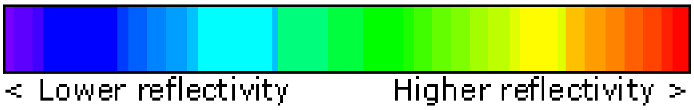

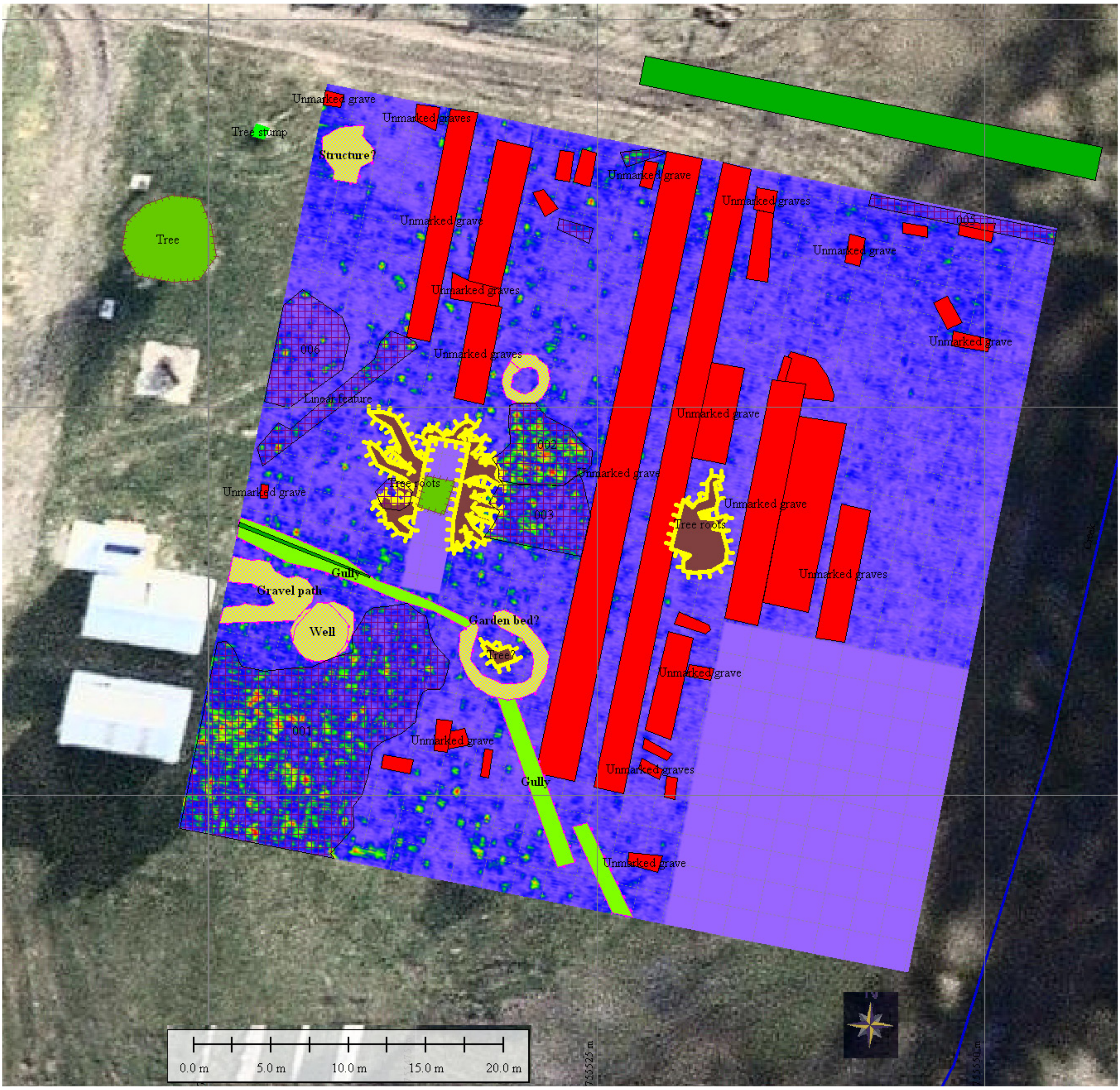

Figure 18: GPR depth slice, 20-30cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

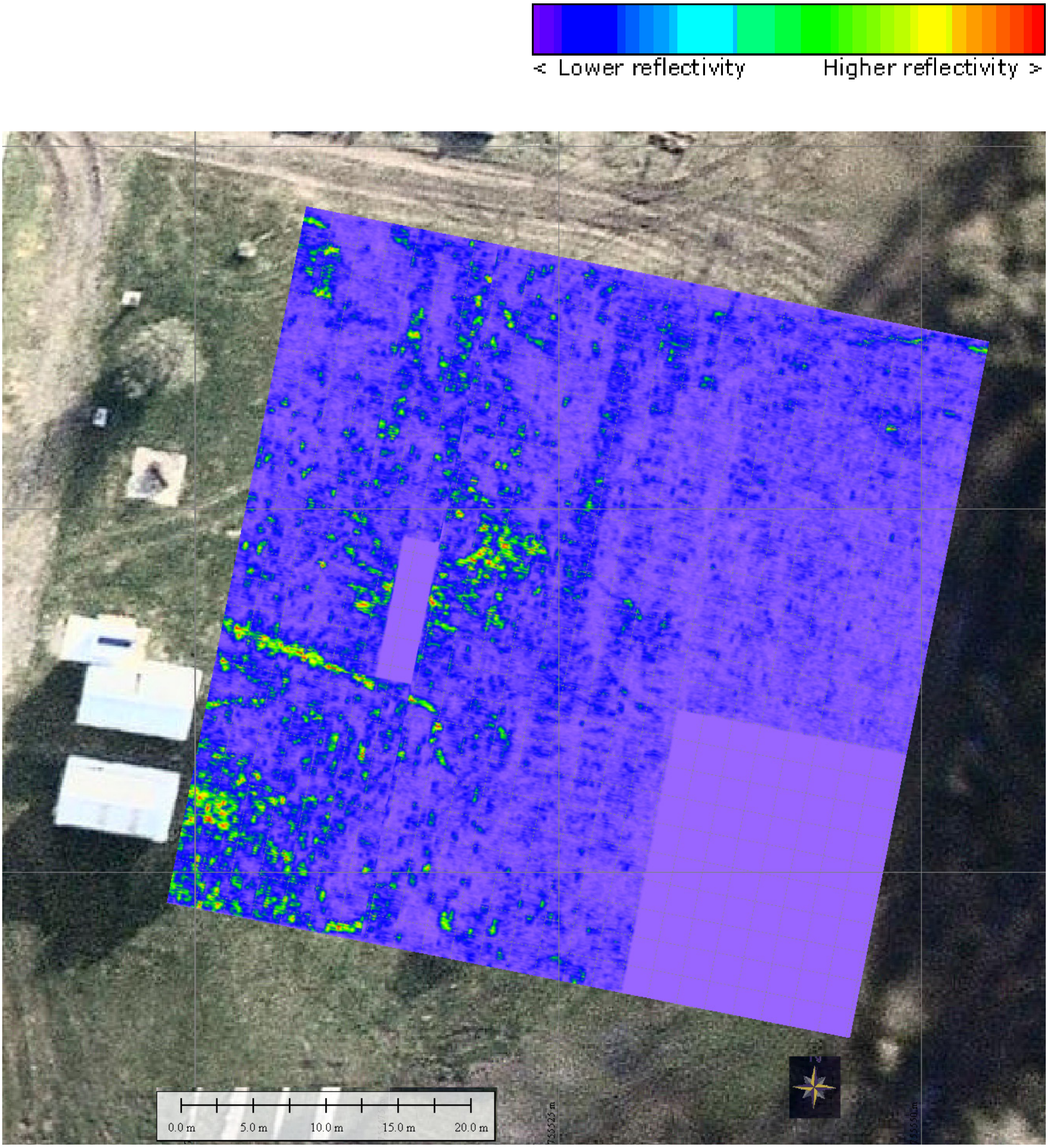

Figure 19: Ground-penetrating Radar (GPR) depth slice, 30-40cm below ground surface.

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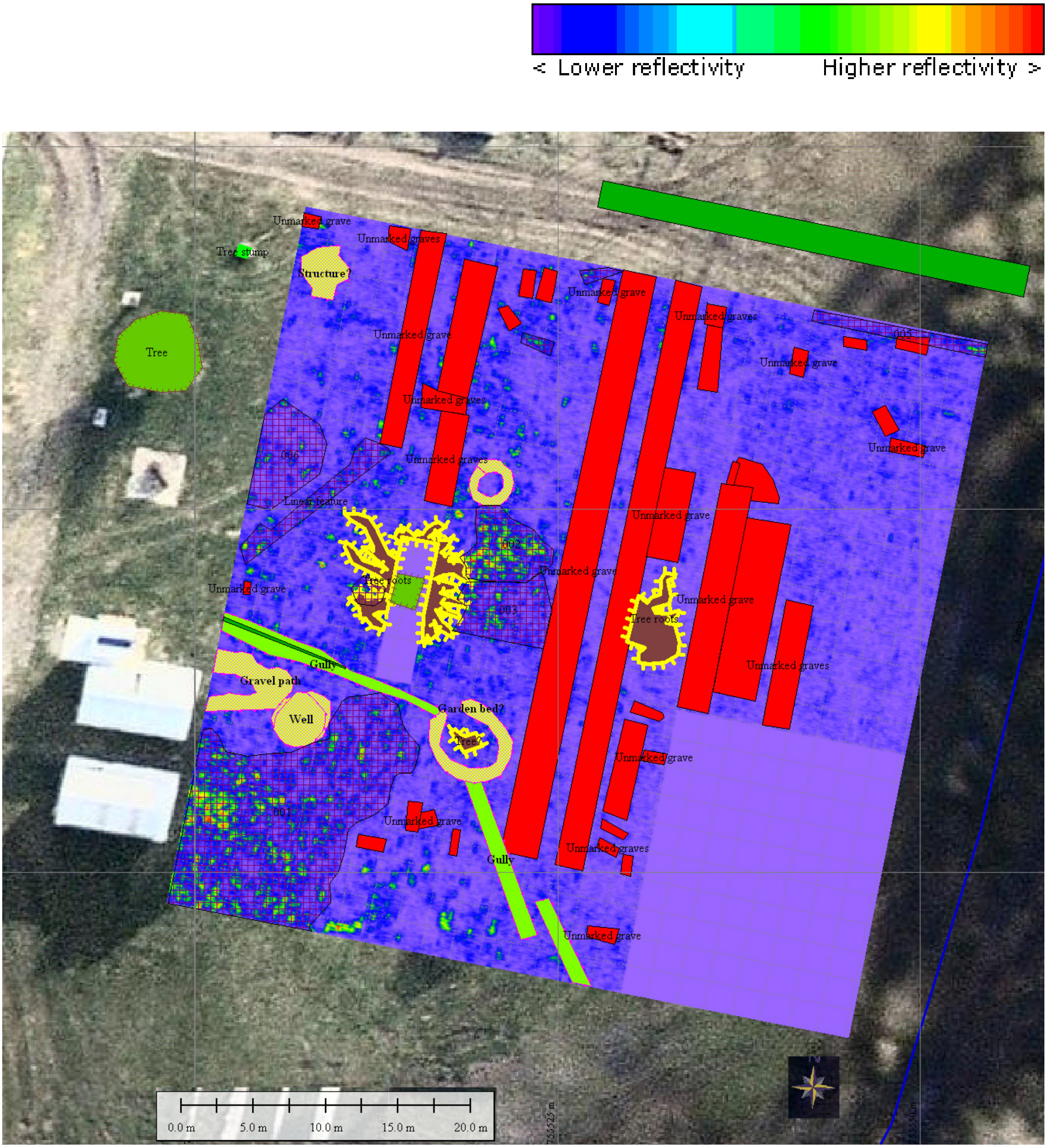

Figure 20: GPR depth slice, 30-40cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

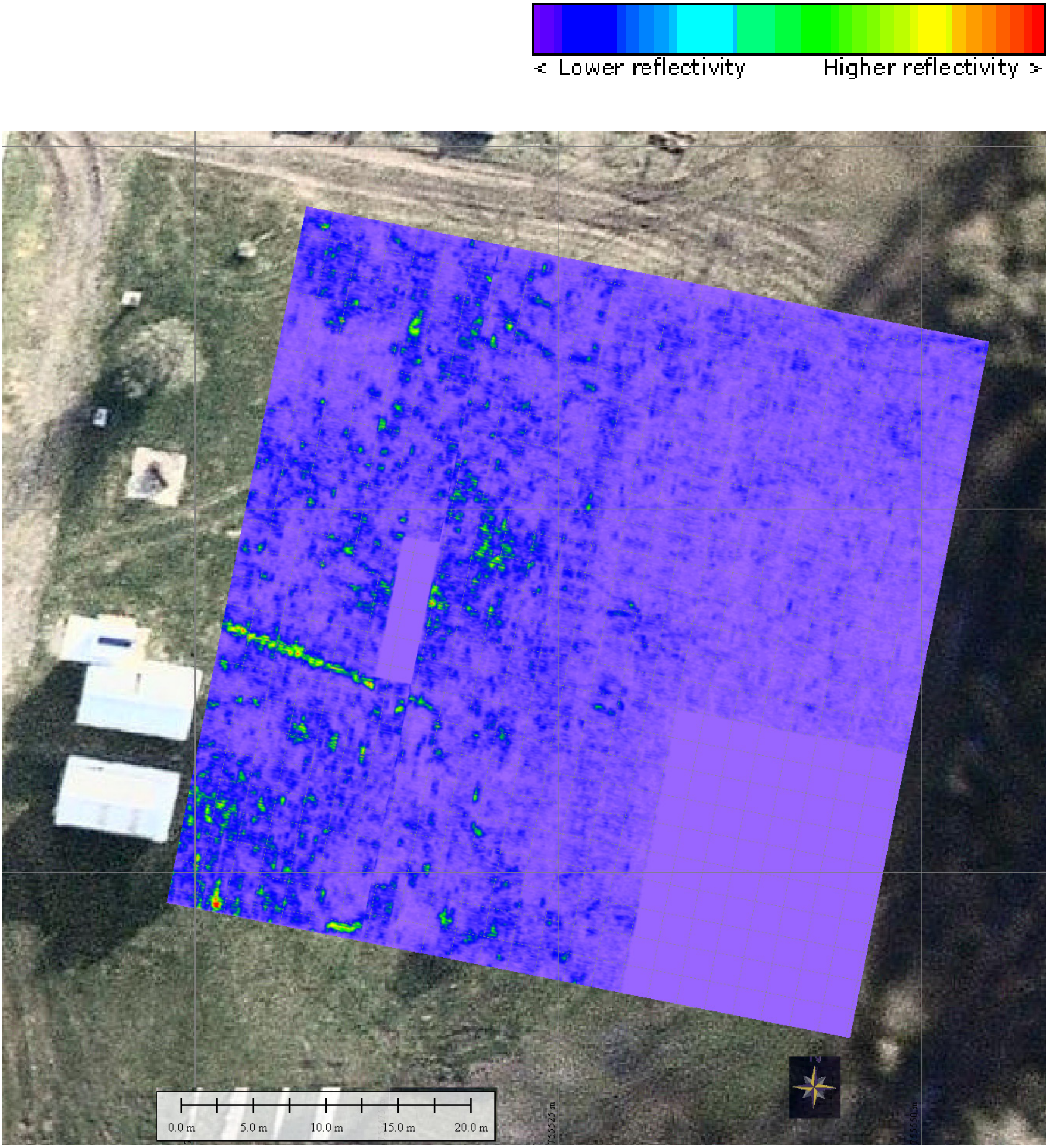

Figure 21: Ground-penetrating Radar (GPR) depth slice, 40-50cm below ground surface.

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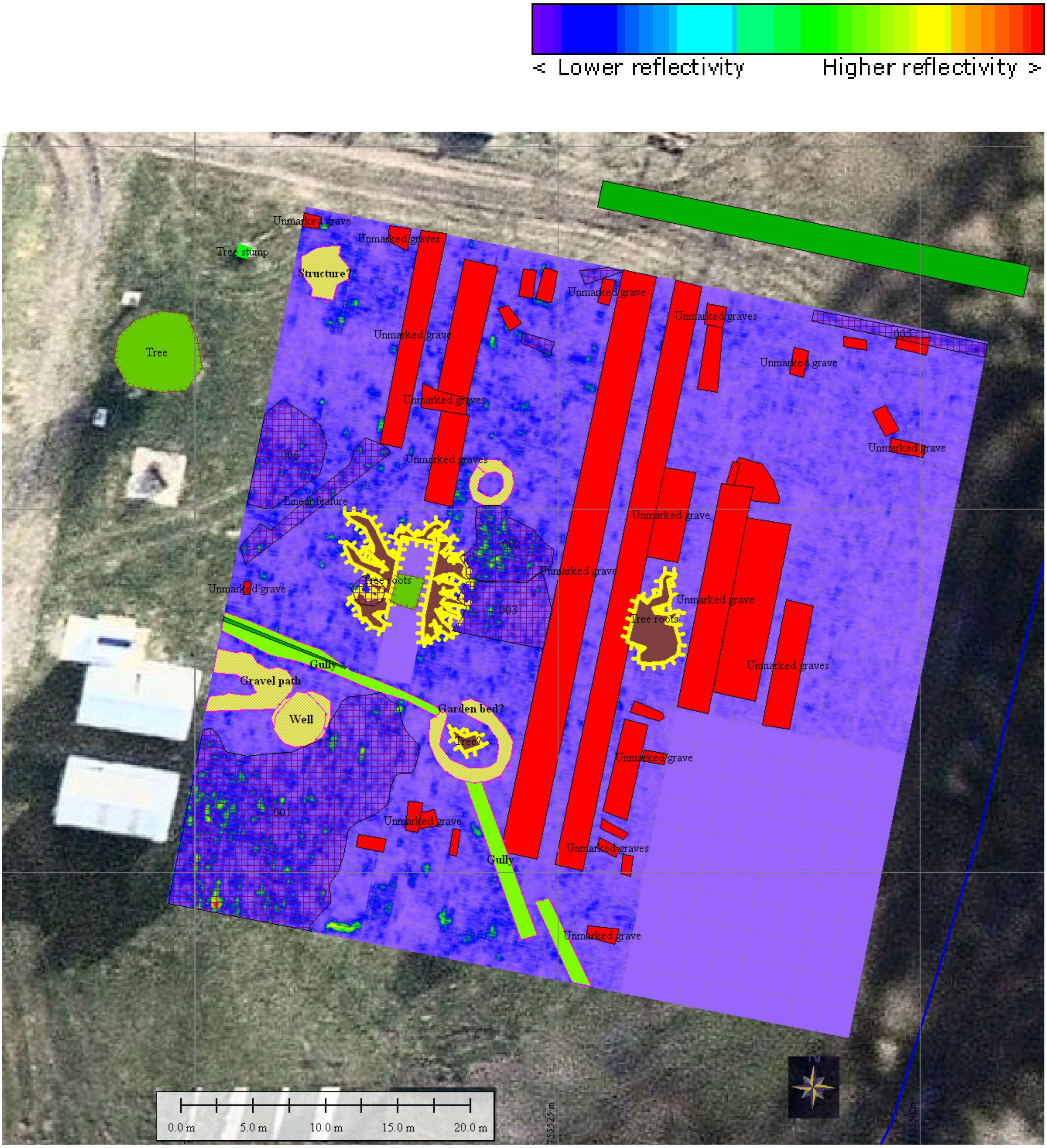

Figure 22: GPR depth slice, 40-50cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

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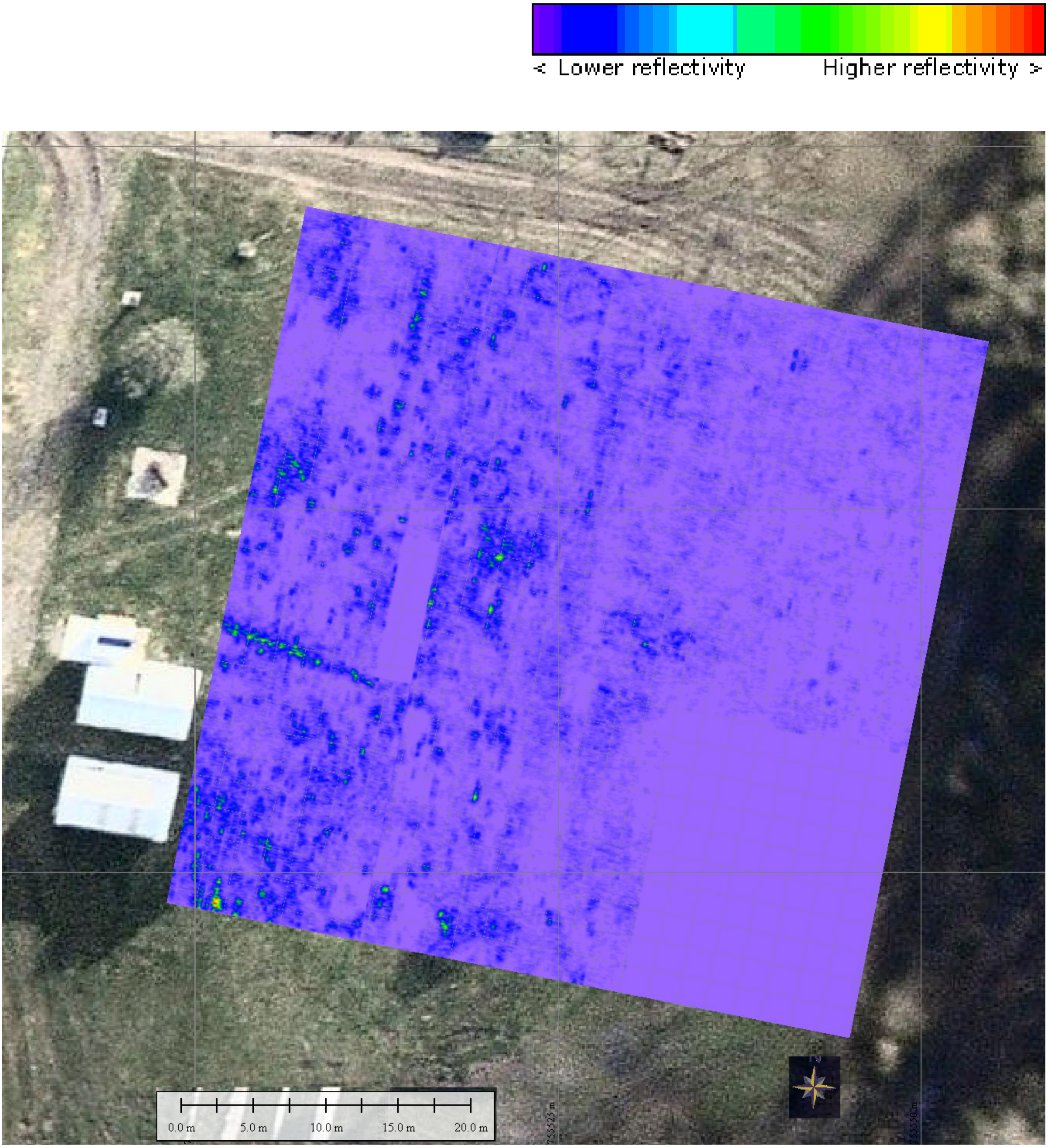

Figure 23: Ground-penetrating Radar (GPR) depth slice, 50-60cm below ground surface.

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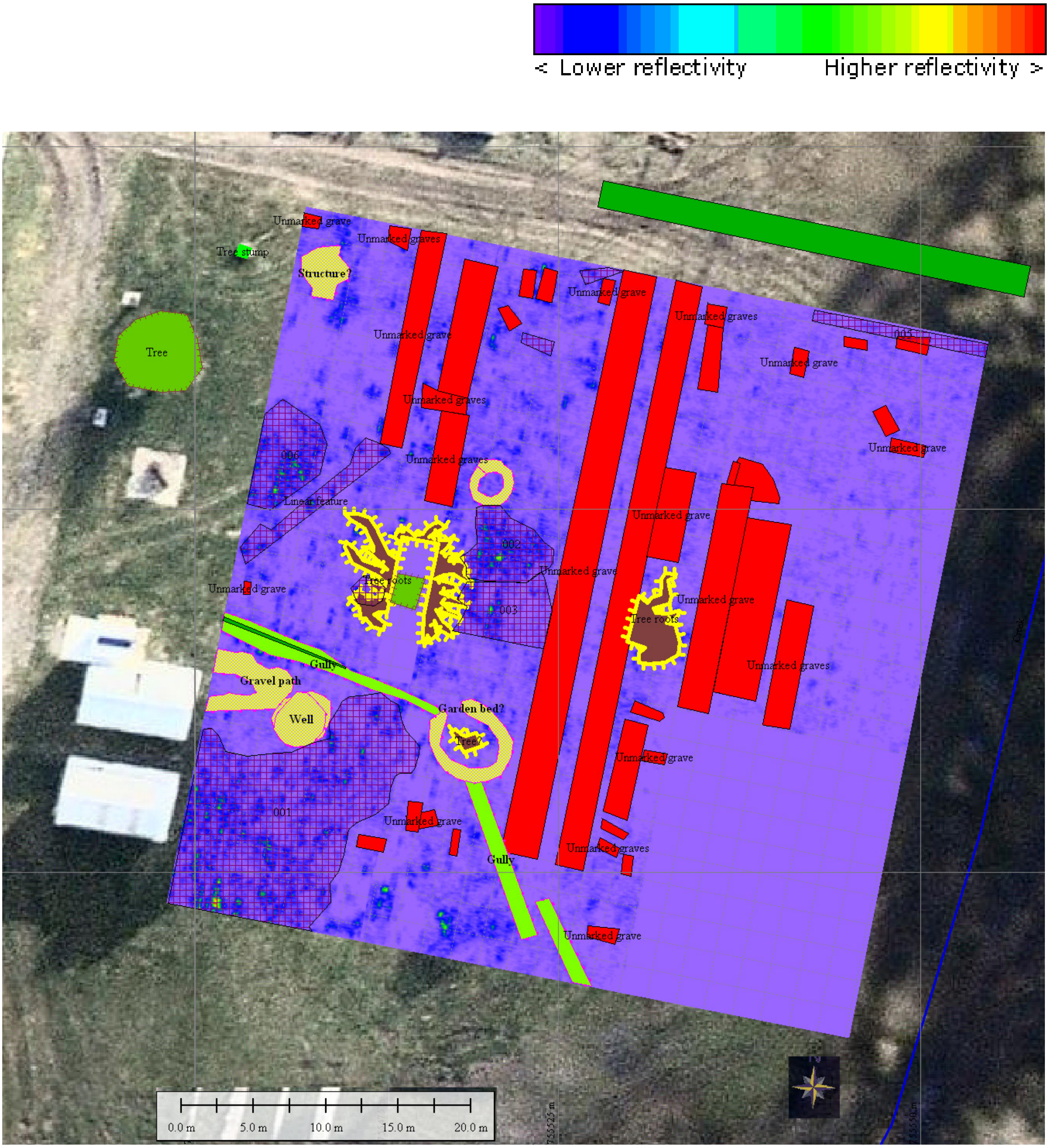

Figure 24: GPR depth slice, 50-60cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

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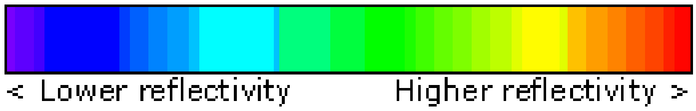

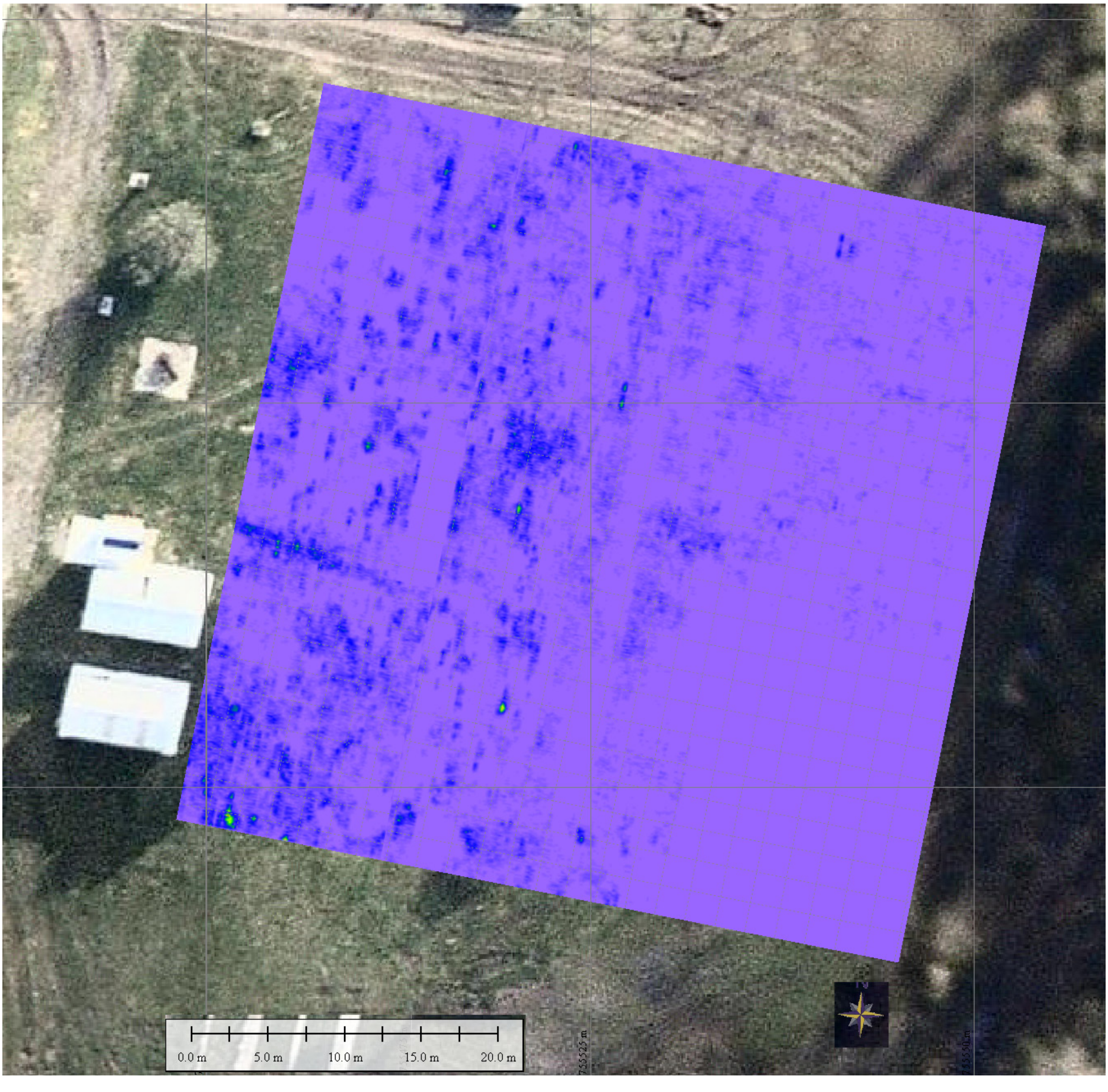

Figure 25: Ground-penetrating Radar (GPR) depth slice, 60-70cm below ground surface.

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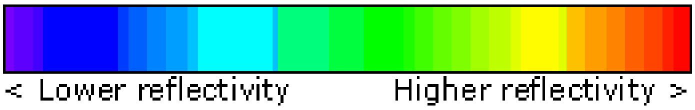

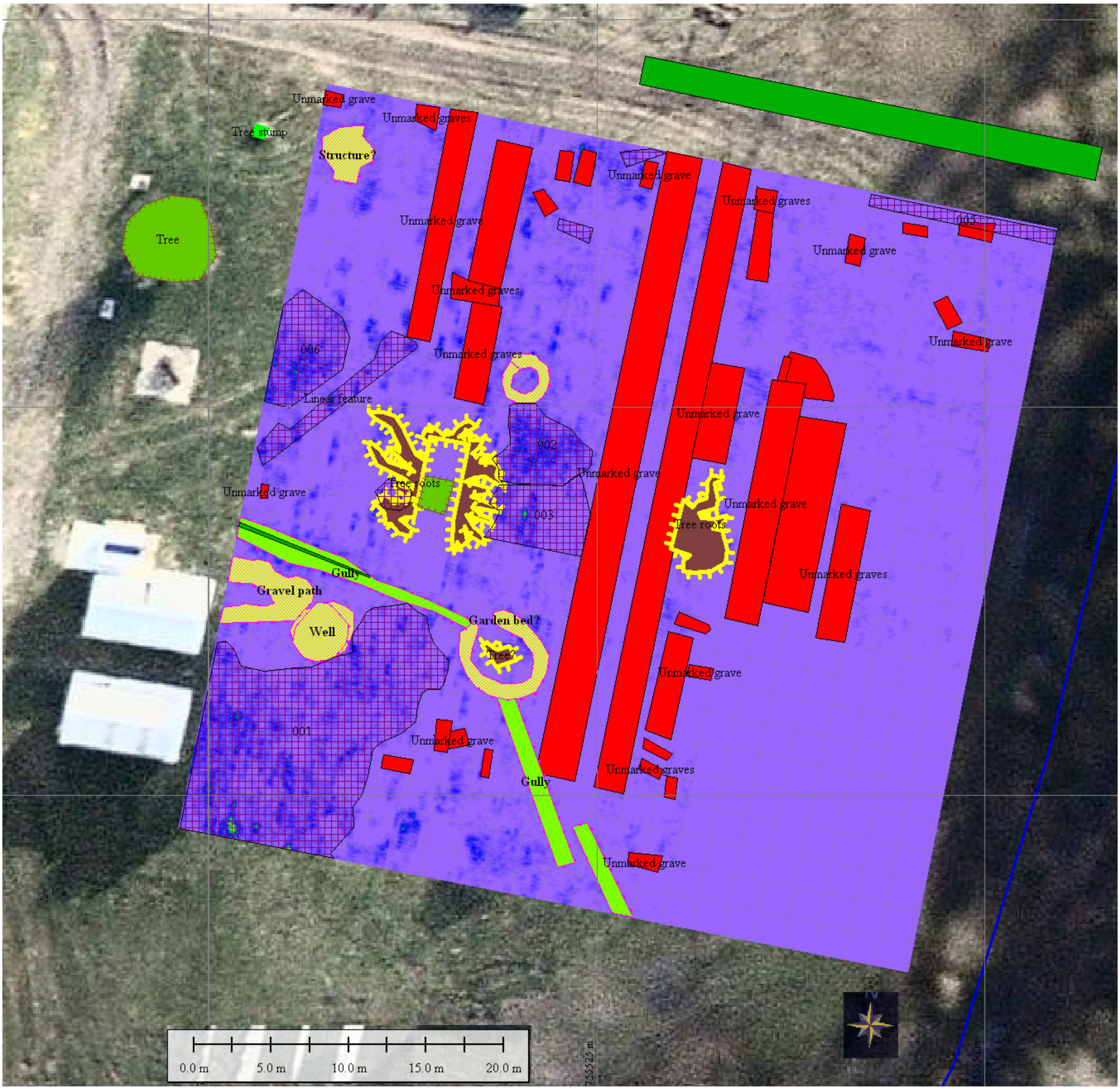

Figure 26: GPR depth slice, 60-70cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

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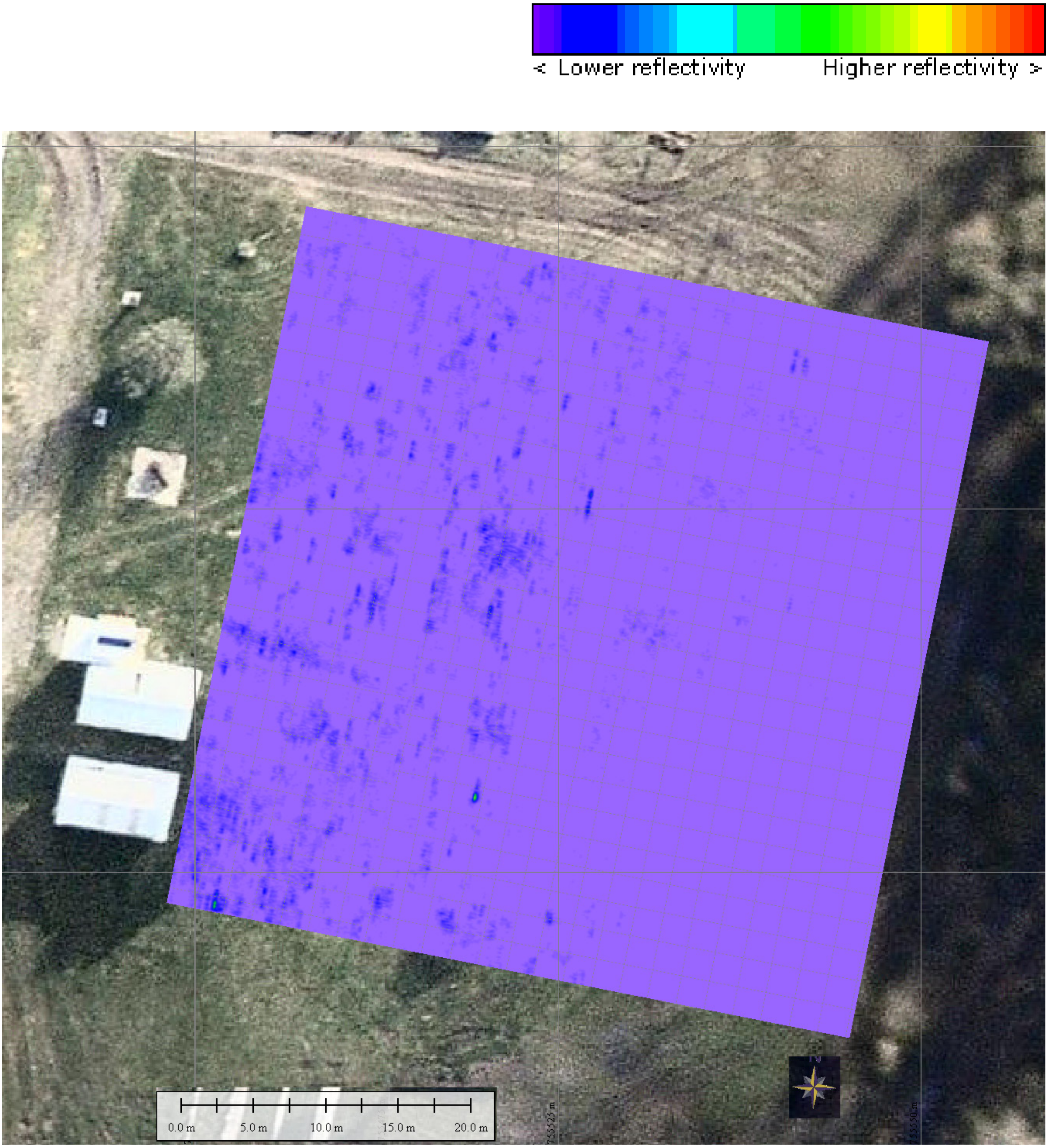

Figure 27: Ground-penetrating Radar (GPR) depth slice, 70-80cm below ground surface.

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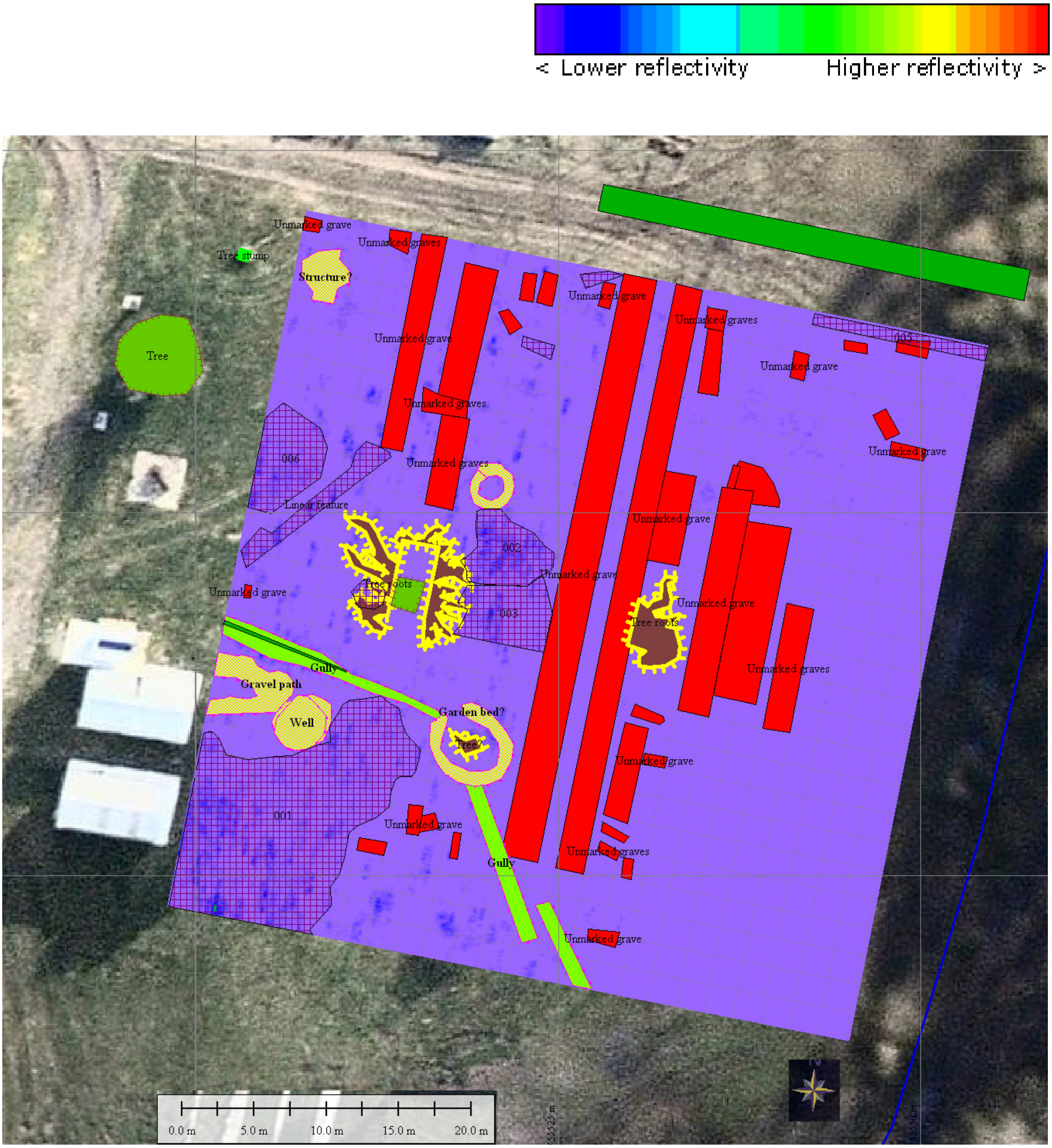

Figure 28: GPR depth slice, 70-80cm below ground surface, with possible detected features outlined.
Key to features:
Dark green = buried pipes. Light green = gully. Yellow = archaeological features.
Red = unmarked graves. Brown with yellow edges = tree roots. Green with brown edges = extant trees.
Cross-hatched areas = unidentifiable features.

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Figure 29: the probable location of the sexton’s cottage, shown with drainage gully revealed by the ground-penetrating radar survey. The location of the surface artefact scatter is shown in yellow stripes.

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Surface artefact scatter

The combined findings of the ground-penetrating radar survey and the examination of aerial photographs reveals a gully running from the sexton's cottage in an easterly direction before turning and heading southeast.

It is likely that, through natural swelling of the clay soils present in the survey area, the artefacts which are now present on the ground-surface to the far south of the survey area (i.e. at the downhill end of the gully) were brought to the surface and, through the movement of rainwater, were washed down to their present location. The artefacts were most likely moved to this area via this process since the cottage's removal in 1969; recent levelling of the area will have buried the gully and artefacts, thereby preventing further movement of artefacts. The surface artefacts were only exposed in August 2011, when heavy machinery drove through the area to remove trees which used to stand along the cemetery's eastern fence line. The machine tracks ripped up the lawn which would have been covering the artefacts.

Magnetic gradiometry survey

The magnetic gradiometry survey did not successfully locate all unmarked graves within the survey area. However, it was able to locate the two rows of rectilinear features within the southern section of two of the burial rows identified through the ground-penetrating radar survey. It is possible that these magnetically enhanced features are buried basalt headstones. These features are highlighted in figure 30.

Additionally, the magnetic gradiometry survey was able to detect palaeochannels and other areas of enhanced magnetization, likely associated with archaeological materials. Specifically, the well - located through the ground-penetrating radar survey - was detected in the magnetic gradiometry data. An area of magnetic enhancement trending westward from the well was also detected and is believed to be a gravel path made of igneous materials such as basalt and quartz (typical of gravel paths).

The magnetic gradiometry survey also located two buried metallic linear features, posited to be pipes.

Finally, five unidentifiable areas of enhanced magnetization were identified (see figure 31):

> 008 and 009 are two rectilinear responses featuring right angles and are, therefore, believed to be anthropogenic in origin. While these features may be structural, as they do not appear in the ground-penetrating radar data, their nature cannot be confirmed. These features may be at a depth greater than the penetrative depth of the radiowaves employed by the ground-penetrating radar system (i.e. approximately 60-80 centimetres); they may be easily resolved with an electrical resistance survey.
>
> 010 and 012 are a series of 'spikes' (very strong, highly localized magnetization), and are most likely rubbish pits associated with the sexton's cottage.
>
> 011 is an unknown feature which does not appear on any other dataset; it is likely to be a metallic object close to the ground surface.

The following pages show an image plot generated from the collected magnetic gradiometry data, along with an interpretation map.

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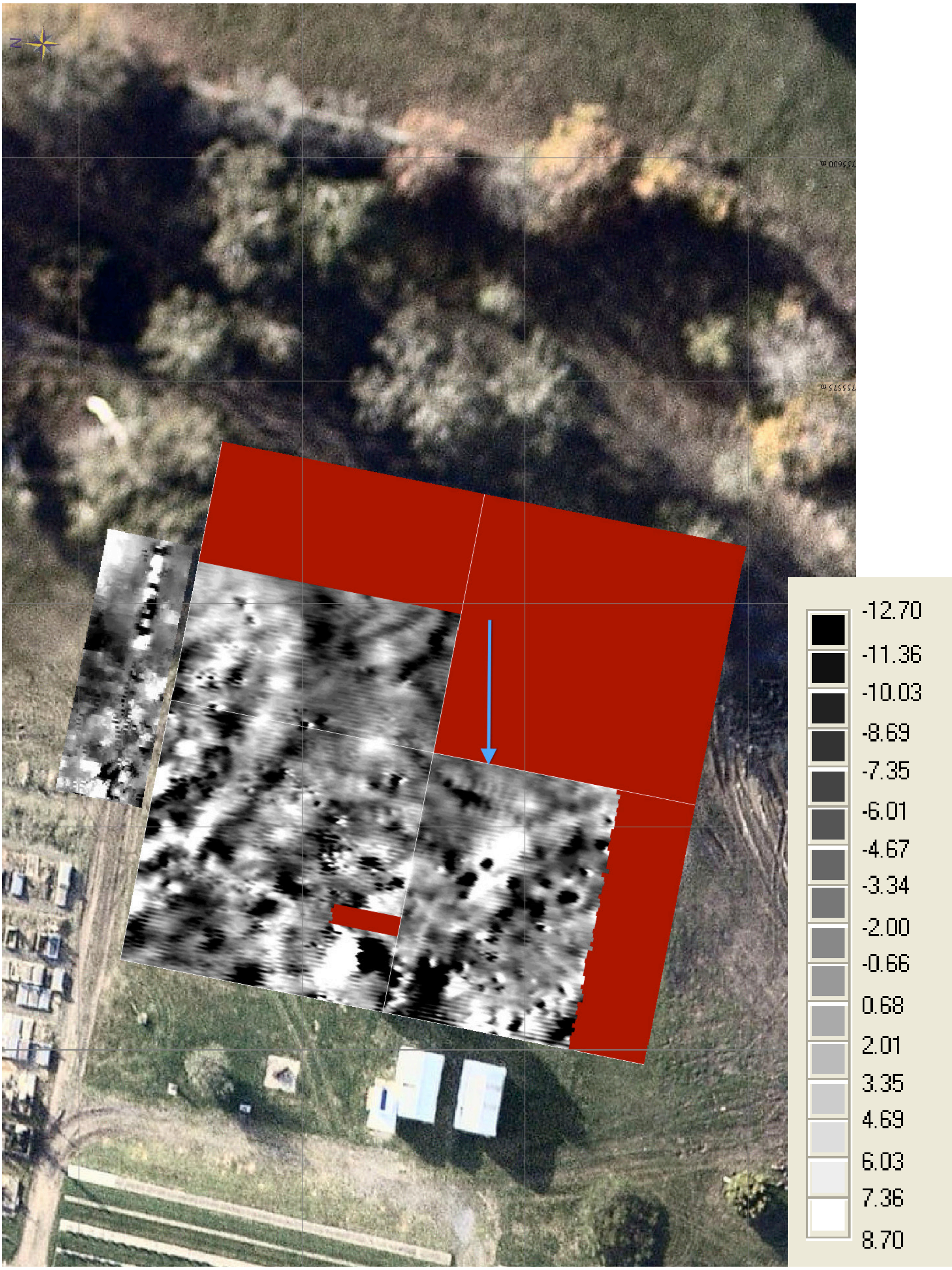

Figure 30: magnetic gradiometry survey data plot. The areas shown in red were not surveyable. The data scale is shown in nanoteslas per metre (nT/m). The rectilinear features detailed on the previous page, which may be buried headstones, are shown in two distinct rows of alternating black-and-white. These are highlighted by a blue arrow.

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Figure 31: interpretation of the magnetic gradiometry data plot. Detected palaeochannels are shown as thin blue lines, two metallic pipes are shown as dark green linear features and a gravel path is shown to the west of the well (both shown in yellow). Other unidentifiable features, numbered and shown with cross-hatches, are present. The data scale is shown in nanoteslas per metre (nT/m).

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Electrical resistance survey

As the electrical resistance survey performed was of an experimental nature, and due to its slow operational speed, only a single survey traverse was collected. However, data collected within the traverse show strong correlation with archaeological features detected through other geophysical datasets collected throughout the project.

Correlation was shown between the electrical resistance data plot and the broad area of rubbish pits to the southwest of the survey area, the well, drainage ditch and tree roots.

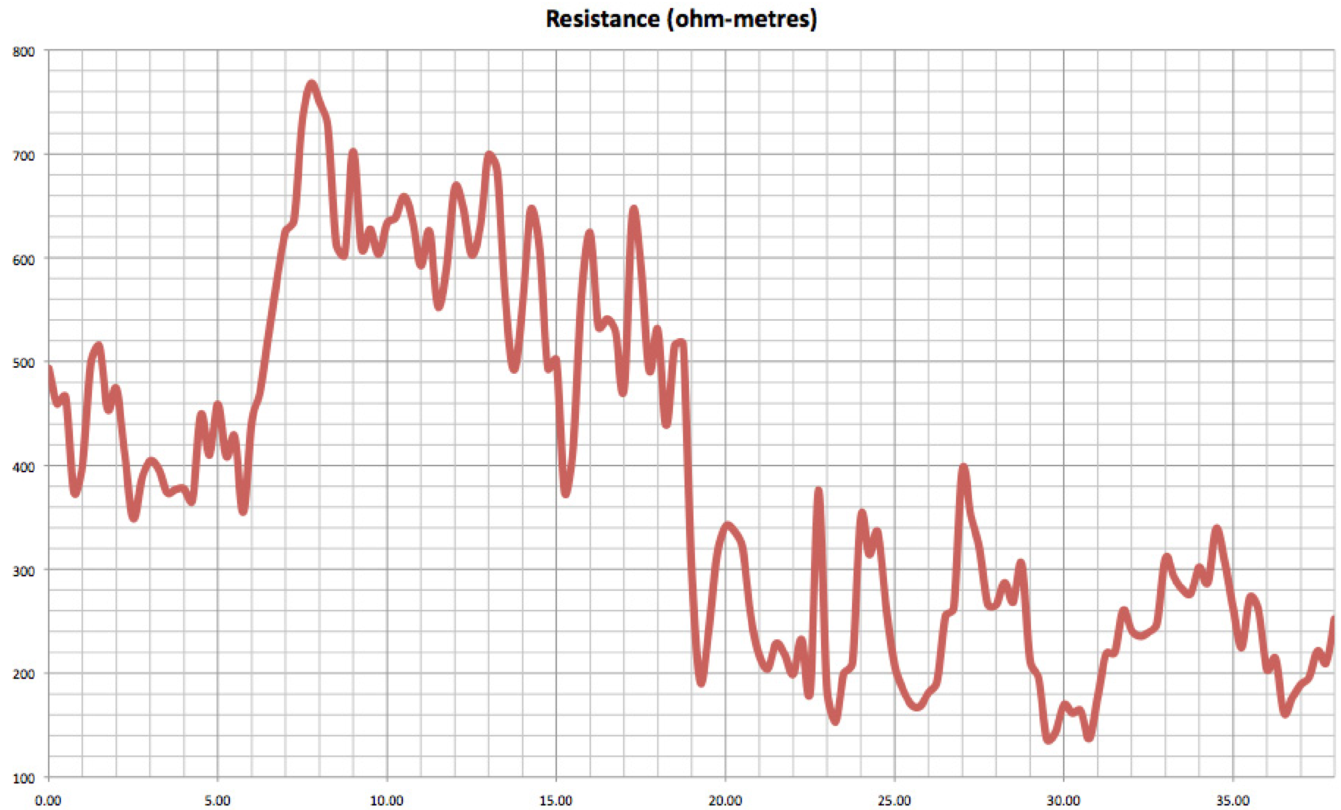

Figure 32: electrical resistance survey data shown as a graph; the northern-most reading is to the left of the graph, with distance in metres shown on the horizontal axis. The verical axis shows electrical resistance (displayed in ohm-metres).

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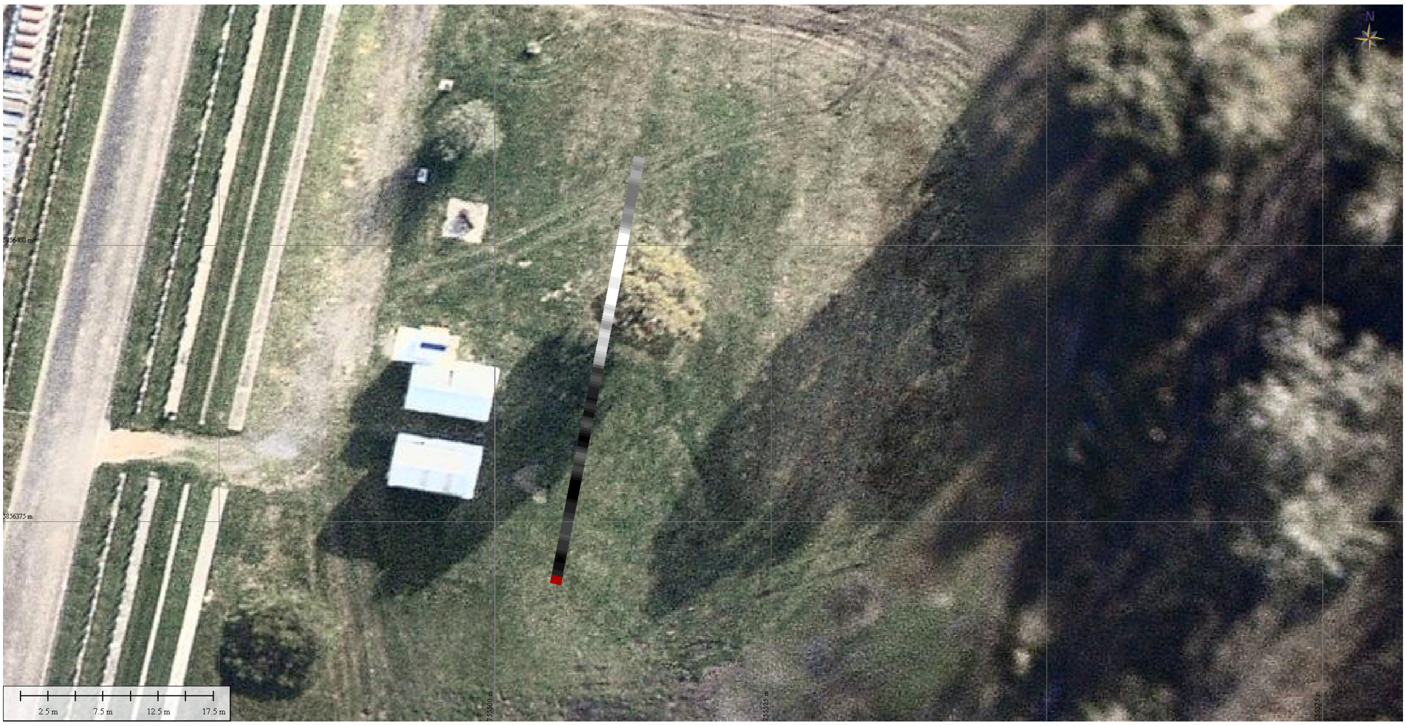

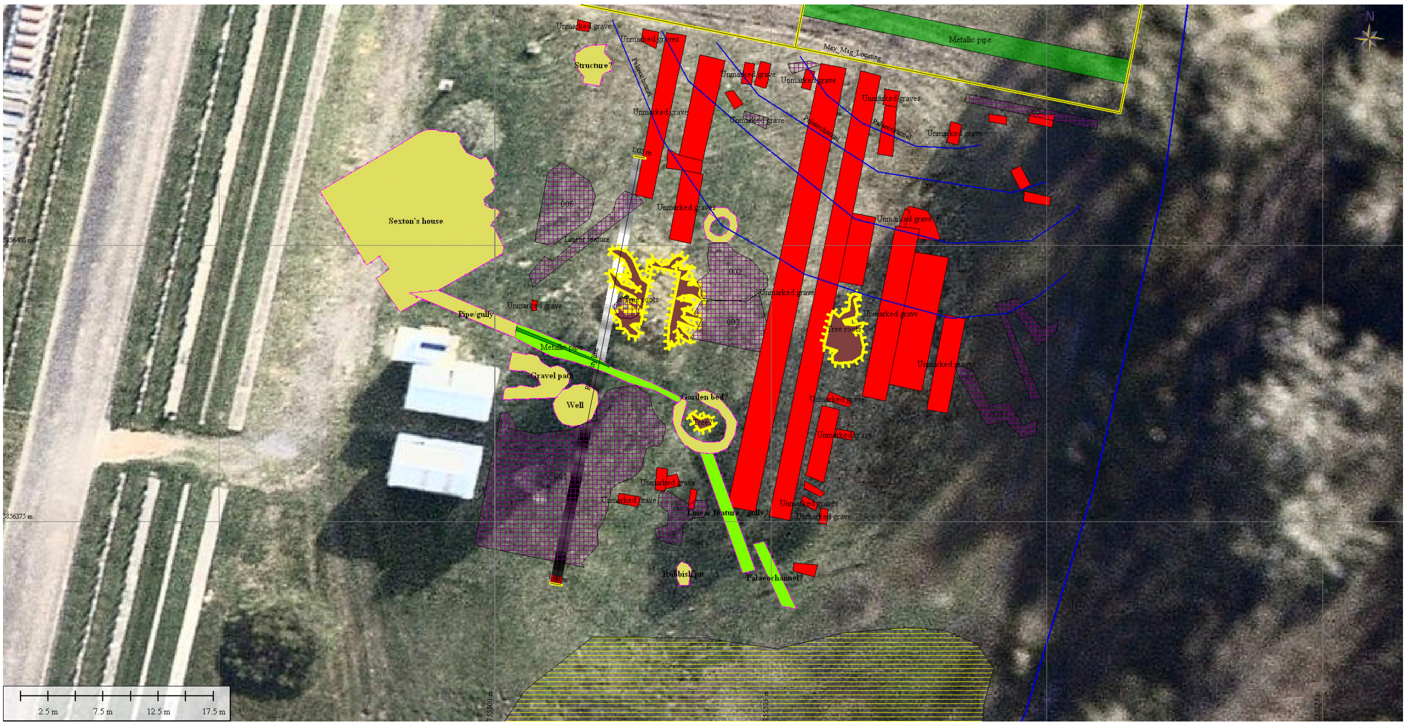

Figure 33 (top): electrical resistance survey data plot; white = lowest resistance, black = highest resistance, red = unsurveyable.
Figure 34 (bottom): map showing the various features detected throughout the survey and how these features correspond to the electrical resistance survey data.

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Electromagnetic (ground conductivity) survey

The ground conductivity survey did not locate any of the previously detected unmarked graves. There was little correlation between the ground conductivity dataset and other datasets collected throughout the project. However, the survey was able to detect the increase in electrical conductivity in the drainage ditch identified through the ground-penetrating radar survey.

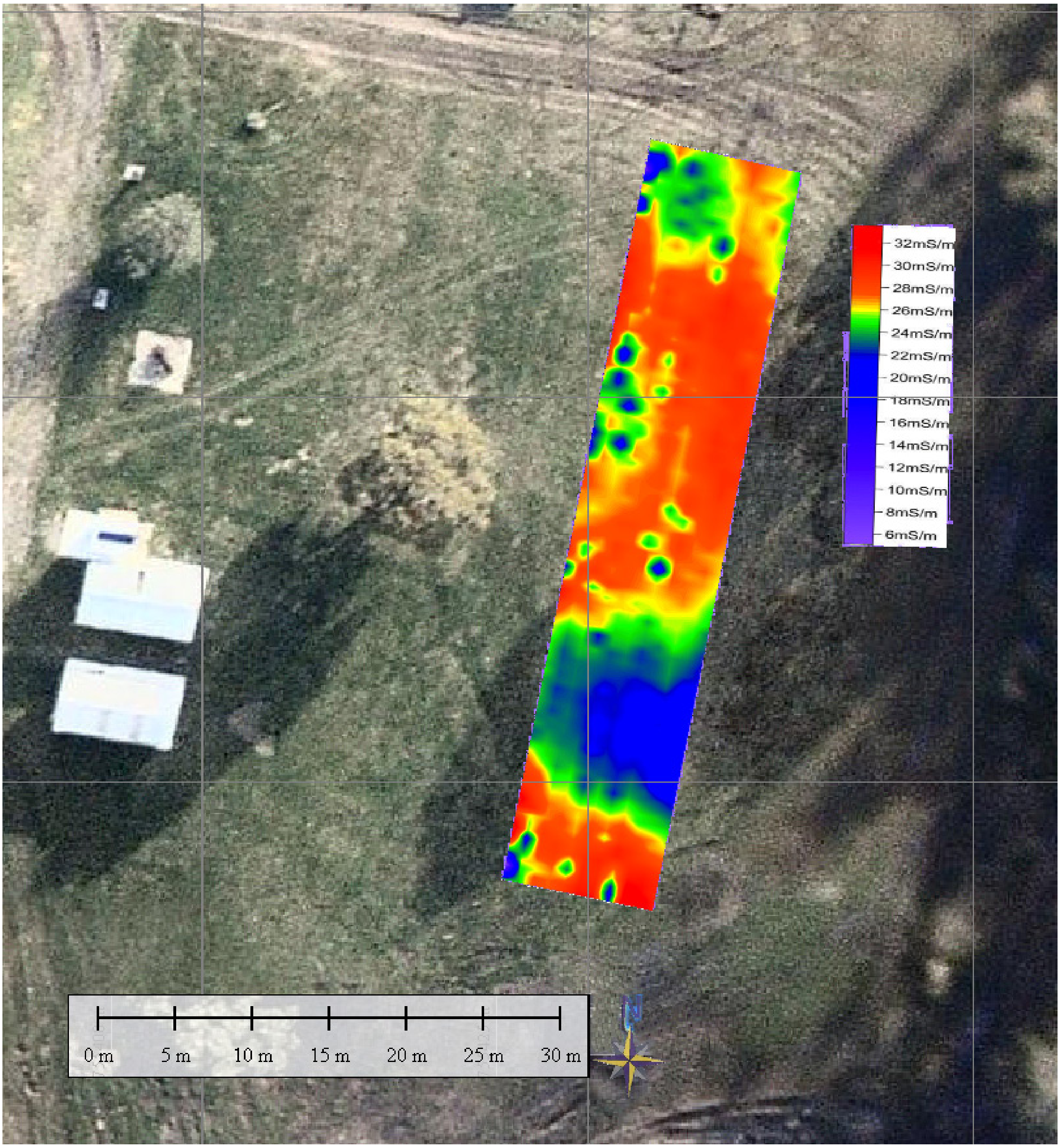

Figure 35: electromagnetic (ground conductivity) survey data plot.

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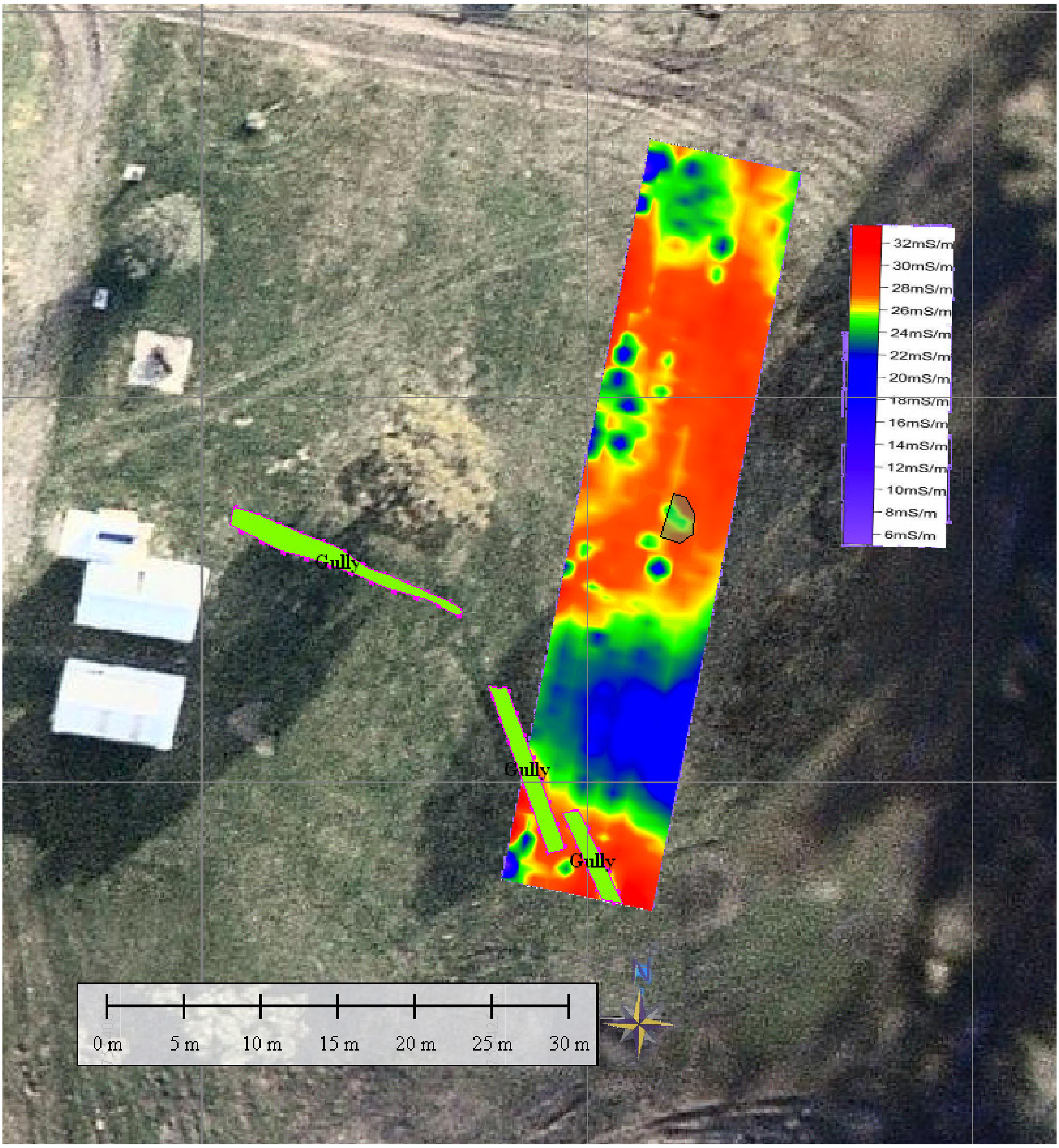

Figure 36: interpretation of the electromagnetic (ground conductivity) survey data plot. The drainage ditch previously identified appears in the ground conductivity data plot as an area of increased electrical conductivity (consistent with a saturated soil such as that found within a ditch). The hole in the ground left behind by the removal of a tree stump prior to the collection of ground conductivity data in December also appears in the ground conductivity data plot (shown above as a small light blue circle in the middle of the conductivity plot).

Acknowledgments

Fieldwork:	David Hunter Shannon Hunter James Butler Matthew Crosbie Dr Zara Dennis BSc (Hons) MSc PhD Michael Lever Jasmyne Pendragon BA Alexander Sly Alexander Stott Zachary Spielvogel BA (Hons)
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Conclusion

Satisfaction of objectives

The geophysical surveys undertaken for this project have successfully located the unmarked graves present in the survey area within Compartment Six at the Creswick Cemetery.

Summary of results

The survey has located several rows of disturbed soil stratigraphy most likely to be associated with unmarked grave shafts and funerary urn burials. The survey has also revealed the extent of historical archaeological features, including the sexton's cottage, an old well, a drainage ditch and two pipelines. Additionally, the magnetic gradiometry survey has detected several palaeochannels in the survey area.

Geophysical research value

The survey area features clay soil and had - in the weeks prior to the December field season - experienced heavy rainfall. Typically, these conditions prevent the detection of archaeological materials through the use of ground-penetrating radar due to a reduction in radiowave penetrative depth (as caused by a higher relative dielectric permittivity). However, radiowaves were capable of penetrating up to fifty centimetres into the ground before being attenuated; the use of ground-penetrating radar on saturated soils such as clay or silt may be suitable when searching for extremely shallow features, such as unmarked graves (as the soil disturbance associated with unmarked graves begins at the ground surface).

While the magnetic gradiometry survey was able to detect several unmarked graves, the technique was not capable of detecting all of the unmarked graves detected through the use of ground-penetrating radar. Therefore, magnetic gradiometry is not a reliable method for the remote detection of unmarked graves. This may be caused by a lack of metal objects or other magnetized materials such as igneous headstones being buried at a depth shallow enough to be detected by the gradiometer. The enhanced magnetization of decomposed timbers (i.e. timber posts) caused by microbial processes typically detectable using a Bartington Grad601 magnetic gradiometer may not be strong enough to be detected by the gradiometer at typical human interment burial depths.

The vertical quadrature-phase electromagnetic (ground conductivity) survey did not successfully locate any of the unmarked graves detected through the use of ground-penetrating radar; the use of electromagnetic methods should be avoided when undertaking searches for unmarked graves under similar soil conditions. It is possible that success may have been experienced had the soil not been saturated. It is also possible that natural swelling of the clay soil may have mixed moisture from outside a grave shaft into the soil within a grave shaft, and that this rendered the graves undectable by the Geonics EM-38 sensor. A more sensitive instrument may have been successful.

The electrical resistance survey provided responses to the various subsurface features identified through the use of ground-penetrating radar and, should the technique be used on a larger scale, should prove a successful (albeit slow) methodology for the remote detection of unmarked graves and archaeological materials.

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Dissemination

This report, detailing the results of this survey were submitted to the Creswick Cemetery Trust in March 2012. Hunter Geophysics will also send copies of the report, along with all digital data, to Heritage Victoria - as per legislative requirements.

Recommendations

Given the findings of this report, Hunter Geophysics recommends the expansion of the geophysical survey to the west of the current survey area in order to confirm the location of the sexton's cottage, as well as to locate any unmarked graves which may be present in the area between the current survey area and the lawn section. An electrical resistance survey of the potentially structural rectilinear features identifed by the magnetic gradiometer survey (see page 37) is also advisable.

Further, Hunter Geophysics recommends the removal of tree roots identified in this survey which are encroaching upon unmarked graves in order to prevent future damage being caused to these graves.

What's on the USB

A Universal Serial Bus v2 (USB) memory stick is included with this report. The following files may be found on the memory stick in digital form:

All figures included in this report.
The report itself in Adobe InDesign v6.05 format and also in Adobe Portable Document Format (PDF).
Global Mapper demonstration edition installation file.
Site map file (with a .gmp file extension) for use with Global Mapper.
All geophysical datasets in their own proprietary digital formats.

References

The Ballarat Australia 1:250,000 geological map (accessed via http://www.geoscience.gov.au/geol250k/250dpi/sj5408.jpg on 9th January 2012), published by the Geological Survey of Victoria, 1996.

DAVID, Andrew, 1995, 'Geophysical Survey in Archaeological Field Evaluation: Research and Professional Services Guidelines', No. 1. English Heritage.

GAFFNEY, Chris, GATER, John. and OVENDEN, Susan, 2002, 'The use of Geophysical Techniques in Archaeological Evaluations', IfA Paper No. 6. Institute for Archaeologists.

PENDRAGON, Jasmyne, via electronic pers. comm., 12th March 2012.

SCHMIDT, Armin, 2001, 'Geophysical Data in Archaeology: A Guide to Good Practice.' Archaeology Data Service, Oxford, Oxbow.

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