Report on a Water Search Program over the Yalata-Ooldea Road for Transport S.A.

REPORT BOOK 99/00027

by

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Groundwater

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PRIMARY INDUSTRIES AND RESOURCES
SOUTH AUSTRALIA

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REPORT ON A WATER SEARCH PROGRAM OVER THE YALATA-OOLDEA ROAD FOR TRANSPORT SA.

Sandy Dodds

A Transient Electromagnetic (TEM) survey was used to prospect for groundwater at three locations on the road between Yalata and Ooldea, on the thesis that water would be available in either deeper overburden or fractured basement. Overburden targets were located at all three sites and fractured basement sites at the 30 km and 60 km sites.

INTRODUCTION

In response to a request form Transport SA, PIRSA conducted a search for groundwater to be used for the building of the Yalata-Ooldea Road. Water was requested at distances of 30 km, 60 km and 100 km from Yalata, with no constraints being placed on water quality but with yields of about 2 L/s being needed.

GEOLOGY

The geology of the area comprises up to 100 m of Tertiary and Quaternary sediments overlying the crystalline basement of the Gawler Craton. These sediments are mainly the Eocene Pidinga formation (lignitic clays with some sandy fractions) overlain by up to 30 m of Miocene Nullarbor limestone. Water in these formations is usually saline (30 000 mg/L or so) and previous drilling has shown that reasonable supplies can be obtained from basal Pidinga sands just above basement, where the sediments are at least 50 m thick. Another likely source of water is in fractures within basement, but such fractures may be difficult to locate.

SURVEY METHOD

Since the waters are expected to be saline and therefore conductive it was decided to search for water using the Transient Electromagnetic method, which responds to conductors in the subsurface. The sediments, being porous, will be saturated with saline groundwater below the watertable and therefore conductive. Unfractured basement is not porous and will therefore be resistive. Thus the survey will indicate both depth to basement and locations where basement is fractured. Areas of deeper basement or fractured basement are regarded as favourable drill targets.

The survey was done with a 100 m transmitter and receiver loop in the single loop configuration, ensuring that soundings penetrated to at least 100 m below surface. In most cases soundings were done at 100 m intervals along the traverses. The background to the technique and loop configuration are given in the appendix.

The field work was done on the 22–23 June 1999, and the results were interpreted on the spot to provide drilling targets for the rig which was due on 24 June 1999. The data were reprocessed on return to Adelaide and a reinterpretation done as described below. No drilling results were available at this time, so it was not possible to re-evaluate the geophysical results with the benefit of the ground truth that such drill logs would provide.

Two lines, one east-west and one crossing and perpendicular to it, were surveyed near the camp 30 km north of Yalata. At Moondrah Tank Bore, 60 km north of Yalata, one line 2 km long was traversed along the road. At the 100 km point two lines were surveyed; one short line over the site of the backfilled P2A well, which produced 2 L/s of saline water; and a longer one along the road due west of well P2A. The general locations are shown in Figure 1, specific sounding locations are shown in Figures 2, 5 and 7, and the survey results are shown as resistivity sections in Figures 3, 4, 6, 8 and 9.

DISCUSSION OF RESULTS

30 km site.

The geology of the first site, 30 km north of Yalata and close to the camp and a derelict shed tank, is known only generally as there are no drillholes nearby. The two traverses shown in Figure 2, one east-west and 1000 m long and one north-south and 700 m long, indicate flat basement at a depth of about 80 m. The watertable is at about 40 m, with the saturated sediments below it having a resistivity of about 1.3 ohm-metres, typical of saline groundwater or saturated clay, and the upper sediments, which are moist but not saturated, having a higher resistivity of about 14–24 ohm-metres. There are no direct indications of potential water yields in this information, and it is expected that one location is as good as another for getting water from the sediments.

So far as a fractured basement aquifer is concerned, the basement is most conductive at the west end of Line 1 and this is regarded as the most favourable location. Stations 0 and 100 (AMG coordinates 221700–221850E, 6525410N), located 100-200 m west of the road and opposite the shed tank, are the optimum site. A second but less favourable site is the north end of Line 2, stations 500–700, (AMG coordinates 222370E, 6525500–6525750N) or 100–300 m north of the shed tank. At either of these locations basement should be intersected at a depth of about 80 m, with the aquifer being intersected within 40 m of bedrock surface and probably closer.

60 km site.

One earlier well, Moondrah Tank Bore (Unit number 5335–2) was drilled in 1964, but could not be located at this time. The current status of the well is listed as ‘unknown’, and the failure to locate it indicates either that the location is greatly wrong or that the well has vanished without trace. The well is listed as having cut water at 61 m depth in basal sands above crystalline basement and under lignite layers. The water was saline (22 000 mg/L) and yielded 1.0 L/s with a SWL (standing water level) of 35.66 m.

Moondrah Tank is located in sand hills which mark the southern edge of the Nullarbor Plain. The southern limit of the TEM survey line was in the same sand hills about 100 m north of the tank.

The TEM survey results (Figure 6) indicates basement at a depth of 50–75 m and the water table at 30 m depth at the north end of the line dropping to 40 m at the south end. Most of this drop occurs at the extreme south end and may indicate a rise in ground level near the sand hills. This level agrees with the SWL of the Moondrah Tank Well. Resistivity levels above and below the water table correspond to moist and saturated sediments with saline groundwater, while basement resistivities are lower than would normally be expected from unweathered crystalline basement. This may indicate that there is a thickness of mild weathering at basement surface sufficient to allow some penetration of moisture. Three locations – 1850 mS (AMG northing 6552795), 1550 mS (6553090N) and 1050 mS (6553540N) – show lower resistivity basement that may be indicative of a fractured basement aquifer.

The deepest basement on this line occurs at the south end (75 m) but this may be accentuated by a rise in the topographic surface as evidenced by a corresponding increase in the depth to the water table. The next deepest is at the north end of the line, stations 0 and 100 (AMG northing 6554500). However, the basement surface does not appear to have great relief, and such variations may not be very significant. The three locations of more conductive basement may be better indicators of the potential for higher water yields. Wells should strike basement within 60–70 m, with potential for water yields within 20–40 m of basement surface.

100 km site.

A well, P2A (Unit number 5336-19) was drilled in this area in 1976 and intersected water at 10 m depth in laterite pebbles. The estimated yield was 2.5L/s of saline water (56 700 mg/L) and the SWL 7.5 m. The well was abandoned, but the site was found marked by a permapine post with the well name engraved on a brass plate. A more accurate location than that given earlier is (224670E, 6589320N). The well is 10 m east of a secondary track in this area and about 600 m east of the location shown in Figure 7.

A TEM traverse over this site, Line 4, is shown in Figure 8. Basement is at a depth of 45 m, with the water table at 5 m. The basement is consistently very resistive, and the saturated sediments very conductive as would be expected with groundwater of the salinity found in this well.

The road is 3.2 km west of this well. A second TEM traverse, Line 5, was done along the road due west of the well to see whether ground conditions were similar and the potential for groundwater equally good. Contrary to the indications of Figure 7 the readings were taken close to the present road, that shown in the figure being presumably out of date. The results indicate a considerable range in depth to basement between 20 and 50 m, and even deeper in places, while the water table is generally at about 10 m. A clear local basement low occurs at 10 000 to 10 400 and is favoured to either duplicate the results in P2A or to yield water from just above basement. There are no clear indications of possible basement conductors.

The most favourable drilling site is close to P2A, where water supplies have been proved in the past. A secondary site, which is less certain but might be preferred because of its location on the road, is at 10 000 to 10 200 on Line 5 (AMG northings 6589000–6589200).

SUMMARY

At the 30 km site the basement surface is flat and there are therefore no preferences for drilling within several hundred metres of the tank, so far as water in the sediments is concerned. The likelihood of basement fracture aquifers is greatest at the west end of line 1, 150 m west of the road, with a second choice at the north end of line 2, approximately 200 m north of the tank.

At the 60 km site basement surface again appears to be relatively flat, so the best option for water from the sediments is close to the location of the earlier well, 5335–2 or Moondrah Tank Bore. While the well could not be found, the most probable location is near the south end of Line 3, just north of the sandhills. There are three locations at which the TEM survey may indicate fracturing, listed above, and these would be equally favourable drilling sites.

At the100 km site the location of the previous well, P2A or 5336–19, is the most favourable site and has been found. Water here is shallow and in sufficient quantities according to the earlier results. Alternatively a site which appears similar has been located on the road, saving some 3 km of cartage if drilling proves the anticipated water supplies. Both of these supplies would be from the sediments. No potential fractured basement aquifers were located in this area.

REFERENCES

Dodds, A.R., 1992. Improvements in electrical (TEM) sounding inversion techniques. South Australia. *Quarterly Geological Notes*, 123:11-17.

Figures

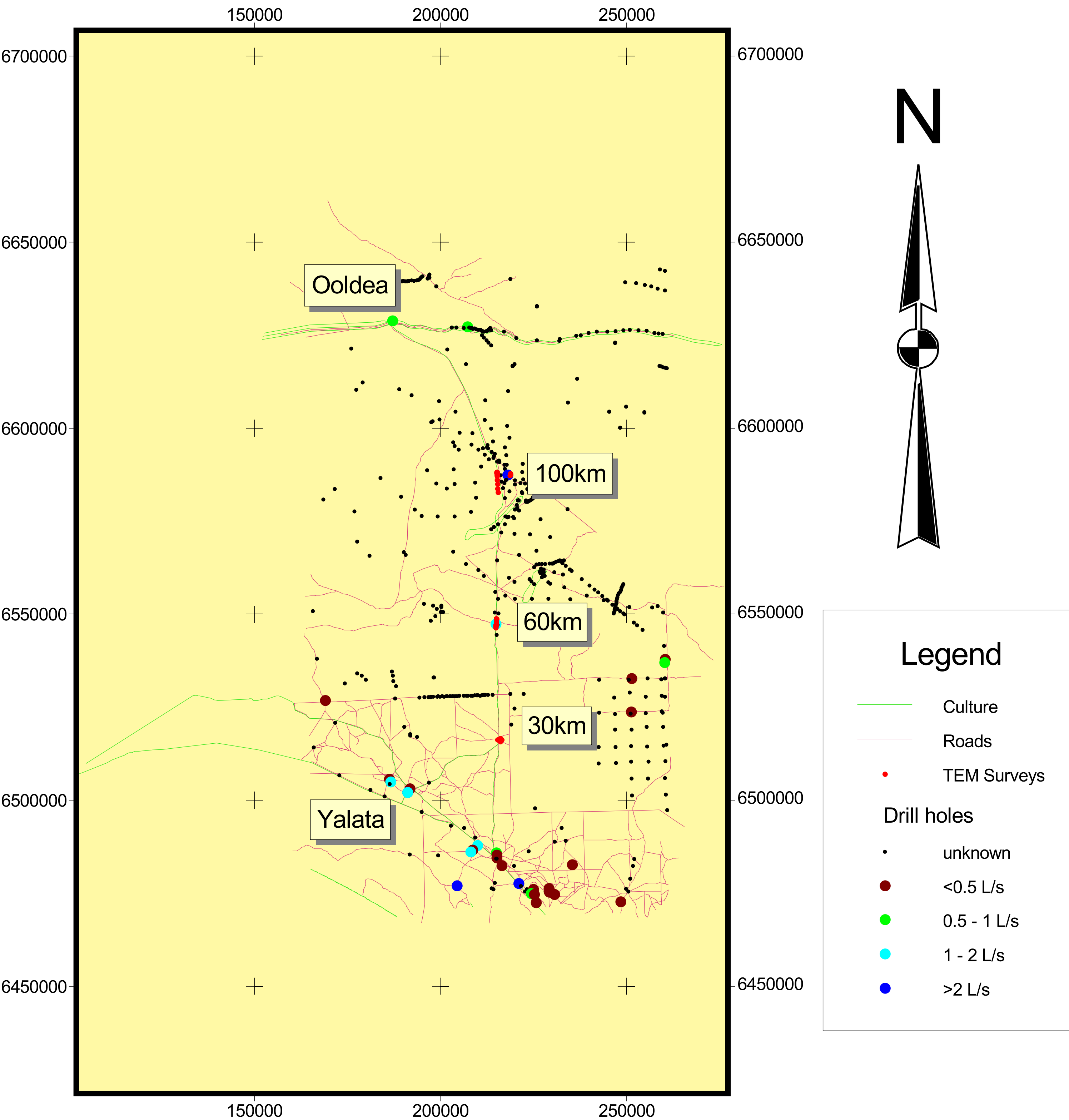
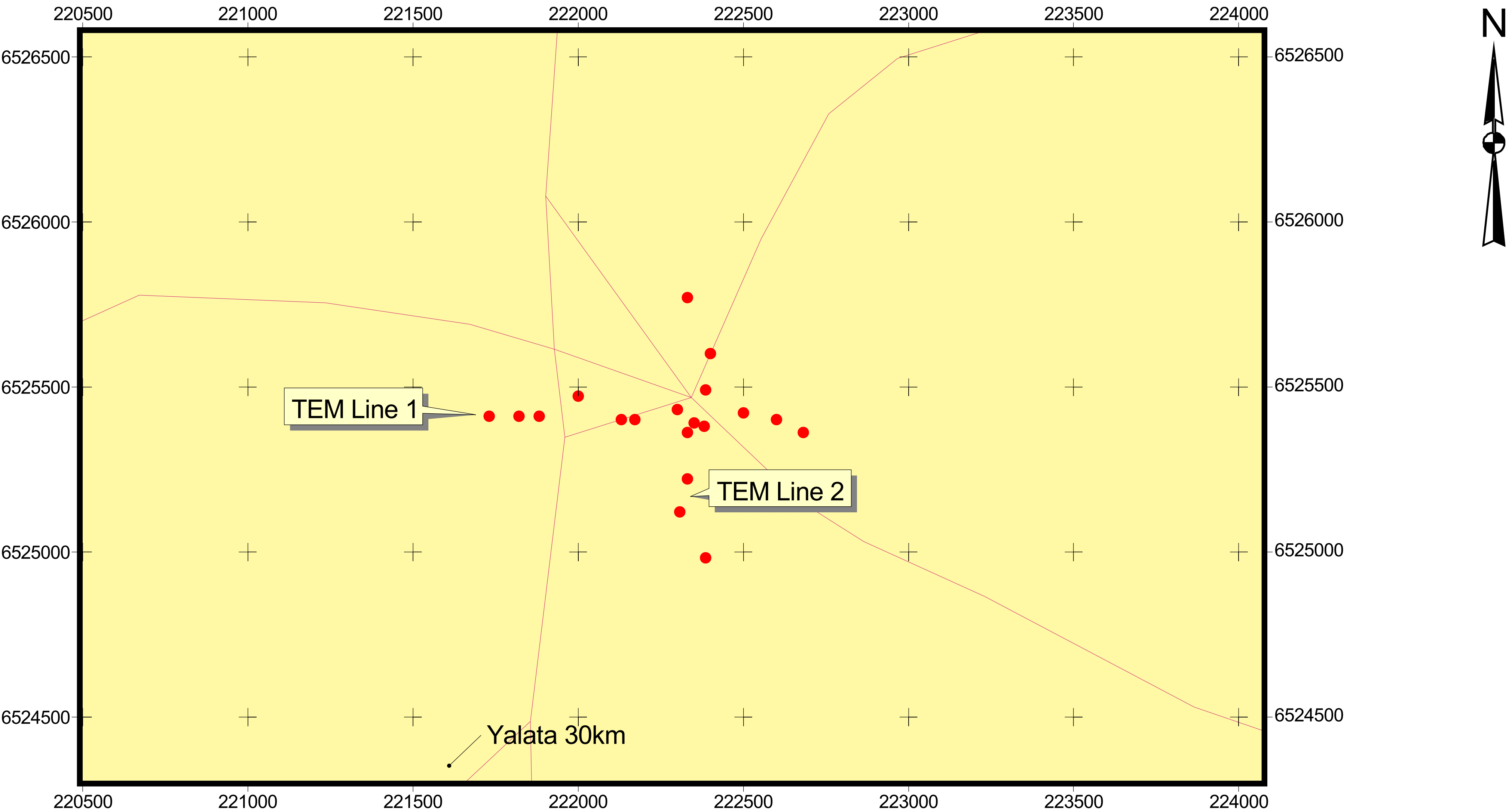


Figure 1.
PRIMARY INDUSTRIES AND RESOURCES SA
Yalata-Ooldea Road Water Search
TEM Surveys Locality Plan



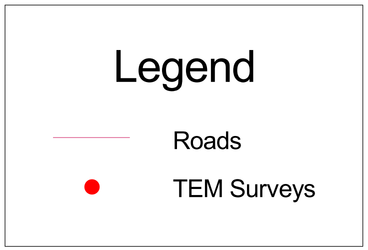


Figure 2
PRIMARY INDUSTRIES AND RESOURCES SA
Yalata-Ooldea Road Water Search
TEM Surveys 30km north of Yalata

Yalata-Ooldea Road Water Search

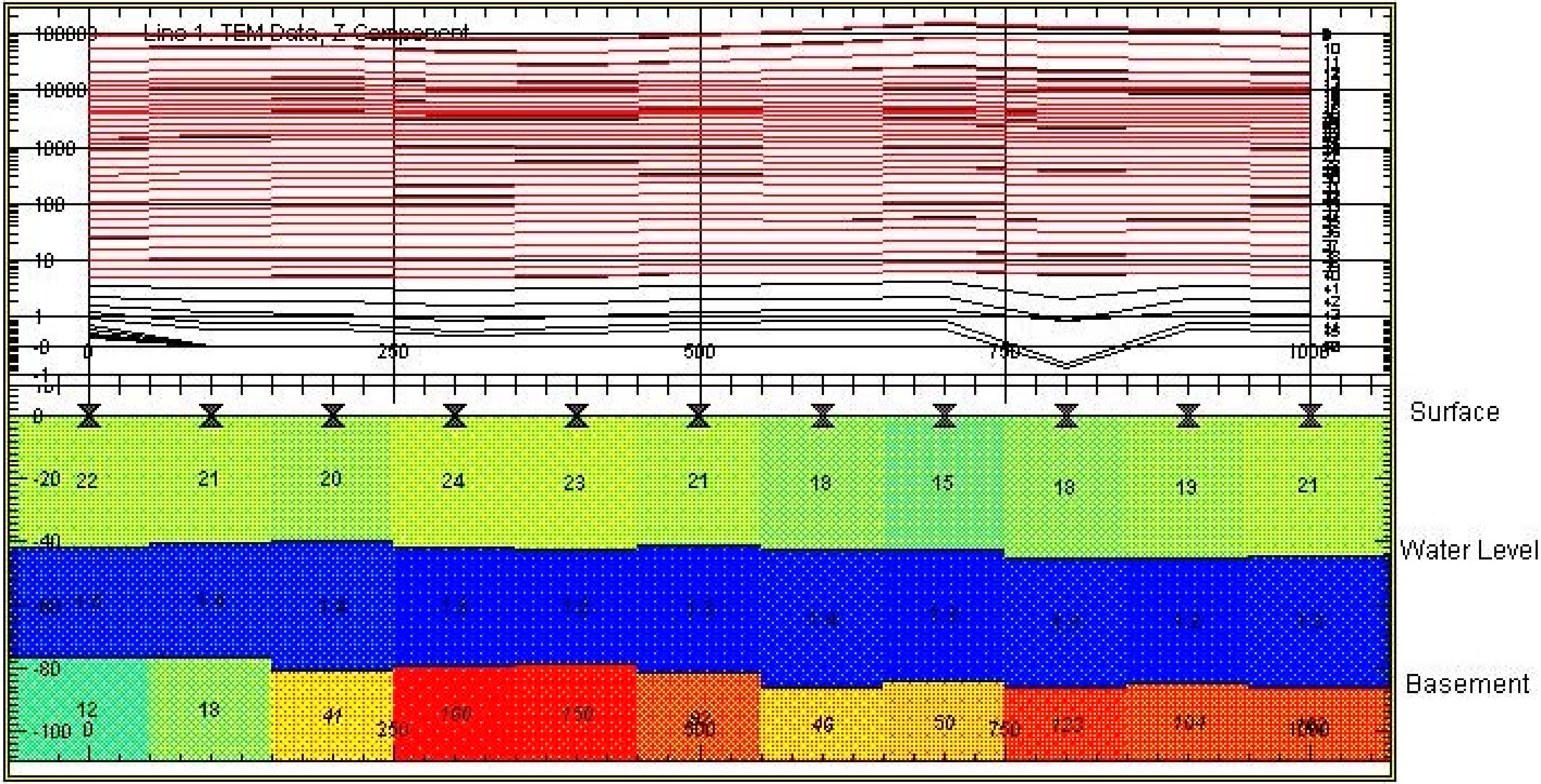


Figure 3. Resistivity Section of Line 1, from TEM Inversion

Yalata-Ooldea Road Water Search

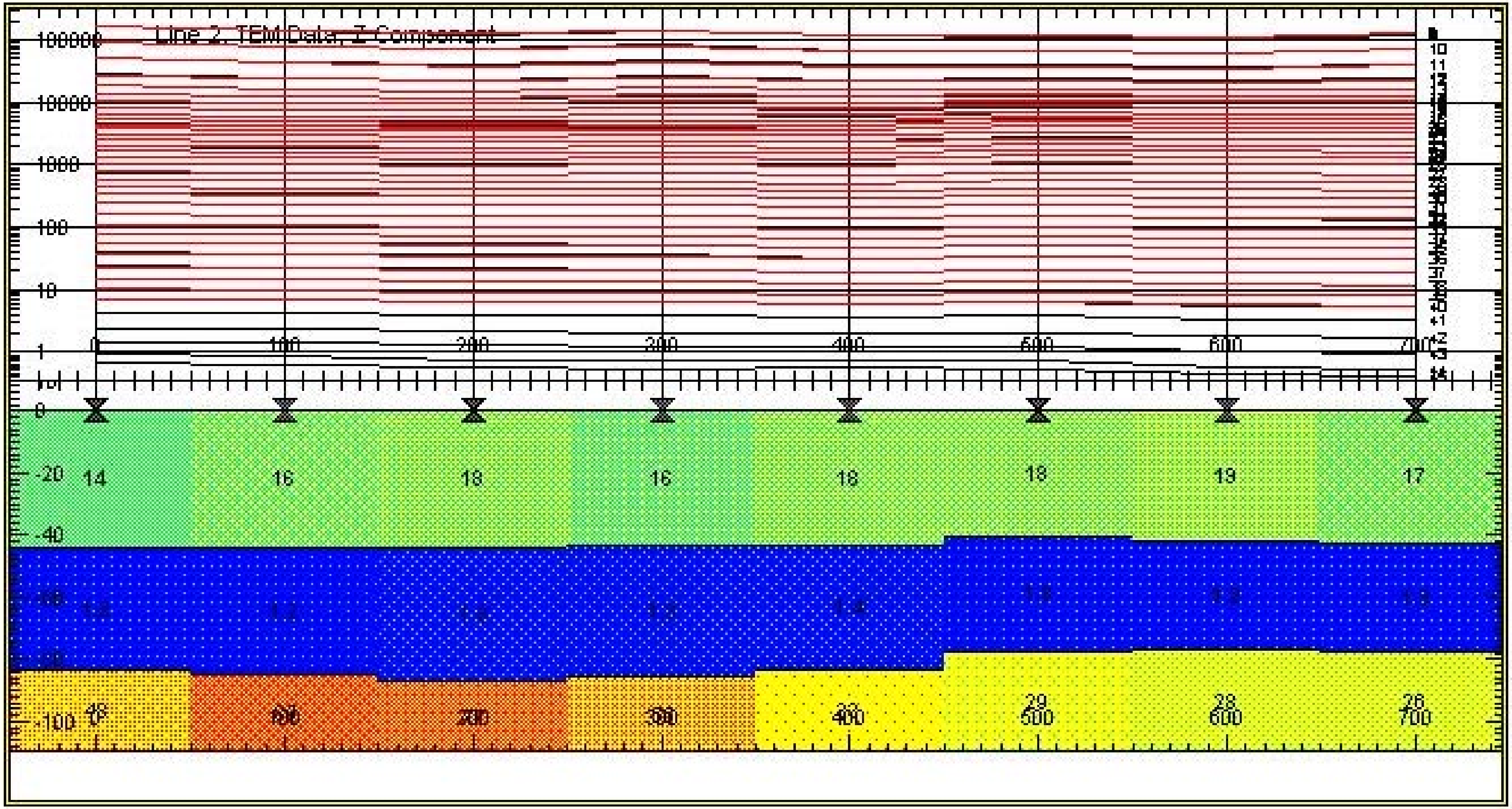


Figure 4. Resistivity Section of Line 2, from TEM Inversion

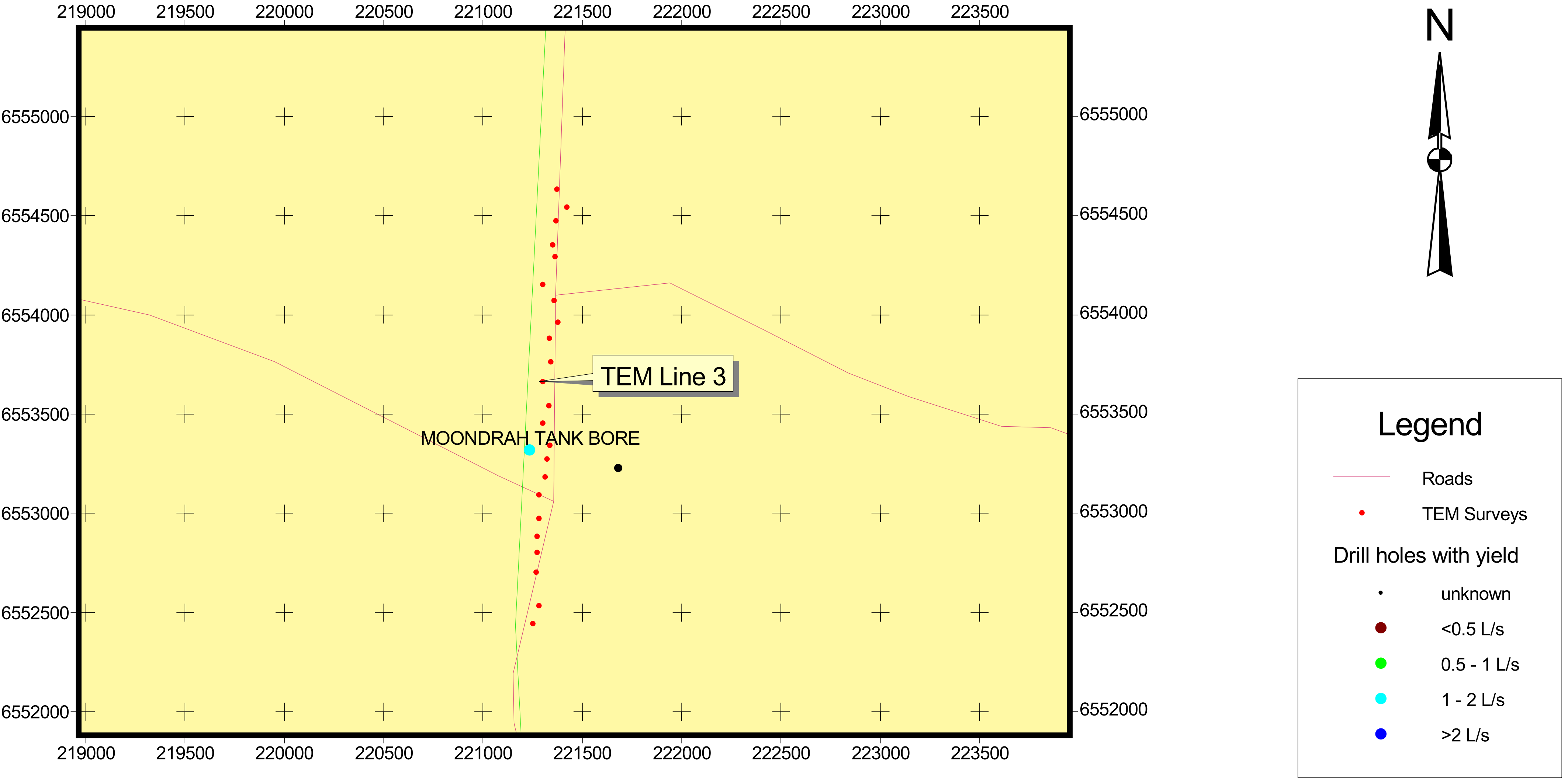


Figure 5
PRIMARY INDUSTRIES AND RESOURCES SA
Yalata-Ooldea Road Water Search
TEM Surveys 60km north of Yalata

Yalata-Ooldea Road Water Search

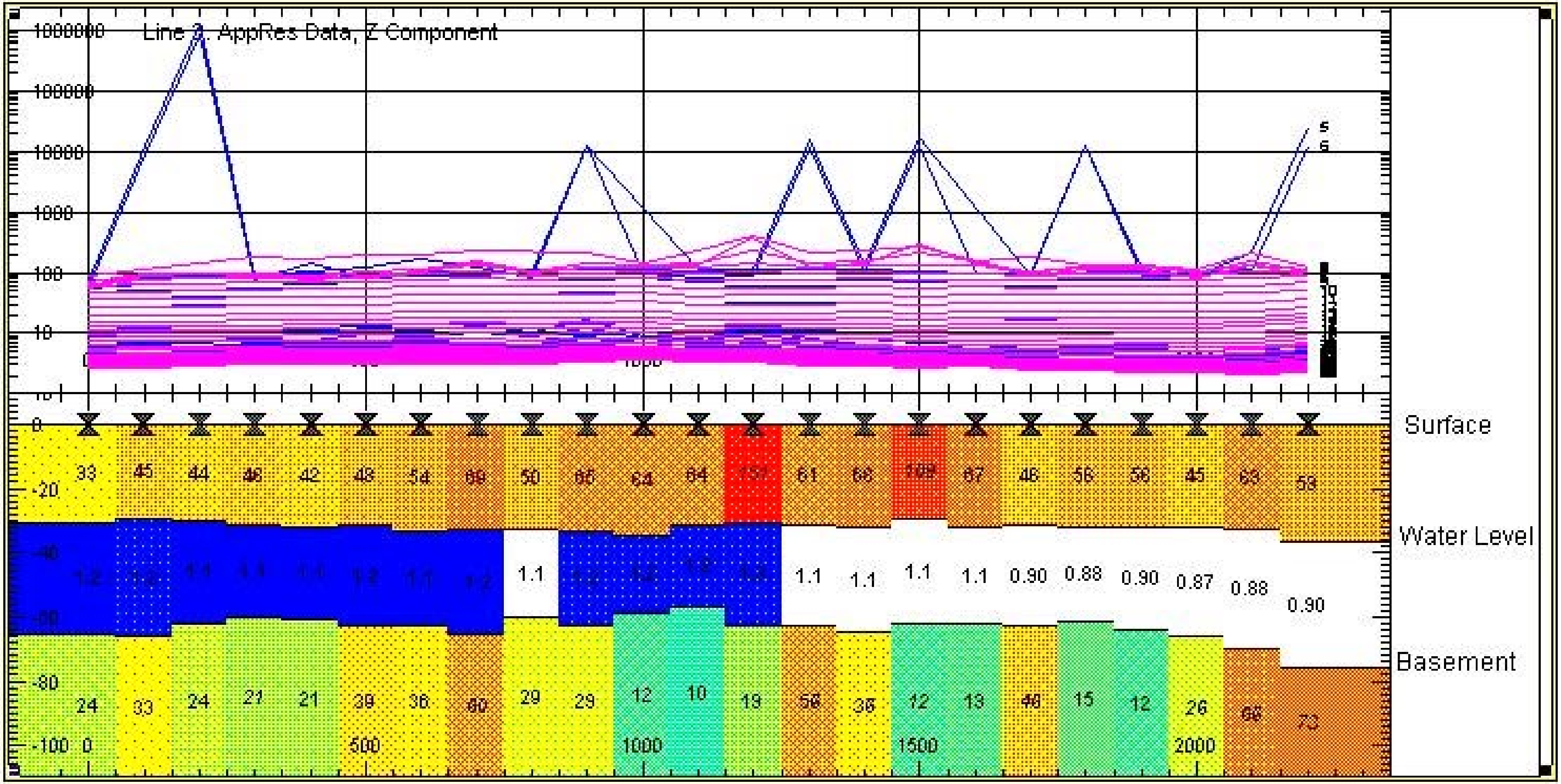


Figure 6. Resistivity Section of Line 3, from TEM Inversion

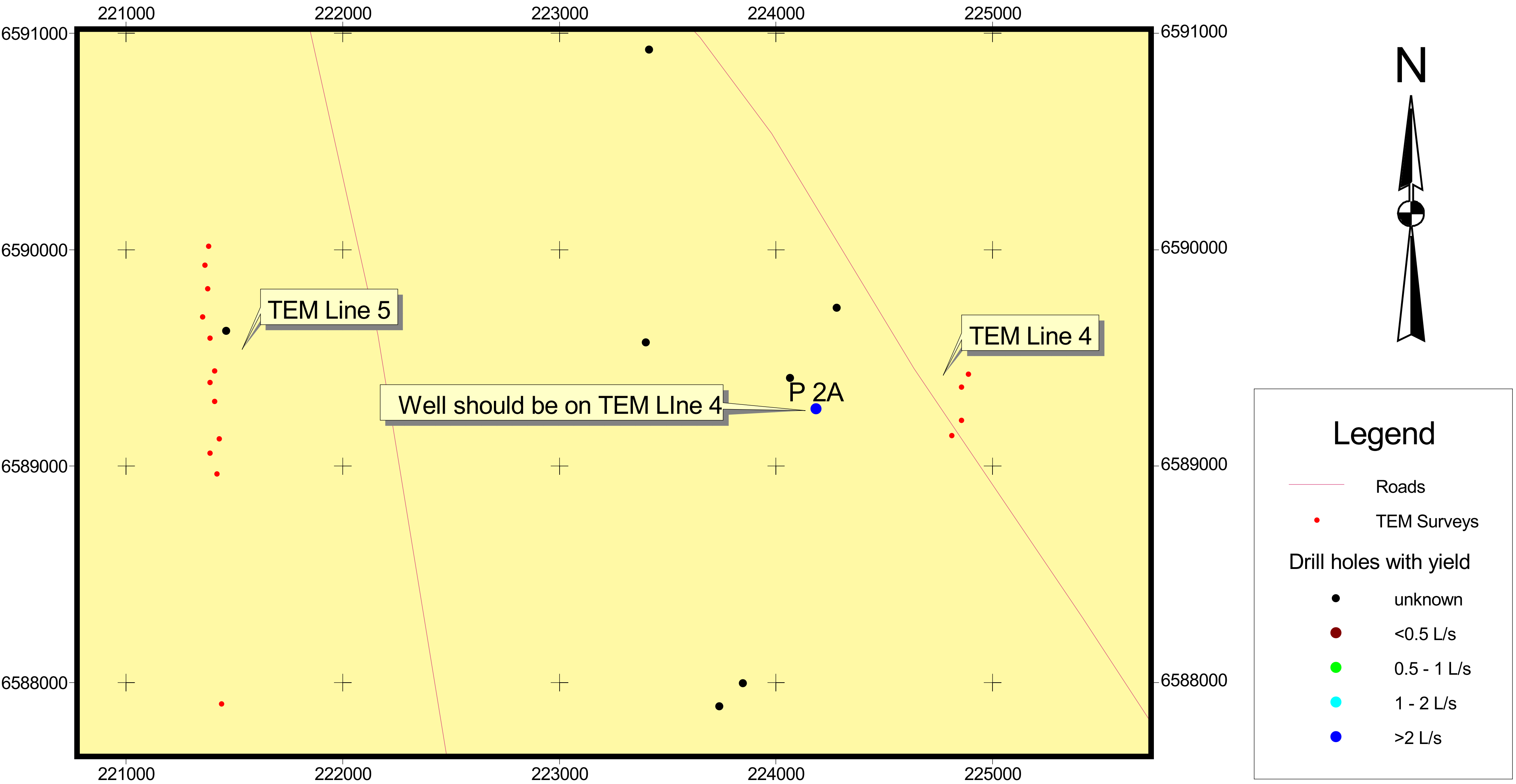


Figure 7
PRIMARY INDUSTRIES AND RESOURCES SA
Yalata-Ooldea Road Water Search
TEM Surveys 100km north of Yalata

Yalata-Ooldea Road Water Search

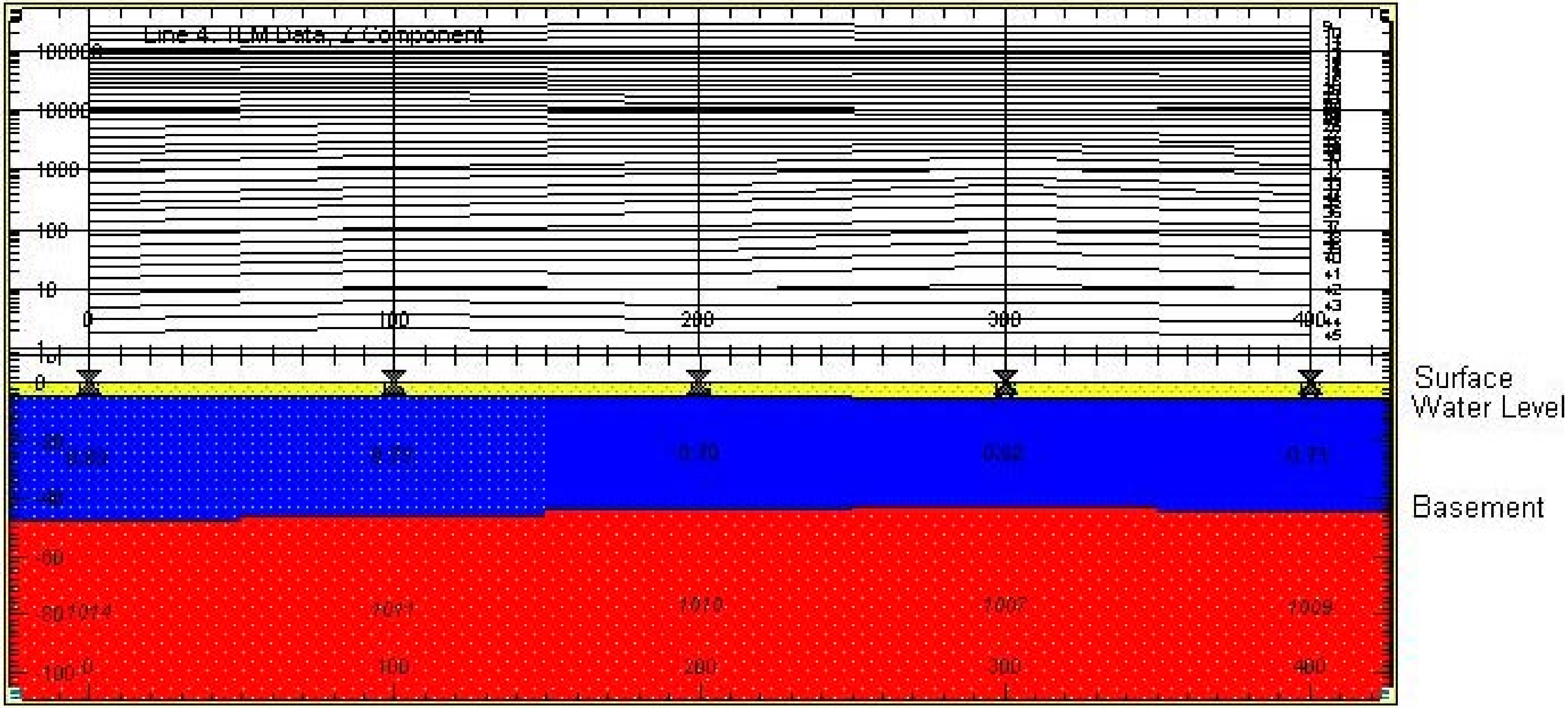


Figure 8. Resistivity Section of Line 4, from TEM Inversion

Yalata-Ooldea Road Water Search

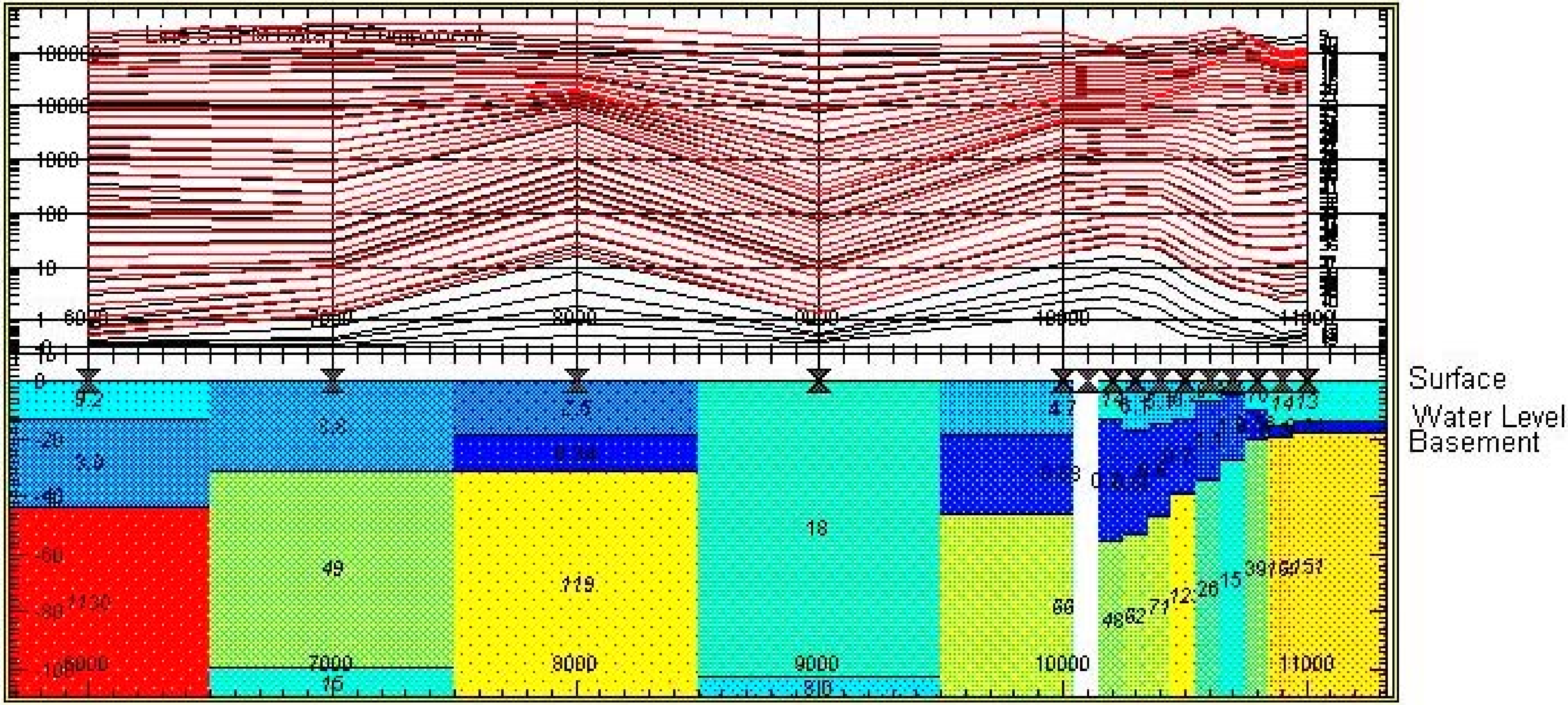


Figure 9. Resistivity Section of Line 5, from TEM Inversion

Appendix

Transient Electromagnetic (TEM) Surveys for groundwater.

INTRODUCTION

The TEM method measures the electrical resistivity of the ground. For groundwater surveys the main interest is a resistivity sounding, which assumes that the ground is laterally homogeneous, ie. that changes in resistivity only occur with depth. From such soundings can be interpreted the depth to crystalline basement and the nature of the sedimentary cover, factors which are basic to the search for groundwater and which are rarely evident at surface. For example, areas of deeper basement often act as collecting points for local recharge, while sandy layers are evidently better water producers than clay. Also, ground resistivity is a direct indicator for the presence of groundwater, since most ground is highly resistive without it, and for the quality of the water, since the resistivity of the water decreases as the salt content goes up.

Thus the electrical resistivity of the ground can be a useful tool for the direct and indirect delineation of groundwater. TEM is a cost-effective method for measuring that resistivity.

FINDING GROUNDWATER

Where do we start? The hydrogeologist is presented with the problem of finding water in an area which may be as large at a sheep station or as small as a back yard. He is told what water quality is needed fresh water for feeding to children or quite saline (stock water) suitable only for sheep in the outback. And he knows how much water supply is required perhaps enough for the operation of a mine or perhaps only enough to hand pump for a small camp water supply. All of these factors will affect how he looks for water, but the basic first step will always be to look at the geology of the area.

Geology controls where water could be stored in the ground. The first requirement is a porous rock in which water can move an aquifer. In a sedimentary environment such a rock might be a sandstone or limestone, where a whole layer might have these characteristics. In more massive rocks such as crystalline granites or metasedimentary shales, the porosity may depend on rock fractures where faulting has broken up the rock. The search for water starts with a geological study of the area looking for features such as these, determining which type of aquifer might be present. This study is usually done from geological maps and air photographs, but should involve some field work since nothing can substitute for personal observations.

Having decided what sort of aquifer should be sought, the next step is to find the aquifer itself. This may be a simple matter, as in the case of the Great Artesian Basin where the aquifer is continuous over vast areas. Other aquifers are more limited in extent, particularly fracture zones. These must be pinpointed as accurately as possible before the ultimate test, drilling a well, is attempted. Topography may help in picking locations where sedimentary layers may be thicker or may contain more water. Alternatively, geophysical methods may be used to map, indirectly, sedimentary layers or fracture zones. Such methods may also be used to search for groundwater directly. Finally, water dowsing or divining, an art which currently lacks satisfactory scientific explanation but appears to have had success in some hands, can be used to detect groundwater directly.

The combination of air photographs and airborne magnetics can be very useful, particularly when large areas are to be covered. Fracture zones frequently show as lineaments on one or both of these. Also, general geological and topographic information is often evident.

Ground resistivity often yields valuable information on groundwater. Generally the resistivity of the ground is largely determined by the quantity and quality of the water contained in it, so the measurement of this parameter is a good indicator. It is a technique that looks below the surface of the ground, adding a third dimension to the information available. However, clay, which is generally an aquitard, usually contains water and is highly conductive, while saline groundwater is much more conductive than fresh, so the use of ground resistivity is by no means definitive, but is one more tool to help in understanding the distribution of water and rock beneath the surface.

The final test in all water search is drilling a well. All the preceding activities lead up to this final test, without which no conclusive proof of the presence or absence of useable water can be claimed. Since drilling is an expensive and intrusive operation, every effort should be made to ensure that each well is located on the best site possible.

METHODS FOR MEASURING GROUND RESISTIVITY

Ground resistivity can be measured galvanically (VES) or inductively (TEM), the main difference being that the former involves electrical contact with the ground while the latter does not.

Vertical Electrical Soundings (VES) involve injecting electrical current into the ground through two current electrodes and measuring the potential drop between two other (potential) electrodes, the four electrodes usually being in a straight line. The depth penetration is a function of the separation of the electrodes. Usually a series of readings are taken at a range of electrode separations, from which the variation of ground resistivity with depth can be interpreted.

For TEM surveys the energising current is passed through a loop of wire, as described more fully below, and eddy currents are induced in the ground. The distribution of eddy currents is likewise detected inductively, with the depth penetration being a function of time. Thus one reading is sufficient for a full sounding.

VES	
Advantages	Disadvantages
• Simple principle • Simple equipment • Sensitive to resistive layers	• Ground contact required • Long spread of electrodes required for deep penetration • Many readings for one sounding
TEM	
Advantages	Disadvantages
• No ground contact required. • One reading for all depths • Sensitive to conductors • Fast • Simple to use • Equidimensional array • Spacial averaging	• Insensitive to resistors • Complex to invert • Expensive equipment

THE TEM SURVEY METHOD

A square loop of wire, usually 50 or 100 metres a side, is laid on the ground and a short pulse of current transmitted through it. On the abrupt termination of this pulse, eddy currents are induced in the ground. Initially these currents are located immediately below the transmitter loop, but they migrate out and down with time until they effectively vanish. The rate of migration depends on the ground resistivity, being faster in resistive ground and slower in more conductive ground.

The ground eddy currents generate a secondary electromagnetic field which is detected by the receiver loop, this being the same as the transmitter loop. This secondary field is measured at a series of delay times and since the response is dependant on the distance between the eddy currents and the receiver loop, the rate of decay indicates the resistivity of the ground through which the eddy currents are passing.

Analysis of this decaying response yields the ground resistivity as a function of depth.

In practice the response is too small to measure directly (low signal to noise ratio) and it is therefore stacked, under microprocessor control, by taking up to 1000 individual measurements and accumulating them. The signal is additive, while the noise largely cancels itself out.

DATA PROCESSING

The basic measurement is a voltage response, measured in microvolts/amp. This response voltage can be easily converted into an apparent resistivity, which is the resistivity which all the ground under the loop would have to have to yield that particular response voltage at that delay time. This gives a general idea of resistivity variations in the ground, but lacks details of depth and formation resistivity. To get these the voltages must be inverted, which is an involved process involving considerable computer resources. There are several software packages available for doing this; GRENDL, an inversion package devised by CSIRO is one of the better known and is incorporated in the EMVISION data processing package marketed by ENCOM in Sydney. The MESA software package GRENOCC is based partly on GRENDL, but has the advantages of permitting many layers and of requiring an initial model (Dodds, 1992). All packages yield the ground resistivity as a function of depth at each station. These figures are much more useful than the apparent resistivities but must be used with caution, as they are the result of an interpretation procedure which includes some assumptions, and may not be totally accurate. Usually, however, the main features of the inversion are correct, and any inaccuracies are restricted to the detail.

PRESENTATION OF RESULTS

The results are presented as contoured resistivity sections. The horizontal axis shows distance along the ground surface, while the vertical axis shows depth below ground or elevation, depending on whether surface elevations were available for the particular traverse. The contour fill and levels are selected to show the more important variations in resistivity, and are usually consistent for all sections in a set. Contours are spaced logarithmically as this normally shows variations in resistivity more effectively.

INTERPRETATION OF RESULTS

The resistivity sections described above show resistivity variations in the sub-surface, both laterally and with depth, to the extent that the inversions are correct. In most cases it is anticipated that the general pattern will be correct, although some of the detail may be inaccurate because nature is complex, and it is necessary to simplify the model to allow mathematical modelling.

The greatest problem in using the resistivity parameter for groundwater search lies in the ambiguity of indications. The ground resistivity is a function of water content and the salinity of the water. A decrease in resistivity can result from an increase in the water content of the ground or from an increase in the salinity of the contained water, two possibilities which have opposite connotations so far as a desirable water source is concerned. Further, water tends to be held in a clay and to be more saline, while it moves through an open textured sand with ease and tends to be fresher. Thus the latter, which would be the better water source, will be more resistive. It is evident that there is no simple interpretation of the nature of “drill the conductors”. Each situation must be interpreted in the light of local geology, and even so there is every possibility that a resistivity feature, whether of high or low resistivity, will turn out to be other than expected on drilling.

As a general guide, the causes of resistors and conductors may be:

Resistors:
- dry material above the water table. which may still be porous
- material of very low porosity, such as granite or other crystalline basement above or below the water table
- porous material below the water table, but containing water of lower salinity than elsewhere.

Conductors:
- material containing more water than the surrounds, such as fracture zones in basement
- material containing more saline water than the surrounds
- clays, in which water does not move readily
- metallic or graphitic conductors, which are not usually encountered in groundwater situations.