DEPARTMENT OF MINES AND ENERGY RESOURCES
GEOLOGICAL SURVEY
SOUTH AUSTRALIA

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AN APPRAISAL OF THE WATER RESOURCES OF THE MUSGRAVE BLOCK, SOUTH AUSTRALIA

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Groundwater Section

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DEPARTMENT OF MINES AND ENERGY RESOURCES
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An appraisal of the water resources of the Musgrave Block, South Australia.

The area divides into two groundwater environments; a hard rock environment containing fresh water in fractures and saprolite; and a sedimentary environment containing more saline water in Adelaidean/Tertiary/Quaternary sediments. The hard rock area is mostly confined to the northern ranges, but may extend under the sediments. Recharge is provided locally by higher rainfall, rapid surface concentration of runoff and ready absorption of water into the fracture/weathered zones. Such resources have low salinity and a low yield, but are sufficient for local communities (<1 L/s). The salinity increases with residence time in the ground and high nitrate levels are a problem. There may be a gradual lithological transition between these hard rock aquifers and the palaeochannel type of Tertiary aquifer. Little is known about the resource in consolidated sediments because it tends towards high salinity and is therefore of little immediate use for current demand. Moreover, no high yielding aquifers have yet been intersected. There is the possibility of larger reserves in the Levenger Graben, with the added possibility of low salinity water and better yields. The provenance of the water in these sedimentary reserves is uncertain, but probably comes ultimately from the hard rock area with some local recharge. The major sedimentary groundwater environment is the unconsolidated Tertiary sediments which are concentrated mainly in the palaeochannels. The search for water in the hard rock area is best done on an 'as needed' basis, since a broad scale analysis of groundwater provenance is of limited value in this environment. An improvement in the availability of basic data, by putting as much of the information as possible on GIS, would help, as would improvements in techniques for pinpointing drill sites. In the sedimentary area, some regional work to better define the palaeochannels and graben and to test for water quality would be beneficial, particularly if saline water will be of value for mining or as feedstock for a desalinization plant. Such a study might indicate some larger scale resources.

INTRODUCTION

The study of the Musgrave Block was instigated as a part of the Western Deserts Water Resources Appraisal. The work entailed collation of data and generalised groundwater assessment of the area, from which future work is recommended. The work completed thus far includes:

- Collation of groundwater information from bore folders.
- Correction and expansion of information into a Drill Hole Data Base (DHDB). Wide reading of previous reports (see Bibliography).
- Collation and initial interpretation of recent work.
- Evaluation of data collated to confirm previous work and expand onto areas not evaluated in past.
- Recommendations for future work to improve the knowledge of groundwater resources in the Musgrave Block area.

LOCATION

The Musgrave Block covers an area of 60 000 km^2 of the northwest region of South Australia (Fig. 1) and also extends into Northern Territory and Western Australia. This report only covers the South Australian portion, which is flanked by the Officer Basin in the south and the Great Artesian Basin in the east.

TOPOGRAPHY

The topography varies considerably (Figure 2). In the north the Musgrave, Mann and Tomkinson Ranges rise abruptly to 1000 meters above the general plain. They are rugged, deeply incised masses extending en echelon along the Northern Territory border (Miller, 1965). The southern portion is essentially flat with occasional inselburg type peaks. In the Birksgate Ranges the peaks are more frequent and of higher elevation.

Well developed drainage channels occur in the elevated masses, but rarely extend for any distance into the plains. The exceptions are the Officer and Currie Creeks, which extend up to 50 km into the Officer Basin; and the Alberga River system, which covers the eastern end of the Musgrave Block and extends for 100 km or more into the Great Artesian Basin.

Well defined water divides run along most of the elevated masses.

CLIMATE

The climate is arid with hot summers and cool winters. The annual rainfall averages 254mm but varies greatly from year to year between approximately 70 mm and 720 mm (Bureau of Meteorology, Melbourne). Table 1 shows rainfall statistics of the stations in and near the Musgrave Block, most of which are located in the ranges to the north.

Higher rainfalls are expected in the ranges due to their elevation. The rainfall is mainly infrequent and heavy, caused by monsoon conditions extending from the north in summer. It is expected, due to lower relief, that the rainfall in the southern portion of the area away from the ranges would be of a much lower order.

AQUIFER RECHARGE

Recharge in the Musgrave block is due to infiltration of rainfall, either direct or from surface streams, into fractured rock aquifers and sedimentary aquifers.

Aquifer recharge has not been studied extensively in the past. Only anecdotal evidence that water levels fall in droughts and rise during wetter periods, indicates that active recharge is occurring. It is likely that most recharge occurs as a result of infrequent heavy summer rainfalls (Read 1989a).

Thornthwaite's equation (Thornthwaite and Mather, 1957) was used to estimate the recharge potential of the region (Appendix B). Using temperature and rainfall data from the Ernabella station, the potential recharge was calculated at an average of 48mm per year, but would vary immensely from one year to the next (Figure 3), with some recharge occurring, on average, every second or third year. The recharge potential would decrease dramatically south of the ranges corresponding with the decrease in rainfall. However, it must be kept in mind that these conclusions, based on Thornthwaite's equation, should only be used as a guide, since the equation does not take into account such variables as wind velocity and the rate at which water penetrates the ground.

The ratio of chloride in rainfall to chloride in groundwater was used by Allen and Davidson (1982) as an indicator of the average rate of recharge. They estimated that the recharge rate for the Musgrave Block would be 0.05% of rainfall, which is significantly lower than that estimated by Thornthwaite's equation (19%). However, the use of chloride ratios so far from the coast is regarded as questionable (Love, A., pers. comm.). Moreover, this estimate is averaged for the whole of the Musgrave Block, whereas Thornthwaite's equation predicted potential recharge for one site only, in the ranges part of the area.

It is evident that these theoretical estimates of recharge must be used with caution and that in this area, water level fluctuations may be a more reliable guide to recharge characteristics.

REGIONAL GEOLOGY

The Musgrave Block is an upthrust sequence of Mesoproterozoic crystalline basement (Drexel et.al. 1993). The rocks can be divided into four

Table 1: Annual statistics of rainfall stations in the Musgrave Block.

Station	High (mm)	Low (mm)	Mean (mm)
Amata Community	987	81	275
Ernabella	739	81	258
Kenmore Park	634	63	260
Granite Downs	463	71	222
Fregon Community	689	71	250
District 13 (Giles M.O.)(WA)	782	38	259
Mean Rainfall	716	68	254

main groups.

- The Birksgate Complex, also called the Musgrave-Mann complex, is a thick sequence of clastic sediments which have been metamorphosed into gneisses. These can be subdivided into granulite facies (Wataru Gneiss), transitional facies and amphibolite facies (Musgrave-Mann Metamorphics).
- Intruded into the Birksgate Complex is a sequence of layered basics called the Giles Complex, which comprises generally norite or gabbro.
- During and after high-grade metamorphism, widespread felsic plutons of the Kulgera Suite, were emplaced. These plutons vary from alkali granite to diorite.
- Basic dyke swarms, which postdate emplacement of the Giles Complex, are found to strike east - southeast.

Structurally the rocks are extensively folded and faulted. They are cut by a system of east - southeast trending shear zones which affect the topography. It is evident that the intrusive Kulgera Suite and the extrusive Giles Complex stand out as rugged hills above a relatively flat plain of weathered Birksgate Complex metasediments.

This crystalline basement is the effective hydrogeological basement and is partly covered by Adelaidean, Tertiary and Quaternary sediments (Fig. 4).

- Consolidated Adelaidean sediments occur around the southern edge of the Musgrave Block and in two major grabens within the Musgrave Block; the Levenger Graben and the Moorilyanna Graben. The sedimentary sequence is predominantly shale and siltstone, with minor sandstone layers.
- A large hiatus in sedimentation culminated in a palaeosurface of preCambrian rocks on which the Tertiary sediments were laid down, primarily in an extensive network of palaeochannels which cut into the plain of Birksgate Complex metasediments. The Tertiary sediments are unconsolidated and consist predominantly of clays with some sands and limestone.
- The Quaternary era is represented by a series of outwash alluvial and lacustrine sediments, infilling depressions in and flanking the ranges. The sediments are generally unconsolidated and consist of gravel, sands and clays with some thin limestone.

Aeolian dunes and sand plains blanket large areas of the Musgrave Block south of the ranges, covering the geology and most of the structural features.

HYDROGEOLOGY

There is a lack of information for undertaking any detailed study of the hydrogeology of the Musgrave Block area. The main reason for insufficient data are that few wells have been drilled in the area and of these, a large number were in non-prospective locations. Such locations were dictated by the need for water at settlements rather than the likelihood of finding it.

On the information available, the hydrogeology appears to be complex at a local level, but broad generalizations can be made on a regional scale.

As already mentioned in the preceding section, the crystalline basement is the effective hydrogeological basement. However, this statement should be qualified to the extent that most known supplies of water are hosted by the weathered or fractured upper layer of the crystalline rocks, so that it is the fresh and unfractured crystalline basement that forms the underlying aquitard.

The main aquifers of the region are of two main types; the fractured/weathered Mesoproterozoic basement rocks; and the sedimentary beds, which are of Adelaidean, Tertiary or Quaternary age.

Mesoproterozoic Basement

Crystalline basement rocks have little or no porosity, and therefore generally are unfavourable for storage or transmission of economically useful volumes of water. A number of overseas studies have shown that some hard rock lithologies statistically produce better yields than others, but the median yields are only around one order of magnitude higher (Banks et al., 1994) and are generally insignificant. Although the water well success rate varies over the Musgrave Block, the rock types cannot be statistically shown to have an effect on aquifer potential. The paucity of data may be instrumental in this, but it is clear that secondary porosity, resulting from weathering and faulting, has a greater influence than rock type on aquifer potential.

Major faulting and shearing strikes approximately east-west and is more extensive in the north and east regions. The resultant fracturing of the rocks can provide the permeability necessary for water penetration and storage. In addition, fractured rock will weather more readily and more deeply than unfractured rock, again altering the hydraulic characteristics.

In fresh rock, fractures and joint spaces become tighter with depth, decreasing the possibility of yielding water. Read (1989a) estimated that below 30 to 35 m, the potential for an unweathered fracture zone yielding water decreases dramatically. However, this depth limit increases if weathering occurs below the optimum level, counteracting the effect of tighter pore spaces. Generally, depths of 25 to 80 m of saprolite are more likely to produce higher yields than are shallow weathered zones. However, the degree of weathering also has an effect, since highly weathered rocks have lower permeability because of increased clay content, and this reduces the potential yield. Thus there is an optimum balance between fracturing, depth and degree of weathering to produce a favourable aquifer.

The rock type will also influence the degree of fracturing and weathering, so that some rock types may be more favourable to the development of aquifers. Lack of data precludes any definite predictions but some observations have been made. The low permeability of weathered but unfractured Wataru Gneiss limits its ability to produce water. For example, at Mt Lindsay in the Birksgate Ranges, the rock is less fractured but highly weathered and produces low yields. However, Wataru Gneiss in the north and north-east regions, where it is more fractured, produces higher yields (Read 1989b).

Other features such as mylonitisation in major fault zones, which cannot be identified from the surface, vary the degree of fracturing over short distances and in turn vary the potential yields obtainable.

In the southern sand-covered areas, the seismic shothole profile produced by AGSO and MESA

(Benbow et al, 1995) shows the depth to basement in an area where there has been little water drilling (Figure 5). Water was found where weathering of basement was deep, with the deepest areas on either side of the Tertiary palaeochannels. The salinity in these aquifers was found to be between 1 000 and 2 000 mg/L. Some water cuts were found in fresh rock at depths of 14 and 18 m, which could possibly be fracture zones or joints.

In the northern region, the success rate of finding water is much higher than further south. The reasons for this are:

1) More holes have been drilled in the north, increasing real knowledge of this area.

2) The geology of the northern area is more exposed, whereas that of the southern area is obscured by wind blown sand.

3) Greater deformation of the crystalline basement rocks has occurred in the northern area compared to the southern area.

4) Higher rainfall in the elevated ranges in the north increases possible recharge in this region.

Adelaidean

Consolidated Adelaidean sediments occur around the southern margin of the Musgrave Block and in two major graben within it; the Levenger Graben and the Moorilyanna Graben.

The sedimentary sequence in the Moorilyanna Graben consists of mainly siltstone underlying 5 to 10m of alluvial sand. The siltstone contains a few thin sand and fractured quartz beds or lenses which are the major source of groundwater. The salinity of the water varies mainly between 4 000 mg/L and 15 000 mg/L. The yields obtained were mainly less than 0.5 L/s although one deep well produced a yield of 4.5 L/s. Water cuts are found to be deeper than in the surrounding area, varying between 25 and 80 m, with water levels being much lower than in the hard rock of the surrounding area. Overall, Moorilyanna Graben shows poor yields and high salinities.

There are only three wells drilled in the Levenger Graben, with only one (5245-2) in the northwest region penetrating any depth of sediments. The sedimentary sequence in this well consists of clay and grit to 21 m, underlain by a thick sand and gravel layer containing water. The yield was poor (0.25 L/s) but had a low salinity between 800 and 1 500 mg/L. The other two wells in the southeast region of the graben hit weathered basement at shallow depths and salinities in the order of 13 000 mg/L were recorded. Water levels in the graben lie at a depth between 20 and 50 m. The salinity has been shown to be good in the only well to penetrate deeper sediments and the aquifer has the potential to have higher yields. Without more wells drilled in this graben, no further determination of the groundwater potential can be made.

The Adelaidean sediments along the margin of the Musgrave Block consist mainly of siltstone with minor sandstone layers. The only drilling is near Mt Chandler, where salinities ranged between 1 100 and 4 000 mg/L and yields between seepage and 3 L/s.

Tertiary

There are numerous deeply incised Tertiary palaeochannels in the Musgrave Block. However, many are very narrow and are covered by aeolian sand, making their location and extent difficult to determine. The potential for reasonable supplies was shown in hole 4945-12 which yielded 1 L/s (Read and Tewkesbury, 1991).

Water in these palaeochannels is usually cut in unconsolidated sands which underlie confining clays, and occur near the base of channels at depths of 40 m or so. The water rises to a depth of some 10 m.

LANDSAT imagery has been used to indicate the location of the palaeochannels, but is not definitive. Geophysics, in conjunction with drilling to ground truth results, would be useful to define them more precisely and to estimate depths and potential water supplies.

The profiles produced from the seismic shothole survey (Benbow et al,1995), cross a number of Tertiary palaeochannels yielding water with salinities of 2 000 to 4 000 mg/L. Salinities up to 10 000 mg/L have been found associated with Tertiary sediments elsewhere in the Musgrave Block. There was no assessment of the yields of these holes.

Overall it appears that the palaeochannels have the potential for greater supplies and resources of groundwater than other aquifers, but salinities will generally be high.

Quaternary

Some good aquifers have been found in the valleys and outwash aprons of major drainage channels in, and in close proximity to the ranges in the north. Rapid runoff and quick infiltration down through permeable material are the main reasons for the low salinity, in spite of low rainfall.

Much of the Quaternary cover is too thin to contain reliable aquifers, with depths of 20 to 25 m of alluvial deposits needed to obtain a reasonable supply (Miller, 1965). Geophysics would be needed to locate these economically.

Aeolian sand in interdunal areas has insufficient thickness to maintain a permanent body of groundwater. However the sand allows the rapid infiltration of rain water and provides temporary storage for recharge water to underlying or nearby aquifers.

Well Groups

Where feasible, groups of wells have been identified (Fig. 6). These groups, which are spatially close, have some similar characteristics. The common characteristics and the differences are described in Appendix A, and may assist in understanding the hydrogeology of specific areas.

GROUNDWATER EXPLORATION TOOLS

At present linear features (lineaments) are commonly used as a guide for siting wells, as they are often associated with lines of structural weakness. Air photos and LANDSAT imagery have been used to find linear features, with each having benefits over the other.

LANDSAT images (Fig. 7) are registered in digital format making them easy to process, analyse and interpret. The quality of output is high and can be used on geographical information systems (GIS). However the resolution is approximately 80 m and this restricts their usefulness to the location of relatively large scale features, such as large valleys, which depict major fractures.

Air photos have a resolution of 1m and are therefore useful for the location of minor features such as drainage and linear vegetation anomalies, depicting individual fractures. The main problem with air photos has been the distortion of the image due to the optical lens and aircraft movement. Recent technology permits air photos to be digitised and distortions corrected, but the process is expensive. Its main usefulness is that the digital images can be joined and used to depict larger features as well as small and can be used on a GIS, allowing easy correlation with other information. However, for small scale investigations of specific areas, stereoscopic pairs of photographs are, and probably will remain, the most useful.

Read (1989a) concluded that wells drilled on air photo lineaments resulted in generally higher yields than those drilled on LANDSAT features. This is largely a result of the finer resolution of the air photos, with the LANDSAT imagery tending to stress large mylonitized zones where the degree of fracturing may vary greatly over short distances.

LANDSAT images and air photos are particularly useful in the northern region where surface features are visible. In the south, the

lack of surface expression due to Quaternary cover makes these methods less definitive.
Aeromagnetic data (Fig. 8), and its previous interpretation (Smith,1979), aids the location of groundwater throughout the area, but particularly in the south where other aids are less available. Major faults and thrust zones are usually reflected in the magnetic data as:

- linear, negative anomalies.
- the lack of magnetic relief along a linear trend.
- or the dislocation of otherwise recognisable trends.

In addition to the previously known faults and fracture zones, a number of lineaments have been identified in the aeromagnetics which could be major structural features. Some of the previously known features were able to be extended with the use of aeromagnetics, but a few faults had no clear magnetic signature and could not be identified.

The aeromagnetics also show sharp boundaries between the Musgrave Block and the Officer Basin, shown as a sudden change from high to low magnetic relief. A similar change in magnetics clearly shows the Levenger and Mooraliyanna Graben, which are filled with non-magnetic Adelaidean sediments.

LANDSAT imagery has also been used to define the locations of palaeochannels, but this interpretation is not definitive. Moreover, the imagery does not give any indications of the depth of the channels or the potential water quality or quantity.

Ground geophysics, particularly those methods measuring formation resistivity such as Transient Electromagnetics (TEM), can be helpful in delineating drilling targets once a fault zone has been identified. This technique has the advantage of detecting the water directly, but unfortunately is most effective for more saline waters, which are better conductors than fresh water. A further problem with the use of TEM in this area is the presence of maghemite in the soils (Lee,1984).

Maghemite is a weathering product of iron-rich rocks in tropical climates, and is very widespread in the saprolite overlying the Musgrave Block (Dodds,1996). It is expected to be less prevalent in the southern areas, where the surface layers are transported sediments, but has been found throughout the area underlain by the Musgrave Block. The effect of maghemite on TEM results, and indeed any electrical measurements, is relatively small, and has the greatest effect where signals are weak, such as the outcrop areas where water is scarce and conductivities are very low. In the southern areas, where conductivities can be expected to be higher because of the thicker overlying sediments, the maghemite effect is expected to be lower in comparison to the signal strength, and it may be possible to remove it completely.

Thus, TEM or a similar electrical method is expected to be useful, in conjunction with drilling, in evaluating the potential of the palaeochannels and graben in particular, and also for pinpointing drilling targets in the hardrock area if problems with maghemite can be overcome.

WATER QUALITY

Much of the groundwater in the Musgrave Block is of low salinity and can be used for human consumption, which is the current useage and demand. Variations in salinity are on a small scale, and cannot be predicted in general (Fig. 6).

The groundwater usually contains nitrates and fluorides greater than the World Health Organisation standards. Read (1986) discusses the level of fluoride and nitrates in the groundwater in the Musgrave Block. The fluoride is mainly derived from fluorite, apatite and mica found in crystalline basement (Driscoll 1989). Nitrates are mainly derived from the biosphere. The sources include plants fixing atmospheric nitrogen and transferring it to the soil, and the decomposition of plant and animal waste (Driscoll 1989).

In recent time the health risk of radioactivity has become a concern in the area. Radioactive elements are known to be associated with granitoid bodies. Although no official testing of water has been undertaken in the past, future work should be aware of the potential health risk.

WELL YIELDS

In the hard rock environment, well yields are invariably low, and in many cases, fragile. Yields may drop after a year or so of pumping, and show little sign of rejuvenation after similar periods of recovery. There have been sufficient wells drilled and used in this area to indicate that this is a characteristic of the area and that higher yields and more robust supplies will be exceptional.

The lack of drilling in the overlying sedimentary environment leaves the potential largely unknown. Wells in the Adelaidean sediments around Mt Chandler and in the Moorilyana Graben yielded 3.0 and 4.5 L/s, but these were exceptional as most wells had much lower yields (<1 L/s). While there is no hard evidence, the possibility of yields of the order of 2-3 L/s is quite good in the graben or the palaeochannels, where extensive beds of porous sands or gravel are possible and have been intersected in places (Levenger Graben, for instance).

GROUNDWATER SCENARIOS

A number of scenarios for groundwater reservoirs are evident from the study of the area. These are:

- in basement fractures at depths of less than 35 m unless the rock is weathered below this depth. These should be sought along shear or fault zones, which frequently stand out on aeromagnetic maps.
- in deeply weathered basement.
- in deeply incised Tertiary palaeochannels, at depths over 30 m.
- in Quaternary sediments along natural drainage lines around the fringes of, and within, the elevated basement rocks.
- in deeper sections of the Levenger Graben, probably at depths upto 100 m.

SUMMARY

The groundwater resources of the Musgrave Block fall into two main categories; good quality small supplies from fractures, weathered zones or basement lows in the rugged basement outcrop areas; and supplies of variable salinity and yield from sediments in basement lows such as palaeochannels and graben in the flat lying areas.

The basic requirement for the existence of hard rock aquifers is a permeable zone at a lower elevation than the surrounding crystalline basement. This usually, but not necessarily, comprises a fracture zone which has increased the porosity of the rock and has encouraged a further porosity increase by facilitating weathering. Such features are relatively small and narrow and may be difficult to locate sufficiently accurately for drilling, but may be indicated by lineaments on magnetic or other imagery, caused by the faults or shears. These indications however, are usually not sufficiently precise for drilling purposes.

The sedimentary environment for aquifers is a similar basement low, in this case filled with unconsolidated sedimentary material. The features tends to be more laterally extensive, but the composition of the sediments within the basement low may be highly variable so far as permeability goes. They frequently have little or no surface expression, and may be more difficult to locate. These aquifers have not been extensively tested, as the water tends to be too saline for human consumption without treatment.

The hard rock aquifers have satisfactory yields for camp or community water supplies, but would not be expected to yield larger supplies. However, the potential for larger yields is much greater in the sedimentary environment, although the quality may be poorer. The storage capacity of such aquifers is expected to be much greater, increasing the potential for large, long term supplies.

RECOMMENDATIONS

This report has summarised favourable environments for finding water in the Musgrave Block, as indicated by current data.

It is considered that finding water in the basement environment will not be made easier by further general research, although better definition of lineaments might help. While some improvement might be achieved with the existing regional data, major progress would depend on more detailed aeromagnetic surveys being flown. Further study of air photography should also assist in lineament definition. However, both of these approaches might be best left to detailed studies of discrete areas where water is required, rather than undertaking a general study of the whole area.

Testing of ground geophysical methods over known resources might also give guidance to improved methodology for locating wells in the future. Thus deeply weathered basement and fracture zones can be accurately located by electrical surveys prior to drilling. However, maghemite will continue to be a problem in such areas, and may well render electrical data worthless in some cases. The emphasis here is on refining the technology for use on discrete areas as the demand arises.

Tertiary palaeochannels are a possible untapped groundwater resource, although the salinity is expected to be too high for immediate human consumption. Large resources and good yields are possible. If it is considered that such resources may be needed, perhaps for mineral exploration or production, it would be valuable at this time to evaluate the potential of this environment. The palaeochannels can be located by TEM or seismic surveys, and likely groundwater resources mapped by TEM. Drilling would be required to test the quality and yield.

The Levenger Graben produced low yields of low salinity water from a promising consolidated sedimentary aquifer. Further study of the feature, comprising geophysics (TEM) and drilling, might map out a useful resource, as well as pinpointing the location and steepness of the edges of the graben itself. The potential recharge for this aquifer should be studied also, to determine whether it is a renewable resource.

Generally, the use of TEM in this area would be recommended for determining basement topography and for predicting water salinity. However, the widespread prevalence of maghemite in the soils of the Musgrave Block (Dodds,1996) severely limits the usefulness of the technique at present. Essentially the method is an economical way of acquiring resistivity soundings, so an investigation into minimising the effect of the maghemite or of obtaining resistivity soundings by another method is desirable to improve the exploration efficiency in the area.

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APPENDIX A

WELL EVALUATIONS

Evaluation of Sub-groupings of wells throughout the Musgrave Block (locations show in Figure 6).
The surface geology was obtained from the S.A. Geological Atlas Series.

MANN SHEET

Group 1

Wells	4744-1, 2, 3
Surface Geology	Tertiary - Quaternary sediments associated with interpreted palaeochannels. No major faulting in the area.
Well Logs	1 to 2 m of Silcrete/Limestone underlain by 3 to 7 m of Clay with Sand found at the base. Depth of wells approximately 45 m.
Hydrogeology	Water cut found to be at the base of the clay (top of the sand) Water level approximately 10 to 12 m from surface. Yield is variable and dependent on the depth to the sand. Where sand is found shallower the yield is lower (0.3 L/s) and where deeper the yield is higher (1.8 L/s) Salinity approximately 1400 mg/L.

Group 2

Wells	4744-4, 5, 6, 7, 8
Surface Geology	Quaternary sediments - Alluvial sand and silt (slope deposits) in close proximity to Mesoproterozoic inselbergs. No major faulting known in the area.
Well Logs	1 to 3 m of sand/ silt overlying granite. No mention of weathering therefore assume little or no weathering of basement rocks. Depth of wells varies from 12 to 60 m. Exception is well 4744-7 where limestone was found at a depth of 12 m, overlain by clay.
Hydrogeology	No water found. Exception well 4744 7 where yield was low (0.6 L/s) and salinity was high (6 500 mg/L).

Group 3

Wells	4944-1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
Surface Geology	Quaternary sediments - Alluvial sand and gravel (slope deposits) in close proximity to Mesoproterozoic inselbergs. No major faulting known in the area.
Well Logs	Mainly thin red brown sand (up to 5 m) overlying weathered basement to approximately 20 m. Exceptions are wells 4944-1,2 where a thick sequence of silt and silty sandstone exists.
Hydrogeology	Where wells are near or in basement outcrop water was found in the weathered part of basement at approximately 8 to 16 m. Exception is well 4944-9 where the water cut was in fresh granite at 33 m. Yield here is poor (0.3 - 0.4 L/s) but the quality of the water is good (700 - 800 mg/L). Dry holes existed where drilling ended at shallow depth 5 to 8 m. Where a thick sequence of silt and silty sandstone occurred no water was found, possibly because the sediment is acting as an aquitard.

Group 4

Wells	4845-1, 2, 4
Surface geology	Tertiary - Quaternary sediments associated with interpreted palaeochannel.
Well Logs	Mainly consists of clay, sandy/gravely clay and sand. Depth approximately 40m to intersection of basement rocks, except 4845-4, which reached 49 m without encountering basement.
Hydrogeology	Water cut at 24 to 40 m within the alluvial sediments/weathered basement. Yields depend on the host material, ranging from 0.3 in the shallower weathered basement to 3.7 L/s in the deeper alluvial sediments. Salinity approximately 800 to 1700 mg/L.

Group 5

Wells	4945-7, 8, 10, 11, 13, 16
Surface Geology	Quaternary - Alluvial sediments (slope deposits) around the fringes of the Mann Ranges. Woodroffe Thrust zone is located to the east of these wells.
Well logs	Thin alluvial cover approximately 6 m with thin to non-existent weathered basement (metasediments) in most wells becoming fresh with depth.
Hydrogeology	Where weathered basement is thin or absent the wells are non-productive. Where weathering is thicker (20 to 50 m) water is found at various depths within the weathered zone. Yields vary with higher yields (2 L/s) found with thicker intervals of weathered granulite.

Group 6

Wells	4945-1, 2, 3, 6, 9, 12, 14, 15, 17
Surface Geology	Quaternary - Alluvial sediments (slope deposits) along the southern fringes of the Mann Ranges Some wells are related to drainage channels in the area. A major fault (Mann Fault) is found to intersect the area.
Wells Logs	Thin alluvial deposits in most wells (6 m) underlain by a thick sequence of weathered basement (up to 50 m). Exceptions are wells 4945-3, 9 and 12 where a thick sequence of alluvial deposits (up to 55 m) is underlain by weathered or broken granite. This is possibly a palaeochannel.
Hydrogeology	Variable water cuts many approx 40 m with waterlevels relatively shallow at 7 to 20 m. Yields variable with most below 1 L/s.Those with higher yields are located on the Mann Fault. Salinity mainly 800 mg/L but some reach 1 500 mg/L. Salinity increases with increases in distance from the basement outcrop of the Mann Ranges. The three wells associated with thick sediments show watercuts at 43 to 51 m with the yields small at the edges to 1 L/s in the deeper parts. Salinity 700 - 800 mg/L on the outer edges decreasing to 500 mg/L in the deeper part.

WOODROFFE SHEET

Group 7

Wells	5045-4, 8, 9, 10, 11, 12, 13, 14, 15, 16
Surface Geology	Tertiary - Quaternary sediments associated with interpreted palaeochannels. There are minor outcrops of Giles Complex within this area.
Well Logs	Limestone underlain by varying thickness of clay and sandy clay (up to 70 m), under which is moderately to highly kaolinised anothosite (weathered to clay - Giles Complex).
Hydrogeology	Water was cut at an approximate depth of 15 - 30 m. Most in weathered basement but a few within the Quaternary/ Tertiary sediments. Water level 16 to 24 m. As these were Mineral Exploration hole there are no yields or salinities.

Group 8

Wells	5145-4, 5, 6, 7, 11, 13, 16, 17, 18, 19, 20, 21, 26, 27, 28, 29, 31, 32, 33, 34, 35, 36, 52, 53, 56, 69, 84
Surface Geology	Quaternary alluvial sediments within the main drainage lines of the Musgrave Ranges.
Well Logs	Varying thicknesses of alluvial sediments, from 3 to over 50 m., underlain by weathered metasediments (10 to 20 m thick). Weathering decreases with depth. A number of holes intersected quartzite or sandstone.
Hydrogeology	Water cut from 25 to 50 m (the majority approximately 32 m) with water levels ranging from 16 to 30m, the average being 23 m. A small number have relatively shallow watercuts and waterlevels. Many wells are dry due to their not reaching the watercut and or watertable. Yields vary from seepage to 2 L/s, the majority being less than 1 L/s. Salinity is less than 1 000 mg/L with most approx 700 mg/L. Wells which intersected the quartzite or sandstone were non - productive.

Group 9

Wells	5145-2, 3, 22, 23, 24, 25, 30, 59, 63, 66, 75, 77, 78, 79
Surface Geology	Quaternary - Alluvial sediments within close proximity to Musgrave Ranges, on the north side of Woodroffe Thrust Zone.
Well Logs	Most have thin alluvial cover at approximately 3 to 6 m, with mainly fresh granite beneath. A few wells have a thicker sequence (9 to 20 m) of alluvial deposits. A few wells also have weathered basement beneath the alluvium.
Hydrogeology	The majority of wells are non-productive due to the lack of a thick alluvial sequence and/or weathered basement. Others have watercuts between 6 and 20 m with similar water levels. Most water is found in a sequence of alluvial cover where this is reasonably thick or in the weathered basement. Yields are variable between 0.5 and 2 L/s. Salinity is also high with a range from 1 800 to 7 000 mg/L.

WOODROFFE - LINDSAY SHEETS

Group 10

Wells	5244-5, 13, 14, 16, 5243-1, 2, 3.
Surface Geology	Tertiary - Quaternary sediments associated with interpreted palaeochannels.
Well Logs	Wells intersected a sequence of clays and sands except for 5243 3, 5244 14 where basement was found at shallow depth.
Hydrogeology	Those wells which intersected thick sequences of alluvial sediments have varying yields, 0.125 L/s in shallower wells to 2.5 L/s in deeper wells. The salinities are high for the area, from 2 300 to 3 100 mg/L. Wells 5243-3 and 5344-14, which are drilled into basement, have low yields around 0.125 L/s and show low salinity of approximately 500 mg/L.

Group 11

Wells	5144-1, 5143-1, 2, 3, 4
Surface Geology	Quaternary alluvial sediments where some small Mesoproterozoic inselbergs (granite) are in close proximity.
Well Logs	Up to 10 m of alluvial cover under which granite was struck. No indication as to weathering. Due to lack of penetration it can be assumed it was fresh granite. Exception is well 5143-2 where there was a sequence of 20 m of sand under which limestone was found. Clay was struck at 30 m.
Hydrogeology	Where basement was struck at a shallow depth the wells were dry but it must be stated that wells did not penetrate any distance into the basement, therefore not reaching the watertable. Well 5143-2 seems to have struck a channel of Quaternary/ Tertiary sediments. The water was cut at 24 m with a yield of 1.4 L/s and a salinity of 900 mg/L.

LINDSAY SHEET

Group 12

Wells	5043-2, 5143-5
Surface Geology	Tertiary - Quaternary alluvial deposits situated within a region of interpreted palaeochannels. Both Wells were in close proximity to an interpreted linear feature.
Well Logs	Approximately 20 to 25 m of sand and limestone were intersected, underlain by clay.
Hydrogeology	Watercut was shallow (3 to 4 m) with waterlevels at a similar depth. Yields of l to 2 L/s have been recorded with salinities of 1 500 to 3 000 mg/L. Relationship of water is with the channel sediments and not with the linear features.

BIRKSGATE SHEET

Group 13

Wells	4943-1, 2, 4, 7
Surface Geology	Tertiary - Quaternary sediments associated with palaeochannels.
Well Logs	Approximately 10 m of limestone under which a thick sequence of sands and clays is found.
Hydrogeology	Variable water cuts (most approximately 10 m) Generally low yields (seepage to 0.5 L/s) due to the high clay content. Salinity are high (4 000 to 30 000 mg/L)

Group 14

Wells	4843-11, 4943-3, 5, 6
Surface Geology	Quaternary sediments - wells 4843-11 and 4943-6 are associated with slope deposits near adamellitic inselbergs(Kulgera suite). The other two wells are within sand dunes.
Well Logs	Alluvial cover is 3-25 m thick. Wells 4943-3 and 5 stopped at hard basement. Well.4943-6 drilled weathered basement to 39 m. Well 4843-11 drilled deep through mafic intrusives.
Hydrogeology	Those wells drilled into slope deposits intersected water. Well 4843-11 intersected water from 60 m associated with fracture zones, the water level reaching 35 m. The yield obtained was 1.2 L/s and salinity approximately 1 000 mg/L. Well 4943-6 intersected water at 29 m within the weathered basement, with the water rising little. The yield was very small(0.1 L/s) and salinity high (1 700 mg/L). The other two wells were non productive due to fact they did not reach the water table at greater than 25 m.

Group 15

Wells	4843-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 16, 17
Surface Geology	Quaternary alluvial (slope deposits) associated with an outcrop of Wataru Gneiss (Mt Lindsay).
Well Logs	Alluvial sediments average 4 m (few up to 20 m thick) with a variable thickness of weathered basement.
Hydrogeology	Water cuts are variable from 8.2 to 86 m due to the steepness of the area, with the majority below 35 meters at or near the base of the weathered zone. The wells (4843-13 to 17) found to be dry have thin weathered basement and have not been drilled deep enough to reach the water table.

ALBERGA SHEET

Group 16

Wells	5345-2,6,8,9,10,11,19,22,23,27,28,30,33,35,37,55,58,63,83.
Surface Geology	Quaternary alluvial deposits associated with the main drainage line (Ernabella Creek) through the Musgrave ranges. Mesoproterozoic outcrop consist of Hypersthene Adamellite (Kulgera Suite).
Well Logs	There are three distinct groups in this locality: a) A number consist predominantly of quartzite or sandstone. b) A few consist of thick sequence of sands and gravels - creek bed sediments c) The remainder intersect weathered and broken granite at shallow depth (5 m).
Hydrogeology	a) water cuts are approximately 12 to 20 m with waterlevels from 10 to 14 m, yields from 0.3 to 1.5 L/s and salinities from 500 to 800 mg/L. b) water cuts are shallower, mainly about 5 m, but some up to 12 m with water levels approximately the same. Yields are between 1 and 3 L/s with salinities from 600 to 900 mg/L. c) water cuts are between 11 and 27 m, mostly at approx 15 m, with water levels at approximately 5 m. Yields are between 2.5 and 5 L/s but a few have lower yields where there is less fracturing. The salinity varyies between 450 and 1 500 mg/L, with normally greater salinities down gradient.

Group 17

Wells	5345-21, 53, 57, 65, 77, 78
Surface Geology	Quaternary alluvial deposits associated with the main drainage line (Ernabella Creek) with Mesoproterozoic metasediments in close proximity. These wells are in lower reaches of Ernabella Creek than are those in group 16.
Well logs	Intersected sequence mainly consists of sand and gravel, but a few wells intersected granite at shallow depth.
Hydrogeology	Water cut is variable between 4 and 16 m, with a water level at 4 to 11 m. Yields are 0.8 to 1.5 L/s where sand and gravel are intersected but are low (0.6 L/s) where granite is intersected at shallow depth. Salinities are variable between good and 1 500 mg/L.

Group 18 **Kenmore Park**

Wells	5345- 4, 7, 29, 34, 46, 47, 52, 66, 67, 68
Surface Geology	Mesoproterozoic metasediments at relatively high elevation, most wells being located along drainage lines filled with Quaternary alluvial deposits. The area is intersected by a major fault (Intersection Fault).
Well Logs	In most wells weathered basement was intersected at from 3 to 15 m with broken granite found below this level.
Hydrogeology	Water cuts are variable from 4 to 30 m with water levels between 3 and 9 m. The yields are variable between 0.5 and 2.5 L/s. Salinities are highly variable with low salinities (less than 1 000 mg/L) north of major fault and high salinities (generally between 1 000 and 2 000 mg/L) found south of the major fault.

Group 19

Wells	5445-4, 5, 6, 8, 14, 20, 50, 51-94, 97
Surface Geology	Quaternary Alluvium with some outcropping Mesoproterozoic metasediments. The wells are along the main drainage line of the Marryat River, North of Marryat fault.
Well Logs	There is little information on the logs
Hydrogeology	Salinities are variable from as low as 400 mg/L to as high as 10 000 mg/L Those found closest to the fault are high in salt and those further north are less saline (up to 1 000 mg/L). Yields are low, between 0.1 and 0.5 L/s.

Group 20

Wells	5445- 2, 11, 12, 13, 15
Surface Geology	Quaternary alluvial deposits, with little Mesoproterozoic outcrop in the area. Located between Camel Pad and Bully's Lineament, out of the ranges.
Well Logs	No log information.
Hydrogeology	High salinities in the range of 2 000 to 14 000 mg/L. Low yields (0.5 L/s).

Group 21

Wells	5544-13, 14, 55, 56, 57, 58, 59, 60, 61, 63, 84, 85, 86, 87, 88, 114, 115, 116, 126, 127, 128, 142, 144, 145, 146, 147, 148, 149, 160
Surface Geology	Quaternary alluvial deposits within the Moorilyanna Graben, which is filled with Proterozoic (Adelaidian) sediments. Major drainage lines are the Alberga River and Tarcoonyinna Creek.
Well Logs	Variable sand/sandstone cover 5 to 20 m thick, under which lies clay/siltstone.
Hydrogeology	Water cuts are at approximately 33 to 35 m and waterlevels at about 24 m. Yields from 0.05 to 1.3 L/s with the average of less than 0.1 L/s. Salinities approximately 3 500 to 11 000 mg/L.

APPENDIX B

POTENTIAL RECHARGE CALCULATIONS

These have been calculated from monthly rainfall and temperature figures.

The potential evapotranspiration is calculated from the average maximum and minimum temperature figures for the month, according to Thornthwaite’s equation. While this equation does not take into account such variables as wind velocity, surface porosity, and density and type of vegetation, it is at least a first step in getting some insight into potential evapotranspiration rates in areas where detailed data on such variables are not available.

The potential evapotranspiration for the month is subtracted from the actual rainfall, giving the recharge for the month. On the assumption that there is no carryover of surface water from one month to the next, negative monthly recharges are set to zero. The sum of positive monthly recharge figures gives the annual recharge.

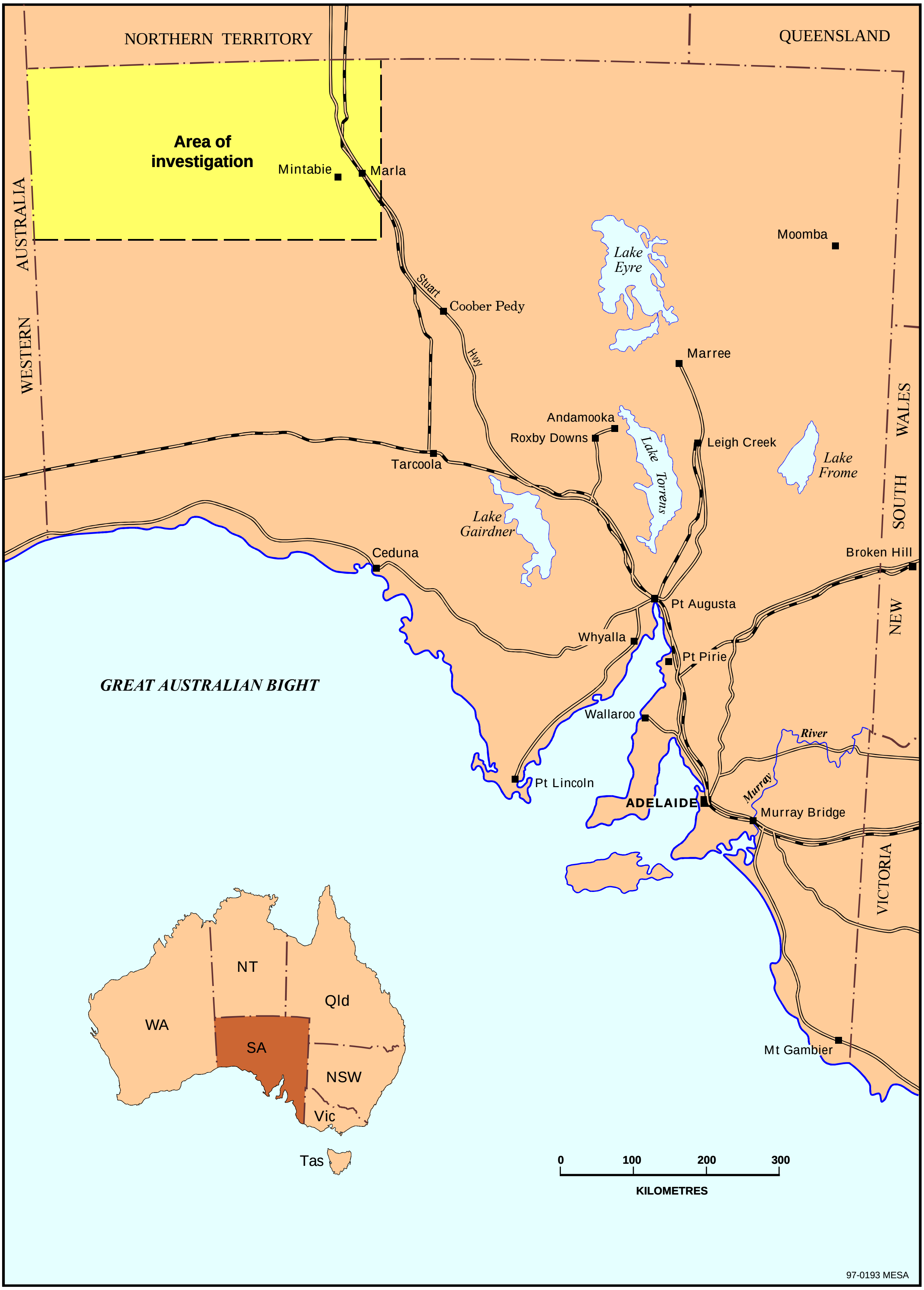


Figure 1 *Locality plan of Musgrave Block water resources evaluation study area.*

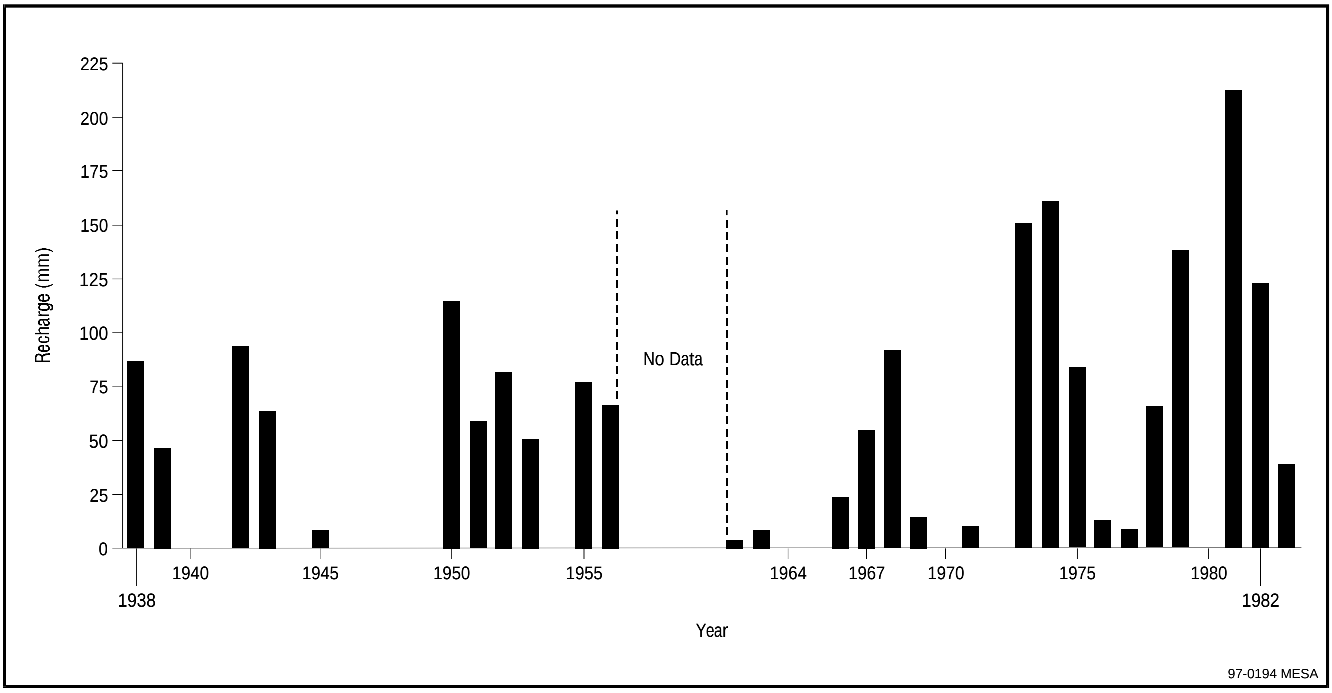
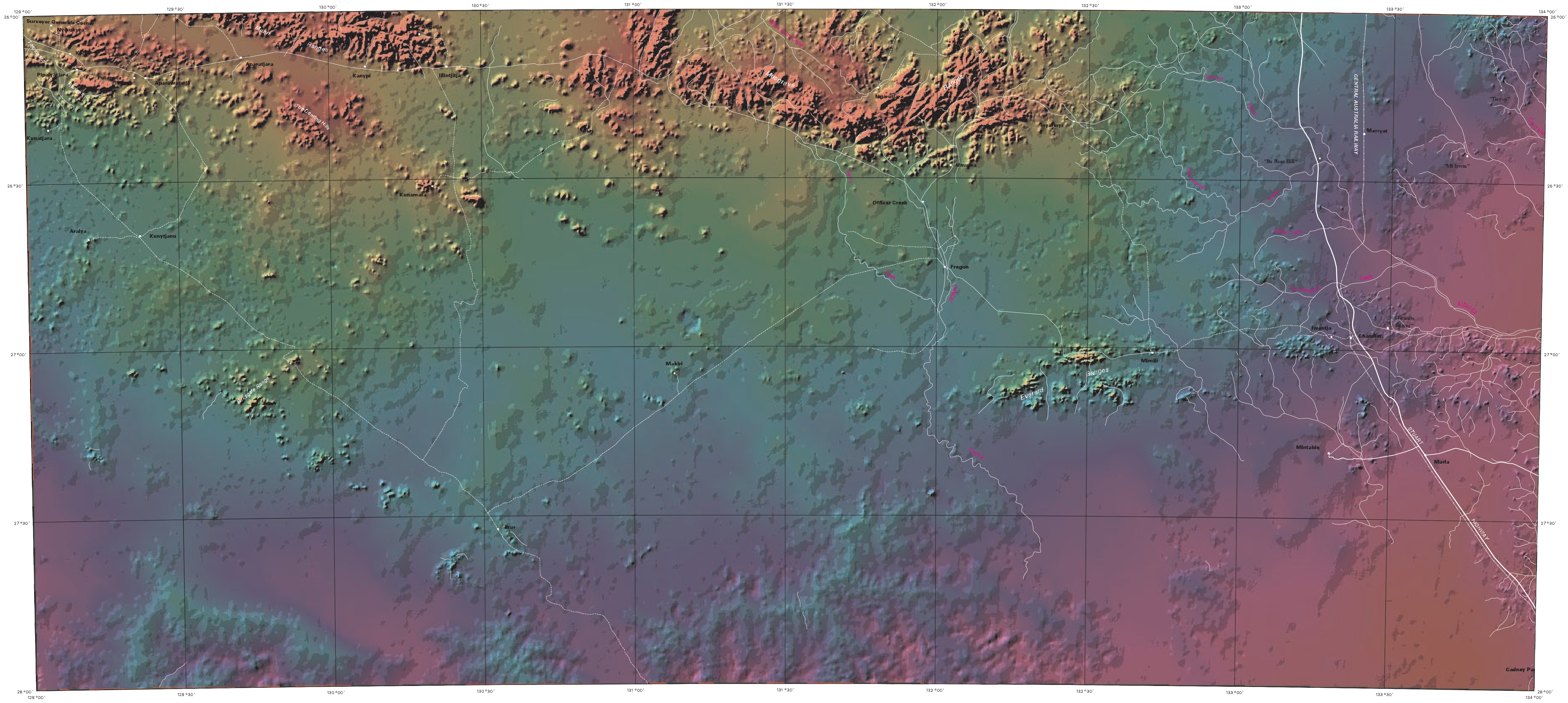


Figure 3 *Groundwater recharge potential - Ernabella.*

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK



METRES AHD

1300
1100
900
700
500
300

SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

Computer generated from SA_GEOLOGY database.

Cartography by the Mapping Section,
Spatial Information Services.

Published by, and with the authority of, the
Department of Primary Industries and Resources SA.

June 1997

Lambert Conformal Conic Projection

Topographic detail based on information supplied by
Department of Environment, Heritage and Aboriginal Affairs, South Australia.
The relationship between this data and PIRSA data is not guaranteed.

TOPOGRAPHY

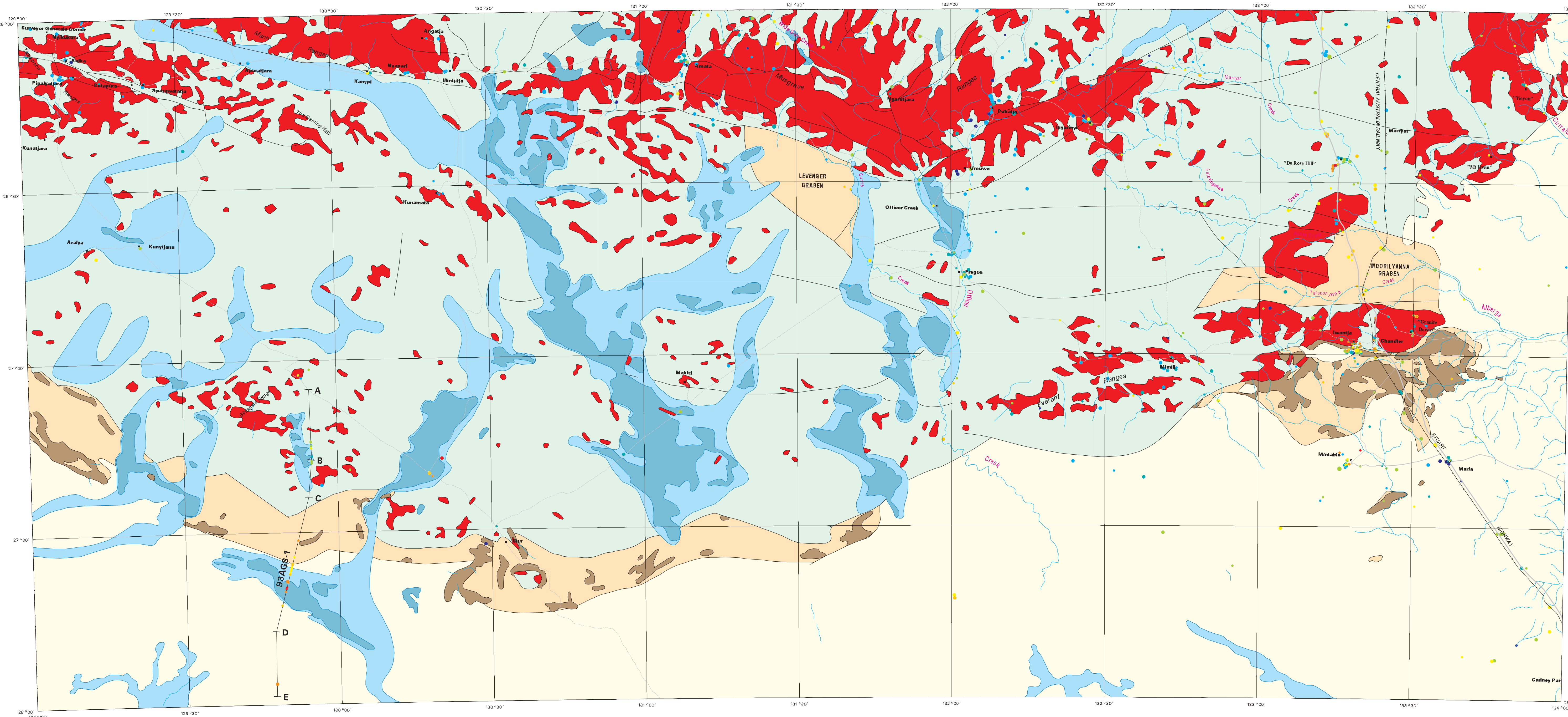
FIGURE 2

MINES and ENERGY RESOURCES
SOUTH AUSTRALIA
J100782

MESA 97-0196

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK



Outcrop	Interpreted subcrop	
		TERTIARY Clay and sand (probable palaeochannels)
		NEOPROTEROZOIC Shale and siltstone
		MESOPROTEROZOIC Crystalline basement

WATER WELL SALINITY mg/L

- 1 - <500
- 500 - <1000
- 1000 - <1500
- 1500 - <3000
- 3000 - <7000
- 7000 - <14000
- 14000 - <35000
- >= 35000

WATER WELL FLOW RATE

- Unknown
- >0 - <0.5
- 0.5 - <1.0
- 1.0 - <5.0
- >= 5.0

SCALE 1:500 000

KILOMETRES

Compilation: P. TEWKESBURY

Computer generated from SA_GEOLOGY database.

Cartography by the Mapping Section,
Spatial Information Services.

Published by, and with the authority of, the
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March 1997

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HYDROGEOLOGY

FIGURE 4

MINES and ENERGY RESOURCES SOUTH AUSTRALIA

J100782

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK

REFERENCE

- Calcrete: Sheet-like or platey masses, concentrically-laminated nodules, palaeosol mottles, and weak, lime-impregnated sand and small, fragile rhizomorphs. …… Qca
- Undifferentiated aeolian and alluvial sediments flanking the Ranges. Includes grits of angular to subangular detritus from the BIRKSGATE COMPLEX. …… Q

GREAT VICTORIA DESERT

- Aeolian sand of the dunefield: Indurated red-brown sand passing up to orange-brown calcareous sand and to red-brown sand of dune crests. Grit lag marks base, or occurs within sequence on southern end of Line 1. …… Qe$_1$

PALAEOVALLEYS OF THE EUCLA BASIN INCLUDING THE FAN OF THE SERPENTINE LAKES PALAEOVALLEY AND FANS FLANKING MOUNT POONDINNA REGION (North end line 1) AND OF THE EUCLA BASIN

- MANGATITJA FORMATION: Alluvial and lacustrine clastics and carbonate. Includes chalcedonic limestone or micrite mudstone (TmQlm$_4$), variably clayey and gritty fluvial sand (TmQlm$_5$) and grit (TmQlm$_8$), flood plain and lacustrine argillaceous, partly sandy mud (TmQlm$_7$ - red-brown upper part, and TmQlm$_6$ - green, blue grey and grey lower part). The unit forms upper part of the fan of the Serpentine Lakes Palaeochannel. Lower part may equate with Tig. …… TmQlm, TmQlm$_4$, TmQlm$_5$, TmQlm$_8$, TmQlm$_7$, TmQlm$_6$
- GARFORD FORMATION: Lacustrine and floodplain green, blue-grey and grey mud including calcareous mudstone. Includes limestone and dolomite (Tig$_2$) and local fluvial basal sands (Tig$_3$). Unit may be mottled or reddened, and basal sands may be silicified. This unit forms lower part of the fan of the Serpentine Lakes Palaeochannel. …… Tig$_2$, Tig, Tig$_3$
- NULLARBOR LIMESTONE: Marine platform deposit of bioclastic skeletal limestone with packstone and minor porous grainstone. Indurated and crystallised. …… Tun
- YARLE SANDSONE: Very fine to fine, well sorted sand, clayey sand and stiff clay-sand with scattered medium to very coarse grains. …… Tiy
- Yellow, yellow-brown weathering and rhizomorph formation. Rhizomorphs may be silicified or lime cemented. Developed primarily in ЄK$_1$ and Tbo. …… TQ$_{we1}$
- Ferricrete: Various forms including some with an associated underlying mottled profile. May have associated polycyclic lags of buckshot gravel. …… T$_{fe}$
- Silcrete: Pedogenic forms characterised by floating fabrics, columnar habit and helmut cap structures; groundwater forms characterised by glassy aspect and framework-supported fabrics. …… T$_{si}$
- Deep weathering: White to off-white, chemical alteration products (mainly clay). Saprolite and clay-quartz rock extensively formed in BIRKSGATE COMPLEX (weathering front indicated). May be capped by ferricrete and silcrete in compound (polycyclic) profiles. …… KT$_{dw}$
- Unnamed sediments: Terriginous quartz-rich partly carbonaceous sand and mud, minor grits and rarely shelly (Ti$_3$). Medium-grained, well-sorted quartz sand of coastal dune cores (Ti$_2$). …… Ti$_2$, Ti$_3$
- Aeolian quartz sand, in part spicule-bearing, of the Ooldea Range. …… Tbo
- HAMPTON SANDSTONE: Marine and esturine sand and grit. In part silceous sponge spicule-bearing. Prominent beach or near shore grit marker of Line 5 (Tbh$_2$). Local pebbly basal grits of Line 6 mark marine flooding surface. …… Tbh, Tbh$_2$
- PIDINGA FORMATION: Partly carbonaceous and wood-bearing quartz sand and grit of buried palaeovalleys. Muddy, very fine sand to sandy mud at base of, and interbedded in Hampton Sandstone deposited in estuaries and interdistributary bays. May contain spicules. …… Tbp

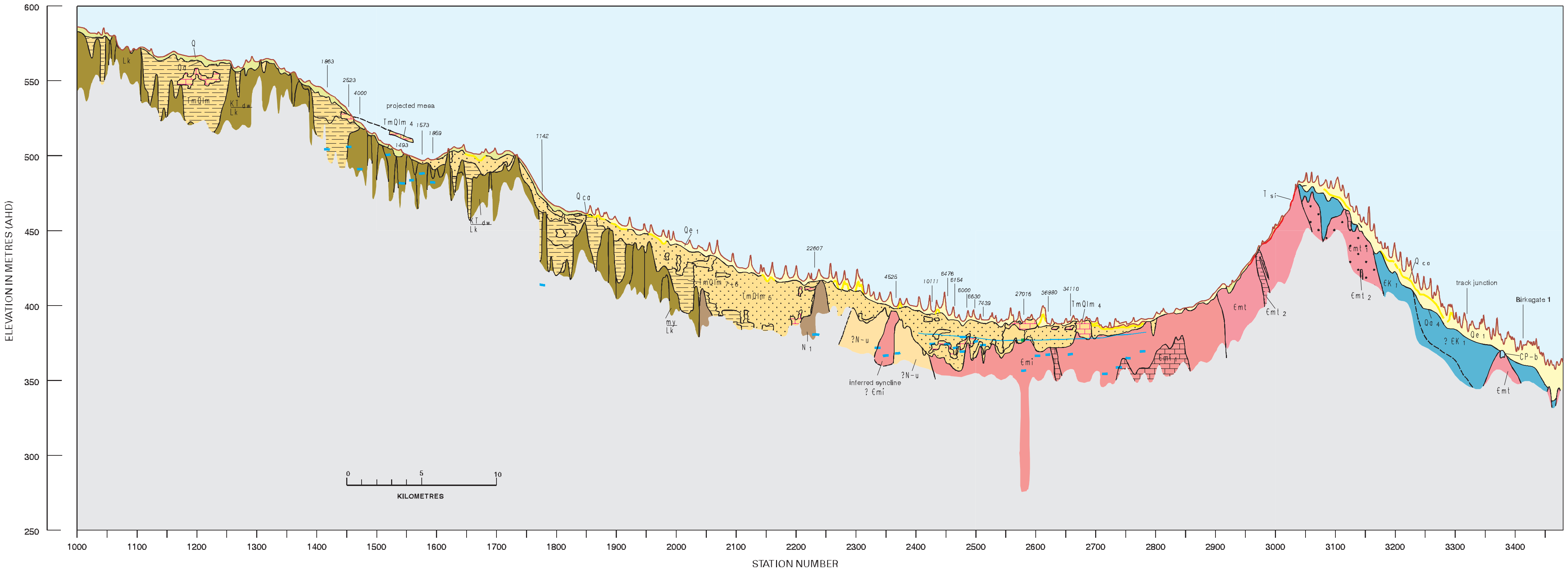
- Undifferentiated deposits of BIGHT BASIN. Includes partly carbonaceous mud and sand intersected on southern end of Line 1. …… K
- ?BOORTHANNA FORMATION EQUIVALENT: Conglomeratic, poorly sorted sand with very small rounded pebbles of diverse lithologies. …… ?CP-b
- Unamed sand: Sand, gritty sand (bimodal) and partly pebbly local basal grit. Unit is clean, white to grey at depth and weathered (TQ$_{we1}$) at top. Locally a marked hiatus with underlying Officer Basin sediments. …… ЄK$_1$

OFFICER BASIN

- MARLA GROUP …… Єm
- TRAINOR HILL SANDSTONE: Very fine to fine grained well sorted kaolinitic sandstone. In upper part may be medium to coarse grained with some rounded, very coarse to granule sized grains (Єmt$_1$). Interbeds of micro-micaceous mudstone including a dark grey organic mud marker on Line 6 (Єmt$_2$). …… Єmt
- WIRRILDAR BEDS: Brown, maroon, purple, variably micaceous mudstone and very fine sandstone. Calcareous mudstone and carbonate including ooid-bearing micrite (Єmi$_1$). …… Єmi
- PUNKERRI SANDSTONE: Very fine to medium grained white clayey and siliceous sandstone and purple, hard, well-sorted ferruginous sandstone. …… N-u
- Undifferentiated WRIGHT HILL BEDS, ALINYA FORMATION and PINDYIN SANDSTONE. Sandstone, microcrystalline carbonate and varicoloured claystone. …… N$_1$

MUSGRAVE COMPLEX

- BIRKSGATE COMPLEX: Granitic gneiss and foliated medium to coarse grained PERMANO ADAMELLITE, which is biotite and hornblende-bearing in part, and porphyritic (Lk). Mylonite (my) near southern end of line. …… Lk, my



- Ground surface (A.H.D.) ……
- Salinity (mg/L) …… 4332
- Standing water level ……
- Water cut ……
- Potentiometric surface, tentative ……

Data extracted from Plate 6,
Geological Atlas of the Officer Basin, South Australia

Computer generated from SA_GEOLOGY database.

Cartography by the Mapping Section,
Spatial Information Services.

Published by, and with the authority of, the
Department of Primary Industries and Resources SA.

MINES and ENERGY RESOURCES SOUTH AUSTRALIA

SEISMIC LINE 93AGS-1

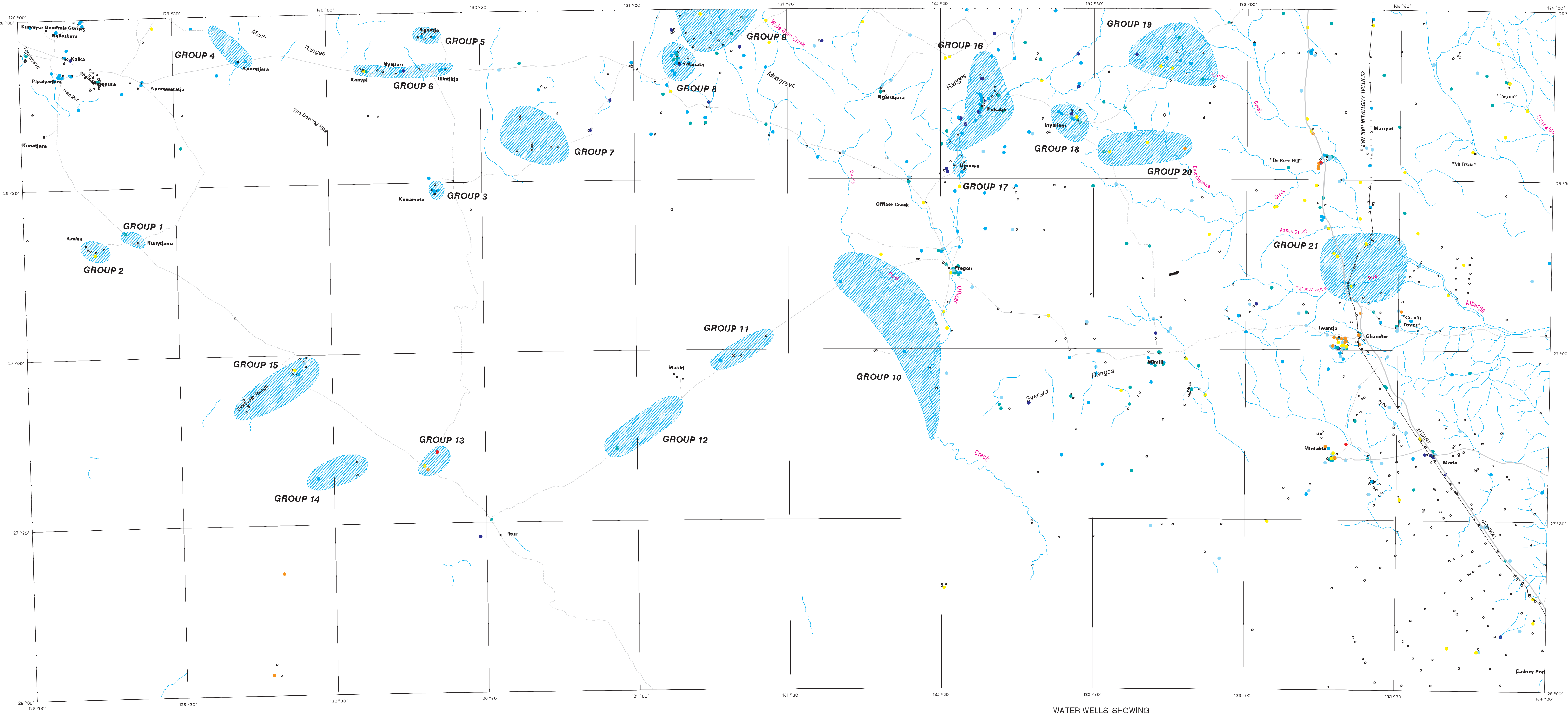
FIGURE 5

J100782

MESA 97-0200

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK



Compilation: P. Tewkesbury

Computer generated from SA_DATA database

Cartography by the Mapping Section,
Mapping and Spatial Data Services.

Published by, and with the authority of,
the South Australian Department of Mines and Energy Resources.

Lambert Conformal Conic Projection

Topographic detail based on information supplied by
Department of Environment and Natural Resources, South Australia.
The relationship between this data and MESA data is not guaranteed.

SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

March 1997

Drillhole
(no water information)

Water well group

WATER WELLS, SHOWING
GROUNDWATER SALINITY in mg/L

- 1 - <500
- 500 - <1000
- 1000 - <1500
- 1500 - <3000
- 3000 - <7000
- 7000 - <14000
- 14000 - <35000
- >= 35000

GROUNDWATER QUALITY
WATER WELL GROUPS

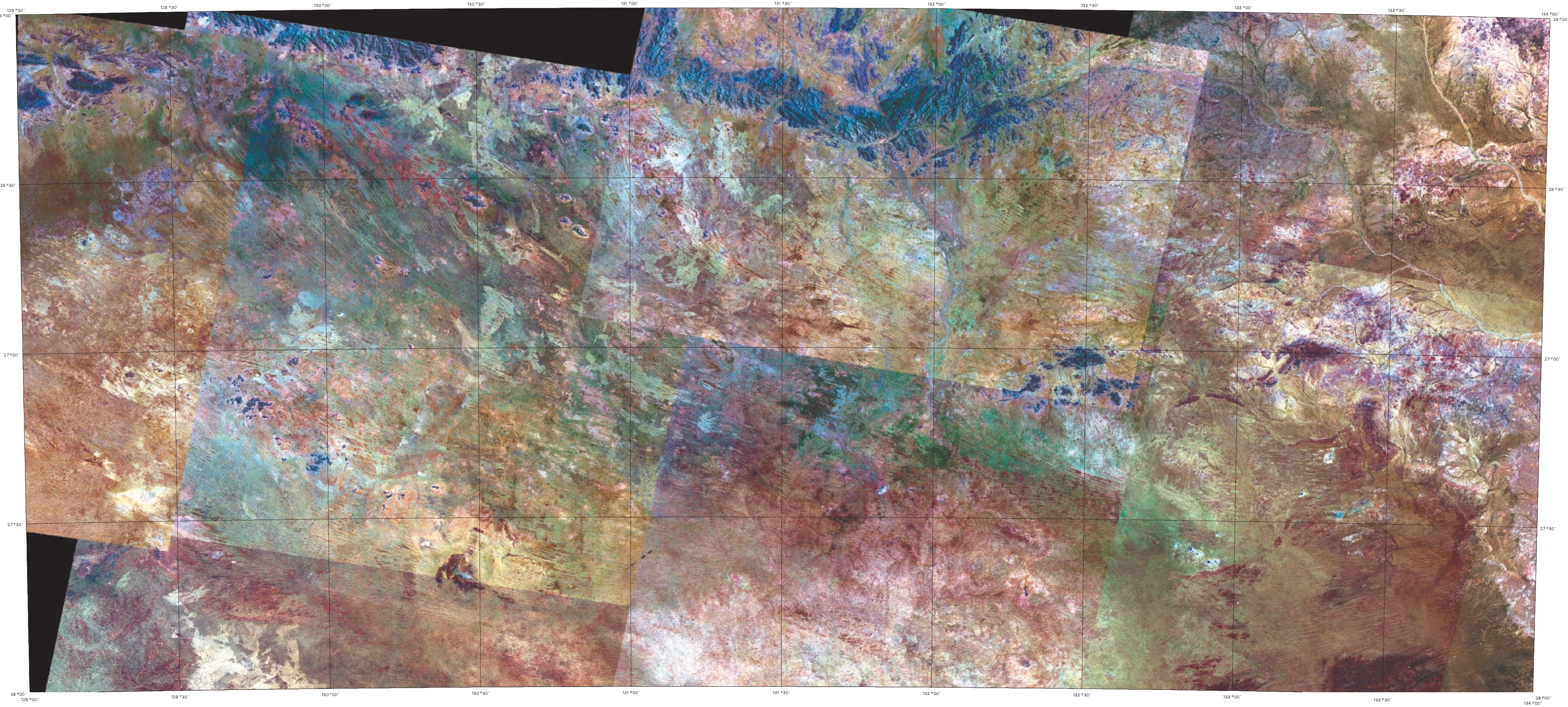
FIGURE 6

The groups of wells here are based on similarities of stratigraphy and geographic location. Groups are not exclusive, nor are the boundaries significant. The characteristics of the wells as groups, and comments on specific wells are given in Appendix A.

MINES and ENERGY RESOURCES SOUTH AUSTRALIA
J100782
MESA 97-0198

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK



SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

March 1997

Cartography by the Mapping Section,
Mapping and Spatial Data Services.

Published by, and with the authority of, the
South Australian Department of Mines and Energy Resources.

Lambert Conformal Conic Projection

Mosaicing by: Mineral Provinces,
using ERMapper Software Digital Data acquired from ACRES.
Available from DENR, 282 Richmond Road, Netley 5037.

Path 101	Row 79	Date 22/02/94
Path 102	Row 78	Date 10/09/94
Path 102	Row 79	Date 06/10/86
Path 103	Row 78	Date 07/02/89
Path 103	Row 79	Date 20/01/94
Path 104	Row 78	Date 10/10/94
Path 104	Row 79	Date 24/11/93
Path 105	Row 78	Date 01/11/88
Path 105	Row 79	Date 01/11/88

Band 5,4,2: Red, Green, Blue

LANDSAT 5
THEMATIC MAPPER IMAGERY

FIGURE 7

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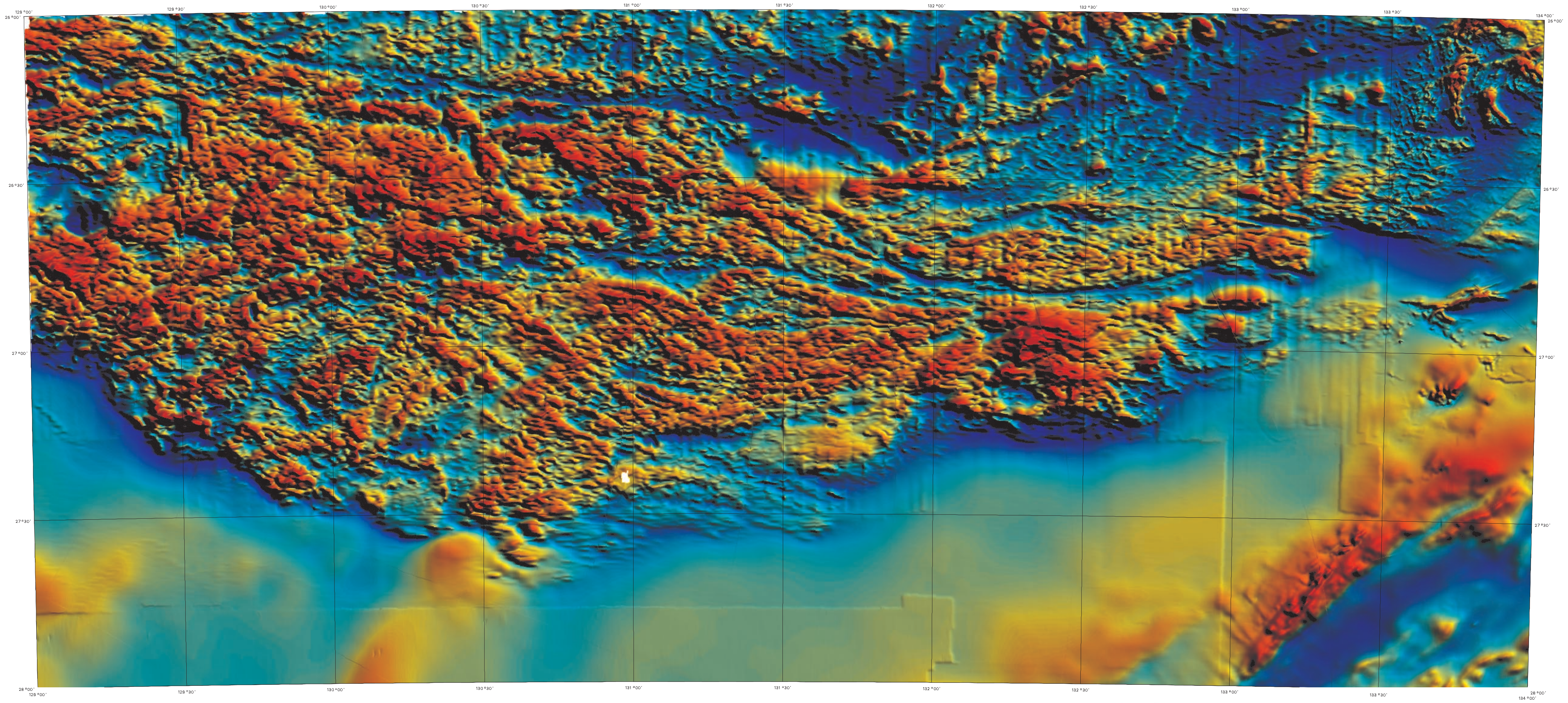
MESA 97-0199

WESTERN DESERT WATER RESOURCES APPRAISAL

MUSGRAVE BLOCK



SCALE 1:1 000 000

KILOMETRES 20 0 20 40 60 80 100 KILOMETRES

March 1997

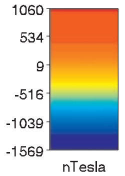
The data used in this merged aeromagnetic pixel image was flown between 1960 and 1969 by the BMR at a line spacing of 1.6 kilometres. This data was gridded, merged using Intrepid and image processed using ERMAPPER by MESA, Mineral Provinces.

This aeromagnetic pixel image is a color scaled total magnetic intensity image with relief shading and highlights from the north-east.

Cartography by the Mapping Section, Mapping and Spacial Data Services.

Published by, and with the authority of, the South Australian Department of Mines and Energy Resources.

Lambert Conformal Conic Projection.



TOTAL MAGNETIC INTENSITY

FIGURE 8

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MESA 97-0197