GEOPHYSICAL SURVEYS & AUGER DRILLING TO MAP SHALLOW GEOLOGY, PROPOSED SITE OF SQUARE KILOMETRE ARRAY (SKA), MRO, WESTERN AUSTRALIA.

Report for

Curtin Institute of Radio Astronomy

GroundProbe Pty Ltd | LI1407CI_1.0 | 30 October 2010

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30 October 2010

Curtin Institute of Radio Astronomy

Department of Science and Computing

Curtin University

Bentley WA 6102

Attention: Mr David Emrich

Dear Mr. Emrich

RE: GEOPHYSICAL SURVEYS AT SITE OF PROPOSED SKA

This document presents GroundProbe's report (GroundProbe Reference: LI1407CI_1.0) for the geophysical surveys and auger drilling carried out at the proposed site for the Square Kilometre Array.

If you have any questions in relation to the report, or if we can be of further assistance, please do not hesitate to contact the undersigned.

Kind regards,

PHILIP MILL

SENIOR COMMERCIAL OFFICER

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Summary

GroundProbe was commissioned by Curtin Institute of Radio Astronomy to conduct investigations at the proposed site of the Square Kilometre Array (SKA), in Western Australia. The objective of this work was to map the shallow geology in order to assess the ease of trenching for cable installation.

Ground-penetrating radar (GPR) was considered the best method to best provide shallow subsurface information at high resolution. Electromagnetic data were collected simultaneously to support the interpretation of the GPR information; while a trailer mounted auger was used to provide ground truthing for the final interpretation.

GroundProbe acquired 46.84 kilometres of GPR and EM38 data over the area of interest, and drilled 41 auger holes to refusal. The combined interpretation of these datasets indicates that a layer of recent sand, gravel, silt and clay, varying between approximately 0.3 and 1.35 metres thick, overlies basement rocks.

The thickness and type of sediment seems constrained by the basement topography. In the central part of the surveyed area, the sediment layer is generally thicker than to the west and east and appears to comprise sand and gravel.

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1 Introduction

GroundProbe was commissioned by Curtin Institute of Radio Astronomy to conduct geophysical surveys and Auger Drilling of the proposed site of the Square Kilometre Array, Western Australia. The objective of these surveys was to map the shallow geology in order to indicate the ease of trenching the area for cable installation. Ground Penetrating Radar was considered the most cost effective method to best provide shallow subsurface information at high resolution. EM38 was collected simultaneously to support the interpretation of the GPR information, while a trailer mounted auger was used to provide ground truthing for the final interpretation.

The survey locations are indicated in **Figure 3.1**.

2 Survey Methodology

2.1 Ground Penetrating Radar (GPR)

GPR is an electromagnetic method that involves analysis of radio wave reflections generated by abrupt changes in electrical properties in the subsurface. It has been used extensively by GroundProbe for mapping shallow soil and sediment layers.

The GPR has an inherent penetration/precision trade off which is regulated by the frequency used. A 500MHz antenna was used in this survey to provide an optimum depth of investigation. A summary of the acquisition parameters is displayed in **Table 3.1**.

2.2 Electromagnetic Induction (EM)

The Geonics EM38 measures the ‘apparent conductivity’ (ECa) of the ground. In the “horizontal dipole” orientation the response is highest at the surface dropping off with depth. The response approximates actual conductivities averaged over the 0-1.5m depth interval. Units are milliSeimens/metre.

The instrument works by creating a transmitting fixed frequency electromagnetic field and then measuring the resultant field, which includes fields induced in the ground, at a sensor approximately one metre from the transmitter. The quadrature is related to ground conductivity.

The EM38 was mounted on a rubber sled towed behind the quad bike, acquired at the same time as the GPR data. An outrigger was used to maintain separation between the instruments to minimise interference.

It is important to note that ECa is function of the bulk conductivity response from the ground which is dependent on clay content, porosity, moisture saturation and moisture conductivity. This is different from ECe or EC 1:5, which relate more directly to the groundwater conductivity.

2.3 Auger Drilling

Auger Drilling is a method of drilling shallow holes using a helical drill bit. Drilling is deemed to have reached “refusal” when the penetration rate is effectively zero due to the ground being too hard. The depth and material type at bottom of hole is then recorded.

3 Data acquisition

The survey proceeded within a project timeframe of 5 days. No OH&S incidents occurred during the data acquisition period. Survey actions are summarised in **Table 3.1**.

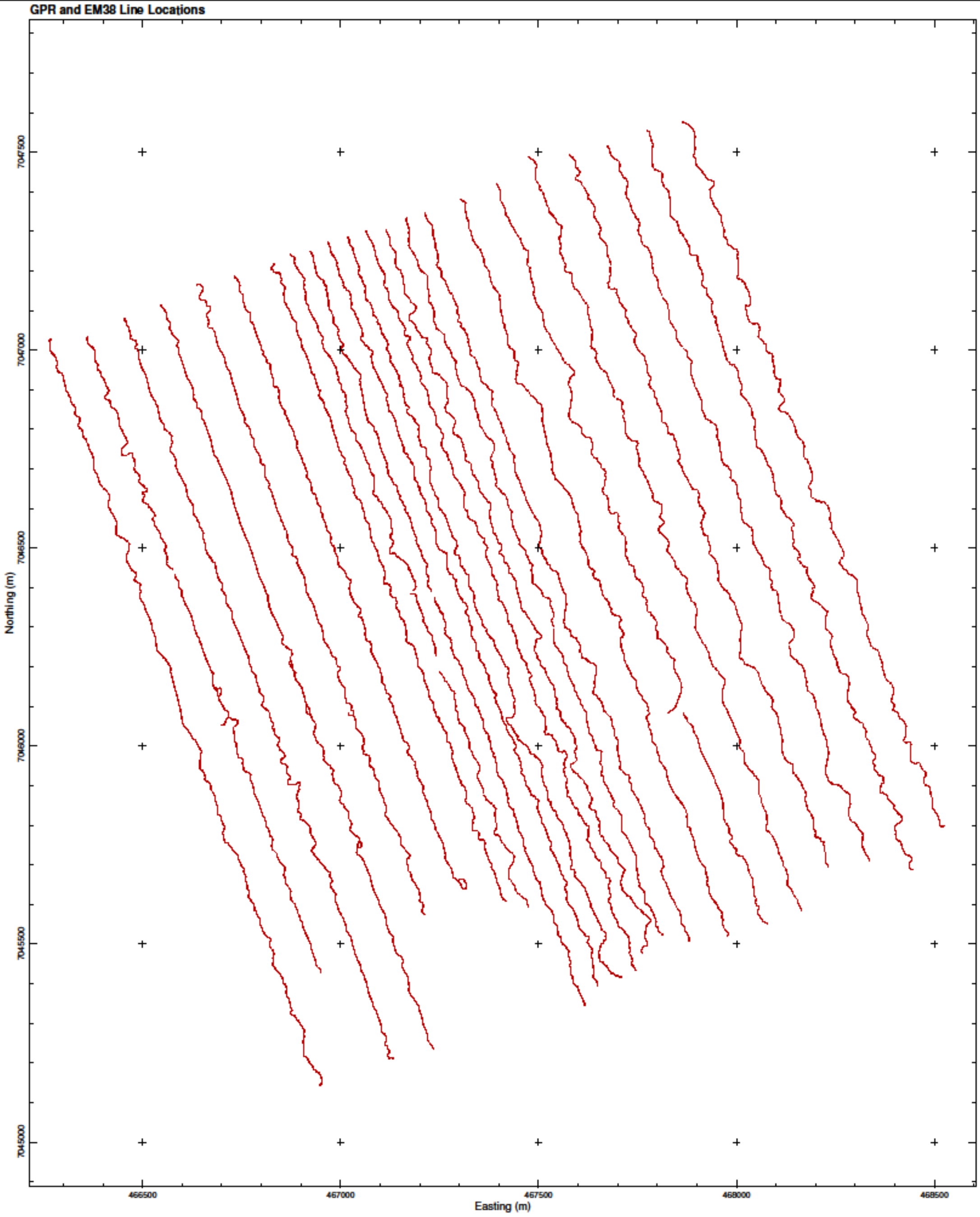
Start date	22 September 2010
End date	26 September 2010
Total days	5 days
Activity breakdown ○ Induction ○ Production ○ Mobilisation	**4 days** *0.5 days* *2.5 days* *2 days*
Length of Survey Lines (calculated from EM38 dataset)	*46.7km*
Total Depth of Auger Drill Holes Number of Holes	*23.16m* *45*

Table 3.1 - Summary of survey logistics

The equipment and acquisition parameters used for this survey are summarised below in **Table 3.**.

GPR SYSTEM	Mala Ramac CUII with XVII monitor (mounted on Rhino)
GPR ANTENNA	500MHz Shielded Antenna
GPR PARAMETERS	10cm sampling along line. 232 samples at 50 ms increments (total 46ns measurement time)
GPR PENETRATION DEPTH	2.4m
EM SYSTEM	Geonics EM38b. Frequency Domain conductivity mapping tool.
EM ORIENTATION	Horizontal dipole, towed on sled 2cm above ground
EM PENETRATION DEPTH	Most of the response is due to 0-50cm interval.
LINE SPACING	variable line spacing (see figure 3.4)
DATA POSITIONING	Standard accuracy Garmin 35 Antenna GPS (Approx +/- 4m)

Table 3.2 - Summary of GPR and EM38 equipment and acquisition parameters



Notes:
-> Coordinates in GDA94 MGA zone 50

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Figure:	
Caption:	GPR and EM38 Line Locations
Drawn By:	GroundProbe GEOPHYSICS

Figure 3.1 – Map showing locations of transects along which GPR and EM data were collected.

4 Data Processing

4.1 *Ground Penetrating Radar*

The raw GPR data were imported into the Reflex GPR data processing software package and GPS data, which were collected once per second, were integrated with the data files so as to assign x, y, and z coordinates to each trace. Optimal processing parameters were then established and applied in batch mode to all lines.

Major processing steps include -

- background removal – to remove constant instrumental and tow-vehicle noise
- subtracting average – to emphasise non-continuous subsurface reflectors
- bandpass frequency – to filter out unwanted frequencies
- Hilbert-Transform filter(envelope) – to create coherent packages of responses based on reflectivity strength

Each profile was then interpreted by "picking" the depth of the first layer. An example of the processed and "picked" GPR data can be seen in **Figure 4.1**.

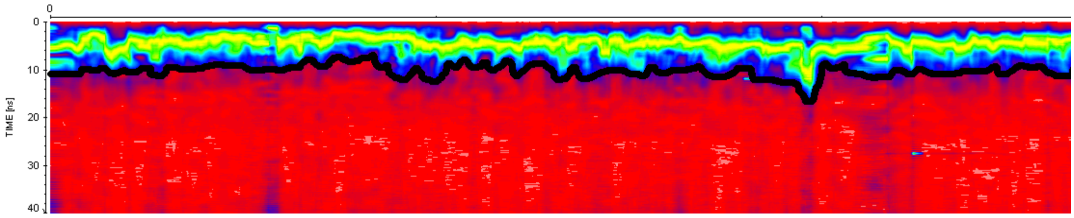


Figure 4.1: Example GPR data, approximately first 50m of Line 1. The black line shows the GPR "picks".

The picks from all profiles were then combined and used to construct a grid showing thickness of surficial materials. This grid can be seen in **Figure 4.2** and is the major product from this work.

4.2 *Electromagnetic Induction*

The located EM raw data were imported into the ChrisDBF data processing software package. A 5 point non-linear de-spiking filter was then applied to the data. The data were gridded using a minimum curvature gridding method. These data can be seen in **Figure 4.3**.

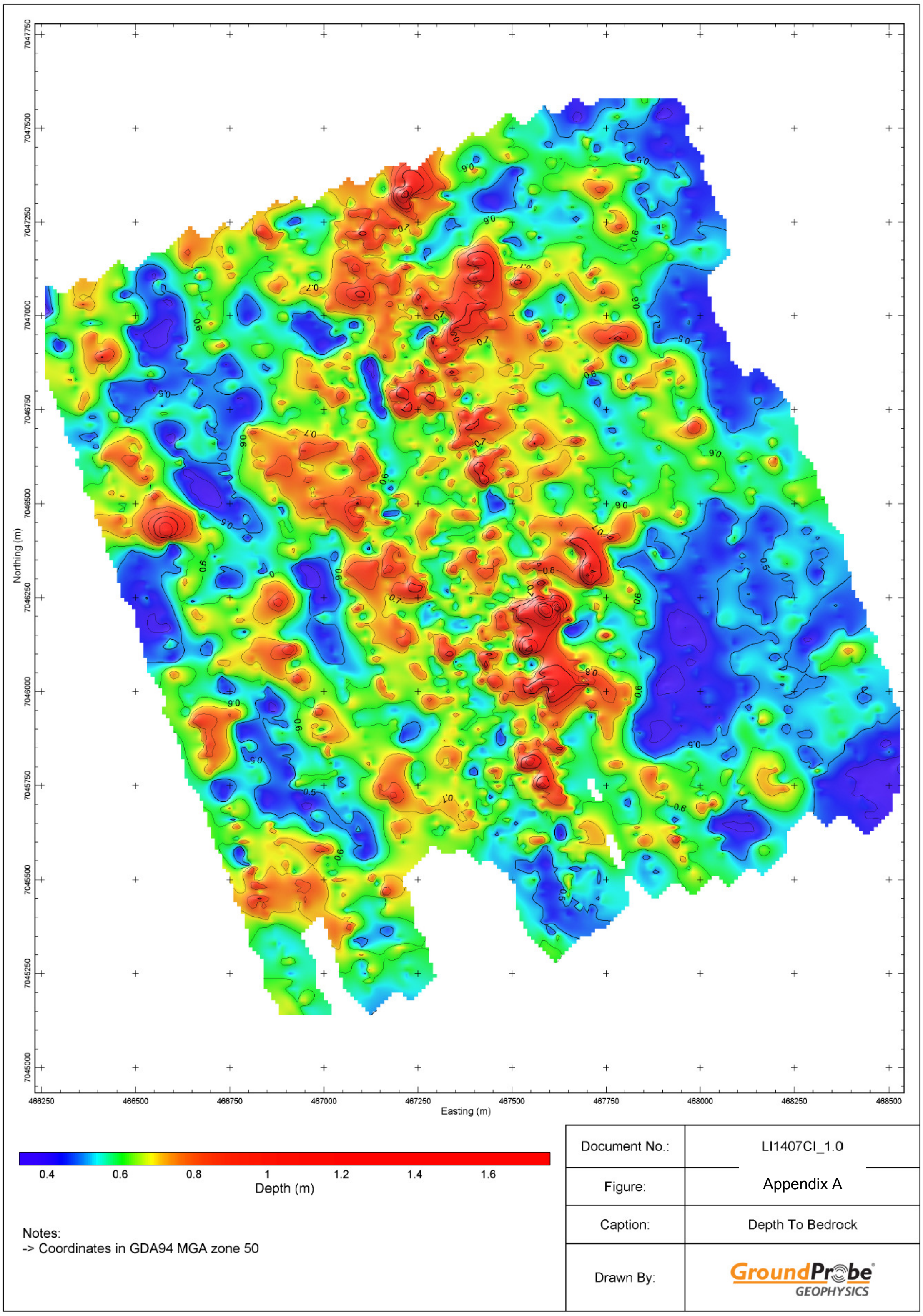
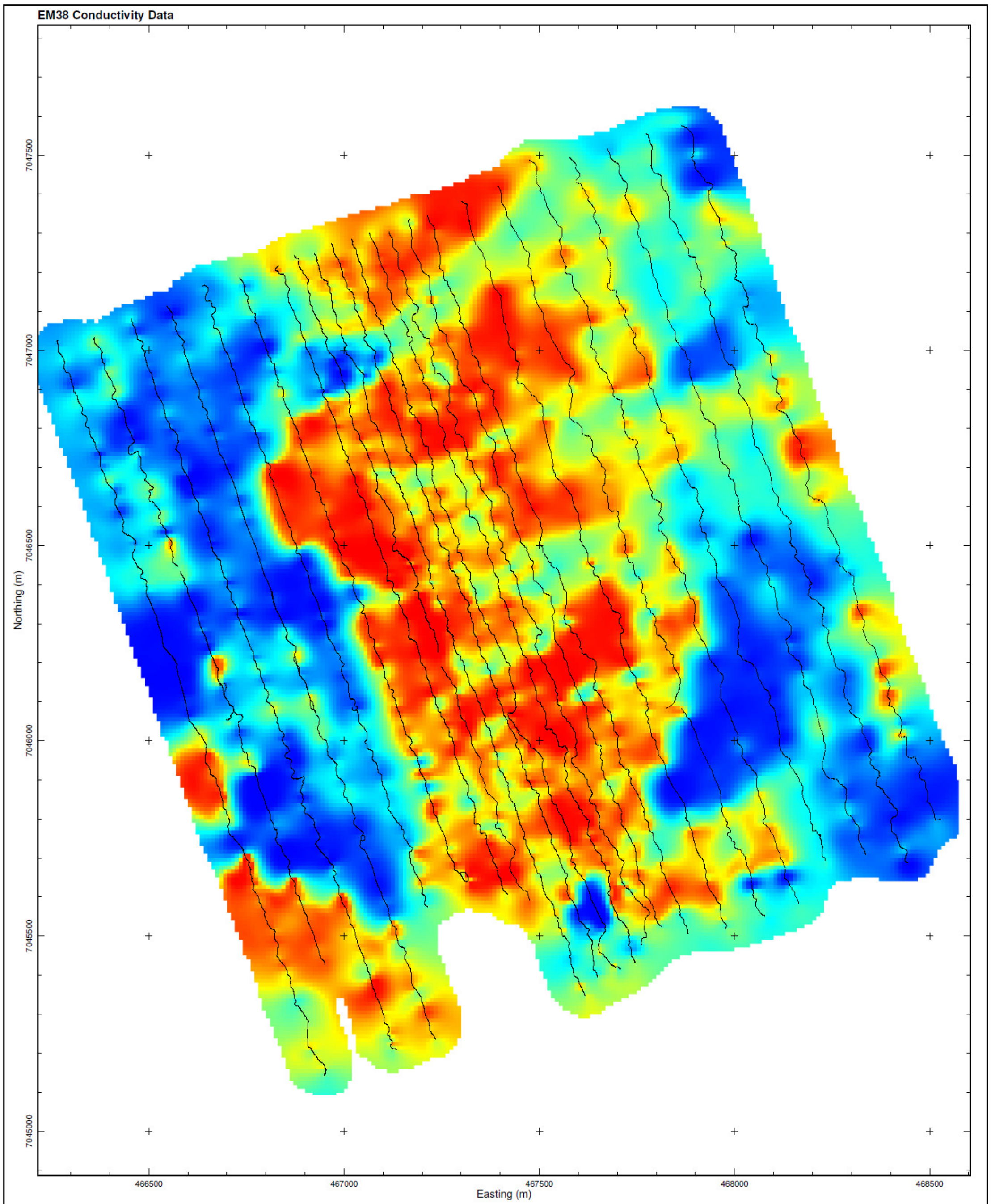
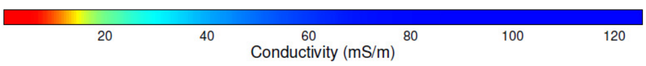


Figure 4.2 – Grid of depth of first layer as interpreted from GPR profiles. Red colours indicate thick and thin surficial materials respectively.





Notes:
-> Coordinates in GDA94 MGA zone 50

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Figure:	Appendix A
Caption:	EM38 Conductivity Data
Drawn By:	GroundProbe GEOPHYSICS

Figure 4.3 - Grid of EM38 data showing relative high and low responses as blue and red respectively.

5 Results & Interpretation

The GPR profiles indicate a generally thin layer of high-amplitude reflectors overlying a region of few or no reflections. This upper layer is interpreted as recent fluvial, colluvial and aeolian sediments comprising gravel, sand, silt and clay. The lower zone is interpreted as granitic basement. This is supported by ground truthing, which finds a loose correlation between depth of drill hole and interpreted depth to second layer. The reason that this correlates only loosely is the indistinct boundary with the second layer, likely due to weathering of bedrock. In such a case, the boundary which the GPR reflects from is indistinct, and may not correlate strongly with an abrupt change in rock type. However, a correlation will still exist and so broad features apparent in the data can be interpreted correctly.

There is reasonable variation of thickness of these surficial responses within the area surveyed, although generally this layer ranges between 0.3 and 0.8 metres thick. There is also considerable lateral variation in the GPR response within this layer across the grid. In some areas the responses are reasonably homogenous and laterally continuous for some distance. These seem to correlate with areas where the layer is thinnest. In other areas, the responses are much more heterogeneous, especially where the layer is thickest. This effect can be seen in **Figure 5.1** which shows examples of shallow and deep upper layer. Depth and response variations are likely due to lateral changes in sedimentary regimes which are probably controlled by the topography of the bedrock.

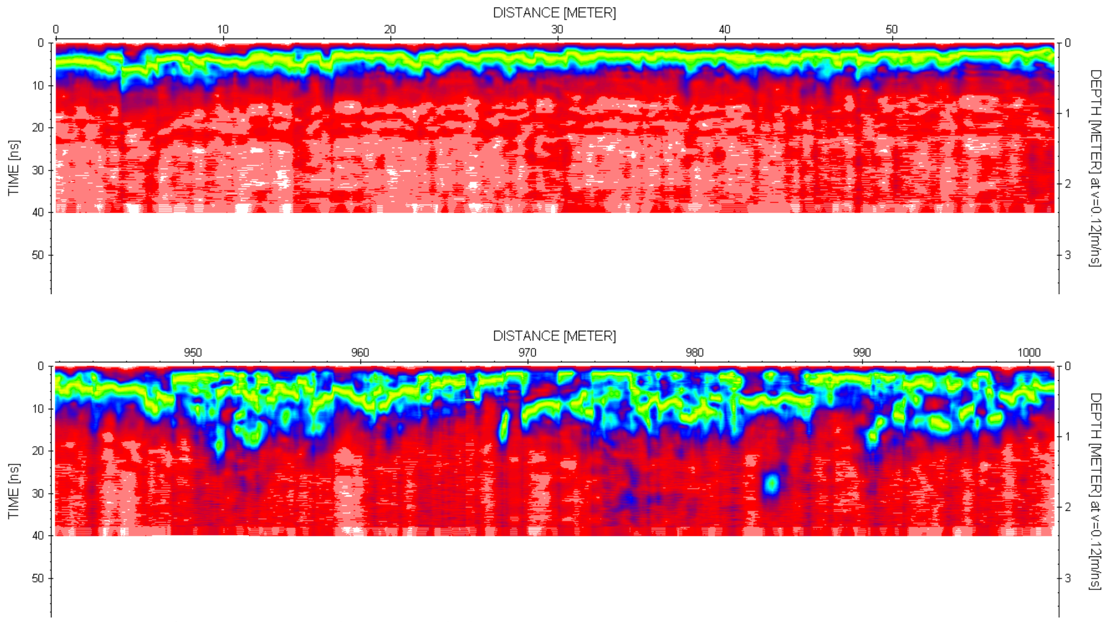

Figure 5.1 – Comparison of types of GPR responses encountered in this area. The upper profile shows a thin, relatively homogeneous layer less than 0.5 metres thick, whereas the lower profile indicates thicker, more heterogeneous materials.

There is strong correlation between thickness of layer 1 and electrical conductivity. Where the sediments are thickest, generally within the central part of the grid, the electrical conductivity is very low (average of 30 to 40 mS/m). This is thought to reflect the increased volumes of sand and gravel. Where the first layer is thinnest, the conductivity is elevated (average of 30 to 40 mS/m). Considering that granite would generally be expected to exhibit very low electrical conductivity, this correlation is somewhat counter-intuitive. There could be two explanations for these responses – a) highly weathered zone within the upper part of the granite which contains significant clays, and b) preferential deposition of clay and silt overbank deposits on areas of shallow bedrock (as compared to larger grained sediments in active channels).

Below these interpreted sediment layers, the GPR response can be generally characterised by an almost complete lack of reflectors which could be due to either significant attenuation of signal by the surficial materials, or because the lower material is relatively homogeneous. Knowledge of the site geology allows us to confidently interpret these responses as granitic basement, which could be quite homogeneous as compared to sedimentary materials.

Although responses from the granite body are largely absent across the site, there are some areas where strong reflectors occur as sub-vertical features well below the interpreted surficial materials. **Figure 5.2** shows an example. These features are interpreted to be caused by fractures within the granite body.

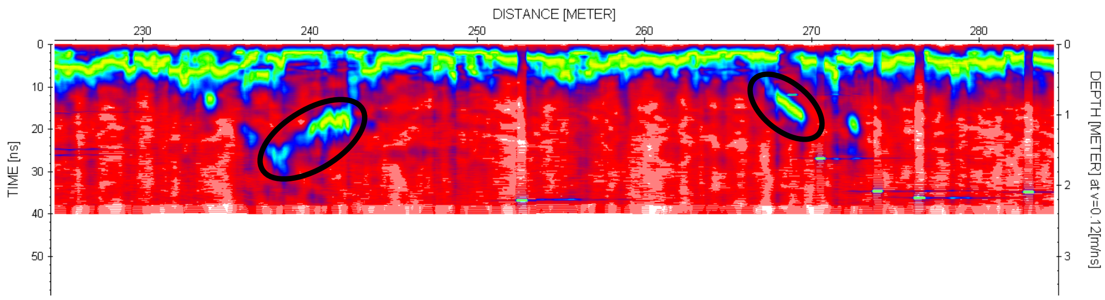

Figure 5.2 – Example of relatively steeply-inclined reflectors within the interpreted granitic basement. These are thought to be clay-filled fractures in the granite.

6 Conclusions

GroundProbe was commissioned by Curtin Institute of Radio Astronomy to conduct investigations at the proposed site of the Square Kilometre Array (SKA), in Western Australia. The objective of this work was to map the shallow geology in order to assess the ease of trenching for cable installation.

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Disclaimer

The interpretations contained in this report are based on the training and experience of the author and information passed on during the course of the investigation. As with all geophysical data, multiple interpretations are possible. The client is advised to consider information from all available sources prior to making a decision on how to proceed.

Appendix A

Map of Surface Layer Thickness / Depth to Basement from Interpretation of GPR Profiles

Map of Apparent Electrical Conductivity Data