



SOUTHERN GEOSCIENCE
CONSULTANTS

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MEMORANDUM

TO	Al Maynard, Francesco Fucilla - Yellow Resources Pty. Ltd.
FROM	Russell Mortimer, Jarrad Trunfull - SGC
DATE	19 th September 2017
REPORT NO.	SGC3247
RE	Lake Darlot - Gravity and Passive Seismic Processing – Interpretation/Modelling

1 INTRODUCTION

SGC was approached to manage/process and interpret recently acquired gravity data acquired at the Lake Darlot project in Western Australia on behalf of Yellow Resources Pty. Ltd. to assist the mapping of palaeochannel features that may contain lithium/potash bearing brines. Passive seismic data were also collected along select target gravity profiles to support/improve modelling efforts.

2 GEOPHYSICAL DATA

2.1 Gravity

Gravity data were collected by Atlas Geophysics Pty. Ltd. between the 10th August and 5th September 2017 (job number P2017104) on north-south, 400-metre spaced lines with 100-metre spaced stations. A total of 4,890 readings were acquired over Yellow Resources' tenements (**Figure 1** and **Figure 2**). A total of 196 readings from the original programme (5,086 stations) were not acquired in two small eastern areas due to access issues/water over the lake.

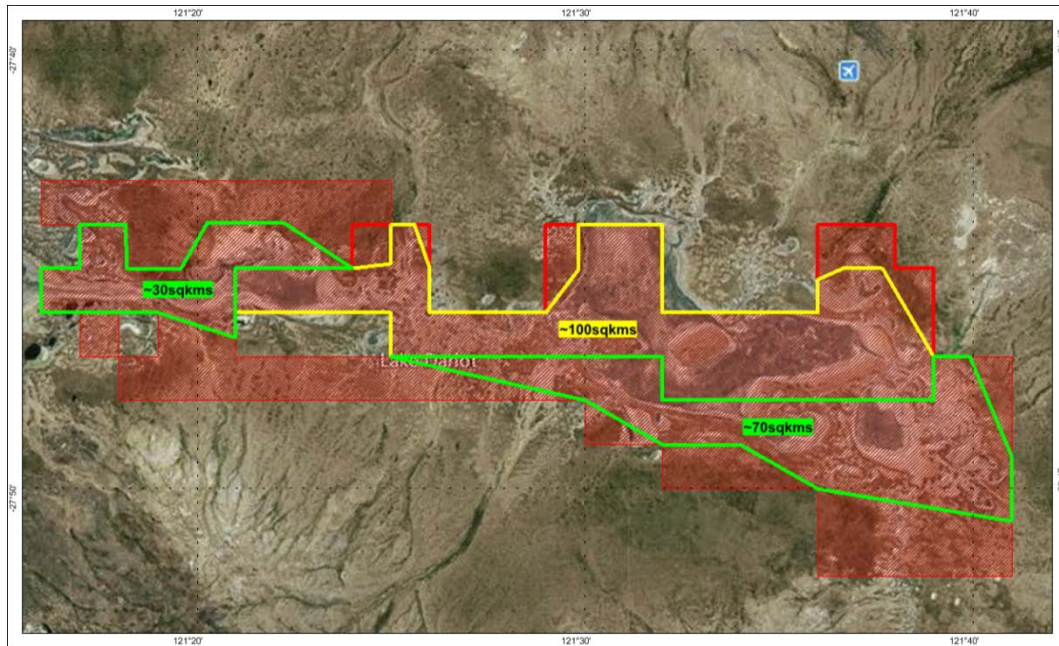


Figure 1. Yellow Resources' tenements E37/1014 & E37/1139 with gravity survey outlines



Figure 2. Gravity readings conducted by Atlas on Lake Darlot.

2.2 Passive Seismic

Passive seismic data were collected using Tromino seismometers along and orthogonal to selected target gravity profiles ([Figure 3](#)), over suspected palaeochannel features observed in the preliminary gravity data. Atlas acquired this passive seismic data at no charge to Yellow Resources Pty. Ltd.

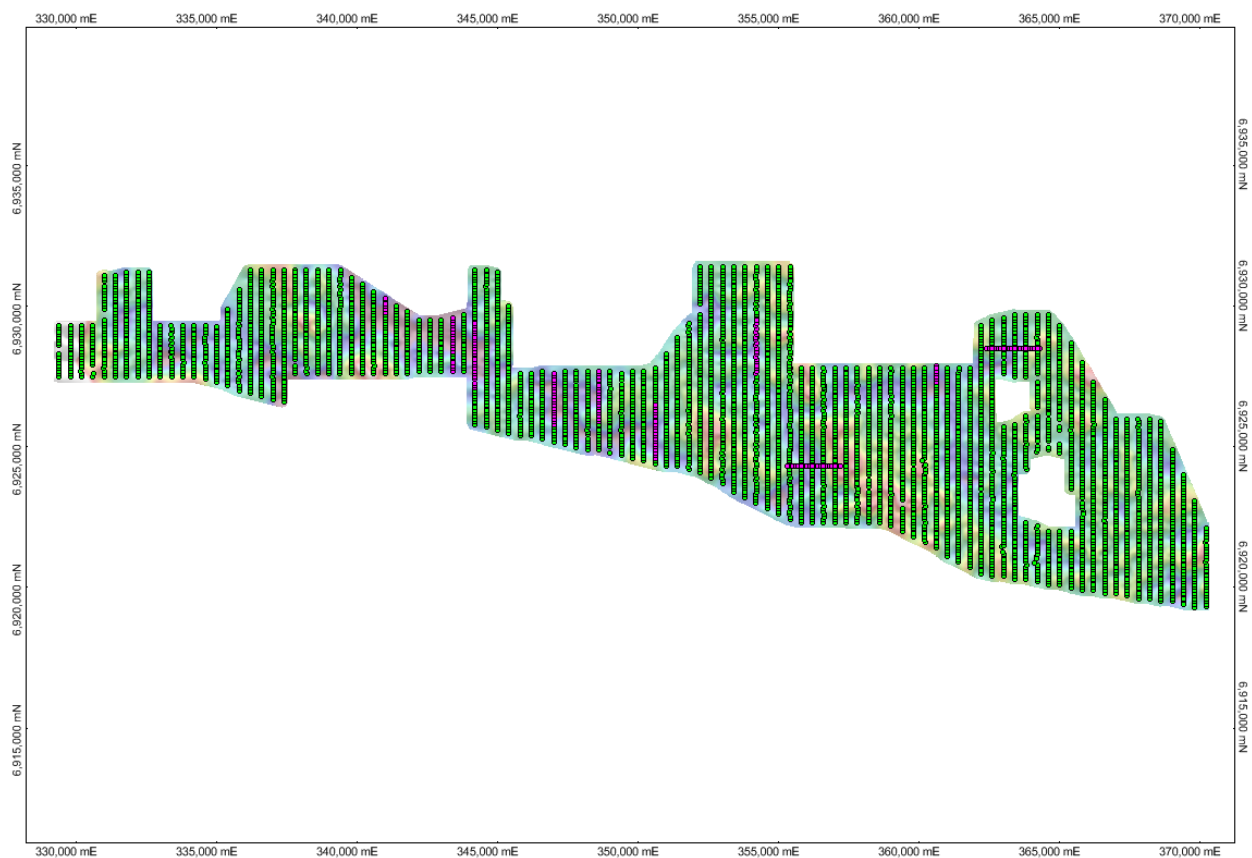


Figure 3. Final gravity stations (green) and Tromino passive seismic stations (purple).

3 DATA PROCESSING

3.1 Detailed Gravity

Observed gravity data for the survey was reduced to the Bouguer anomaly using a correction density of 2.67 g/cm^3 . A terrain correction was deemed unnecessary given the relatively flat terrain. This Bouguer data was then gridded at 100 metre cell size ($\frac{1}{4}$ of the line spacing and equal to station spacing).

Calculation of a residual Bouguer gravity anomaly is important to remove the regional gravity gradients and isolate the anomalous gravity features of interest. Multiple residuals were calculated by ‘upward-continuing’ (UC) the Bouguer anomaly data (filtering the data to simulate it being collected from further above) to 100, 200, 500 and 1000 metres, and then subtracting this upward continued data from the original Bouguer anomaly data. The half and first vertical derivatives of the Bouguer anomaly data were also calculated, and found to be very similar to the UC residual data. Additionally, the total horizontal derivative (THD) is useful for highlighting the edges or margins of gravity features, e.g. the potential edges/widths of the gravity lows that are interpreted as palaeochannel responses.

Two sets of stacked profiles were generated - one for the Bouguer anomaly, and one of a line-filtered half vertical derivative of the Bouguer anomaly.

The final set of processed gravity products are delivered in MapInfo and ArcGIS formats using the GDA94/MGA51 datum and projection. Full details are documented in the dataset’s readme but products include:

- Contractor and SGC merged and processed located data.

- GeoTIFF and ECW images.
- Line paths and station locations.
- Contours at 1:25,000 scale.
- Stacked profiles of the Bouguer anomaly and $\frac{1}{2}$ vertical derivative of Bouguer anomaly.
- ER Mapper grids.

3.2 Passive Seismic Transects

On the basis of preliminary gravity data, 10 transects across gravity lows were selected for survey using passive seismic recordings. Eight north-south and two east-west transects were recorded with 100 metre station spacing. Figure 4 shows the location of the selected transects on a Bouguer 1VD image and Table 1 lists the survey specifications. Some stations were not able to be recorded due to difficult terrain.

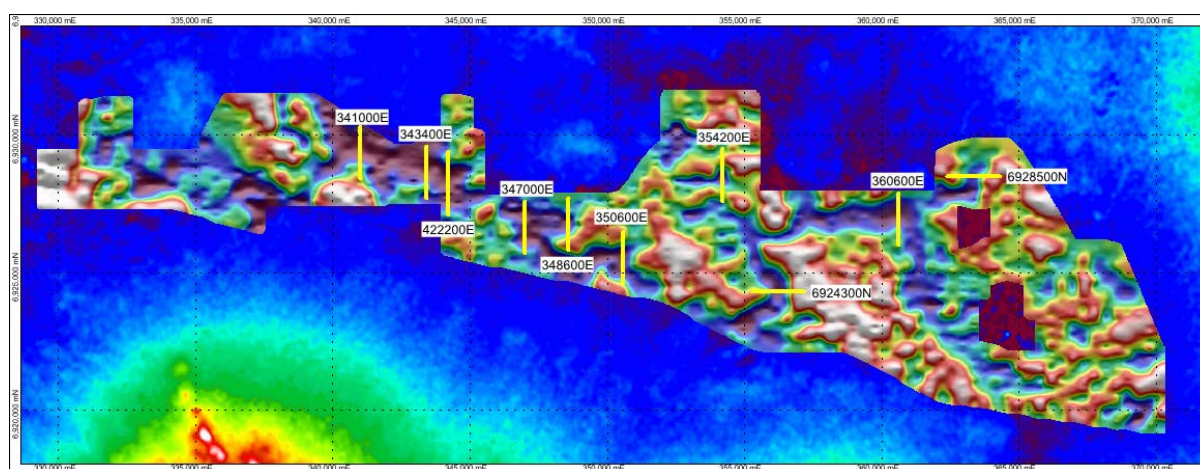


Figure 4. Lake Darlot passive seismic transects (yellow) on a Bouguer 1VD image and background DEM image.

Table 1. Passive Seismic survey specifics

Contractor	Atlas Geophysics
Instrument	Tromino TE3-0163
Station Spacing	100 m
Measurement Duration	12 minutes
Sample Rate	128 Hz
Components	NS, EW, Z

The seismic data were delivered to SGC in the Tromino instrument binary format. These data were exported to ASCII format for processing using SGC proprietary software. Some recordings were edited due to low signal levels or excessive noise. The recorded seismic signals were transformed into frequency spectra for each of the three components and combined to produce an estimate of the depth to the first sub-surface reflector below each recording station. The quality of the depth estimates depends on the acoustic contrast between the upper layer and the first layer boundary and the seismic velocity in the upper layer. For this processing, the seismic velocity is taken to be 125 m/s. More accurate depth estimates can be made if the seismic velocity is known or can be inferred from drill hole information.

4 PALAEOCHANNEL INTERPRETATION

4.1 Methodology

Profiles of the $\frac{1}{2}$ vertical derivative of the Bouguer anomaly (akin to residual of 500 metre upward continuation) profiles were displayed in MapInfo and each 'gravity low' was 'picked' on a line by line basis ([Figure 4](#)). These picks were compared with gravity imagery and contours (residual of 500 metre UC – [Figure 5](#)), and those that appeared to represent palaeochannels were kept and ranked ([Figure 6](#)). The rest were discarded. Polygons were then drawn around these interpreted palaeochannels and labelled as areas of interest with a name (LD-xx) and rank (see [Table 2](#)) - [Figure 7](#).

The data has very good line-to-line detail; hence imaging is a good way to interpret the data. The data has acceptable along-line resolution (100 metre stations). Improving this resolution over areas of interest (which time/budget did not permit) would allow more accurate modelling of the palaeochannel shape and allow for better refinement of drill targets.

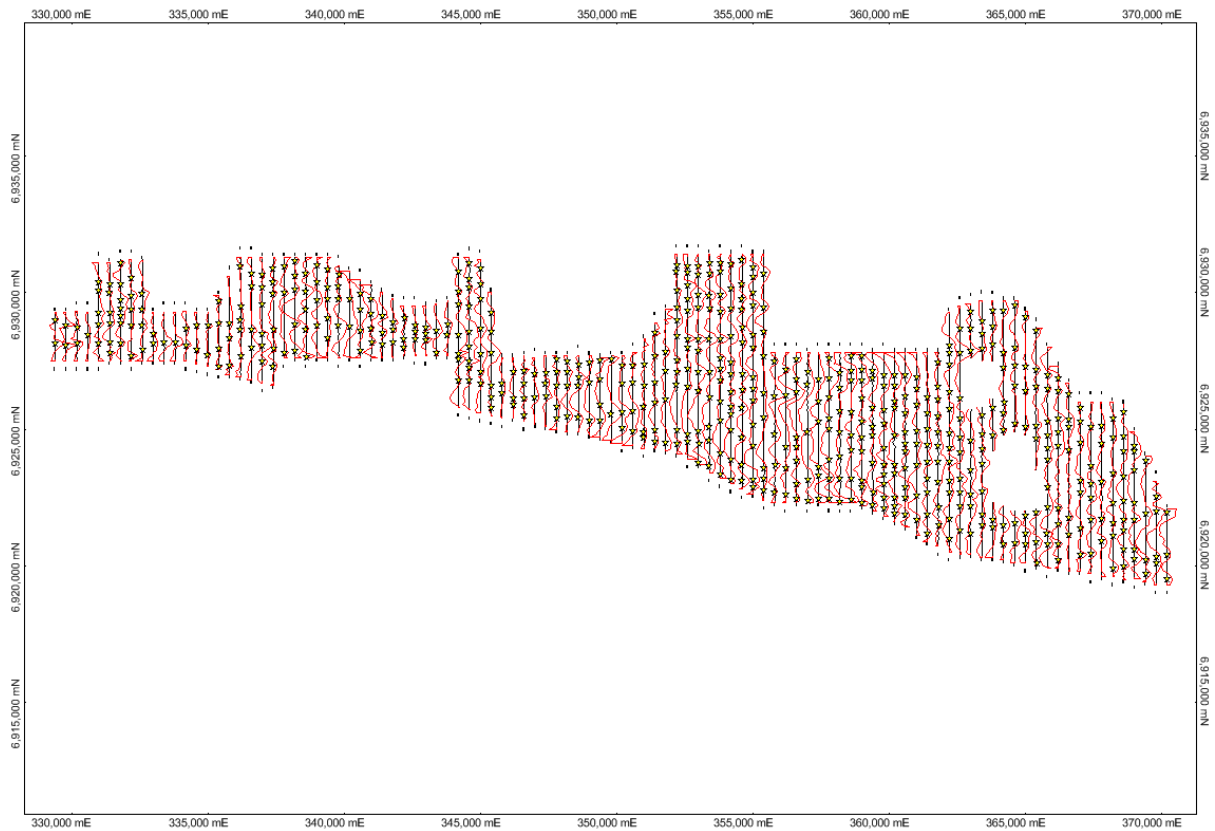


Figure 5. Bouguer anomaly 0.5VD (equivalent to UC 500m Residual) stacked profiles were manually examined and gravity lows picked along each line.

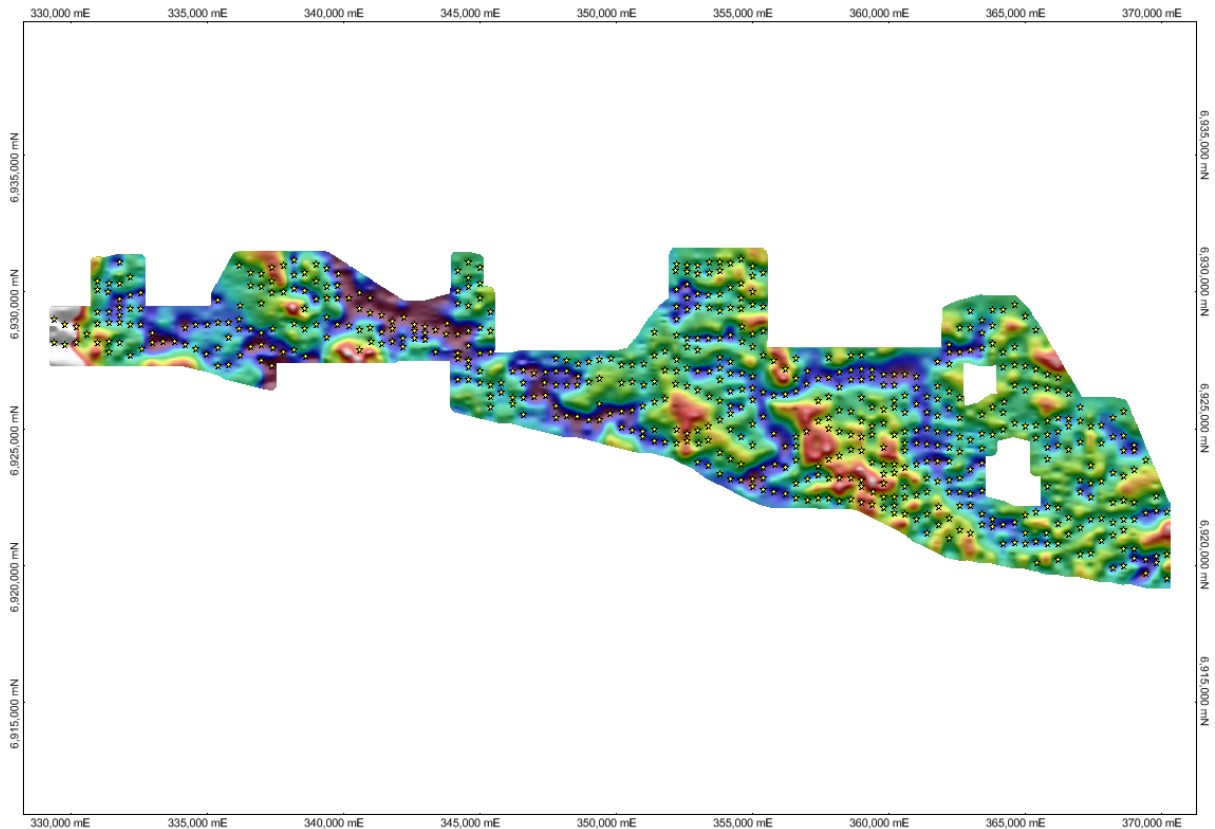


Figure 6. Picks were compared with Bouguer anomaly 500m Residual image.

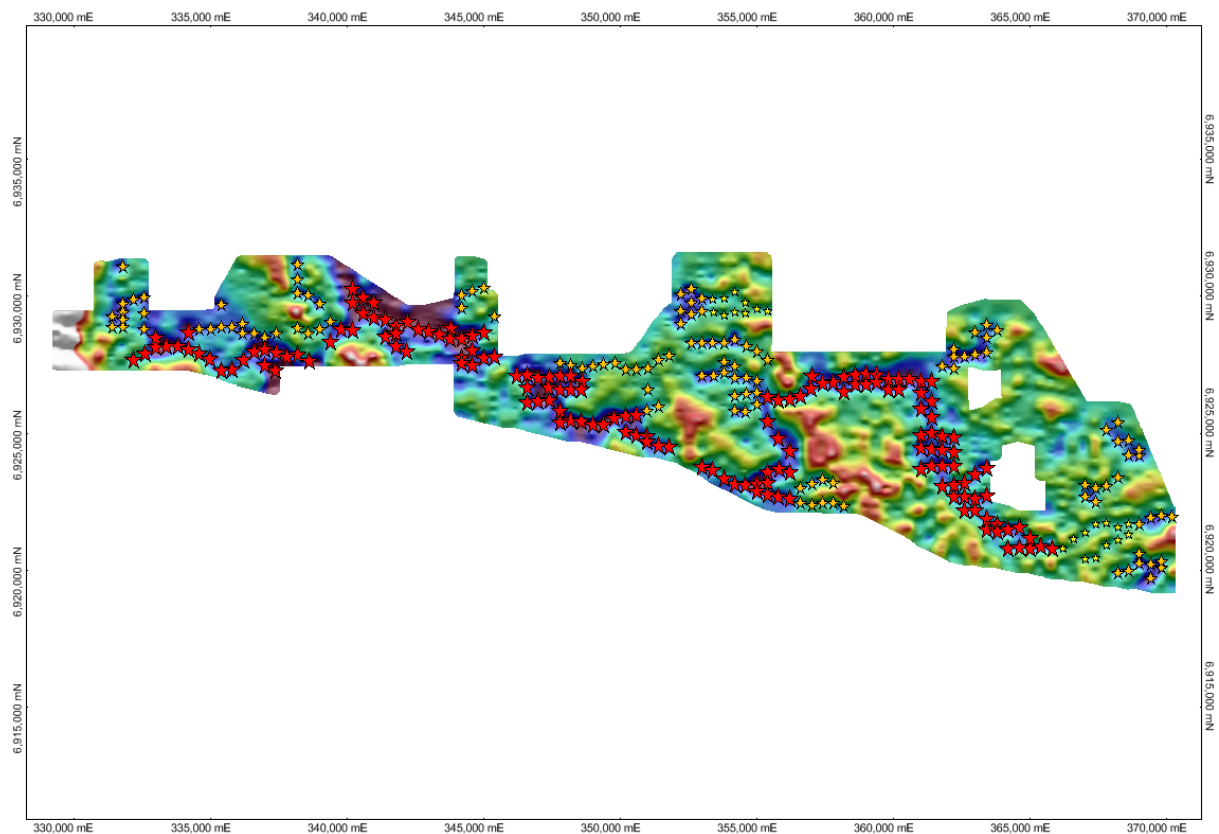


Figure 7. Picks related to probable and possible palaeochannel features were classified. Unrelated picks were discarded.

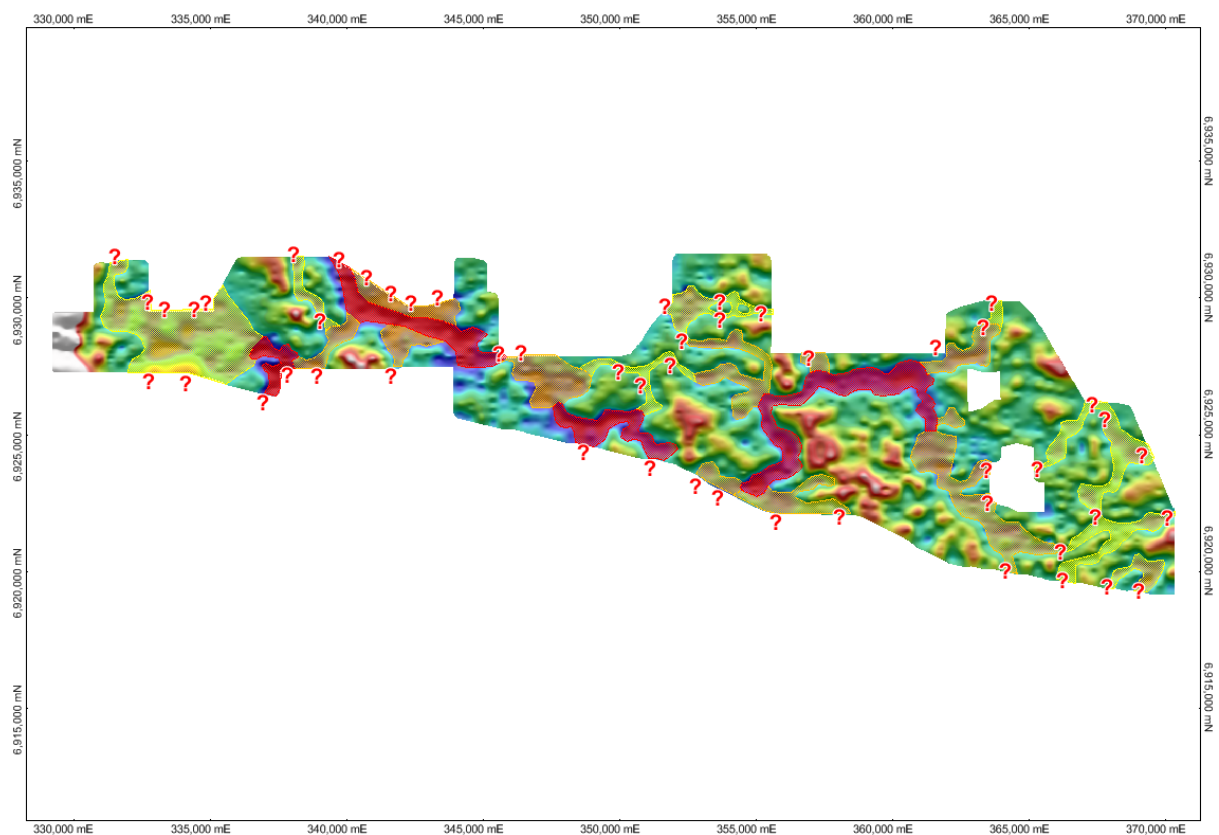


Figure 8. Polygons of predicted palaeochannels are filled in to give a targeting map.

4.2 Results

Gravity surveying has shown to be an effective tool for locating palaeochannel features underneath Lake Darlot. Multiple areas of potential interest have been identified from the survey data. Overall there appears to be one main palaeochannel with several possible sub-channels in the central section of the survey area. Ambiguous gravity results/data were observed in the far east and west of the survey area, with no clear palaeochannel targets being defined.

A map of the gravity interpretation with targets is provided in [Appendix A](#).

5 TARGETING

A number of areas of interest have been identified in the gravity data and are listed below in [Table 2](#).

Table 2. Areas of interest from gravity interpretation.

Area of Interest ID	Priority	Comment
LD-01	Low	Possible widening of main channel/floodplain; possibly lithological difference. Gravity high to the south appears to be an edge effect (referring to regional gravity).
LD-02	High	Appears to be part of the main channel, relative gravity low. Open to the south.
LD-03	Moderate	Possibly part of the main channel, not as low gravity as surrounding. Open to the south.
LD-04	Low	Possible sub-stream feeding into main channel.
LD-05	High	Possibly part of the main channel, relative gravity low. Open to the north and east.
LD-06	Moderate	Flanks LD-05 on the north, possible widening of channel. Open to the north.
LD-07	Moderate	Flanks LD-05 on the south, possible widening of channel /sub-stream feeding or draining main channel. Open to the south.
LD-08	Moderate	Possible widening of the main channel, open to the north.
LD-09	High	Thin section of main channel, relative gravity low. Open to the south.
LD-10	Low	Possible sub stream or “short cut” for main stream.
LD-11	Moderate	Sub stream, possibly draining into main channel. Relative gravity low.
LD-12	Low	Sub stream, possibly draining into LD-11. Relative gravity low. Open to the west.
LD-13	High	Possible main channel, relative gravity low. Multiple turns indicate possible high-energy area.
LD-14	Moderate	Extension of possible main channel, edge of survey boundary. Open to the south.
LD-15	Moderate	Possible sub channel feeding or draining main channel. Open to the north.
LD-16	Moderate	Possible sub channel, relative gravity low. Potentially related to DEM (elevation effect).
LD-17	Low	Possible sub channel, open to the north.

LD-18	Moderate	Possible sub channel.
LD-19	Moderate	Possible widening of main channel, becoming increasingly ambiguous.
LD-20	Low	Possible sub channels feeding main channel.

6 2D MODELLING

6.1 Potent Forward Modelling

The Potent modelling software calculates the theoretical ‘gravitational response’ from simple shapes (dykes, cylinders, blocks, spheres, etc.) which can be compared to the gravity profiles from field surveys. The orientation, dimensions, location and density of these model bodies can be adjusted until the calculated response matches the observed response; this process is referred to as ‘forward modelling’. Limitations of the forward modelling routine include;

- There is no unique solution for modelling an observed gravity field, in most scenarios there are more variables than there are known parameters. There are trade-offs between different parameters that produce similar results. For example, a wider and less dense body may produce a similar response to a thinner and denser unit. If some of the parameters can be constrained from known geological information (drill-hole data or density measurements) then the range of solutions can be reduced producing a higher degree of confidence in the modelling.
- The gravitational field decreases strongly with distance. This means that material closest to the gravity meter has the strongest response and generally produces better constrained models than material that is further from the meter. For ground or airborne gravity surveys, the top of the bodies are easier to model than the deeper extents.
- Multiple bodies that are closer to each other than their distance to the meter cannot be resolved as separate sources – their fields will superimpose to look like that of a single body. What has been modelled as a single body may actually be composed of a number of smaller and closely spaced bodies.
- When modelling bodies the thickness and density values cannot be resolved individually. The gravitational field will be a product of the volume of material (i.e. thickness x density) such that a 10 metre thick body with density of 3.00 g/cm³ will produce the same result as a 20 metre thick body of 1.50 g/cm³ (in empty space).
- Potent forward modelling uses simple shapes to model what can be very complex geological scenarios. The best results are achieved where simple geology is modelled using gravity profiles that are close to being perpendicular to the dominant strike direction. Modelling gravity profiles that are oblique or parallel to strike can be very difficult, particularly where geology is very complex.
- Forward modelling is often referred to as 2D modelling. The models generated apply only to the profile being modelled. Data from nearby lines can be used to help constrain the orientation (strike, dip, plunge, length) of the model bodies, in which case the modelling is sometimes referred to as 2.5 D modelling. The models generated for each profile are valid only for that data on that profile; the results should not be extrapolated too far away from the modelled data.

In general the modelling can be improved by constraining parameters with known information and by recording data profiles closer to the source rocks.

An example of a 2D magnetic model section is shown below in [Figure 9](#). For each model profile the total magnetic intensity (TMI, top panel) and the two derivatives TMI_dz (first vertical derivative of TMI – second panel) and Manalytic (analytic signal of TMI – third panel) have been modelled. The derivatives help to isolate the response of closely spaced magnetic bodies and identify the edges of shallow targets. The observed profiles are shown in blue and the calculated profiles in red. The lowest panel on each profile shows the cross section of the profile with the relevant model bodies and drill holes projected onto the section. The AMAG survey flight path is shown as a green trace and the terrain as a brown trace (all RL positions are relative to the aircraft GPS heights). The model body cross sections are filled in and the ends are projected onto the section (near side is solid and the far side is dashed). The cross section direction is labelled in the lower right-hand corner (“AZ=89.9 deg”)

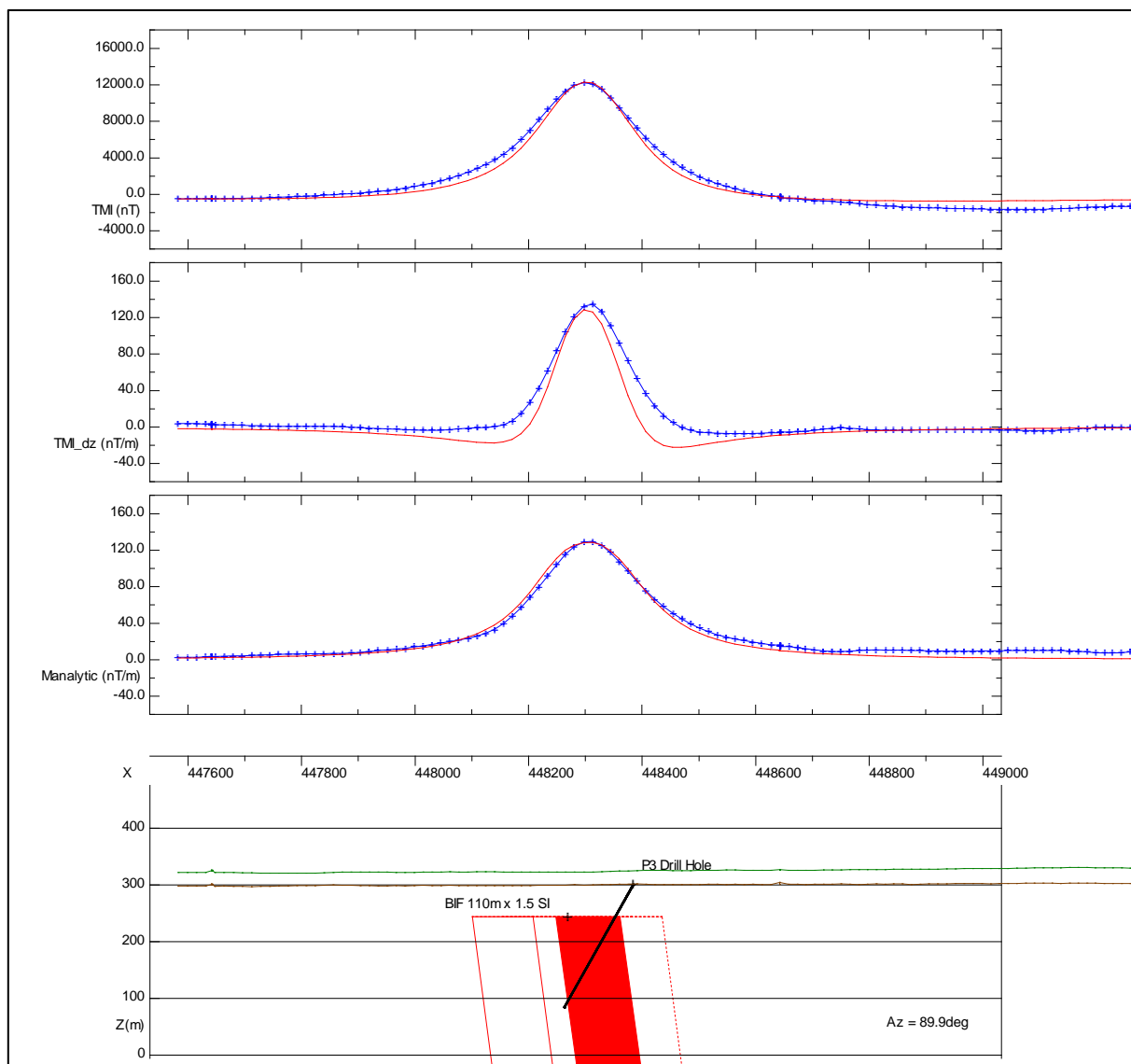


Figure 9. Example of a Potent 2D model profile

6.2 Lake Darlot Forward Density Modelling

Features of interest along 5 lines were identified for 2D modelling efforts (Figure 10). A polygon with a density of -0.75 g/cm^3 relative to basement (i.e. 1.92 g/cm^3) was used to model channel fill. The models are simplistic and assume a 2-layered earth with homogenous densities (Figure 11, Figure 12, Figure 13, Figure 14, Figure 15). All models are shown with vertical exaggeration.

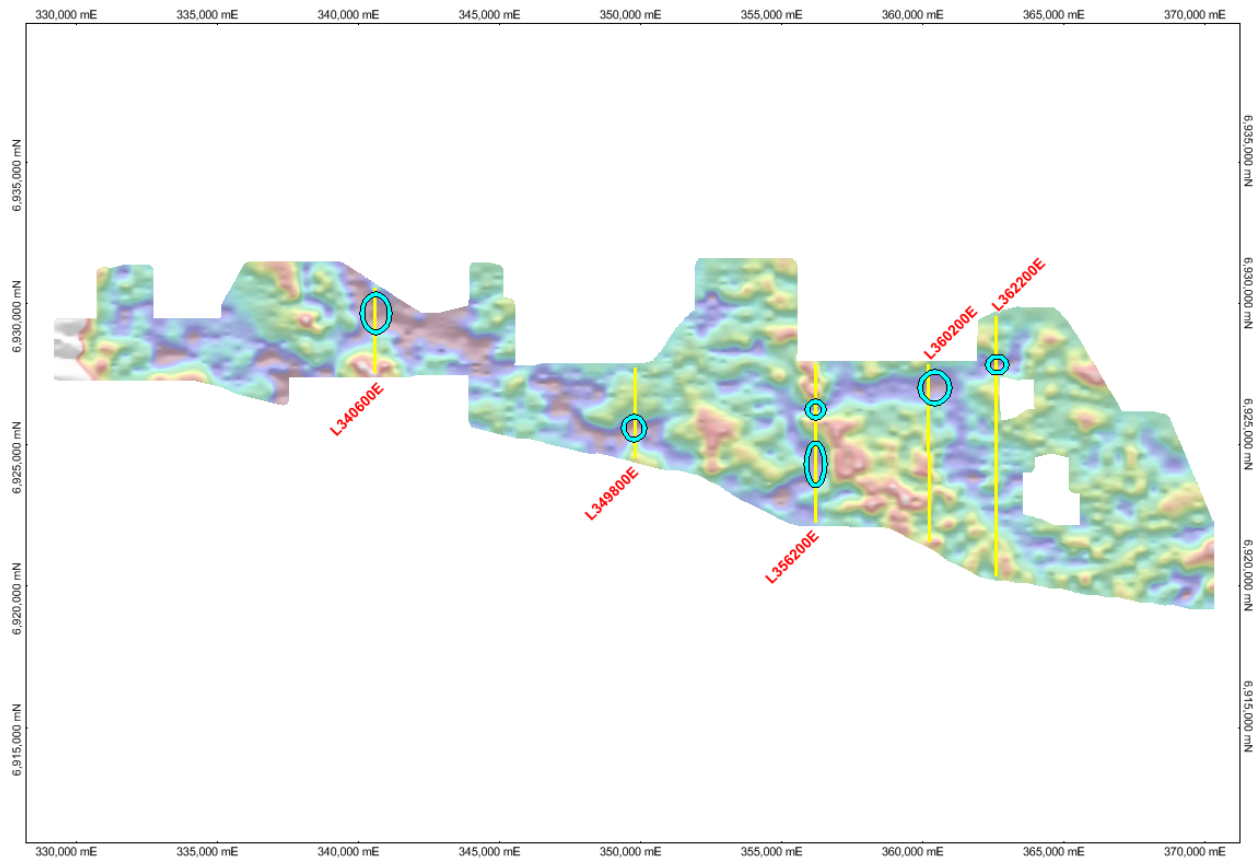


Figure 10. Selected 'features of interest' (blue circles) and lines used in 2D modelling (yellow).

Modelling on line 340600E shows a broader part of the channel with a max depth of 50-60m at around 6929450 mN (**Figure 11**).

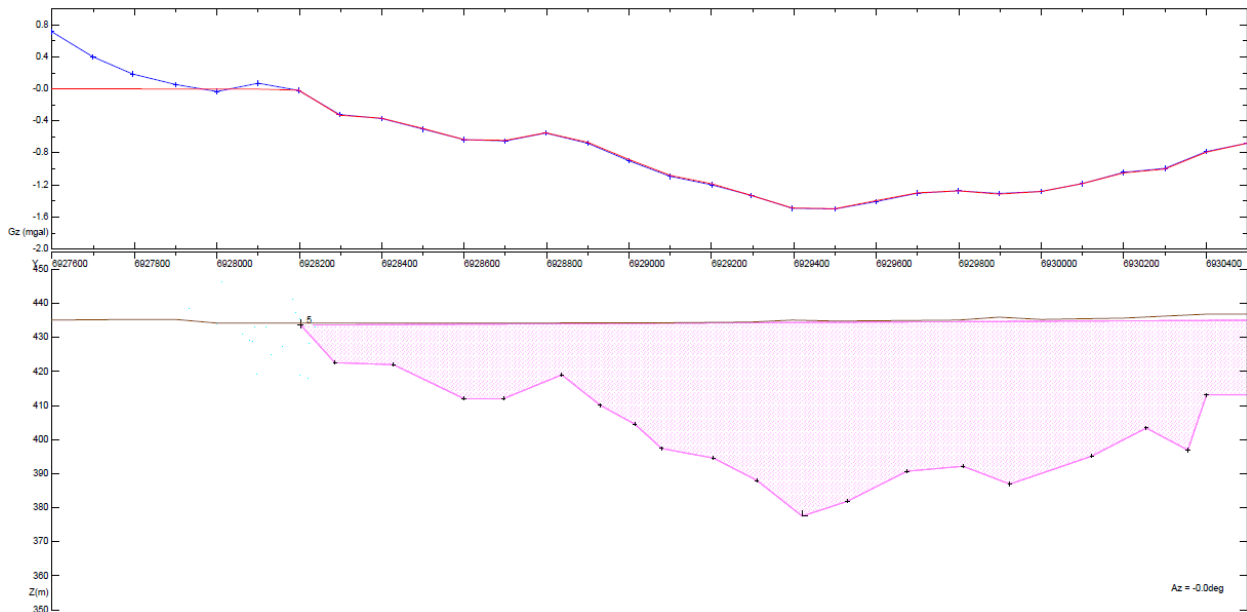


Figure 11. 2D modelling of line 340600E; the pink polygon represents channel fill with an estimated density of -0.75 g/cm^3 relative to basement.

Modelling on line 349800E shows a part of the channel that may be 300-400 metres wide, with its deepest point (50-60 metres) at around 6925600 mN. The modelling suggests this part of the channel is narrow and steeply banked, making it an ideal drill target (**Figure 12**).

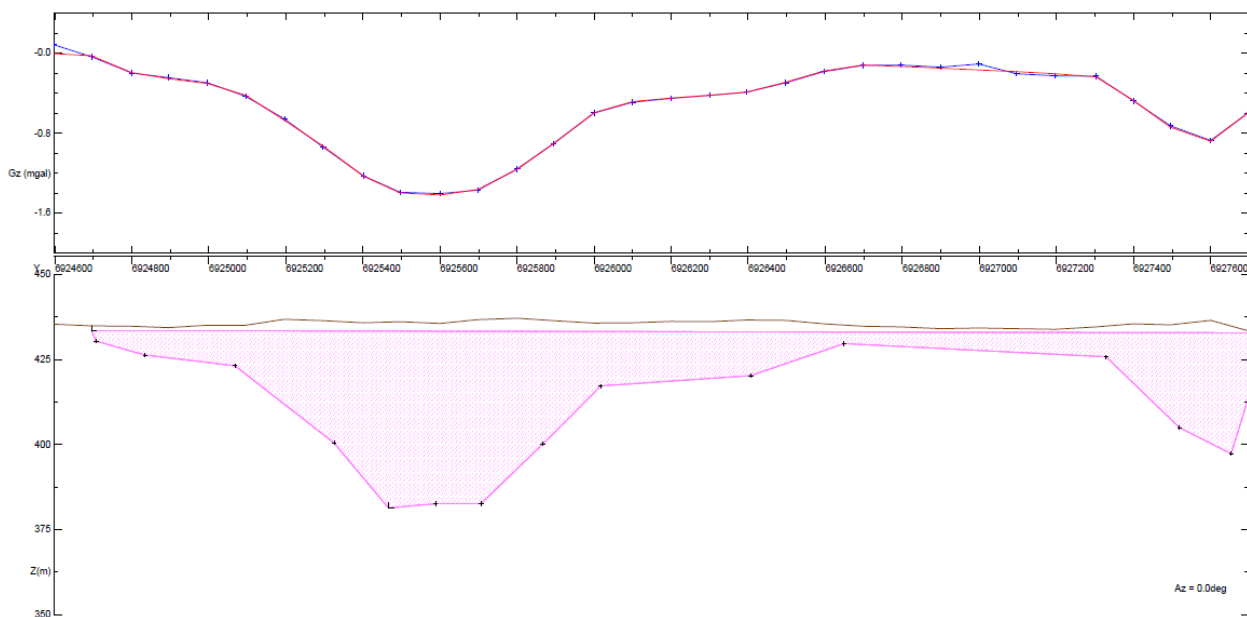


Figure 12. 2D modelling of line 349800E; the pink polygon represents channel fill with an estimated density of -0.75 g/cm^3 relative to basement.

Modelling on line 356200E attempts to capture two parts of the main palaeochannel (LD-13). The northern part (located at approximately 6926200 mN) appears to be a narrow and steeply banked part of the main channel, with a depth of around 30 metres. Note that this part of the channel appears to cross a higher density feature, possibly a lithology change in the basement, which may impact the accuracy of the 2-layer model (and implies that channel could be deeper than modelled, probably around 50 metres as shown by the other models). The southern part of this channel (located at approximately 6924400 mN) crosses the gravity profile nearly perpendicularly, so the 2D model does not give an idea of width of the channel. It does also show the depth to be approximately 50 metres ([Figure 13](#)).

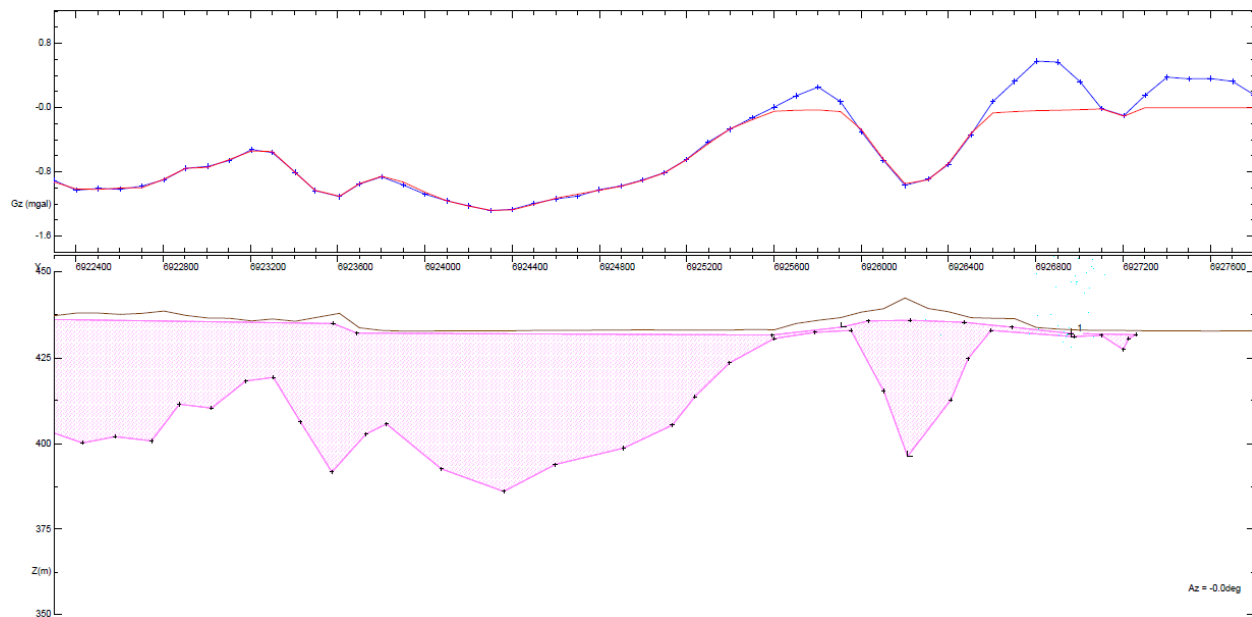


Figure 13. 2D modelling of line 356200E; the pink polygon represents channel fill with an estimated density of -0.75 g/cm^3 relative to basement.

Modelling on line 360200 was only conducted on the northernmost feature, as the rest of the profile is interpreted to represent only basement response. This part of the channel is modelled to be approximately 50 metres deep and 800-1000 metres wide, centred on 6927000 mN.

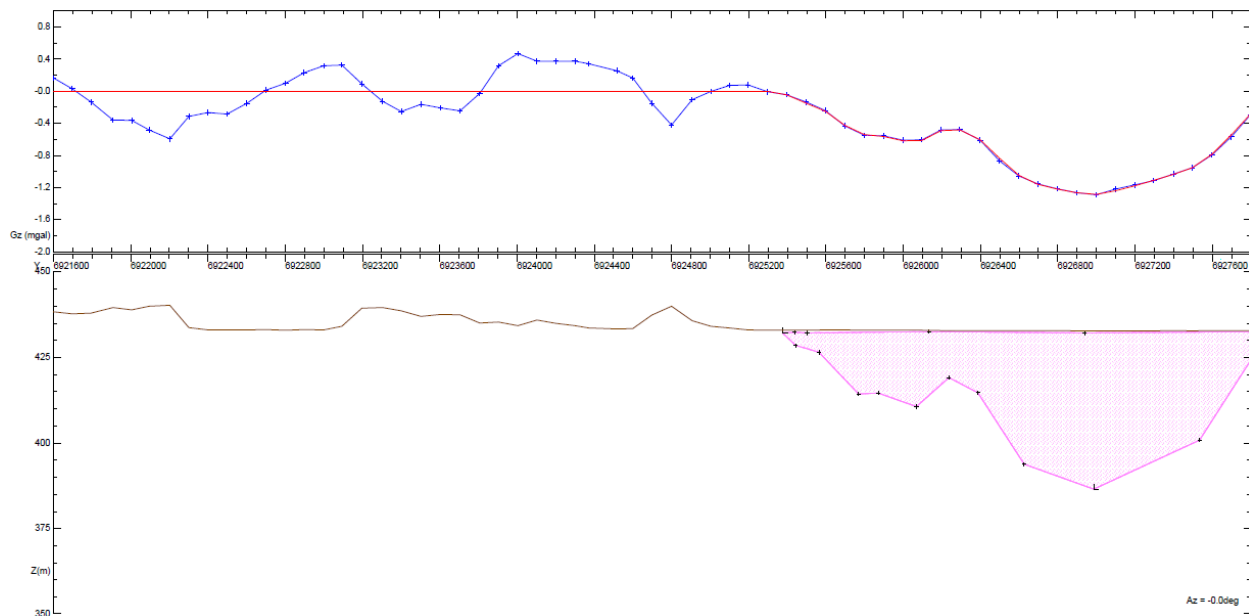


Figure 14. 2D modelling of line 360200E; the pink polygon represents channel fill with an estimated density of -0.75 g/cm^3 relative to basement.

Modelling on line 362600 focusses on the anomaly located at approximately 6927750 mN, but also attempts to characterise the palaeochannel response in the south (i.e. where the gravity data become less clear and interpretation becomes more ambiguous) (Figure 15). The feature in the north coincides with a local hill in the DEM, potentially creating an artefact in the gravity data and over-representing the depth of the valley (Figure 16). Modelling shows the channel to be approximately 50 metres deep and 500 metres wide, centred on about 6927600 mN. Towards the south, the profile becomes choppy and difficult to interpret but there are potentially palaeochannel features < 25 metres deep.

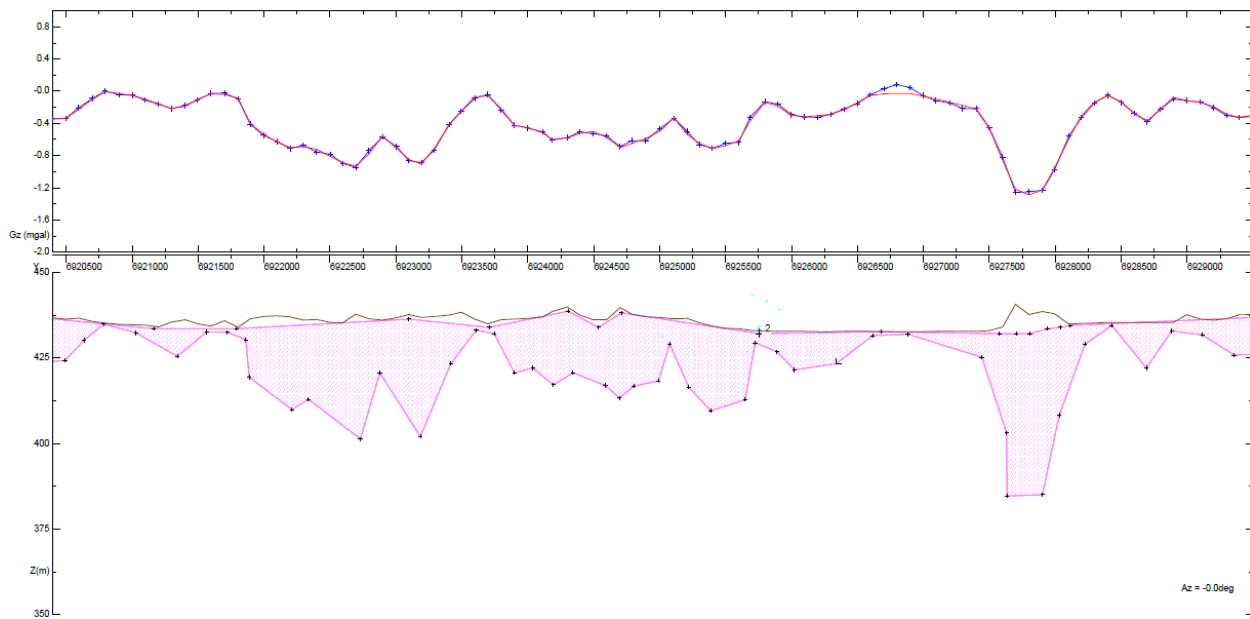


Figure 15. 2D modelling of line 362600E; the pink polygon represents channel fill with an estimated density of -0.75 g/cm^3 relative to basement. Note the topographic profile (brown) relative to the position of the modelled channel.

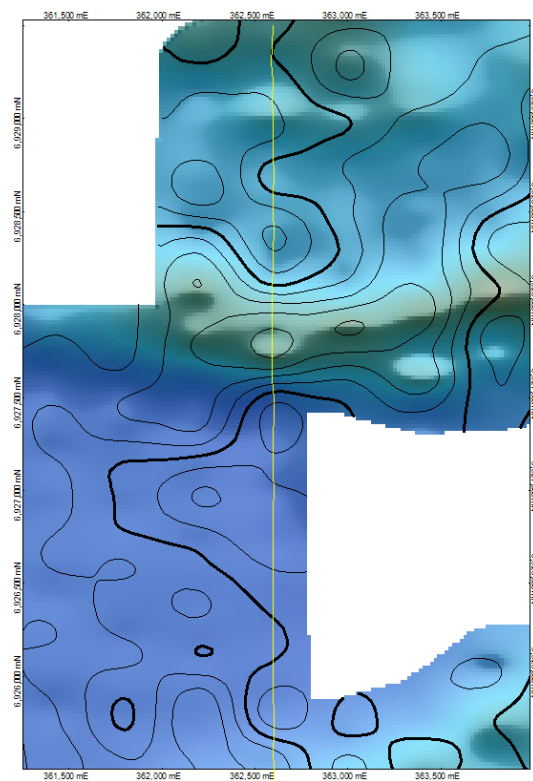


Figure 16. DEM (image) with BA267 1VD contours to illustrate the coincident DEM high (hill) and gravity low. Line 362600E in yellow.

7 PASSIVE SEISMIC (TROMINO) PROCESSING

The following sections represent the reflectance of the subsurface from which an estimate of the thickness of the top layer can be determined. The black line on the figures represents the most likely depth to the first reflective boundary. Unfortunately the nearby drilling did not provide any useful information to help constrain the depth estimates. Extreme variations in the interpreted depths should be viewed with caution and further investigation is recommended. Only 6 stations were able to be recorded for lines 341000E and 360600E due to difficult access.

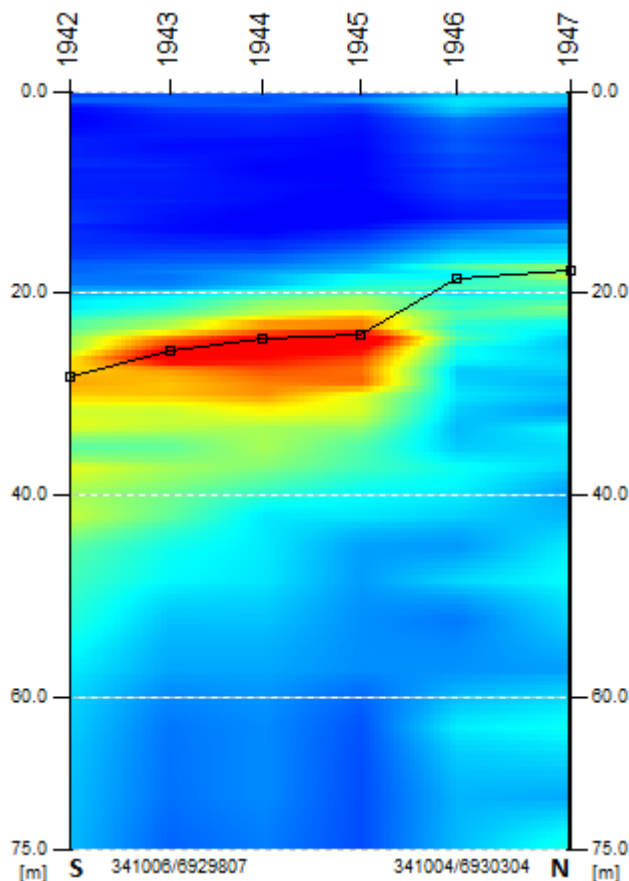


Figure 17. Cross-section showing the variation in overburden thickness for line 341000E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

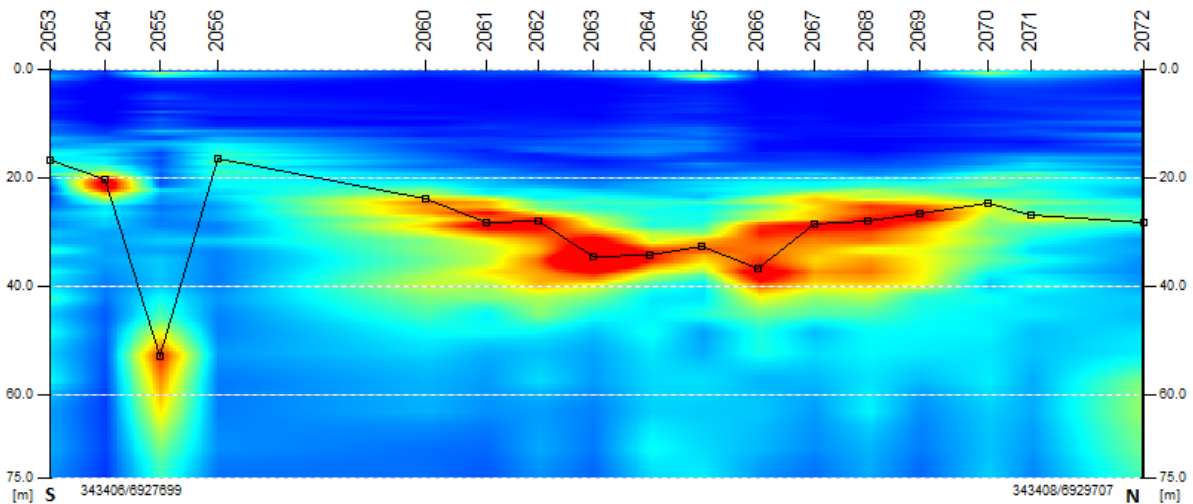


Figure 18. Cross-section showing the variation in overburden thickness for line 343400E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

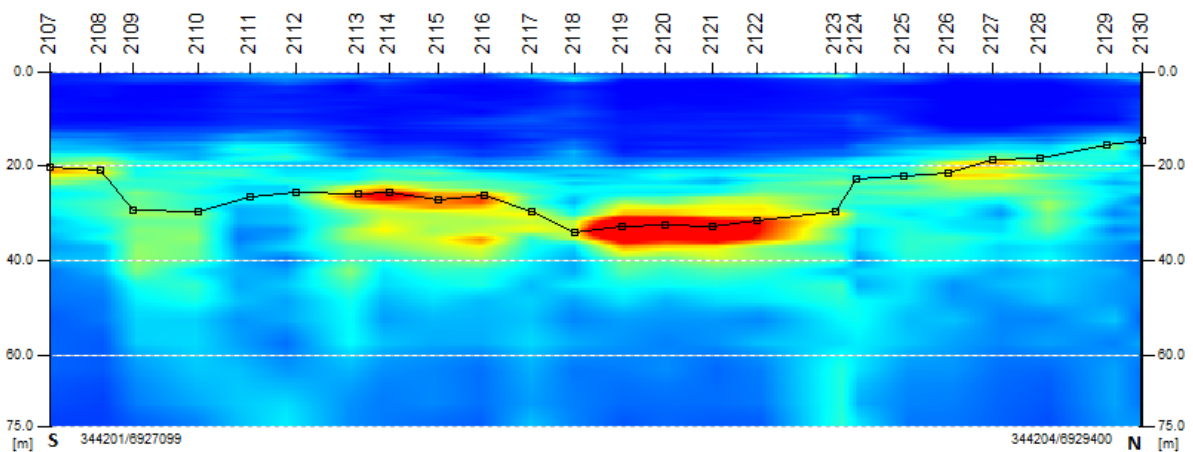


Figure 19. Cross-section showing the variation in overburden thickness for line 344200E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

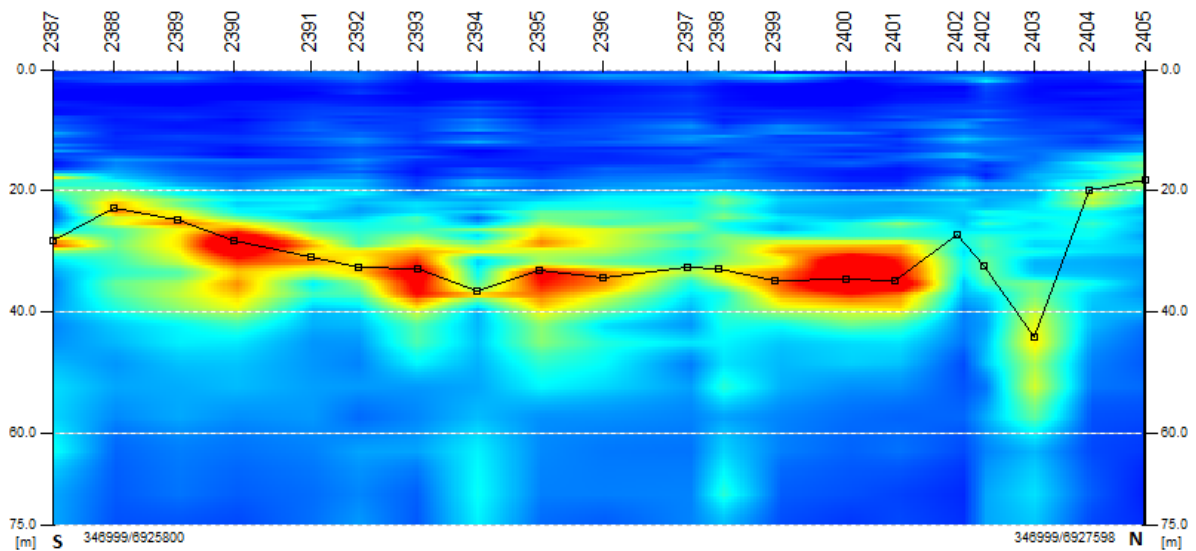


Figure 20. Cross-section showing the variation in overburden thickness for line 347000E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

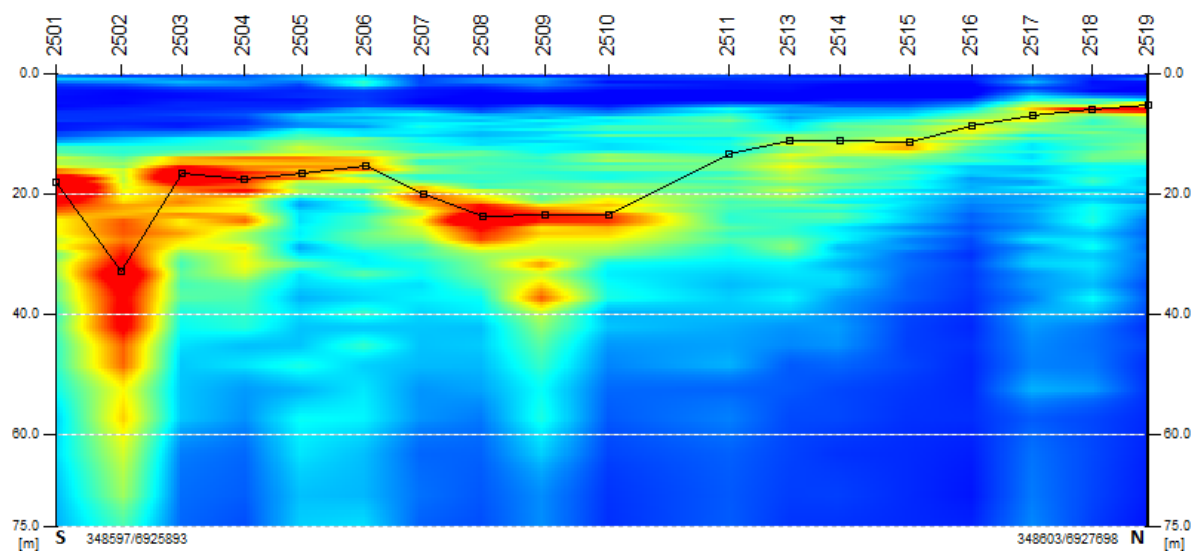


Figure 21. Cross-section showing the variation in overburden thickness for line 348600E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

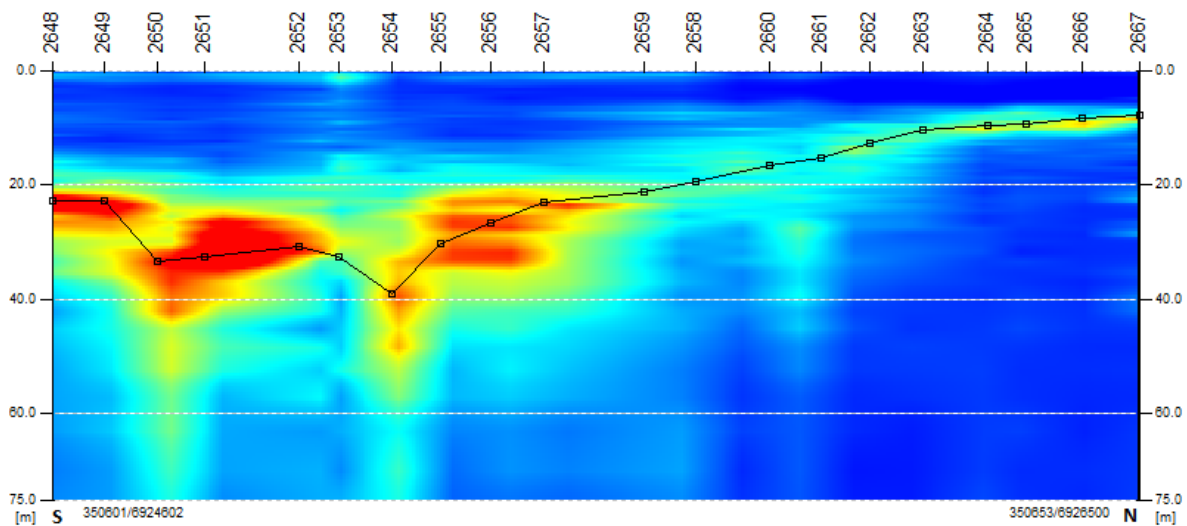


Figure 22. Cross-section showing the variation in overburden thickness for line 350600E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

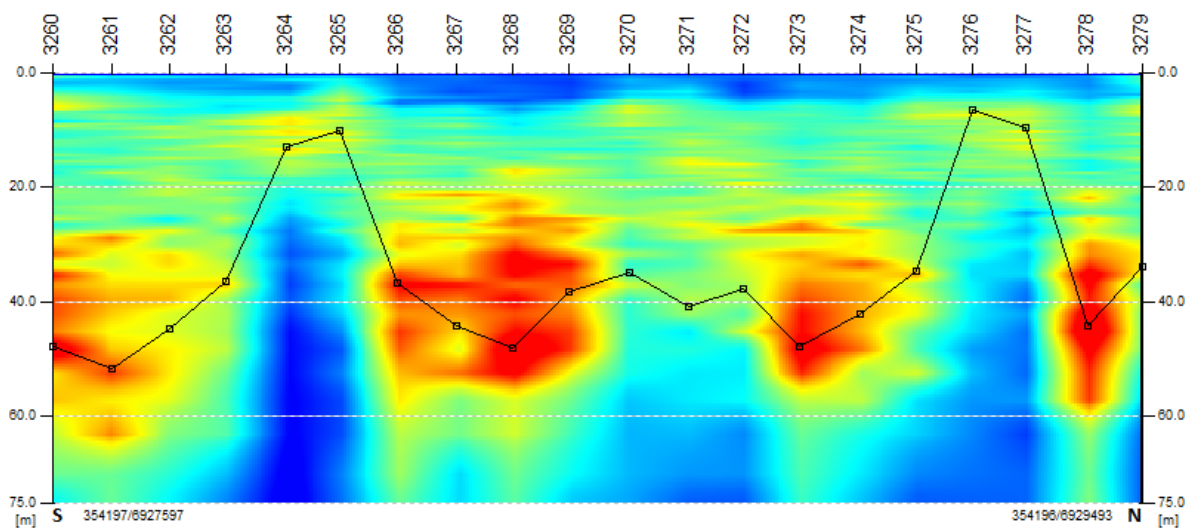


Figure 23. Cross-section showing the variation in overburden thickness for line 354200E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

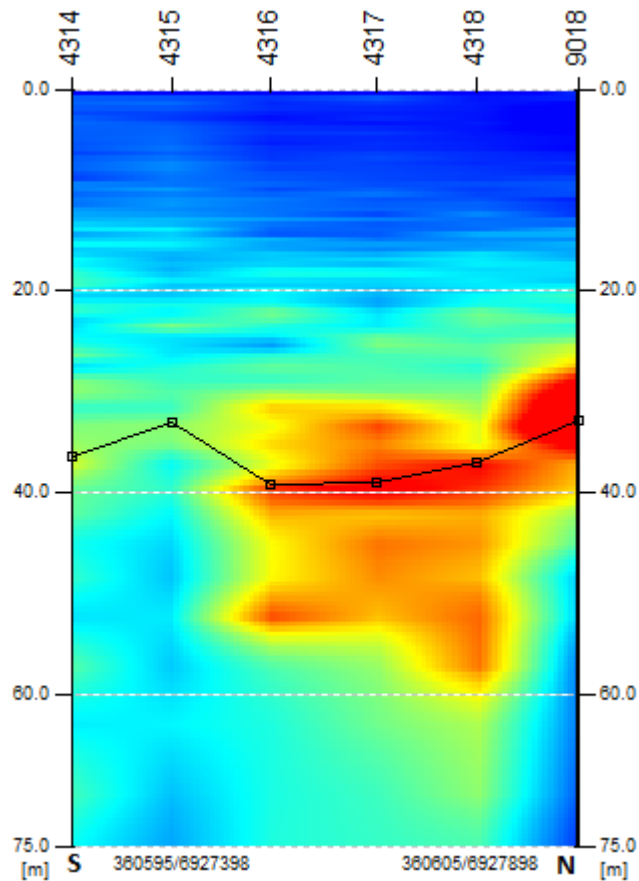


Figure 24. Cross-section showing the variation in overburden thickness for line 360600E interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

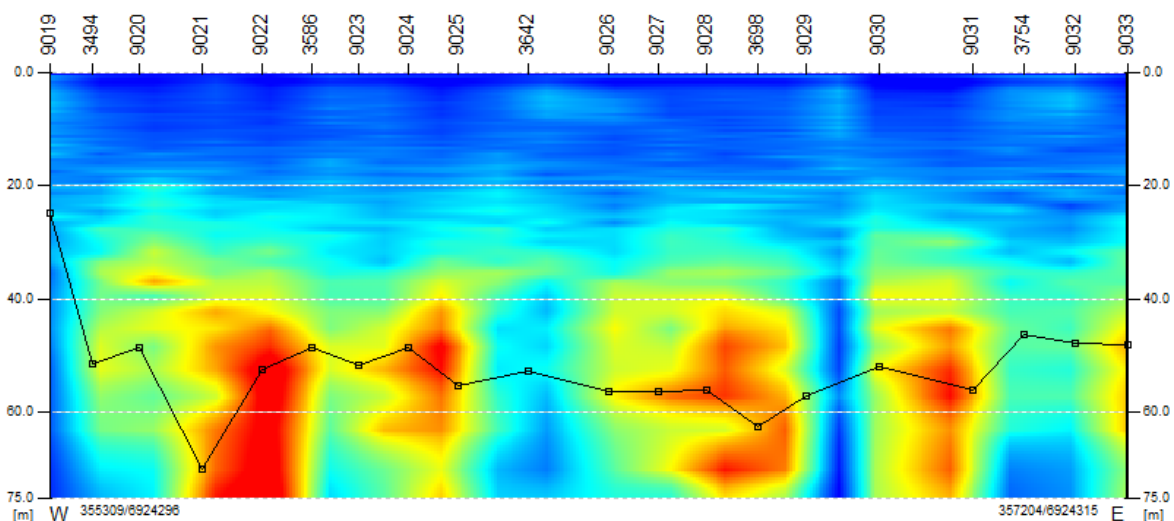


Figure 25. Cross-section showing the variation in overburden thickness for line 6924300N interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

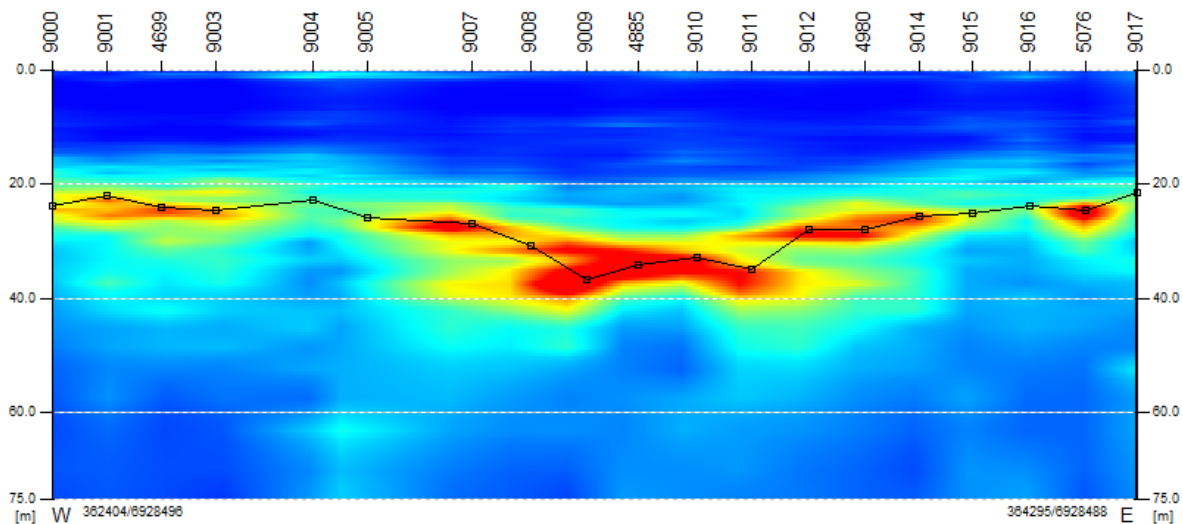


Figure 26. Cross-section showing the variation in overburden thickness for line 6928500N interpreted from passive seismic data. Black line is the estimate of the depth to the boundary.

8 SUMMARY AND CONCLUSIONS

Gravity data has been examined and appears to define a strong palaeochannel feature, which has been divided into areas of interest (LD-01 to LD-16) for follow up. In the gravity images, a lower gravity reading (i.e. blue colours) is generally taken to indicate a deeper channel.

Some lines of gravity data have been modelled and returned estimated depths of around 50 metres with varying widths. The physical densities of the channel fill and bedrock are at this point unknown and so have been estimated based off of similar environments – until these rock properties are confirmed the results of modelling should be treated with caution.

Areas where the palaeochannel is thinner and deeper indicate a higher energy palaeo-environment (i.e. fast flowing water), which is favourable for the deposition of coarse sands. These coarse sands are necessary for groundwater permeability and successful extraction of brines from the aquifer.

Passive seismic data recorded along 10 transects at Lake Darlot have been processed and used to generate estimates of the depth to the base of the top layer. The interpretations made from the passive seismic data provide a best-guess of the variations of the depth to the first main reflector – assumed to be the base of the regolith. The estimate is based on an assumed seismic velocity which is very likely to be incorrect. The relative depth variations shown in the figures can be relied upon where the measured seismic signal is strong but the magnitude of those variations cannot be considered absolutely correct without additional information from drilling.

The passive seismic data from lines 350600E and 6928500N tend to show good correlation with the nearby gravity modelling. Lines 341000E and 360600E are too short to convey anything meaningful but show what could be the bank of a palaeochannel. Line 6924300N showed almost no correlation with the gravity modelling (too noisy), and the other lines were not near modelled gravity data.

9 RECOMMENDATIONS

Determination of densities for the channel fill and basement rock (via petrophysical testing) is recommended as a follow-up to better refine modelling and interpretation over the broader project area.

Recommended first priority drill targets (GDA94/MGA51):

LD-13 – Proposed vertical drill holes to intersect the ‘main’ palaeochannel feature located at

1. 360440 mE, 6927010 mN
2. 356210 mE, 6924350 mN
3. 356450 mE, 6926300 mN

LD-05 – Proposed vertical drill hole located at 340980 mE, 6929500 mN (centre of gravity low and presumed deep point of palaeochannel).

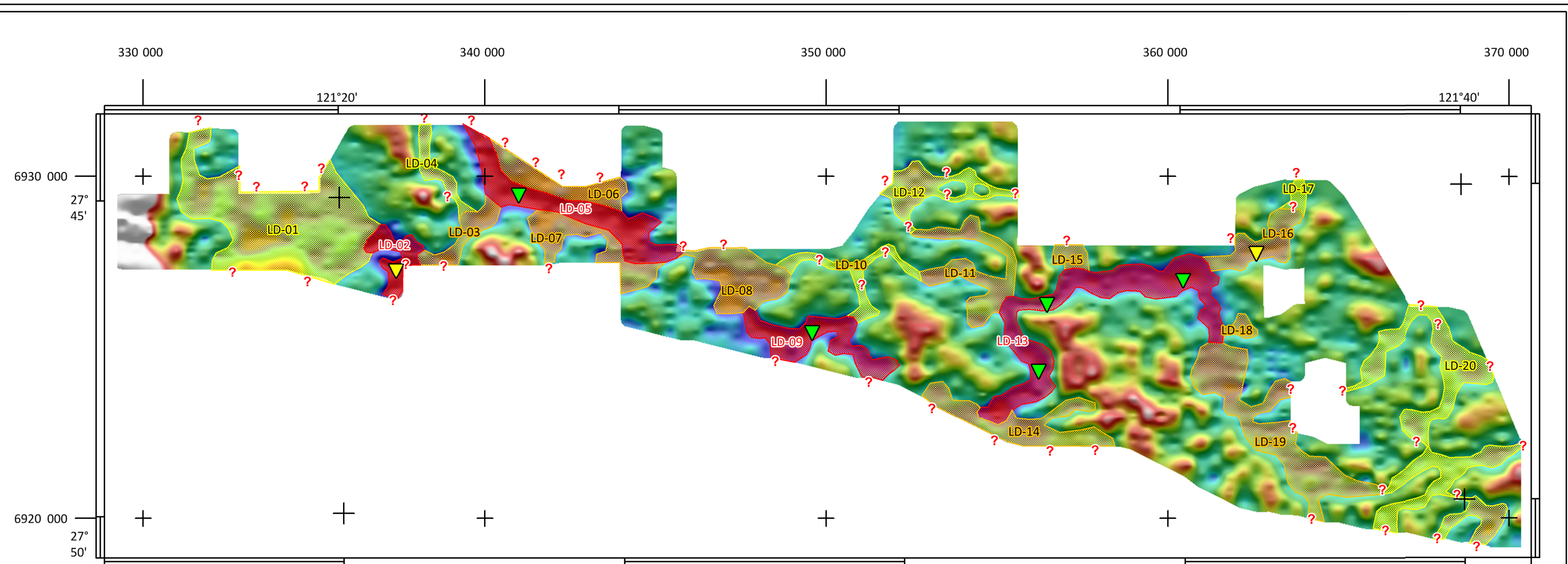
LD-09 – Proposed vertical drill hole located at 349590 mE, 6925480 mN.

Recommended second priority drill targets (GDA94/MGA51):






LD-02 – Proposed vertical drill hole located at 337390 mE, 6927300 mN (gravity low) - moderate priority as near the edge of the data.

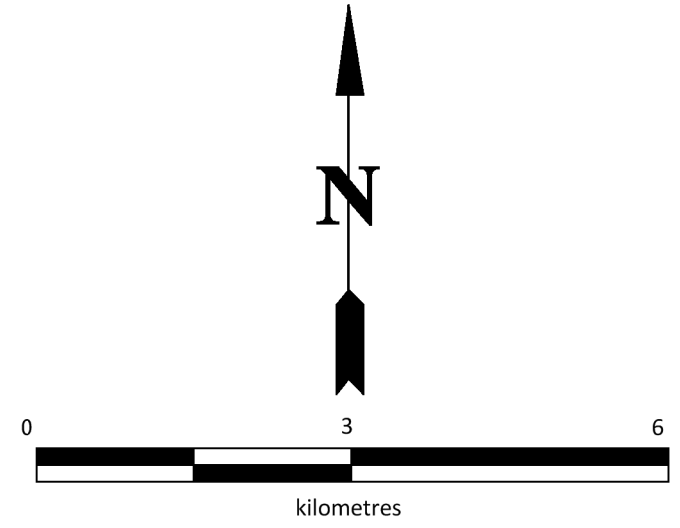
LD-16 – Proposed vertical drill hole located at 362580 mE, 6927800 mN (centre of gravity low and presumed deep point of palaeochannel) – moderate priority as could be related to terrain effect.

Appendix A – Gravity Interpretation




LEGEND

-  High Priority Area of Interest
-  Moderate Priority Area of Interest
-  Low Priority Area of Interest
-  High Priority Drill Target
-  Moderate Priority Drill Target



SCALE 1:120 000
DATUM: GDA94
GRID: MGA ZONE 51S



SOUTHERN GEOSCIENCE
CONSULTANTS

YELLOW RESOURCES PTY LTD

Lake Darlot Project

Ground Gravity

Palaeochannel Interpretation

Residual (500m) Image

SCALE: 1:120 000	GEO: J. TRUNFULL
DATE: 19-09-2017	GIS: S. HARDY-JOHNSTON
WWW.SGC.COM.AU	