	<p>INTERPRETATION REPORT:</p> <p>HISTORICAL DATA REVIEW</p> <p>GROUND PENETRATING RADAR (GPR)</p> <p>FREMANTLE PRISON, FREMANTLE, WA</p>	<p>DG1732GLD</p>	<p>Rep. No. 2.0</p>
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To: Tristan Jónsson Menzies (Golder Associates)

From: Lee Tasker (Draig Geoscience Pty. Ltd.)

Subject: Historical Data Review – Ground Penetrating Radar (GPR), Fremantle Prison, Fremantle, WA

1. Introduction & Objectives

Golder Associates (Golder) approached Draig Geoscience Pty. Ltd. (Draig) to review historical GPR data from a GPR survey carried out by the University of Western Australia (UWA) in April 2016 (email comms. Tristan Menzies, Golder, 13/12/2021). The objectives for the historical GPR data review were to assist with locating a possible buried well location within the area of interest. A general map of the GPR survey area and GPR profiles was provided by Golder¹ (see Figure 1).

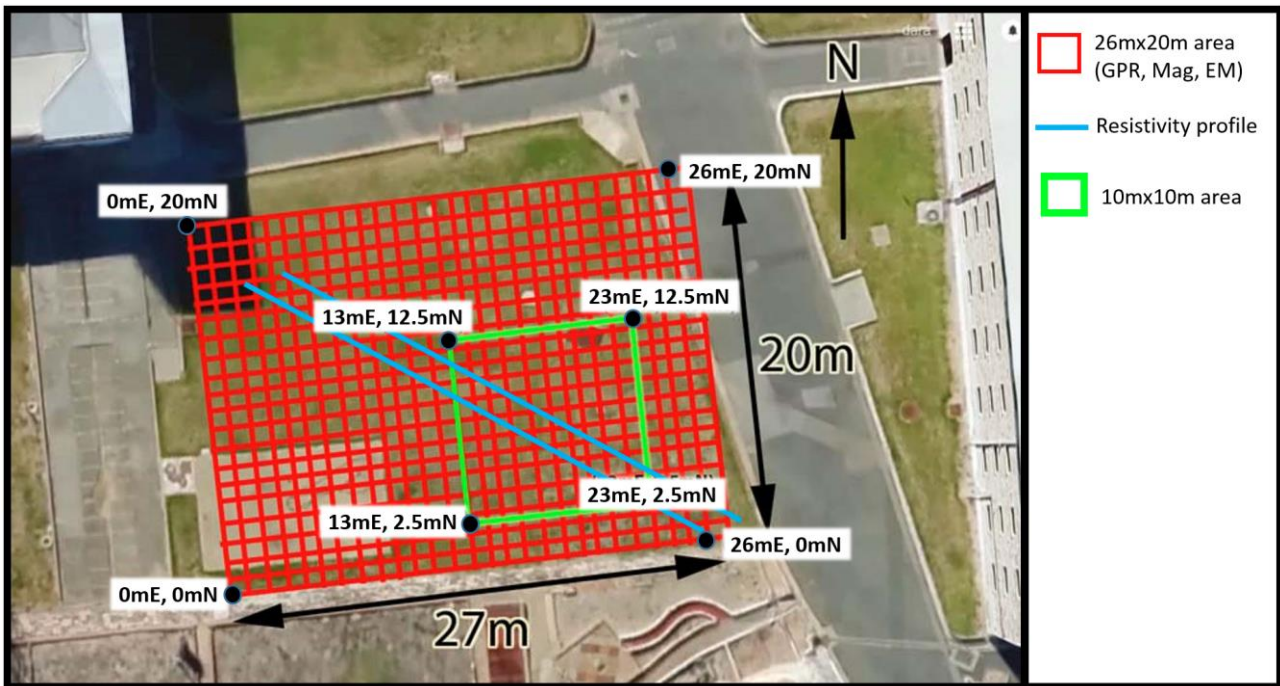



Figure 1. A general site map of the April 2016 GPR survey profile lines (red lines) and key area of interest (green square) (image source: Golder).

¹ Shragge, J. (2016) "Geophysical Investigation at the Fremantle Prison – Summary from the UWA GEOP4002 Class Unit Findings". University of Western Australia / Centre for Energy Geoscience.

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2. Data Acquisition

2.1 Geographical Location and Fieldwork Dates

Data acquisition was conducted by a volunteer student team from UWA geophysics department at Fremantle Prison, in the interior parade grounds between 23/02/2016-25/02/2016. Draig georeferenced the historical GPR profile map in relation to surface features in the satellite imagery and also the alignment of those surface feature with surface responses observed in the GPR data. The georeferenced location map is shown in Appendix A, Figure A1.

2.2 Equipment Details and Data Acquisition Parameters

Approximately 2,250 line-m of GPR profile data were acquired across the investigation site over 96 GPR profiles. Y-orientated GPR profiles (“east-west”) were labelled A_001y to A_041y. X-orientated GPR profiles (“north-south”) were labelled A_001x to A_055x.

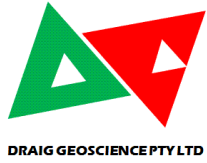
GPR data were acquired using a Mala GPR 500 MHz antenna and calibrated wheel encoder. A sample frequency ~6800 MHz and a trace record length ~107 nanosec were utilised for the data recording parameters. With these parameters the 500 MHz antenna provided a depth of coverage to ~5-6 m.

3. Results and Interpretation

3.1. GPR Data Processing Steps

GPR data processing was conducted in the GPR data processing software ‘GPR-Slice’ (<https://www.gpr-survey.com/>).

2D raw GPR data were processed to produce “data section images” ready for interpretation (these vertical section-view data images are also known as radargrams). These processed 2D radargrams were also combined into a 3D data volume, creating a 3D volume of GPR amplitude intensity. Multiple overlapping horizontal blocks of this 3D data volume, of a specified thickness at incremental depth intervals, were gridded and exported to produce a set of 2D plan-view “average GPR amplitude intensity map” images ready for interpretation (also known as depth slice images). (A diagram of this concept is shown in Figure 2) These average GPR amplitude intensity maps were exported as Surfer grid (.grd) files from GPR-Slice, and were both presented as ERMapper (.ers) images and provided as an electronic deliverable to this report (and also displayed in Appendix B, Figures B1-B7).

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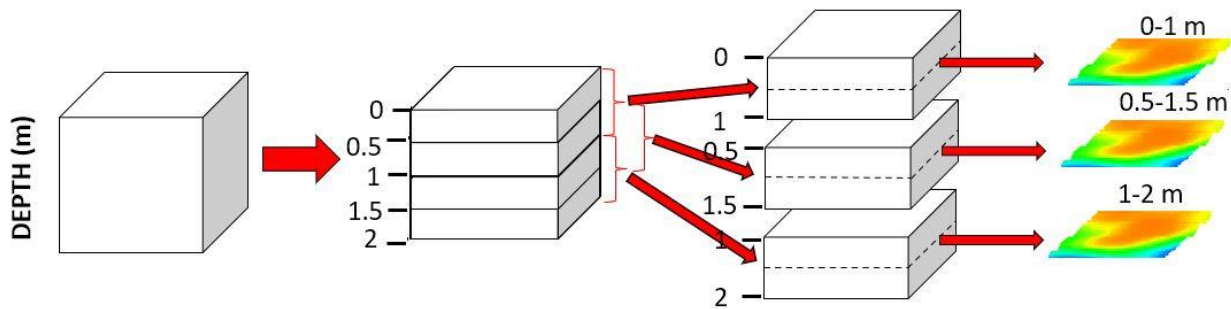
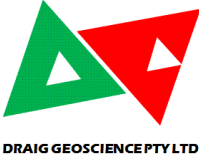


Figure 2. Conceptual diagram of the production of depth slice images from a 3D GPR data volume.

A general processing flow for the GPR data processing is listed below:

- Import raw radar data into GPR-Slice;
- Post-process GPR with GPS data (QC data, check GPS points);
- Time-zero and truncate samples;
- Filter data;
 - Estimate dielectric constant (7.44) and background electromagnetic velocity (0.11 m/ns) (a depth of coverage ~6 m has been achieved with the 500 MHz GPR antenna using these values), apply background filter, apply amplitude gain, apply bandpass filter (250 MHz data: low-cut = 87 MHz, high-cut = 485 MHz);
- Combine the 2D radargrams into a 3D volume of data and slice through the volume of combined data at a specified depth interval;
 - Number of slices for volume = 36;
 - Thickness of slices = 38 samples, 5.58 nanosec (~0.31 m);
 - Overlap in slices = 50%;
- Grid these data slices to produce average GPR amplitude intensity maps;
 - Grid cell size = 0.1 m;
 - X-search radius = 0.8 m, Y-search radius = 0.8 m, Blanking radius = 0.8 m;

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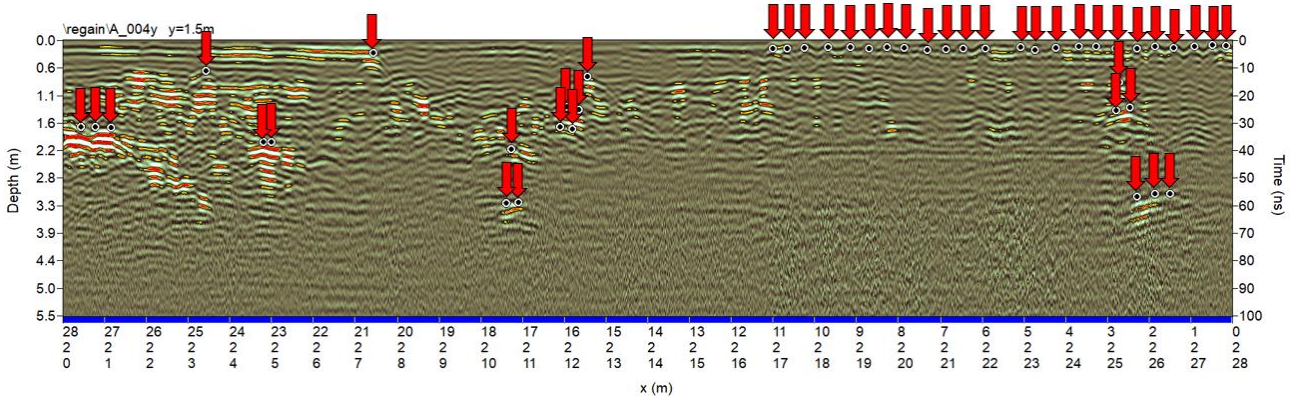


Figure 4. Radargram A_004y interpreted high amplitude/hyperbola response features (black dots/red arrows – top of high amplitude/hyperbola response feature).

1,706 GPR radargram point features were interpreted across the dataset. These radargram feature points were grouped into designated depth intervals and coloured as shown in Figure 5.

- Radargram Interpreted Points**
- Depth 0 to 0.9 m
 - Depth 1.0 to 1.9 m
 - Depth 2.0 to 2.9 m
 - Depth 3.0 to 3.9 m
 - Depth 4.0 to 4.9 m
 - Depth >= 5.0 m

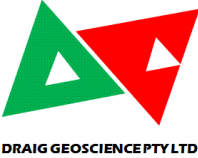
Figure 5. Radargram point feature interpretation designated depth intervals and colour coding.

3.2.2. Average GPR Amplitude Intensity Map (Depth-Slice) Interpretation

Figures presenting a representative seven of the average GPR amplitude intensity maps are shown in Appendix B – Figure B1-B7.

To aid with interpretation, Draig applied a colour-clip to the average GPR amplitude intensity maps to highlight regions of high amplitude response (red-coloured “hot spots”).

A linear (increasing) transform (rainbow colour-scale) was applied to each individual average GPR amplitude intensity map with a bandpass cut-off/clip of 1-97%. (The linear transform stretches the colour-scale from the lowest value data value to lowest mapped colour, to highest value mapped to highest mapped colour.) Figure 6 shows an example of an unclipped and clipped average GPR amplitude intensity map.

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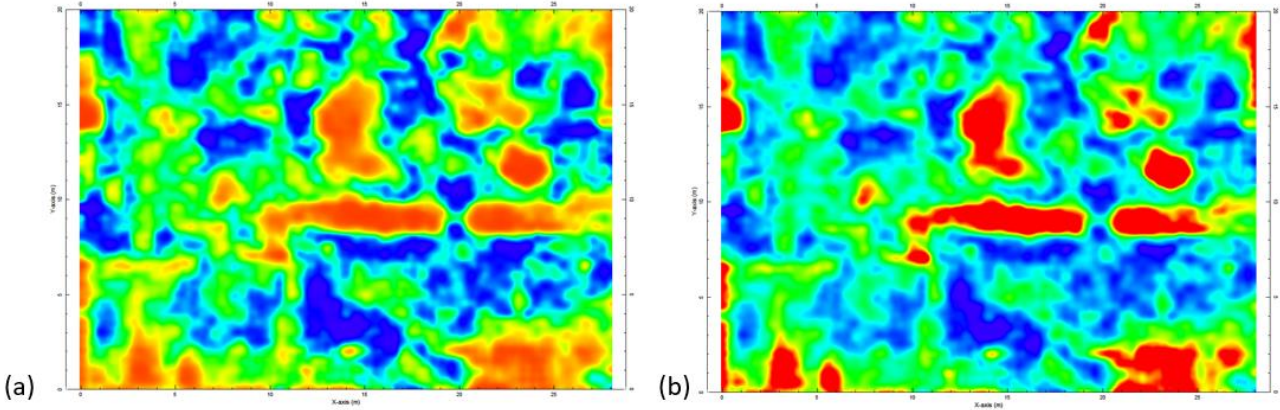


Figure 6. (a) An average GPR amplitude intensity map (Depth-Slice 02) showing no colour clip (full colour-scale) and (b) showing a 1-97% clipped colour-scale. The clipped colour-scale was the colour-scale used for data interpretation.

Once colour-clipped, high amplitude response targets were interpreted and traced. Figure 7 shows an example of the interpretation linework to outline a zone of high amplitude (hot spot).

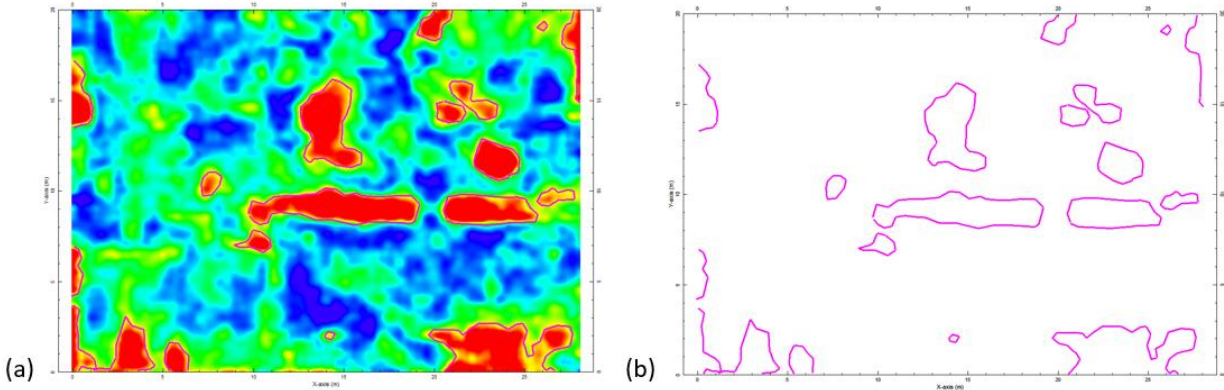
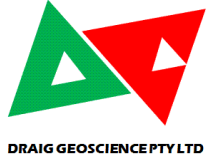


Figure 7. Example of interpretation of average GPR amplitude intensity map for high amplitude zones (hot spot). (a) An average GPR amplitude intensity map (Depth-Slice 02) with 1-97% clipped colour-scale applied and interpretation drawn (magenta line), (b) interpretation linework only (magenta line).

756 high amplitude zones were interpreted over the 36 average GPR amplitude intensity maps (depth-slices). These high amplitude zones were grouped into designated depth intervals and coloured as shown in Figure 8.

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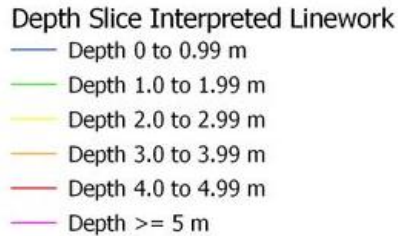


Figure 8. High amplitude zone (depth-slice interpretation) designated depth intervals and colour coding.

3.2.3. Comparison of estimated location of the historical well with 2016 GPR interpretation features

Comparing the area within which the historical well is estimated to exist, from the site plans illustrated in the UWA geophysical report (see previous footnote 1 for reference), it can be seen that there are some GPR interpretation features observed at multiple depths orientated approximately east-west through the northern section of this area (length ~ 25 m, from 382297 mE / 6452729 mN to 382322 mE / 6452732 mN) (see Figure 9). There is a “gap” in this east-west feature, where the observed GPR amplitude intensity is relatively lower. To the west of the “gap” are high amplitude zones observed over multiple depth-slices. This area has been labelled as W1 and could possibly be an historical well feature (centre coordinate ~382313 mE, 6452731 mN).

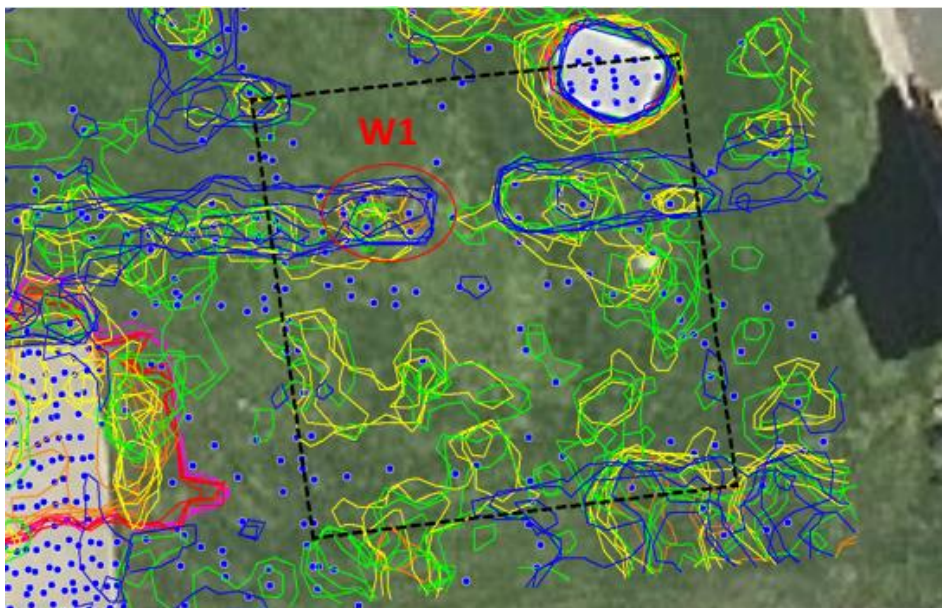
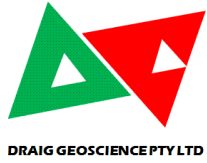


Figure 9. Radargram point feature interpretation and high amplitude zones (depth-slice interpretation) in relation to the area estimated to contain the historical well of interest (black dashed line). “W1” indicates possible location of historical well (satellite image source: ESRI World Map Online).

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Following the observation of a gap in the high amplitude east-west feature, Draig proceeded to examine historical photos to correlate any GPR features with observed surface features. In doing so, Draig found some interesting correlations, many of which likely represent historical foundation remanence from previous site infrastructure (see Figure 10 to Figure 15). A summary table of an estimated description of the observed historical aerial photographs and the GPR interpretation features is shown in Table 1.

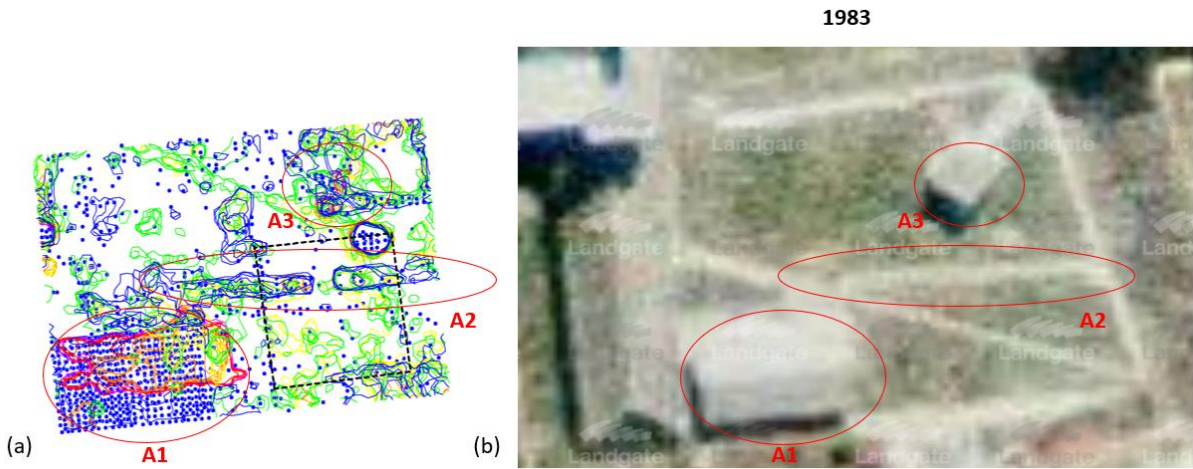


Figure 10. Common features highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 1983) (satellite image source: Landgate Imagery Online).

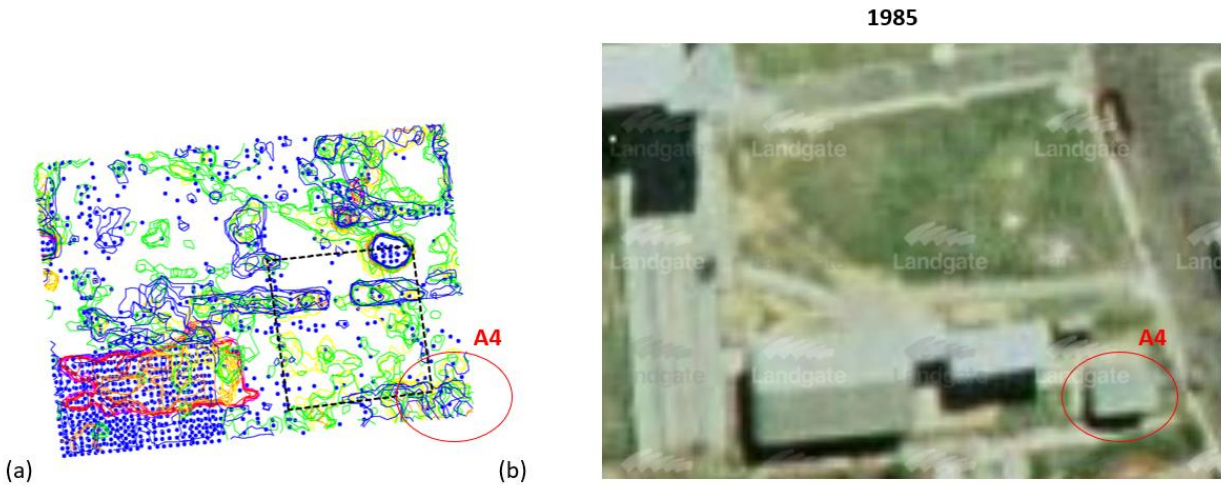
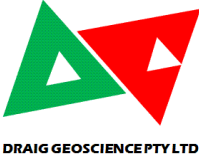


Figure 11. Common feature highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 1985) (satellite image source: Landgate Imagery Online).

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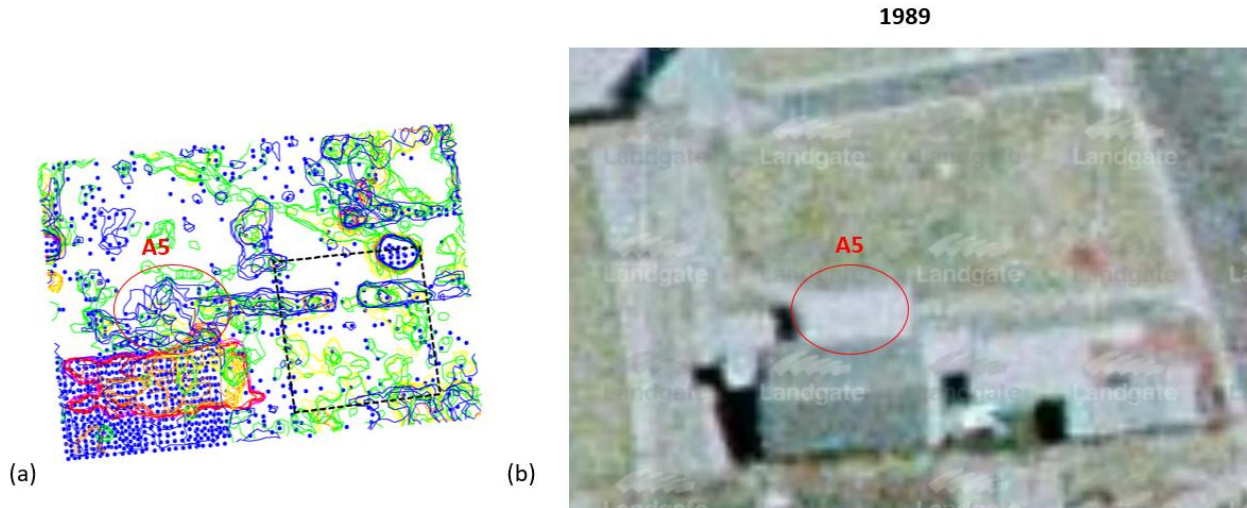


Figure 12. Common feature highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 1989) (satellite image source: Landgate Imagery Online).

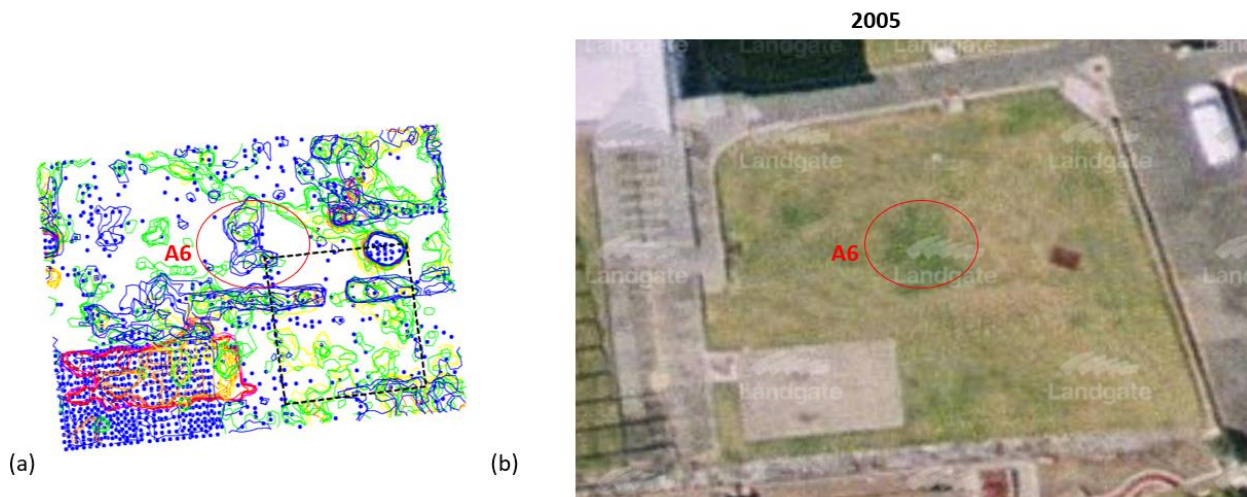


Figure 13. Common feature highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 2005) (satellite image source: Landgate Imagery Online).

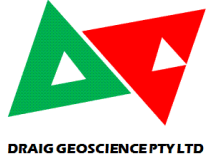
	<p>INTERPRETATION REPORT:</p> <p>HISTORICAL DATA REVIEW</p> <p>GROUND PENETRATING RADAR (GPR)</p> <p>FREMANTLE PRISON, FREMANTLE, WA</p>	<p>DG1732GLD</p>	<p>Rep. No. 2.0</p>
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Figure 14. Common feature highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 2008) (satellite image source: Landgate Imagery Online).

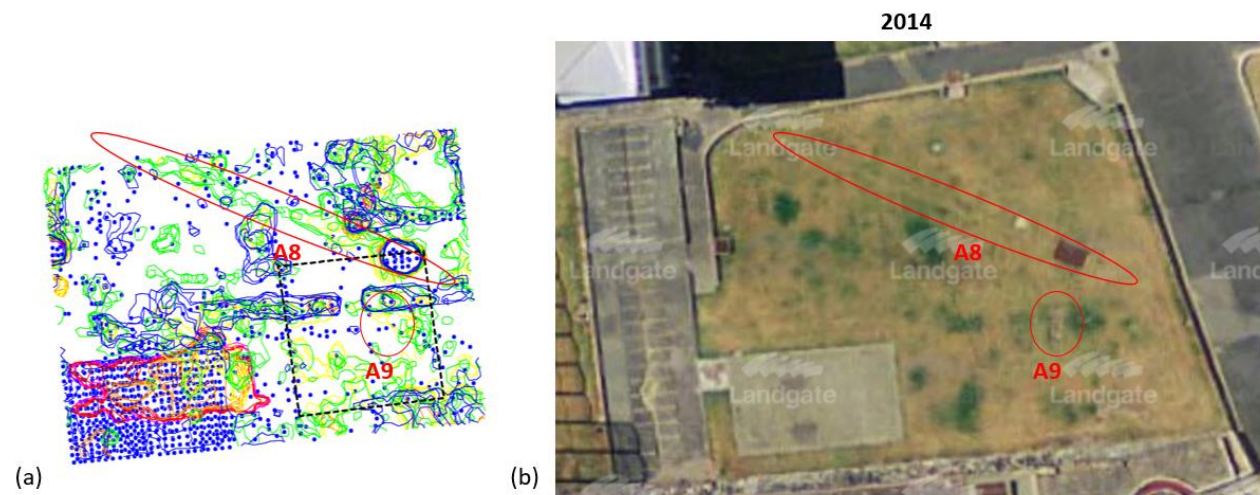


Figure 15. Common features highlighted (red outline) between (a) GPR interpretation (showing area estimated to contain the historical well of interest (black dashed line)) and (b) historical satellite image (circa. 2014) (satellite image source: Landgate Imagery Online).

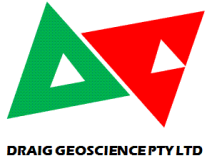

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Table 1. Brief description summary table of correlated historical aerial photograph features and GPR interpretation features.

Historical Aerial Photograph Feature ID	Brief Description
A1	Building foundation footprint
A2	Buried pipe / concreted or paved pathway
A3	Building foundation footprint
A4	Building foundation footprint
A5	Building foundation footprint
A6	Moisture catchment zone / topographic depression
A7	Trench
A8	Buried pipe
A9	Trench

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4. Conclusions

In summary, 1,706 GPR radargram point features were interpreted across the dataset. In general, 1,623 points (95% of points) were found within the top 2 m. Many of these shallow features are likely associated with buried/surface infrastructure.

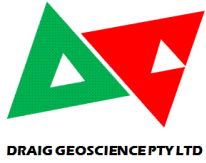
756 high amplitude zones were interpreted over the 36 average GPR amplitude intensity maps (depth-slices).

1 feature (W1) was interpreted as a possible historical well site for future investigation within the estimated boundary of the historical well location.

9 features (A1-A9) were interpreted as possible buried structures or remnants associated with evidence observed in historical aerial photography. The estimates of possible buried structures ranged from building foundation footprints to trenches and buried pipelines / pathways.

5. Recommendations

Following a review of the UWA 2016 electrical resistivity, magnetic and shallow electromagnetic (EM) datasets, Draig recommends a repeat data acquisition of the shallow EM dataset to improve on the dataset and provide greater clarity on the EM conductivity response in the top 1-2 m. Draig also recommends a repeat of the data acquisition of the electrical resistivity dataset to improve on the dataset and provide greater clarity on the electrical resistivity response in the top 5 m of the soil column.

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APPENDIX A – SITE PLAN



Legend

- GPR Survey - April 2016
- 10m x 10m area
- Area A1 GPR survey line
- GPR survey - October 2021
- GPR survey line

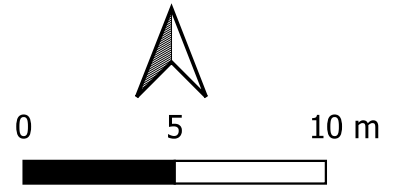

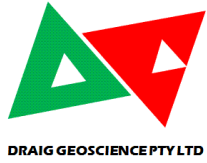


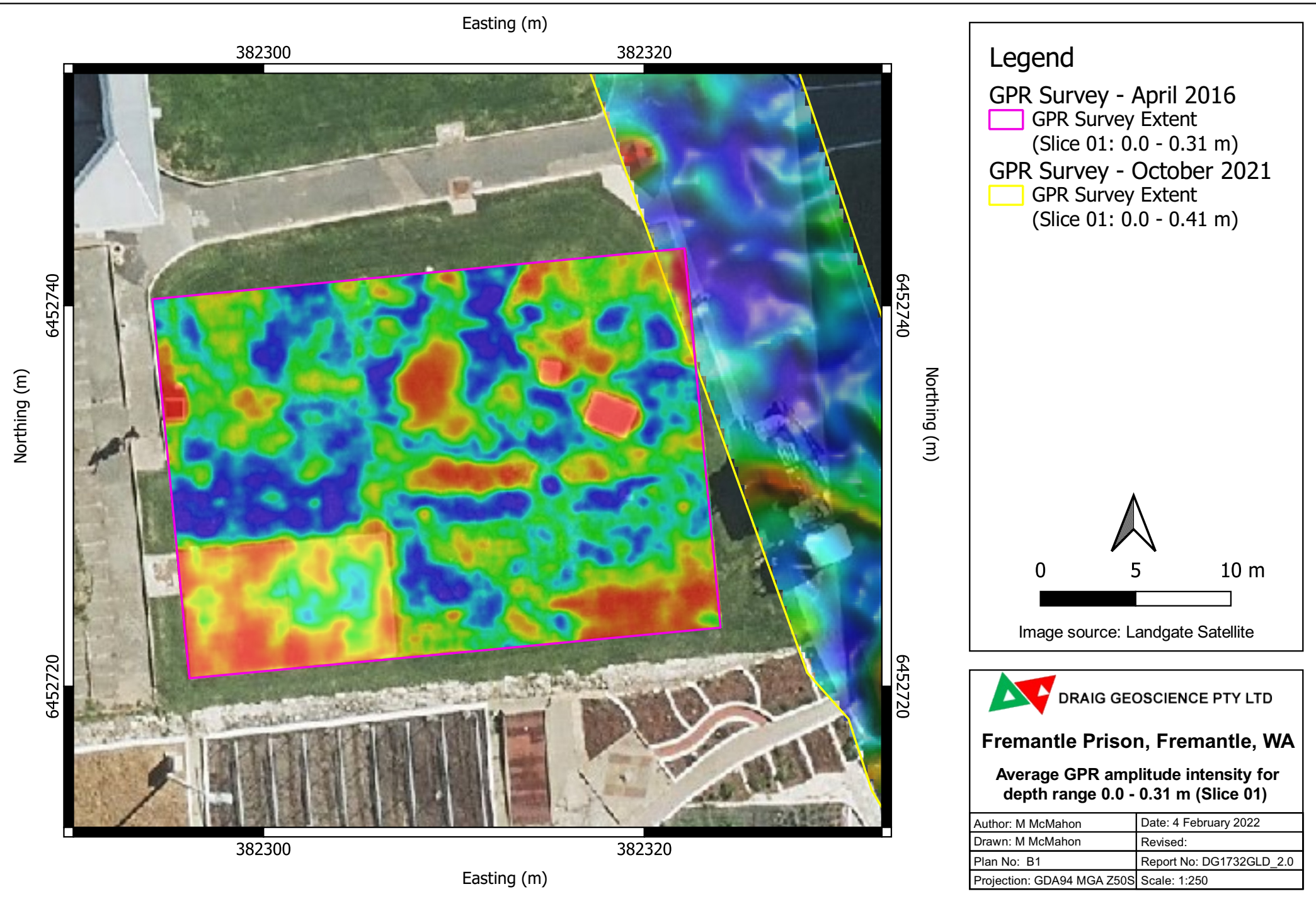
Image source: Landgate Satellite

 **DRAIG GEOSCIENCE PTY LTD**
Fremantle Prison, Fremantle, WA
GPR Survey - Site Plan

Author: M McMahon	Date: 28 January 2022
Drawn: M McMahon	Revised:
Plan No: A1	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250

	<p>INTERPRETATION REPORT: HISTORICAL DATA REVIEW</p> <p>GROUND PENETRATING RADAR (GPR) FREMANTLE PRISON, FREMANTLE, WA</p>	DG1732GLD	Rep. No. 2.0
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**APPENDIX B – MAPS OF AVERAGE GPR AMPLITUDE INTENSITY
(DEPTH-SLICES)**



Easting (m)

382300

382320

Northing (m)

6452740

Northing (m)

6452740

6452720

6452720

382300

382320

Easting (m)

Legend

GPR Survey - April 2016

GPR Survey Extent
 (Slice 01: 0.0 - 0.31 m)

GPR Survey - October 2021

GPR Survey Extent
 (Slice 01: 0.0 - 0.41 m)



0 5 10 m



Image source: Landgate Satellite

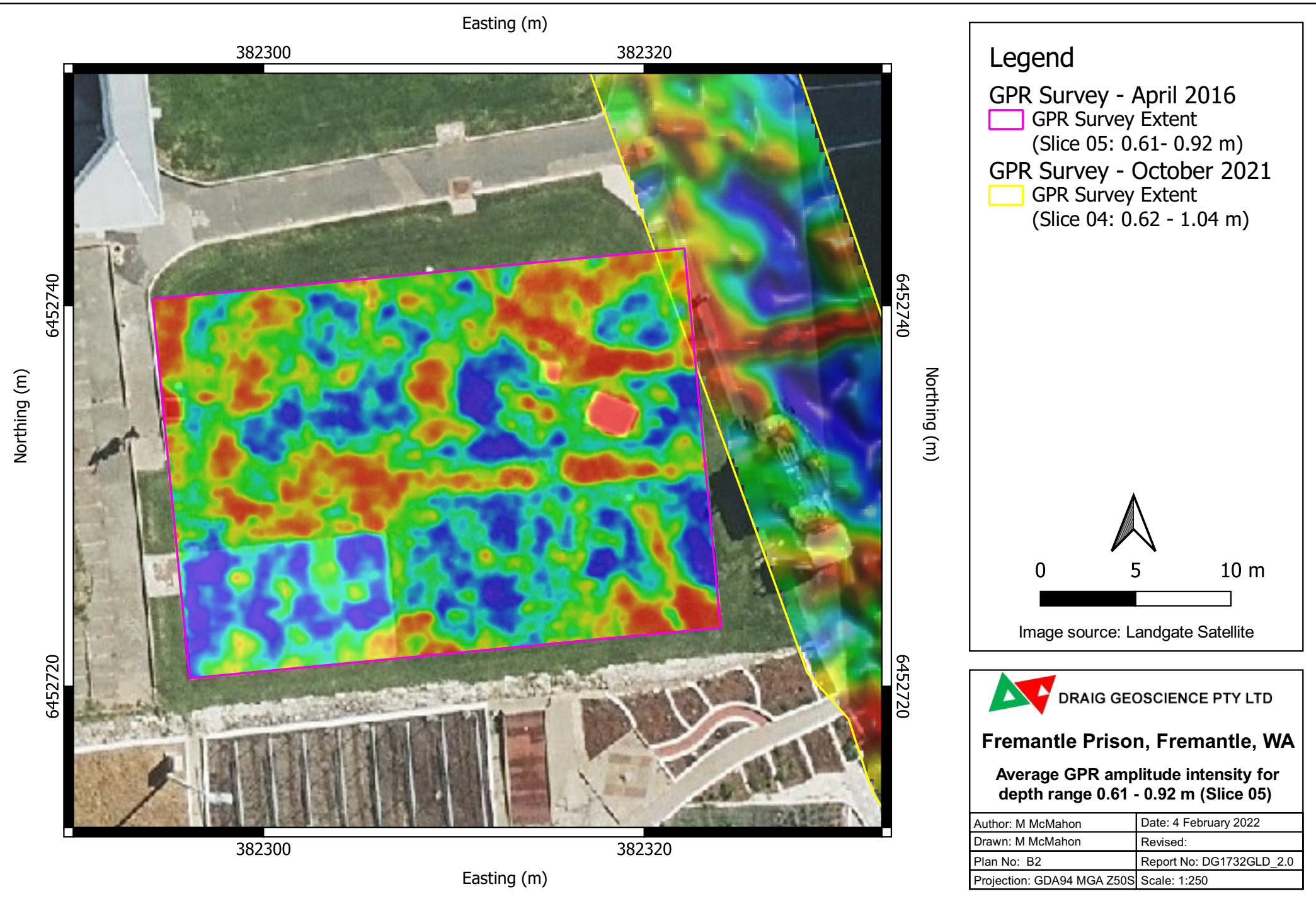


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Fremantle Prison, Fremantle, WA

Average GPR amplitude intensity for
depth range 0.0 - 0.31 m (Slice 01)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B1	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Easting (m)

382300

382320

Northing (m)

6452740

Northing (m)

6452740

6452720

6452720

382300

382320

Easting (m)

Legend

GPR Survey - April 2016

GPR Survey Extent
(Slice 05: 0.61 - 0.92 m)

GPR Survey - October 2021

GPR Survey Extent
(Slice 04: 0.62 - 1.04 m)



0 5 10 m



Image source: Landgate Satellite

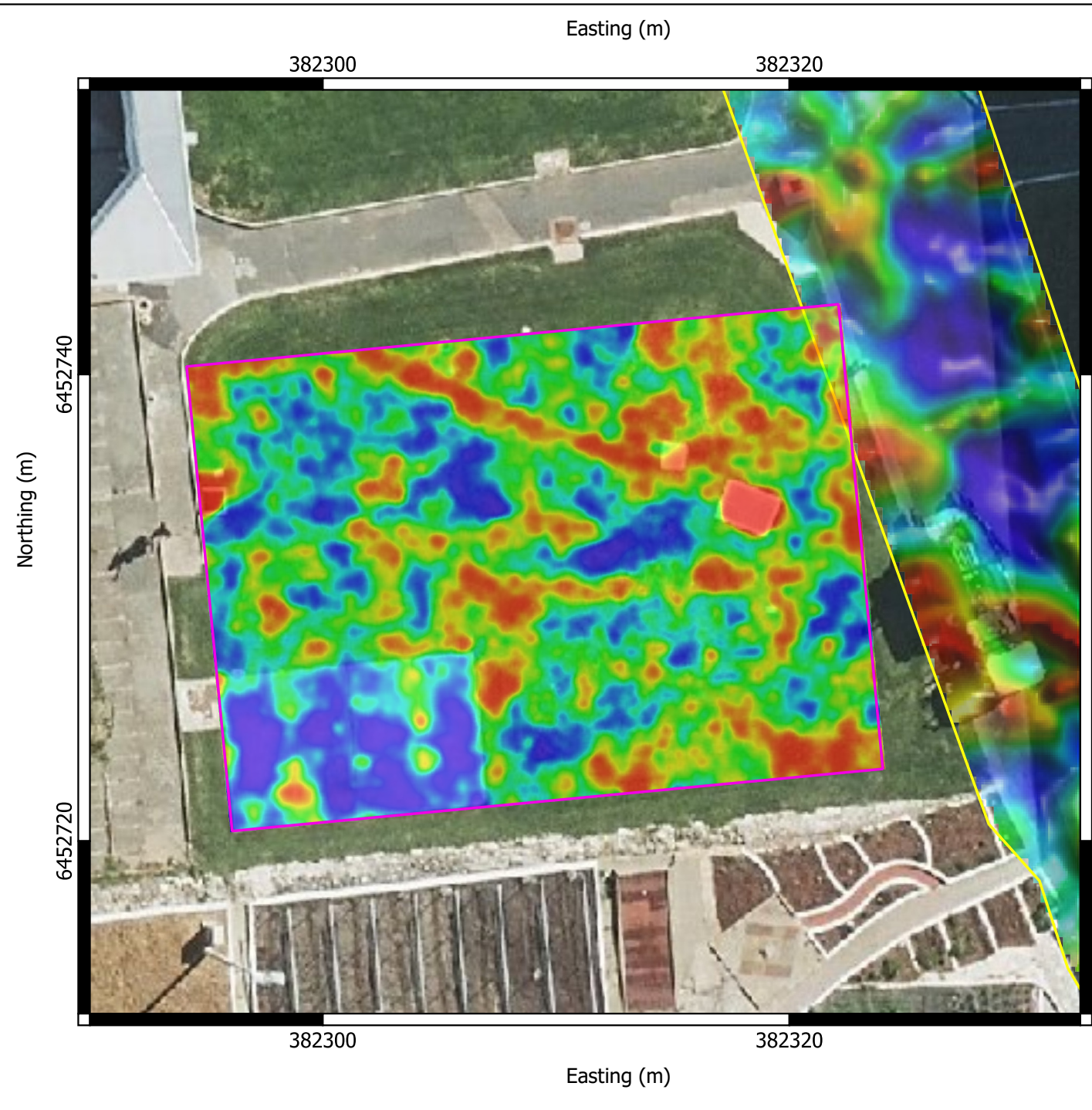


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Fremantle Prison, Fremantle, WA

**Average GPR amplitude intensity for
depth range 0.61 - 0.92 m (Slice 05)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B2	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- GPR Survey - April 2016
 - GPR Survey Extent
(Slice 10: 1.38 - 1.69 m)
- GPR Survey - October 2021
 - GPR Survey Extent
(Slice 07: 1.25 - 1.66 m)

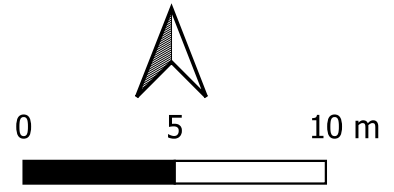


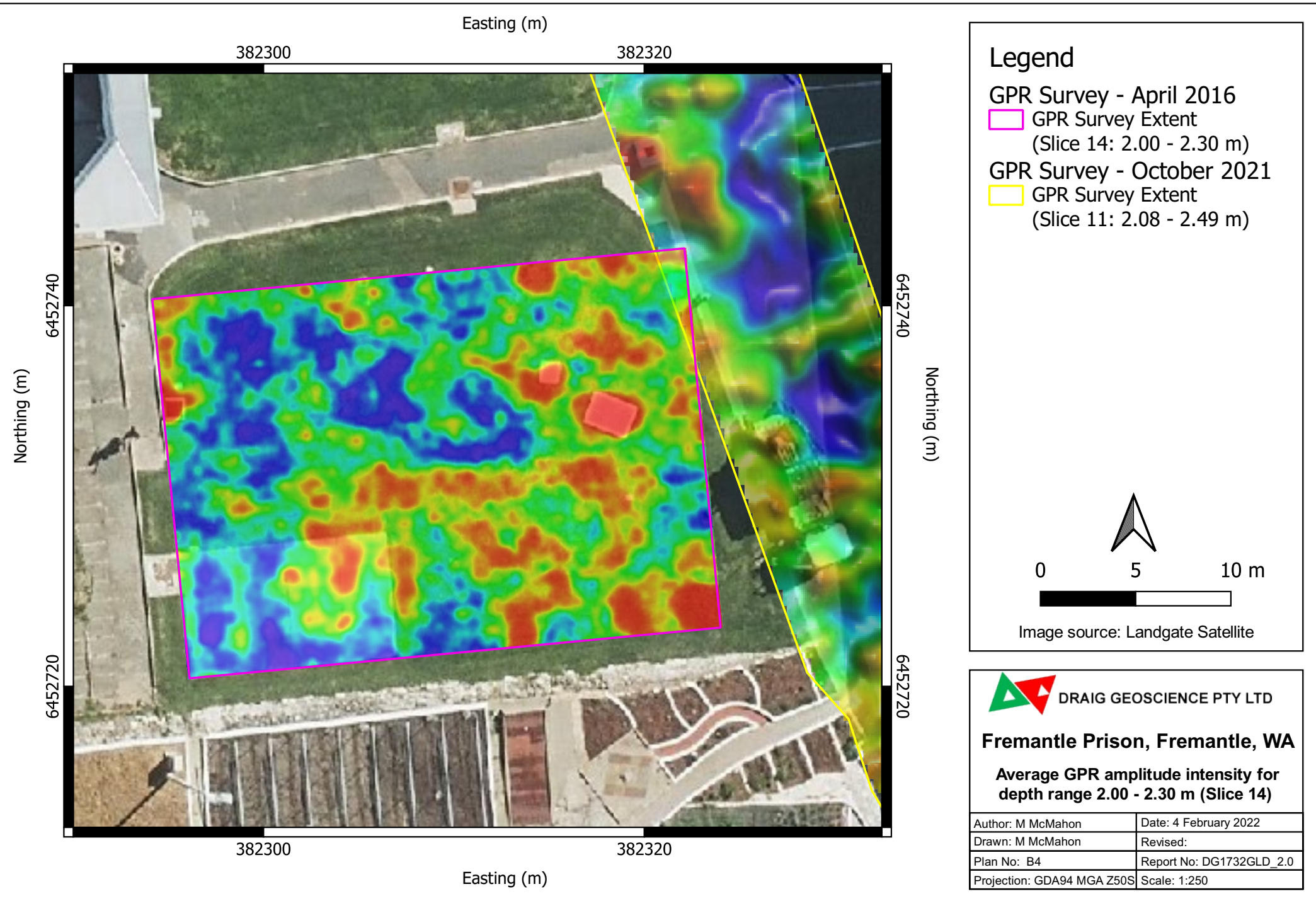
Image source: Landgate Satellite

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Fremantle Prison, Fremantle, WA

**Average GPR amplitude intensity for
depth range 1.38 - 1.69 m (Slice 10)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B3	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- GPR Survey - April 2016
 - GPR Survey Extent
(Slice 14: 2.00 - 2.30 m)
- GPR Survey - October 2021
 - GPR Survey Extent
(Slice 11: 2.08 - 2.49 m)

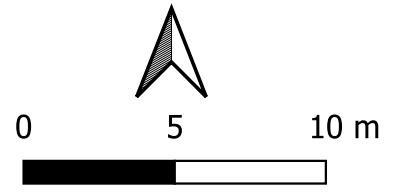


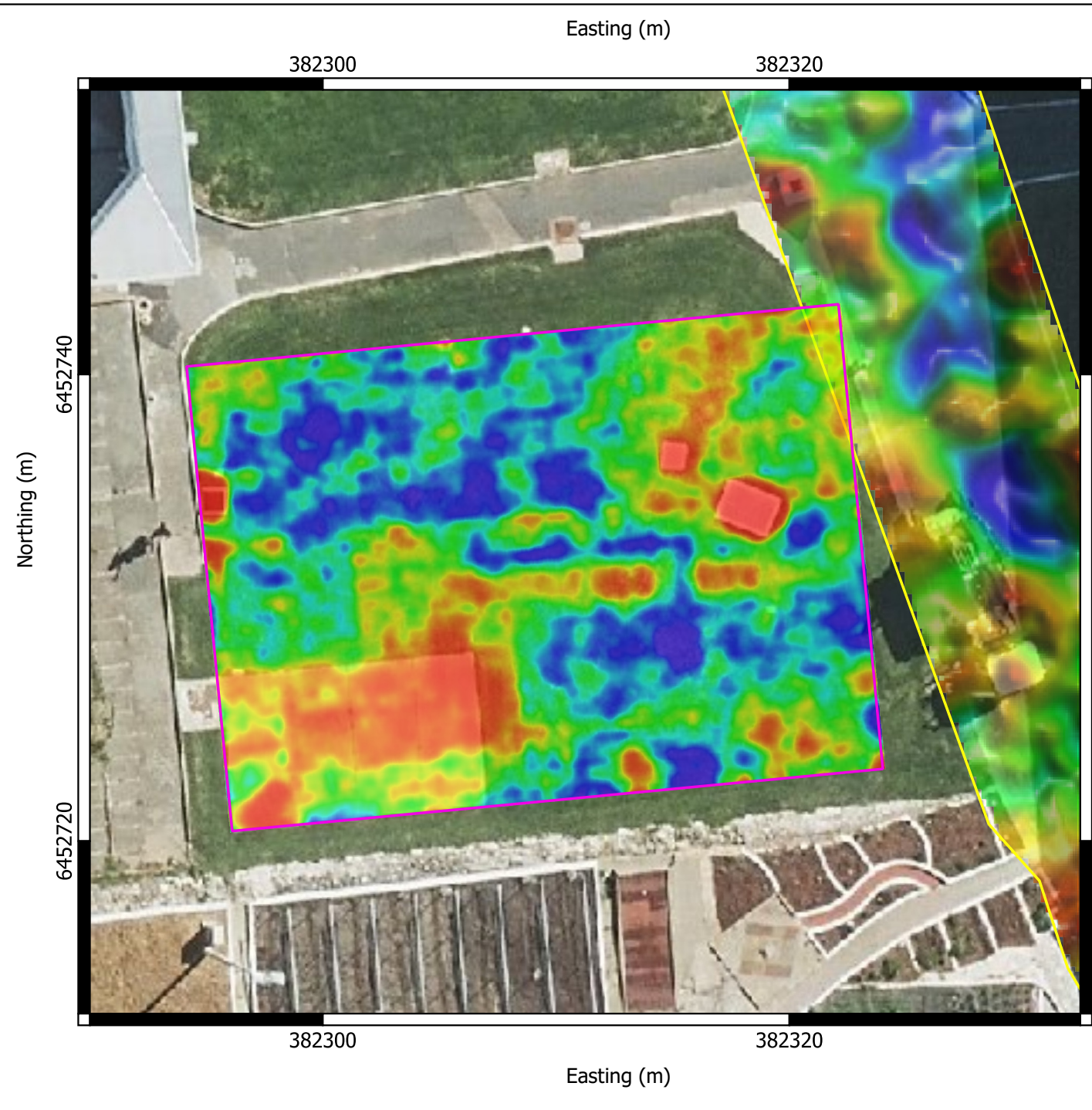
Image source: Landgate Satellite

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Fremantle Prison, Fremantle, WA

Average GPR amplitude intensity for depth range 2.00 - 2.30 m (Slice 14)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B4	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- GPR Survey - April 2016
 - GPR Survey Extent (Slice 22: 3.23 - 3.53 m)
- GPR Survey - October 2021
 - GPR Survey Extent (Slice 16: 3.11 - 3.53 m)

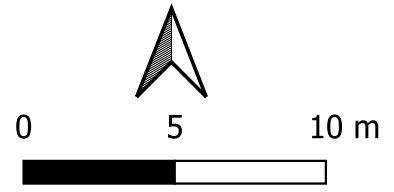


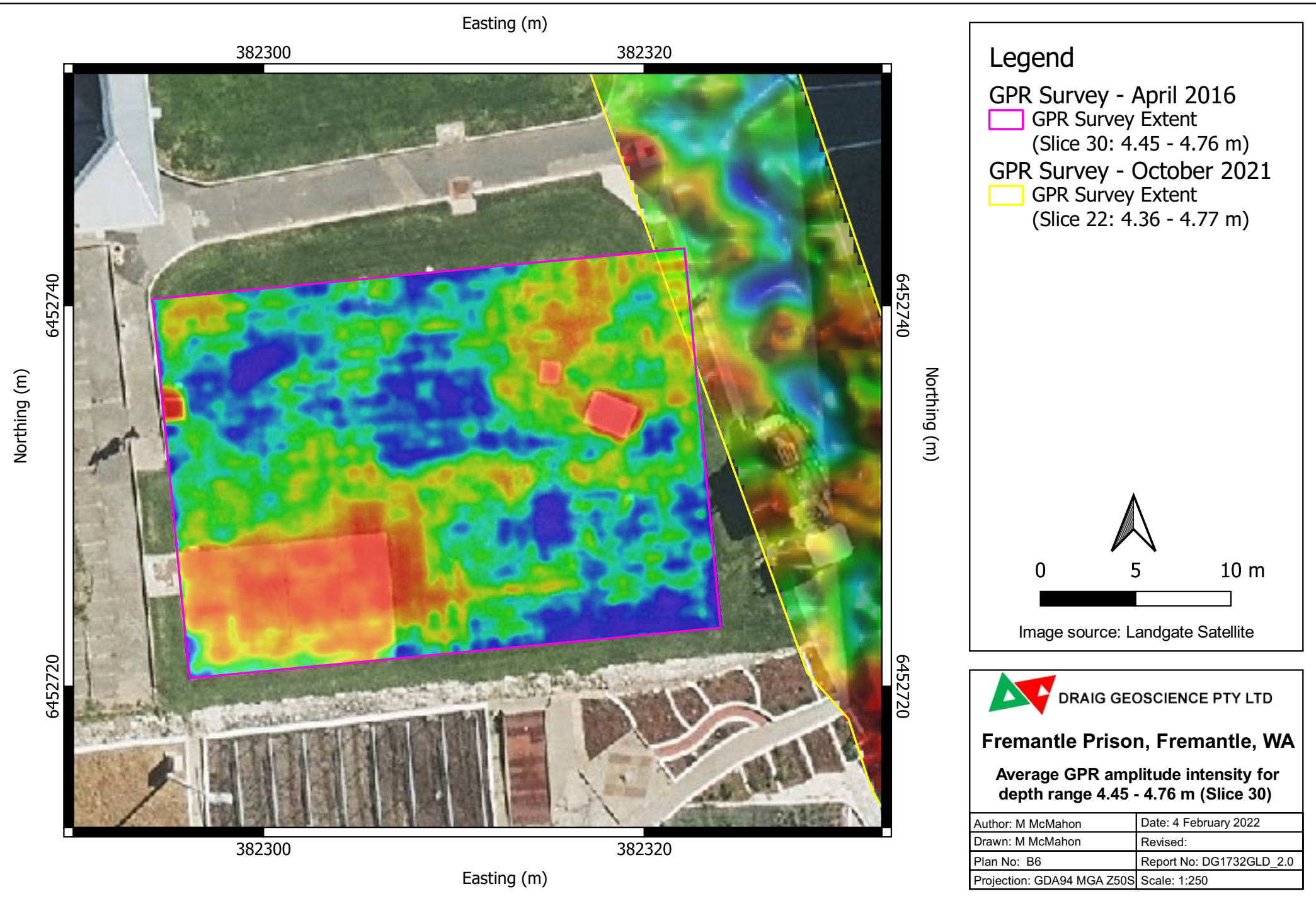
Image source: Landgate Satellite

DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

Average GPR amplitude intensity for depth range 3.23 - 3.53 m (Slice 22)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B5	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- GPR Survey - April 2016
 - GPR Survey Extent
(Slice 30: 4.45 - 4.76 m)
- GPR Survey - October 2021
 - GPR Survey Extent
(Slice 22: 4.36 - 4.77 m)

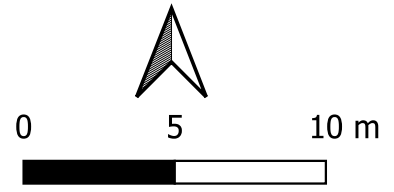


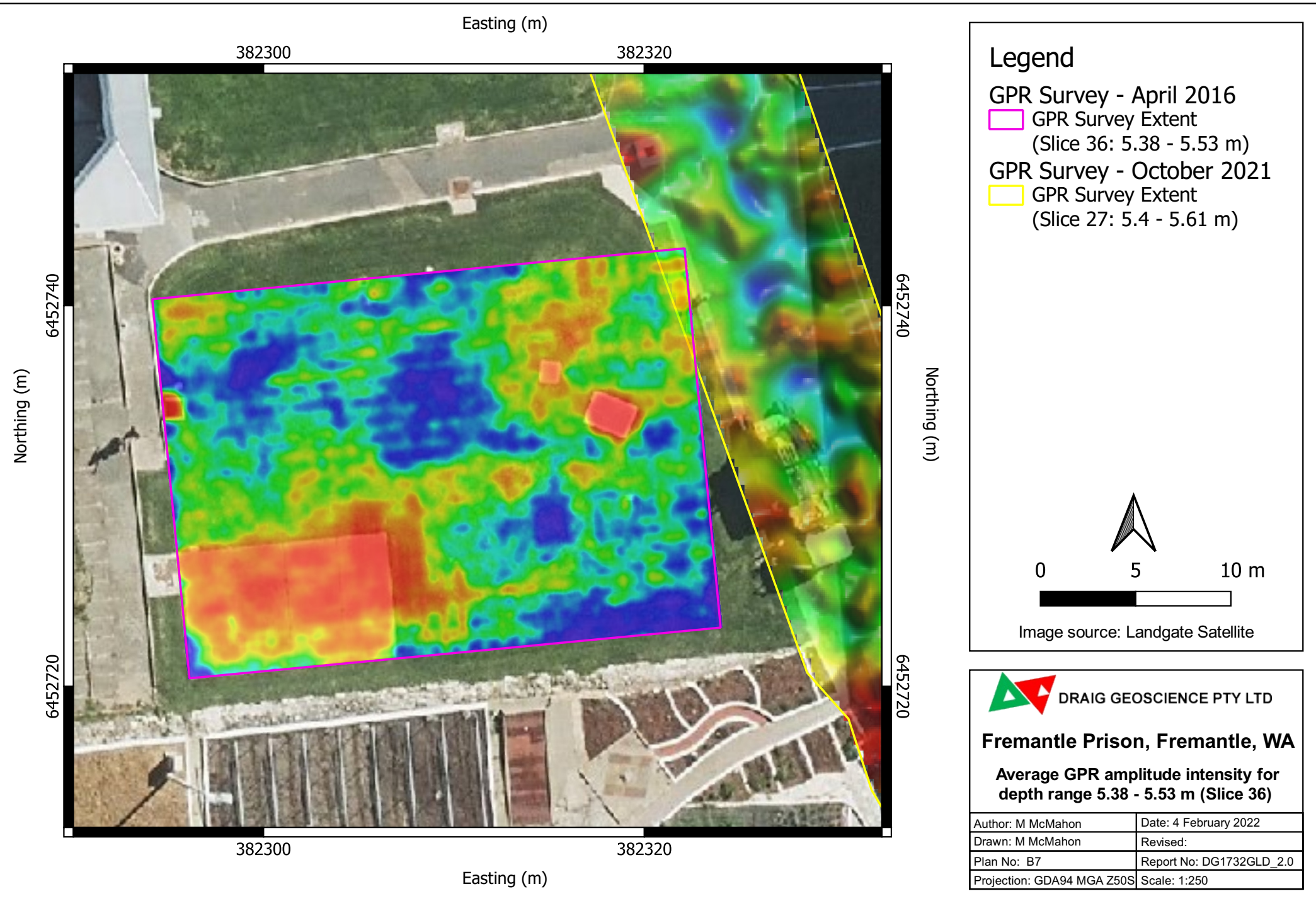
Image source: Landgate Satellite

DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

Average GPR amplitude intensity for depth range 4.45 - 4.76 m (Slice 30)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B6	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Easting (m)

382300

382320

Northing (m)

6452740

Northing (m)

6452740

6452720

6452720

382300

382320

Easting (m)

Legend

GPR Survey - April 2016

GPR Survey Extent
(Slice 36: 5.38 - 5.53 m)

GPR Survey - October 2021

GPR Survey Extent
(Slice 27: 5.4 - 5.61 m)



0 5 10 m



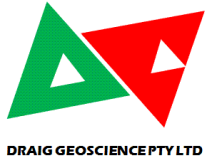
Image source: Landgate Satellite



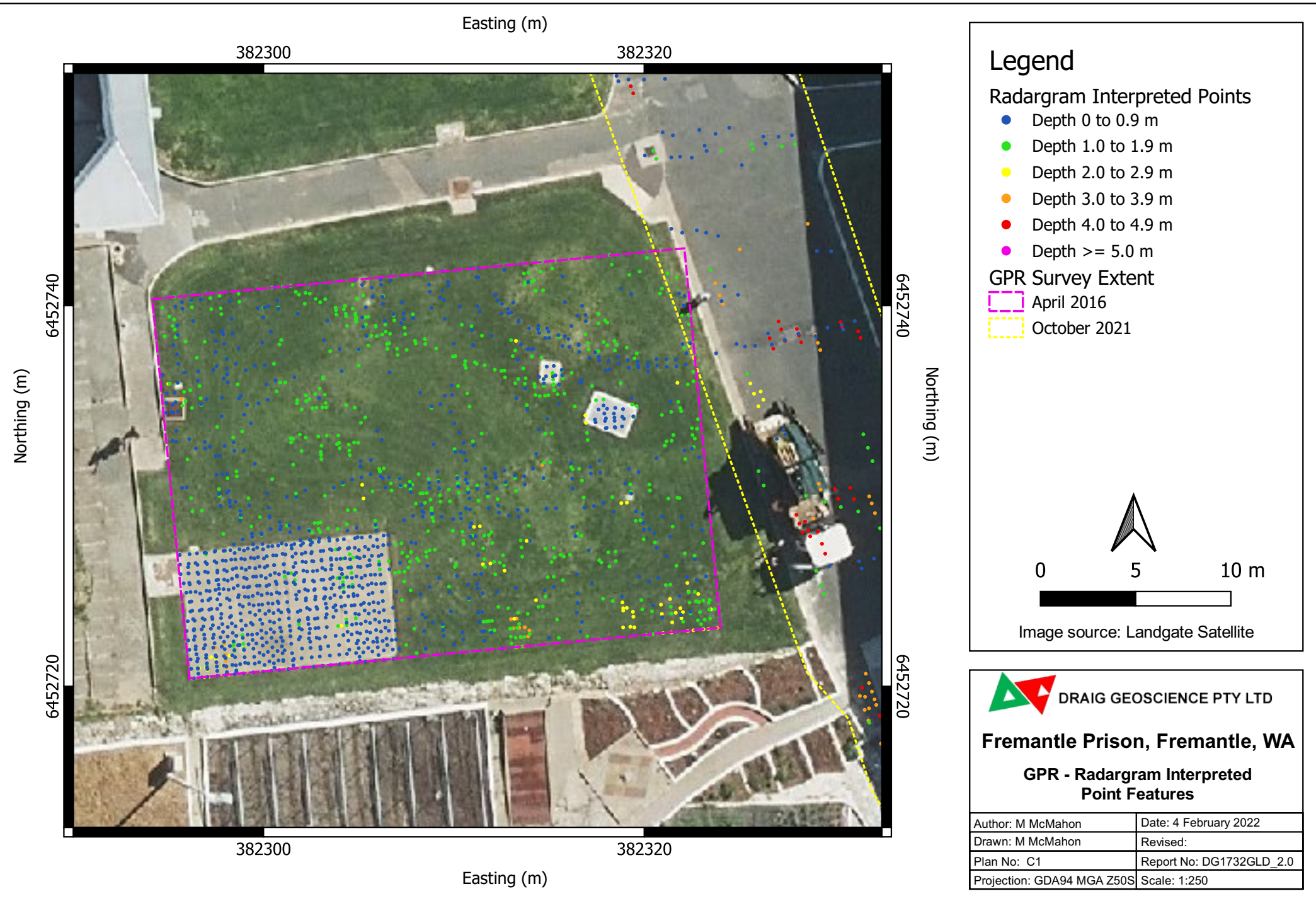
Fremantle Prison, Fremantle, WA

**Average GPR amplitude intensity for
depth range 5.38 - 5.53 m (Slice 36)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: B7	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250

	<p>INTERPRETATION REPORT: HISTORICAL DATA REVIEW GROUND PENETRATING RADAR (GPR) FREMANTLE PRISON, FREMANTLE, WA</p>	DG1732GLD	Rep. No. 2.0
		<p>Issue date: 09/02/2022</p>	Page 23 of 31

APPENDIX C – COMBINED INTERPRETATION OF GPR DATA IMAGES AND MAPS FOR POINTS AND ZONES OF HIGH AMPLITUDE



Legend

Radargram Interpreted Points

- Depth 0 to 0.9 m
- Depth 1.0 to 1.9 m
- Depth 2.0 to 2.9 m
- Depth 3.0 to 3.9 m
- Depth 4.0 to 4.9 m
- Depth \geq 5.0 m

GPR Survey Extent

- ▭ April 2016
- ▭ October 2021

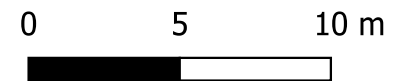



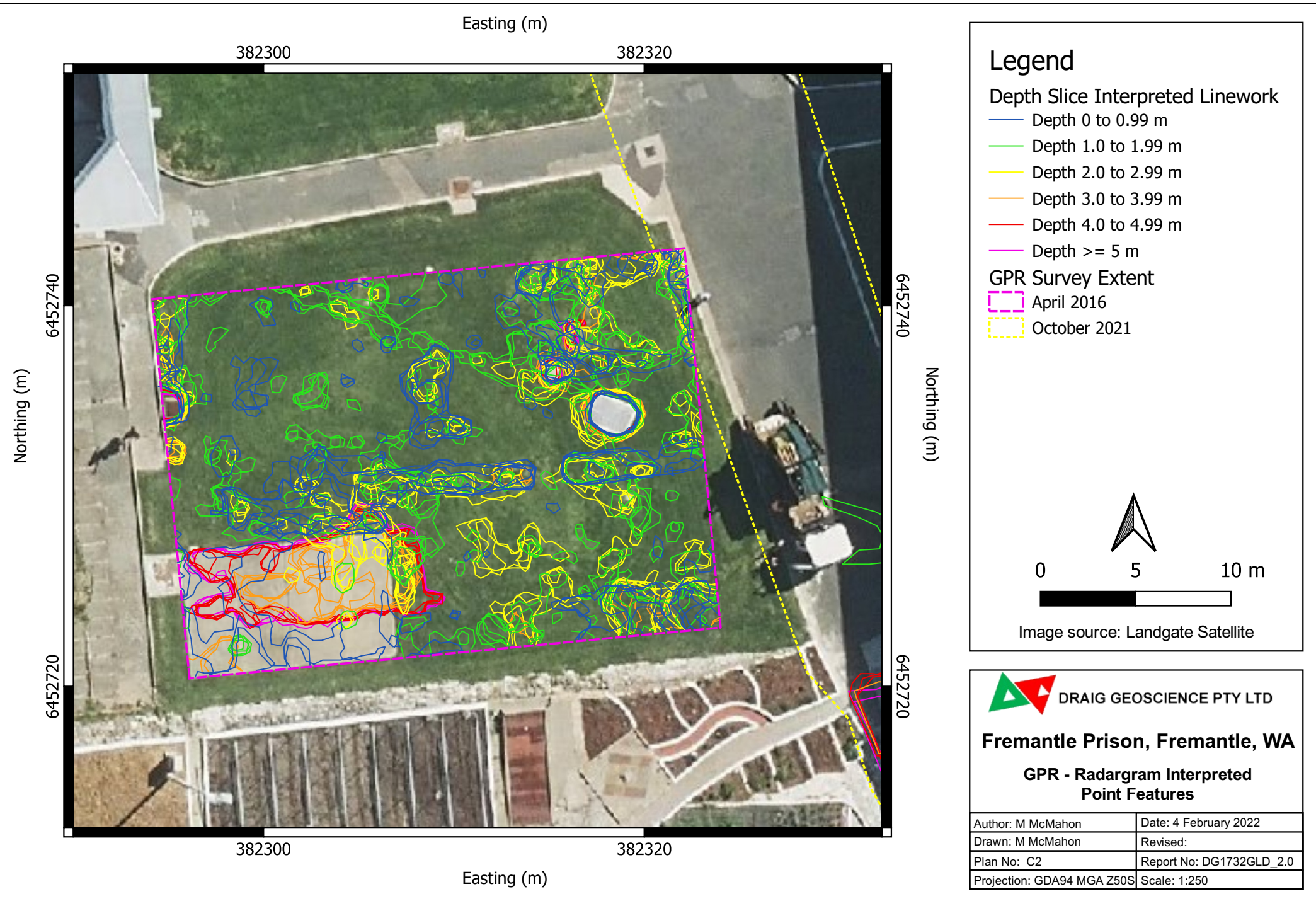
Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

GPR - Radargram Interpreted Point Features

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C1	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

Depth Slice Interpreted Linework

- Depth 0 to 0.99 m
- Depth 1.0 to 1.99 m
- Depth 2.0 to 2.99 m
- Depth 3.0 to 3.99 m
- Depth 4.0 to 4.99 m
- Depth \geq 5 m

GPR Survey Extent

- April 2016
- October 2021

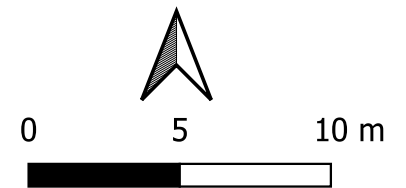


Image source: Landgate Satellite

DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

**GPR - Radargram Interpreted
Point Features**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C2	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



- ### Legend
- Radargram Interpreted Points
 - Depth 0 to 0.9 m
 - Depth Slice Interpreted Linework
 - Depth 0 to 0.92 m
 - GPR Survey Extent
 - April 2016
 - October 2021

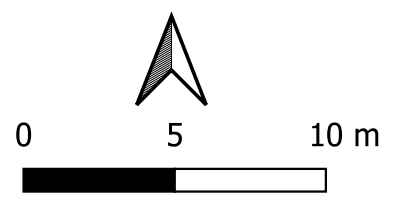

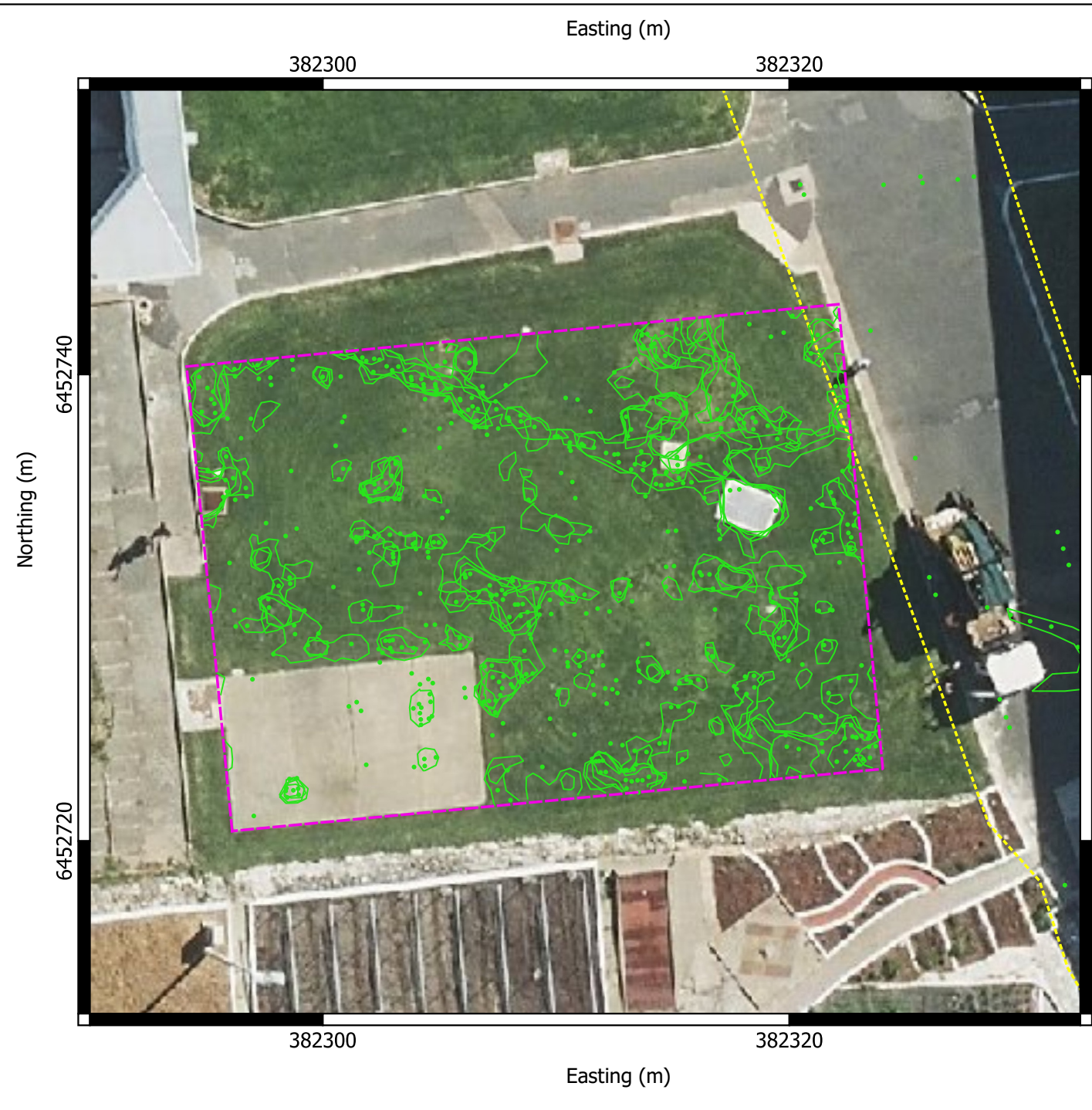


Image source: Landgate Satellite

 **DRAIG GEOSCIENCE PTY LTD**
Fremantle Prison, Fremantle, WA
GPR Feature Interpretation
(Depths 0 - 0.99 m)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C3	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- Radargram Interpreted Points
 - Depth 1.0 to 1.9 m
- Depth Slice Interpreted Linework
 - Depth 1.04 to 1.87 m
- GPR Group Extent
 - ▭ April 2016
 - ▭ October 2021

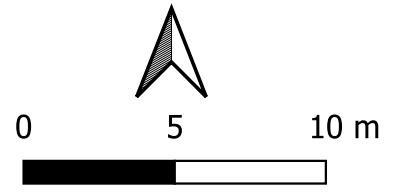


Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

GPR Feature Interpretation (Depths 1.0 - 1.99 m)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C4	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- Radargram Interpreted Points
 - Depth 2.0 to 2.9 m
- Depth Slice Interpreted Linework
 - Depth 2.00 to 2.92 m
- GPR Survey Extent
 - ▭ April 2016
 - ▭ October 2021

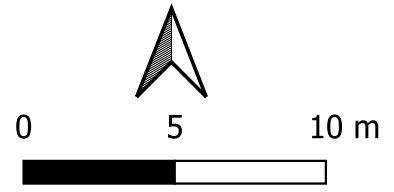


Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

**GPR Feature Interpretation
(Depths 2.0 - 2.99 m)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C5	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- Radargram Interpreted Points
 - Depth 3.0 to 3.9 m
- Depth Slice Interpreted Linework
 - Depth 3.07 to 3.99 m
- GPR Survey Extent
 - ▭ April 2016
 - ▭ October 2021

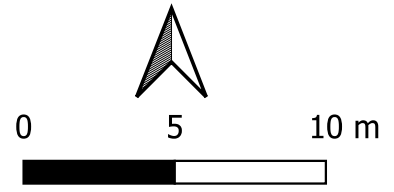


Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

**GPR Feature Interpretation
(Depths 3.0 - 3.99 m)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C6	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- Radargram Interpreted Points
 - Depth 4.0 to 4.9 m
- Depth Slice Interpreted Linework
 - Depth 4.15 to 4.98 m
- Group
 - April 2016
 - October 2021

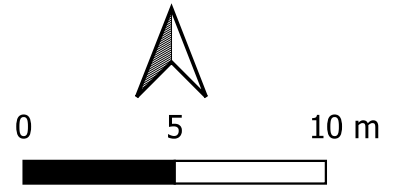


Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

**GPR Feature Interpretation
(Depths 4.0 - 4.99 m)**

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C7	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250



Legend

- Radargram Interpreted Points
 - Depth ≥ 5.0 m
- Depth Slice Interpreted Linework
 - Depth 5.07 to 5.61 m
- GPR Survey Extent
 - ▭ April 2016
 - ▭ October 2021

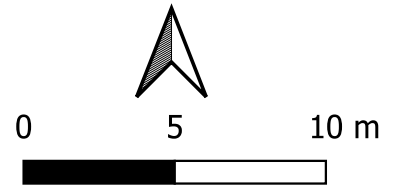


Image source: Landgate Satellite

 DRAIG GEOSCIENCE PTY LTD

Fremantle Prison, Fremantle, WA

GPR Feature Interpretation (Depths 5.0 m and greater)

Author: M McMahon	Date: 4 February 2022
Drawn: M McMahon	Revised:
Plan No: C8	Report No: DG1732GLD_2.0
Projection: GDA94 MGA Z50S	Scale: 1:250