MNG SUBSPATIAL

REPORT:

GROUND PENETRATING RADAR GEOPHYSICAL INVESTIGATION TO IDENTIFY POTENTIAL UNMARKED BURIALS ON WADJEMUP (ROTTNEST ISLAND), WESTERN AUSTRALIA.

Date: 20th April 2026

MNG Ref: 107754

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ACKNOWLEDGMENT OF COUNTRY

McMullen Nolan Group (MNG) acknowledges the Traditional Owners and Custodians of the land on which these proposed works are situated—the Whadjuk Noongar People. MNG pays respects to their Elders, both past and present, as well as those emerging.

MNG understand the cultural sensitivity of Wadjemup (Rottnest Island), with its complex and dark history as an Aboriginal prison. The known Wadjemup Aboriginal Burial Ground is of exceptional significance to not only the Whadjuk Noongar People, but many more Aboriginal nations across what is now known as Western Australia. Wadjemup is a unique place that serves as the final resting place of many Aboriginal leaders and highly respected individuals who were forcibly removed from their lands and imprisoned on Wadjemup.

Through these works, MNG is dedicated to taking a significant step towards recognition, reconciliation, and healing for Aboriginal people.

CONTENTS

1. INTRODUCTION

Rottnest Island Authority (RIA) engaged MNG SubSpatial (MNG) to undertake a targeted geophysical investigation within and surrounding the proposed bus terminal development area on Wadjemup/Rottnest Island. The primary objective of the investigation was to identify potential grave-like anomalies associated with unmarked Aboriginal burials, following the discovery of ancestral remains during recent earthworks within the development footprint.

Wadjemup holds significant cultural and historical importance as a site of Aboriginal incarceration between 1838 and 1903, with continued use as a forced labour camp until 1931. Historical records indicate that approximately 4,000 Aboriginal men and boys from across Western Australia were imprisoned on the Island, with at least 373 individuals known to have died in custody and subsequently buried within the Wadjemup Aboriginal Burial Ground (WABG). In addition to these recorded burials, there remains the potential for unmarked graves both associated with the incarceration period and from earlier Holocene occupation of the Island.

The current investigation forms part of ongoing efforts to better understand and delineate burial extents in areas subject to development. The discovery of human remains within the bus terminal works area highlights the sensitivity of the site and reinforces the requirement for non-invasive subsurface investigation to guide culturally appropriate management and decision-making processes. At the time of investigation, the identified remains were retained in situ pending direction from the Whadjuk Aboriginal Corporation regarding respectful reburial procedures.

Previous geophysical investigations undertaken by MNG across multiple locations on the Island, including the Quod (former prison), areas north of the WABG, the Oval, European Burial Ground, Garden Lake, and the main settlement area, did not identify burial-like anomalies. However, these results do not preclude the presence of isolated or previously undetected burials in other areas, particularly where historical records are incomplete or where ground conditions and past disturbances may have obscured earlier geophysical responses.

To address the current scope, MNG proposed the use of Ground Penetrating Radar (GPR) utilising the IDS GeoRadar Stream DP system, representing a high-resolution, multi-channel 3D GPR platform capable of providing continuous subsurface coverage. The system was integrated with a Leica Total Station to ensure accurate spatial positioning of all acquired data and associated surface features within the survey area.

2. CULTURAL AWARENESS

All MNG personnel and contractors (Dominic Howman) underwent cultural awareness training prior to commencing any works on Wadjemup. This initiative provided all personnel with an understanding of the cultural significance of Wadjemup, and the sensitivity of the WABG. All works strictly adhered to cultural safety protocols established throughout the project, ensuring the utmost respect for this profoundly significant and sensitive Aboriginal site.

MNG ensured to uphold the *Aboriginal Heritage Act 1972* for the WABG – Section 18, which consents to have two Aboriginal Monitors always monitoring the works within the registered WABG site.

3. GEOPHYSICAL INVESTIGATION SITE

Surface conditions across the investigation area were variable and, in places, not ideally suited for high-quality GPR acquisition due to the site being an active construction zone at the time of survey. The bus terminal development works had already commenced, and the ground surface had been significantly disturbed prior to mobilisation. This included areas of turned-up and reworked sand, stockpiled materials, and irregular ground conditions associated with recent excavation and earthmoving activities. These factors introduced challenges for consistent antenna coupling and smooth data acquisition, particularly where loose, uneven surfaces reduced contact between the GPR array and the ground.

The investigation area comprised a combination of partially cleared construction zones, open sandy ground, and areas of retained vegetation. In one section of the site, dense vegetation further restricted access and limited the ability to achieve uniform survey coverage. As a result, while the majority of accessible areas were surveyed, data density and quality varied locally depending on ground conditions and physical access constraints.

Subsurface conditions also introduced complexity to the investigation. Given the active construction environment, the near-surface profile is likely to have been altered through excavation, backfilling, and material reworking, resulting in a heterogeneous and disturbed subsurface. This type of ground disturbance can obscure or disrupt the natural stratigraphy and any subtle contrasts typically relied upon for identifying grave-like anomalies. In particular, previously excavated and backfilled zones may present geophysical signatures similar to burial features, increasing ambiguity in interpretation.

In addition, the sandy nature of the Wadjemup soils, while generally favourable for GPR penetration under undisturbed conditions, can become highly variable when reworked. Changes in compaction, moisture content, and grain structure associated with construction activities can produce inconsistent radar responses and reduce the continuity of subsurface reflections.

Across the survey area, GPR data acquired using the IDS GeoRadar Stream DP system provided variable but generally moderate penetration depths, with effective imaging achieved to depths of approximately 2–4 m below ground level (BGL), depending on local ground conditions. However, in areas of significant disturbance or poor surface coupling, data quality was reduced, and coherent reflections were less continuous. These factors limit the confidence in identifying and characterising subtle subsurface anomalies, particularly those associated with unmarked burials, which are often defined by low-contrast and discontinuous geophysical signatures.

Overall, both surface and subsurface conditions at the time of investigation introduced a level of uncertainty to the GPR results, requiring careful and conservative interpretation of any identified anomalies within the context of the disturbed ground environment.

Figure 1: Extent of the GPR geophysical investigation. The green shaded areas indicate the locations where GPR data were acquired, with the location of the identified remains marked by the red cross.

4. GEOPHYSICAL DATA ACQUISITION

Ground Penetrating Radar (GPR) is a non-destructive and non-invasive geophysical technique for imaging the shallow subsurface and producing high-resolution colour sections in real time. The method works by transmitting electromagnetic energy into the material being tested, most usually the ground.

The transmitted electromagnetic energy propagates through the subsurface as a function of the subsurface material's electrical properties, which are in turn dependent on its physical and chemical properties. Reflection of radar energy occurs at boundaries between differing stratigraphic layers or inclusions which have contrasting electrical properties. Conversely, no reflections occur from a homogenous material where there are no internal reflectors. The reflections are detected by the receiving antenna placed adjacent to the transmitter. The depth to the target is proportional to the time (in nanoseconds) taken for the signal to travel from the transmitting antenna at the surface to the target and back to the receiver – Figure 2.

The achievable depth of penetration depends on the frequency of the antenna used and is also influenced by the local subsurface conditions. GPR is generally effective in clean sands, which provide an optimal medium for radio waves to propagate through, enabling successful subsurface imaging and analysis.

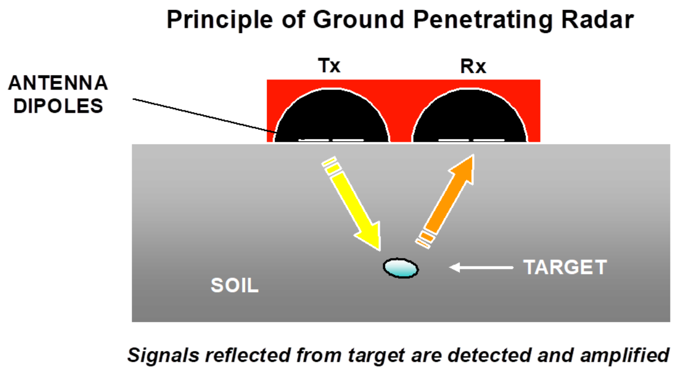


Figure 2: Schematic illustration of the principle behind ground penetrating radar.

Limitations: The quality of the acquired data may be compromised over certain surfaces which are directly related to the GPR method. These limitations are inherent to the geophysics *** technique and are listed below:

- Reduction of penetration is experienced in areas with high clay and/or water content. This is with reference to the dielectric properties of the materials which may result in a significantly higher absorption of radio wave energy.
- Soil with pools of water, soil after heavy rain, high salinity soil, and high mineral containing soil with iron ore.
- A requirement for good coupling between the antenna and the ground. GPR data cannot be collected where surface obstructions are present, including but not limited to infrastructure and vegetation.

- GPR collected over reinforced concrete slabs, or some paving materials may adversely affect the data, and hence the reliability of the information obtained may be compromised in such situations.

4.1 INVESTIGATION LOGISTICS

The geophysical data acquisition was conducted between on the 14th and 15th of April 2026.

4.2 GROUND PENETRATING RADAR – STREAMDP

GPR data was acquired using an IDS GeoRadar Stream DP system, employing a ground-coupled antenna with a centre frequency of 600MHz. the StreamDP unit and Table 1 provides the acquisition parameters.

The GPR data acquisition involved manually pushing the unit at a deliberate and consistent pace along parallel profiles spaced at 0.5m intervals. Distances along these profiles were logged using a calibrated distance measuring device (odometer wheel) attached to the system.

Relocation referencing of the GPR data was achieved through a Global Positioning System (GPS) with live coordinates fed to the GPR control unit, ensuring accurate relocation along each GPR profile.

The StreamDP possess a multichannel 3D antenna with 30 channels in double polarization (19 channels in the vertical plane and 11 channels in the horizontal plane). The system essentially “paints” the floor in a swathe sense acquiring data both inline and orthogonal to the direction of movement.

The StreamDP also features Equalized scrambled Technology - EsT a new Patented Technology by IDS GeoRadar, that overturns the traditional definition of GPR. EsT brings out the deepest signal at the same signal level as shallow targets through noise rejection, both the clarity of shallow targets and high penetration depth are achieved. After equalization, the data is 'scrambled' together into a single radar trace, providing an extended depth range and an ultra-high resolution.

The StreamDP was release in July 2022 and represents the pinnacle of GPR technology in the industry at this current time.

Table 1 – Stream DP GPR Acquisition Parameters

Acquisition Parameter	Specification
Antenna centre frequency	600MHz
Sampling step	0.0397m
Sampling time	0.125ns
Polarization	Vertical and Horizontal
Uncalibrated radar wave velocity	0.1m/ns
Maximum apparent depth	6m

4.4 LOCATING AND POSITIONING

The StreamDP GPR system relies on an external GPS device, the Leica Zeno FLX100 Smart Antenna with SmartNet RTK technology was used for precise positioning. This GPS device is paired with a Wi-Fi-enabled tablet for data acquisition. The integration of Pulse-per-second (PPS) into the antenna ensures accurate synchronisation with the external GPS, facilitating precise positioning.

In areas with substantial tree canopy or near buildings, where the StreamDP's external GPS was hindered, a Total Station with multiple base station setups was employed to maintain enhanced accuracy in relocating the GPR data, with projected accuracies of:

- ±100mm Horizontally Accuracy, and
- ±200mm Vertically Accuracy

The requested datums from RIA used for this project are:

a) Horizontal: Perth Costal Grid 2020 (PCG 2020)
b) Vertical: Australian Height Datum (AHD)

5. UNDERGROUND UTILITY AND ASSET DETECTION

The identification of services was undertaken as a secondary outcome of the Ground Penetrating Radar (GPR) dataset, rather than as a dedicated utility locating exercise. No electro-magnetic (EM) locator or electro-magnetic induction (EMI) techniques were employed as part of this scope; all service interpretations were derived solely from GPR responses in conjunction with observable surface features and site context.

Records from a previous locating investigation were used as a reference during acquisition and interpretation to support correlation between observed GPR responses and expected service alignments, noting that the available documentation indicated a complex and partially uncertain subsurface service environment.

The GPR data was reviewed in real time and during post-processing to identify linear reflectors, disturbed ground signatures and trenching features consistent with buried services. Where present, these features were interpreted as potential utilities or service corridors; however, it is noted that without complementary EM locating or physical verification (e.g. potholing), all identified services remain interpretative in nature.

Service mapping derived from the GPR dataset is therefore considered to be indicative only and does not meet the requirements for Quality Level B classification under AS 5488.1-2022. Instead, the outputs are more appropriately classified as Quality Level C, supported by geophysical interpretation and surface observations, with positional accuracy dependent on site conditions, signal penetration and the clarity of reflected responses. Horizontal and vertical uncertainties are inherently higher than conventional EM-based locating, particularly in areas of complex subsurface conditions or where multiple services are present within the same corridor.

All interpreted services and linear anomalies were captured and recorded during processing, with locations provided relative to the project coordinate system for integration with the broader site investigation dataset.

6. GEOPHYSICAL DATA PROCESSING

The acquired geophysical datasets were processed and analysed with current industry standard software by qualified geophysicists using MNG standard processing routines. This was reviewed and constantly under Quality Assurance from Dominic Howman.

6.1 GROUND PENETRATING RADAR - STREAMDP

The acquired GPR data was processed and interpretated using Geolitix, a cloud computing GPR software which provides post-processing, data analysis and 3D time / depth slices. The following processing routine was used to generate 2D radargrams:

1. Correct Max Phase – Set GPR zero time to the first crossing of the reflection wavelet.
2. Manual Gain – Apply a gain curve function in the y-direction to account for GPR signal attenuation with depth.
3. 1D Bandpass Filtering – High-cut and low-cut frequency filter to improve signal to noise ratio.
4. Dewow – Removes low frequency 'wow' effects caused by inherent antenna characteristics.
5. 2D Filtering – Background removal and running average filters to suppress horizontally coherent energy, effectively emphasising signals which vary laterally.

The following steps were then applied to enable the generation of 3D time slices.

1. Kirchoff Migration – Sums the amplitude of a hyperbola into a focused point at its apex, removing the tails
2. Hilbert Transform – Calculate the overall reflectivity strength for each trace by using adding a phase shift and eliminating negative frequency components.
3. Time Slicing – Amplitude is calculated for each trace in each swath at a specific travel time and then gridded to generate a map image of radar reflectivity, this is repeated for all travel times in a specified range.

Following the application of the above processing flow, the GPR data was predominately observed to be of high quality, with strong signal to noise ratio and expected penetration depth for the antenna frequency used. The processed GPR data was analysed to delineate interpreted subsurface features including high amplitude features. Analysis of the GPR data consisted of viewing and digitising the profiles sequentially with consideration to the:

- **Signal travel time** which, combined with the material radio-wave velocity, defines the depth of the target [1]
- **Amplitude and phase of the signal** which defines the dielectric contrast between different materials [2]

- **Continuity of the signal** which shows the general dimension, condition, and shape of the target

[1] With the GPR method, the depth to a given subsurface target is obtained by measuring the two-way travel time of the radar pulse from the antenna to that target and by multiplying this time by the radar wave velocity within the overlying layers. For this investigation, a bulk radar wave velocity of 0.12m/nS was used.

[2] The amplitude of the radar wave reflection signal is a function of the contrast in dielectric properties of the subsurface material. Near zero amplitude reflections occur where there is no or minimal change in the dielectric properties indicative of a homogeneous material. High amplitude reflections (either positive or negative) occur where there is a significant change in dielectric properties for example within an inhomogeneous material with multiple inclusions such as buried utilities or the interface between differing geological layers.

7. RESULTS AND INTERPRETATION

The results of the geophysical investigation carried out across the Holy Trinity Catholic/Bus Terminal Development Site are provided in Appendices A, B and C of this report as follows:

Appendix A:

- **107754-01 SITE PLAN** Site Plan

Appendix B:

- **107754-02 IDENTIFIED GPR BURIAL-LIKE ANOMALIES:** Identified burial-like anomalies across The Holy Trinity Catholic Church/Bus Terminal Development Site

7.1 GROUND PENETRATING

Interpreting GPR data involves the analysis of radar signals reflecting from subsurface features to deduce details about the subsurface composition and geometry. The expertise of a qualified Geophysicist with a background in GPR investigations is crucial for accurate interpretation.

When interpreting GPR data (radar-grams) for unmarked burials the following parameters need to be considered:

1. Vertical discontinuities in soil/strata profile: More pronounced for new burials, less evident in older burials.
2. Depressions in Soil Layers Above the Grave.
3. Mottled GPR Signal Above the Grave: Result of the unconsolidated nature of the fill material.
4. Typical Depth Extent: 1.5 to 3.0 meters below ground level.
5. Consistent Amplitude and Phase Across Multiple Parallel Profiles with a clear start and end.

These considerations are crucial when employing GPR for the identification of unmarked burials. Understanding these parameters enhances the accuracy of the analysis and increases the reliability of the results. It is important to recognise that both the ground conditions and the site history introduce significant limitations to the reliability of GPR data and, consequently, the confidence of any interpretation.

The effectiveness of GPR is highly dependent on subsurface conditions. In this case, the site is made up of disturbed and reworked materials associated with prior construction, including variable fill, compacted surfaces, and potential debris. These conditions typically result in elevated electrical conductivity and heterogeneous dielectric properties, which lead to attenuation of the GPR signal and increased scattering. Additionally, construction related disturbance disrupts the natural stratigraphy that GPR relies upon to identify anomalous features, making it difficult to distinguish between anthropogenic disturbance related to burial and that associated with site works.

The identification of graves using GPR is generally based on the detection of subsurface anomalies that contrast with the surrounding material. High-confidence interpretations are typically supported by clear, coherent reflections that define grave cuts, identifiable stratigraphic truncation, and, where present, strong hyperbolic reflections associated with coffins or void spaces. However, in the absence of coffins, such as in direct in-ground burials, these diagnostic features are significantly reduced or absent. As a result, the geophysical response is often limited to subtle and diffuse changes in signal character, such as minor variations in amplitude, disrupted layering, or weak, poorly defined reflectors.

Within this context, a *Feature of Interest* GPR interpretation of a possible unmarked grave is characterised by the presence of weak, inconsistent, or discontinuous anomalies that do not exhibit a clearly defined geometry or continuity consistent with a grave cut. These anomalies may be localised zones of slight amplitude variation, minor disturbances in otherwise incoherent data, or isolated reflections that cannot be reliably differentiated from background noise. The lack of repeatability across adjacent transects and the absence of supporting stratigraphic context further reduce interpretive confidence. In such cases, the anomaly cannot be distinguished from non-burial-related subsurface heterogeneity.

A “*Potential Unmarked Burial”* is assigned where anomalies exhibit some characteristics consistent with a potential grave but remain inconclusive due to data quality limitations or environmental factors. These may include zones of semi-coherent reflection patterns suggestive of ground disturbance, subtle truncation of layering, or low-amplitude, laterally continuous features that approximate the expected dimensions of a burial. However, these features lack the clarity, contrast, or diagnostic signatures required for a high-confidence interpretation. The anomaly may be partially obscured by signal attenuation, overprinted by construction disturbance, or insufficiently resolved due to limited penetration depth. While the spatial characteristics may be broadly consistent with a grave, alternative explanations such as construction-related excavation, backfilled service trenches, or heterogeneous fill cannot be excluded.

Given the site conditions and the nature of the burials (i.e. absence of coffins), all GPR interpretations must be considered inherently uncertain. The disturbed ground conditions significantly reduce the reliability of anomaly-based interpretation, and the geophysical response of in-ground burials without structural elements is inherently subtle. As such, low to medium confidence anomalies should be treated as areas of interest only and cannot be considered definitive evidence of unmarked graves without corroboration from intrusive investigation methods.

A list of data examples has been provided between Figures 3 to 5, to illustrate the variety of GPR radar-gram potential burial-like anomalies interpreted across the Investigation site.

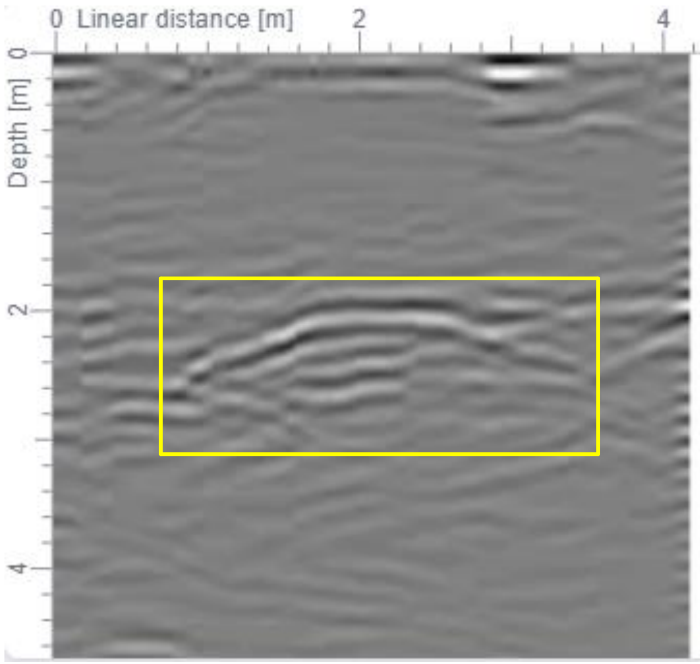


Figure 3: Radar-gram example of Potential Unmarked Burial – Medium Confidence with no obvious layering above.

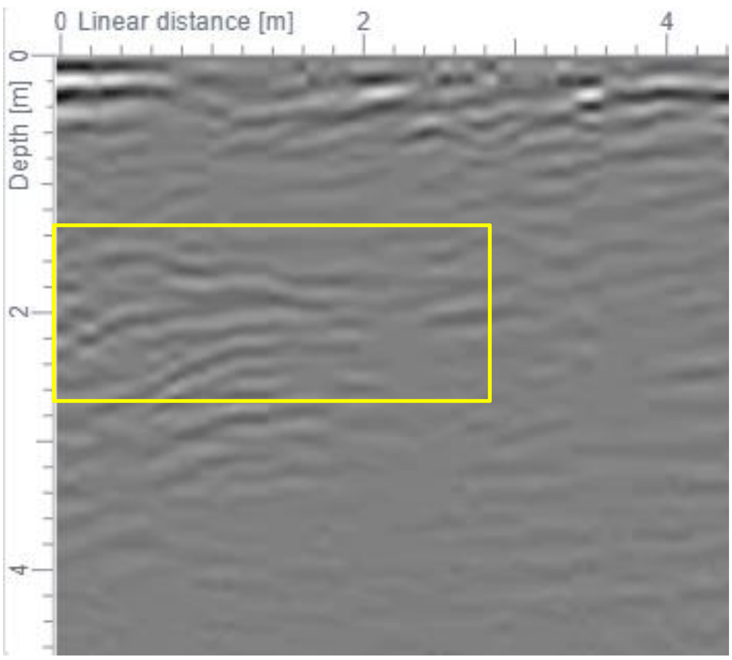


Figure 4: Radar-gram example of Potential Unmarked Burial – Medium Confidence showing Vertical Discontinuities

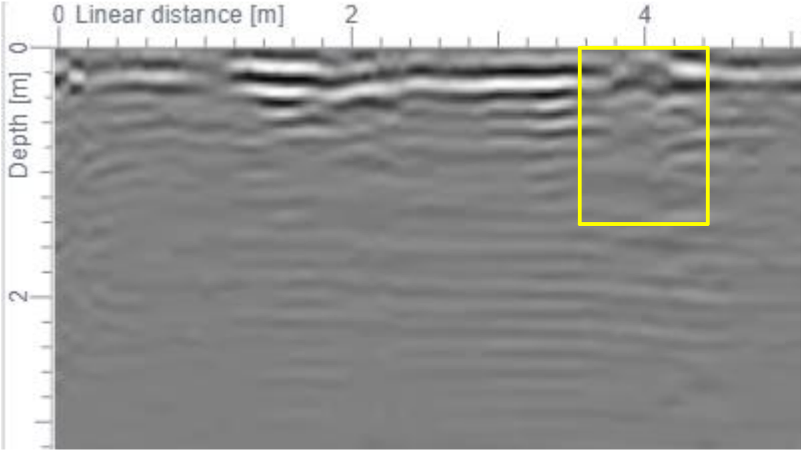


Figure 5: Radar-gram example of a Feature of Interest, showing a layer break, with a mottled GPR signal

7. INVESTIGATION SUMMARY

MNG SubSpatial (MNG) undertook a targeted geophysical investigation within the proposed bus terminal development area on Wadjemup/Rottnest Island following the discovery of ancestral remains during construction works. The investigation used 3D multi-channel Ground Penetrating Radar (GPR) to assess the potential presence of additional unmarked burial-like anomalies within and surrounding the site footprint.

The purpose of the investigation was to provide non-invasive subsurface information to support culturally appropriate management of the site, recognising its significance within the broader Wadjemup Aboriginal Burial Ground (WABG) and the wider historical context of Aboriginal incarceration on the Island. The results of the geophysical investigation are presented in both digital and PDF formats, with interpreted anomalies and survey coverage provided in the accompanying drawings and appendices.

Due to the site having undergone active construction prior to the investigation, both surface and subsurface conditions were highly disturbed, introducing significant limitations to the quality of the GPR data and the reliability of interpretation. The reworked nature of the ground, including excavation, backfilling, and material redistribution, has resulted in a heterogeneous subsurface environment that produces complex and often incoherent geophysical responses. These conditions reduce the ability of GPR to clearly resolve subtle anomalies typically associated with unmarked burials.

No high-confidence burial-like anomalies were identified within the investigation area. A number of low to medium confidence anomalies were detected; however, these features are characterised by weak, inconsistent, or poorly defined responses that do not exhibit the clear geometry, continuity, or stratigraphic context typically required for confident interpretation as graves. Given the disturbed nature of the site and the absence of coffins or structural burial elements, such anomalies cannot be reliably distinguished from construction-related ground disturbance, backfilled excavations, or natural subsurface variability.

Accordingly, all identified anomalies should be treated as areas of interest only. The results of the GPR investigation do not provide definitive evidence of additional unmarked burials within the surveyed area. Any confirmation of burial presence would require corroboration through appropriate intrusive or archaeological investigation methods, undertaken in consultation with relevant Aboriginal stakeholders, including the Whadjuk Aboriginal Corporation.

Overall, the investigation demonstrates the limitations of GPR in highly disturbed construction environments and highlights the need for cautious, conservative interpretation when assessing potential burial sites under such conditions.

The results presented in this report are based on indirect geophysical measurements, targeted intrusive verification, and interpretation of available data. Due to the limitations identified during the investigation, the alignment of the recycled water pipeline within the study area remains unconfirmed.

We trust that this report and the attached drawings provide you with the information required. If you require clarification on any points arising from this geophysical investigation, please do not hesitate to contact the undersigned on (08) 6436 1599.

For and on behalf of
MNG SubSpatial

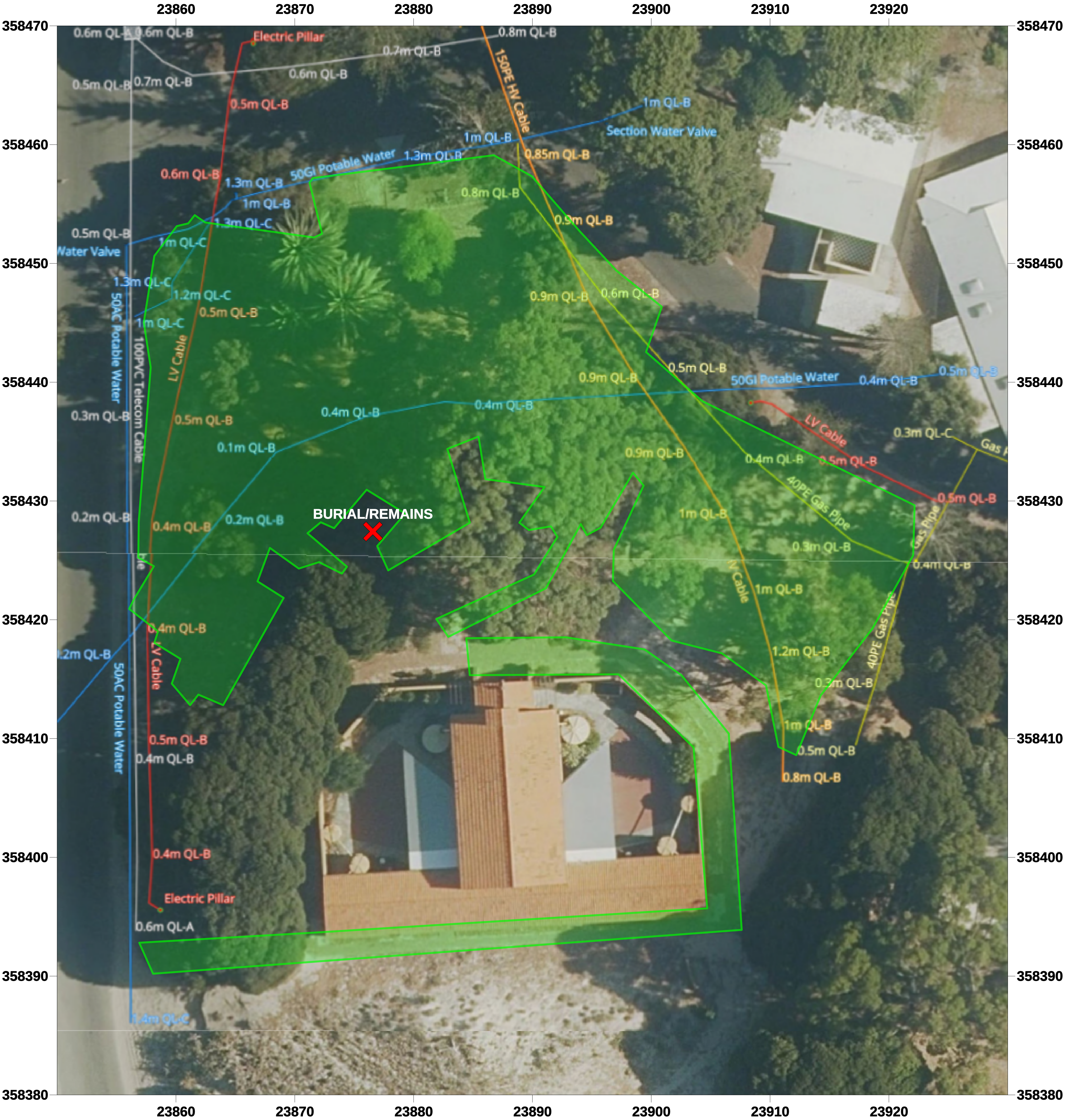
PRUDENCE WARNER

Geophysicist

APPENDIX A – GEOPHYSICAL INVESTIGATION SITE PLAN

GEOPHYSICAL INVESTIGATION - WADJEMUP

SITE PLAN



Scale: 1:330	Metres (m) 0 5 10 15
Paper Size: A3	

Drawing to be used in conjunction with Report 107754.
Image Source: MetroMap 31/01/2026

LEGEND:

Extent of GPR Transects
(Acquired by MNG in April 2026)

Identified Underground Utilities
Type, Depth and QL-Level
(Acquired by Mack1 Locating in March 2026)

N

Rev.	Description	Drawn	Date	Checked
B	Final Issue	PWA	01/05/2026	TLA
A	Preliminary	PWA	23/04/2026	TLA

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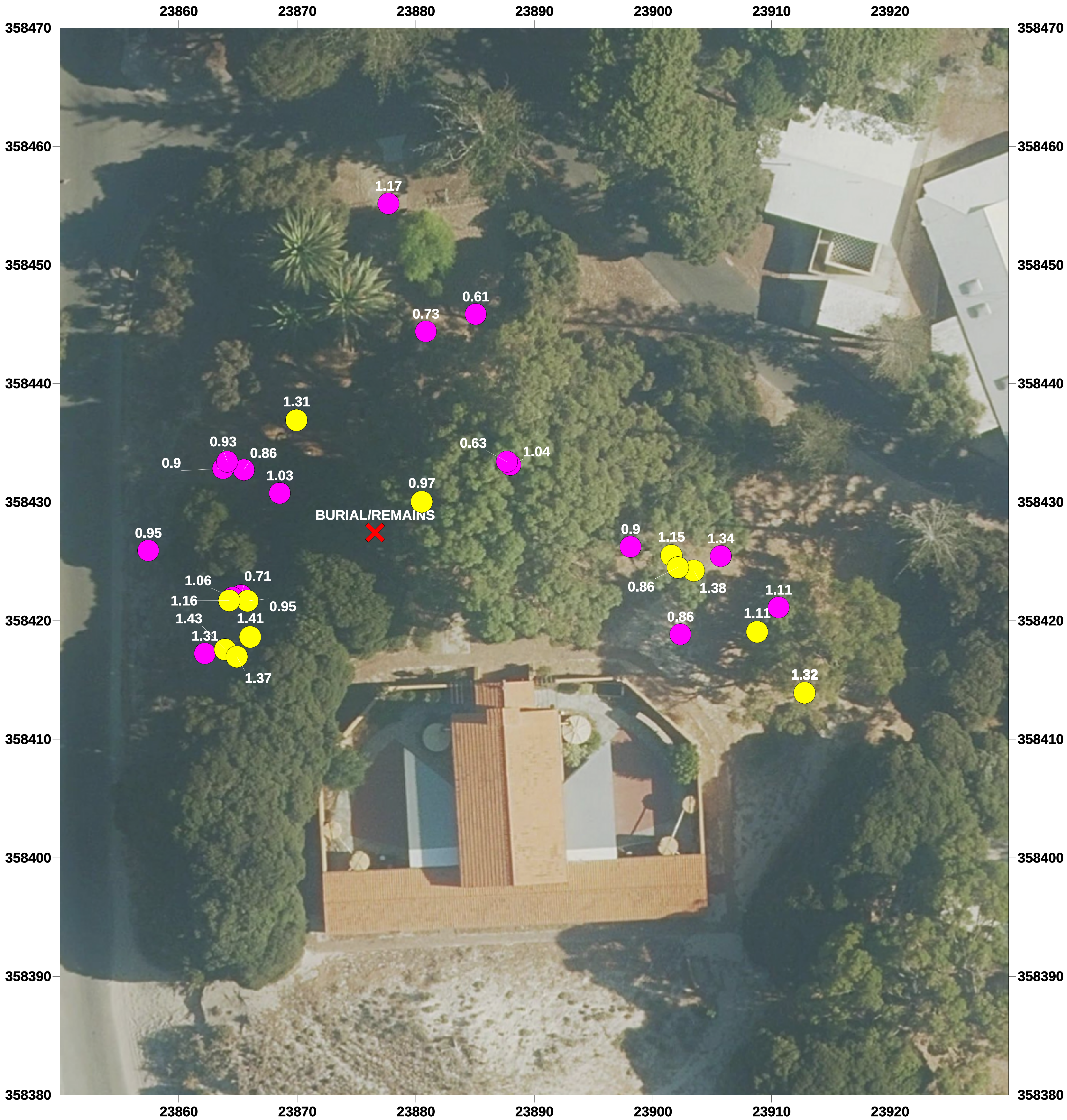
Title: GPR GEOPHYSICAL INVESTIGATION TO IDENTIFY POTENTIAL UNMARKED BURIALS AT HOLY TRINITY CHURCH, WADJEMUP (ROTTNEST ISLAND), WA.

Client:	Proj. Mngr.	PWA	Datum	PCG2020 / AHD
ROTTNEST ISLAND AUTHORITY	Drawing:	107754-01		

APPENDIX B – IDENTIFIED GPR BURIAL-LIKE ANOMALIES

GEOPHYSICAL INVESTIGATION - WADJEMUP

IDENTIFIED ANOMALIES



Scale: 1:330

Metres (m)

0 5 10 15

Paper Size: A3

Drawing to be used in conjunction with Report 107754.
Image Source: MetroMap 31/01/2026

ISO 9001 - ISO14001 - ISO45001 Global-Mark.com.au ®

LEGEND:

- Yellow circle: **Identified GPR Anomalies (Potential Unmarked Burials - Medium Confidence)** (Symbol size 1.8m in diameter)
- Magenta circle: **Identified GPR Feature of Interest (NOT Interpreted as Unmarked Burial)** (Symbol size 1.8m in diameter)
- 1.23 **Depth in Metres (mBGL)**

N

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B	Final Issue	PWA	01/05/2026	TLA
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Client: ROTTNEST ISLAND AUTHORITY

Proj. Mngr. PWA | **Datum** PCG2020 / AHD

Drawing: 107754-02