18 Fennell Street,
North Parramatta, NSW. 2151.
Tel: (02) 9890 2122. Fax: (02) 9890 2922.
E-Mail: simon.c@gbgoz.com.au.

A.B.N. 77 009 550 869.

13 April 2015 GBGA1800

FAO: Ms Kay Murray
Landscape Architect/Project Manager.
Shoalhaven City Council
36 Bridge Road,
Nowra NSW 2541

RE: NON-DESTRUCTIVE SUBSURFACE INVESTIGATION USING GROUND PENETRATING RADAR TO LOCATE UNMARKED GRAVE SITES AT THE HUSKISSON ANGLICAN CHURCH GROUND, HUSKISSON, NEW SOUTH WALES.

INTRODUCTION

GBG Australia Pty Ltd (GBG) carried out a geophysical investigation using Ground Penetrating Radar (GPR) of a section of the Anglican Church grounds in Huskisson, New South Wales.

The object of the investigation was to:

- Confirm where possible the existence and location of unmarked historical graves.
- Locate any other unmarked graves within the survey area.

The work was commissioned by Mike Poidevin on behalf of Shoalhaven City Council. The geophysical data collection, processing and analysis were undertaken by staff from GBG.

As the technique used during the investigation is geophysical, the results are based on indirect measurements and the interpretation of electrical signals. The findings in this report represent the best professional opinions of the author, based on their training and experience.

The following report outlines the investigation and discusses the results.

SURVEY AREA AND TIMING

Huskisson is located approximately 140 km south of the Sydney CBD. The church ground is approximately 10,000 square metres in area and is bounded by Bowen, Hawke and Currambene Streets. The area investigated during this survey is located within the south western section of the church grounds. The area is 875 square metres and is 35 m along the east-west axis and 25 m along the north-south axis. An aerial view of the Church Ground and the investigated area is given below in Figure 1.

Figure 1. Aerial image of the survey site with Investigation area highlighted in red.

The GPR field work was conducted by a two person crew from GBG on 18th March 2015.

GROUND PENETRATING RADAR THEORY

Ground Penetrating Radar is a non-destructive technique that provides reflection profiles of the subsurface. The technique works by pulsing electro-magnetic energy, in the form of radio waves, into the subsurface with a transmitting antenna. This energy propagates through the subsurface material as functions of its electrical properties, which are in turn, are a function of its physical and chemical properties. Reflection of energy occurs at boundaries between media which have contrasting electrical properties such as between disturbed ground and consolidated ground. These reflections are detected by the receiving antenna and converted into electrical signals.

A radargram profile is built up of scans collected along a selected line path. A sample radargram has been selected from the data and is shown in Figure 2 below. Each profile consists of an enhanced radargram that provides subsurface information based on the variations in the Dielectric Constants (the electrical conductivity and resistivity) of materials. The recorded reflections can be analysed in terms of shape, travel time, signal amplitude and phase to provide information about a target's size, depth and orientation in relation to the material around it.

GPR antennae of higher frequency provide higher resolution data but penetrate to shallower depths, whilst lower frequency antennae provide deeper penetration with decreased resolution. The depth of penetration achievable with an antenna of a particular frequency is also dependant on the local subsurface conditions. The GPR method is generally less successful in soils with high clay content due to the clay's high attenuation of radar wave energy. In contrast, clean sands provide a good medium for radar waves to propagate through, with good data often collected under such conditions.

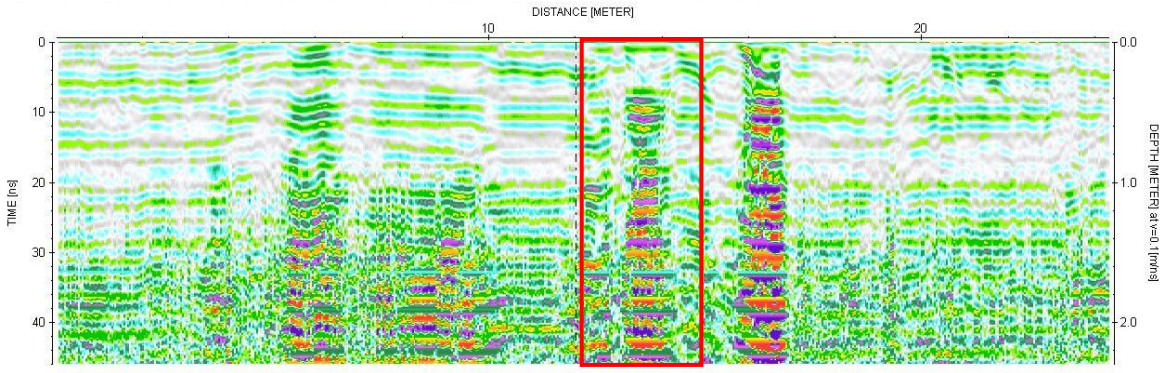

Figure 2: Sample radargram showing suspected grave within the survey area.

DATA COLLECTION METHODOLOGY

The data for this investigation was acquired using a GSSI SIR3000 GPR data collection system with a ground coupled antennae. Chainages along the profile line were logged by a calibrated distance measuring device attached to the antenna with an accuracy of better than ±0.5 m every 100 m. Both the 400 and 270 MHz antennae were trialled at the site, however the 400 MHz antenna was deemed to give the best combination of depth of penetration and resolution. The survey equipment is shown in Figure 3 below.

The GPR data was collected as a series of parallel longitudinal profiles in an approximate north-south direction perpendicular to the expected east-west orientation of the graves. Some sections along the profile lines were not scanned due to the presence of obstacles such as trees. The extent of the survey area, and profile locations are shown in drawing file GBGA1800-01R.dwg, which is an amended version of drawing file 27-2015 Husky Anglican Church.dwg, which was supplied by Shoalhaven City Council.

GPR profile lines were collected by pushing the 400 MHz centre-frequency antenna over the ground surface at a constant rate. The GPR system was set to record a two-way-travel time of 44 ns which equates to an effective depth of investigation of approximately 2.2 m. Data was recorded with 16-bit amplitude resolution, at 512 samples per scan and at a scan rate of 50 scans/m.

The GPR profiles were collected at close line spacing typically at 0.25 m intervals. Closely spaced GPR profile lines provided a higher degree of subsurface target resolution and to ensure a number of profile lines would cross cut any particular grave. This enables the ruling out of point source anomalies such as rocks as potential targets of interest.

Field notes including the line position and the start and end chainages of the GPR profile lines were taken. On-site quality control of the data was achieved in real-time by viewing profiles during acquisition. The profiles were recorded digitally for processing, analysis and interpretation at our Sydney office.

Figure 3: Survey area with scan in progress. Tapes were used to ensure that correct line separations and directions were achieved.

DATA PROCESSING AND ANALYSIS

The collected data was of moderate quality with limited depth of penetration and low signal to noise ratio. This was principally due to the local subsurface having a moderate clay content which has a high attenuation of radar wave energy, as well as the survey area being quite damp. The low signal to noise ratio was partially overcome during processing with filters being applied to the data.

The collected GPR data was processed and analysed using Reflex for Windows Version 7.5 developed by Sandmeier Software. The data processing steps were performed as follows:

- Static correction to the first crossing; set surface reflection interface to zero depth.
- Move start time and end time; to make all radargrams uniform.
- Background removal filter; to eliminate temporally consistent flat noise bands from the whole record, making signals previously covered by this noise visible.
- Combine the 2D files to produce a single 3D image.
- Adjust the colour palette for signal amplitudes, to improve the contrast of phase changes and signal variation.

The typical response from a GPR profile running perpendicular over a grave is a hyperbolic signal of increased amplitude, the peak of which gives the depth to the top of the grave and an indication of the size and width of the grave. With the GPR method it is quite often that features associated with graves are imaged, rather than the graves themselves. This may include depressions in the soil layers above the grave, vertical discontinuities in the soil profile caused by the grave trench and a mottled GPR signal above the grave due to the unconsolidated nature of the fill material.

GPR signals reflected from within a subsurface structure contain a large amount of visual information much relating to the minor variations in the electrical properties of the materials profiled. Consideration was given to the nature and possible cause of the signals recorded by the GPR. The target responses which are consistent with those expected from graves were identified in the profiles and compared across the complete data set with anomalies that match up across adjacent profiles being joined.

RESULTS AND DISCUSSION

The results of the GPR investigation have been plotted in the attached drawing file GBGA1800-01R.dwg. The locations of the collected GPR profiles are plotted as green lines. Other features are shown as per the legend and as described below.

One level of reporting has been used to categorise subsurface anomalies identified in this investigation. This level represents possible grave locations (plotted in orange hatch and border) – lower degree of confidence in target. Generally low to moderate amplitude response typically in near surface soil profile, disturbance and / or soil depression, no direct evidence of coffin.

A total of seven (7) possible unmarked graves were identified during the investigation, and the position of these graves relative to the zero datum as specified on GBGA1800-01R.dwg file is listed in Table 1 below. The approximate depth range of the observed anomalies is included in this table.

Table 1: Possible grave locations relative to zero datum.

Possible Grave	West	South	Depth (m)
1	23.8	13	0.3-1.5
2	13	9.5	0-1.8
3	8.5	11.2	0.5-1.6
4	5.4	11.2	0.6-1.6
5	3.6	13.6	0.3-1.6
6	3.6	16.4	0-1.4
7	3.6	18.2	0.7-1.3

There are seven (7) possible graves in the survey area. These predominately show as low amplitude responses in the 2D sections however in the 3D time slices (Figure 4 below), they typically appear as higher amplitude rectangular responses approximately 2.0 m long, orientated in a predominately east-west direction. This uniform shape and orientation indicates that the responses highlighted are likely to be manmade and should be investigated further to determine the true origins of the anomalies. Several anomalies identified as possible graves are located close to large trees; the possibility that these anomalies are the result of the root systems of these trees cannot be excluded.

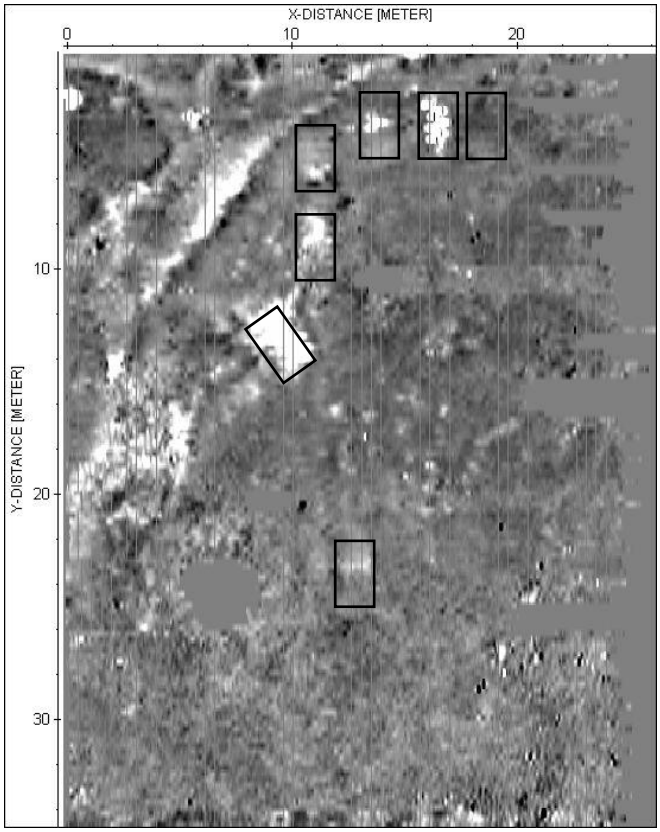

Figure 4: 3D depth slice of survey area at 700 mm showing 7 possible grave locations. Very high amplitude responses (white) due to water ponding in depressions.

CONCLUSIONS

The GPR investigation at the Huskisson Anglican Church Ground has provided moderate quality reflection images of the subsurface. The collected GPR data is of moderate quality with a low signal to noise ratio. This is likely caused by damp conditions and clay content within the subsurface which has had an adverse effect on the collected data. This has been partially overcome by applying filters during the processing stage.

The target anomalies have been classified as possible grave locations.

An amended plan view drawing file of the survey site has been provided showing the locations of the seven (7) unmarked graves identified in the GPR data.

I hope that this report provides you with the information required by your brief. If you require clarification on any points arising from this investigation please contact me.

For and on behalf of

GBG AUSTRALIA PTY LTD

SIMON HUGH COOK

Geophysicist

Attachments: GBGA1800-01R.dwg file.