

Indulkana town water supply drilling and discharge testing, 1998

REPORT BOOK 2000/00006

by

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**PRIMARY INDUSTRIES AND RESOURCES
SOUTH AUSTRALIA**

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INDULKANA TOWN WATER SUPPLY DRILLING AND DISCHARGE TESTING, 1998

Clarke, D.K.

Aerial photography, satellite imagery, geological maps and on-ground geological and geophysical (transient electromagnetic) investigations were used to select well sites for Indulkana township in the far north of South Australia in early 1998.

In April and June, 1998, seventeen wells were drilled within a thirty-kilometre radius of Indulkana. Only two of the wells produced barely acceptable yields of potable water, while several others produced either very small yields of acceptable quality or larger yields of unacceptably saline water.

Three wells having moderate yields (0.4, 1.4 and 1.5 L/sec. sustainable for one year) of water of sufficient quality (1360 to 1920 mg/L) to provide feed water for a desalination unit were developed for production. These wells were on the Indulkana Range and had the advantage of being within a very few kilometres of existing pipelines.

INTRODUCTION

A reliable supply of potable quality water (<1000 mg/L total salts), within a radius of about 50 km was required for the township of Indulkana in South Australia's far northwest, (see Figure 1).

Office studies and two field trips used aerial photography, satellite imagery, geological maps and on-ground geological and geophysical (transient electromagnetic) investigations to select a total of seventeen well sites in five areas. Subsequent drilling resulted in no wells having both yields and water qualities as high as required.

The Mt John, Jimmy's Well, Rodda Well, and Sweet Water Well areas all produced disappointing results. Three of the four wells drilled in the Indulkana Range produced yields and water qualities typical of, or slightly better than, those achieved by previous wells, (see Figure 2).

Increasing the volume of the Indulkana water supply will be possible using the new Indulkana Range wells. The only option for substantially improving water quality is desalination.

AREAS CONSIDERED

In the first place, salinities of all recorded wells within a radius of 50 to 100 km were viewed and the potential of any areas showing good quality water was considered.

Areas close to the larger watercourses were considered, because of the obvious availability of periodic recharge. Unfortunately, higher salinities can be associated with the longer water courses in the Indulkana area (eg. earlier drilling has shown that Indulkana Creek is associated with highly saline water, and this project indicated saline water associated with Ammaroodinna Creek in the Mullawapinna dam area). As a general rule, groundwater quality is better the closer one goes to the recharge area.

After office studies the areas tabled below seemed to warrant further attention.

Area name	Why considered	Comments
Jimmy's Well	Known good quality water in one well, moderate distance from Indulkana.	The area was drilled, see below.
West Indulkana Range	Moderate distance from Indulkana, should have similar quality water to the current well field in the Eastern Indulkana Range. This area has never been drilled.	The area was found to be inaccessible, except on foot. Building a road into the area was not felt to be justified.
East Indulkana Range	The current Indulkana well field was in this area.	Areas accessible before the current program were fully exploited. Salinities were poor, yields limited.
'Top of' Indulkana Range	Close to Indulkana, might have somewhat better quality water than current well field.	Accessibility was felt to be impractical until an old track was noticed from an exploratory flight over the area. The area was drilled, see below.
Rodda Well	Good quality water (no yield recorded), moderate distance from Indulkana.	The area was drilled, see below.
Mullawapinna Dam	There is a flood-out plain on Ammaroodinna Creek in the area and this could lead to increased recharge.	Mullawapinna Well (which was not recorded on SA_Geodata) was sampled and found to contain saline water (18 800 ECU, 11 100 mg/L).
Mt John Range	While this area was about 20 km from Indulkana, known salinities were moderate and the rock-type was favourable. There had been very little drilling in this area before the current program.	The area was drilled, see below.
Sweet Water Bore area	A good yield of fair quality water had been obtained here, and used for upgrading the Stuart Highway.	The area was drilled, see below.
Everard Ranges	Recorded salinities were good, yields fair, some fluoride levels were high	The area was too far from Indulkana.

SPECIFIC AREAS, WELL SITING AND DRILLING RESULTS

Of the areas tabled above the five selected for further investigation are listed below in the order drilled.

JIMMY'S WELL AREA

Jimmy's Well (5543–16) is in a small northeast to southwest trending valley on the southwestern side of the Indulkana Range. The PIRSA water-well database (SA_Geodata) indicated that the salinity of water from Jimmy's Well was 617 mg/L. No yield was recorded, although local knowledge indicated that it was very small. A sample was bailed from the well on 27/03/98 and tested at 1182 ECU (approximately 650 mg/L).

A second well, close to Jimmy's Well and previously not recorded on SA_Geodata (easting 312 990, northing 7 008 520), was found during the investigations. Local knowledge (pers. com. Hughie Cullinand) indicated that while the water quality from this well was good, the yield was very small.

No more than scattered, mainly gneiss, outcrop occurs in the floor of the valley while Jimmy's well was dug through dolerite. The hills on each side of the valley showed sandstones (Burra Group; some sandstones bordered on quartzite) and siltstones in outcrop (See Figure 3 and the well logs in Appendix B).

Four wells were drilled, three based partly on geophysical evidence and the fourth, I98J4, based purely on geology and topography. The best quality water found was 1550 mg/L and the well that produced this sample had a negligible yield. The only new well with a useful yield (1.5 L/sec.) had a salinity of 3700 mg/L.

All wells were capped with surface casing left in place.

RODDA BORE AREA

Rodda Bore (5543–17) is south of the Indulkana Range, (see Figure 4). SA_Geodata indicated that the salinity of water from this well was 727 mg/L. A sample pumped from the well during the first field trip of this investigation tested at 1815 ECU (approximately 1000 mg/L).

There is scattered outcrop through this area. I98R1 was drilled on a low ridge of outcropping dolomite (or dolomitic siltstone), this being regarded as a favourable environment. Only a trace of water was seen.

There was no outcrop in the near vicinity of the other two wells, which were drilled on geophysical evidence. One well (I98R3) obtained a yield of 0.9 L/sec. of water at 1718 ECU (app. 950 mg/L), which is marginal for both salinity and yield. The other failed to obtain a useful quality or quantity of water.

All three wells were capped, with surface casing left in place.

This area should not necessarily be ruled out for further investigation. However it is felt that the well failure rate will be high in any possible future drilling because no confident technique for site selection has been discovered.

INDULKANA RANGE

The best yields of reasonable quality water during this investigation were obtained on top of the Indulkana Range. Of the four wells drilled, three obtained fair yields (from 0.8 to 2.0 L/sec.), and in these, salinities ranged from 1360 to 1920 mg/L, (see Figure 5).

The wells of this investigation were drilled along the old track that was built to service the fence running southwest across the range. Blue Hills Sandstone outcrops commonly along the fence line. Abundant current bedding makes dip angles very difficult to estimate. Going southwest the well collars are 39 m (I98IR1), 55 m (I98IR2), and 51 m (I98IR3) above Canyon spring. Reduced standing water levels (RSWLs) in these wells were very close to the water level in Canyon spring. The RSWL could not be measured in the last well (I98IR4).

The northern and southern sides of the Indulkana Range indicate a synclinal structure. However, the four wells drilled from the 'top' of the range showed that while water quality improves slightly toward the centre of the syncline, yield decreases markedly because the wells encountered the 'Indulkana Shale' earlier. It seems, therefore, that there is an anticline in the centre of the syncline and wells drilled here enter the Indulkana Shale

before penetrating sufficient sandstone to obtain useful yields.

MT JOHN AREA

Policeman's Well (5543-14) yielded water of 1255 mg/L according to SA_Geodata (no figure was available for yield), Sailor's Well, further to the south (5543-5) was recorded as having water of 1800 mg/L. The aquifer supplying Sailor's Well is probably recharged by ephemeral flows in Ammaroodinna Creek, and it was felt likely that Policeman's Well gave a truer indication of the general salinity in the Mt John Range.

The Mt John Range, like the Indulkana Range, is dominated by outcrops of the Mt Chandler Sandstone (the outer hills of both ranges) and the Blue Hills Sandstone. The best well drilled in the Mt John area during this exercise was sited in a fracture zone in the Mt Chandler Sandstone close to Policeman's Well. The three wells drilled into the Blue Hills Sandstone, located on the basis of geophysical data, were disappointing in their salinities and especially their yields, (see Figure 6).

The poor yield is mainly attributable to the wells having entered the 'Indulkana Shale' before penetrating sufficient thickness of the Blue Hills Sandstone to obtain useful yields. Well logs indicated that the Mt John Range probably has the same 'anticline within a syncline' structure as the Indulkana Range.

All four wells were capped, with surface casing left in place.

SWEET WATER BORE AREA

Sweet Water Bore (5543-63) was drilled in 1984 to provide water for road construction. It yielded 5 L/sec. of water with a salinity of 1100 mg/L.

No other wells drilled within ten or more kilometres of Sweet Water Bore have achieved comparable yields. The two wells of this investigation (one drilled 500 m north and the other 500 m south of Sweet Water Bore) both produced very poor yields, although the more northerly bore produced good quality water (1380 ECU, app. 760 mg/L).

It seems that Sweet Water Bore happened to intersect a well interconnected set of fractures and

that it is unlikely that any other well will produce a similar yield without many trial-and-error wells being drilled. The geophysical method used during this project failed to show any differences in the subsurface in this area. (A later trial with another geophysical method, electrokinesis, also produced no useful results.)

GENERAL HYDROGEOLOGY - COMMENTS

BLUE HILLS SANDSTONE, INDULKANA SHALE, MT CHANDLER SANDSTONE

In both the Mt John and Indulkana Ranges Blue Hills Sandstone overlies the unfortunately named Indulkana Shale which overlies the Mt Chandler Sandstone. In both ranges several holes drilled in this investigation went through the Blue Hills Sandstone into the Indulkana Shale. The Indulkana Shale, as encountered in these wells, is better described as a weakly indurated sandy silt than as a shale.

The Blue Hills Sandstone is typically palely coloured (eg. pinkish gray 7.5YR 7/2, pink 5YR 7/4, light gray 10YR 7/1 {colours according to the Munsell soil colour charts}), fine grained (medium grained in places), silty, and moderately indurated. The Indulkana Shale is more strongly coloured, more weakly indurated, and contains a larger proportion of finer grains (in colour it is typically weak red 7.5R 4/2, 10R 4/4). The Mt Chandler Sandstone is very similar to the Blue Hills Sandstone, except it is a little more strongly indurated.

Although the differences between these three formations are far from clear-cut, it appears that the Indulkana Shale acts as an aquitard. Finding useful yields would therefore be facilitated if geophysics could be used to discriminate between the two Sandstones and the 'Shale' at depth and to indicate where greater thicknesses of Blue Hill Sandstone can be found. In hindsight this appears possible, since the TEM results for Line 21 (Figure A9, Appendix A) clearly show a shallower conductor under well I98IR4 than under I98IR2 or I98IR3.

FUTURE WORK

If required, further wells with moderate yields could be drilled, either in the vicinity of the wells drilled during this investigation, or toward the southern side of the Indulkana Range. The latter option would require significant further track construction. The wells should be sited, if possible, where there is reason to believe that the Blue Hills Sandstone is deepest; and they should not be within 200 m of existing production wells to avoid competing for the available water.

SUMMARY AND RECOMMENDATIONS

The investigation of areas around Indulkana for water supplies resulted in sufficient resources of brackish water being located in the Indulkana Ranges. Although potable water was being sought, the discovery of remediable water close to the community represents partial success.

The search for water in the other three selected areas was less successful.

The geology of the Mt John Range proved less favourable to the storage and recovery of groundwater than had been anticipated, the thickness of Blue Hills Sandstone being less than expected and Indulkana Shale being more widespread. Further search in this area will require a re-evaluation of the geology to develop new models.

The Rodda Bore area proved to have resources of good quality water, both in the original Rodda 1 Well and in I98R3, but this is in insufficient quantity to justify the infrastructure needed for its use at Indulkana. While it seems probable that there are more resources in the area, the discovery of them needs more effective techniques than were available for this program. This is discussed further below.

Drilling at Jimmy's Well was disappointing, but the potential for good quality water in fractures in the granite and gneiss underlying the area still exists. More effective techniques are required to locate such resources. There is no indication of saline groundwater in these rocks, unlike the metasediments on either side of the valley.

The geophysical method used here, TEM, proved technically effective at Indulkana Range and Mt John, but did not contribute much to the search for water because of the shielding effect of clays. It might be indirectly effective in future by assisting in mapping areas of thicker Blue Hills Sandstone. The method was less effective still in the areas with maghemite present – Rodda Bore and Jimmy’s Well - for reasons that are discussed in Appendix A. New generations of TEM equipment, currently available, may cope with the problems of these and similar areas better, or other geophysical techniques could be considered. Any reliance on ground resistivity contrasts for such exploration is made questionable by the high resistivity of the fresh water being sought, so that a direct water detector, such as Nuclear Magnetic Resonance (NMR) might be more effective. Such techniques are not readily available in Australia, however, and the cost of importing them on a trial basis might preclude their use.

Figures

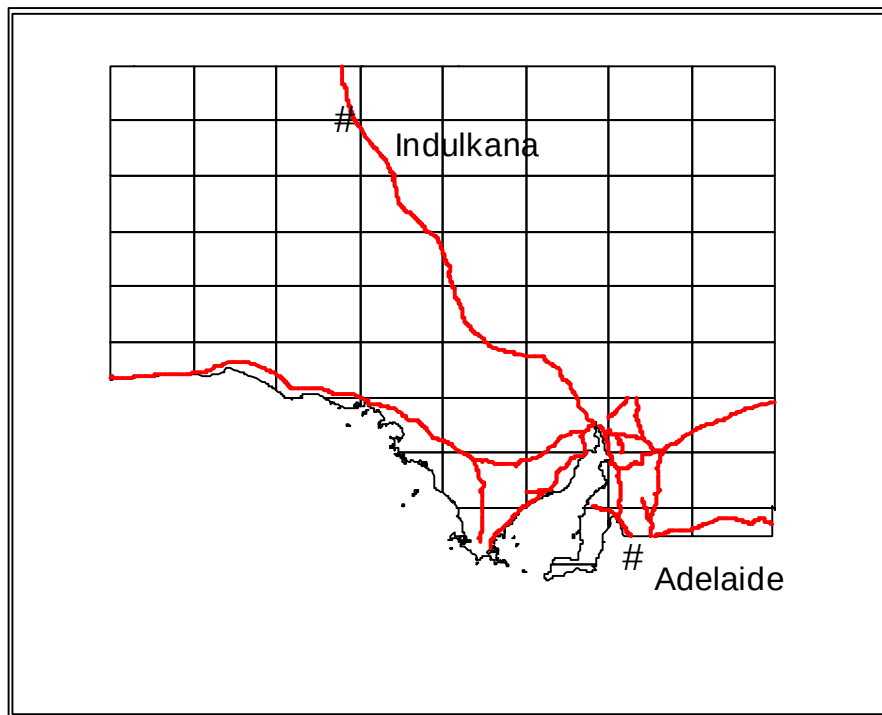


Figure 1 Location of Indulkana within South Australia

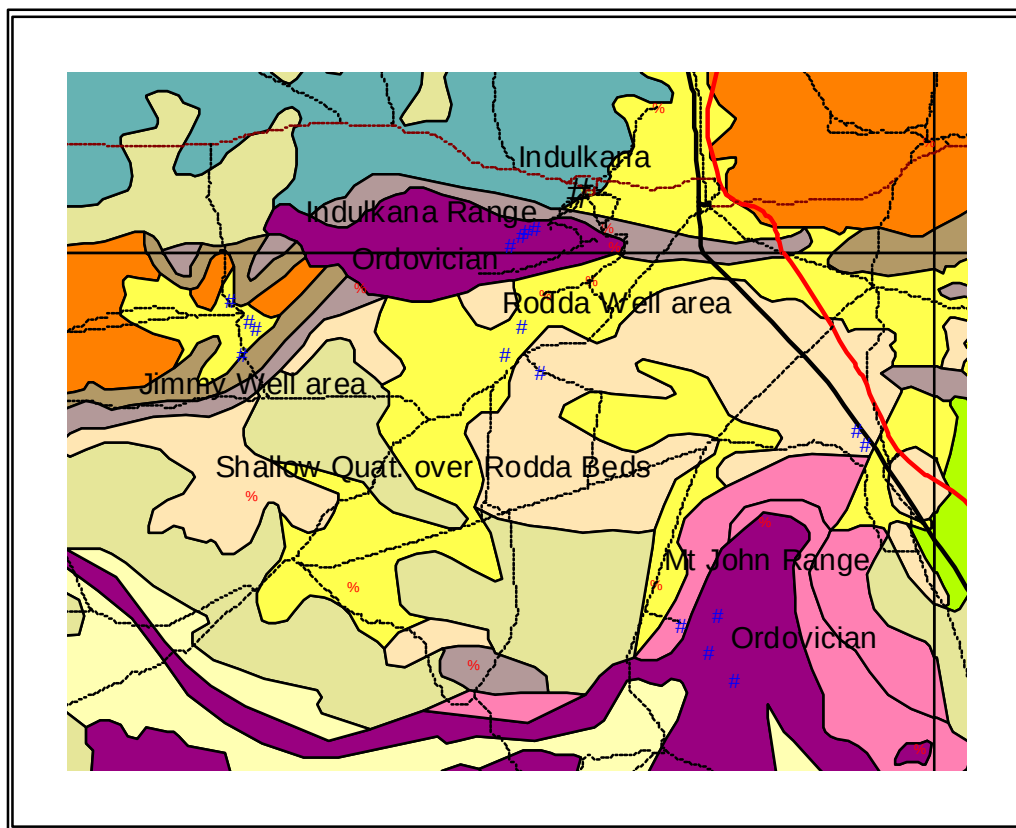


Figure 2 Location of the main exploration areas

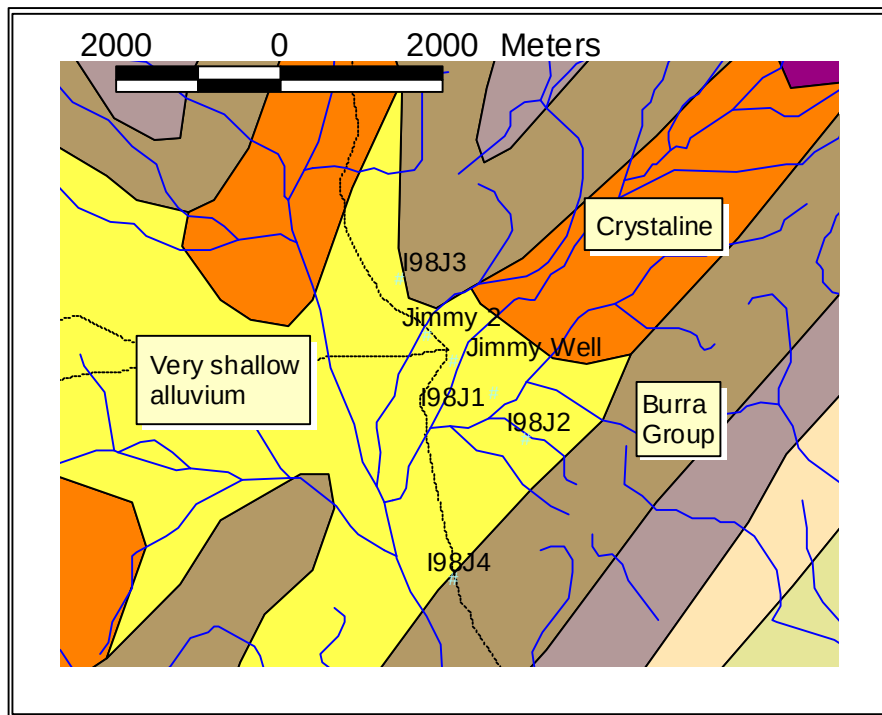


Figure 3 The Jimmy Well area

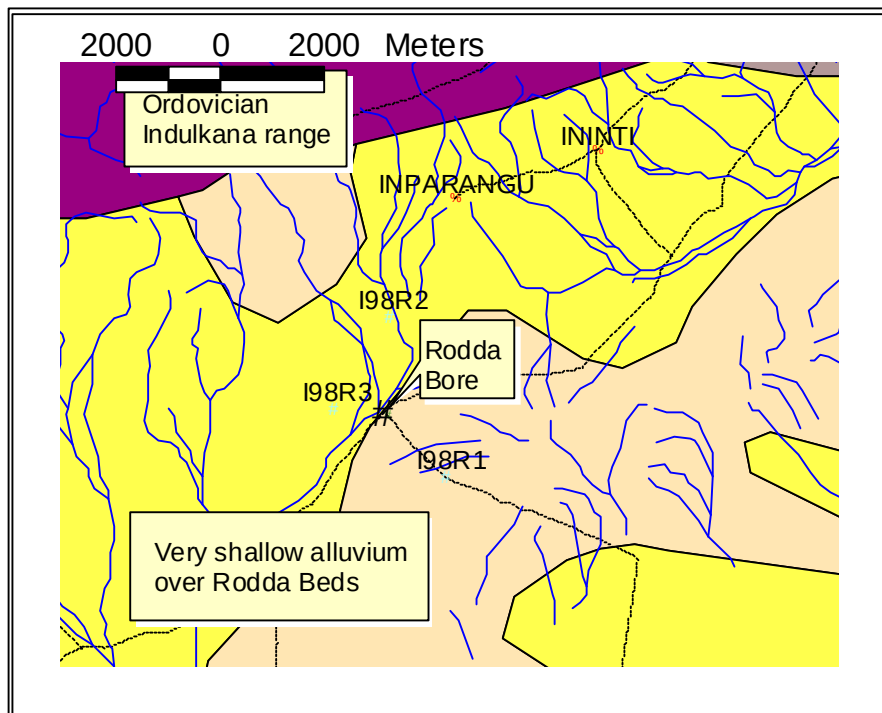


Figure 4 The Rodda Bore area

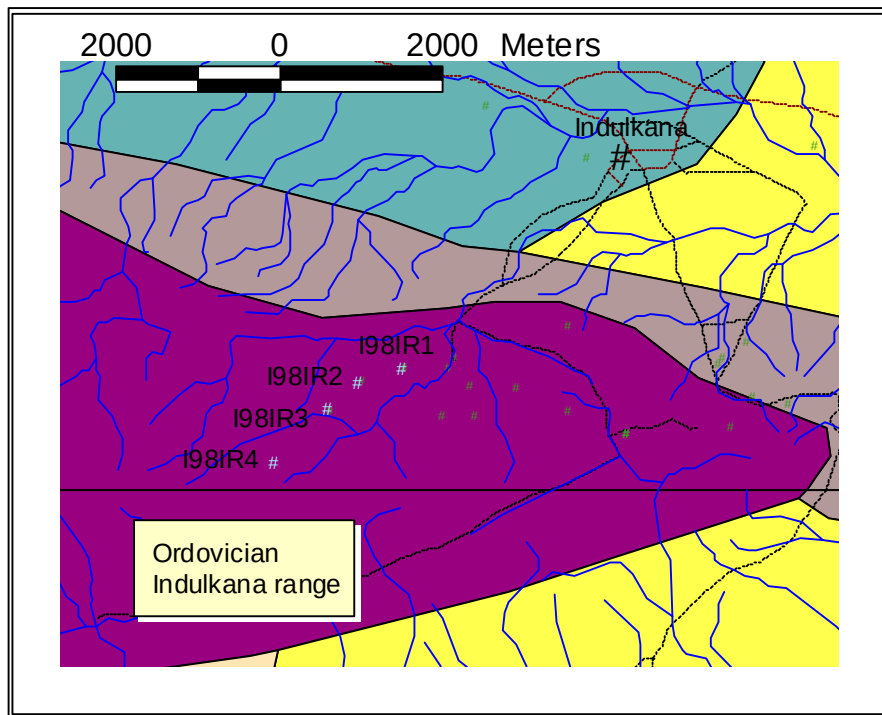


Figure 5 The Indulkana Range area

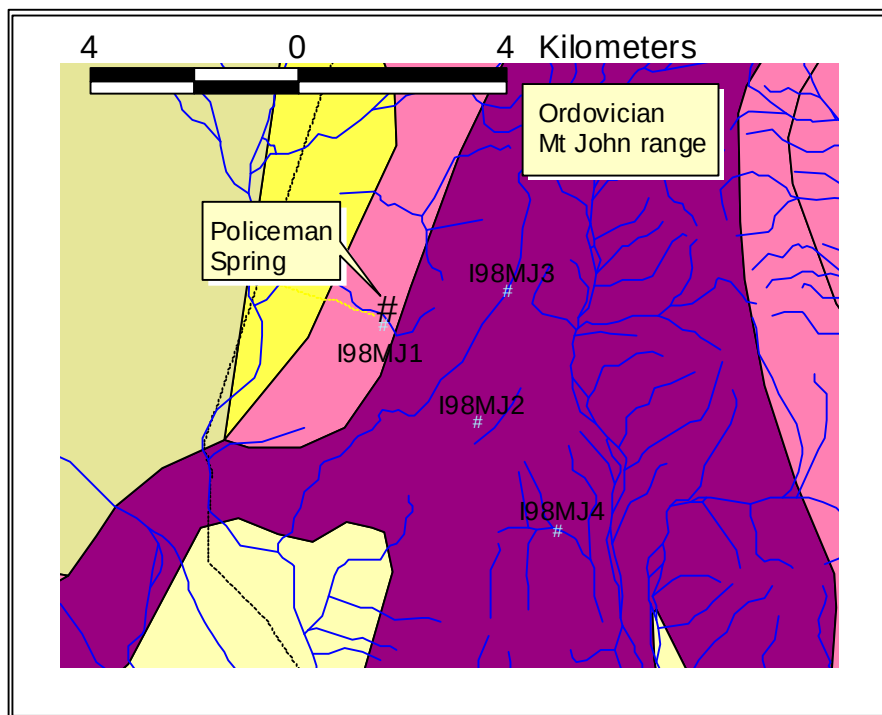


Figure 6 The Mt John area

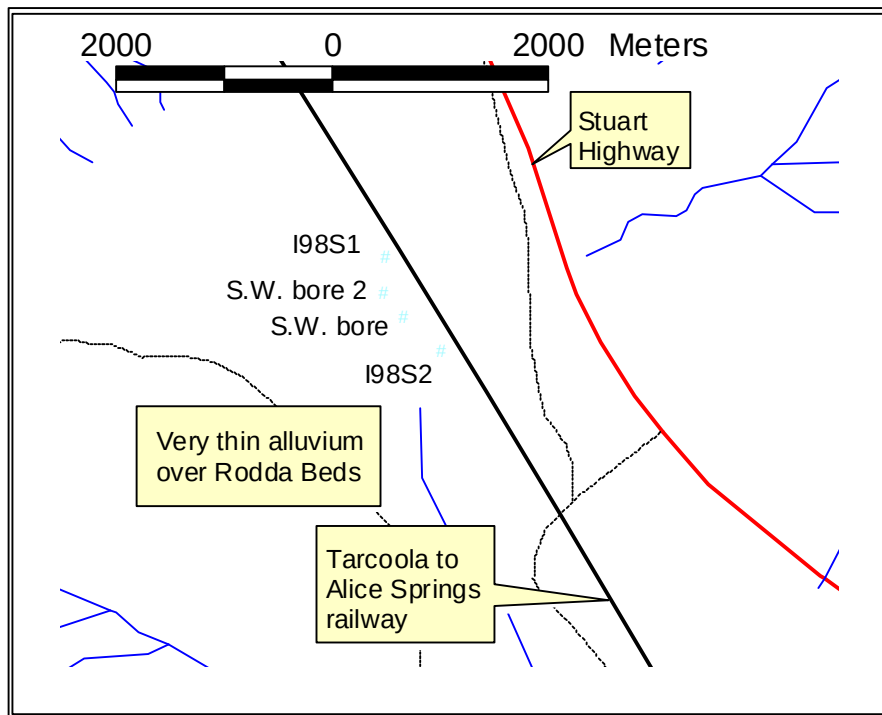


Figure 7 Sweet Water Bore area

Appendix A

GEOPHYSICAL SURVEYS

A.R. DODDS

INTRODUCTION

Transient Electromagnetic (TEM) surveys were carried out in the Indulkana area in 1997 and 1998. Surveys done at various locations in the AP lands in 1996 (Dodds, 1996) showed that conditions are sometimes complicated by the presence of maghemite in the near surface detrital material. At that time the combination of maghemite and high resistivities made the use of TEM in such areas impracticable. However, developments in instrumentation have overcome some of these problems such that TEM surveys, although still more difficult to use than in more friendly areas, are now feasible in areas where such conditions occur.

THE TEM SURVEY METHOD

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 when dry, and for the quality of the water, since the resistivity of the water varies inversely as the salt content.

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.

TEM THEORY

A square transmitter loop of wire 50–200 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 that is detected by a receiver 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.

SURVEY SPECIFICATIONS

For this survey a 50 m square transmitter loop was used, giving a depth penetration of about 100 m. In some areas, such as the Indulkana Range and the Mt John Range, the same loop could be used as a receiver, there being no maghemite present. In other areas, such as Rodda Bore, maghemite was present in the soil and it was necessary to use a multi-turn 3 m diameter hexagonal loop as receiver, placed at the centre of the transmitter loop. Use of the High-Resolution (Hi-Res) delay time windows ensured that adequate data was recorded to define resistivity variations at shallow depths.

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 that 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 that 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.

In this case much of the data was unsuitable for inversion because of weak signals and high resistivity. Such data indicates a general absence of groundwater, and is therefore still indicative in a negative sense.

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 the depth below the surface. The contour fill and levels are selected to accentuate the more important variations in resistivity. Contours are spaced logarithmically as this normally shows variations in resistivity more effectively.

For those lines where data were unsuitable for inversion the data are presented as apparent resistivity pseudo-sections, with channel numbers replacing depth as the vertical axis. The vertical axis is, therefore, still representative of depth in a qualitative sense.

MATCHING GEOPHYSICS TO GEOLOGY

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 clay and to be more saline, while it moves through open textured sand with ease and tends to be fresher. Thus the latter scenario, 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 was expected prior to 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.

DISCUSSION OF RESULTS

TEM traverses were done in 5 areas within 20 km or so of Indulkana; Indulkana Range, Jimmy's Well, Rodda Bore, Mt John Range and Sweet Water Bore. Readings taken in March 1998 were used to guide the drilling of wells the following April, after which additional surveys were done in

June 1998 to assist selection of further drilling targets for that month.

RODDA BORE

This area includes all of the area south of the Indulkana Range and west of the Mt John Range, where ephemeral creeks flow out of the Indulkana Range to join the Amaroodinna Creek further south. The area is underlain by steeply dipping shales of Adelaidean age.

The first line surveyed here was just south of Mt Chandler, on the edge of the Indulkana Range. The area was chosen because of a fault striking roughly east interpreted at this location (W. Preiss, pers. comm.). The results (Figure A2) showed the rock in this area to be relatively conductive, but without any discernible layering to justify data inversion. Initial testing suggested that maghemite might be present and giving the data the appearance of lower resistivity than was actually the case, but this was disproved by decay rate (as t^{-3}) and checking using an in-loop receiver. The only feature of note is a change in resistivity at about station 16, on the lower slopes of the Indulkana Range, which could indicate a fault. None of the rocks appear resistive enough to be younger sandstones such as occur in the Range.

Lines 6 and 7 (Figures A4 and A5) cover the immediate area of Rodda Bore itself, the former striking east and the latter north. Testing here showed that the use of an in-loop receiver was necessary to overcome maghemite effects, and this configuration was used for all other data gathered in the Rodda Bore area. Resistivities are consistently high and the data is unsuitable for inversion. However two areas, one 500 m west of Rodda Bore and the other 1600 m north, show marginally lower resistivities, dropping from over 500 ohm-metres to about 200 ohm-metres. Such a resistivity level could indicate an increase in porosity with low salinity water contained in the pores, and on this anticipation both features were drilled. Drilling results were disappointing. The more hopeful of the two, drilled by well I98R2 1700 m north of Rodda Bore on Line 7, was virtually dry and it must be assumed that the increased conductivity resulted from an increased clay content. This, which could result from weathering, would increase the conductivity without the increase in permeability necessary to provide available water. The second well, I98R3 drilled 1000 m west of Rodda Bore on Line 6,

yielded good quality water but in too small quantities (0.9L/s) to be useful for this project.

Lines 24, 25 and 26 (Figures A11, A12 and A13) were surveyed to check the original results near the wells and produced similar but rather less clear results. It is evident that TEM does not give clear indications of favourable drilling targets in this area.

Line 13 (Figure A7) traversed a creek bed to the northeast of Rodda Bore. There is no conductor associated directly with the creek, as might be anticipated, but a shallow conductor was detected at the southwest end of the line, under the gibber plain. The target is not particularly encouraging, and was not drilled.

JIMMY'S WELL

Like Rodda Bore, this area showed signs of maghemite such that it was necessary to use the in-loop configuration. The results were still poor, but sufficient to indicate the difference between very resistive rocks and those that were sufficiently conductive to allow the possibility of water being present. Two lines were surveyed, one through Jimmy's Well and the other some 3 km to the northeast. Both lines were oriented at 135 degrees magnetic to cross the valley orthogonally.

The first line, through Jimmy's Well, is identified as Lines 5 and 14, having been run in two parts to the west and east of the well (Figure A3). Most of the line is very resistive, but more conductive material is observed at each end, presumably as the array moves onto metasediments – shales – from the granitic or gneissic rocks in the centre of the valley. The only favourable location for drilling was a deepening of resistive basement some 650 m to the southeast of Jimmy's Well, which was interpreted as a possible basement fracture zone with a consequently deeper weathering profile. The depth to fresh basement here was interpreted as about 30 m. Drilling at this location revealed some 30 m of sediments (sandstone) overlying granite, but no water. Similarly drillholes at either end of the line, where more conductive material was observed, failed to intersect water. In all three locations the conductivity is interpreted as being caused by water trapped in clays.

Line 15, some 3 km northeast of Jimmy's Well, showed similar resistive rocks to the above (Figure A8), again with conductive material at the

southeast end of the line. The interpretation is the same, with generally very resistive granites under most of the profile and Adelaidean metasediments at the end.

While the results here are not encouraging, in that no water of useful quality or quantity was found, this may be a failure of the technique rather than indicating that no potable water is present. The area still has potential for water resources, but other techniques for detecting either the water itself or the fracture zones should be sought.

INDULKANA RANGE

Two lines were surveyed on the Blue Hills Sandstone of the Indulkana Range, which hosts the current water supplies of Indulkana. This rock type does not contain iron, and maghemite was not present so the single loop configuration could be used, thereby simplifying survey procedures.

Line 12 was surveyed initially, in March 1998, to test the technique in this environment. The results, shown in Figure A6, inverted satisfactorily and show resistive near surface rocks with a conductor underlying at a depth of 60–80 m. Subsequent drilling (I98IR1) identified the water table at 70 m with moderately saline water (TDS 1 800 mg/L).

Line 21 (Figure A9) was surveyed along the fence line where a track provided easy access in a very rocky environment. The results show the same picture as in Line 12, but with the conductor shallowing from 60 m at the northeast end to 20 m at the southwest. Three holes were drilled with I98IR2 intersecting water at 72 m and an eventual SWL of 55 m. This fits reasonably with the TEM results. I98IR3 intersected water at 78–84 m with SWL at 51 m, being deeper than would be expected from the geophysics. I98IR4 intersected little water. It is therefore evident that the technique is not confidently predicting water presence or depth, perhaps because of the nature of the aquifer which is presumed to be fractured. Fractured rock aquifers are notoriously difficult to locate, with the possibility of success and failure wells being within a few metres of each other. It appears possible that the conductor being detected in this area is, in fact, the Indulkana Shale.

MT JOHN

This range has similar geology to the Indulkana Range, it being possible to use the single loop configuration for the TEM survey. Three lines were surveyed, one extending along the main valley southeast of Policeman's Well and the other two cutting across a side valley. It was hoped that reasonable thicknesses of Blue Hills sandstone might be found, but the conductivities appear to indicate Indulkana Shale.

Line 23 (Figure A10) shows a weak conductor at a depth of 20–30 m, which could indicate the water table and fair quality groundwater. There being no variation in the response along the line a hole, I98MJ3, was drilled at the most convenient location, producing very little water from a water cut at 27 m.

Line 27 (Figure A14) shows similar results to Line 23, although there is more variation in the thickness of the upper (resistive) layer. The drilling results were similar also with the exception of I98MJ1, which was drilled near Policeman's Well and yielded 0.9 L/s of potable water.

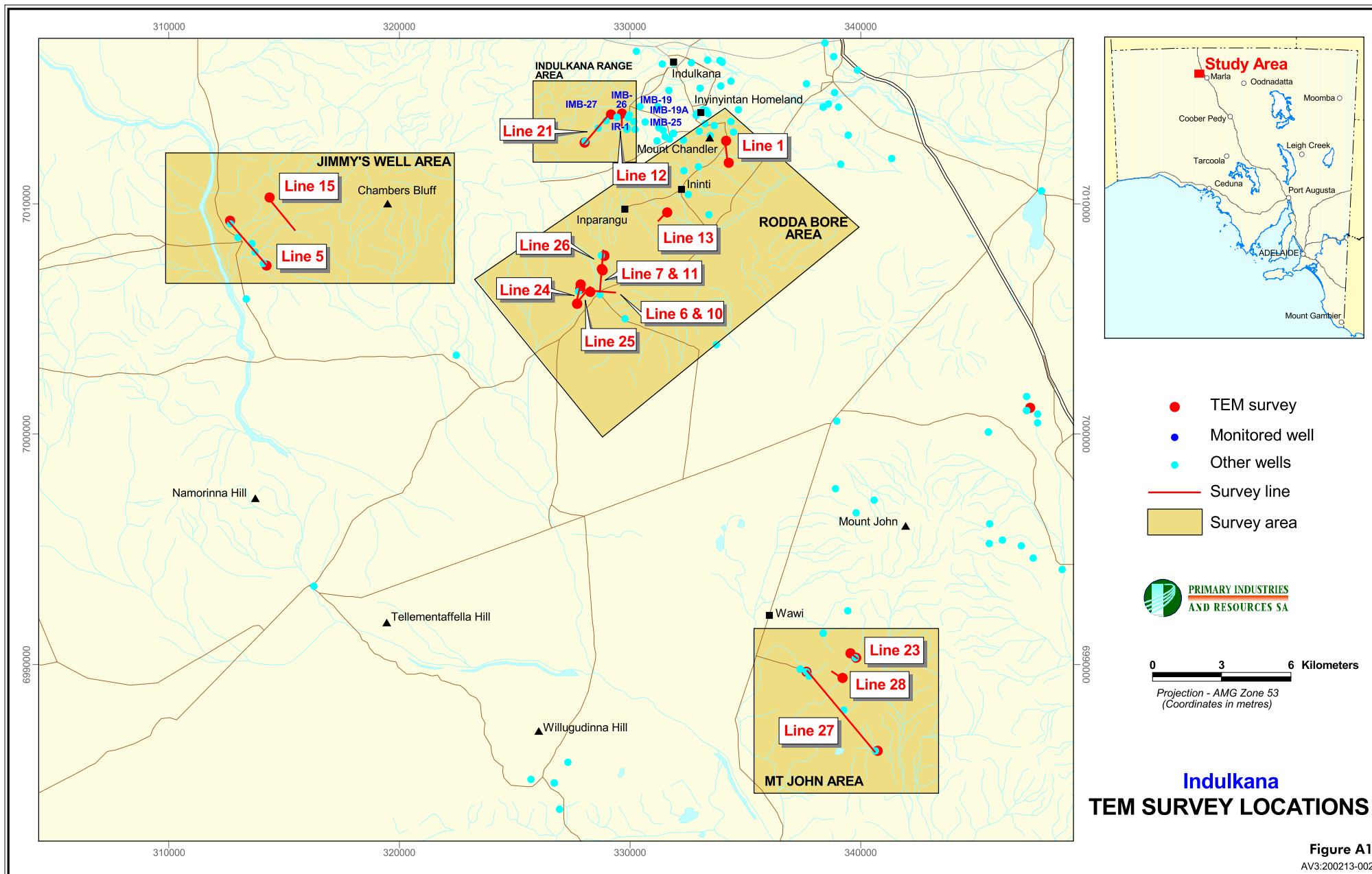
Line 28, across the same valley as Line 23 but closer to Line 27, again showed similar results and was not drilled.

Overall the results at Mt John Range were disappointing. Geology indicated that a reasonable thickness of Blue Hills Sandstone might be present and with a good catchment the prospects for groundwater storage looked good. The geophysics and drilling show that the Indulkana Shale underlying the Sandstone is shallower than anticipated and the hoped for aquifer is not present in the areas surveyed.

CONCLUSIONS

The geophysical results at Indulkana are disappointing and have not contributed greatly to water search in this area. This can be attributed to several factors, chief of which is the unfavourable geology. Over much of the area ground resistivities are high, so that inductive signals are low. In the absence of electrical and geological noise such high background resistivities would make the detection of weak conductors, such as might be the case with low salinity groundwater, easier. The presence of maghemite in much of this area largely offsets this advantage, since the advances in TEM equipment design have not fully offset the problems resulting from this material. Additionally, and perhaps more importantly, the groundwater appears to be available in fracture zones and these, because of their small extent, are difficult to detect with geophysics. A final complication is the presence of clays that, in this environment, may cause conductors that are unrelated to groundwater search. On the other hand, the clays may relate to the Indulkana Shale and knowledge of their location may assist in understanding the geology and, thereby, the hydrogeology.

The TEM technique worked effectively here in the Indulkana and Mt John Ranges, where the single loop configuration could be used. It was less effective at Rodda Bore and Jimmy's Well, where the presence of maghemite required the use of the in-loop configuration. This resulted in a weaker signal – by an order of magnitude – which, in a resistive area with already weak signals, made the gathering of clean data extremely difficult. This does not mean that the method should be discarded for such areas, however, since a new generation of equipment with major modifications in data gathering techniques is now available. This equipment could be tested for such areas or other geophysical techniques investigated.



INDULKANA WATER SEARCH TEM SURVEY

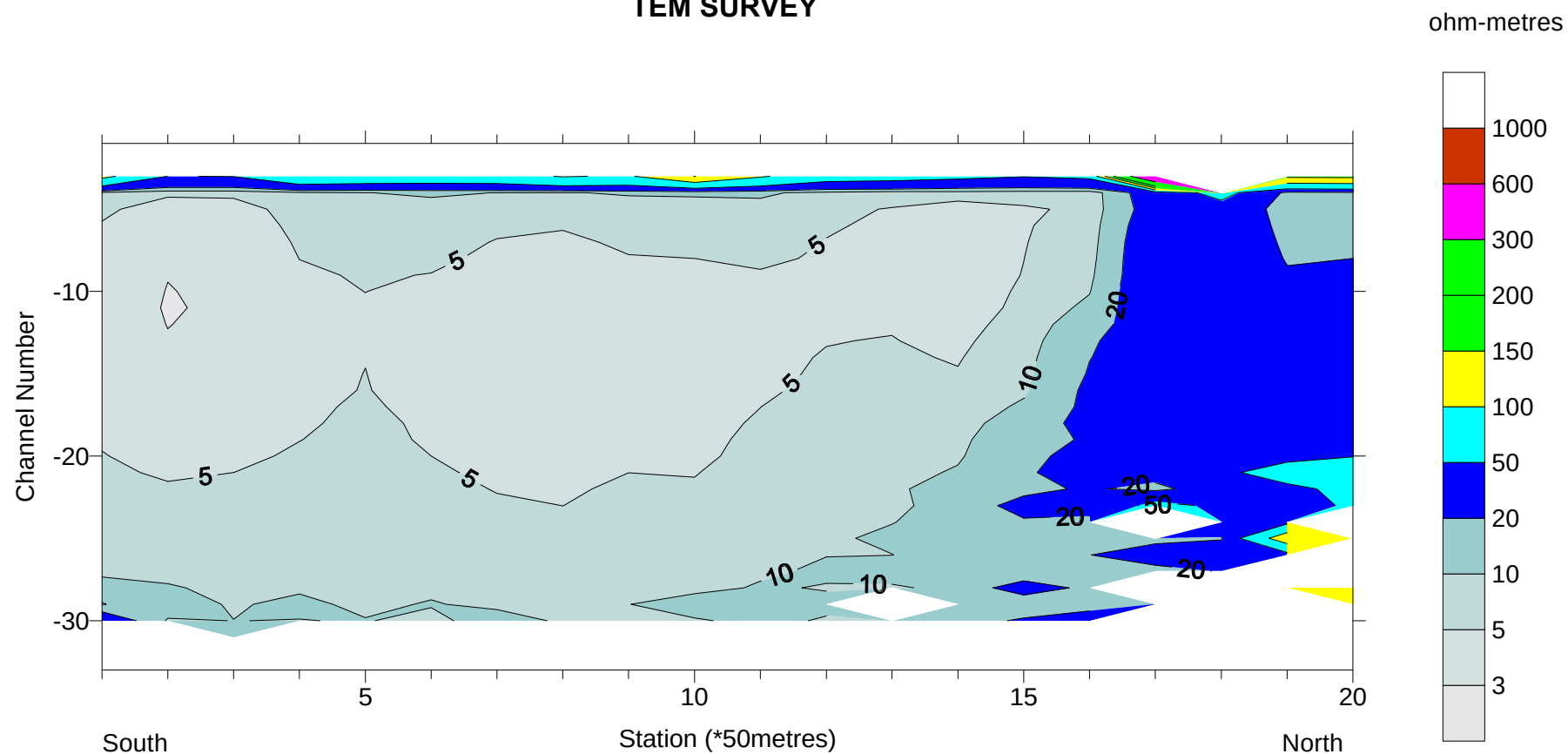


Figure A2. Apparent Resistivity Pseudosection - Line1 Wolff's Fault.

INDULKANA WATER SEARCH TEM SURVEY

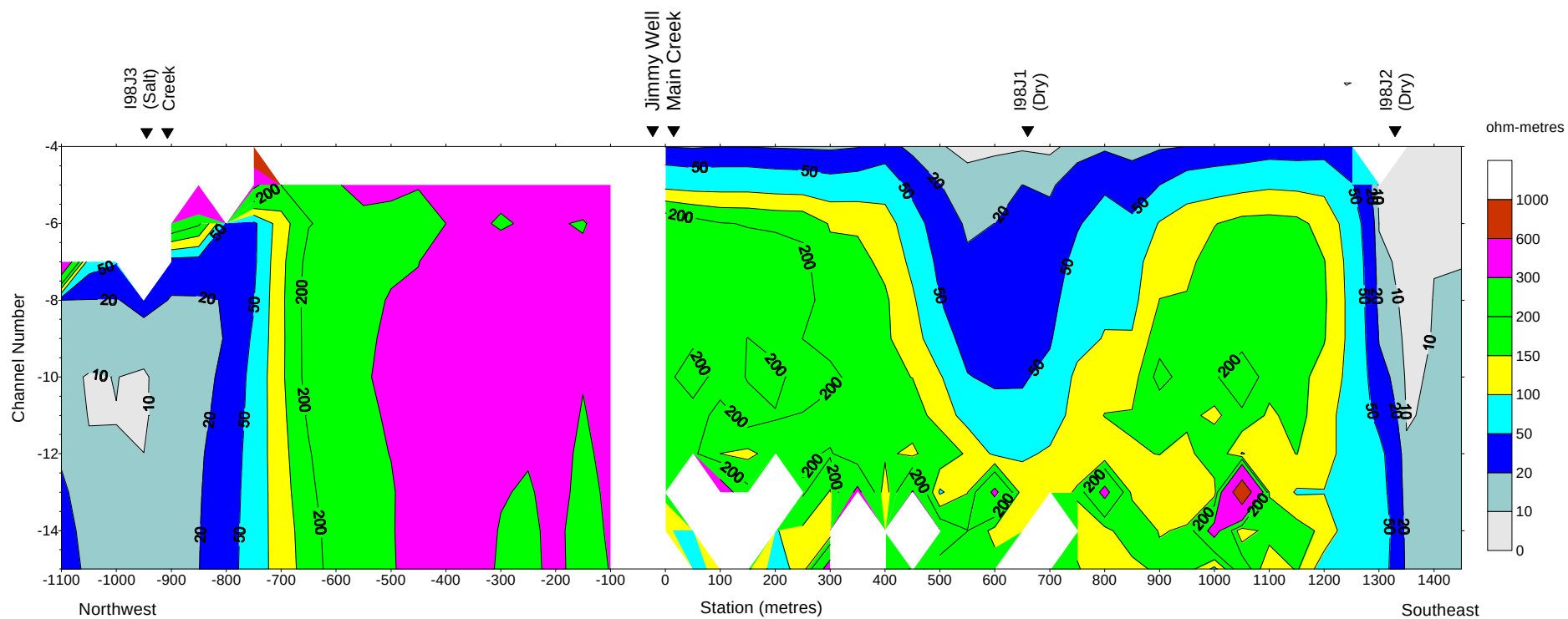


Figure A3. Apparent Resistivity Pseudosection, Lines 5 and 14 - Jimmy's Well.

INDULKANA WATER SEARCH TEM SURVEY

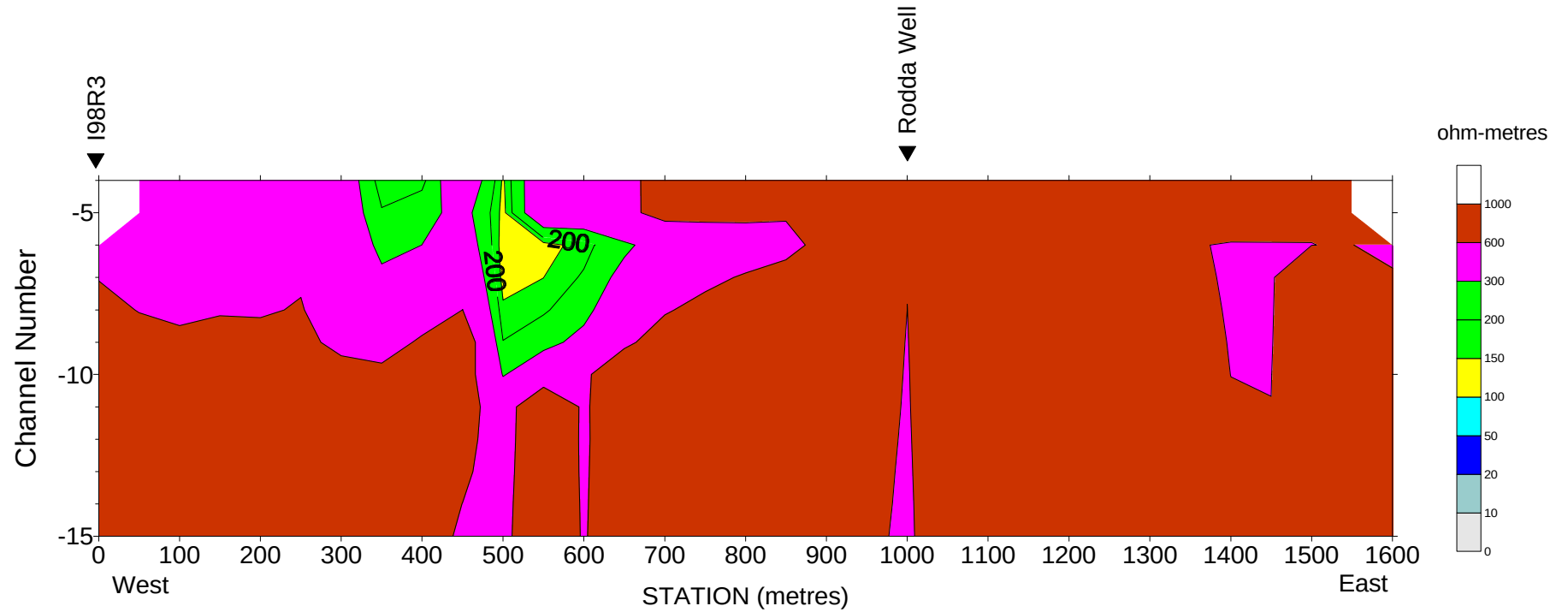


Figure A4. Apparent Resistivity Pseudosection - Line 6 Rodda Bore

INDULKANA WATER SEARCH TEM SURVEY

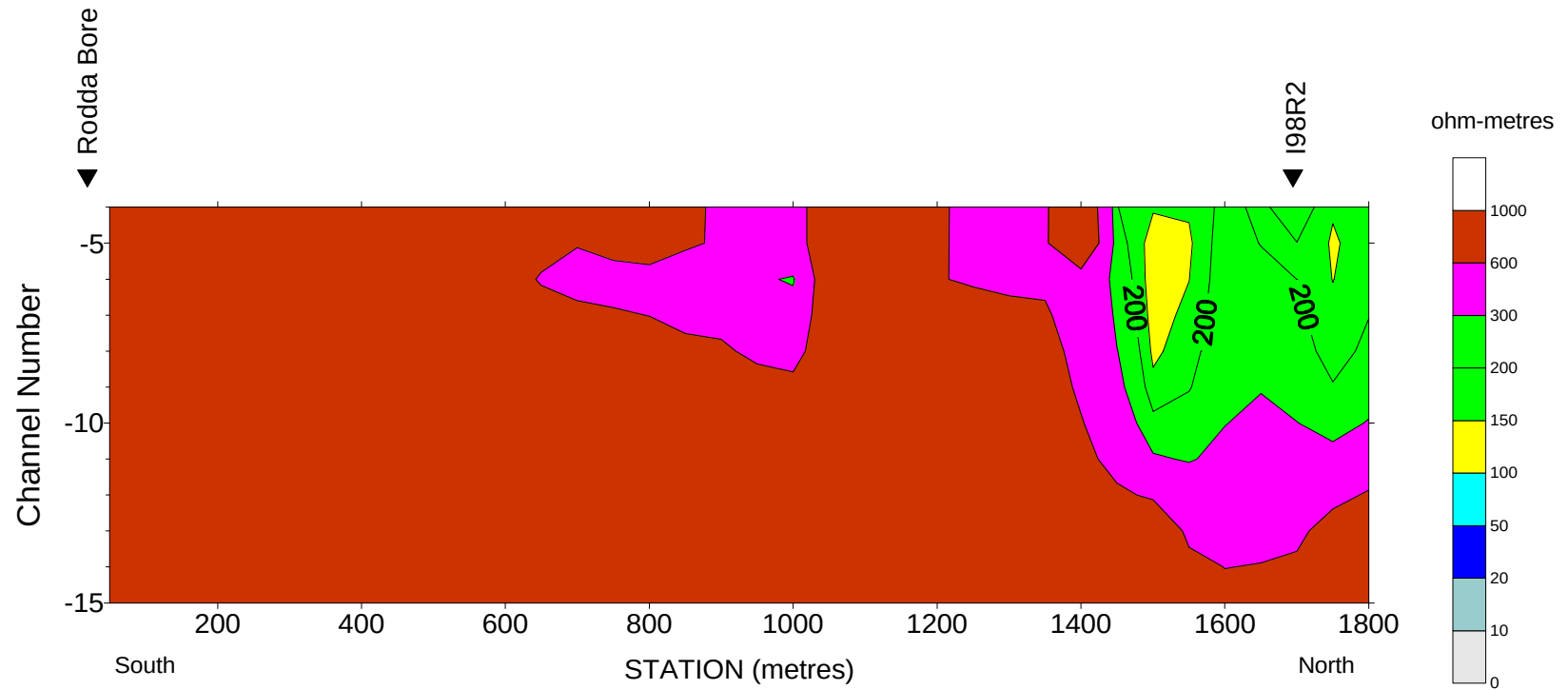


Figure A5. Apparent Resistivity Pseudosection -Line 7 Rodda Bore

INDULKANA WATER SEARCH TEM SURVEY

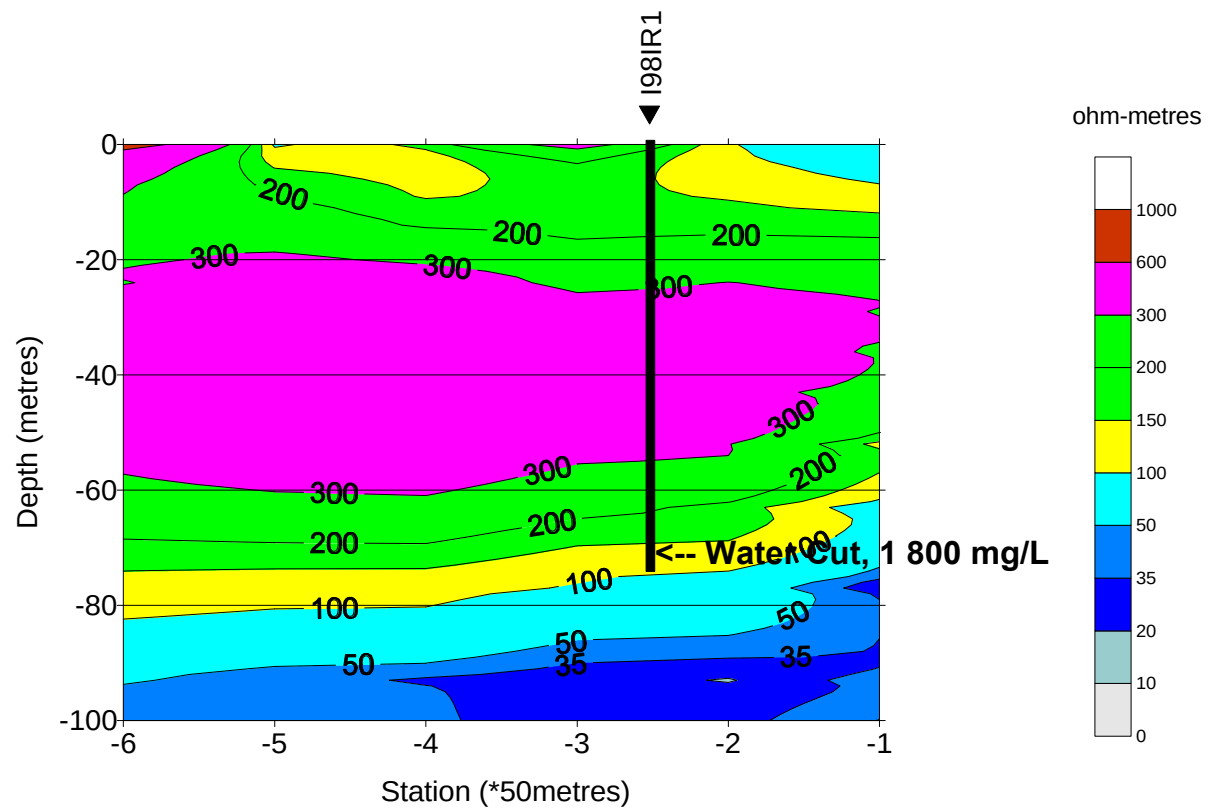


Figure A6. Resistivity Section from TEM Inversion - Line 12 Indulkana Range.

INDULKANA WATER SEARCH TEM SURVEY

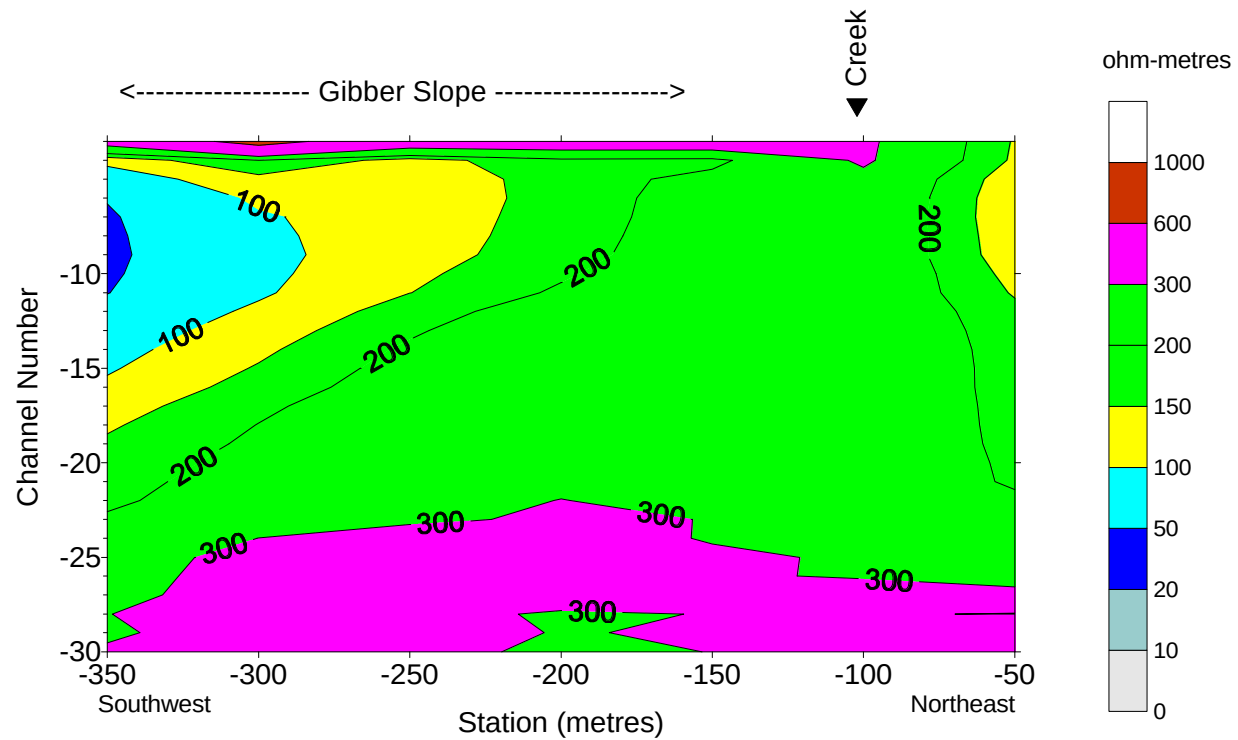


Figure A7. Apparent Resistivity Pseudosection - Line 13 Rodda Bore Area.

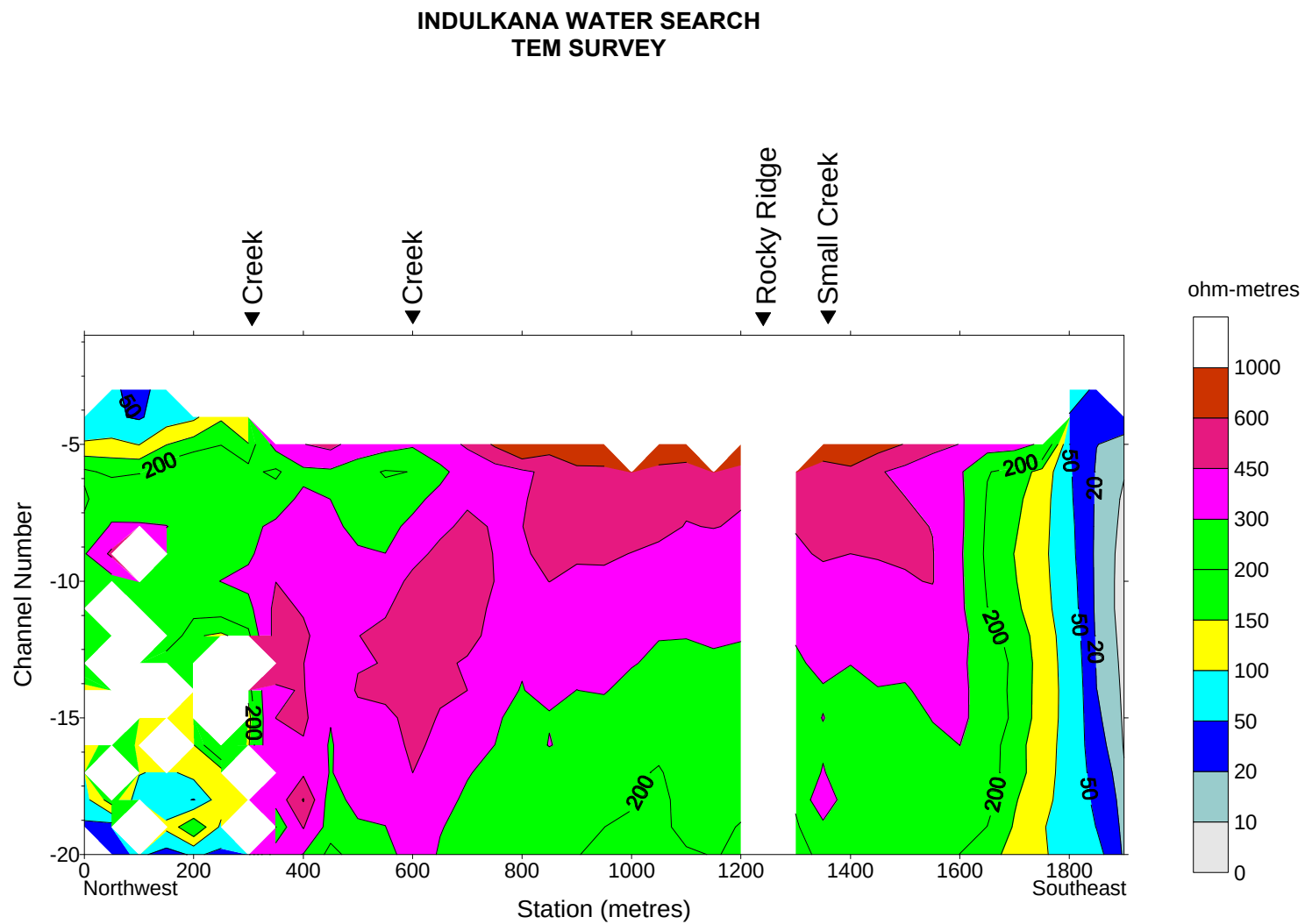


Figure A8. Apparent Resistivity Pseudosection, Line 15 - Jimmy's Well

▼ I98IR4

▼ 1981R3

▼ 1981R2

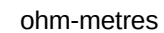


Figure A9. Resistivity Section from TEM Inversion, Line 21 - Indulkana Range

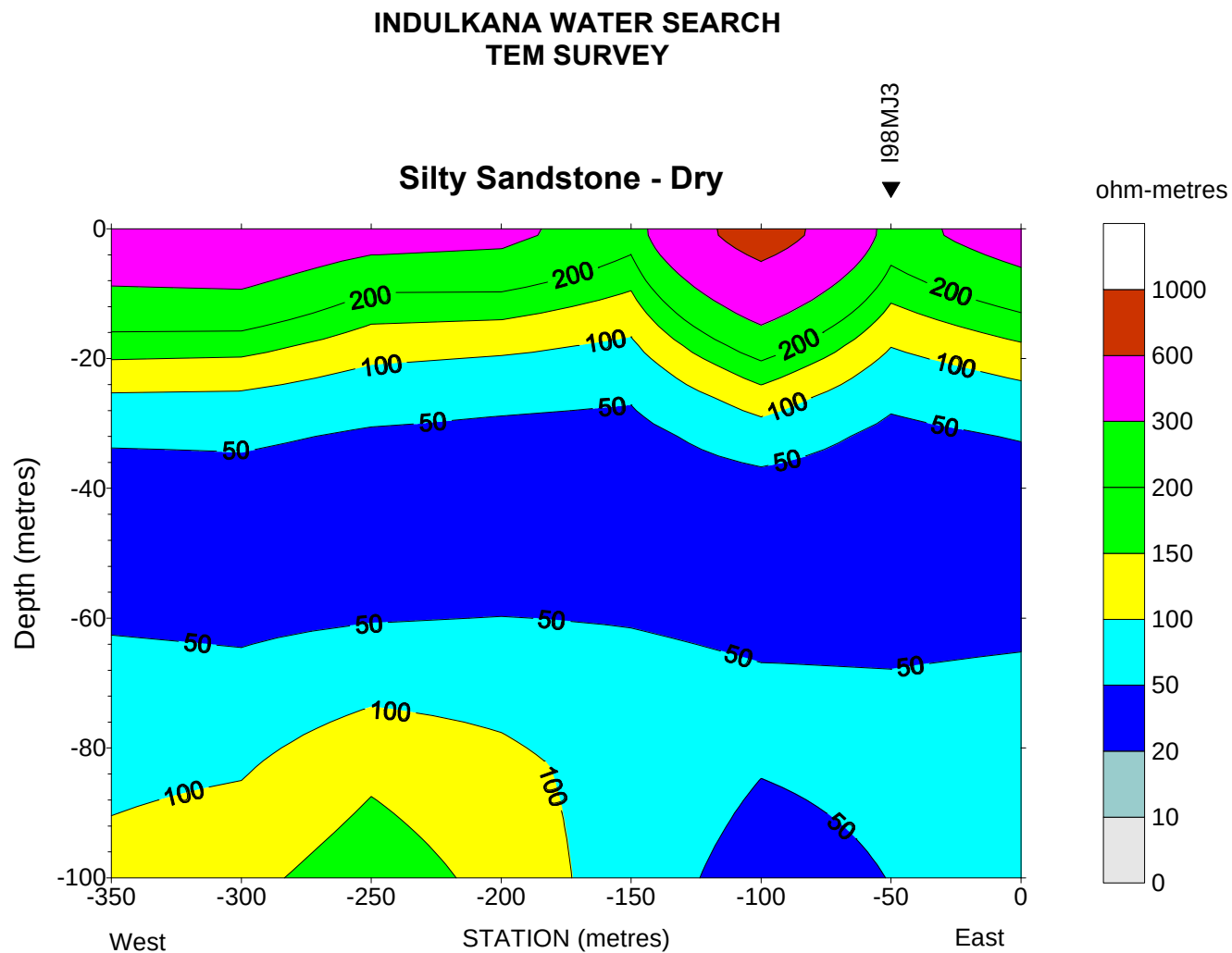


Figure A10. Resistivity Section from inversion of TEM data. Line 23 - Mt John

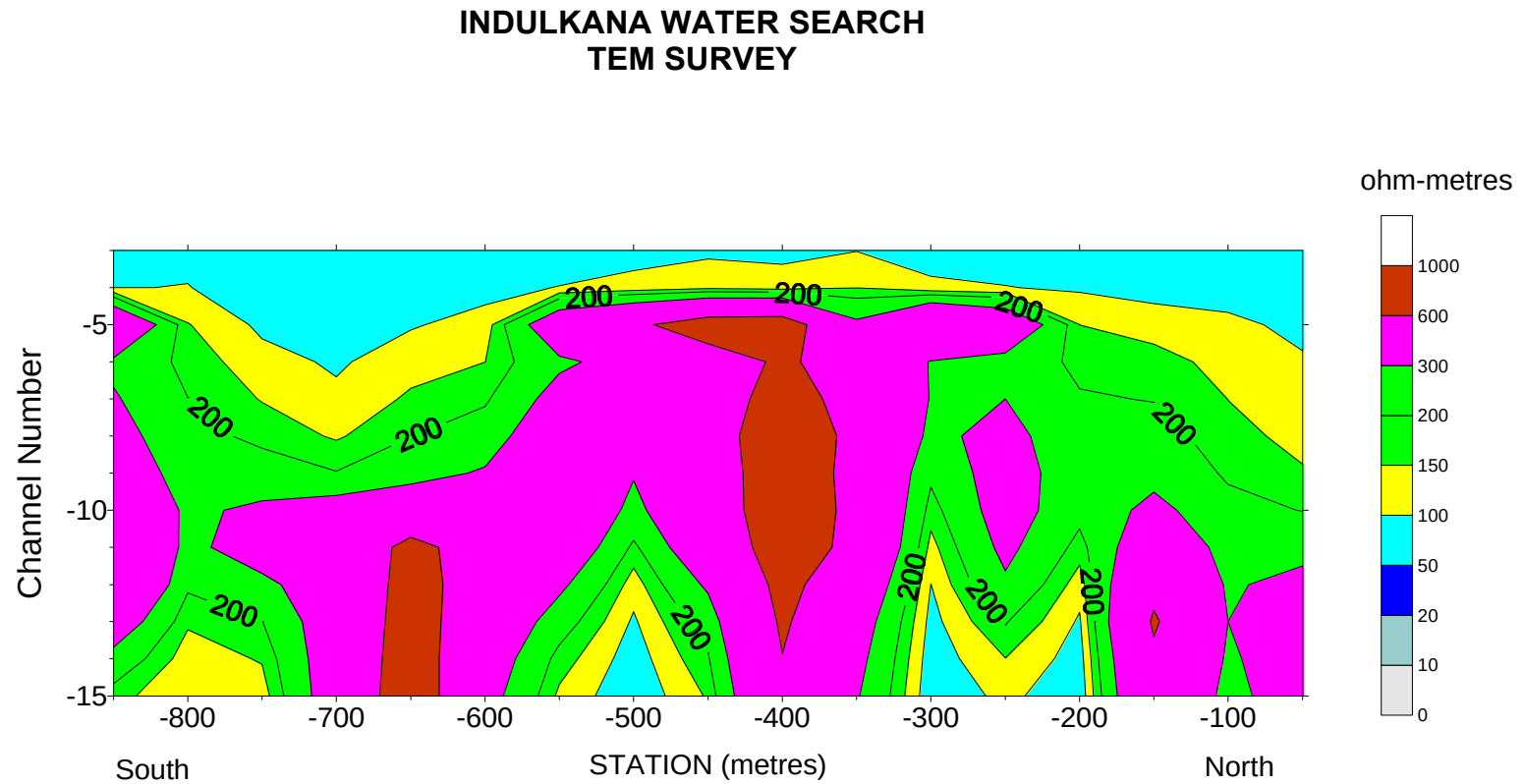


Figure A11. Apparent Resistivity Pseudosection, Line 24 - Rodda Bore

**INDULKANA WATER SEARCH
TEM SURVEY**

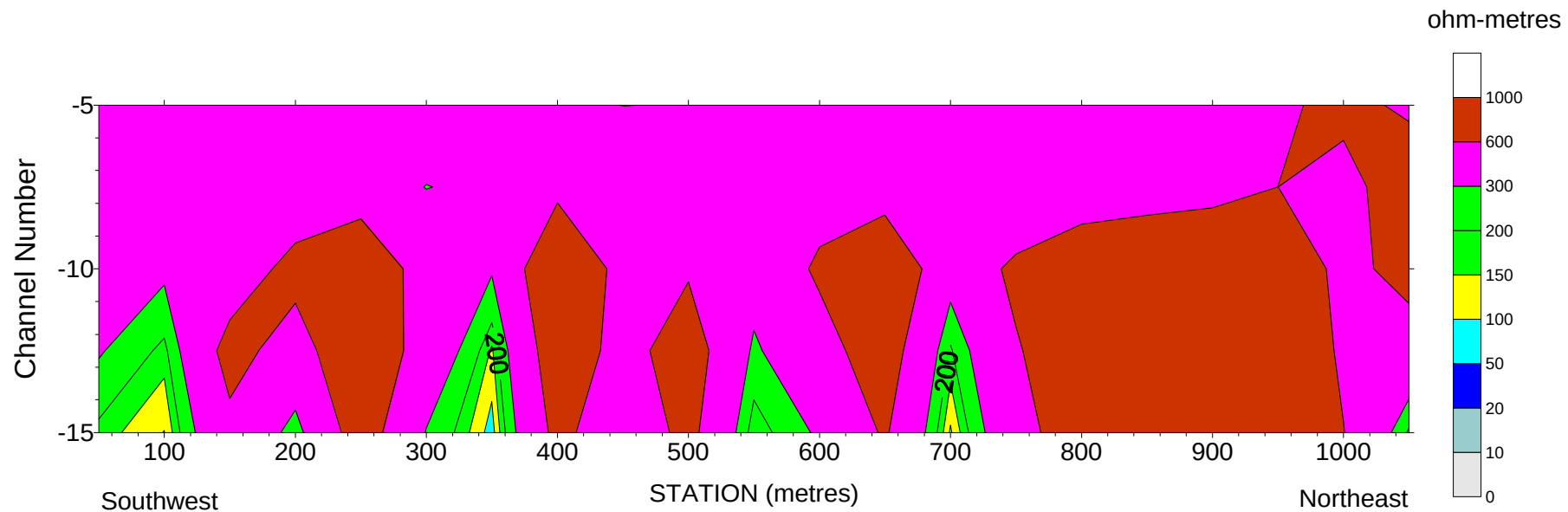


Figure A12. Apparent Resistivity Pseudosection, Line 25 - Rodda Bore

INDULKANA WATER SEARCH TEM SURVEY

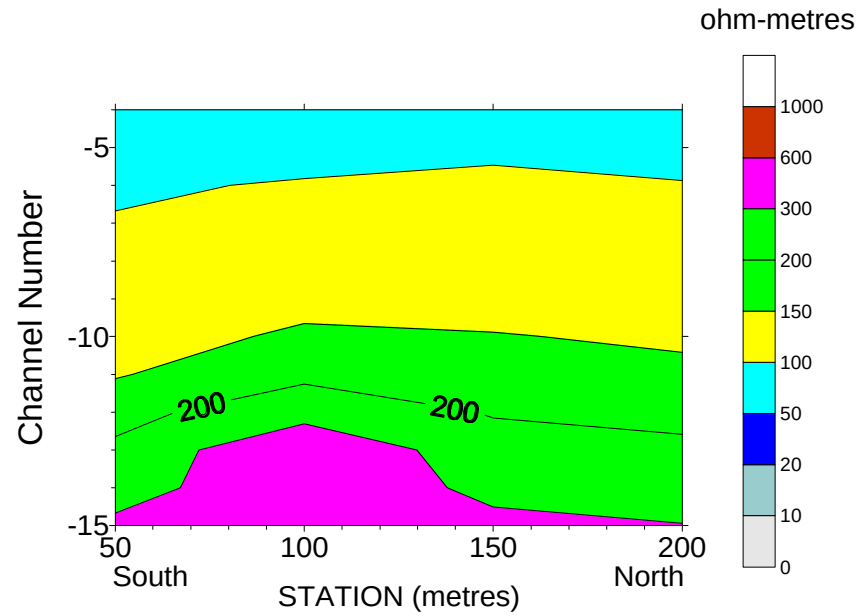


Figure A13. Apparent Resistivity Pseudosection, Line 26 - Rodda Bore

INDULKANA WATER SEARCH TEM SURVEY

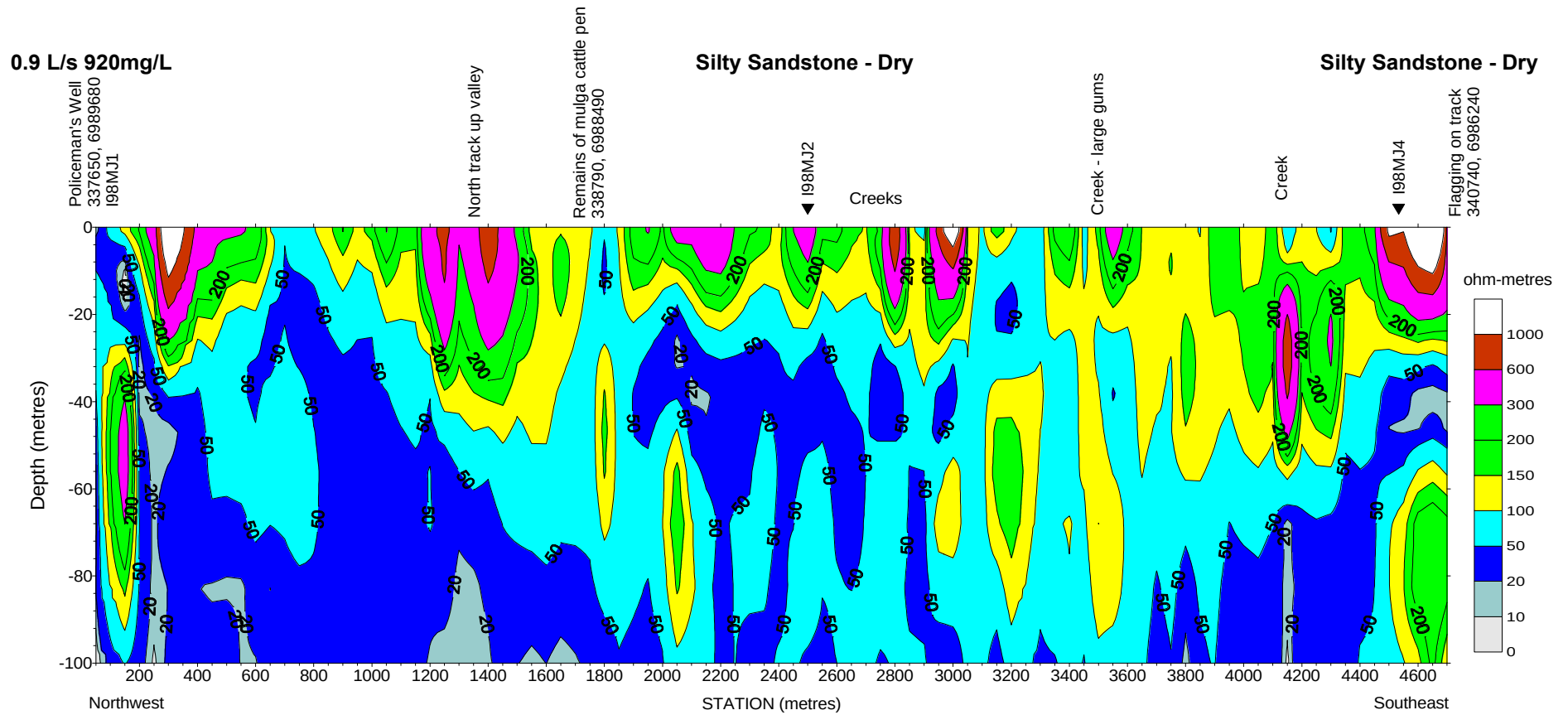


Figure A14. Resistivity Section from inversion of TEM data - Line 27, Mt John. Bearing 135.

INDULKANA WATER SEARCH
TEM SURVEY

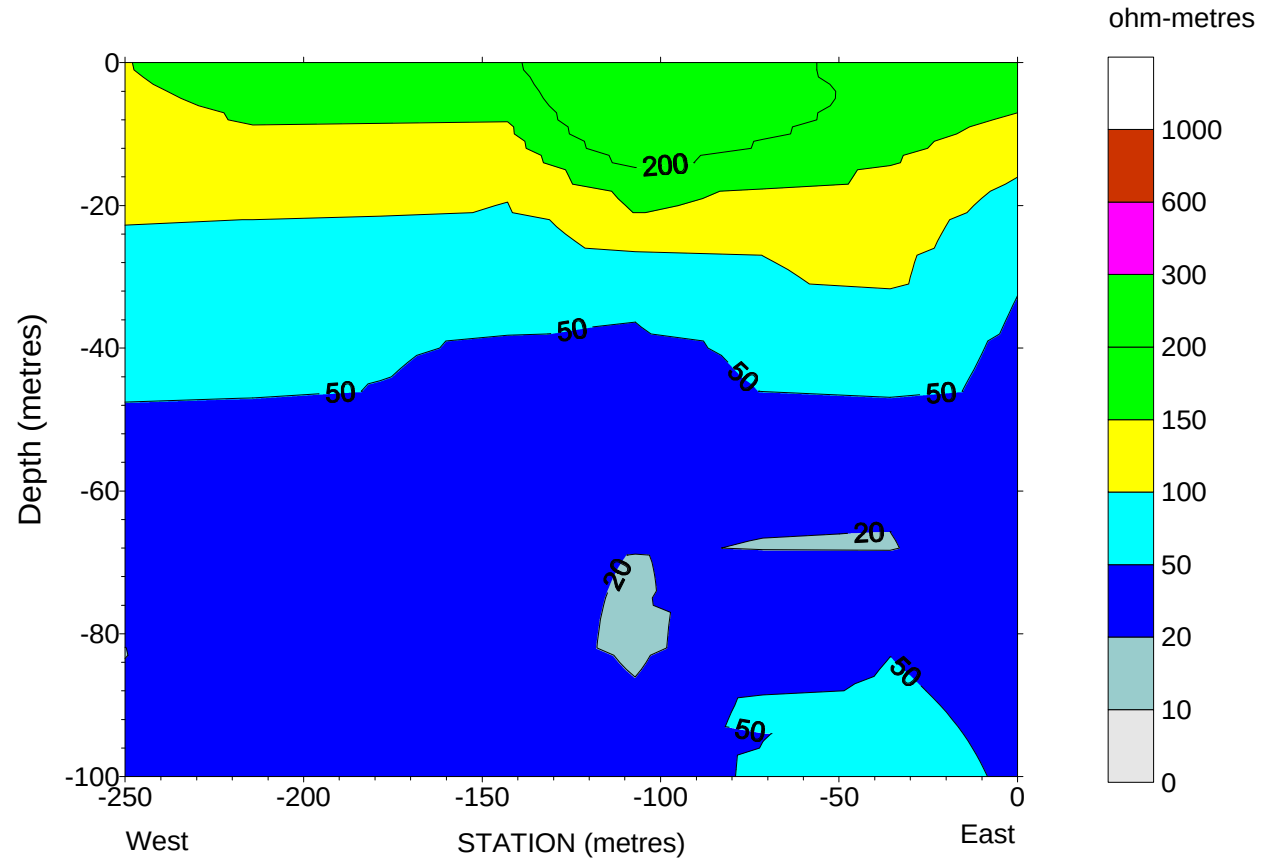


Figure A15. Resistivity Section from inversion of TEM data. Line 28, Mt John..

Appendix B

DRILLING RESULTS

WELL DESCRIPTION TABLES

Project well numbering: In addition to the 'I' for Indulkana and the '98' indicating the year, the project numbers indicate the areas in which the wells were drilled and the sequential number of each well in that area.

J Jimmy's Well
R Rodda Well
IR Indulkana Range

MJ Mount John Range
S Sweet Water Well area

For example: I98MJ3 is the third well drilled in this project in the Mount John Range area.

WELL NUMBERS AND LOCATIONS

Project well No.	Date completed	Permit No.	Unit No.	Easting*	Northing	Potential	Fully cased**	Capped
I98IR1	7/4/98	44083	5544-172	329 430	7 013 720	Production	No	Yes
I98IR2	14/6/98	45204	5544-169	328 960	7 013 580	Production	No	Yes
I98IR3	15/6/98	45205	5544-170	328 620	7 013 260	Observation	No	Yes?
I98IR4	16/6/98	45208	5544-171	328 040	7 012 690	Production	No	Yes
I98J1	1/4/98	44070A	5543-143	313 736	7 007 890	Observation	No	Yes?
I98J2	2/4/98	44070B	5543-144	314 100	7 007 400	Observation	No	No
I98J3	3/4/98	44070C	5543-145	312 680	7 009 120	Observation	No	Yes
I98J4	3/4/98	44070D	5543-146	313 330	7 005 860	Observation	No	Yes
I98MJ1	17/6/98	45206	5543-136	337 652	6 989 680	Observation	No	Yes
I98MJ2	17/6/98	45209	5543-137	339 270	6 988 010	Observation	No	Yes?
I98MJ3	18/6/98	45210	5543-138	339 760	6 990 285	Observation	No	No
I98MJ4	19/6/98	45211	5543-139	340 636	6 986 250	Observation	No	Yes
I98R1	5/4/98	44082A	5543-147	329 750	7 005 000	Production	No	No?
I98R2	5/4/98	44082B	5543-148	328 741	7 007 740	Observation	No	No
I98R3	6/4/98	44069	5543-142	327 770	7 006 180	Production	Yes	Yes
I98S1	19/6/98	45212	5543-140	347 200	7 001 628	Production	No	Yes
I98S2	20/6/98	45213	5543-141	347 670	7 000 853	Observation	No	Yes

* All wells are in Australian mapping zone number 53, and are shown as AMG co-ordinates

** Details of casing are given in another table below

WELL WATER DATA (GENERAL)

Project well No.	Total depth (m)	SWL (g.l.) (m)	SWL date	ECU	mg/L	How Sampled	Date sampled	Yield (L/sec)	How measured
I98IR1	72	37.53	7/4/98	3460	1920	Airlift	7/4/98	2.0	bucket/watch
I98IR2	90.7	55.07	14/6/98	2710	1500	Airlift	14/6/98	1.0	bucket/watch
I98IR3	103.3	50.6 app.	1/10/98	2460	1360	Airlift	15/6/98	0.8	bucket/watch
I98IR4	78	-	-	?	?	-	-	0.02?	estimate
I98J1	36	9.12	13/6/98	2790	1550	Bailer	13/6/98	0.01?	estimate
I98J2	48	15.44	13/6/98	2950	1630	Bailer	13/6/98	0.01?	estimate
I98J3	58	11.47	13/6/98	6650	3700	Airlift	3/4/98	1.5	bucket/watch
I98J4	42	10.78	13/6/98	3360	1870	Airlift	3/4/98	0.15	bucket/watch
I98MJ1	43.3	1.03	18/6/98	1630	900	Airlift	17/6/98	0.9	bucket/watch
I98MJ2	49.3	44.23	18/6/98	4630	2600	Bailer	18/6/98	0.1?	estimate
I98MJ3	43.3	18??	19/6/98	?	?	-	-	0.05?	estimate
I98MJ4	42	-	-	2500	1400	Airlift	19/6/98	0.05?	estimate
I98R1	72	42.04*	5/4/98	2750	1520	Airlift	5/4/98	0.56	bucket/watch
I98R2	42	27.92	9/6/98	7220	4100	Bailer	9/6/98	0.005?	estimate
I98R3	72	27.82*	6/4/98	1718	950	Airlift	6/4/98	0.9	bucket/watch
I98S1	61	-	-	1380	760	Airlift	19/6/98	0.25	bucket/watch
I98S2	30	-	-	?	?	-	-	0.02?	estimate

* SWL measured soon after airlifting

The yields in this table are those recorded during drilling. Sustainable yields calculated from well discharge test results for I98IR1, 2 & 3 are tabled in the Well Discharge Test section of this report.

WELL WATER DATA (WATER CUTS)

Project well No.	Water cut (m)	Cumulative water cut (L/sec)	Conductivity (ECU)
I98IR1	39	trace	?
	66	0.5	3710
	72	2.0	3460
I98IR2	75	1.0	2710
I98IR3	53	0.19	2580
	78	0.6	2460
	84	0.8	(2660, field test only)
I98IR4	58	trace	?
I98J1	?	trace	?
I98J2	?	trace	?
I98J3	37	0.25	8200 (field test)
	51.5	1.5	6650
I98J4	36	0.15	3360
I98MJ1	18	0.4	1540 (field test)
	25	0.65	1540 (field test)
	26	0.9	1630
I98MJ2	45	0.1	4630
I98MJ3	27	0.05	?
I98MJ4	36	0.05	?
I98R1	48	0.03	2440? (field test)
	60	0.05	?
	61	0.56	2800
I98R2	?	trace	7220
I98R3	32	1.5	1720
	42	1.8 (dropped back to 0.9)	1750 (field test)
I98S1	24	0.25	1380
I98S2	18	0.02	?

CASING DETAILS

Project well No.	Casing from	Casing to	Casing dia. Mm	Casing type	Surface casing cement type
I98IR1	-0.3	5.7	210 i.d. 220 o.d.	Steel	Cement
I98IR2	-0.5	2.0	210	Steel	Plastic foam
I98IR3	-0.5	3.0	210	Steel	Foam
I98IR4	-0.5	1.0	210	Steel	Foam
I98J1	-0.5	6 (5.5?)	210	Steel	Cement
I98J2	-0.2	5.5	210	Steel	Cement
I98J3	-0.3	5.7	210	Steel	Cement
I98J4	-0.3	5.7	210	Steel	Cement
I98MJ1	-0.5	4.0	210	Steel	Foam
I98MJ2	-0.5	5.5	210	Steel	Foam
I98MJ3	-0.5	5.5	210	Steel	Foam
I98MJ4	-0.5	5.5	210	Steel	Foam
I98R1	-0.3	5.7	210	Steel	Cement
I98R2	-0.3	5.7	210	Steel	Cement
I98R3	-0.3	5.7	210	Steel	Cement
	-0.5	72	145 i.d.	PVC	-
I98S1	-0.5	1.5	210	Steel	Foam
I98S2	-0.3	3.0	210	Steel	Foam

REASON FOR STOPPING DRILLING

Project well No.	Depth (m)	Reason for stopping drilling
I98IR1	72	Water more saline than desirable, possibility of increased salinity with greater depth
I98IR2	90.7	Possibility of cutting more saline water with increased depth
I98IR3	103.3	Unpromising rock type in deeper part of well
I98IR4	78	Unpromising rock type - too large a proportion of silt and clay
I98J1	36	Unpromising rock type, negligible water cut
I98J2	48	Unpromising rock type, no weathering, negligible water cut
I98J3	58	Water too saline
I98J4	42	Water too saline
I98MJ1	43.3	No increase in the amount of water cut in the deeper part of the hole
I98MJ2	49.3	Water too saline
I98MJ3	43.3	Unpromising rock type
I98MJ4	42	Higher than desirable salinity and poor prospects of obtaining a good yield
I98R1	72	Water too saline
I98R2	42	Negligible water cut (a bailed sample later showed that the water was saline)
I98R3	72	Little evidence of weathering below 48 metres, no water cut below 42 metres.
I98S1	61	Very poor prospects of obtaining a useable yield
I98S2	30	Very poor prospects of obtaining a useable yield

WELL LOGS

All colours in these logs are from the Munsell soil colour charts and refer to damp samples.

LOG OF WELL I98IR1

Drilled 7/4/98, the first hole on the Indulkana Range drilled in 1998

0–6 m	<u>Soil and sandstone</u> The surface sandstone is very siliceous.
6–9 m	<u>Sandstone</u> , feldspathic, moderately indurated, fine grained (around 0.3 mm). Pink 5YR 8/3. Apparently no primary porosity.
9–12 m	<u>Sandstone</u> , as above, but with iron staining in joints.
12–15 m	As above, but no staining.
15–18 m	<u>Sandstone</u> , feldspathic. Poorly sorted grains, up to 0.6mm.
18–24 m	<u>Sandstone</u> , feldspathic, poorly sorted, up to 0.6 mm. Pink 5YR 7/4.
24–36 m	As above.
36–39 m	As above, but the sample was damp.
39–42 m	<u>Sandstone</u> , feldspathic, poorly sorted (the larger grains are rounded), moderately strongly indurated. Pinkish gray 7.5YR 7/2.
42–66 m	As above, but damp. Water cut at 66m, 3450 ECU, 0.5 L/sec.
66–72 m	<u>Sandstone</u> The grains are well rounded, poorly sorted, up to 0.8 mm. Total water cut at 72 m was 2 L/sec.

LOG OF WELL I98IR2

Drilled 14/6/98, the second hole on the Indulkana Range drilled in 1998.

0–3 m	<u>Sandstone</u> , silicified, red 10R 4/6
3–6 m	<u>Sandstone</u> , feldspathic, fine grained, pink 5YR 8/3. Very little, if any, primary porosity.
6–9 m	<u>Sandstone</u> , fine grained, silty, pink 10R 7/3.
9–12 m	<u>Sandstone</u> , fine grained, silty, moderately indurated (small pieces can be broken between the fingers).
12–18 m	As above but pink 10R 7/4.
18–33 m	As above but pink 5YR 7/3.

33–36 m	As above, but some coarse quartz grains are present.
36–39 m	<u>Sandstone</u> , fine grained, silty, moderately indurated, very pale brown 10YR 7/3.
39–44 m	As above but pink 5YR 7/4.
44–48 m	<u>Sandstone</u> , apparently weakly indurated (the sample is loose sand), silty. The grains are up to 0.6 mm, poorly sorted. Reddish yellow 7.5YR 7/6.
48–51 m	As above, but yellow 2.5Y 8/6.
51–54 m	<u>Sandstone</u> , ?weakly indurated, silty. Grains up to 0.5 mm, poorly sorted. The larger grains are rounded. White.
54–60 m	As above, but up to 0.6 mm (the sample looks like beach sand). Very small water cut at 60 m, sufficient to dampen the samples.
60–66 m	<u>Sandstone</u> , moderately indurated, pink.
66–69 m	<u>Sandstone</u> with minor clay, gray N 6/.
69–72 m	<u>Clayey sandstone</u> (the pulverised sample is moderately plastic). Gray 10YR 5/1.
72–75 m	<u>Sandstone</u> , some fine grained gray, some coarse grained pale brown. The coarse grains are well rounded. Water cut at 75 m, 1.0 litre per second, 2570 ECU.
75–78 m	<u>Sandstone</u> , fine grained, mainly pink, some gray, minor yellow (ferruginous).
78–84 m	<u>Sandstone</u> , mostly fine grained, but includes some coarse grained beds (some parts very poorly sorted from coarse to fine). Mainly gray, but also a lot of pink.
84–90 m	<u>Sandstone</u> , mostly coarse grained, gray. Total water cut is still 1.0 litres per second.

Lithology: Blue Hills Sandstone for full depth.

LOG OF WELL I98IR3

Drilled 15/6/98, the third hole on the Indulkana Range drilled in 1998

SWL unable to measure because of hammer oil in well; 2660 ECU (field), 2460 (1360 mg/L, C.B. Office); air lift yield 0.8 L/sec.

0–3 m	<u>Sandstone</u> , fine grained, red 2.5YR 5/6.
3–6 m	<u>Sandstone</u> , silty, poorly sorted, up to 0.8 mm. Pinkish white 5YR 8/2.
6–9 m	<u>Sandstone</u> , silty, fine grained, up to about 0.2 mm. Pinkish white 7.5YR 8/2.
9–12 m	As above.
12–15 m	<u>Sandstone</u> , very silty, fine grained. White 10YR 8/1.
15–18 m	<u>Sandstone</u> , fine grained. Weak red 2.5YR 5/2.
18–27 m	<u>Sandstone</u> , medium grained (up to 0.7 mm), the larger grains are rounded. Light gray 10YR 7/1.
27–30 m	<u>Sandstone</u> , silty, mostly fine grained, less medium grained, pink.
30–33 m	<u>Sandstone</u> , silty, fine grained, pink.
33–36 m	<u>Sandstone</u> , silty, very poorly sorted, up to 0.5 mm.
36–39 m	<u>Sandstone</u> , silty, very poorly sorted up to 1 mm.
39–42 m	<u>Sandstone</u> , silty, very poorly sorted, up to 0.4 mm, pink.
42–48 m	<u>Sandstone</u> , silty, very poorly sorted, mainly fine grained, pink.
48–51 m	<u>Sandstone</u> , silty, very poorly sorted.
51–54 m	As above, with marked iron/manganese staining, possibly associated with a water cut at 53 m (0.19 litres per second).
54–57 m	<u>Sandstone</u> , fine grained. Pinkish gray 7.5YR 6/2.
57–60 m	<u>Sandstone</u> and clay. The sandstone is as above, the clay gray N5/.
60–66 m	<u>Sandstone</u> , fine grained. Light reddish brown 5YR 6/4.
66–69 m	<u>Sandstone</u> , light brownish gray 10YR 6/2, some iron staining.
69–72 m	<u>Sandstone</u> , fine grained. Pinkish gray 7.5YR 6/2.
72–75 m	<u>Sandstone</u> , fine grained, minor weathering apparent (iron staining), mostly gray N5/.
75–82 m	As above, some pink, minor well sorted. (Total water cut at 78 m was 0.6 L/sec.)
82–84 m	<u>Siltstone</u> , fine grained, very silty, weakly indurated, micaceous in places. Weak red 7.5R 4/2. (The colour change was sudden and conspicuous). (Total water cut at 84 m was 0.8 L/sec.)
84–88 m	<u>Siltstone</u> , fine grained, very silty. Light gray 10YR 7/1.
88–90 m	<u>Siltstone</u> , fine grained, very silty. Weak red 5R 4/4, trace of green (malachite?).

90–95 m Siltstone, fine grained, very silty. Weak red, pink, and light pinkish gray.
 98–97 m Clay Weak red.
 97–102 m Siltstone, fine grained, silty, light gray 5YR 6/1.

Lithology: Blue Hills Sandstone to 82 metres, then Indulkana Shale.

LOG OF WELL I98IR4

Drilled 16/6/98, the forth hole on the Indulkana Range drilled in 1998
 SWL and salinity not measured because of very poor yield; estimated yield 0.02 L/sec.

0–3 m Sandstone, red (silicified, feruginised) followed by white, some fine grained, some medium.
 3–6 m Sandstone, silty, very poorly sorted up to 1 mm; the larger grains are rounded. Pinkish gray 5YR 7/2.
 6–9 m Sandstone, ?weakly indurated, white.
 9–11 m Shale, pinkish white 7.5YR 8/2, minor mottling with red.
 11–18 m Sandstone, very poorly sorted up to 1.2 mm; the larger grains are rounded. Pinkish gray 5YR 7/2.
 18–21 m As above, but up to 0.5 mm.
 21–24 m As above, but up to 0.8 mm.
 24–27 m Sandstone, very poorly sorted up to 0.5 mm, light reddish brown 5YR 6/3.
 27–30 m As above, but up to 1.0 mm.
 30–36 m As for 24–27 m.
 36–39 m Sandstone and silt (seemingly poorly consolidated).
 39–44 m Sandstone, very poorly sorted up to 1.0 mm. Pinkish gray 7.5YR 7/2.
 44–51 m Shale, red and gray, damp.
 51–54 m Sandstone, very poorly sorted up to 0.4 mm. Light brownish gray 10YR 6/2.
 54–57 m Sandstone, very poorly sorted, mainly around 0.2 mm.
 57–60 m Sandstone, very poorly sorted up to 0.8 mm. Light brownish gray 10YR 6/2.
 60–63 m Shale, silty, red 7.5R 4/6, damp.
 63–66 m Sandy siltstone and shale. The siltstone is weakly indurated, red and gray 10YR 5/1.
 66–74 m Sandy siltstone, fine grained, moderately sorted. Dark grayish brown 10YR 4/2.
 74–78 m Sandy siltstone and clay. The siltstone is gray and weak red 10R 5/4.

Lithology: Blue Hills Sandstone to 44 metres and Indulkana Shale after 60 metres. Between 44 and 60 metres could be either.

LOG OF WELL I98J1

Drilled 1/4/98, the first hole in the Jimmy Well area drilled in 1998

0–3 m Silt and sandstone gravel The sandstone is poorly sorted. The sample also contains some weathered feldspar and dark rock fragments. Reddish brown 2.5YR 4/4.
 3–9 m Feldspathic sandstone Highly weathered. Yellow 10YR 8/6. Some clay, dry.
 9–12 m Feldspathic sandstone No clay apparent. Less weathering than above. White.
 12–15 m Silty feldspathic sandstone Clayey. Mostly very fine grained.
 15–21 m Silty feldspathic sandstone The coarser grains are quartz, rounded, pink and white.
 21–24 m As above, but pinkish gray 7.5YR 7/2.
 24–27 m Weathered granite (Fairly quick drilling.) Light brown 7.5YR 6/4.
 27–30 m Granite Gray N5/. Medium, rather than coarse grained.
 30–33 m Granite, with minor epidote.
 33–36 m Granite Dark grayish brown 10YR 4/2

Only a trace of water cut

LOG OF WELL I98J2

Drilled 2/4/98, the second hole in the Jimmy Well area drilled in 1998

0–3 m	<u>Sand and rubble</u> , red
3–6 m	<u>Gneiss rubble</u>
6–12 m	<u>Gneiss</u> , showing some weathering. Brown 7.5YR 5/4.
12–18 m	<u>Gneiss</u> Weathering in joints. Dark grayish brown 10YR 4/2.
18–21 m	<u>Gneiss</u> Showing weathering on joint surfaces. Dark grayish brown 10YR 4/2.
21–24 m	<u>Gneiss</u> , minimal weathering. Dark grey 10YR 4/1. Some garnet?
24–30 m	<u>Gneiss</u> Minor weathering visible, some epidote (filling old joints?) Dark gray N4/.
30–39 m	<u>Gneiss</u> Some weathering showing on joint surfaces, some epidote in joints. Dark gray N4/.
39–42 m	<u>Gneiss</u> Gray, as above, with pink translucent crystalline mineral with good cleavage (no reaction with acid).
42–45 m	<u>Gneiss</u> Gray, with minor epidote and pink, translucent ?feldspar, similar to above. No weathering apparent.
45–48 m	<u>Gneiss</u> , with garnet and minor epidote. No weathering, no pink ?feldspar.

LOG OF WELL I98J3

Drilled 3/4/98, the third hole in the Jimmy Well area drilled 1998

0–3 m	<u>Soil</u> and sandstone rubble.
3–6 m	<u>Silty sandstone</u> Brownish yellow 10YR 6/6.
6–15 m	<u>Shale</u> Very pale brown 10YR 7/4. Clayey.
15–18 m	<u>Silty shale</u> Reddish yellow 7.5YR 6/6.
18–33 m	<u>Shale</u> , fresh Reddish yellow 5YR 6/6.
33–36 m	<u>Sandstone</u> , poorly sorted, mainly coarse grained. Yellowish red 5YR 4/6.
36–39 m	<u>Gritty clay</u> Red 2.5YR 5/6.
39–45 m	As above, but Brownish yellow 10YR 6/6.
45–51 m	<u>Quartzite</u> or metasiltstone (fine grained, very well indurated). Dark gray N4/.
51–54 m	<u>Siltstone</u> Shades of olive.
54–57 m	<u>Quartzite</u> (some of which is oolitic, small spheres containing numerous concentric shells (agate)).
57–58 m	<u>Quartzite</u> or fine grained well indurated sandstone. Dark gray 10YR 4/1.

LOG OF WELL I98J4

Drilled 4/4/98, the fourth hole in the Jimmy Well area drilled 1998

0–6 m	<u>Clayey shale</u> Pale red 5R 6/4.
6–9 m	<u>Shale</u> Mainly pink 7.5YR 8/4.
9–12 m	<u>Clayey shale</u> Weak red and pink.
12–15 m	As above, but reddish yellow 7.5YR 7/6.
15–18 m	As above, but 5YR 7/6.
18–21 m	<u>Shale and clay</u> , mainly yellowish.
21–27 m	As above, but mainly weak red 10R 4/6.
27–30 m	<u>Silty sand</u> , poorly sorted, subangular, mainly 0.3 to 1 mm. Yellowish red 5YR 5/6.
30–33 m	<u>Sand</u> , moderately sorted, mainly 0.4 to 0.9 mm, subangular. Yellowish red 5YR 5/6.
33–36 m	<u>Sand</u> , subangular, moderately sorted, mainly 0.3 to 0.6 mm. Brownish yellow 10YR 6/6.
36–42 m	<u>Sand</u> , poorly sorted, up to 0.8 mm, well rounded. Minor water cut at 36 m. Total water cut at 42 m was about 0.15 L/sec., 3700 ECU, app. 2200 mg/L.

As the standing water level settled down at 15.92 m in this well, it is curious that there was no water cut earlier.

LOG OF WELL I98MJ1

Drilled 17/6/98, the first hole in the Mt John area drilled in 1998

There was a lot of evidence of a shear zone or fracture zone in this area (very numerous rocks showing slickensides). It seemed likely that the gap at Policeman Spring (where this bore was drilled) owes its existence to a fault crossing the Mt Chandler Sandstone at this point.

0–3 m	<u>Shale/clay</u> White and very pale brown.
3–6 m	<u>Sandstone</u> , with siliceous cement. White and light red.
6–9 m	<u>Sandstone</u> , fine grained, poorly sorted, siliceous cement in places.
9–12 m	<u>Sandstone</u> , fine grained, poorly sorted. Light gray 10YR 7/1, minor iron staining.
12–15 m	<u>Sandstone</u> , fine grained. White 10YR 8/1.
15–18 m	<u>Sandstone</u> , as above, a fair amount of iron staining (in joints?).
18–25 m	<u>Sandstone</u> , white, fine grained (bordering on siltstone), scattered iron staining.
25–26 m	As above, but more fracturing and more iron stained joints.
26–42 m	<u>Sandstone</u> , very fine grained. White, variable iron stained joints.

Lithology: Indulkana Shale to 3 metres, then Mt Chandler Sandstone.

LOG OF WELL I98MJ2

Drilled 17/6/98, the second hole in the Mt John area drilled in 1998

This well site was 20 metres higher than I98MJ1. Surprisingly the reduced standing water level was around 20 m lower than for I98MJ1.

0–3 m	<u>Sandstone</u> , feruginised and silicified, poorly sorted, mainly fine grained, silty, white.
3–12 m	<u>Sandstone</u> , mostly fine to medium grained, white, larger grains (up to 1.0 mm) are well rounded.
12–15 m	<u>Sandstone</u> , varying in grain size (due to current bedding?), mainly poorly sorted up to 0.5 mm, silty. White 10YR 8/1.
15–22 m	<u>Sandstone</u> , mainly poorly sorted to 1.2 mm; the larger grains well rounded, white. Poorly indurated in places.
22–24 m	<u>Shale</u> , white.
24–30 m	<u>Sandstone</u> , silty, poorly sorted, mainly fine grained. Pinkish gray 7.5YR 7/2.
30–33 m	<u>Sandstone</u> , fine grained, silty. One shaly band at about 32.5–33 m.
33–39 m	<u>Sandstone</u> , fine grained, silty, with bands of poorly consolidated silt and fine sand.
39–42 m	<u>Sandstone</u> , mainly fine grained, some coarser, poorly sorted, silty. Mainly light gray 10YR 7/2, some very pale brown.
42–45 m	Mainly as above, but also a shale band at around 44.5–45 m.
45–48 m	<u>Sandstone</u> , fine grained, mainly light gray, a little iron stained (reddish yellow 7.5YR 6/6).

Lithology: Blue Hills Sandstone for full depth.

Fulgurites (tubular rods of fused sand caused by a lightning strike) were noted from the surface to 18 metres in this hole. They were very well indurated, being little crushed by the drill bit. They seemed to become smaller with depth.

LOG OF WELL I98MJ3

Drilled 18/6/98, the third hole in the Mt John area drilled in 1998

0–1 m	<u>Sandy soil</u> .
1–6 m	<u>Sandstone</u> , fine grained, silty, ferruginous (?and silicified) on top.
6–9 m	<u>Sandstone</u> , fine grained, silty. White 10YR 8/2.
9–12 m	<u>Sandstone</u> , as above, but some very pale brown 10YR 7/4.

12–15 m	<u>Sandstone</u> , mainly fine grained, silty; some medium grained. Light gray 10YR 7/1.
15–18 m	<u>Sandstone</u> , fine grained, silty; some light gray, some light brown 7.5YR 6/4.
18–21 m	<u>Sandstone</u> , as above, but including some dark reddish brown (5YR 3/3) siltstone.
21–24 m	<u>Sandstone</u> , fine grained, silty. Weak red 10R 4/4 (and similar shades).
24–27 m	<u>Sandstone</u> , fine grained, silty, gray and red (the red is more weakly indurated). Water cut at 27 m, approximately 0.05 L/sec.
27–30 m	<u>Siltstone</u> , with some gray sandstone as above. The siltstone was red 10R 5/6.
30–36 m	<u>Siltstone</u> , red, as above, with less fine grained, gray, sandstone.
36–42 m	<u>Siltstone</u> , shaly. Weak red 10R 4/4.

Lithology: Blue Hills Sandstone to about 20 metres, top of Indulkana Shale 20–27 metres (indefinite).

LOG OF WELL I98MJ4

Drilled 18/6/98, the forth hole in the Mt John area drilled in 1998

0–6 m	<u>Sandstone</u> ?
6–8 m	<u>Sandstone</u> , fine grained. White 5Y 8/2.
8–9 m	<u>Shale</u> , white 5Y 8/2.
9–12 m	<u>Sandstone</u> , mainly fine grained, some medium, silty. Light gray 10YR 7/1.
12–17 m	<u>Sandstone</u> , fine to medium grained (up to 0.8 mm), poorly sorted, silty. (The grain size varied considerably through the section.) Light gray.
17–18 m	<u>Shale</u> , white 5Y 8/1.
18–21 m	<u>Sandstone</u> , fine to medium grained, poorly sorted, light gray.
21–26 m	As above, with about 20 cm of shale about 23 metres.
26–27 m	<u>Shale</u> , very dark gray.
27–30 m	<u>Sandy siltstone</u> , weakly indurated (small pieces easily broken between the fingers), with a variable percentage of sand. Dark to very dark gray.
30–34 m	<u>Silty sandstone</u> , weakly indurated, fine grained. Light brownish gray.
34–35 m	<u>Shale</u> , very dark grey.
35–36 m	<u>Sandy silt</u> , brown 7.5YR 5/2. Very small water cut at 36 m.
36–40 m	<u>Sandy siltstone</u> , weakly indurated. Dark brown 7.5YR 3/2.

Lithology: Blue Hills Sandstone to 26 metres, then Indulkana Shale.

LOG OF WELL I98R1

Drilled 4/4/98, the first hole in the Rodda Bore area drilled in 1998

0–3 m	<u>Silty soil</u> and dolomite Black, very hard drilling, massive (very fine grained).
3–6 m	<u>Dolomite</u>
6–9 m	<u>Dolomite</u> , black, fine grained, massive. With 2% lighter coloured chips.
9–30 m	<u>Dolomite</u> , black.
30–33 m	<u>Dolomite</u> , black, with minor white crystalline calcite or dolomite.
33–39 m	<u>Dolomite</u> , black.
39–42 m	As above, but with a trace of white.
42–48 m	<u>Dolomite</u> , black, massive (featureless).
48–60 m	<u>Dolomite</u> , black, massive. Water cut at 52–53 m, about 0.03 L/sec., app. 2440 ECU.
60–72 m	<u>Dolomite</u> , black. Water cut at 61 m 0.5 L/sec., 2650 ECU. Total water cut at 72 m 0.56 L/sec.

LOG OF WELL I98R2

Drilled 5/4/98, the second hole in the Rodda Bore area drilled in 1998

0–3 m	<u>Soil</u> and (float) gravel.
3–6 m	<u>Shale</u> or siltstone Light yellowish brown 2.5Y 6/4.
6–9 m	<u>Siltstone</u> , weathered, especially in joints. Light olive brown 2.5Y 5/4.
9–12 m	<u>Siltstone</u> , weathered. Grayish brown 2.5Y 5/2.
12–21 m	<u>Siltstone</u> , weathering showing in joints. Dark grayish brown 2.5Y 4/2.
21–24 m	<u>Siltstone</u> , weathering showing in joints. Dark gray 10YR 4/1.
24–30 m	<u>Siltstone</u> Very dark gray and very dark brown. Showing a trace of effervescence with acid.
30–36 m	<u>Siltstone</u> , very little weathering showing. Dark gray N4/.
36–42 m	<u>Siltstone</u> (as above), with minor veins of calcite.

The drill bit broke off and was left in the bottom of this hole.

LOG OF WELL I98R3

Drilled 6/4/98, the third hole in the Rodda Bore area drilled in 1998

0–6 m	<u>Siltstone</u> Dark gray N4/
6–9 m	As above, unweathered.
9–12 m	<u>Siltstone</u> Dark gray 5Y 4/1, unweathered.
12–15 m	As above, some weathering showing.
15–30 m	<u>Siltstone</u> Dark gray N4/. No weathering apparent.
30–33 m	<u>Siltstone</u> , as above, but showing some weathering in joints. Water cut at 32 m, 1.5 L/sec., 1760 ECU
33–36 m	<u>Siltstone</u> , as above, but no weathering.
36–42 m	<u>Siltstone</u> Dark gray N4/, minor weathering in joints. Total water cut at 42 m was 1.8 L/sec., 1750 ECU.
42–48 m	<u>Siltstone</u> Dark gray N4/. Fairly common weathering in joints.
48–54 m	As above, with a trace of white calcite.
54–66 m	<u>Siltstone</u> Dark gray N4/. Scattered indication of weathering in joints.
66–72 m	<u>Siltstone</u> Dark gray N4/. No indication of weathering seen. Final air–lift yield 0.9 L/sec.

LOG OF WELL I98S1

Drilled 19/6/98, the first hole in the Sweet Water Bore area drilled in 1998

0–6 m	<u>Siltstone</u> , well indurated, dark grayish brown 2.5Y 4/2.
6–9 m	<u>Siltstone</u> , light olive brown 2.5Y 5/4.
9–12 m	<u>Siltstone</u> , dusky red 2.5YR 3/2.
12–15 m	As above but 10R 3/4.
15–18 m	As above, but including some dark grey.
18–24 m	<u>Siltstone</u> , weak red 2.5YR 4/2. Water cut at 24 metres, approximately 0.2 L/sec.
24–30 m	<u>Siltstone</u> , mainly weak red 2.5YR 4/2, some grey N 5/.
30–36 m	As above, iron staining in some joints. Total water cut is still about 0.2 L/sec.
36–42 m	<u>Siltstone</u> , mainly weak red 2.5YR 4/2, some grey N 5/.
42–48 m	As above. Total water cut at 48 metres is 0.25 L/sec. (tested with bucket and stop watch).
48–60 m	<u>Siltstone</u> , mainly weak red 2.5YR 4/2, some grey N 5/.

Drilling abandoned because of poor prospects.

Lithology: ?Rodda Beds.

LOG OF WELL I98S2

Drilled 20/6/98, the second hole in the Sweet Water Bore area drilled in 1998

0–6 m Siltstone, well indurated, dark grayish brown and dark gray.
6–9 m Siltstone, very dark gray N3/.
9–15 m Siltstone, very dark gray N3/ and light olive brown 2.5YR 5/4.
15–21 m Siltstone, mostly very dark gray N3/. Trickle of water cut at 18 metres (approx. 0.02 L/sec.?).
21–30 m Siltstone, very dark gray N3/.

Drilling abandoned because of poor prospects. (The main water cut in Sweet Water Bore {5543–63} was at 15 metres, and most of the water in I98S1 was at 18 m.)

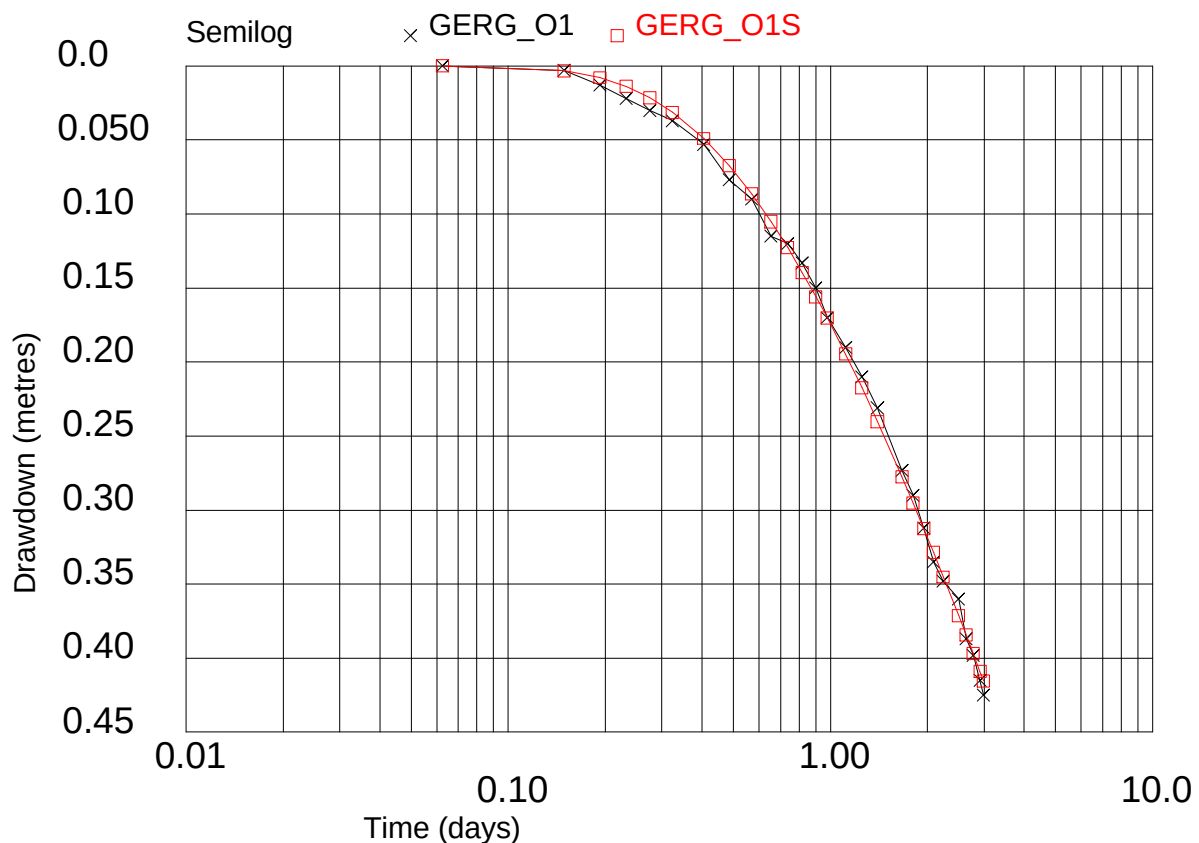
Lithology: ?Rodda Beds

WELL DISCHARGE TEST ANALYSES

SWEET WATER BORE

Figure W1 Test on Sweet Water Bore

Data from observation well 5543–25 (SW Bore 2) responding to discharge from 5543–63 (Sweet Water Bore), together with simulated data for an isotropic aquifer with $T=104$ and $S=0.0031$. The measured data (gathered by N. Gerges in 1984) are from file GERG_01 and are indicated on the graph by 'x' marks, the simulated data are from file GERG_01S and are indicated on the graph by squares.



Of at least four wells drilled in the Sweet Water Bore area, only Sweet Water Bore itself obtained a good yield. In a heterogeneous hard rock environment such as this, one would expect to find strip aquifer conditions, (ie. preferential groundwater flow along a narrow strip rather than groundwater flowing in toward a pumping well similarly from all directions). Discharge test data from the pumped well indicated a strip aquifer at early times, but there are no indications of strip aquifer conditions present for late times or for recovery. Data from the observation well indicated only radial flow conditions.

It seems most likely that Sweet Water Bore happened to intersect a major fracture, and came close to several other major fractures striking in very different directions; flow to Sweet Water Bore is therefore close to radial. The other three wells in the vicinity missed the major fractures.

Well I98IR1

The well was pumped at 1 L/sec. for one day resulting in a maximum drawdown of 13.67 m. The total depth of the well was 72 metres, the main water cut was close to the bottom (71 m assumed), and the standing water level was at 38.7 m, giving an available drawdown of about 32.3 metres.

The well equation for a single stage well test is:

$$s = AQ + BQ \log(t)$$

where s is drawdown, A and B are constants, Q is discharge rate, and t is time. (All units are based on metres and days.)

For this well, A=0.157 and B=0.0095 (transmissivity of the aquifer is approximately 19 m²/day).

Recommended maximum pumping rates based on the above well equation:

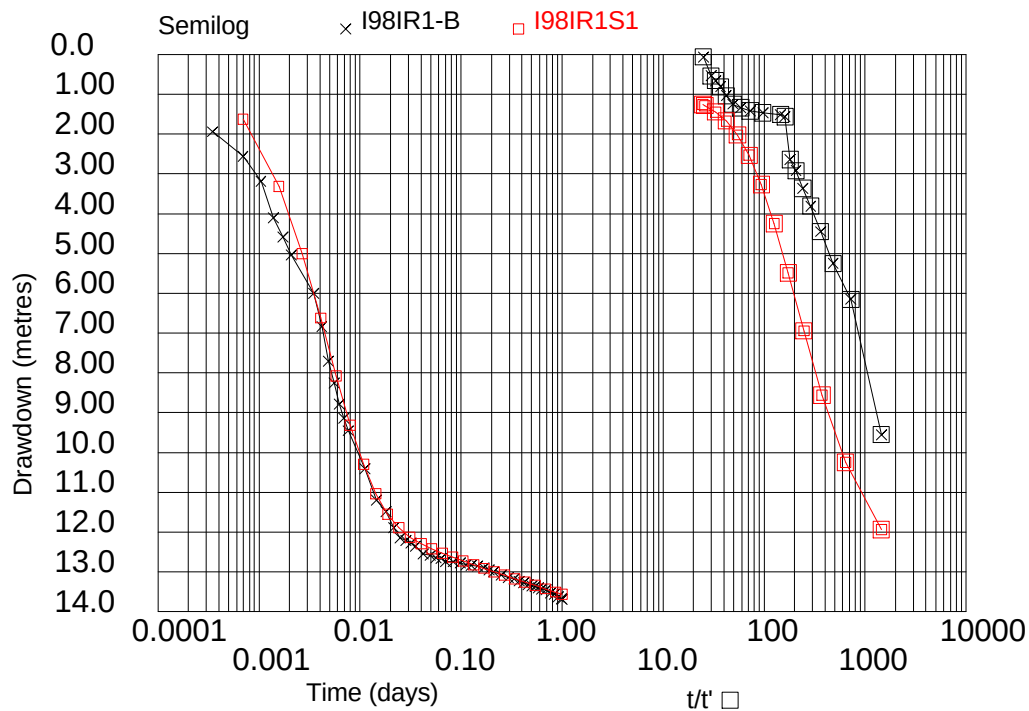
(Note that it would have been possible to be more confident about the rates had a stepped rate discharge test been carried out. This applies to all of these tests. The discharge rates below are calculated to result in a drawdown of 24.2 m, being 25% less than the 32.3 m available drawdown.)

Duration of discharge	Pumping rate (KL/day)	Pumping rate (L/sec.)
1 day	154	1.78
20 days	143	1.66
1 year	133	1.54

Figure W2 shows the recorded drawdown and recovery (the 'x' shapes) and the simulation based on the above well equation (the small squares). The two curves on the right are recoveries expressed as t/t'. Well storage effects are considered. Note that the actual recovery was quicker and more complete than expected according to the well equation.

Figure W2 - Test on I98IR1

Discharge test and simulated data from Well I98IR1



Well I98IR2

The well was pumped at 1 L/sec. for one day resulting in a maximum drawdown of 9.4 m. The main water cut was at 75 m, and the standing water level at 56 m, giving an available drawdown of about 19 m.

The coefficients for this well equation are $A = 0.109$, $B = 0.0027$ (transmissivity is about $69 \text{ m}^2/\text{day}$).

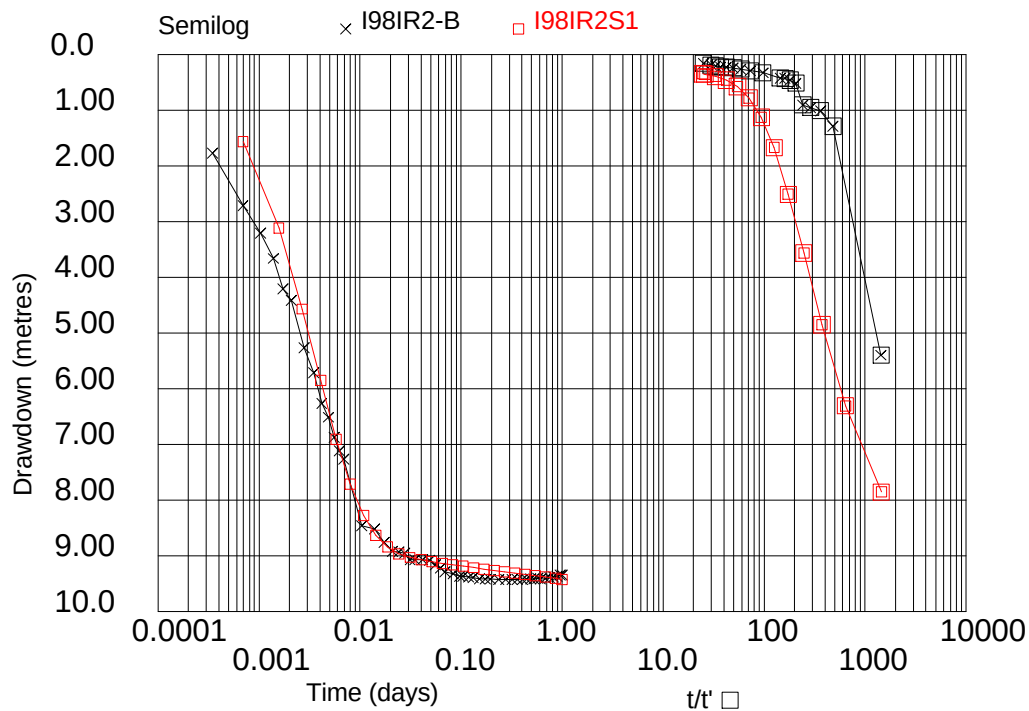
The calculations below are based on an available drawdown of 14.25 m, 25% less than the actual 19 m.

Duration of discharge	Pumping rate (KL/day)	Pumping rate (L/sec.)
1 day	131	1.52
20 days	127	1.47
1 year	123	1.42

Figure W3 shows the recorded drawdowns and the calculated drawdowns based on the well equation (as for well I98IR1, above).

Figure W3 - Test on I98IR2

Discharge test and simulated data from Well I98IR2



Well I98IR3

Figure W4 shows the data from the two short discharge tests done on this well. Curve B corresponds to the 0.9 L/sec. discharge rate and curve D is the 0.6 L/sec. rate; the pair of curves on the right are recoveries plotted as t/t' . Both pairs of curves show that an aquifer was dewatered at about 8 metres below SWL (about 59 metres from the surface, a water cut was recorded at 53 metres during drilling). The 0.6 L/sec. drawdown curve was showing signs of stabilising (at around 77 metres) when the pump was stopped after 100 minutes pumping. The major water cuts were recorded at 78 and 84 metres during drilling.

Mathematical analysis of these data is very difficult because of the complexity of the two-aquifer response. The estimated safe long-term yield from this well is around 0.4 L/sec (this is an 'educated guess' rather than a calculation).

Figure W4 - Test on I98IR3

Discharge test data from Well I98IR3

