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SPENCER REGIONS STRATEGIC WATER MANAGEMENT STUDY

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Executive Summary

The availability of adequate water supplies is crucial to future development, particularly in the arid areas of the State. Primary Industries and Resources South Australia (PIRSA), as part of the Spencer Regions Strategic Water Management Study, has undertaken a review of the available groundwater resources throughout the study area. Unexploited groundwater resources are not uniformly available throughout this region and the groundwater that is available is highly variable in quantity and quality. This report provides an inventory of the total groundwater resources available in the region and makes an appraisal concerning the potential for enhanced aquifer recharge.

Although there are a variety of techniques that can be adopted to enhance the natural recharge to the different aquifer types that are found throughout the study region, each sub-region is considerably different. There are still many issues that are not well known concerning the environmental sustainability of the arid regions and how vital the severe storm events are to the ecology of the area. Any development that incorporates enhanced aquifer recharge will require an in-depth feasibility study to address many of the outstanding issues and to determine the best technique suitable for the selected area.

New developments can arise within the area of interest which have the potential to require large annual volumes of water. Such developments are likely to occur in locations where the water yield is inadequate, or the quality of the local water may not be suitable for the intended use without treatment. Some of the future developments within the study region are likely to be linked to mineral processing, tourism, development of aquaculture ventures along the coastal regions and, to a lesser extent, pastoral development.

Groundwater exploration in this region has traditionally focussed on the search for potable or stock quality water supplies. With the emergence of new industries such as, aquaculture, and the increased potential for mining development, quantity rather than quality has become the new focus for the sustainable use of groundwater. Consequently, sources of groundwater that were previously considered unusable because of the high salinity may now provide the region with significant potential for increased economic development.

Throughout the study region, the mixed geology (marine, terrestrial, hardrock and aeolian) resulting from the diverse depositional environments has resulted in a variety of complex aquifer types and the estimates made in this report, concerning the total volume of water in storage and the sustainable yield should be considered as a first order approximation only.

Groundwater underlies most of the region, but is highly variable in quantity and quality. Large sustainable reserves exist in the sedimentary sequences of the Great Artesian and Officer Basins. Saline groundwater occurs in the sedimentary sequences of the Eucla Basin. Throughout the Pirie–Torrens Basin there are substantial supplies of groundwater ranging in quality from potable to highly saline and similarly, within the deeper sediments in the smaller groundwater basins of Willochra, Walloway and Booborowie, supplies of good quality groundwater can be obtained.

Eyre Peninsula and the aeolian deposits on Yorke Peninsula host a number of fresh groundwater lenses. The areal extent of these potable supplies do not correlate to a groundwater or geological basin but are defined throughout the region by the 1000 mg/L isohaline contour. Many of these lenses are currently utilised to augment the reticulated water supply for Eyre Peninsula.

The extensive network of Tertiary palaeochannels, which act as drainage courses from the Gawler Craton region to the Eucla Basin, are potential sources for supplies of saline groundwater suitable for mineral processing. The Garford palaeochannel to the north of the Challenger prospect contains a 10 to 15 m thick saturated sequence with an estimated 300 000 ML of water in storage. The Tallaringa palaeochannel on the north-west margin of the Gawler Craton contains a considerable thickness of sand which may potentially contain upwards of 900 000 ML of water in storage. Similar palaeochannels occur to the south-west of Tarcoola and also to the south of the Gawler Range Volcanics.

Other small localised supplies of potable fresh water occur throughout the region in small playas of which their occurrence is closely controlled by Pleistocene and late Tertiary shoreline features. Substantial reserves from low yielding wells are also available from within the fractured crystalline rocks of the Musgrave Complex in the northern part of the state and along the extent of the Adelaide Geosyncline.

In terms of supplying or creating additional reserves of potable water, opportunities for the integration of surface water capture and underground storage throughout the study area are numerous. There are probably few if any areas where this integration cannot be applied beneficially to meet a variety of needs;

- **where water resources are unreliable due to seasonal variability in flow or quality, enhanced natural recharge incorporating aquifer storage and recovery (ASR) techniques can be used to enhance reliability and supplement the yield**

- **where water resources are scarce, ASR may be used to store the available supplies underground, eliminating evaporation losses associated with surface reservoirs.**

Incorporating ASR as one of the tools to assist with resource management can reduce the reliance of users on imported waters by;

- **improving groundwater quality locally for irrigation and industrial use.**

- **creating low salinity lenses for domestic water supply within saline aquifers.**

- **reduce the dependence of urban and rural users on traditional high cost water supplies such as the River Murray.**

- **maintain groundwater systems for current and future development.**

Stormwater is the most obvious source of surplus water to be stored (390 000 ML/year generated in SA). An alternative approach to the harvesting of stormwater, would be to take water from the pipeline during periods of low demand and inject into the deeper aquifers; thereby, providing a balancing storage for later reuse during periods of high demand. This would facilitate in balancing the demand over some sections of the pipeline that are already heavily committed during peak demand periods.

INTRODUCTION

The Spencer Regions Strategic Water Management Study covers an area of approximately 1 million km^2 which is over 75% of the state of South Australia (Fig. 1). The overall objectives of this study have been to evaluate all conventional and unconventional water resources within the region to assist in the development of strategic water management plans which optimise the ecologically sustainable contribution of local and imported waters to the future development needs of the region. The project has been structured to focus on a number of best management practices including: a catchment (water management area) approach to total water cycle management and waste minimisation; water management options including the integrated development of all ground, surface and waste waters, matched to demands of different quantity and quality requirements; assessing local characteristics to determine how best to apply emerging technologies relating to; loss minimisation; aquifer storage and recovery (ASR); wastewater treatment and reuse; desalinisation utilising local industrial waste heat and demand management.

Primary Industries and Resources South Australia (PIRSA), as part of the Spencer Regions Strategic Water Management Study, has undertaken a review of the available groundwater resources throughout the study area. The area has been divided into three broad regions: the first encompasses the Pirie–Torrens, Willochra, and Walloway Basins and part of the Flinders Ranges covering an area of approximately 25 000 km^2; the second region encompasses Yorke Peninsula, Eyre Peninsula and the South Australian portion of the Eucla Basin and the third region covers the mid and far North including the Great Artesian Basin, Western Deserts, northern Gawler Craton and the Officer Basin (Fig. 2).

New economic developments can arise within the area of interest which have the potential to require large annual volumes of water. Such developments are likely to occur in locations where the water yield is inadequate, or the quality of the local water may not be suitable for the intended use without treatment. Some of the future developments within the Southern Pirie–Torrens region are likely to be linked to mineral processing, tourism, and to a lesser extent, pastoral development, and the development of aquaculture ventures.

Developments in the mining industry are particularly difficult to predict because of the influence of such factors as development costs and volatile market conditions which affect the viability of any new project. The highly successful South Australian Exploration Initiative (SAEI) has stimulated a huge increase in exploration activity especially in the Gawler Craton region with several encouraging prospects already located.

In general the majority of mineral processing operations can utilise water which is up to three times more saline than that of seawater. Consequently, sources of groundwater that were previously considered unusable because of the high salinity may now provide the region with significant potential for increased economic development. Quantities demanded; however, are generally large ranging from 3 ML/day for the estimated life of a mine (5–20 years) up to 42 ML/day for large scale projects such as Olympic Dam.

The techniques used to provide potable water supplies vary widely: desalination of groundwater, although expensive, is used by several communities throughout the region. Others mix poor quality groundwater with better quality rainwater collected from roofs, rocky outcrops or specially prepared catchments to reduce salinity. Some communities such as Woomera duplicate reticulation to conserve potable water (brackish/saline water or treated sewage effluent is reticulated for non-consumptive and irrigation uses).

The conventional storage of surface water within the arid areas of the Northern region is fraught with difficulties although, these difficulties are not insurmountable. Through innovative design, such as integrating surface water interception with underground storage the region's surface water potential may be realised. Underground storage in aquifers generally provides a stable and predictable environment for storage.

In light of the perceived difficulties to be overcome in developing surface water resources in the northern areas of the region, the focus has been on groundwater from the Great Artesian Basin (GAB) to supply the bulk of the large demands in the foreseeable future. Although these reserves are extensive, careful management of large scale extraction will still be required to ensure the long-term sustainability of supplies and the preservation of the delicate ecology of the area.

Groundwater contained within the palaeochannel network throughout the northern region may provide an alternative supply to that of the GAB, which may be too far away to provide an economic water supply for the development of many smaller mineral discoveries within the Gawler Craton area.

Throughout the study region, the mixed geology (marine, terrestrial, hardrock and aeolian) resulting from the diverse depositional environments has resulted in a variety of complex aquifer types. The key to economically harvesting stormwater or using water from the pipeline for ASR, is the existence of a suitable host aquifer within close proximity of the water source. The first part of this report focuses on the groundwater potential for the region and opportunities for enhanced natural recharge. The estimates made in this report, concerning the total volume of water in storage and the sustainable yield should be considered as a first order approximation only. The remainder of this report provides background information on the geology and hydrogeological characteristics of the study area.

POTENTIAL FOR ENHANCED NATURAL RECHARGE IN THE NORTHERN SPENCER GULF STUDY REGION

In South Australia, an increasing amount of stress is being placed on surface and groundwater resources to meet the demands of expanding irrigated horticultural areas and urban populations. The availability of adequate water supplies are crucial to the future development prospects of most regions throughout South Australia.

Groundwater exploration throughout the study region has traditionally focussed on the search for potable or stock quality water supplies. With the emergence of new industries such as, aquaculture, and the increased potential for mining development, quantity rather than quality has become the new focus for the sustainable use of groundwater. Consequently, sources of groundwater that were previously considered unusable because of the high salinity may now provide the region with significant potential for increased economic development.

In the early days of settlement, considerable reliance was placed on the development of local water resources. However, as time progressed, the lack of security offered, particularly during periods of extended drought, saw the demise of many local schemes and a dependence on high cost imported waters. These waters are reticulated over long distances from more secure sources such as the River Murray, ground water from the Great Artesian Basin (GAB), and ground/surface waters in southern areas of Eyre Peninsula. The continued quantitative supply of water from these sources is not of immediate concern. However, the maintenance of quality is a critical management issue and notions of increased supplies in future would require careful consideration of the impacts of development and protection of the environment.

Some reticulation systems are operating at, or near, full capacity during peak demand periods. A continued sole reliance on current sources would raise the prospect of an expensive duplication or augmentation of supply capacity to meet growing demand. Potential alternative sources of second class water supplies such as sewage effluent, urban stormwater runoff and industrial wastewater are largely ignored in many areas and could be used to reduce current demands on potable supplies from external sources.

The Aquifer Storage and Recovery (ASR) concept represents a significant new development in how water can be managed, and has the potential to increase the availability of water resources in terms of both quantity and quality; thereby, relieving the pressure on traditional water resources.

In the broader sense, opportunities exist to use ASR, to rethink traditional water management and distribution policies, and to provide cost-effective and innovative alternatives to current methods of water supply management. Optimal benefits can be obtained by conjunctively using both surface water *(including urban catchment runoff and treated wastewater)* and groundwater resources to help meet present and future water requirements.

ASR involves the opportunistic harvesting of stormwater, streamflow, or even wastewater and the storage of these waters in aquifers via injection through wells, and their subsequent recovery for beneficial use. ASR has the greatest potential in those regions which are approaching full development of their water resources or have degraded or low quality groundwater (Gerges, 1995).

Some of the issues that must be addressed to achieve successful enhanced natural recharge include:

- surface water availability of sufficient quality and quantity
- suitable land for surface works involved in surface water capture, temporary storage, treatment, transfer to the recharge site, headworks and reticulation to the demand location.
- a suitable aquifer for long term storage, additional quality modification and transmission (as may be required).
- pretreatment of the captured water as necessary to reduce suspended solids concentrations, whether by wellhead filtration or by movement through surficial sandy soils.
- a capital funding source for establishing the system, and;
- a contracted demand for the water product, adequate to ensure the ongoing profitability of the scheme.

ENHANCED NATURAL RECHARGE VIABILITY

Opportunities for the implementation of enhanced natural recharge using ASR techniques in the Northern Spencer Gulf study region are boundless.

There are probably few if any localities where ASR cannot be applied beneficially to meet a variety of needs:

- Where water resources are unreliable due to seasonal variability in flow or quality, ASR can be used to enhance reliability and supplement the yield.

- Where water resources are scarce, ASR may be used to store limited available supplies underground, eliminating evaporation and seepage losses associated with surface reservoirs.

Incorporating ASR as one of the tools for resource management can reduce the reliance of users on imported water by:

- improving groundwater quality locally for irrigation and industrial use;

- creating low salinity lenses for domestic water supply within saline aquifers;

- reducing outflow of stormwater to the marine environment;

- reducing the dependence of urban and rural users on the River Murray and;

- maintain groundwater systems for current/future development.

Stormwater is the most obvious source of surplus surface water to be stored (390 000 ML/year generated in SA). Although, the degree to which stormwaters and treated wastewaters can be put to use as economically attractive alternatives to the continued import of water from external catchments depends on the availability of sufficient storage to balance mismatches between rates of water supply and demand over seasonal and longer term drought periods. ASR offers a potentially low cost method of storing water as an alternative to surface storage where aquifers are favourable.

In some country towns of SA, annualised unit costs of SA water supplies may be considerably higher than in Adelaide due to long pipelines and relatively low water consumption. For example, in the northern region these range from $3.50 to $4.70/kL and on Eyre Peninsula $5.50 to $7.20/kL (Van der Wel and McIntosh, 1996). Expansion of water supply capacity in these locations could be more economic by development of ASR, making use of surplus pipeline capacity in winter.

Typical costs for two scales of ASR schemes are summarised in Table 1 and compared to the annual cost of mains water supply. This Table assumes that maintenance, monitoring, and depreciation costs are fixed annual costs, and that the only variable costs are for energy at 5c/kL/pump. In reality the quantity of runoff may restrict the amount of recharge. Costs will vary from site to site, depending on the depth of the target aquifer, drilling conditions, the extent of pretreatment and surface storage costs, and investigations required as part of the environment management plan (Dillon and Pavelic,1996).

Summary of 1996 costs for domestic and municipal scale ASR schemes.

Table 1 *Typical Figures*

Costs	Domestic Consumption 300 kL pa	Municipal Consumption 100 ML pa
Initial Costs	$2400	$200 000
Annual Cost - fixed Annual Cost - variable	$200 $25	$10 000 $10 000
cf. Annual cost of mains water	$270	$90 000

Without progressing through a present value analysis, using the typical figures from Table 1, it can be seen that break-even time for the domestic scale facility exceeds 10 years, and for the municipal scale facilities break-even would occur in around four years. Given that the expected lifetime of an ASR facility may exceed 20 years, municipal facilities appear to be economically attractive.

The following example provides an indicative cost of developing an ASR scheme to capture stormwater runoff assuming a catchment area of 20 sq km and an average rainfall of 200 mm. In many cases, depending on aquifer characteristics, type of well construction required, surface water availability and the nature of existing infrastructure, the costs for establishing an ASR scheme could be substantially lower than is indicated here. For each potential scheme an assessment should be undertaken to determine the feasibility of the proposed ASR scheme in order to optimise the design of the scheme to meet the perceived demand.

If up to 5% of the total rainfall runoff from the catchment can be harvested, this equates to 200 ML. Indicative costing for the construction of an ASR scheme are as follows and it is assumed that in this case existing reticulation infrastructure will be used to deliver the water to the demand centre.

Investigation	$ 100 000
Retention Basin for 200 ML	$ 250 000
3 injection wells to a total depth of 150m @ $250/m	$ 115 000
6 observation wells to total depth of 150m @ $150/m	$ 135 000
Capital Infrastructure (headworks)	$ 200 000
Operational costs over life of scheme (20 years)	$ 200 000
Total project cost	**$1 000 000**

Consumption per household is estimated to be 300 kL per year which is considered to be an average consumption within the metropolitan area (SA Water personal comm.).

Injection rate	10 L/sec
Injection Period required to inject 200 ML through 3 wells at a rate of 10 L/sec.	80 days
Cost per kL over 20 year life of scheme	$ 0.25
No. of households that could be supported using 300 kL/year	667

ASR is a technique which, under favourable conditions, can expand water supply and/or water supply capacity competitively with conventional water supplies and water supply infrastructure investments. There is ample opportunity to develop ASR facilities at the scale of municipal or large industrial water supplies, where potability standard water is not required.

Although, there are a number of techniques that can be adopted to enhance the natural recharge to the variety of aquifer types that are found throughout the study region, each sub-region is considerably different. Any developments that incorporate enhanced aquifer recharge will require an in-depth feasibility study to address many of the outstanding issues and to determine the best and most cost effective ASR scheme to satisfy the demand for the selected area.

GROUNDWATER INVENTORY

From the assessment of the geology and groundwater occurrence Table 2 has been constructed which summarises the total groundwater resources, providing a first order approximation of the estimated sustainable yield, estimated current use and, the estimated volumes available for additional use throughout the study region.

These figures represent a first order approximation and in many of the areas throughout the study region, ongoing resource assessment is likely to further refine these estimates of the total resource and sustainability.

Table 2 has been constructed from the following equation:

$$vol\ (ML) = area(m^2) \times thickness\ of\ aquifer(m) \times porosity\ (n)$$

and then divided into the categories of fresh/marginal, brackish and saline based on the isohaline contours for each group. In some regions such as the Musgrave Block estimates of the total resource availability have not been made because of the scarcity of available information.

The sustainable yield has been determined from natural recharge via rainfall as identified throughout the text and it is assumed that only 70% of the natural recharge is available for use.

Estimated use per year has been derived principally from the E&WS 1987 Water Resources Inventory and it is considered that usage of groundwater has not increased greatly over the past decade to significantly alter these figures for the majority of areas throughout the study region. Current data concerning estimated usage of groundwater on Eyre Peninsula has been provided by S. Evans (Department of Environment Heritage and Aboriginal Affairs (DEHAA)).

Estimates concerning the further potential use of the fresh/marginal groundwater resources have been derived by taking the difference between the two values of estimated sustainable yield and estimated usage. In the case of brackish and saline groundwaters the potential for additional use has been derived by determining the ratio between the total volume of fresh water and the sustainable yield and applied to the total volumes of brackish and saline groundwaters.

POTENTIAL FOR ENHANCING GROUNDWATER RECHARGE IN THE STUDY REGION

Within the Pirie–Torrens portion of the study area there is an estimated 180 GL of groundwater (Table 2) although not all of this water is available for extraction. Several areas, such as the Willochra and Walloway Basins, and localities within the lower Pirie Basin and Lochiel–Snowtown district have recorded artesian flows, but generally yields are relatively low, typically between 2 and 5 L/sec.

The low yields, coupled with a high proportion of poor quality groundwater (<10 000 ML could be considered suitable for domestic supply) has resulted in limited use of the available groundwater throughout the Pirie–Torrens region. In addition, reliance upon surface water catchments and groundwater has diminished over the past several decades, especially in those areas serviced by the Morgan–Whyalla pipeline. These areas are generally located within the Pirie Basin and include the major towns of Port Pirie, Port Augusta, Whyalla and smaller communities along the pipeline route. Other areas, such as Baroota, still place a heavy reliance upon groundwater for irrigation purposes and stock supplies.

The potential for enhancing the natural recharge via ASR techniques, within the Pirie–Torrens study area is dependent upon sufficient surface water resources being available, and also a suitable aquifer for storage of the harvested water.

Within the Pirie–Torrens portion of the study area the Flinders Ranges possess an extensive drainage network of ephemeral rivers. Although they are normally dry, extensive areas can be inundated during flood. Moreover, whilst the surface water quite fresh during high flow periods, high evaporation rates contribute to a rapid deterioration in water quality as the flows subside. Another important and distinctive feature is the high sediment load frequently encountered, particularly during early flows.

There are a number of viable alternatives for ASR within this region, predominantly along the base of the Flinders Ranges and also within the Willochra Basin. Within the Willochra Basin, water for recharge could be harvested from the Willochra Creek, thereby maintaining the sustainability of the groundwater resource. In the Pirie–Torrens Basin, many of the water courses draining from the Flinders Ranges could be harvested using off-stream storage to minimise siltation problems and to provide sufficient water for recharge.

The most prospective host sediments to target for ASR are the Tertiary sediments, notably the Cotabena Formation, Kanaka Beds and the Melton Limestone. These sediments contain up to 117 GL of water in storage (Fig. 6 and Table 2). Of the total quantity, ~18 GL is suitable for stock and irrigation supplies. The remaining supplies are likely to be suitable for a variety of industrial uses, notably ore processing. Because the Quaternary aquifers are not laterally extensive and thicknesses are highly variable, they are not considered suitable host aquifers for the inception of ASR schemes.

The Cotabena Formation of the Torrens Basin (comprising of fine to coarse grained sand, silt and sandstone) is typically between 50 to 120 m thick in places, but is more commonly 80 m thick and is overlain by between 80 and 200 m of Tertiary/Quaternary sediments (App. 2).

The Melton Limestone is a dense crystalline limestone and yields are typically low. It is considered that the storage capacity is likely to be low also; however, the possibility of large dissolution cavities existing within the rock matrix cannot be neglected. Intersecting a series of these cavities which will yield suitable quantities of water and accept the required quantities of water, relies on a degree of chance. It is considered that the best prospect for additional water supplies and/or aquifer storage are the basal sands of the Kanaka Beds. Drilling carried out during this study intersected artesian groundwater supplies at a depth of 90 m.

In order to facilitate the harvest of catchment runoff and to eliminate potential problems with siltation, off stream storage would be required. An example of using off-stream storage to harvest catchment runoff and provide a source of water suitable for recharge, is provided by the existing Nelshaby Reservoir which was originally constructed to supply Port Pirie with its water requirements prior to the establishment of the Morgan–Whyalla pipeline.

Table 2 *Groundwater inventory*

SOURCE	GROUNDWATER RESOURCES (ML) Salinity as measured by Total Dissolved Solids			
	Total Resource	Sustainable Yield/yr	Estimated use/yr	Estimated Potential/yr
PIRIE–TORRENS BASIN				
Fresh (0 – 1500 mg/L)	6 850 000	3600	1 400	2200
Brackish (1500 – 7 000 mg/L)	19 000 000		300	10 000
Saline (> 7000 mg/L)	90 500 000			47 500
WALLOWAY/WILLOCHRA				
Fresh (0 – 1500 mg/L)	5 350 000	5700	4 250	1300
Brackish (1500 – 7000 mg/L)	4 000 000			6300
Saline (> 7000 mg/L)	3 650 000			4600
ADELAIDE GEOSYNCLINE				
Fresh (0 – 1500 mg/L)	400 000 000	58 000	20 000	38 000
Brackish (1500 – 7000 mg/L)	925 000 000			135 000
Saline (> 7000 mg/L)	1 300 000 000			190 000
YORKE PENINSULA				
Fresh (0 – 1500 mg/L)	2 600 000	1800	230	1500
Brackish (1500 – 7000 mg/L)	7 000 000			4800
Saline (> 7000 mg/L)	6 500 000			4500
EYRE PENINSULA				
Fresh (0 – 1500 mg/L)	26 000 000	18 400	7800	10 600
Brackish (1500 – 7000 mg/L)	78 000 000			55 200
Saline (> 7 000 mg/L)	100 000 000			70 000
EUCLA BASIN				
Fresh (0 – 1500 mg/L)	310 000	36 000	15 000	21 000
Brackish (1500 – 7000 mg/L)	720 000			84 000
Saline (> 7000 mg/L)	5 460 000			635 000
OFFICER BASIN				
Fresh (0 – 1500 mg/L)	120 000	7	2	5
Brackish (1500 – 7000 mg/L)	240 000			14
Saline (> 7000 mg/L)	8 000 000			500
MUSGRAVE BLOCK				
Fresh (0 – 1500 mg/L)	unknown	unknown	unknown	unknown
Brackish (1500 – 7000 mg/L)	unknown			
Saline (> 7000 mg/L)	unknown			
GREAT ARTESIAN BASIN				
Fresh (0 – 1500 mg/L)	8 700 x 10^6	155 000	155 000	*Vertical leakage
Brackish (1500 – 7000 mg/L)	unknown			
Saline (> 7000 mg/L)	unknown			
PALAEOCHANNELS				
Fresh (0 – 1500 mg/L)	unknown	unknown	unknown	unknown
Brackish (1500 – 7000 mg/L)	unknown			
Saline (> 7000 mg/L)	12 x 10^6			
COASTAL DUNES				
Fresh (0 – 1500 mg/L)	170 000	6300	10	2200
Brackish (1500 – 7000 mg/L)	unknown			
Saline (> 7000 mg/L)	unknown			

Note: All values were derived by determining the saturated thickness and areal extent of the aquifers. Storage estimates are based on an effective porosity of 0.2.
* There may be a potential to harvest the vertical leakage component from the GAB.

The Nelshaby Reservoir at maximum capacity can hold up to 105 ML and has an average catchment yield of 220 ML (*source:* DENR Reservoir Tables) if all the available water was diverted. Artificial recharge using injection wells is dependant upon the targeted aquifer characteristics, but assuming that the Nelshaby Reservoir could be utilised to store water for ASR, a single recharge well operating at an injection rate of 28 L/sec could recharge 220 ML within 90 days. A single recharge well operating at an injection rate of 5 L/sec would take ~510 days to recharge 220 ML.

Water is piped into the Region from the River Murray via the Morgan–Whyalla pipeline system which has a capacity of 66 000 ML. This water provides a reticulated supply to the Iron Triangle towns (Whyalla, Port Pirie and Port Augusta), much of Yorke Peninsula and as far north as Woomera. River Murray water supplies to the Mid-North are augmented by water from the Beetaloo, Baroota and Bundaleer reservoirs. These supply, on average, 5250 ML/yr to the system at a fraction of the cost of pumping an equivalent volume from the River Murray (EWS Rpt. 86/52).

The Morgan–Whyalla pipeline offers a readily available source of supply for ASR, provided that the water recovered from the pipeline is charged at a rate equal to the cost of pumping that quantity of water. Water from the pipeline could be used for injection during periods of low demand into an appropriately constructed well field. An initial assessment indicates that 5 wells recharging at a rate of 1 ML/day/well (11.6 L/sec) could recharge up to 750 ML in 150 days which could sustain 2500 households using 300 KL/yr.

On Yorke and Eyre Peninsula's the most directly useable (TDS <7000 mg/L) groundwater resources have been identified by previous investigation drilling. However, the occurrence of relatively large reserves of saline groundwater which could be feed water for desalination or processing of mineral ore are quite substantial as shown in Table 2. The dunes along the coastal margin could be further developed to supply potable water to smaller communities located inland from the coast eg. Bookabie.

Along the coastal margin the dunes and aeolianite extend from Streaky Bay to the head of the Bight (Fowlers Bay) covering an area of approximately 420 km^2. The mobile dunes reach heights of >30 m in places although, they are not continuous across the whole area. Vegetation is sparse and generally confined to the base of the dunes. Potable supplies of water (<500 mg/L) are obtained from the dunes by many of the smaller communities eg. Fowlers Bay.

Because of the sparse vegetation and loosely consolidated sand infiltration rates are high and extremely rapid. It is assumed that almost all of the available rainfall percolates through the dunes to form a perched aquifer which may have a saturated thickness of up to 5 m beneath some of the larger dunes. More typically; however, the saturated thickness is likely to be between 1 and 2 m.

The coastal dunes rise to a height of some 15 to 20 m approximately 12 km south of Bookabie. Ground water in the immediate vicinity of Bookabie tends to be saline (>3000 mg/L) however, there are small isolated lenses where the quality of ground water is less than 3000 mg/L. These lenses are relatively small and seepage from rainfall is the dominant mechanism for natural recharge to these lenses. Ground water is typically between 5 and 10 m below natural ground surface in this region and yields are typically less than 1 L/sec.

The coastal dunes lie some 12 km south of Bookabie and in this region cover an area of approximately 35 km^2. Yields from the dunes are likely to be low (approximately 0.5 to 1 L/sec) because of the characteristics of the loose unconsolidated sands. Consequently, in order to meet a large demand of 1 to 2 ML/day it would require approximately 50 wells to deliver 2 ML/day.

Given the area of the dunes within a close proximity of Bookabie (35 km^2) an estimated porosity of 0.2 (medium value for unconsolidated dune sand) and a saturated thickness of 2 m, this equates to a potential volume in storage of ground water with a salinity <1500 mg/L of some 14 000 ML although not all of this ground water is available for extraction. If the annual recharge from rainfall is equal to 15 mm/year, this equates to a total recharge volume of 525 ML/year. A first order approximation of the sustainable yield, assuming 70% of the recharged water could be recovered, is equal to 370 ML/year.

There is considerable scope to further develop this ground water resource, however any future development would require that the volumes and sustainability be proved up to determine the potential of supplies from this source. The perched aquifer within the coastal dunes is very dependant on rainfall and as such is likely to be a very fragile system. Over-pumping by large extraction wells would result in upconing of saline water. Therefore, stringent management guidelines would need to be adopted to ensure the sustainable use of ground water from this source.

One method of development would be to “harvest” the winter infiltration from the dunes and then pipe the water inland and store in the nearby ground water lenses around Bookabie. Harvesting the natural recharge to the dunes in winter would effectively capture water which may otherwise be lost as discharge to the sea or evaporative losses during summer.

A large diameter central collector well could be constructed with several small galleys radiating away from the collector well. During winter the excess infiltration could be harvested and pumped inland to Bookabie where it could be recharged into the ground water lenses via infiltration basins thereby providing balancing storage for later re-use in the summer. Using the following assumptions the expected rise in water table levels beneath the infiltration basin have been calculated.

Volume of water required to be stored
100 ML
Rate of recharge
0.56 ML/day over six month period
Rate of withdrawal (max)
1.76 ML/day over two month period

Using an infiltration basin partially filled with gravel then covered by a thin veneer of graded sand for filtration and entrapment of suspended solids, organic and biota, an infiltration rate of 0.22 m/day could be sustained. An infiltration rate of this magnitude would result in a rise in the potentiometric surface beneath the infiltration basin of 5.4 m (within about 3–4 m of ground level) at the completion of the recharge period.

This rise is calculated based on the following aquifer parameters:

Hydraulic conductivity	k	=	(2 m/day)
saturated thickness	b	=	(20 m)
specific yield	Sy	=	0.1
Time	T	=	180 days (6 months)
Infiltration rate		=	0.224 m/day

from the relationship cited in Bouwer (1978).

An estimated cost for such a scheme to supply a small community may be in the following order and assumes some form of distribution infrastructure already exists.

Construction of Collector well and galleys	\$3 000
Construction of Infiltration Basin approximately 100 m^2 and 3 m deep lined with gravel.	\$5 000
12 km of 100 mm dia pipe (buried)	\$10 000
Pump for pumping to distribution tank	\$3 000
Distribution tank	\$4 000
TOTAL	**\$25 000**

These are only indicative costing and variations would occur depending on the type of material used for the pipeline, if there is an existing distribution pipeline to the community and type, size and number of tanks installed. However, the costing do provide a guide for a simple scheme with the total cost per kilolitre equating to approximately 3c.

The numbers presented in Table 2 are a first order approximation only and significantly more detailed investigations would be required to accurately define total volumes of water in storage for each respective region. Detailed investigations would also be required to determine the annual sustainable yield for each area.

The potential for augmenting natural recharge in the more remote areas of the State via artificial recharge is fraught with difficulty. The scarcity of surface water precludes most forms of artificial storage and recovery. The infrequency of rainfall will hinder any attempts at improving the native groundwater quality by harvesting and injecting stormwater from major flood events. Factors, such as scarcity and frequency of rainfall, may impose constraints on the types of systems that are considered for enhancing natural recharge to aquifers, but the difficulties associated with undertaking such projects in the arid regions are not insurmountable.

If quality of the groundwater is not a major concern then a number of methods such as, paved catchment areas or detention basins may be employed to capture the surface runoff from storm events and then used to artificially enhance natural recharge to the aquifer. Such schemes would need to be designed to react quickly and economically to capture the infrequent flood events as and when they occur.

Mining sites which require dewatering (such as the Ingomar Coal deposit) may have water surplus to requirements, which could be re-injected into adjacent aquifers/palaeochannels to augment supplies for users located down gradient. The economics and feasibility of such an alternative would need to be weighed up against more traditional methods of water supply; however, this does provide an alternative strategy rather than allowing the unused water to evaporate from open storages.

Improvements in membrane filtration technology may allow for the reuse of water in mining operations. Excess water could be treated and reinjected into the aquifer to maintain aquifer pressures thereby ensuring supplies for the projected life of the mine.

The palaeochannels in the Gawler Craton and far west of the state can potentially supply much of the demand for mineral processing but are not considered suitable candidates for enhanced recharge because of the scarcity of surface supplies. Smaller channels to the south adjacent to more permanent water supplies offer the capacity to provide balancing storage during periods of low demand on the pipeline for later reuse during periods of high demand.

One such smaller palaeochannel exists in the southern portion of the Gawler Craton, and is thought to provide a connection between the southern Pirie Basin and the St. Vincent Basin south of Melton. Although very little is known about this palaeochannel, it could (if the infilling sediments are suitable) provide a balancing storage for water which could be recharged from the nearby Morgan–Whyalla pipeline, thereby increasing the amount of water available to areas of Yorke Peninsula.

In the more remote areas of the state storm events occur infrequently but with significant intensity to cause major flooding throughout the outback region. Within a relatively short time, much of this surface water has drained into the larger lakes, namely, Lakes; Eyre, Frome, Gairdner and Torrens plus a host of smaller lakes and surface depressions where it becomes progressively more saline as a result of evaporation. A proportion of this water also naturally seeps into the ground to recharge the underlying aquifers.

If demand were forthcoming from mining, pastoralists or smaller communities in these arid regions then it could be conceivable to harvest some of this surface runoff to augment natural recharge.

A second alternative may be to harvest any available surface water and inject into saline aquifers. Limited injection into saline aquifer/s will result in an improvement in water quality. Desalination plants could then be used resulting in some savings on the final water product, as the cost of desalinating groundwater of 20 000 mg/L compared to groundwater of 40 000 mg/L is more economical.

There are many areas within the study region where ASR can be incorporated as a management tool for enhancing the natural recharge, but the primary driving force as to where ASR will occur is always going to be in locations where there is a demand for the water product.

Figures 3, 4 and 5 provide an overview of the shallow groundwater resources across the state. In many areas, groundwater of considerably better quality and supply can be obtained from the deeper confined aquifers such as the GAB or Tertiary sediments in the Pirie–Torrens Basin.

Figure 3 illustrates the salinity distribution of the shallow groundwater resources as measured by TDS. The better quality groundwater can be found on the west coast and lower part of Eyre Peninsula, isolated pockets occur throughout the Northern Flinders Ranges and Musgrave Block. The latter area contains limited information and the areal extent of the better quality groundwater as illustrated on this map throughout this region may be a result of the grid cell size and contouring algorithm used to generate this coverage. In all cases, where the density of data points is small (illustrated on the insert map) the groundwater conditions in those areas should be considered as indicative only.

The coverage’s have been compiled using the best available information; however, the data is potentially skewed towards the identification of the better quality groundwater as wells that intersect saline water are often abandoned and no information is supplied. The three coverage’s (Figs 3, 4 and 5) were compiled from information held on PIRSA’s database. Each map was constructed using a 5000 m grid cell size and contoured using PETROSIES software before being recompiled in ARCVIEW to present the final coverages.

Figure 4 provides an indication as to the potential yield that may be obtained from the shallow aquifers. In general the majority of yields lie between the range of 0.5 to 2.5 L/sec.

Figure 5 gives an indication as to the depth of the water table for the shallow aquifers throughout the study region. Areas where the water table occurs at a depth of 2 m or less below ground surface such as, Cowell, on eastern Eyre Peninsula may be subjected to land salinisation. In areas where the density of data points is scarce such as, in the Western Gawler Craton Region the groundwater conditions should be considered as indicative only.

By overlaying these three coverages with surface drainage, areas can be identified where enhanced natural recharge using ASR techniques may be considered. In the more remote areas of the state where the shallow aquifer is between 5 and 20 m below natural ground surface the ASR techniques are more likely to involve the interception of surface water and infiltration via spreading basins rather than direct injection through wells. In other localities, such as hardrock, injection via a well is likely to be more practical.

The methods employed for enhanced natural recharge using ASR techniques will depend largely on the availability of surface water, and the type of sub-surface geology that constitutes the receiving aquifer.

NORTHERN SPENCER GULF STUDY REGION

CLIMATE AND SURFACE WATER

The region is semi-arid in the south, changing to arid in the north. Rainfall varies considerably over this region from areas of the Flinders and Northern Mount Lofty Ranges, which receive in excess of 500 mm/year; to the arid regions of the far north which receive less than 100 mm/year. Potential evaporation rates typically exceed rainfall, ranging from ~2000 mm/year at Port Lincoln to in excess of 3000 mm/year at Coober Pedy and Tarcoola.

Surface drainage of the Pirie–Torrens Basin flows westerly from a series of short steep water courses originating in the ranges which form the eastern margin of the basin. Two relatively large systems, the Broughton River and Willochra Creek, traverse the basin in the southern and northern parts respectively, but catchment areas for these streams lie mainly outside the Pirie–Torrens Basin (Clarke, 1990). The Willochra Creek for example, flows in a northerly direction from the Willochra Basin, through a gorge in Precambrian rocks and enters the northern part of the Pirie–Torrens Basin before subsequently discharging into Lake Torrens. These streams and rivers provide a significant proportion of the natural recharge to the aquifers within the outwash alluvium.

Over the central and northern parts of Eyre Peninsula surface runoff is almost non-existent, being confined to minor ephemeral creeks in the upland areas. Drainage is local into internal closed depressions eg. Poelpena Swamp. On lower Eyre Peninsula the Todd River is the only major surface water resource. Supplies are drawn from the Todd River into an off stream reservoir which services the reticulated water supply on lower Eyre Peninsula. The reticulated water supply is also augmented by groundwater. Although other watercourses rise in the eastern uplands and run towards Spencer Gulf, most of them disappear into salt lakes or marshes in their lower reaches.

The principal drainage pattern from the GAB feeds into the Lake Eyre depression and includes such major channels as the Diamantina River and Cooper Creek from the northeast, and the Finke, Macumba and Neales Rivers from the northwest. Subsidiary drainage systems to the west of the Peake and Denison Ranges feed into Lake Cadibarrawirracanna and the Lake Phillipson–Lake Woorong system. Lake Frome takes much of the drainage south of Cooper Creek and provides a further local base level and evaporation pan (Shepherd, 1978).

The Musgrave Ranges in the far north-west possess an extensive drainage network. These rivers are ephemeral. Although they are normally dry, extensive areas can be inundated during flood. Moreover, whilst the water can be of low salinity during high flow periods, the high evaporation rate contributes to the rapid deterioration in water quality as the flows subside. Another important and distinctive feature is the high sediment load frequently encountered, particularly during early flows.

Drainage features throughout the central portion of the state typically coincide with shallow surface depressions and small gullies. Rainfall throughout many parts of the far north is often of short duration but high intensity, and the limited drainage results in considerable overland flow and localised flooding. Many of the shallow drainage courses terminate in closed depressions and clay pans where the water accumulates and subsequently evaporates.

SOUTHERN PIRIE–TORRENS BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

The Pirie–Torrens Basin is a north-south trending structural depression coincident with the Torrens Hinge Zone, with the greatest accumulation of sediments along the flank of the Flinders and Willouran Ranges. The basin is generally considered to extend northwards between the Flinders Ranges and Lake Torrens, with the lake itself forming part of the basin. It is approximately 400 km long, varying in width from 0.8 to 40 km and with a total area of approximately 10 000 km^2 (Fig. 6) (Shepherd, 1978).

Tertiary sediments beneath the Lake Torrens lowland are non-marine, with deposition commencing in the Early Eocene, whereas those of the Pirie Basin contain marine facies, with deposition commencing in the Late Eocene. For this reason, geologically, the Pirie Basin and Torrens Basin are recognised as two discrete basins (Alley and Lindsay, 1995). However, the two basins are connected via a narrow corridor containing Cainozoic sediments north of Port Augusta (Fig. 6) and for the purposes of this report, will be treated as one groundwater basin.

Aquifers contained in the overlying Quaternary sediments are generally unconfined or semi-confined and are the major exploited aquifers for groundwater in the region. As these aquifers are contained within the outwash alluvium along old drainage courses, they are limited in areal extent and groundwater quality is variable. Throughout the Pirie–Torrens Basin, salinity in these Quaternary aquifers increase from less than 1000 mg/L near the foothills, to more than 40 000 mg/L near Lake Torrens and Spencer Gulf. Yields from these aquifer/s vary widely, but are typically between 0.6 and 2 L/sec. In some areas, the yield is only about 0.5 L/sec rising to 12 L/sec where the aquifer is more permeable.

Tertiary sands (mainly fine grained) overlie the basement rocks throughout much of the basin, with the upper boundary ~110 m below ground level. The early Tertiary Kanaka Beds contain the most prospective confined aquifers within the region in regard to further development of groundwater. Although the Tertiary sediments form a major aquifer in parts of the basin, only eleven water wells are completed in the Tertiary sediments and much of the information has been obtained from mineral exploration wells where information on water quality and yield is lacking. Recent drilling, as part of this project, confirmed that the Tertiary aquifers would be suitable for injection and could provide balancing storage for water from the Morgan–Whyalla pipeline. Results of this drilling are contained in Appendix 1 of this Report and both wells proved to be artesian where water flowed to surface at a rate of 1 L/sec. In the southern part, mainly near the foothills east of Port Pirie in the Nelshaby–Napperby area, there is limited use of groundwater from this source for market gardening purposes.

Yields obtained from the Tertiary sediments of the Pirie–Torrens Basin are also highly variable ranging between 0.5 and 22 L/sec, but typically lie in the range of 0.5 to 2 L/sec. The Tertiary aquifer is thickest along the base of the Flinders Ranges where most of the recharge occurs. As a consequence, groundwater quality in this area is typically between 1500 and 3000 mg/L rising to 40 000 mg/L westwards towards Lake Torrens and Spencer Gulf.

The structure of the Pirie–Torrens Basin is poorly known, although natural boundaries are formed by Cambrian and Precambrian basement rocks of the Mount Lofty – Flinders Ranges in the east and by Proterozoic rocks of the Stuart Shelf to the west. The western basin margin is defined by the Torrens Hinge Zone whilst along the eastern basin margin, refraction seismic studies and drilling indicate a locally complex structure of fault-controlled horsts and troughs. The northern boundary is determined by basement rock outcrops but the southern boundary is somewhat indefinite as stratigraphic evidence is lacking (Alley and Lindsay, 1995).

The southeastern boundary of the Pirie–Torrens Basin encompasses northern Yorke Peninsula, extending from Port Broughton south to Melton, then west to Wallaroo in order to include the distribution of the Melton Limestone. A connection between the northern-most St Vincent Basin and Pirie Basin occurs via a narrow trough containing Clinton Formation facies in the Crystal Brook area (Fig. 6).

Fill within the Pirie Basin comprises three major stratigraphic units (Fig. 7). The early Tertiary Kanaka Beds are unconformably overlain by late Oligocene to Early Miocene un-named marine sand and Miocene Melton Limestone, and then Gibbon Beds which comprise a sand-clay succession. The Kanaka Beds extend discontinuously from Port Augusta to northern Yorke Peninsula along the eastern basin margin and from north of Whyalla to south of Cowell in the west. In the latter area this unit is up to 60 m thick, with the basal part of the beds comprising 10–15 m of carbonaceous sand and minor conglomerate (Alley and Lindsay, 1995).

Between Whyalla and Cowell, up to 20 m of fossiliferous glauconitic gravelly sand and sandy marl may unconformably overlie the Kanaka Beds and underlie the Melton Limestone. In marginal situations, the unit becomes less fossiliferous, sandier and more gravelly laterally, and overlies basement rocks (Alley and Lindsay, 1995). Previous studies in the region (Shepherd, 1978), identified this area as the Cowell Basin, and was considered to be a separate groundwater basin; however, it is a sub-basin of the larger Pirie Basin.

Tertiary sediments within the Torrens Basin occur at a minimum depth of about 80 m to a maximum of about 270 m, as recorded in a test well drilled on Lake Torrens. Tertiary sediments include the fluvio-lacustrine Cotabena Formation which contain partly carbonaceous, fine to coarse grained sand, silt, and sandstones occasionally with thin carbonaceous clay beds (Fig. 7).

The Neuroodla Formation overlies the Cotabena Formation and is commonly ~100 m thick although up to ~250 m may be present in some areas of the basin. It is thickest along the western flank of the Flinders Ranges and generally comprises green, grey to black argillaceous and white calcareous mudstone. In the northern part of the Pirie–Torrens Basin, this unit forms a confining bed to the deeper Tertiary aquifers of the Cotabena Formation (Alley and Benbow, 1995).

Quaternary sediments within the Pirie–Torrens Basin consist of clays, gravels and sands, with some areas of surface limestone and aeolian sands. The thickness of these deposits is variable, and in places up to 180 m has been recorded.

In the Pirie Basin, Pleistocene alluvial fans comprise Hindmarsh Clay, Telford Gravel and Pooraka Formation. The Hindmarsh Clay crops out in the low ‘red cliffs’ at Port Augusta. This sequence overlies an irregular bedrock topography and total thickness is highly variable, from 40 m at Port Augusta to 150 m at Port Pirie (Callen et al., 1995). The Hindmarsh Clay is a consolidated, red, yellow and grey mottled clay and sandy clay with discrete sand and gravel lenses throughout. The Telford Gravel is typically coarse grained with large boulders throughout and forms extensive fan and colluvial deposits. The Pooraka Formation consists of unconsolidated silty clay, sand and carbonate earth with occasional gravel lenses.

These units generally occur along the eastern margin of the Pirie Basin between Port Pirie and Port Augusta. An equivalent to the Telford Gravel is an un-named sandy gravel outwash alluvium which occurs along the eastern margin of the Torrens Basin between Lake Torrens and the Flinders Ranges.

The hydrogeological units within the Pirie–Torrens Basin were separated on the basis of similar lithological and hydraulic characteristics with the nomenclature being consistent with that used by Alley and Lindsay, 1995 (Table 3). A number of cross sections (App. 2) have been constructed which show the relationship of the various hydrostratigraphic units.

HYDROGEOLOGY OF THE PIRIE–TORRENS BASIN

Aquifers contained in the Quaternary sediments (Telford Gravel) are generally unconfined or semi-confined, and are the major aquifers exploited for groundwater in the region. Figure 8 illustrates the spatial distribution of salinity throughout the Quaternary sediments and in general, groundwater ranging in salinity from 500 to 3000 mg/L is confined to a narrow strip at the base of the

Flinders Ranges and isolated pockets adjacent to drainage courses.

It should be noted that the salinity distribution map is only indicative of groundwater quality throughout the study area, and has been compiled from the latest available information held within PIRSA databases. It is probable that there are users extracting groundwater of suitable quality and quantity whose records are not held on the database.

Natural recharge is difficult to quantify and is dependant upon rainfall intensity and duration. Hydrographs from selected wells within the Baroota irrigation district (Fig. 9) from unconfined/semi confined aquifers show seasonal fluctuations with groundwater levels rising during late winter. Although the overall trend is that of declining groundwater levels (0.07 m/yr in response to pumping demands) natural recharge is between 5 and 7 mm/yr in those years with average rainfall.

Natural recharge has been determined from the following equation:

$$R_g = S_y \times \Delta_s$$

where
R_g = recharge to groundwater
S_y = specific yield
Δ_s = rise in watertable due to a specific event

For the above calculation, the specific yield has been determined to be 0.2. In exceptionally wet years eg. 1992–93, up to 20 mm of recharge can occur as is illustrated by the hydrograph for observation well NAP 002 (Fig. 10).

Figure 11 shows that the better quality groundwater (1500 to 3000 mg/L) in the Tertiary sediments also occurs adjacent to the faults along the foot of the ranges, suggesting that the faults act as preferential downward flow paths. In addition, the extensive faulting along the eastern margin of the basin potentially inhibits the lateral movement of groundwater towards Lake Torrens. However, further work would be required to substantiate these conclusions. Recent drilling, as part of thisstudy, resulted in artesian flows (0.5 to 1 L/sec) from aquifers within the Tertiary sediments.

As the Quaternary aquifers are not laterally extensive across the whole of the basin an estimate has been made as to the actual area that these aquifers occupy using the cross sections (App. 2) and from the available drilling information held on PIRSA's database. The total area of the Tertiary and Quaternary aquifers is estimated to be 15 350 km^2; however, the area that contains groundwater with a TDS of <3000 mg/L is only 1020 km^2.

Some throughflow is required to maintain the quality of the groundwater and the assumption is made that these areas of fresh to marginal groundwater occurrence are the only regions which receive recharge over the Pirie–Torrens Basin. Accordingly, the annual natural recharge from rainfall of 5 mm/year to the aquifers within the Pirie–Torrens Basin is estimated to be 5100 ML/year. However, only a percentage of the estimated annual recharge can be recovered.

Assuming that 70% of the annual recharge can be recovered, the estimated sustainable yield from the Pirie–Torrens Basin is ~3600 ML/year. Figures from a 1987 study carried out by the then Engineering and Water Supply Department estimate the use of groundwater from the Pirie–Torrens Basin to be 1700 ML/year of fresh to brackish groundwater. These figures; therefore, suggest that there is potentially a further 1900 ML/year of fresh to brackish groundwater available for other uses from within the Pirie–Torrens Basin.

Table 3 *Pirie–Torrens Basin — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
Quaternary	*Pooraka Formation:* unconsolidated silty clay, sand and carbonate earth with occasional gravel lenses.	Laterally discontinuous and occurs mainly along eastern margin of Pirie Basin.	Not known as an aquifer but small supplies may be obtained adjacent to watercourse drainage channels.
	Telford Gravel: coarse-grained sand and gravel with boulders which form fan and colluvial deposits.	Laterally discontinuous and occurs over most of Pirie–Torrens Basin.	*Semi-confined aquifer*, and is the major exploited aquifer in the region. Salinity is highly variable ranging from <1000 to 40 000 mg/L. Yield varies between 0.6 and 15 L/sec but is typically 0.6 to 2 L/sec.
	Hindmarsh Clay: mottled red, yellow grey clay. Overlies irregular bedrock topography and contains discrete sand and gravel lenses.	Only occurs between Port Augusta and Port Pirie.	Not known as an aquifer but gravel lenses may provide small stock supplies. Forms a confining bed to Tertiary aquifer where present.
Tertiary	*Gibbon Beds:* Pliocene – Pleistocene age comprising mottles clayey sand, sandy clay and conglomerate, unfossiliferous.	Occurs predominantly along western margin of Pirie Basin.	*Unconfined and semi-confined aquifer*, confining bed to Tertiary aquifer with yield typically of 0.5 to 2 L/sec. Salinity ranges between 3000 to >15 000 mg/L.
	Neuroodla Formation: green, grey to black argillaceous and white calcareous mudstone.	Occurrs throughout Torrens Basin but absent in Pirie Basin.	Regional *confining bed* across Torrens Basin, commonly ~100 m thick although up to ~250 m may be present. Thickest along western flank of the Flinders Ranges.
	Melton Limestone: upper section is composed of a fine-grained densely recrystallised quatzosed calcarenitic limestone. The middle unit typically consists of quartzose, bryozoal rich recrystallised coarse calcarenite and calcirudite. The basal unit is a gravelly quartzose, byrozoal, horizontally bedded to cross bedded calcarenite, calcirudite and calcareous sandstone.	Occurs over both the eastern and western portion of Pirie Basin.	*Confined aquifer*, typically yielding between 0.5 to 2 L/sec. Because of crystalline nature effective porosity is assumed to be low. Salinity varies from 1000 to >15 000 mg/L.
	Un-named poorly sorted thin lenticular quartzose sandstone up to 3 m thick.	Only occurs over the western margin of Pirie Basin along the Tickera Myponie Point coast.	*Confined aquifer*, salinity and yield unknown.
	Un-named glauconitic fossiliferous gravelly sand and sandy marl.	Only occurs between Whyalla and Cowell over the western margin of the basin.	*Confined aquifer*, salinity and yield unknown.

Tertiary	*Kanaka Beds:* succession of carbonaceous siltstone, shale and sand, with minor legnite. In Cowell–Whyalla area, the basal part of the beds comprise 10–15 m of carbonaceous sand and minor conglomerate. *Cotabena Formation:* comprises fluvio-lacustrine, partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite.	Widespread throughout Pirie Basin and absent in Torrens Basin. Widespread throughout Torrens Basin but absent in the shallower western and northern parts of the basin.	*Confined aquifer*, yields typically between 0.6 L/sec. Salinity variable with the better quality (<5000 mg/L) found along western margin in Cowell–Whyalla area. Often >15 000 mg/L along eastern margin. Sands form a confined aquifer with maximum thickness ~100 m, which is used for irrigation supplies in the southern part of the basin. Salinity ranges from 800 mg/L near the ranges to 30 000 mg/L near Lake Torrens.
Proterozoic	*Adelaidean:* sequence of quartzites, sandstones, limestones and siltstones. Forms the basement of the Pirie Basin.		Groundwater contained in fracture porosity. Stock supplies obtained on the edge of the basin at the foothills of the Flinders Ranges. Salinity and yield are variable. Volume in storage and rate of recharge unknown.

after Alley and Lindsay, 1995

WILLOCHRA BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

The Willochra Basin, which occupies a series of bedrock depressions between Booleroo Centre in the south and the Simmonston area in the north (Fig. 6) has an areal extent of 1165 km^2. The southern part of the basin is a graben delineated by approximately north-south trending faults, but the origin of the remainder of the depression is unknown (Alley and Lindsay, 1995). The basin is bounded by late Proterozoic and Cambrian rocks of the Adelaide Geosyncline, forming a line of rugged hills, particularly along the western margin (Shepherd, 1978). Maximum known thickness of sediments within the basin is 140 m.

Quaternary sediments consist of mottled clays, with frequent thin sand and gravel beds, particularly near the drainage lines. The basal unit, the Tertiary Langwarren Formation, comprises sand and clay with minor gravel beds and carbonaceous intervals believed to have been deposited under fluvial piedmont conditions or in a lacustrine environment (Alley and Lindsay, 1995). The confined aquifer within the Tertiary succession is a relatively fine-grained sand bed with a maximum thickness of 15 m recorded in the south. This aquifer decreases in thickness to approximately 6 m in the north, but is apparently continuous over the whole basin, yielding artesian water in the northern part of the basin margin (Shepherd, 1978). The hydrogeological units within the Willochra Basin were separated on the basis of similar lithological and hydraulic characteristics with the nomenclature being consistent with that used by Shepherd, 1978 (Table 4).

HYDROGEOLOGY OF THE WILLOCHRA BASIN

Salinity from the Tertiary aquifer is lowest around the recharge area near Mount Remarkable, being less than 1400 mg/L. Over much of the southern half of the basin, the salinity is less than 2000 mg/L rising to more than 7000 mg/L in the north. It has been estimated that the safe yield of the basin is 3400 ML/year (Shepherd, 1978).

There is adequate water suitable for stock available from the confined aquifer. Although the quality in the southern half of the basin is suitable for pastures, depletion of the aquifer would probably occur if large scale irrigation were carried out.

Potential natural recharge to the Tertiary sediments is estimated to lie in the range of 5–10 mm/yr from infiltration (Shepherd, 1978).

Given the areal extent of the basin and assuming an average thickness of sediments of 40 m, a storativity of 0.2 the estimated volume of water in storage is ~9.3 million ML although not all of this water is available for use (Table 2). Assuming an annual natural recharge from rainfall of 5 mm/year and 70% recovery of the annual recharge, the sustainable yield from the Willochra Basin is estimated to be 4000 ML/year. The Engineering and Water Supply Department study of 1987 estimated the use of groundwater from the Willochra to be 3250 ML/year of fresh groundwater.

Shepherd’s (1978) estimate of safe yield (3400 ML/year) and the 3250 ML/year currently used suggest that this basin is approaching its sustainable limit and any substantial increase in water use could threaten established town and rural water supplies.

Table 4 *Willochra Basin — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrology
Quaternary	*Unnamed*: mottled sandy clays, thin sandy clays and thin sandy beds, overlain by a hard marly limestone.	Occurs throughout basin and in places up to 90 m thick	Comprises an *unconfined aquifer* over part of the basin where more sandy facies occur. Yields generally low. Groundwater varies from stock quality to saline-unsuitable for domestic use.
Tertiary	*Unnamed*: white to creamy clays, sandy clays and clayey sands, slightly pyritic, lignitic in part. Aquifer consists of fine clayey sand overlying basement rocks at base of Tertiary.	Occurs throughout basin with maximum known thickness of 50 m	*Confined aquifer*, in sandy section 6–15 m thick overlying basement. Yield generally moderate, 200–300 kl/day. In southern half of basin groundwater is generally suitable for irrigation purposes (1000–2000 mg/L). Salinity higher in northern part of basin. Recharge by runoff from flanks of ranges. Measured hydraulic conductivity is 3 m/day.
Proterozoic	*Adelaidean:* phyllites and slates.		Small supplies occur in fractured and folded rocks. Salinity generally similar to that of the confined Tertiary aquifer.

after Shepherd, 1978

WALLOWAY BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

The Walloway Basin is a north-south orientated intermontane basin, approximately 80 km long, 16 km maximum width, occupying an area of about 650 km^2. The Tertiary succession occurs entirely subsurface, mostly in the lowland north of Orroroo (Shepherd, 1978). The Walloway Basin has been interpreted to extend ~35 km south of Orroroo to Mannanarie, but little geological information is available for the southern portion and it is uncertain whether Tertiary sediments exist beneath the Quaternary in this area (Alley and Lindsay, 1995).

Geophysical surveys indicate that the basin is probably a fault angle depression, with a fault along the southwestern margin. The unnamed Tertiary succession thickens southwestwards and also west of a probable major basement fault extending north-northwest from Orroroo. The greatest thickness of Tertiary sediments (250 m) was penetrated in SADME Walloway 1, 10 km north of Orroroo. Two lithological units have been recognised, a lower fluvial fine-grained sand with interbeded silt and clay, and an upper more extensive and continuous lacustrine unit of grey brown and black clay (Alley and Lindsay, 1995).

Artesian and non-artesian groundwaters are available from various aquifers in the basin. The artesian aquifers are more uniform and apparently extend throughout the basin in contrast to the shallow non-artesian aquifers. The latter include up to 70 m of clays with coarse gravel beds, often lenticular, which occur mainly along old drainage lines ranging in age from mid-Tertiary to Quaternary. Obscuring the older deposits are beds of Recent alluvium and outwash material, derived from the surrounding Precambrian rocks (Alley and Lindsay, 1995). Over 300 wells have been drilled in the basin. The hydrogeological units within the Walloawy Basin were separated on the basis of similar lithological and hydraulic characteristics with the nomenclature being consistent with that used by Shepherd, 1978 (Table 5).

HYDROGEOLOGY OF THE WALLOWAY BASIN

The best quality groundwater in the Tertiary aquifers occurs near Ororroo, where salinities of less than 3 000 mg/L are recorded, with a minimum of 1500–1700 mg/L in the most favourable area. Flow rates for the artesian wells are generally low, normally less than 4 L/sec. In a number of older wells, the flow rate has declined considerably, possibly through partial collapse of the fine silts and sands in the aquifer, or of the overlying clay. In properly constructed wells, yields of up to 18 L/sec may be obtained. Development to this extent; however, may result in a drawdown of up to 46 m (Shepherd, 1978).

Aquifer characteristics are almost unknown, but the results of one pump test indicated a transmissivity of 123 m/day. This test was done in a relatively low salinity area, where the sands are probably coarser and more permeable than elsewhere. For this reason it is considered that the above transmissivity value is trending toward a maximum (Shepherd, 1978).

Natural recharge is difficult to quantify and is entirely dependant upon rainfall intensity and duration. Potential natural recharge is estimated to lie in the range of 5–10 mm/year from infiltration (Shepherd, 1978). The annual sustainable yield assuming 5 mm/year recharge to the aquifer and 70% recovery is estimated to be 2300 ML/year.

Given the areal extent of the Walloway Basin and assuming an average thickness of sediments of 35 m, and a storativity of 0.2, the estimated volume of water in storage is ~4.5 million ML although not all of this water is available for use.

BOOBOROWIE VALLEY

GEOLOGY AND GROUNDWATER OCCURRENCE

The Booborowie Valley is a small alluvial basin located within the Flinders Ranges. The valley is of low relief and bounded on either side by low hilly terrain. It is infilled with ~30 m of poorly sorted piedmont gravels, silts and clays. The underlying Adelaidean rocks consist of slates, siltstones, tillites, sandstones and quartzites (Shepherd, 1978).

The main aquifer from which groundwater is abstracted, is contained within the piedmont gravels although some wells penetrate both alluvial deposits and basement rocks to augment supplies. Supplies of groundwater are predominantly used for irrigation of lucerne and stock purposes, with yields and water quality varying over a wide range.

Table 5 *Walloway Basin — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrology
Quaternary	*Recent*: loam; brown, silty, calcareous. Outwash and alluvial sandy clays and gravels.	Laterally discontinuous across basin, often lenticular. Sediments up to 70 m thick	*Unconfined aquifer* yielding stock supplies. Salinity 1000–1500 mg/L. Irrigation supplies available over a limited area from gravels at 25 m.
Tertiary	(upper undiff.) *Unnamed*: mainly sandy clays, yellow and mottled with thin sandy beds. Lacustrine and fluviatile. *'Walloway sands and clays'*: fine-grained sands and clayey sands. (lower undiff.) *'Walloway sands and clays'*: fine-grained sands, white to pale brown with minor clay interbeds.	Generally extends across most of basin. Laterally extensive across whole basin. Extends across whole basin.	Not exploited for groundwater. Forms part of the confining bed for artesian aquifer below. Not exploited for groundwater. Forms part of the confining bed for artesian aquifer below. *Artesian aquifer*, used for town water supply and irrigation purposes. Salinity ranges between 1500 and 1700 mg/L.

ADELAIDE GEOSYNCLINE

GEOLOGY AND GROUNDWATER OCCURRENCE

The quality and quantity of groundwater in the fractured rock of the Adelaide Geosyncline depends on a number of factors, the most important being:

- Degree and extent of joints and fractures
- Lithology
- Extent of weathering
- Recharge, which is dependent on quantity and frequency of rainfall or run-off.

The area included is from Mount Remarkable to Mount Painter and the rocks consist of Adelaidian metasediments with Cambrian limestones and dolomites in the northern part. Groundwater is used mainly for stock, and is suitable for irrigation in some regions (notably Clare) and is also used for water supply at Arkaroola, Hawker and Wilpena.

Groundwater with a salinity of less than 1000 mg/L is obtainable throughout regions of the Clare Valley and areas of the ABC Quartzite south of Crystal Brook. Significant areas throughout the Adelaide Geosyncline typically contain groundwater of less than 3000 mg/L concentration as shown in Figure 3; however, there are many small pockets where salinity as measured by TDS exceeds 7000 mg/L.

Yields are also extremely variable from within the metasediments of the Adelaide Geosycline ranging from 0.1 L/sec to in excess of 20 L/sec (Fig. 4). Typically, the majority of wells yield less than 2 L/sec and this large degree of variability makes it difficult to predict the quantity and quality of groundwater at a particular location.

Natural recharge to groundwater within a fractured basement rock may occur regionally or along stream lines; however, it is very difficult to predict the quantity of recharge occurring within this type of environment.

The volume of water in storage across this region of the Adelaide Geosyncline has been estimated as ~2640 GL (Table 2) however, because of the variable nature of these fractured rocks, this figure may be a gross overestimation.

An example of one region within the Adelaide Geosyncline which contains good quality groundwater is the Clare Valley. The area of the Clare Valley is approximately 400 km^2 and has an estimated annual recharge (calculated by chloride mass balance) of 7000 ML (Love, 1997). Only a percentage of the annual recharge is recoverable. Assuming that 70% could be recovered then the estimated sustainable yield of the Clare Valley is approximately 4900 ML/year. If these volumes are considered typical for the Adelaide Geosyncline, then transposing these values to encompass the entire region would imply that the potential sustainable yield of the Adelaide Geosyncline (an area of 150 000 km^2) is 58 000 ML/year.

Given the complexities of groundwater supplies from fractured rocks, any future development of these resources would require detailed studies to determine the recharge and sustainability of the resource.

YORKE PENINSULA

GEOLOGY AND GROUNDWATER OCCURRENCE

Along the east coast of Yorke Peninsula the sediments comprise Tertiary sandstones, limestones and marls of the St. Vincent Basin. They reach a maximum thickness of approximately 40 m and rest on Permian sands, Cambrian or Adelaidean rocks.

The western margin of northern Yorke Peninsula marks the southeastern boundary of the Pirie Basin, extending from Port Broughton south to Melton, then west to Wallaroo. A connection between the northern most St Vincent Basin and Pirie Basin occurs in the Crystal Brook area via a narrow trough containing Clinton Formation facies (Fig. 6).

The stratigraphy of the south-western portion of Yorke Peninsula consists essentially of two units, Pleistocene calcareous aeolianite unconformably overlying Archaean/Lower Proterozoic basement (Hussin, 1966). Recent vegetated coastal dunes consisting of fine unconsolidated sands overlying partially consolidated limestones form the western boundary of the Carribie lens. To the east, the boundary is formed by a basement high while to the south it is bounded by limestone ridges. There are no permanent or clearly defined watercourses and any surface runoff collects in interdunal depressions.

Permian and older rocks throughout Yorke Peninsula contain groundwater, but salinity is highly variable and yields are relatively low.

Groundwater occurs in the aeolianite of the Bridgewater Formation on the lower south-western part of Yorke Peninsula in the Carribie and Para Wurlie lenses: the latter providing a water supply for the township of Warooka. Aeolianite also occurs over much of the western part of the ‘foot’ of the peninsula but groundwater salinities are highly variable (Shepherd, 1978).

Evaluation of the data currently held within PIRSA’s database has resulted in the identification of an additional source of groundwater supply from within the fractured hardrock of the ABC quartzite located adjacent to The Hummocks Range at the northern end of the Yorke Peninsula. Although well records indicate the yields to be low 0.5–2 L/sec the water quality is between 500 and 1500 mg/L.

A second, potential source for groundwater is a palaeochannel southeast of Wallaroo which connects the southern portion of the Pirie Basin with that of the St. Vincent Basin (Fig. 6). No wells have been drilled in this locality and supplies, quality and yield of groundwater are unknown. The hydrogeological units across Yorke Peninsula have been separated on the basis of similar lithological and hydraulic characteristics with the nomenclature being consistent with that used by Shepherd, 1978 (Table 6).

HYDROGEOLOGY OF YORKE PENINSULA

The low salinity Carribie groundwater lens is generally less than 10 m Australian Height Datum (AHD) to a maximum of 40 m AHD. This aquifer is considered to be unconfined, although in some places it is likely to be semi-confined as a result of calcrete capping or clay layers which occur throughout the sedimentary profile. Aquifer thickness varies between 11 m in the north eastern part to a maximum thickness of 24 m in the centre of the lens.

Sediments of the Para Wurlie lens are very similar in composition to the Carribie lens and comprise calcareous sands, aeolianite and travertine limestone estimated to be a maximum of 30 m thick. The two lenses are separated by the topographic high which forms the eastern boundary of the Carribie lens. The eastern and southern boundaries of the Para Wurlie lens are believed to be structurally controlled by major faults not in evidence at the surface (Bowering, 1972).

Groundwater of less than 1000 mg/L is available from most of the wells within the Carribie and Para Wurlie lenses. Typically around the coastal margins along the ‘foot’ of Yorke Peninsula, groundwater exceeds 7000 mg/L possibly as a result of mixing between groundwater and seawater; however, further investigations would be required to confirm this.

The average transmissivity and hydraulic conductivity for the Carribie lens have been determined from pumping tests to be 2000 m/day/m and 110 m/day respectively (Mathews, 1988). Yields from the Carribie lens vary between 0.5 to 2.5 L/sec in contrast to the Para Wurlie lens were yields as high as 6.2 L/sec have been recorded.

The Tertiary sediments contain groundwater of relatively high salinity, which is suitable only for stock.

Natural recharge is by direct infiltration which is dependant upon the duration and intensity of a rainfall event. Recharge from rainfall has been estimated at 47 mm/yr determined from fluctuations in the piezometric surface (Wischusen, 1987) and 35 mm/yr from chloride concentration (Mathews, 1988*)* for the Carribie lens. Given the proximity of the Para Wurlie lens to the Carribie lens, natural recharge rates are likely to be of the same order of magnitude.

The total area of these two lenses is relatively small ~75 km^2. The annual sustainable yield assuming 35 mm/year recharge to the aquifer and 70% recovery is estimated to be 1800 ML/year while estimated usage from the E&WS Report (1987) was 230 ML/year. Therefore, there is potentially a further 1500 ML/year that could be available from this source

The Hallett Cove Sandstone contains a good aquifer along the eastern margin of the St Vincent Basin; however, on Yorke Peninsula (western margin) this formation crops out in low cliffs south of Wool Bay and is not known as an aquifer across Yorke Peninsula.

Table 6 *Yorke Peninsula — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
Recent	*Unnamed aeolian sand*: fine grained white to light brown, possible equivalent to Molineux Sand.		Not known as an aquifer
Quaternary	*Bridgewater Formation*: aeolianite; calcareous sand and rounded shell debris.	Occurs mainly from Corny Point to Cape Spencer.	*Unconfined aquifer* of Carribie and Para Wurlie Basins. Yields of 3 – 15 L/sec are obtained but may exceed 30 L/sec in some areas. Salinity variable, in basins less than 850 mg/L but rising to 3 000 – 4 000 mg/L elsewhere. Best quality groundwater generally within 3 – 4 m of the surface.
Tertiary	*Hallett Cove Sandstone*: dense sandy Limestone, rich in fossils	Occurring in east coast cliffs, south of Wool Bay.	Not known as an aquifer.
	Port Willunga Beds: doft bryozoal limestones and sandy limestones,	Occurring mainly in cliffs along the east coast south of Port Julia.	*Unconfined aquifer*, yielding stock water supplies in the Stansbury-Edithburg areas. Salinity in the range 2000–7000 mg/L and known yields less than 2 L/sec.
	Blanch Point Marls: shelly clays with discontinuous bands of dense fine-grained fossiliferous sandstone.	Occurrence confined mainly to east coast near Pine Point.	*Confining bed* where present.
	Muloowurtie Clay: ochreous sandy clays with lenses of fossiliferous sand (Maslin Sands); the latter having a thickness exceeding 120 m near Price.		Confining bed (Muloowurtie Clay). Associated sands (Maslin Sands) possibly contains only saline groundwater.
	Permian Clay: boulder till and fluvio-glacial sand occupies depressions in Precambrian basement.	Occurring mainly near Yorketown in floor of salt lakes and beneath Tertiary and Quaternary sediments.	Generally a *confining bed*, but with sandy variants which may contain small quantities of saline groundwater.

Cambrian	*Ramsay Limestone*: blue-grey crystalline nodular limestones. *Unnamed*: red beds, clastics, evaporates and shales *Parara Limestone*: blue-grey crystalline nodular limestones. *Kulpara Limestone*: blue-grey limestones with Archeocyantha.	Occurs mainly in the Minlaton-Curramulka area Occurs in the Kulpara-Ardrosan-Urania area.	The limestone may contain small quantities of groundwater, quality unknown. Generally an *unconfined aquifer* in the Minlaton-Curramulka area. Salinity 2 000-3 000 mg/L and yields 1-3 L/sec. Not known as an aquifer but may contain small quantities of groundwater. Generally an *unconfined aquifer* in the Minlaton-Curramulka area. Salinity 2 000-3 000 mg/L and yields 1-3 L/sec.
Proterozoic	*Adelaidean*: conglomerates, sandstones and shales. Lower Proterozoic gneisses, schists, granite and pegmatite, including Moonta Porphyry.	Basement across whole region. ABC quartzite forms principal unit of the Hummocks range.	Water is contained in fracture porosity notably ABC quartzite which has small yields of good quality water.

after Shepherd, 1978

EYRE PENINSULA

GEOLOGY AND GROUNDWATER OCCURRENCE

Regionally, Eyre Peninsula is underlain by crystalline basement gneisses, volcanics and granites of the Gawler Craton. A significant feature incised within the basement meta-sediments is the Polda Trough which is a narrow east-west intracratonic graben that extends about 200 km offshore from Elliston. The trough contains Permian and Jurassic sediments of sand, clay and lignite (Fig. 12).

Overlying the Polda Basin and crystalline basement is a thin veneer of Tertiary and Pleistocene sediments that form the major low salinity aquifers throughout the region (Love et al., 1996).

Sediments of Tertiary-Recent age occupy a basin extending northward from Wanilla to beyond Cummins on south-central Eyre Peninsula. The sediments consist of clays, sands, gravels and thin lignites, with a maximum thickness recorded at Cummins of 136 m. The maximum known thickness of early Tertiary (Eocene) carbonaceous, silty sands, with lignite, is 116 m. Groundwater occurs in thin sand or gravel beds, and varies considerably in yield and salinity. In some wells, salinity was found to exceed 20 000 mg/L, and yields were as low as 0.3 L/sec (Shepherd, 1978).

Northward towards Cummins, salinity increases, probably because of poorer recharge conditions and lower rainfall.

The coastal area varies from mobile sand dunes up to 30 m high to sub-vertical cliffs rising 30 to 120 m above sea level. Ephemeral lakes and swamps occur in broad depressions running sub-parallel to the coast from between 2 and 8 km inland. These salt lakes represent the final discharge for many of the groundwater lenses.

The Cowell Basin, previously identified as a separate groundwater basin by Shepherd, 1978 is in fact a sub-basin of the much larger Pirie Basin. Sediments in the Cowell sub-basin are of Tertiary–Holocene age with a maximum known thickness of 114 m. The groundwater is invariably of high salinity; at only one locality near Yeldulknie Creek on the margin of the basin can the groundwater be used for sheep. The recharge rate is unknown, but is probably quite small. Surface water entering the basin generally has a high salinity, eg. Salt Creek.

Across Eyre Peninsula the Quaternary limestone aquifer contains lithology of the Bridgewater Formation, consisting of calcareous sands, broken shell fragments and limestone. The sequence often has calcrete at the surface and can be indurated to unconsolidated throughout. It forms a thin veneer, widespread throughout western Eyre Peninsula but only becomes saturated within the fresh water lenses towards the coast. These freshwater lenses are typically surrounded by brackish to saline groundwater and because of their importance to the overall regional water resources have been proclaimed. The quality of the groundwater is almost uniform over large areas which is a reflection of the homogeneity of the rock type and a shallow groundwater depth, combined with rapid recharge over the area.

Many of the lenses within the Musgrave Proclaimed Wells Area (PWA) are not used for extraction at this time but are available for use in the future if supplies from the Tod Reservoir cannot meet demand. The major lens linked to the pipeline infrastructure servicing the upper portion of Eyre Peninsula is the Polda lens where Evans, 1994 has determined between 1350 and 2500 ML/yr is abstracted. The Polda Basin offers considerable scope for saline groundwater to be extracted from the deeper sedimentary sequences. The basement has been defined as Pre-Permian lithology consisting of metasediments, gneisses, schists and granites.

There are other similar, but smaller, Tertiary basins in the Northern part of Eyre Peninsula notably near Caralue, Kimba, Kyancutta, Rudall and Warramboo. These basins invariably contain highly saline groundwater. Across Eyre Peninsula groundwater also occurs within weathered basement; however, the salinity is often high and yields are low. The hydrogeological units across Eyre Peninsula have been separated on the basis of similar lithological and hydraulic characteristics with the nomenclature being consistent with that used by Shepherd, 1978 (Table 7).

HYDROGEOLOGY OF EYRE PENINSULA

Eyre Peninsula hosts a number of fresh groundwater lenses within the Quaternary limestone sequence. The areal extent of these potable supplies do not correlate to a groundwater or geological basin but are defined throughout the region by the 1000 mg/L isohaline contour (Love et al., 1996). The lenses can be separated into two groups: the Lincoln A, B and C, Uley-Wanilla, Uley South, Uley East A and B, Coffin Bay A, B, and C, all lie south of Yeelanna on the Lincoln 250 000 mapsheet. Other lenses along the western margin of Eyre Peninsula all lie within the Musgrave Proclaimed Wells Area (PWA) between Mt Hope and Streaky Bay and include: the Sheringa A and B, Kappawanta, Bramfield, Polda, Talia, Port Kenny and Robinson lenses.

The potable groundwater lenses occur across Eyre Peninsula due to the ability of the host rock to receive rapid recharge via sinkholes and dissolution features. This has resulted in higher recharge rates and significantly lower salinity groundwater than would normally be associated with similar semi-arid environments (Love et al., 1996). Salinity of the groundwater within the Quaternary limestone aquifer ranges from <1000 to >6000 mg/L.

Love et al., 1996 has identified that the shallow groundwater systems on Eyre Peninsula are recharge controlled and a strong correlation exists between changes in groundwater levels and rainfall indicating a positive relationship between rainfall and recharge events.

The Jurassic sequence occurring in the Polda Trough (Table 7, Fig. 13) consists of sands, silts, carbonaceous clays and lignite. Aquifers within the sequence are considered to be confined and typically have low hydraulic conductivity. The groundwater is saline ranging between 30 000 to 50 000 mg/L. The transmissivity of the sequence is low (between 0.6 and 45 m/day/m) with a storage coefficient in the range of $1x10^{-4}$ to $1x10^{-6}$ (Love et al., 1996). The aquifer is not considered to have any potential for development for potable supplies due to its low hydraulic conductivity and saline water but may have considerable scope for industrial use. The Tertiary sands of the Polda Trough are a thick interbedded sequence of unconsolidated sands, silts and clays containing a series of confining beds and aquifers.

Across the remainder of Eyre Peninsula the Tertiary sediments are often clayey at the top grading to fine sand at the base, where the sequence lies unconformably on weathered crystalline basement (Fig. 14). The Tertiary sand aquifer is distributed throughout Eyre Peninsula and contains aquifers that are either semi-confined or confined. The transmissivity varies from 20 to 270 m/day/m whilst the storage coefficient is between $1x10^{-3}$ to $1x10^{-4}$.

In the County Musgrave PWA there is only a small head difference (<1 m) between the Tertiary sand aquifer and the overlying Quaternary limestone aquifer. This suggests that there is minimal inter-aquifer leakage between the two systems under the current day hydraulic regime. Salinity is variable, typically increasing with depth, and ranges between 800 to <30 000 mg/L in places (Love et al., 1996).

Love et al., 1996 reports that the aquifer has the hydraulic characteristics of a dual porosity media with both karstic and porous medium flow. Karstic flow occurs through solution enlarged cavities and fractures allowing rapid downward infiltration in the indurated limestone while porous medium flow occurs in the unconsolidated sediments. The transmissivity of the aquifer varies from 800 to 3500 m/day/m which corresponds to a hydraulic conductivity of between 160 to 700 m/day for a saturated thickness of 5 m. The specific yield for those areas that are semi-confined varies from $3x10^{-5}$ to $6x10^{-2}$.

Recharge to the Quaternary limestone aquifer has been estimated by Cook et al., 1996 using chloroflurocarbons (CFC) age dating. Results from this work indicate that recharge rates are typically between 20 and 50 mm/yr, with some wells exhibiting rates of up to 150 mm/yr. Cook et al. suggests that these higher recharge rates result from wells which are in close proximity to large dissolution features which allow rapid infiltration of rainfall events.

Love et al., (1994) reports that the maximum permissible yield of groundwater that has a TDS of ≤1000 mg/L TDS from the Musgrave Proclaimed Wells region (incorporating the Polda, Kappawanta, Sheringa A and B, Bramfield and Talia lenses) is 6 400 ML/year. From the Cummins Basin and southern lenses (Lincoln A, B and C, Uley-Wanilla, Uley South, Uley East A and B, Coffin Bay A, B, and C,) Evans (1997) has estimated that the sustainable yield is 12 000 ML/year. These figures provide an annual sustainable yield for Eyre Peninsula of some 18 400 ML/year of potable water.

Usage of fresh groundwater (TDS <1000 mg/L) for stock and domestic supply on Eyre Peninsula is estimated to be 280 ML/year whilst, use of groundwater to supplement the reticulated water supply is ~7500 ML/year (Evans, 1997). The conservative sustainable yields which are applicable to Eyre Peninsula allow for only 75% of the remaining 10 400 ML to be used for other purposes. Therefore, there is potentially an additional 7800 ML/year of potable water that could be used. There are also substantial quantities of brackish to saline water (18 million ML) that as yet are not utilised, but would be suitable for various types of aquaculture or for mineral processing.

***Table 7** Eyre Peninsula — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
Pleistocene	*Bridgewater Formation*: calcareous sands and limestone. Generally calcrete at surface, karstic.	Widespread veneer over entire region, increases in thickness in aquifers along western coastal margin.	*Unconfined aquifer*, in Quaternary limestone, generally low salinity. Karstic with variable permeability ranging from low to very high. Often has semi-confining characteristics and is often not laterally continuous. Transmissivity lies between 800 and 3 500 m/day/m.
Tertiary	*Un-named*: clays, ranging from stiff to soft, red to grey with sand and gravel in part. *Poelpena Formation*: clayey sand near top grading to fine grained sand, minor carbonaceous and lignite horizons.	Generally continuous over whole region ranging in thickness from 1–5 m.	*Confining bed* *Semi-confined, confined aquifer*, variable salinity fresh to saline. Variable transmissivity from 20 to 270 m/day/m. Storage coefficient varies from 1×10^{-3} to 1×10^{-4}.
Jurassic	*Polda Formation*: contains carbonaceous clay at top of sequence with underlying interbedded sands, silts and clays. Sand consists of quartz grains usually less than 0.5 mm, occasionally up to 3 mm.	Occurs only in Polda trough.	*Confined aquifer* with very low permeability, and high salinity generally exceeding 14 000 mg/L.
Permian	*Coolardie Formation*: predominantly claystone	Occurs only on eastern margin of Polda Trough,	not known as groundwater resource, only minor significance.
Lower Proterozoic	*Flinders Group, Middleback Group, Hutchison Group*: schists, gneisses, and quartzites intruded by granites and basic rocks. Deeply weathered in places.	Basement across whole region cropping out in some locations.	Useable groundwater obtainable in the southern part of the peninsula. Weathered basement can contain brackish water with low yields. Salinity generally at least 7000 mg/L, but lower in a few localities.

after Shepherd, 1978

EUCLA BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

The Eucla Basin occurs beneath the flat Nullarbor Plain comprising a total area of approximately 176 000 km^2 of which 41 000 km^2 is in South Australia. Maximum thickness of sediments (~1500 m) is attained offshore towards the platform margin; in South Australia Tertiary sediments intersected in Yangoonabie Well, reach a thickness of 423 m.

Alley and Lindsay (1995) describe the Eucla Basin to include Tertiary sediments deposited in marine and terrestrial settings in the south western part of the State. The onshore limit of the marine Tertiary limestones largely coincides with the margin of the Bunda Plateau where the sediments are relatively thin (Fig. 15).

The Tertiary succession is divided into the Eucla Group of marine limestones, and the Immarna Group of predominantly terrigenous sediments. The Immarna Group commonly forms the base of the succession and extends around the northern margin, where it makes up the greater part of the section.

Stratigraphy interpreted by Alley and Lindsay (1995) shows that sedimentation during the middle to late Eocene was widespread, leading to the deposition of five major units: the Pidinga Formation, Hampton Sandstone, Ooldea sand, Wilson Bluff Limestone and Toolinna Limestone (Table 8 and Fig. 13).

The terrigenous clastics of the Pidinga Formation and equivalents average 30–60 m in thickness, consisting of interbedded carbonaceous sands, silts and clays which include poor quality lignite and pyritic inclusions. Onshore they are mostly confined to topographically low settings such as palaeochannels and broader depressions marginal to the Bunda Plateau. The Poelpena Formation commonly exceeds 100 m in thickness in the eastern part of the Polda Basin, but is also widespread over central Eyre Peninsula.

The lensoid to sheetlike marine, estuarine and fluvial Hampton Sandstone overlies the Pidinga Formation. These quartz-rich sands are widespread around the inner margin, particularly beyond the Bunda Plateau where this unit is up to 50 m thick. The formation is partly clayey at the base and glauconitic and fossiliferous at the top, where it is overlain by Wilson Bluff Limestone.

The large dunes of the Ooldea and Barton Ranges, formed during regression probably in the Late Eocene are composed of Ooldea Sand, a predominantly medium grained quartz sand up to at least 112 m thick, conformably overlying Hampton Sandstone. The sand varies from clean to slightly clayey, although some horizons are clay rich; sand grains are well rounded and some show aeolian frosting.

The Nullarbor Limestone is mostly bioclastic and micritic limestone deposited over much of the emergent Eucla Basin with the Ooldea Range acting as a barrier, separating marine deposition on the platform from extensive lacustrine sedimentation inland. In contrast to the underlying carbonates, the Nullarbor Limestone is remarkably uniform in thickness, averaging 20–35 m with a maximum of 45 m (Alley and Lindsay, 1995).

Aquifer characteristics of the Eucla Basin are not well understood as very few wells have been drilled across the South Australian portion of the basin. Those wells that have been drilled, typically intersected saline water; exceeding 9000 mg/L which has discouraged further development of this resource. The water table in the Wilson Bluff Limestone is just above, or very close to sea level, with a very gentle seaward slope. If it were not for the porous and cavernous nature of the limestone, there would be very little intake from the very low rainfall over the basin averaging about 180 mm/yr.

HYDROGEOLOGY OF THE EUCLA BASIN

Although the total resource of the Eucla Basin appears large, potable supplies are discrete and scattered throughout the basin where recharge potential is highest. It is probable that natural recharge over some areas could be similar to that of Eyre Peninsula due to the abundance of sink holes and dissolution features.

As a first order approximation recharge can assumed to be 1 mm/year and; therefore, natural recharge to the South Australian portion of the Eucla Basin could potentially be 41 000 ML/year. Assuming 70% of the natural recharge could be recovered then the sustainable yield from this groundwater resource could be up to 29 000 ML/year. Estimated usage of fresh to marginal groundwater (TDS <3000 mg/L) is 15 000 ML/year (E&WS Report, 1987). These figures suggest that conservatively, there is an additional 14 000 ML/year of groundwater available from the Eucla Basin.

It is considered that the Ooldea and Barton Ranges, together with the underlying Hampton Sandstone offer considerable scope for additional groundwater supplies as the palaeochannels draining from the Musgarve Complex and Officer Basin appear to terminate along this margin (Fig. 16). However, very little drilling has been carried out in this area due to difficulties of access for drilling rigs and also limited demand. Should a demand occur within this region in the future it is recommended that these areas be evaluated for their potential to supply groundwater.

COASTAL DUNES

GEOLOGY AND GROUNDWATER OCCURRENCE

The dunes and aeolianite along the coastal margin extend from Streaky Bay to the head of the Bight (Fowlers Bay) covering an area of approximately 420 km^2. The mobile dunes reach heights of >30 m in places although, they are not continuous across the whole area. Vegetation is sparse and generally confined to the base of the dunes. Potable supplies of water (<500 mg/L) are obtained from the dunes by many of the smaller communities eg. Fowlers Bay.

Because of the sparse vegetation and loosely consolidated sand infiltration rates are high and extremely rapid. It is assumed that almost all of the available rainfall percolates through the dunes to form a perched aquifer which may have a saturated thickness of up to 5 m beneath some of the larger dunes. More typically, however, the saturated thickness is likely to be between 1 and 2 m.

Given the area of the dunes 420 km^2, an estimated porosity of 0.2 (medium value for unconsolidated dune sand) and a saturated thickness of 2 m, this equates to a potential volume in storage of groundwater with a salinity <1500 mg/L of some 170 000 ML although not all of this groundwater is available for extraction.

If the annual recharge from rainfall is equal to 15 mm/year, this equates to a total recharge volume of 6300 ML/year. A first order approximation of the sustainable yield, assuming 70% of the recharged water could be recovered, is equal to 4400 ML/year. It is likely that these volumes are overestimated by as much as 50% because the coastal dunes are not continuous between Streaky Bay and the head of the Bight. A more conservative estimate would imply that only 2200 ML/year is available from this source Table 2.

Any future development of this groundwater resource would require that the volumes and sustainability be proved up to determine the potential of supplies from this source. The perched aquifer within the coastal dunes is very dependant on rainfall and as such is likely to be a very fragile system. Overpumping by large extraction wells would result in upconing of saline water. Therefore, stringent management guidelines would need to be adopted to ensure the sustainable use of groundwater from this source.

Table 8 *Eucla Basin — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
Pleistocene	*Holocene un-named*: aeolianite and unconsolidated sand which forms large coastal dunes	Occurs between Ceduna and the head of Bight	May contain minor quantities of groundwater. 'Soaks' also occur in sandhills of coastal area, quality variable.
Middle Miocene	*Nullarbor Limestone*: dense crystalline limestones with abundant mollusca and foraminifera; frequently cavernous.	Occurs throughout Basin up to the Ooldea Ranges	*Unconfined aquifer*, comprising Nullarbor Limestone, Wilson Bluff Limestone and Hampton Sandstone; groundwater occurring at 50–85 m. Lowest salinity is approximately 9500 mg/L near head of the Bight; exceeding 14 000 mg/L over most of the basin. Low salinity water occasionally found at exposed water table in caves after heavy rain resulting from rapid recharge.
Middle-Late Eocene	*Wilson Bluff Limestone*: bryozoal chalky limestones, glauconitic at base.	Occurs across Basin	
Middle Eocene	*Hampton Sandstone*: paralic sandstones and conglomerates, limonitic and glauconitic.	Widespread around inner margin of Basin	
	Pidinga Formation: sands, silts and clays; carbonaceous and pyritic.	Occurs in palaeochannels and marginal to Bunda Plateau	Sands contain *confined aquifers* although groundwater is typically very saline.
Early Cretaceous	*Unnamed*: coarse sandstones at base overlain by a thick sequence of shales.	Occurs mainly beneath Barton and Ooldea ranges along northeastern basin margin	The sandstone is a *confined aquifer*, water is under considerable pressure rising to 62 m from surface at Guinewarra Well. Salinity generally exceeds 14 000 mg/L.
Early Permian	*Unnamed*: claystone with foraminifera and abundant microflora.		Not known as an aquifer.
Proterozoic	*Unnamed:* laminated slates (early Adelaidean) granite and feldspar porphyry (Lower Proterozoic)		Not known as an aquifer.

GREAT ARTESIAN BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

The Great Artesian Basin (GAB) covering parts of three states and part of the Northern Territory occupies a total area of 1.74 million km^2 or approximately 22% of the Australian continent. The volume of water in storage has been estimated as 8700 million ML. The portion of the basin in South Australia covers an area of 310 330 km^2 (about $^1/_3$ of the state of South Australia) and extends from the Northern Territory southwards to Kingoonya, Marree, Lake Frome and to the west of Coober Pedy (Fig. 17.). It includes, as Proterozoic inliers, the Peake and Denison Ranges and the Mount Woods area.

The Flinders, Willouran and Peake and Denison Ranges provide an almost continuous Proterozoic basement outcrop marginal to the basin in the south and southwest, except for that subsidiary part of the basin to the west of the Peake and Denison Ranges. In this southwestern lobe, the margin is formed by granite, either outcropping or occurring at shallow depths, and also by occasional outcrops of Lower Proterozoic quartzite or conglomerate (Shepherd, 1978).

The GAB is a multi-aquifer system comprising Jurassic and Cretaceous sediments of the Eromanga, Surat and Carpentaria Basins (Armstrong and Aldam, 1995). Sediments recognised as belonging to the artesian basin ‘system’ overlie three sub-basins containing sediments of pre-Jurassic age. In the northeast part of the State, artesian sediments overlie Triassic and Permian sediments of the Cooper Basin which form the hydrogeologic basement in this area. To the west of the Cooper Basin, artesian sediments overlie thinner Permian sediments of the Pedirka Basin. West of the Peake and Denison Ranges, thinner equivalent artesian sediments overlie rocks of Permian and Devonian age of the Arckaringa Basin (Shepherd, 1978).

In South Australia, the GAB sequence is composed entirely of Eromanga Basin sediments forming two major confined aquifers. Table 9 provides a summary of the hydrogeology of the GAB. The most important is the lower confined aquifer, which consists of sand, silt and gravel of the Algebuckina Sandstone and Cadna-owie Formation. To the east of the Birdsville Track Ridge this aquifer thickens considerably and includes sediments of the Namur Sandstone, Murta Formation, Birkhead Formation and Hutton Sandstone (Armstrong and Aldam, 1995). The thickness of the GAB sequence varies from <100 m on the edges to over 3000 m in the deeper parts of the basin. Individual well depths vary up to 2000 m with the average being 500 m (Sampson, 1996).

The Hutton Sandstone intertongues with the Poolowanna Formation in the Cooper Basin region and, where the Poolowanna Formation is absent, the Hutton Sandstone lies unconformably on Cooper and Warburton Basin units. The unit intertongues with and is overlain by Birkhead Formation and is restricted to the subsurface in South Australia. The Hutton Sandstone consists of fine to coarse-grained, white sandstone with minor dark grey lenticular carbonaceous siltstone and shale interbeds and pebble conglomerate layers. The unit is a mineralogically mature quartzarenite with minor feldspar and muscovite, and trace amounts of zircon, garnet and tourmaline (Gravestock et al., 1983).

The Birkhead Formation intertongues with the upper Hutton Sandstone in the Cooper region (Watts, 1987) and with the Algebuckina Sandstone west of the Birdsville Track Ridge. The unit is conformably overlain by Namur or Adori Sandstone in the eastern Cooper region in South Australia. The Birkhead Formation consists of interbedded dark grey and brown siltstone, mudstone and buff, fine to medium-grained sandstone with thin lenticular coal seams (>0.3 m thick), and thin silcretes and calcretes (Gravestock *et al*., 1983).

The Algebuckina Sandstone extends subsurface eastwards into the Poolawanna Trough depocentre, where a maximum recorded thickness of 750 m occurs (Moore, 1986b), and across to the southern Cooper region. Other thin discontinuous occurrences of Algebukina Sandstone and correlative clayey units, such as Birkhead Formation and Namur Sandstone equivalents, extend southwest onto the Gawler Craton, southwards to Stuart Creek, and along the western margin of, and as outliers within, the northern Flinders Ranges as far south as Mount Bayley (Alexander and Krieg, 1995).

The Algebuckina Sandstone is a fine to coarse-grained quartzose sandstone with granule and pebble layers; shale interclasts are common in the coarser beds. Clasts of reworked Adelaidean units occur on the basin margin. Minor lenses of siltstone and shale are locally developed (Alexander and Krieg, 1995).

The Adori Sandstone unit occurs in the northeastern part of the Cooper region, where it conformably overlies the Birkhead Formation and is an equivalent of the Namur and Algebuckina Sandstone. The Adori Sandstone consists of well-sorted, subrounded, cross-bedded, fine to coarse grained sandstone. Diagenetic calcite cement is developed locally in the basal Adori and Namur Sandstones (Gravestock, 1982). These calcite cemented zones are up to 45 m thick. The origin of the calcite has been related to vertical migration of CO_2 from the underlying Cooper Basin, via faults into the Adori or Namur Sandstones and reacting with groundwater to precipitate calcite (Schultz-Rojahn, 1993).

In South Australia the Westbourne Formation is restricted to the northern Cooper region where it lies conformably on the Adori Sandstone and is overlain by and intertongues with Namur Sandstone. The formation consists of interbedded dark grey shale and siltstone with minor sandstone.

The Namur Sandstone conformably overlies the Birkhead Formation and intertongues with Westbourne Formation. The unit is overlain by Murta Formation or McKinlay Member, is distributed throughout the Cooper region, and is a lateral equivalent of the Algebuckina Sandstone. Namur Sandstone consists of white to pale grey, fine to coarse-grained sandstone with minor interbedded siltstone and mudstone deposited in a braided fluvial environment. Channel lag conglomerates consist of lithic and quartz pebbles, carbonaceous mudstone intraclasts and carbonised plant fragments. The basal Namur Sandstone, like the Adori Sandstone, has been strongly cemented with diagenetic calcite in some drillholes.

The Murta Formation overlies and intertongues with the McKinlay Member and Namur Sandstone, and is overlain transitionally by the Cadna-owie Formation. The Murta Formation occurs throughout the Cooper region and intertongues with the Algebuckina Sandstone west of the Birdsville Track Ridge (Alexander and Hough, 1990). The unit consists of finely interbedded dark grey siltstone, shale and pale grey fine to very fine-grained sandstone, and minor medium to coarse-grained sandstone. Rusty diagenetic siderite nodules and layers have cemented sandstone and siltstone beds. The Murta Formation gradually fines upwards into thin graded siltstone beds of the Cadna-owie Formation.

The Cadna-owie Formation extends throughout the GAB and records the transition from terrestrial-freshwater to marine conditions. The formation is typically 10-20 m thick in exposures around the basin margin, increasing to between 75 and 100 m thick in the deeper parts of the basin. The Cadna-owie Formation is mainly a thick-bedded sequence of pale grey siltstone and very fine to fine-grained sandstone with laterally extensive or locally developed medium to very coarse-grained sandstone interbeds and minor carbonaceous claystone intervals (Krieg and Rogers, 1995).

The upper confined aquifer consists of sediments from the Winton and Mackunda Formations, and is overlain and confined by the Tertiary sediments of the Lake Eyre Basin. It is separated from the lower confined aquifer by marine shale of the Oodnadatta Formation and the Bulldog Shale which forms an effective confining bed between the lower and upper aquifers. The Coorikiana Sandstone occurs between these shaly units and forms a discrete aquifer of high salinity and low yield. The upper confined aquifer is not as important in resource terms as the lower aquifer because water quality is poor and supplies are less easily obtained (Armstrong and Aldam, 1995).

The Bulldog Shale (Freytag, 1966) is a grey marine mudstone with a maximum known thickness of ~340 m in northeastern South Australia, but thins to <200 m in the Oodnadatta and Marree regions. The Bulldog Shale consists of dark grey, bioturbated and fossiliferous mudstone, with pale grey micaceous silt to very fine sand intervals that commonly show fine cross-lamination or irregular interlamination with mudstone. Carbonaceous matter and pyrite are also present. Detrital quartz, glauconitic and feldspar are the main constituents of the sandy fraction (Radke and Brown, 1985).

The Coorikiana Sandstone is predominantly a calcareous, clayey, very fine to fine-grained sandstone and sandy siltstone with minor siltstone interbeds. Along the southwestern margin of the Eromanga Basin, the Bulldog Shale is conformably overlain by Coorikiana Sandstone. From the southern margin, the formation extends northwards in the subsurface to the Cooper region where it attains a maximum thickness of 18 m (Moore and Pitt, 1985).

The Oodnadatta Formation consists of laminated and thin bedded claystone and siltstone with interbeds of fine-grained sandstone, calcareous and ferruginous concretions, and celestite-barite veins. The formation reaches a maximum thickness of ~300 m in the Moomba area.

The Toolebuc Formation consists of laminated black, carbonaceous, clayey mudstone with fish remains, dark grey, calcareous, clayey mudstone or coqinite with abundant shells.

The Mackunda Formation (Vine and Day, 1965) is a sandy, regressive marine unit conformably overlying the Oodnadatta Formation. In the southwestern Eromanga Basin, the Mackunda Formation comprises ~100 m of interbedded partly calcareous sandstone, siltstone and shale (Moore and Pitt, 1985).

The Winton Formation (Whitehouse, 1955) is a sequence of non-marine shale, siltstone, and sandstone, with minor coal layers, which reaches a maximum thickness of ~1200 m in the Patchawarra Trough (Moore and Pitt, 1985). The formation consists of laminated to medium bedded claystone, siltstone and very fine to fine-grained sandstone, with varying amounts of carbonaceous material. Clay interclasts are common, and the sandstone layers show small-scale cross-bedding (Rogers, 1995).

HYDROGEOLOGY OF THE GAB

The groundwater resources of the GAB support a large pastoral industry, mining industries (eg. Olympic dam) and many naturally flowing mound springs (the ‘Bubbler’, and Dalhousie Springs complex). The springs are located around the southern and western edges of the artesian basin. Townships such as Marree, Coober Pedy and Oodnadatta are dependant on the basin for their town water supplies (Sampson, 1996). Any future development must take into account these existing users of groundwater from the GAB. New wellfields must be positioned such that drawdown has an acceptable impact on the existing user, ie. the supply or pressure must not be diminished to a level which prevents the existing beneficial use of the water or pressure (Sibenaler, 1996).

The lower confined aquifer is artesian throughout much of the basin, including large areas of South Australia. Recharge occurs by direct infiltration of rainfall through outcropping aquifer units in The Great Dividing Range in central Queensland and has been estimated at 425 ML/day into the South Australian part of the GAB. Minor recharge also occurs around the southern and western margins. Groundwater in the GAB flows generally westward towards the southwest over most of the basin but, in the northern part of the basin flow is in a northwesterly direction (Sampson, 1996). Flow velocities are very low, with time taken for water to travel ~1 000 km from the recharge to the discharge zone estimated in the range of 10^5 to 10^6 years on the basis of hydraulic gradient, hydraulic conductivity and porosity, and $2.5x10^6$ years from isotopic studies (Habermehl, 1980).

Water quality in the main aquifers is generally good, with total dissolved solids (TDS) varying between 700 mg/L in the north and northeast to >40 000 mg/L in the southwest, but generally lie between 1000–5000 mg/L (Sampson, 1996). A broad plume of <1000 mg/L TDS water extends south along the Birdsville Track Ridge, suggesting shorter residence time or variation in upward leakage and mixing from deeper aquifers. The sub-artesian area (western margin) water quality is variable, with salinity ranging from ~2000 mg/L to >40 000 mg/L, which may result from contact with saline formations on infiltration, evaporitic discharge and slow movement (Armstrong and Aldam, 1995).

Water temperatures vary from 25ºC in shallow wells along the basin margin, up to 100ºC in the deeper wells in the central part of the basin. Well yields vary from <1 L/sec up to 235 L/sec (Sampson, 1996).

Discharge of aquifer waters occurs through:

- Upward vertical leakage throughout the basin, estimated at ~190 ML/day.

Since it occurs at a rate that is a fraction of the potential evaporation, it is a mechanism which is unseen and difficult to quantify.

- Flowing wells, estimated at 132 ML/day.
- Natural discharge from ground springs, estimated at 132 ML/day.
- Cooper Basin product and process water, 22 ML/day.
- Wells supplying the Olympic Dam mining operations, (presently15 ML/day but upgrading to 42 ML/day).

Development in South Australia has had surprisingly little effect on the potentiometric surface on the lower confined aquifer of the GAB. A major factor in minimising the impact on withdrawal is believed to be the importance of vertical leakage, ie. a flowing well 'harvests' water which would have been lost by leakage and evaporation near surface. The above figures indicate that water flowing into the basin is ~55% committed assuming that all the vertical leakage can be 'harvested' (Sibenaler, 1996).

Aquifers contained in the shallow Tertiary and Quaternary sediments are generally not used for groundwater supplies, either because the groundwater is too saline (>7000 mg/L) or yields are low. However; in the northeast corner of the State; the south-western margin; and, the Frome Embayment, useful supplies of stock quality groundwater may be obtained from the shallow sediments. In general, pastoralists prefer to drill deeper to the more assured supplies of good quality, high yielding groundwater from the artesian aquifer.

Table 9 *GAB — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
Quaternary/Tertiary	*Un-named:* aeolian sands; alluvium; lacustrine and fluvial sands, silts and clays; occasional limestone beds. May be cemented at surface by silica, iron or gypsum.	Forms a thin veneer of surficial sediments across the whole basin.	Usually *unconfined aquifer*, stock and domestic supplies only. Salinity variable from 1000 to >100 000 mg/L in desert areas. Transmissivities probably <100 m/day/m. water table contours probably focus on Lake Eyre, where groundwater is concentrated brine. Recharge is from low rainfall. Depth to water table up to 90 m.
Cretaceous	*Winton Formation*: fresh water fluvio-lacustrine sequence of fine-grained sands, silts, clays and lignite. Predominantly grey-green, little quartz, mostly feldspathic (salt and pepper sandstone).	Occurs across most of Eromanga Basin	*Confining bed* in part - may be an unconfined aquifer. Very low transmissivity as formation is tight. No information on aquifer parameters in SA
	Oodnadatta Formation: marine sequence of sands, silts and clays inter-fingering with above formation. Predominantly fine-grained basal sandstone, gritty in marginal areas.	Occurs mainly over central portion of Eromanga Basin	*Confining bed* - similar to Winton Formation. May be an unconfined aquifer around margins of basin.
	Bulldog Shale: similar to Oodnadatta Formation mainly shale with occasional calcareous nodules.	Occurs throughout the basin and crops out along western basin margin	Regional *confining bed* but contains discrete saline aquifers within sandier facies
	Cadna-owie Formation: variable lithology, more sandy towards basin margin.	Extends throughout the GAB and is exposed around the western basin margins	*Confined aquifer*, insignificant compared with Algebuckina Sandstone - hydraulically connected to it and forms an *Unconfined aquifer* on extreme western margin of GAB. Salinity varies from 600–10 000 mg/L. Supplies up to 850 kl/day. Aquifer parameters unknown.
Late Jurassic	*Algebuckina Sandstone*: fluvio-lacustrine sequence - mainly fine to coarse-sandstone. sequence thickens basinwards.	Continuous across most of central basin but becomes discontinuous along western margin and southwest towards the Gawler Craton.	*Confined aquifer*, artesian flows may exceed 4.3×10^3 kl/day. Salinity 600 to 4000 mg/L. Water discharge temperature up to 99ºC. Very corrosive near margins. Dominant ions Cl with varying SO_4 and HCO_3. Natural outlets in form of mound springs, with total discharge about 30×10^6 kl/year.

Late Jurassic	*Birkhead Formation*: micaceous and carbonaceous shale. Recognised beneath Simpson Desert and further east.	Extensive over Cooper Basin, intertongues with Algebuckina west of the Birdsville Track Ridge.	*Confining bed.*
Early-Middle Jurassic	*Hutton Sandstone*: coarse-grained, conglomeratic, loosely cemented. Occurs in eastern part of the basin in South Australia.	Occurs throughout SA portion of the Cooper Basin	*Confined aquifer*, good quality water, high yielding. Not generally used in this State because of its depth, generally exceeding 1500 m.
Triassic	*Nappamerrie Formation*: green dolomitic siltstones and sandstones.	Occurs throughout SA portion of the Cooper Basin	*Confining bed* to Gidgealpa Group.
Early-Late Permian	*Gidgealpa Group*: sandstones, shales, siltstones and coal.	Occurs throughout SA portion of the Cooper Basin	*Confined aquifer*, generally containing highly saline groundwater. In the southern Cooper Basin flushing by pressure water from Jurassic aquifers has occurred in areas where Triassic sediments are missing. Salinity in this area is generally less than 5000 mg/L.
Early Permian	*Merrimelia Formation*: sandstones, conglomerates, shales and siltstones.	Occurs throughout SA portion of the Cooper Basin	No known aquifers.
Ordovician-Cambrian	*Un-named*: sandstones, carbonate rocks and volcanics.	-	No known aquifers.
Adelaidean	Undifferentiated sediments and volcanics.		No known aquifers.

OFFICER BASIN

GEOLOGY AND GROUNDWATER OCCURRENCE

Little is known of groundwater in the Officer Basin. Investigations have been limited to those for water supply at Oak Valley (Maralinga Lands), and similar studies around the northern margin of the basin for Anangu Pitjantjatjara Council, plus occasional well surveys. At best, most drilling records contain total depth, supply and salinity, but very few records exist of strata or depth of water cut. Very little potable groundwater has been found. Exceptions are small supplies derived from basement runoff near the edge of the Musgrave ranges, and perched groundwater at Oak Valley. (Read, 1988).

The stratigraphy of the Officer Basin consists of a number of units of Late Proterozoic, Cambrian and Ordovician age deposited in environments ranging from playa lake and fluvial to marine (DME, 1993). Table 10 provides a summary of the known hydrogeological units for the Officer Basin. The rock units are thought to dip gently toward the centre of the basin from the north and south. The northern margin is overthrust by the Musgrave Block.

The Trainor Hill Sandstone is a very fine to fine grained well sorted Kaolinitic sandstone. In the upper part it can be medium to coarse grained with some rounded, very coarse to granule sized grains. Interbeds of micromicaceous mudstone occur throughout the sequence including a dark grey organic mud.

The Wirrildar Beds are composed of a variably micaceous mudstone with very fine sandstone interbeds. The mudstone is calcareous and includes ooid-bearing micrite. The Punkerri Sandstone is typically a very fine to medium grained, well sorted, white clayey and siliceous sandstone.

Groundwater is the major source of water supply in the area although, very little potable groundwater has been found. Surface water is limited to a few stock dams and minor rockholes.

HYDROGEOLOGY OF THE OFFICER BASIN

The Officer Basin is regarded generally as an area of ‘insufficient data’. The relatively low salinity groundwater, which has been intersected in a few wells, is regarded as fossil water, derived from intakes along the southern margin of the Musgrave Block.

The limited amount of available information concerning groundwater occurrence, quality and yield and depth to water in these more remote regions makes it difficult to estimate the available groundwater quantity or quality. Therefore, no attempt has been made to quantify the volume of water in storage or the quality (fresh/marginal, brackish or saline) apart from those values that appear throughout the text for the GAB and some of the better understood palaeochannels in the Gawler Craton.

Groundwater in these sediments in the southern part of the basin has a very high salinity, exceeding 35 000 mg/L. Towards the northern boundary of the basin, however; salinity is low in sediments occurring between 60 and 300 m below the surface, as revealed in several wells south of the Birksgate and Everard Ranges. In addition one well penetrated aquifers where salinity was less than 5000 mg/L at depths down to 1220 m.

From the limited Hydrogeological data available it has been inferred that groundwater in this region generally flows in a southerly direction away from the Musgrave Complex.

Table 10 *Officer Basin — Summary of hydrogeology*

Age	Unit, Lithology	Occurrence	Hydrogeology
	Trainor Hill Sandstone: very fine to fine grained kaolinitic sandstone with interbeds of micromicaceous mudstone. In upper part can be medium to coarse grained.	<120 m thick in northern section of basin up to 420 m thick in the Mt. Johns Range area. Occurs widely from Marla in the north to Ungoolya in the south.	Main aquifer in region but groundwater is typically saline. Some shallow groundwater of reasonable quality has been intersected in some drillholes. Yields are generally low.
	Wirrildar Beds: composed of variably micaceous mudstone with fine sandstone interbeds. In lower sequence can contain coarse grained arkose sandstone.	Occurs throughout basin and can reach thicknesses of 2700 m in eastern part of basin.	Not known as an aquifer.
Adelaidean	*Punkerri Sandstone:* very fine to medium grained white well sorted sandstone. Clayey and siliceous throughout.	Occurs over western portion of Officer Basin but is absent over eastern section.	Contains groundwater but very little is known about this aquifer.

Note: The relationship between the Trainor Hill Sandstone and Wirrildar Beds is poorly known, and no age diagnostic fossils have been found. For these reasons no subdivision has been proposed for these formations.

GAWLER CRATON

GEOLOGY AND GROUNDWATER OCCURRENCE

The Gawler Craton region encompasses Eyre Peninsula and as far north as Coober Pedy. This part of the report focuses on the northern Gawler Craton area and in particular the extensive network of palaeochannels which formed ancient drainage courses from the Musgrave Complex.

A brief summary of the Regional Geology is outlined by Dodds, 1997 which identifies the major geological sequences found in the northern Gawler Craton region. Basement comprises crystalline Gawler Craton rocks which crop out in places. These rocks may be weathered to a depth of as much as 50 m.

Permian sediments (clays) may overlie the Craton and are generally restricted to east-west trending narrow (1–5 km) troughs of which the Mulgathing Trough is the best known.

In the eastern part of the area Jurassic-Cretaceous sediments of the Great Artesian Basin (GAB) lap onto the older rocks, and comprise mainly kaolinitic Algebuckina sandstone. These sediments get sparser and more patchy to the west, but are still seen as far west as the Barton sheet.

A cover of Tertiary (Pidinga and Garford formations) and Quaternary sediments is generally present. The Tertiary sediments, which reach thicknesses of 50 metres or more in the palaeochannels, comprise intebedded clays and sands, with lignite being typical of the Pidinga formation.

The weathered basement rocks, Algebuckina sandstone and Tertiary sediments have similar hydrogeological properties and can be difficult to differentiate in drilling logs.

HYDROGEOLOGY OF THE GAWLER CRATON REGION

There are no extensive sedimentary sequences in the northwest Gawler Craton area that could support the development of an expansive aquifer system similar to that of the GAB. Generally, groundwater occurs in Tertiary sediments and weathered basement or is contained within the sedimentary infill within the palaeochannels (Fig. 16). Supplies have been obtained from Permian troughs; the best known of these features is the Mulgathing Trough although yields are small and an elaborate setup of windmills and pipe network has been established to distribute the water to stock.

Evaluation of the limited hydrogeological data for this area appears to indicate that the best quality groundwater (~1500 mg/L) is associated within the weathered zone atop basement highs.

Currently local wells yield sufficient supplies of stock quality groundwater to support grazing. These supplies have been developed over many years by the grazier and, combined with an extensive piping network, provide an adequate supply. The yield of each well is normally below 1 L/sec, and there have been many unsuccessful wells.

The groundwater usually occurs in sediments and weathered basement rocks within 50 m of surface, the sediments being either Tertiary Pidinga Formation or Jurassic Arckaringa Sandstone, which is kaolinitic in this area and can be difficult to distinguish from the Pidinga Formation or even from weathered basement.

Natural recharge throughout this area is assumed to be low due to the infrequency of rainfall and high evaporation rates.

PALAEOCHANNELS GROUNDWATER OCCURRENCE

Within the Gawler Craton and far western portion of the state an extensive region of palaeodrainage exists terminating along the margins of the Eucla Basin (Fig. 16). These palaeorivers drained the Musgrave Block, Stuart Range and Gawler Ranges. Aquifers were formed by the infilling with sand of the ancient surface drainage channels that were incised in the crystalline Precambrian basement rocks during the Jurassic. The palaeochannels, although partly obscured by a veneer of more recent sediments are remarkably intact and have the potential to contain large quantities of groundwater, albeit saline.

In many instances, salt lakes form a present-day surface expression of the ancient drainage network and are also the sites of evaporative discharge from the palaeochannel aquifers. However, the palaeochannel aquifers are not always geographically associated with salt lakes.

The groundwater resources of the aquifers within the palaeochannel network are of crucial importance to the mining industry as they may provide a significant source of water that could be used for ore processing. This source of water would provide an alternative supply to that of the GAB which may be too far away to provide an economic water supply for the development of many smaller mineral discoveries within the Gawler Craton area.

The extent of the Garford palaeochannel is reasonably well known and drilling has indicated a 10–15 m thick sand aquifer containing saline groundwater which potentially contains up to 300 000 ML in storage. The Tallaringa palaeochannel on the northwestern margin of the Gawler Craton contains a considerable thickness of sand with an estimated 900 000 ML of water in storage. Similar palaeochannels occur to the southwest of Tarcoola and south of the Gawler Range Volcanics (Narlaby and Thurlga palaeochannels) but no estimates of storage have been made. A first order estimate of the total groundwater resources of the palaeochannel network throughout this region would indicate that up to ten times the combined total of the Garford and Tallaringa palaeochannels may be available.

Water quality ranges from ~5000 mg/L to <70 000 mg/L and although yields are not well known, anecdotal reports have indicated that some of these groundwaters may be artesian.

MUSGRAVE BLOCK

GEOLOGY AND GROUNDWATER OCCURRENCE

The oldest rocks in the Musgrave Block are Lower Proterozoic granulites intruded by basic and ultra basic dykes and granitoid rocks. Overlapping the older rocks are Adelaidean metasediments and Palaeozoic rocks, which outcrop at Indulkana. Mesozoic sediments, of the GAB occur to the east overlying the older rocks.

The Musgrave Block consists principally of granite, gneiss and foliated, medium to coarse grained permano adamellite which is biotite and hornblende bearing in part, and porphyritic.

Little is known of groundwater in the Musgrave Block. At best, most drilling records contain total depth, supply and salinity, but very few records exist of strata or depth of water cut. Very little potable groundwater has been found and the salinity of groundwater in the area varies between wide extremes reflecting differing rock texture, structure and recharge conditions.

CONCLUSIONS

Developments in the mining industry are particularly difficult to predict because of the influence of such factors as development costs and volatile market conditions which affect the viability of any new project. New developments can arise within the area of interest in response to a number of factors, with little warning, and, with the potential demand for large annual volumes of water. Moreover, such developments are likely to occur in locations where the water yield is inadequate, or the quality of the local water may not suitable for the intended use without treatment.

In general, the majority of mineral processing operations can utilise water which is up to three times more saline than that of seawater. Quantities demanded; however, are generally large ranging from 3 ML/day for the estimated life of a small to medium scale mine (5–20 years) up to 42 ML/day for large scale projects such as Olympic Dam.

The techniques used to provide potable water supplies vary widely: desalination of groundwater, although expensive, is used by several communities throughout the region. Others mix poor quality groundwater with better quality rainwater collected from roofs, rocky outcrops or specially prepared catchments to reduce salinity. Some communities such as Woomera duplicate reticulation to conserve potable water (brackish/saline water or treated sewage effluent is reticulated for non-consumptive and irrigation uses), while Arkaroola Village is considering experimenting with the use of surface water to recharge the local aquifer, thus reducing evaporation losses.

There are many areas within the study region where ASR can be incorporated as a management tool for enhancing the natural recharge, but the primary driving force as to where ASR will occur is going to be in those locations where there is a demand for the water product. The methods employed for enhanced natural recharge using ASR techniques will depend largely on the availability of surface water, and the type of sub-surface geology that constitutes the receiving aquifer.

It is acknowledged that the conventional storage of surface water within the arid areas of the Northern region is fraught with difficulties. However, through innovative design, such as integrating surface water interception with underground storage the Region's surface water potential may be realised. Many of the techniques listed in the preceding paragraph could be applied throughout the study region to augment existing water supplies. For example:

- Within the Pirie-Torrens region there are a number of groundwater basins utilised for stock and irrigation supplies. These include; the Pirie-Torrens, Willochra, Walloway and smaller Booborowie Basins. Water supplies are also obtained from fractured rock aquifers in the Adelaide Geosyncline.

- There is an estimated 180 GL (Table 2) of groundwater stored within the Pirie-Torrens region of the study area, although less than 10 GL could be considered suitable for domestic supply.

- The low yields, coupled with uncertainty of supply and poor quality, has resulted in limited use of the available groundwater throughout the Pirie-Torrens area. In addition, reliance upon surface water catchments and groundwater has diminished over the past several decades, especially in those areas serviced by the Morgan-Whyalla pipeline.

- Within the Pirie-Torrens Basin, many of the wells utilise supplies from within the Quaternary sediments with only eleven wells penetrating the deeper Tertiary aquifers (of which only two or three wells are operational).

- Within the Willochra and Walloway Basins, the majority of groundwater is sourced from aquifers within the Tertiary sediments (some of which is artesian).

- In all areas, yields are relatively low (typically between 2 and 5 L/sec) which has been one of the factors limiting the use of groundwater to supply large demands throughout the region.

- Salinity is also highly variable with the better quality groundwater (<3000 mg/L) confined to a narrow strip along the base of the Flinders Ranges, which increases rapidly in salinity (>40 000 mg/L) away from the ranges towards Lake Torrens.

- Despite the apparent low yields and variable salinity, the Pirie-Torrens region offers significant potential in respect to the establishment of ASR schemes. Suitable host aquifers for the receipt of injected water exist within the Tertiary sediments of the major basins. There also exists a variety of sources of water for injection including;

    - harvesting catchment runoff from the water courses which discharge from the Flinders Ranges and through the Willochra Basin;

    - injecting water from the Morgan-Whyalla pipeline during periods of low demand to provide balancing storage for later reuse during periods of high demand and;

    - injecting treated wastewater and stormwater from the larger communities of Port Pirie, Port Augusta and Whyalla.

- Across Yorke Peninsula, scope exists to provide balancing storage from the pipeline by injecting water into the palaeochannel which connects the southern Pirie Basin with the St. Vincent Basin, provided there is a suitable host aquifer.

- Additional supplies of water could be obtained from the Tertiary sediments of the Polda Trough on Eyre Peninsula to meet the demand of an end user requiring brackish or saline water.

- Around the larger urban centres (eg. Whyalla and Port Lincoln) stormwater runoff and treated effluent could be injected/infiltrated into the aquifer to sustain demand. In the event that treated effluent was to be injected into the aquifer an extensive hydrological assessment would be required to ensure that potable supplies would not be affected.

- The small community of Penong could be supplied by groundwater from the adjacent coastal dunes. Groundwater from the dunes could be harvested during winter to capture the natural recharge that may otherwise be lost to the sea as discharge or through evaporation.

- Although the total resource of the Eucla Basin appears large, potable supplies are discrete and scattered throughout the basin where recharge potential is highest. Further investigation may produce sufficient supplies to sustain smaller communities throughout the region.

- The groundwater potential from the Ooldea and Barton Ranges, plus the underlying Hampton Sandstone also need to be fully assessed as these sources could yield significant quantities of potable water.

- The aquifers contained within the palaeochannels could provide significant supplies of saline water to the mining industry. Alternatively, these palaeochannels could be used to store any harvested water from surface interception schemes or excess treated mine process water.

- Surface water interception schemes in the far north of the state would need to be designed to react quickly and economically to capture the infrequent flood events as and when they occurred.

- Surface water interception and recharge to the deeper aquifers of the GAB may not be economically viable or practical, but some regions along the western margin or the shallow overlying saline aquifers may be suitable storage mediums for any captured surface runoff.

- In all cases, any interception scheme coupled with recharge to an aquifer would require detailed hydrogeological assessment and feasibility studies to determine the viability of the scheme.

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Fig. 1 *Boundary of study area.*

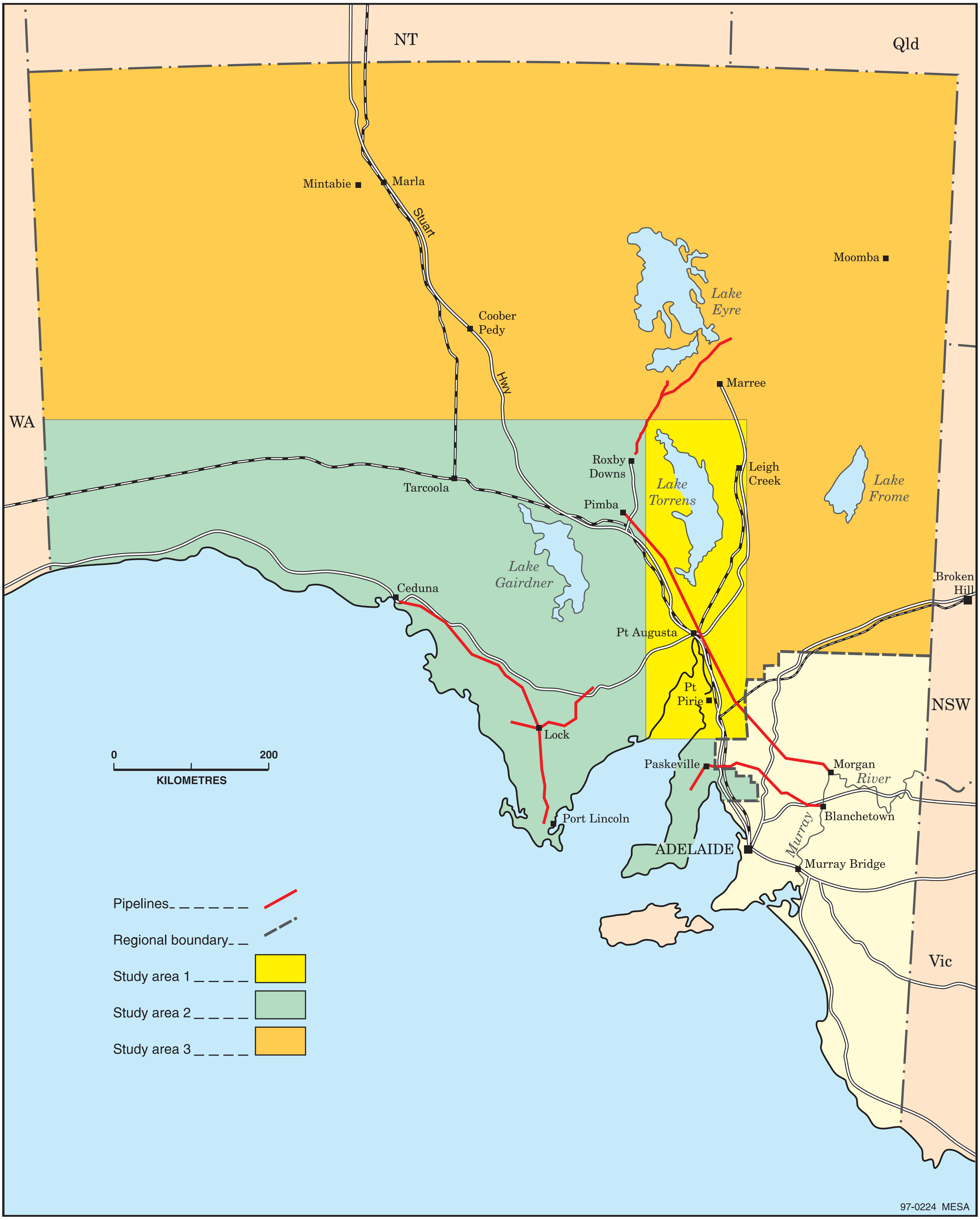


Fig. 2 *Study area sub-regions.*

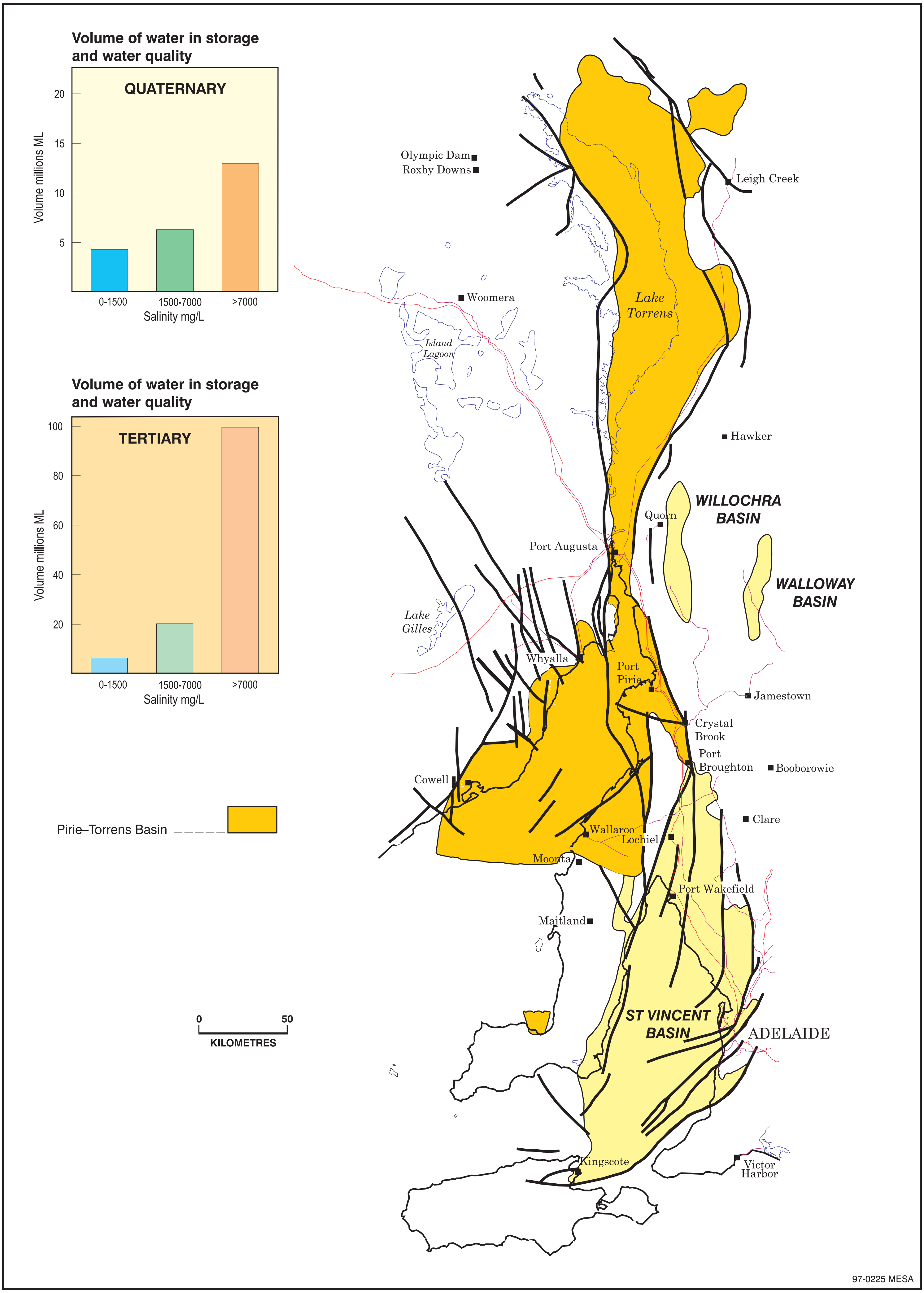


Fig. 6 *Extent of Pirie–Torrens Basin; estimate of volume of water in storage in Quaternary and Tertiary sediments and water quality.*

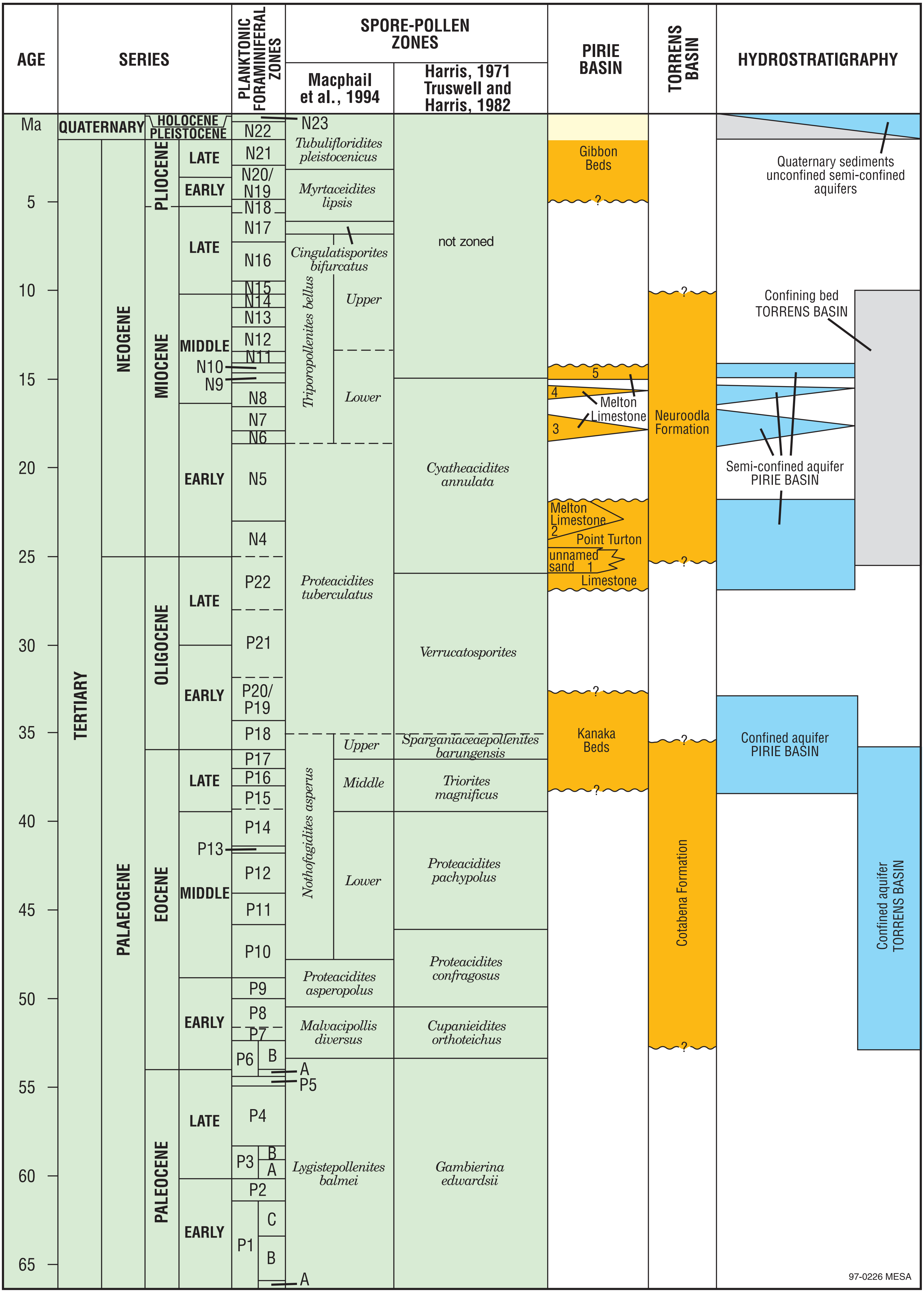


Fig. 7 *Hydro-stratigraphic units of the Pirie–Torrens Basin.*

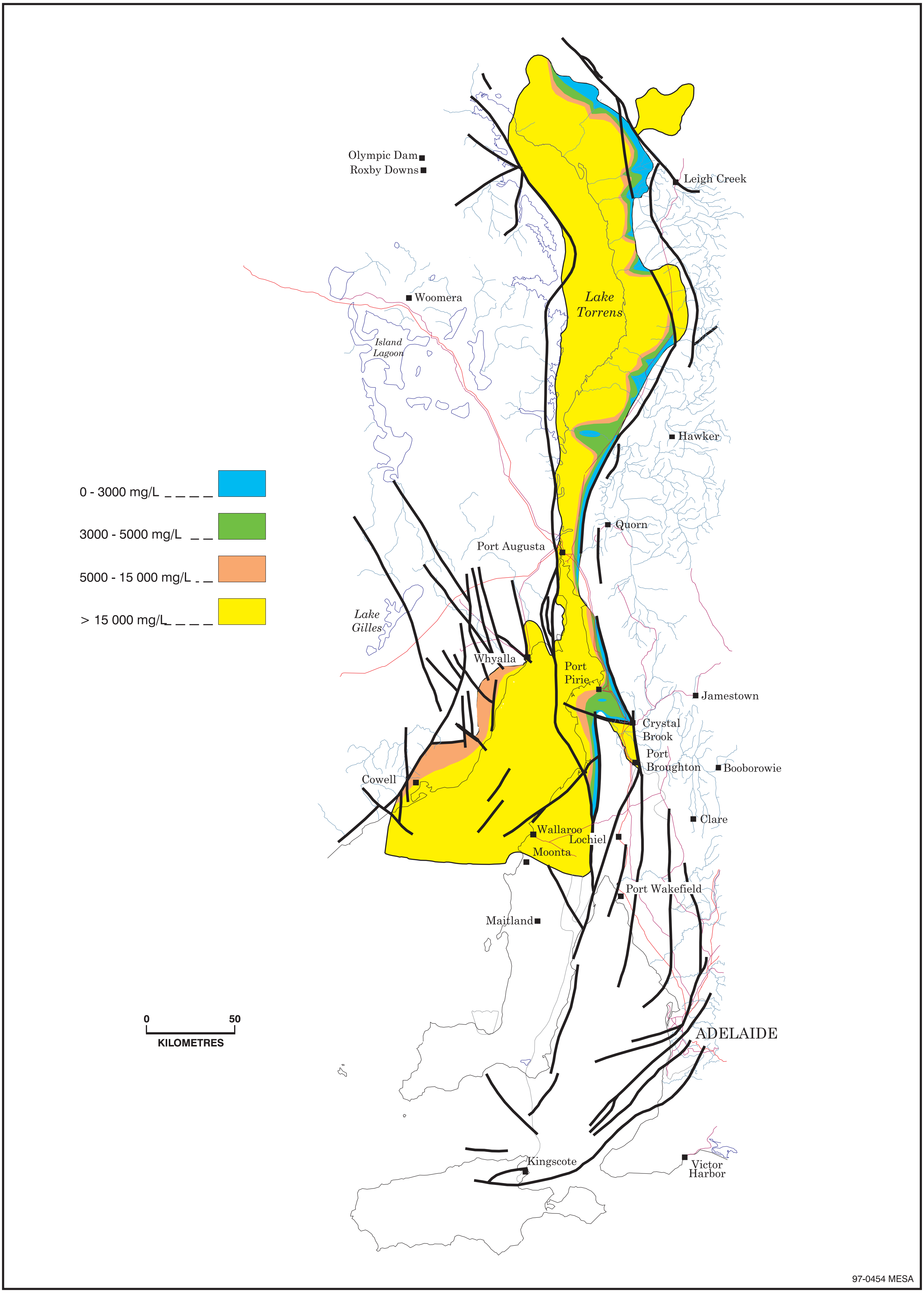


Fig. 8 Salinity distribution in Quaternary sediments of the Pirie–Torrens Basin.

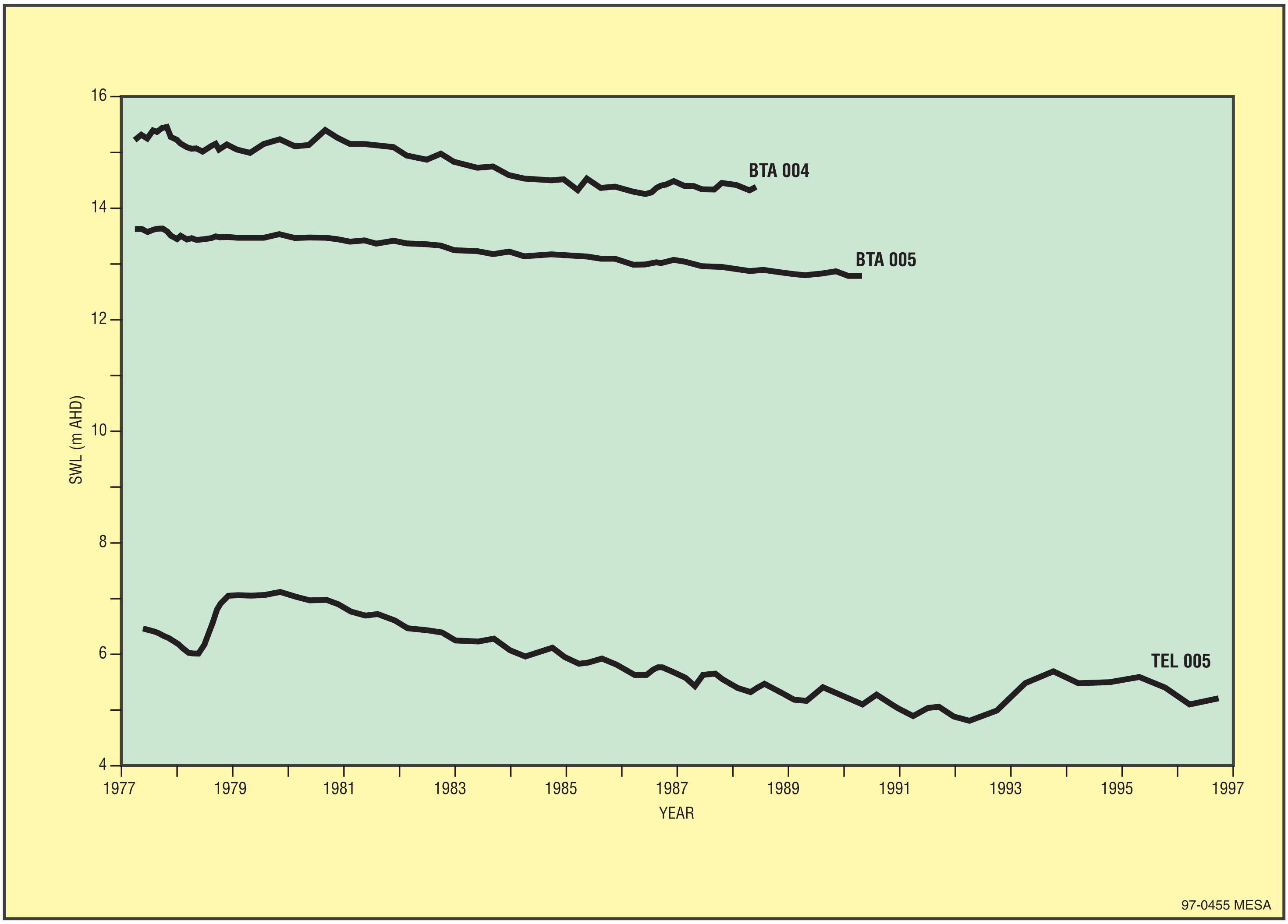


Fig. 9 *Hydrographs for selected wells in the shallow aquifers of the Pirie–Torrens Basin.*

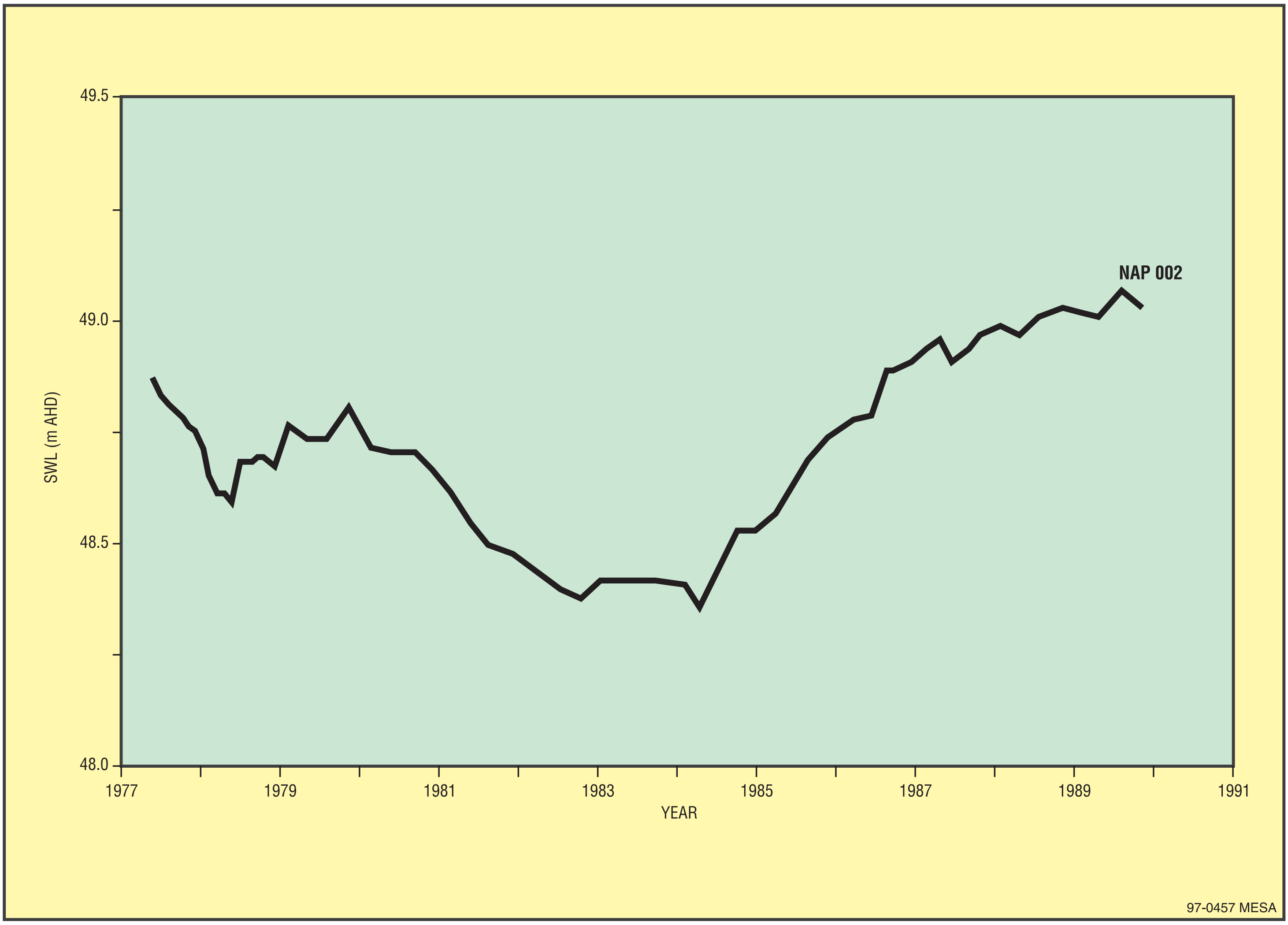


Fig. 10 *Hydrograph for NAP 002 in the confined aquifer within the Pirie–Torrens Basin.*

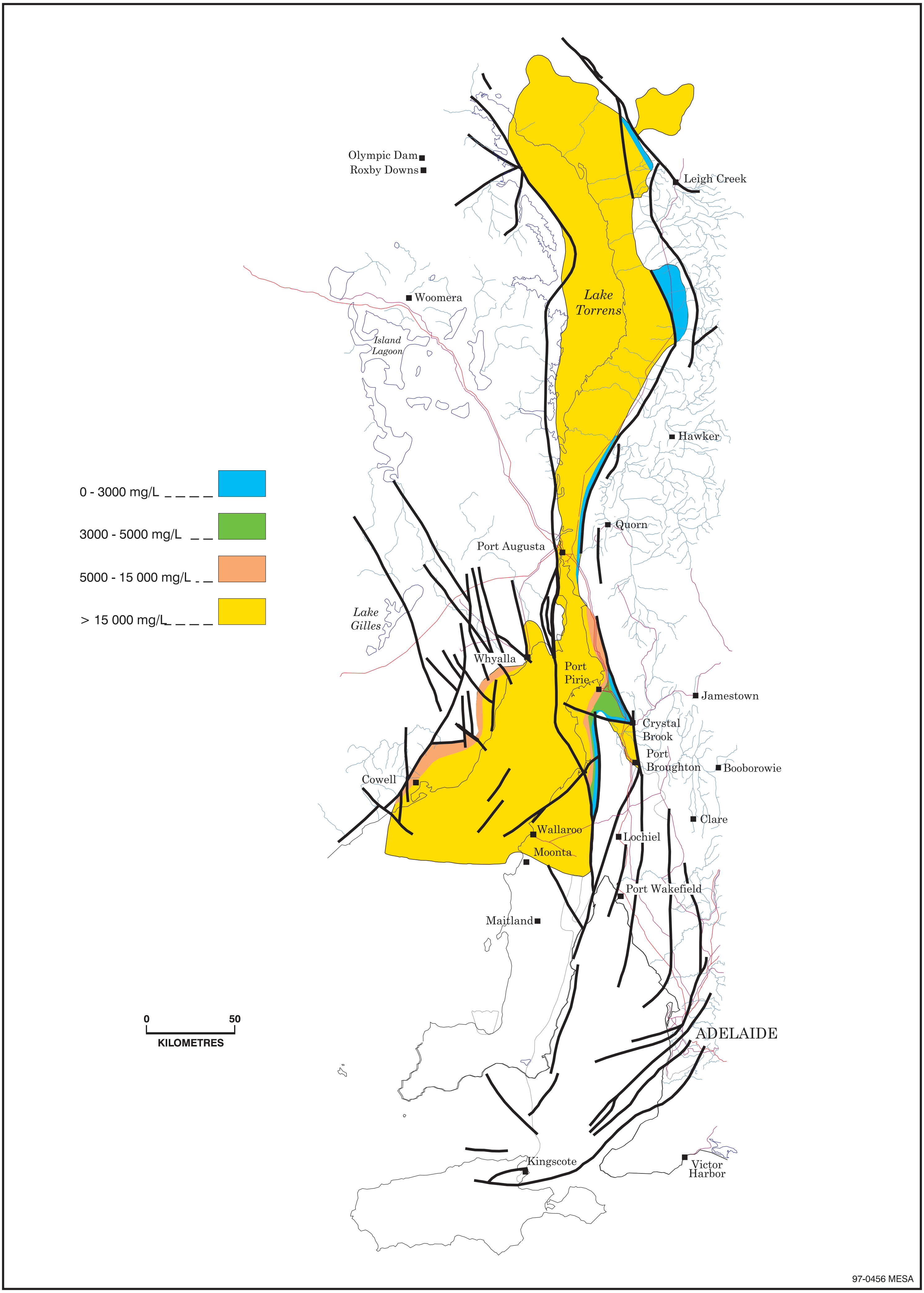
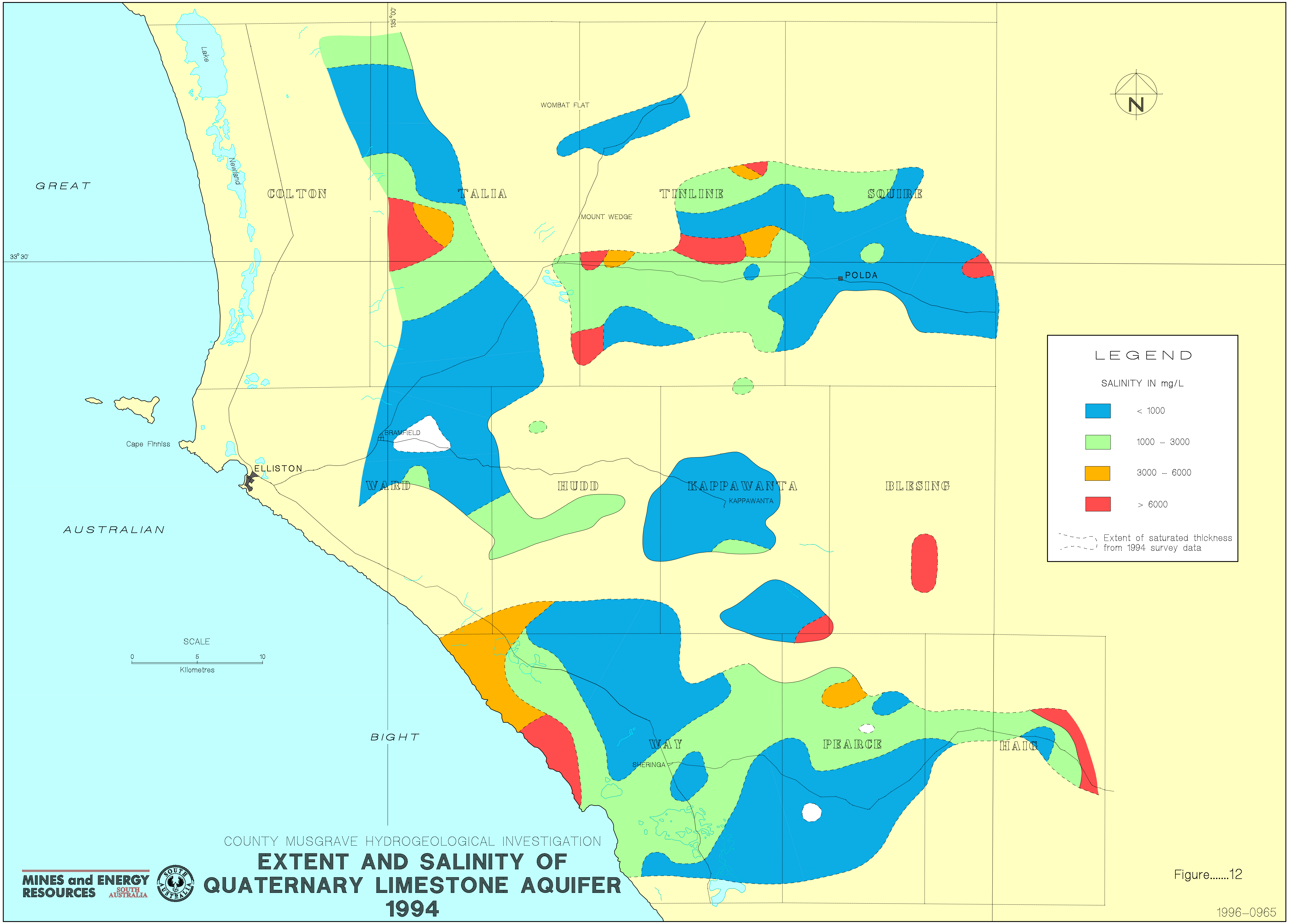


Fig. 11 *Salinity distribution in Tertiary sediments of the Pirie–Torrens Basin.*



COUNTY MUSGRAVE HYDROGEOLOGICAL INVESTIGATION

EXTENT AND SALINITY OF QUATERNARY LIMESTONE AQUIFER 1994

MINES and ENERGY RESOURCES SOUTH AUSTRALIA

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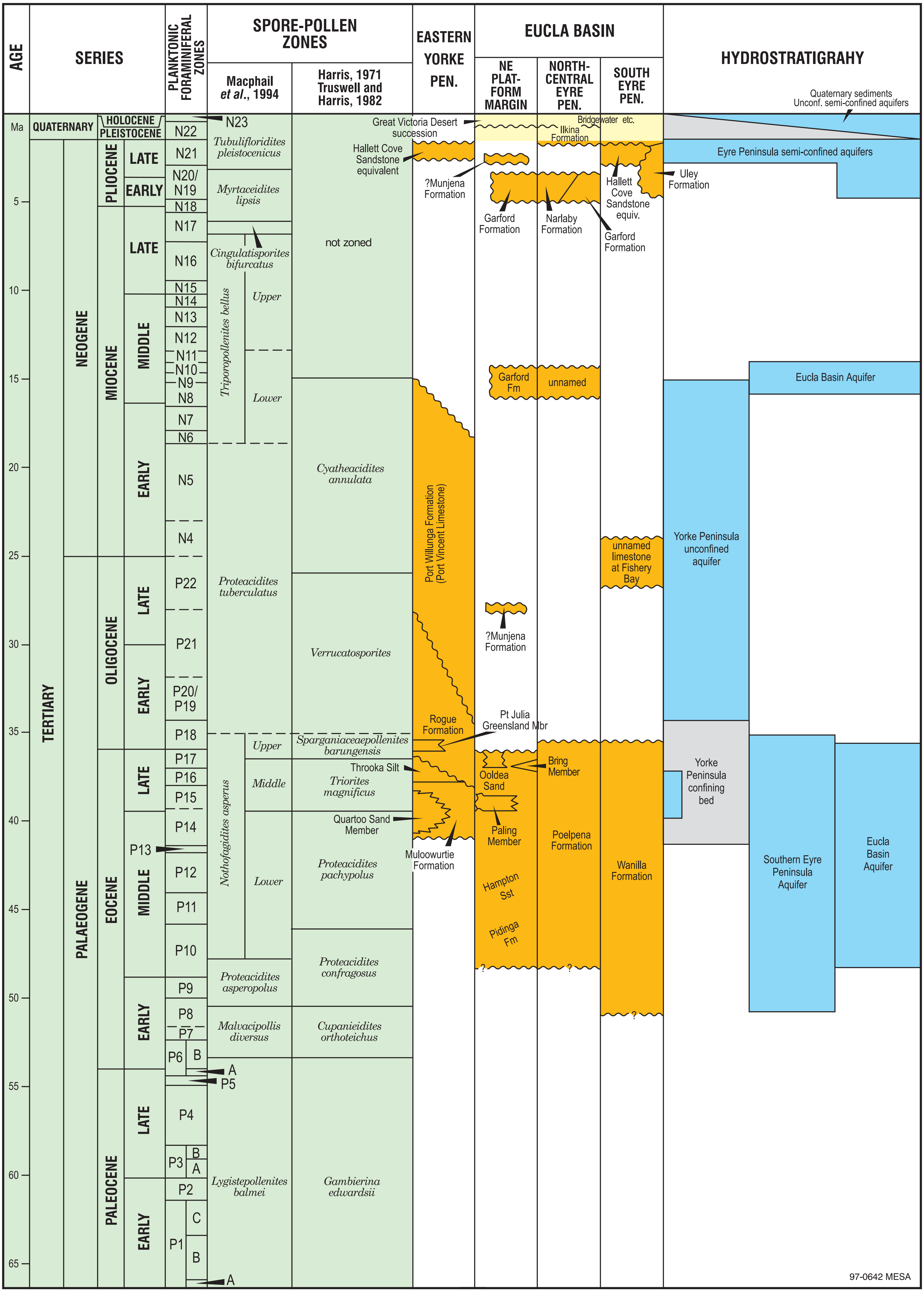


Fig. 13 Hydrostratigraphic units of Yorke Peninsula, Eyre Peninsula and the Eucla Basin.

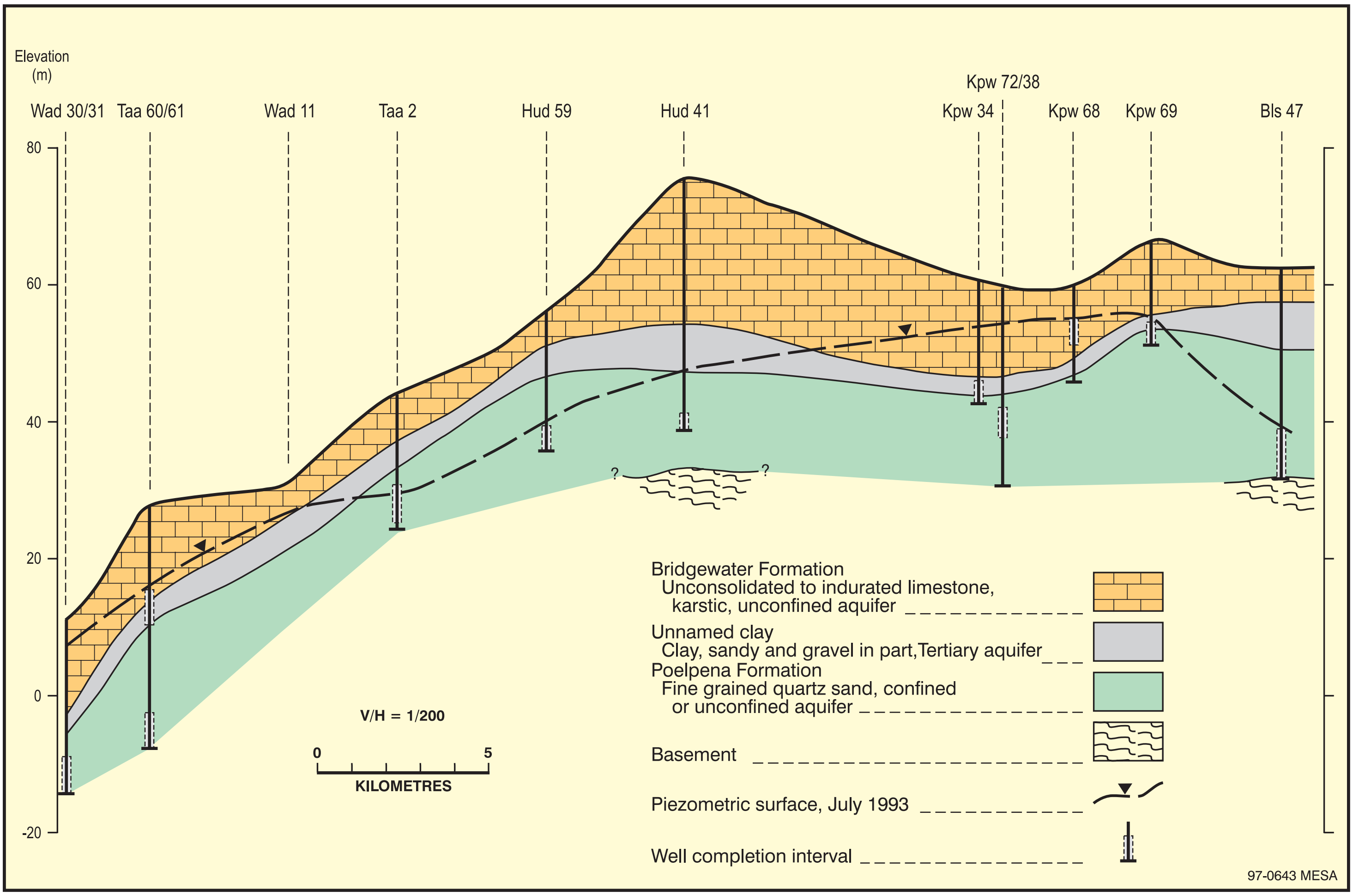
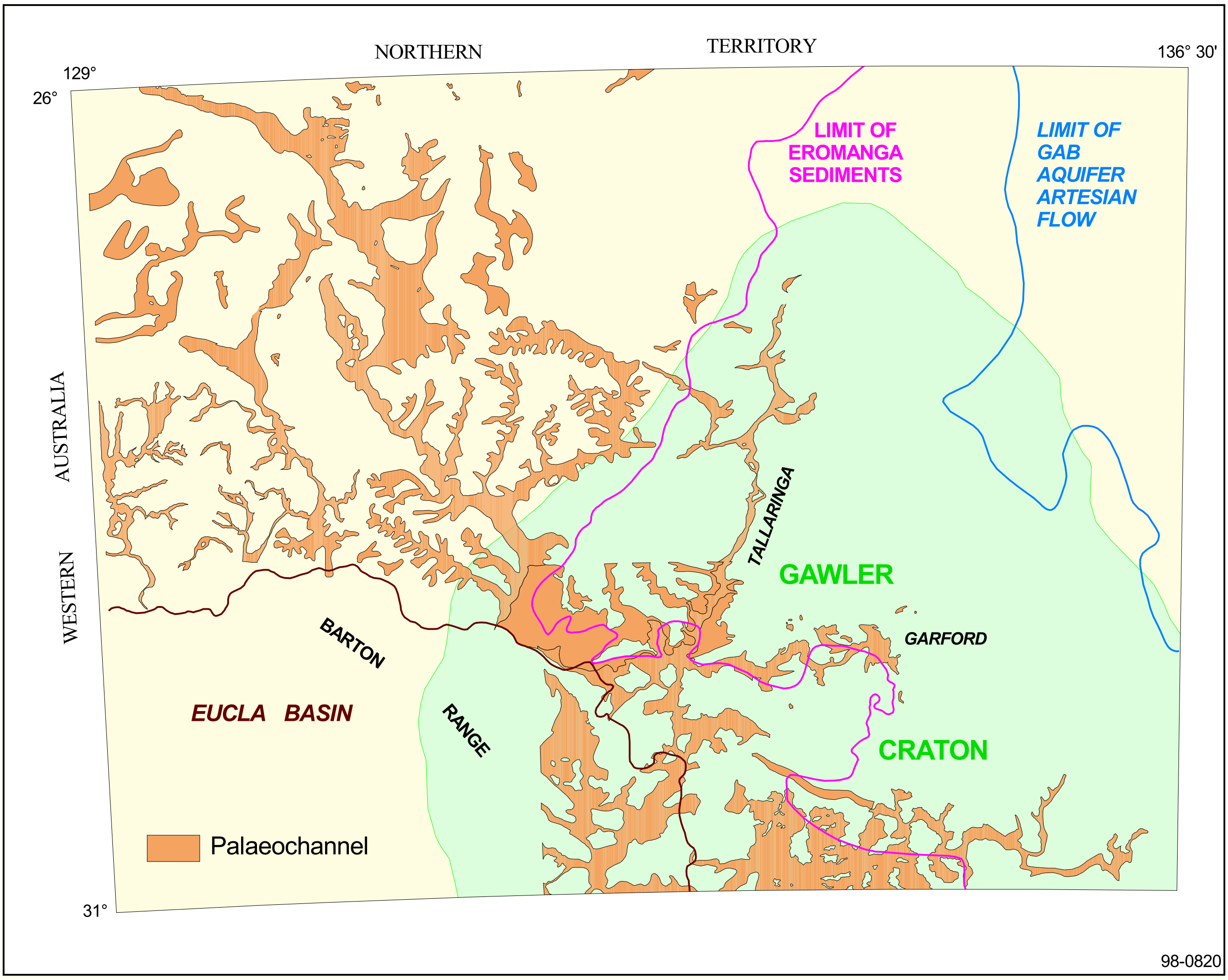


Fig. 14 *Cross section through County Musgrave Prescribed Wells area on Eyre Peninsula.*


NORTHERN
TERRITORY
129°
26°
136° 30'
LIMIT OF
EROMANGA
SEDIMENTS
LIMIT OF
GAB
AQUIFER
ARTESIAN
FLOW
WESTERN
AUSTRALIA
TALLARINGA
GAWLER
CRATON
GARFORD
BARTON
RANGE
EUCLA BASIN
Palaeochannel
31°
98-0820

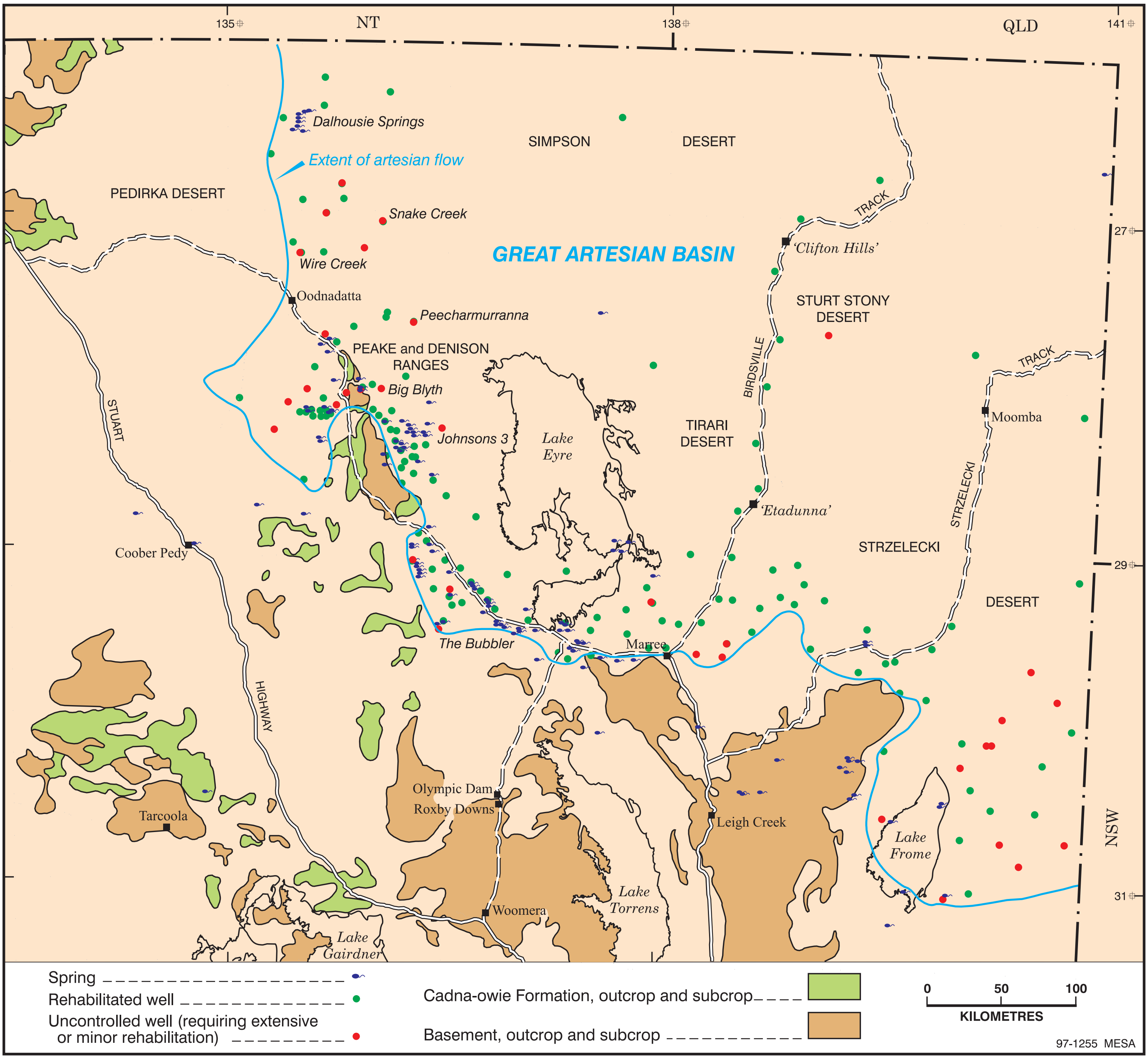


Fig. 17 Great Artesian Basin sub-region.

APPENDIX 1

GROUNDWATER DRILLING IN THE PIRIE–TORRENS BASIN

DRILLING IN THE PIRIE–TORRENS BASIN

INTRODUCTION

A total of seven wells were drilled during February and March 1997 as a follow up to the transient electro-magnetic (TEM) survey carried out by PIRSA in 1994 *(Dodds, 1994).* From the TEM results two targets were identified, approximately 2 km east of Nelshaby and Napperby and 12 km north-east of Port Pirie, in South Australia's mid-North (Fig. A1-1.). Upon drilling the first of these wells, basement was intersected at a relatively shallow (<20 m) depth. It was necessary to drill five step out wells in order to define the boundary between the Adelaidian rocks of the Flinders Ranges and the Quaternary/Tertiary sediments of the southern Pirie Basin. The indistinct boundary probably is a result of the complex faulting that occurs along the eastern margin of the Pirie Basin.

One of the two 'production' wells produced a yield of 3.3 L/sec from a Tertiary sand facies during airlifting, whilst the other well produced a small yield (0.75 L/sec) from fractured/weathered basement. Water quality in both wells was between 800 to 900 mg/L.

GEOHYDROLOGY

The structure of the Pirie-Torrens Basin is poorly known, although natural boundaries are formed by Cambrian and Precambrian basement rocks of the Mount Lofty - Flinders Ranges in the east and by Proterozoic rocks of the Stuart Shelf to the west. The western basin margin is defined by the Torrens Hinge Zone, whilst along the eastern basin margin refraction seismic studies and drilling indicate a locally complex structure of fault controlled horsts and troughs (Alley and Lindsay, 1995).

Adelaidean rocks, mainly Nelshaby Sandstone, form the conspicuous range to the east of Nelshaby and Napperby. In contrast, the two townships are underlain by more than 100 m of Tertiary and Quaternary sediments of the Pirie Basin. An attempt to define the boundary between the hard rocks and the sediments using transient electro-magnetic (TEM) geophysics (Dodds, 1994) produced somewhat ambiguous results. The step out drilling of this project indicated that the Adelaidian rocks continue, beneath the surface, from the base of the range to close to the eastern boundary of the old travelling stock route (Fig. A1-1).

BACKGROUND AND PROJECT AIM

Nelshaby and Napperby have had a history of market gardening. The location of the market gardening area is partly due to a historical accident. A travelling stock route 300 m in width (Fig. A1-1) was subdivided into approximately 8 ha sections and sold. Many of these sections were taken up by market gardeners because they were a convenient size and the local climate was well suited, especially as it is frost-free. Unfortunately, the groundwater beneath the old stock route is commonly over 1000 mg/l in salinity and is expensive to develop due to unconsolidated sands and the need to seal off the shallower aquifers which are usually more saline.

This project was carried out with the aim of demonstrating that better quality water could be obtained, using simpler and less expensive well completions, closer to the range. It was anticipated that useful supplies of good quality water should be obtainable, either in fractured Adelaidean bedrock near the fault at the foot of the range, or in coarser alluvium likely to occur close to the range.

In addition to demonstrating that better quality water could be obtained closer to the foot of the ranges the Tertiary sediments were to be investigated to determine their suitability as a storage medium for injecting water from the adjacent Morgan-Whyalla pipeline.

SUMMARY OF RESULTS

Five step-out wells, varying in depth from 11 to 29 m were drilled in an attempt to find the boundary between the Adelaidean rocks of the Flinders Range and the sediments of the Pirie Basin. In practice it was found to be very difficult to discriminate between fractured or weathered bedrock and alluvium with boulders; however, it is believed that all these holes intersected Adelaidian bedrock.

It was concluded that the most likely explanation for the rocks disclosed by the drilling was that there is a fault at the base of the range (running parallel with the range) and that there is a second fault between buried Adelaidean and the Pirie Basin, within a very few hundred metres to the west of the most westerly of the scout holes. The second fault most likely parallels the first.

Of the two intended production wells, Nos. 6 and 7, No. 6 obtained an air-lifted yield of 3.3 L/sec. of water having 1670 electrical conductivity units (ECU; approximately 920 mg/L total dissolved solids, TDS). It should be noted that the standing water level (SWL) of this well was 84.3 metres below ground level and that this resulted in a highly inefficient air-lift configuration; pumped yield could be substantially greater.

Well No. 7 obtained a yield of approximately 0.5 to 0.75 L/sec. of 1490 ECU (820 mg/L) water.

Well 6 was completed as a production well, while Well 7 was abandoned due to its low yield and highly unstable formation.

The project was considered a limited success because while it did demonstrate that good quality groundwater was available, it did not fully demonstrate that useful yields could readily be obtained.

FURTHER WORK

- Well No. 6 should be discharge tested to obtain a more accurate yield and to measure the transmissivity of the aquifer.
- A gravity survey should be done to try to discover the boundary between the buried Adelaidean bedrock and the Pirie Basin in the vicinity of the scout holes.
- Well No. 6 could be equipped by a consortium of small market gardeners. Until then it will be used to monitor regional water levels.

REFERENCE

Dodds, A.R., 1994. A Transient Electromagnetic Survey for Hydrogeology in the Hundred of Napperby, South Australia. *South Australia. Department of Primary Industries and Resources. Report Book*, 94/23.

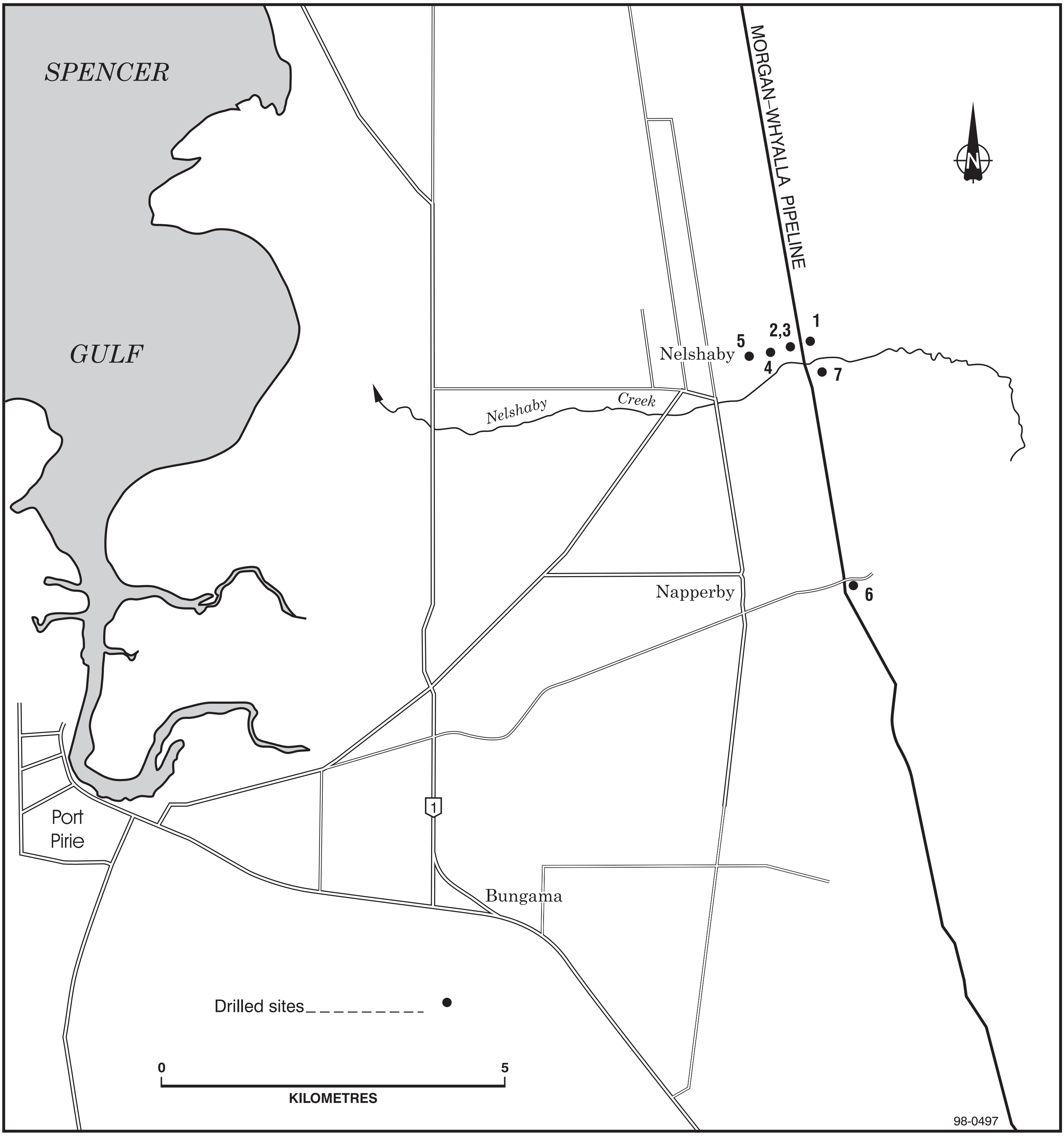


Fig. A1-1 Drilling locations of Napperby area.

GROUNDWATER EXPLORATION WELLS AT NAPPERBY AND NELSHABY, DRILLED 26/2/97 TO 6/3/97

WELL DATA TABLES

Well numbers and locations

Project Well No.	Permit No.	Unit No 6531-IV-	Easting	Northing	Descriptive Location	Section No.
1	PN 38493	Not Issued as at 5/97	231770	6331320	115 m from top (eastern end) of clearing	103
2	PN 38494A		231570	6331296	200 m W of No. 1, a few metres north of Pt. Pirie TWS pipeline.	103
3	PN 38494B		231565	6331296	5 m west of No. 2	103
4	PN 38495A		231261	6331220	300 m west of No. 3	103
5	PN 38495B		230990	6331170	300 m west of No. 4	103
6	PN 38500		232459	6327860	On roadside just SW of gate to Cunningham's Quarry	adj. 120
7	PN 38501		231820	6330865	Approx 70 m NE of the SA Water valve shed	327

General Well details

Project Well No.	Depth (m)	Purpose/ Status	Drilling Fluid
1	19.5	Scout	Air/foam
2	11.0	Stepout, abandoned	Air/foam
3	12.0	Stepout	Mud
4	29.0	Scout	Mud
5	24.0	Stepout	Mud
6	175.8	Production	Air/foam
7	154.0	Production, abandoned	Air/foam

Production Wells

SWL, Yield versus depth, Water Quality

Project Well No.	Depth (m)	SWL (m)	Cumulative air-lift yield (L/sec)	Conductivity ECU (mS/cm)	Casing type	Casing depth (m)
6	108.0	-	<0.1	980	200 mm PVC	0 to 9.5 m
	113.0	-	0.2	-		
	123.0	-	0.3	-		
	129.0	-	1.1	1400		
	144.0	-	2.4	1500		
	156.0	-	2.8	1565		
	168.0	-	3.1	1616		
	175.8	84.3	3.3	1670		
7	99.0	-	<0.5	1100	200 mm PVC	0 to 11 m
	136.0	-	0.5 to 0.75	1490		
	154.0	72.3	0.5 to 0.75	-		

Well Logs

All colours are from Munsell and apply to damp samples.

Scout Hole No. 1
PN 38493

Interval (m)		Description
from	to	
0	3	Silty clay with minor quartzite gravel, brownish red.
3	6	Clayey gravel. The gravel is quartzite. Red 2.5YR, various shades.
6	9	Gritty clay. Red 2.5YR 4/8
9	12	Gravelly clay. Red 2.5YR 5/8. The gravel is quartzite.
12	15	Quartzite seems to be consistent (bedrock). Red 2.5YR 5/6. The quartzite grades to sandstone.
15	19.5	As Above

Stepout Hole No. 2
PN 38494A

Interval (m)		Description
from	to	
0	3	Gravelly silt with sand. The gravel is quartzite. Reddish Yellow 5YR 6/6
3	6	Sandy gravel. Reddish yellow 5YR 6/6.
6	9	Gravel and sand, bouldery.
9	11	Boulders, gravel, quartzite.
		Hole abandoned at 11m because of collapsing walls

Stepout Hole No. 3
PN 38494B

Interval (m)		Description
from	to	
0	3	Gravelly silt with some clay. Red 2.5YR 5/8. The gravel is quartzite/sandstone.
3	6	Gravelly silt Most of the sample is quartzite, with some grey (5YR 6/1) shale.
6	9	Gravelly silt no shale, quartzite/sandstone. Red 2.5YR 5/8. Appears to be bedrock at about 8 m
9	12	Quartzite bedrock. Light red 2.5YR 5.5/6.

Scout Hole No. 4
PN 38495A

Interval (m)		Description
from	to	
0	3	Silty gravel. Red 10R 5/6. Hard even drilling for alluvium.
3	6	Clayey gravel. Yellowish red 5YR 5/6.
6	9	Gravelly clay. The clay is pinkish grey 5YR 7/2 to brown. Approx 20% quartzite gravel. Some red clay.
9	12	Clayey gravel. Most of the clay is light grey (or pinkish grey) the gravel is quartzite.
12	15	Boulders and clay, The boulders are quartzite, red; the clay is sandy, mainly light grey 5YR 7/1. (The formation seems to alternate between boulders and clay).
15	18	Boulders and clay, similar to above. Pale red 10R 6/4. (This could either be alluvium or weathered Adelaidian interbedded quartzite and shale).
18	24	Quartzite and clay similar to above.
24	27	Quartzite little clay. (Adelaidian bedrock).
27	29	Quartzite, very little clay. Red 2.5YR 5/6.

Stepout Hole No. 5
PN 38495B

Interval (m)		Description
from	to	
0	6	Silt and quartz rubble. Red 2.5YR 5/6
6	9	Silt and quartz rubble. Red 10R 5/6
9	12	Sandy clay with gravel. The sandy clay is pinkish grey 7YR 7/2, the gravel is quartzite, in various shades of red. Approx 40% gravel.
12	15	Sandy clay with 10% gravel
15	18	Gravel and sandy clay. Red quartzite gravel, with about 40% pinkish grey sandy clay.
18	21	As Above (possibly some indication of the gravel being broken from rounded pieces).
21	24	As Above until about 22.5 m, then quartzite bedrock (hard drilling, finer cuttings, practically no clay).

In all the scout holes discrimination between bedrock and bouldery alluvium was found to be very difficult and uncertain. This applies particularly to holes 4 and 5.

Production Well No. 6
PN 38500

Interval (m)		Description
from	to	
0	3	Gravel and sand with silt. The gravel is quartzite/sandstone (transitional between the two). Yellowish red 5YR 5/6.
3	6	Gravelly sand Red 2.5YR 5/6 (drilling with air circulation, the hole is unstable).
6	9	Sand moderately indurated. (The adjacent quarry has an exposure of about 9 m of boulder beds interspersed, apparently randomly, with lenses of moderately indurated sand/sandstone).
9	12	Sand/sandstone with boulders and gravel. Reddish yellow 5YR 6/6.
12	15	Gravel and sand, weakly indurated. Reddish yellow 5YR 6/6
15	18	As Above but more silty.
18	21	Sandy and gravelly clay. Pinkish white 7.5YR 8/2 (the clay is colouring the sample, the sand and gravel are red) weakly indurated.
21	24	Sandy gravel with white clay. The gravel is red (10R 4/6) sandstone.
24	27	Sandstone (crushed to sandy gravel by the bit) little clay. The sandstone is red 10R 4/6, is brittle and easily crushed.
27	36	Sandstone pale red 10R 6/3 (less coloured by iron oxide than above) quartz and weathered feldspar are more conspicuous than above.
36	39	Sandstone weakly indurated light red 10R 6/6. The sand is iron stained quartz with minor weathered feldspar.
39	45	Sandstone weakly indurated. The grains are angular around 1mm or less.
45	48	Sandstone weakly indurated with some quartz and some bedded silt (white).
48	51	Sandstone mainly weakly indurated, some moderately to well indurated, Sandstone mainly weakly indurated, some moderately to well indurated, light reddish brown 5YR 6/3.
51	54	As Above with minor white bedded clay
54	57	Sandstone mainly weakly indurated, some moderately to strongly indurated, some white clay, light reddish brown 2.5YR 6/3.5YR 6/4. The clay seems to be in beds.
57	60	Sandstone mostly weakly indurated. Mainly weak red 2.5YR 5/2 with white clay and weakly indurated siltstone.
60	66	Sandstone light reddish brown 2.5YR 6/4, weakly indurated with clay and silt both white.
66	72	Sandstone/Quartzite, moderately to strongly indurated, includes some weathered feldspar. Pinkish grey 5YR 7/2.
72	75	As Above but less indurated
75	96	Sandstone weakly to moderately indurated, pale red 10R 6/4, with white silt (weathered feldspar?).
96	99	As Above with minor quartz veins.
99	111	Sandstone light reddish brown 2.5YR 6/4, mainly weakly indurated with minor quartz.
111	117	Sandstone weakly to moderately indurated, some pieces are red 2.5YR 4/8 most are light reddish brown 2.5YR 6/4, the red sandstone is probably adjacent to fractures.
117	120	As above but a little more red weathered material, also a little clay.
120	123	Sandstone minor red weathered fragments, minor clay. Weak red 10R 5/4.
123	126	Sandstone moderately indurated. No clay in sample but the sandstone is feldspathic. Weak red 10R 5/4.
126	129	As Above but weak red 10R 4/4.
129	132	Sandstone moderate to well indurated, weak red 10R 5/3. With some white shale beds.
132	135	As Above with some pinkish grey, highly feldspathic, weakly indurated sandstone.
135	138	Sandstone weak red 10R 5/4 (minor red 10R 4/8, weathered sandstone).

138	141	As Above with minor highly feldspathic, pinkish grey, weakly indurated sandstone and minor quartzite.
141	144	Sandstone weak red 10R 5/4.
144	147	As Above minor red 10R 4/8 weathered.
147	150	Sandstone weak red 10R 5/4, minor white clay, minor quartz. Moderate to well indurated.
150	153	Sandstone pale red 10R 6/4.
153	162	sandstone mainly pale red 10R 6/4, some weathered red 2.5YR 5/8. Minor white sandy clay. Minor quartz
162	175.8	Sandstone red 7.5R 5/6. Moderate to well indurated. Minor quartz and white shale.
		Drilling stopped because of small but steady increase in salinity.

Production Well No. 7
PN 38501

Interval (m)		Description
from	to	
0	3	Clay and gravel. The clay is red 10R 4/8, the gravel is sandstone.
3	8.5	Clay with minor gravel 10R 4/8.
8.5	9	Clayey gravel. The gravel is coarse quartzite. No rounding is apparent.
9	12	Gravel with sand. The gravel is coarse quartzite ?unstable.
12	13	Quartzite (or quartzite rubble), well indurated.
13	15	Clay red 10R 4/3 minor sand and gravel.
15	21	Clay red 2.5YR 4/8 minor sand and gravel.
21	24	Sandy clay red 2.5YR 4/8 no gravel
24	27	Sandy clay with minor gravel. Red 2.5YR 4/8.
27	30	Sandy clay with minor gravel. Red 2.5YR 5/8.
30	33	Sandy clay. The clay is stiffer than above, light red 2.5YR 6/8 (this is the bulk sample, in detail it is mottled red and light grey).
33	36	Sandy clay mottled red and light grey, stiff.
36	39	Clayey gravel mottled red and light grey.
39	42	Clayey grit red 2.5YR 5/8.
42	51	Sandy clay (about 50/50), light red 2.5YR 6/8 with minor gravels
51	54	Clayey gravel the gravel is well indurated sandstone, quartzite and quartz. Reddish yellow 5YR 6/8.
54	57	Sandy clay (50/50) very little gravel. Yellow 10YR 8/6.
57	60	As Above but 20% sand no gravel. Mottled grey brown and red (bulk sample is very pale brown).
60	63	Sandy clay (approx 10% sand) mottled dark reddish brown abd grey (bulk sample is pink 5YR 7/4).
63	69	Gritty clay (approx 20% sand) with minor fine gravel. Reddish brown 5YR 5/4.
69	72	Sandy clay with approx 10% gravel (30% sand). Reddish yellow 5YR 6/6.
72	75	As Above but pink 7.5YR 7/4.
75	81	Sandy clay with minor gravel.
81	87	Sandstone (no clay). Reddish yellow 5YR 6/8.
87	90	Sandstone and clay reddish yellow 7.5YR 6/6.
90	96	Sand mainly weakly indurated, reddish yellow 7.5YR 6/6.
96	102	Sand mainly weakly indurated, red 2.5YR 5/6.
102	105	Silty sand weakly indurated. Reddish yellow 5YR 6/6.
105	108	Silty sand The sand is coarser than above. Reddish yellow 5YR 6/6.
108	111	Sandstone and sand, silty.
111	114	As above with some sandy clay.
114	117	Sand weakly indurated and sandy clay. Reddish yellow 5YR 7/8.
117	120	Sandstone with light grey sandy clay. Reddish yellow 5YR 7/6.
120	123	Sand with minor sandstone (the whole must be weakly indurated).
123	126	As Above but a little more stony.
126	129	Sandstone red 2.5YR 4/8 and silty, clayey sand light grey 5YR 7/1.
129	141	Sand and sandstone silty. Reddish yellow 5YR 6/8.
141	150	Sand and sandstone with minor sandy clay. Light red 2.5YR 6/6.
150	153	Sand and sandstone with quartz. The sandstone is red and brownish red (the bulk sample is red 2.5YR 5/6)
		This hole became unstable and had to be abandoned at 154m. Samples from 72 to 153 m in this hole were logged from the driller's sample piles, all other samples were logged as they came from the hole.

APPENDIX 2

CROSS SECTIONS THROUGH PIRIE TORRENS BASIN

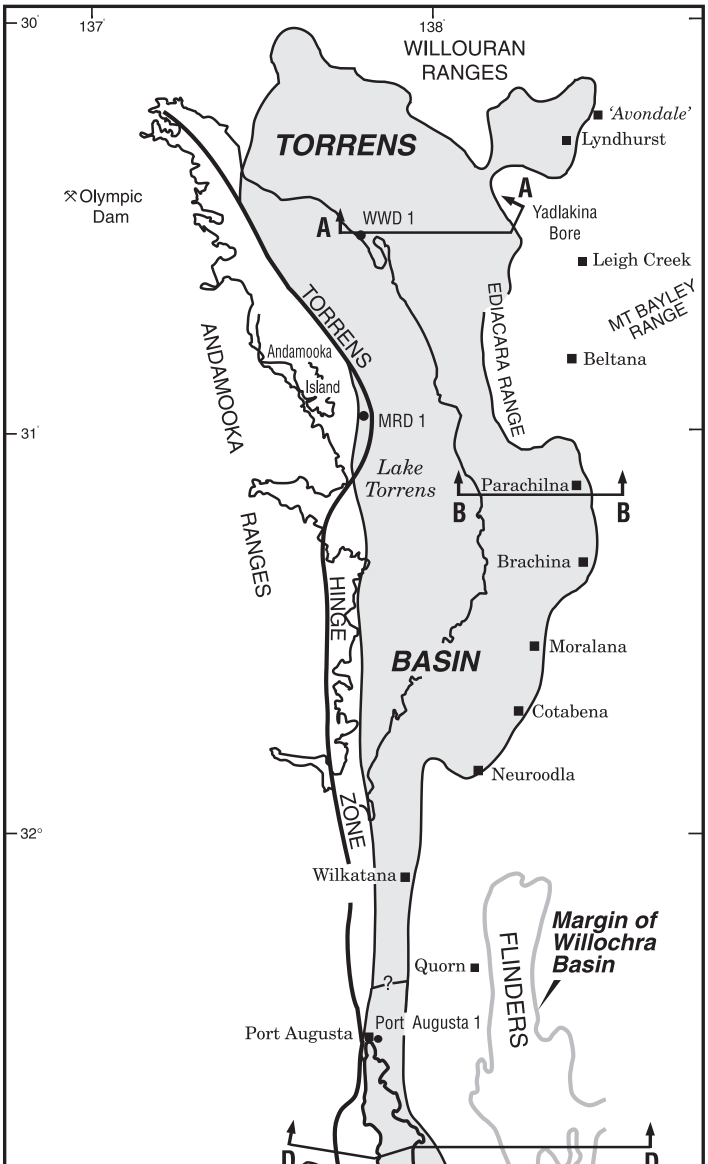
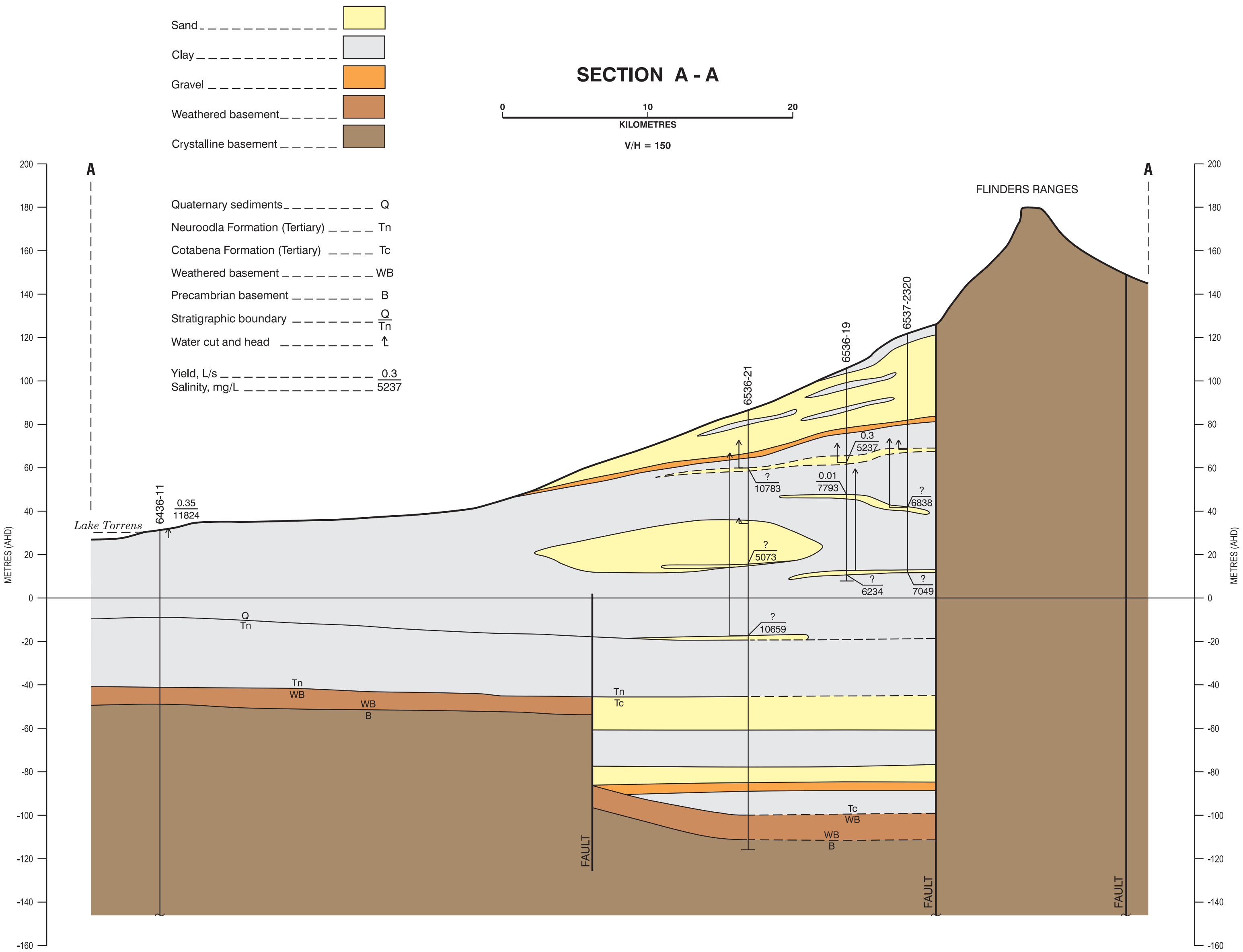
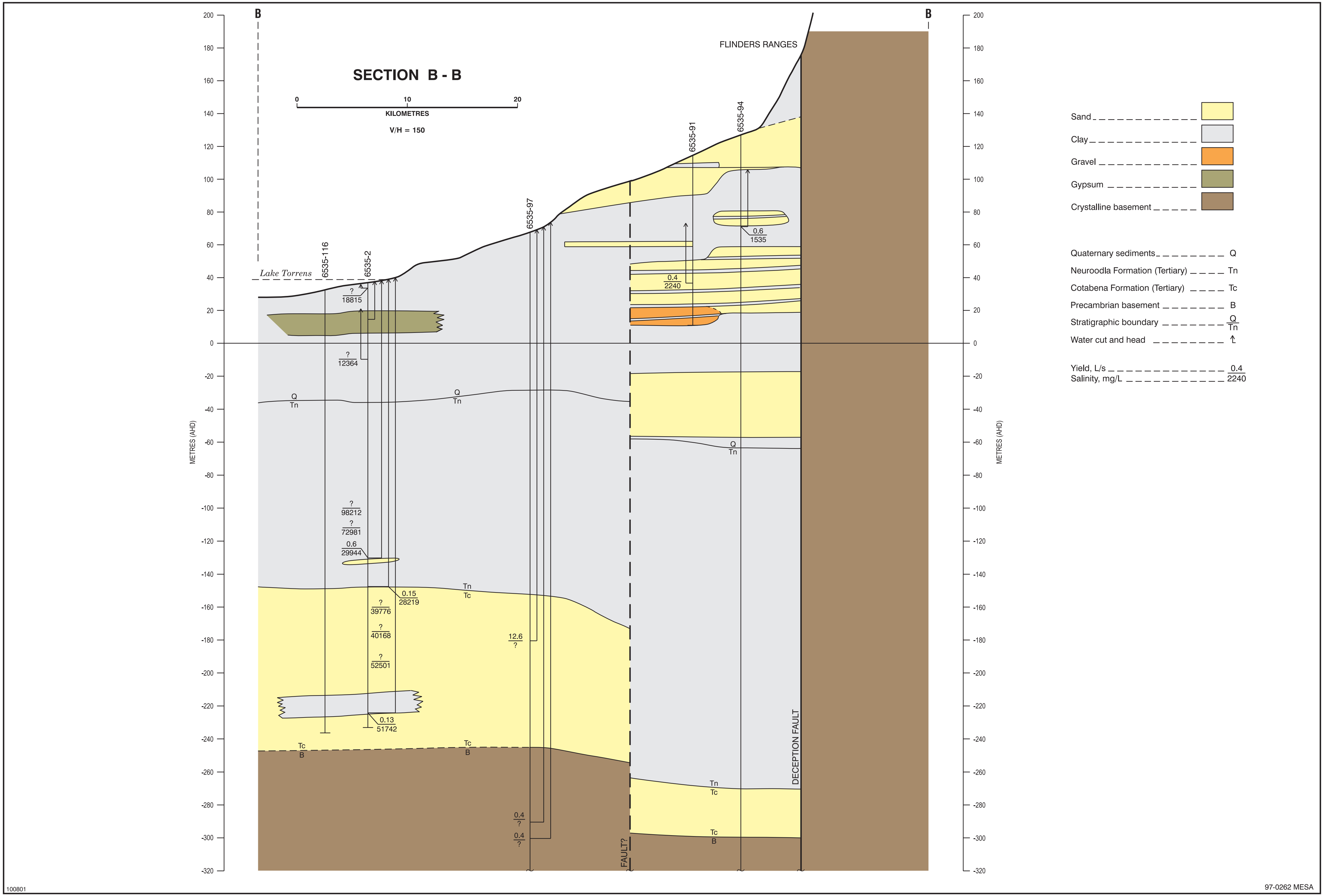


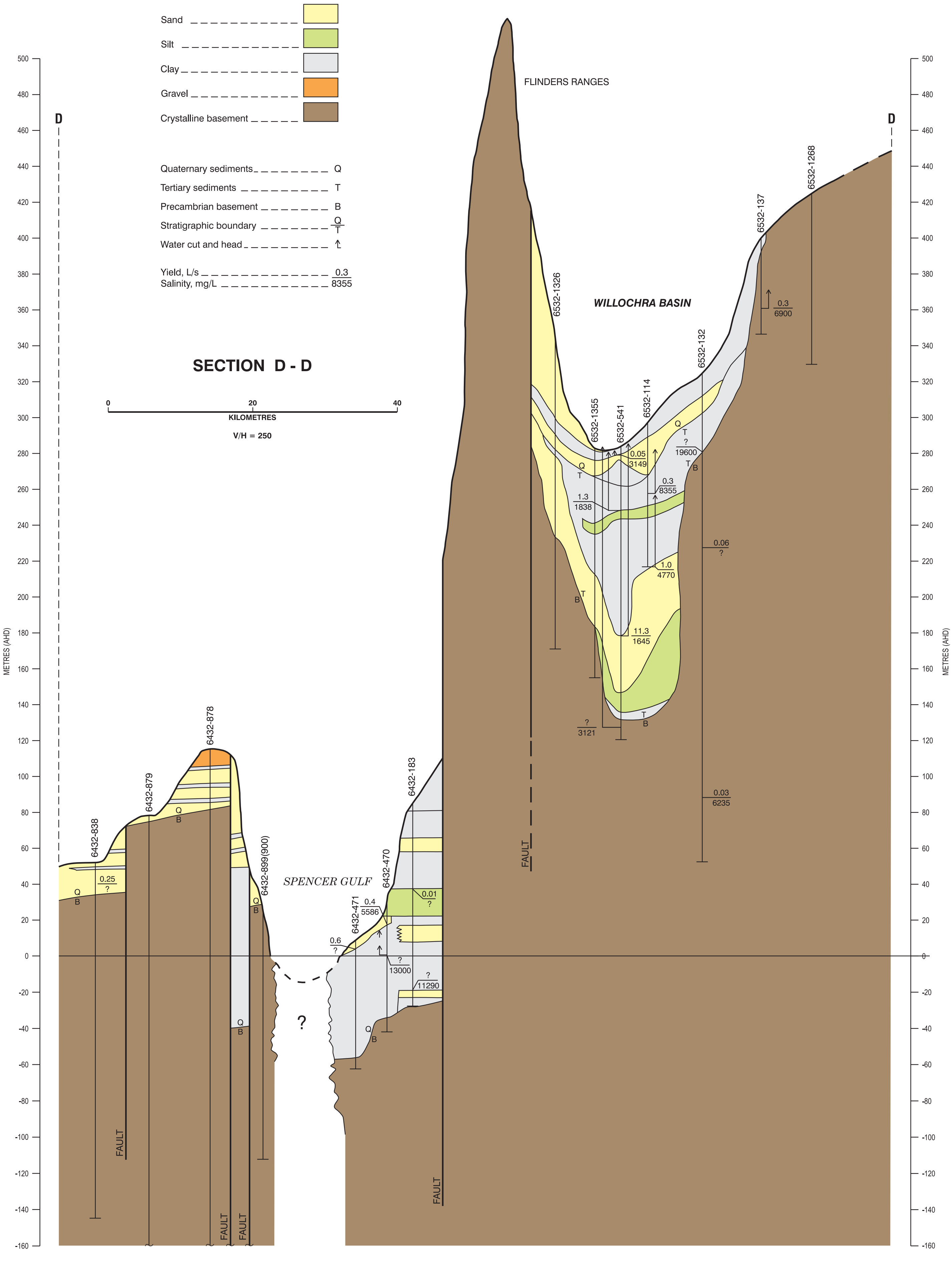
Fig. A2-1 Pirie-Torrens Basin showing cross section locations.

SECTION A - A

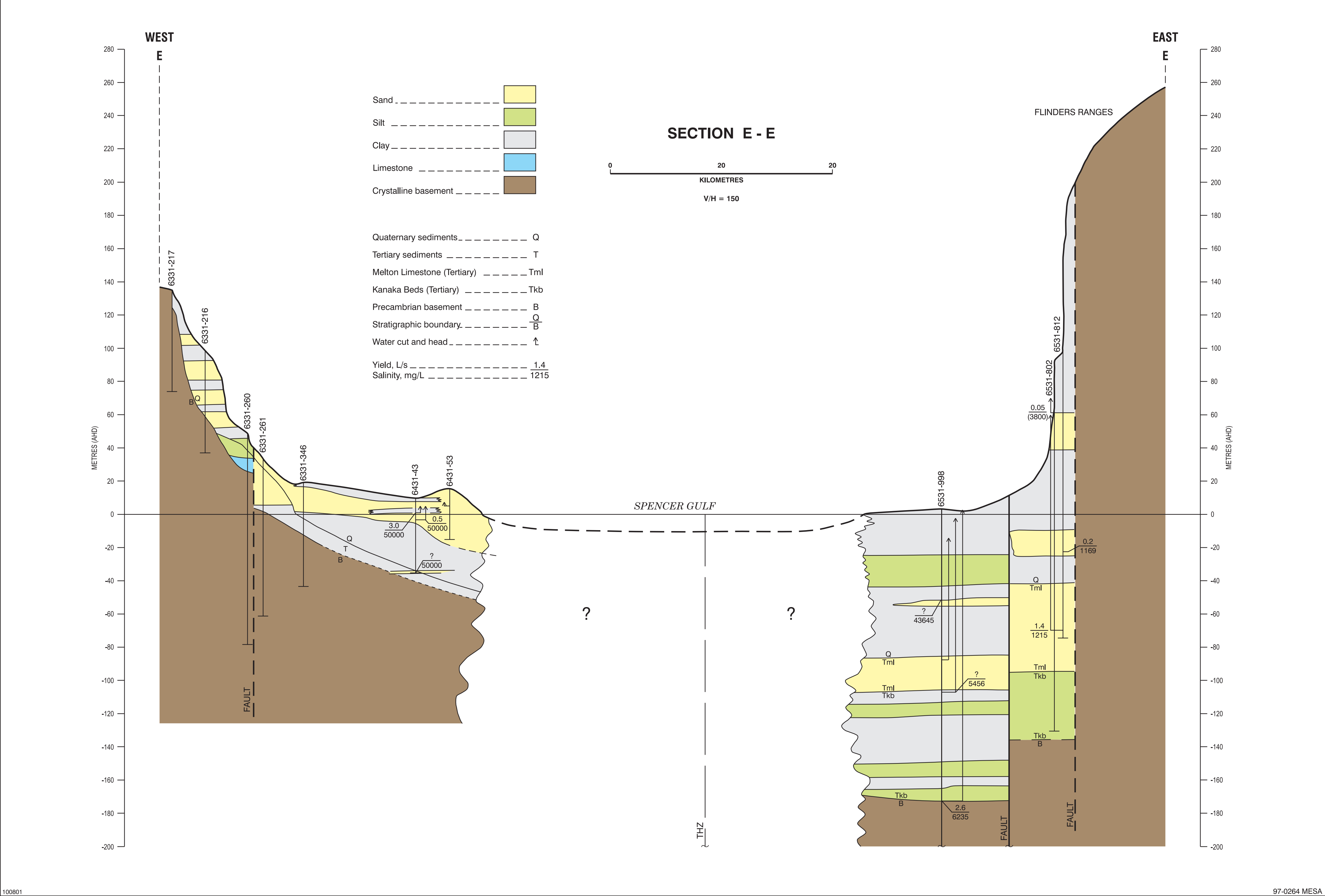


Sand
Clay
Gravel
Weathered basement
Crystalline basement
0 10 20
KILOMETRES
V/H = 150
Quaternary sediments Q
Neuroodla Formation (Tertiary) Tn
Cotabena Formation (Tertiary) Tc
Weathered basement WB
Precambrian basement B
Stratigraphic boundary Q/Tn
Water cut and head
Yield, L/s 0.3
Salinity, mg/L 5237
A
A
FLINDERS RANGES
Lake Torrens
6436-11
6536-21
6536-19
6537-2320
METRES (AHD)
FAULT

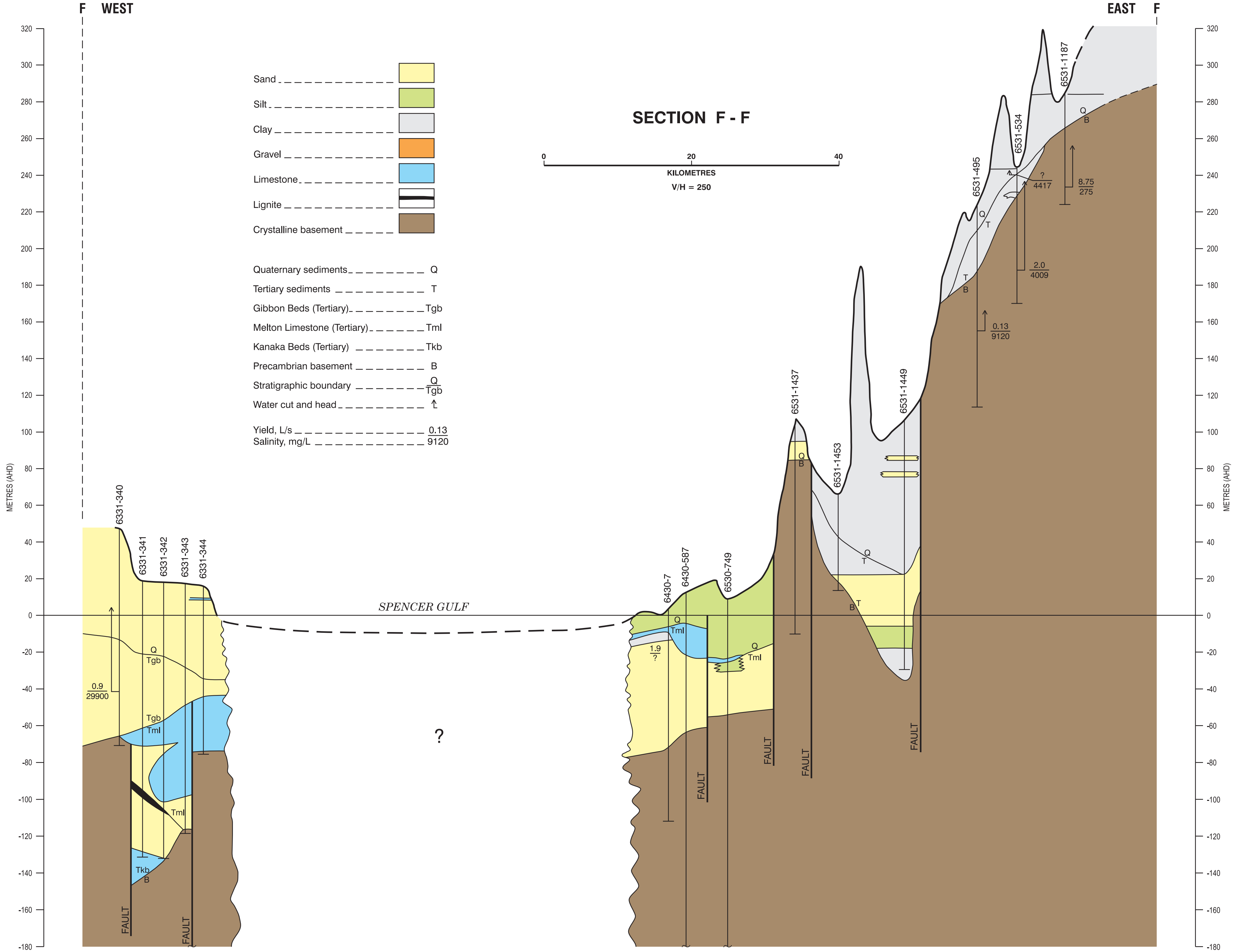

SECTION B - B
0 10 20
KILOMETRES
V/H = 150
B
B
FLINDERS RANGES
Lake Torrens
6535-116
6535-2
6535-97
6535-91
6535-94
DECEPTION FAULT
FAULT?
METRES (AHD)
Q
Tn
Tc
B
Sand
Clay
Gravel
Gypsum
Crystalline basement
Quaternary sediments Q
Neuroodla Formation (Tertiary) Tn
Cotabena Formation (Tertiary) Tc
Precambrian basement B
Stratigraphic boundary Q/Tn
Water cut and head
Yield, L/s 0.4
Salinity, mg/L 2240
100801
97-0262 MESA



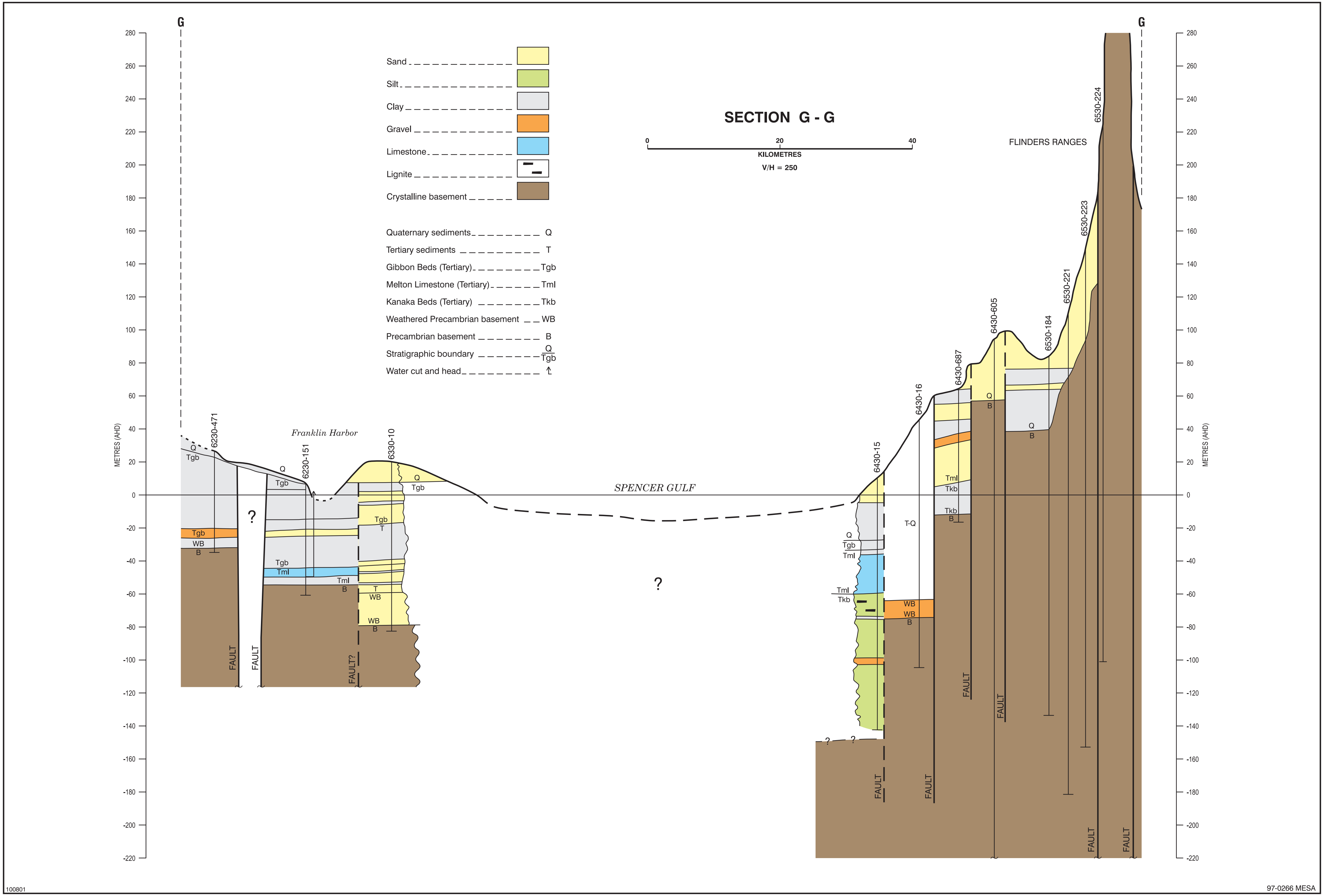
SECTION D - D
Sand
Silt
Clay
Gravel
Crystalline basement
Quaternary sediments Q
Tertiary sediments T
Precambrian basement B
Stratigraphic boundary Q/T
Water cut and head
Yield, L/s 0.3
Salinity, mg/L 8355
0 20 40
KILOMETRES
V/H = 250
D
D
FLINDERS RANGES
WILLOCHRA BASIN
SPENCER GULF
METRES (AHD)
FAULT
6432-838
6432-879
6432-878
6432-899(900)
6432-471
6432-470
6432-183
6532-1326
6532-1355
6532-541
6532-114
6532-132
6532-137
6532-1268



SECTION E - E
WEST
E
EAST
E
0
20
20
KILOMETRES
V/H = 150
Sand
Silt
Clay
Limestone
Crystalline basement
Quaternary sediments Q
Tertiary sediments T
Melton Limestone (Tertiary) Tml
Kanaka Beds (Tertiary) Tkb
Precambrian basement B
Stratigraphic boundary Q/B
Water cut and head
Yield, L/s 1.4
Salinity, mg/L 1215
METRES (AHD)
FLINDERS RANGES
SPENCER GULF
6331-217
6331-216
6331-260
6331-261
6331-346
6431-43
6431-53
6531-998
6531-802
6531-812
3.0
50000
0.5
50000
?
50000
0.05
(3800)
0.2
1169
?
43645
1.4
1215
?
5456
2.6
6235
FAULT
THZ
?



F WEST
EAST F
SECTION F - F
0 20 40
KILOMETRES
V/H = 250
Sand
Silt
Clay
Gravel
Limestone
Lignite
Crystalline basement
Quaternary sediments Q
Tertiary sediments T
Gibbon Beds (Tertiary) Tgb
Melton Limestone (Tertiary) Tml
Kanaka Beds (Tertiary) Tkb
Precambrian basement B
Stratigraphic boundary Q/Tgb
Water cut and head
Yield, L/s 0.13
Salinity, mg/L 9120
METRES (AHD)
SPENCER GULF
?
6331-340
6331-341
6331-342
6331-343
6331-344
6430-7
6430-587
6530-749
6531-1437
6531-1453
6531-1449
6531-495
6531-534
6531-1187
0.9
29900
1.9
?
0.13
9120
2.0
4009
?
4417
8.75
275
FAULT


SECTION G - G
0
20
40
KILOMETRES
V/H = 250
Sand
Silt
Clay
Gravel
Limestone
Lignite
Crystalline basement
Quaternary sediments Q
Tertiary sediments T
Gibbon Beds (Tertiary) Tgb
Melton Limestone (Tertiary) Tml
Kanaka Beds (Tertiary) Tkb
Weathered Precambrian basement WB
Precambrian basement B
Stratigraphic boundary Q/Tgb
Water cut and head
FLINDERS RANGES
Franklin Harbor
SPENCER GULF
METRES (AHD)
G
6230-471
6230-151
6330-10
6430-15
6430-16
6430-687
6430-605
6530-184
6530-221
6530-223
6530-224
FAULT
FAULT?
T-Q
100801
97-0266 MESA

APPENDIX 3

GROUNDWATER DRILLING IN THE GAWLER CRATON

GAWLER CRATON DRILLING

INTRODUCTION

Primary Industries and Resources South Australia (PIRSA) Groundwater Program undertook an investigation in the northern Gawler Craton area for groundwater potential of the Permian-Tertiary sediments in the palaeochannel north of the Mulgathing trough and basement fractured rock on the fringes of the Tallaringa trough (Fig. 1). The programme carried out by PIRSA, involved:

- the drilling and completing 5 appraisal/ monitoring wells;
- estimating groundwater quality and yield of potential aquifers;
- pump testing and calculating aquifer parameters.

RESULTS OF DRILLING

Drilling of the five appraisal/monitoring wells commenced on 23 April 1997 and was concluded on 10 May 1997. Geological logs are contained on pages 90 through 111 of this report.

The first well (**P/N 40629**) was drilled to a total depth of 75.5 m using rotary mud drilling up to Precambrian fractured rock and using percussion air drilling in fractured rock. Cuttings and bulk samples were collected at 3 m intervals over the entire penetrated depth. The well was completed using 152 mm OD PVC casing with the casing shoe set at a depth of 54 m. The casing was cemented over the interval 30 to 54 m and remaining section of the well was left as an open hole completion.

The well was developed by airlifting with rate of 0.5 L/s and a water sample was obtained (2 litres). The field Electrical Conductivity of 122 500 µS/cm inferred a Total Dissolved Solids (TDS) content of 88 100 mg/L. The sample was sent for full chemical analysis and mineral content on 26 May 1997. After recovering a standing water level (SWL ie. depth to water) was 19.70 m. on 26 April 1997.

The second well (**P/N 40630**) was drilled in a Permian? Trough to a total depth of 180.5 m using rotary mud drilling. Cuttings and bulk samples were collected at 3 m intervals over the entire penetrated depth. The well was completed using 152 mm OD PVC casing with the slotted interval set from 132 to 156 m and blank casing set at interval from 156 to 168 m. The casing was cemented over the interval 0 to 6 m.

The well was developed by airlifting with rate of 3.5 L/s and duration was 120 minutes. On completion of airlifting a water sample was obtained (2 litres). The field Electrical Conductivity of >200 000 µS/cm (off-scale of Conductivity Meter) inferred a Total Dissolved Solids (TDS) content of >150 000 mg/L. The sample was sent for full chemical analysis and mineral content on 26 May 1997. After recovering a standing water level was 17.25 m on 2 May 1997.

The third well (**P/N 40631**) was drilled in Anthony Palaeochannel to a total depth of 70.6 m using rotary air drilling. Cuttings and bulk samples were collected at 3 m intervals over the entire penetrated depth. The well was completed using 152 mm OD PVC casing with the slotted interval set from 29 to 41 m. The casing was cemented over the interval 0 to 5.8 m.

The well was developed by airlifting with rate of 0.5 L/s and duration was 60 minutes at which a water sample was obtained (2 litres). The field Electrical Conductivity of 410 000 µS/cm inferred a Total Dissolved Solids (TDS) content of 26 000 mg/L. The sample was sent for full chemical analysis and mineral content on 26 May 1997. After recovering a standing water level was 22.1 m on 6 May 1997.

The fourth well (**P/N 40632**) was drilled to a total depth of 57.4 m using rotary mud drilling up to Precambrian fractured bedrock and using percussion air drilling in fractured bedrock. Cuttings and bulk samples were collected at three metre intervals over the entire penetrated depth. The well was completed using 152 mm OD PVC casing with the casing shoe set at a depth of 35.7 m. The casing was cemented over the interval 8 to 38.3 m and remaining section of the well was left as an open hole completion.

The well was developed by airlifting with rate of 1.0 L/s and a water sample was obtained on completion of development (2 litres). The field Electrical Conductivity of 136 200 µS/cm inferred a Total Dissolved Solids (TDS) content of 98 600 mg/L. The sample was sent for full chemical analysis and mineral content on 26 May 1997. After recovering a standing water level was 15.52 m on 8 May 1997.

After checking on 10 May 1997 the open hole of this well was collapsed back to a depth of 36 m. On the same day the well was cleaned to a depth of 55.5 m but collapsed back after drill string was removed. This is possibly a result of fractured intervals which were not detected during percussion drilling.

The fifth well (**P/N 40633**) was drilled to a total depth of 55.7 m using rotary mud drilling up to Precambrian fractured rock and using percussion air drilling in fractured basement. Cuttings and bulk samples were collected at 3 m intervals over the entire penetrated depth. The well was completed using 152 mm OD PVC casing with the casing shoe set at a depth of 35.6 m. The casing was cemented over the interval 11 to 36 m and remaining section of the well was left as an open hole completion.

The well was developed by airlifting with rate of 0.5 L/s and a water sample was obtained (2 litres). The field Electrical Conductivity of 56 500 µS/cm inferred a Total Dissolved Solids (TDS) content of 37 600 mg/L. The sample was sent for full chemical analysis and mineral content on 26 May 1997. After recovering a standing water level was 17.0 m on 10 May 1997.

All wells were geophysically logged at the completion of the drilling programme. Composite water well logs are contained at the end of this Report.

RESULTS OF PUMPING TESTS

The most critical well for potential water supply is well which was drilled at site 2 (**P/N 40630**) to the total depth 180.5 m. The thickness of Permian? sand aquifer at that site is more than 55 m (from 125 to 180.5 m interval, see log).

A step drawdown test on this well was carried out on 4/06/97 and constant discharge tested on 5/06/97 with pump set depth of 80m.

Equation (1) was defined by analysing of step drawdown tests.

$$S(t)= aQ+b\log(t)Q+cQ^2 \quad (1)$$

Where $S(t)$ = drawdown at time t (m);
Q = discharge/injection rate (m^3 /min);
t = time (minute);
a = constant related to well loss for laminar flow;
b = constant related to aquifer loss for laminar flow;
c = constant related to well loss for turbulent flow.

Equation (1) defines drawdown S(t) at any time for varying discharge rates.

The step drawdown test was carried out over 3 steps at rates of 2.0; 4.0; 6.0 L/sec with a duration of 100 minutes for each step and has been used for determining the well equation:

$$S(t) = 34.86Q + 7.12 \log (t)Q + 5.86Q^2$$

This equation generally reflects the well behaviour at rate between 2.0 and 6.0 L/sec.

An average transmisivity for three steps is 37 m^2/day and maximum drawdown at the end of third step was 19.5 m.

The step drawdown test did not attain steady-state flow and therefore, a specific capacity for this well cannot be calculated.

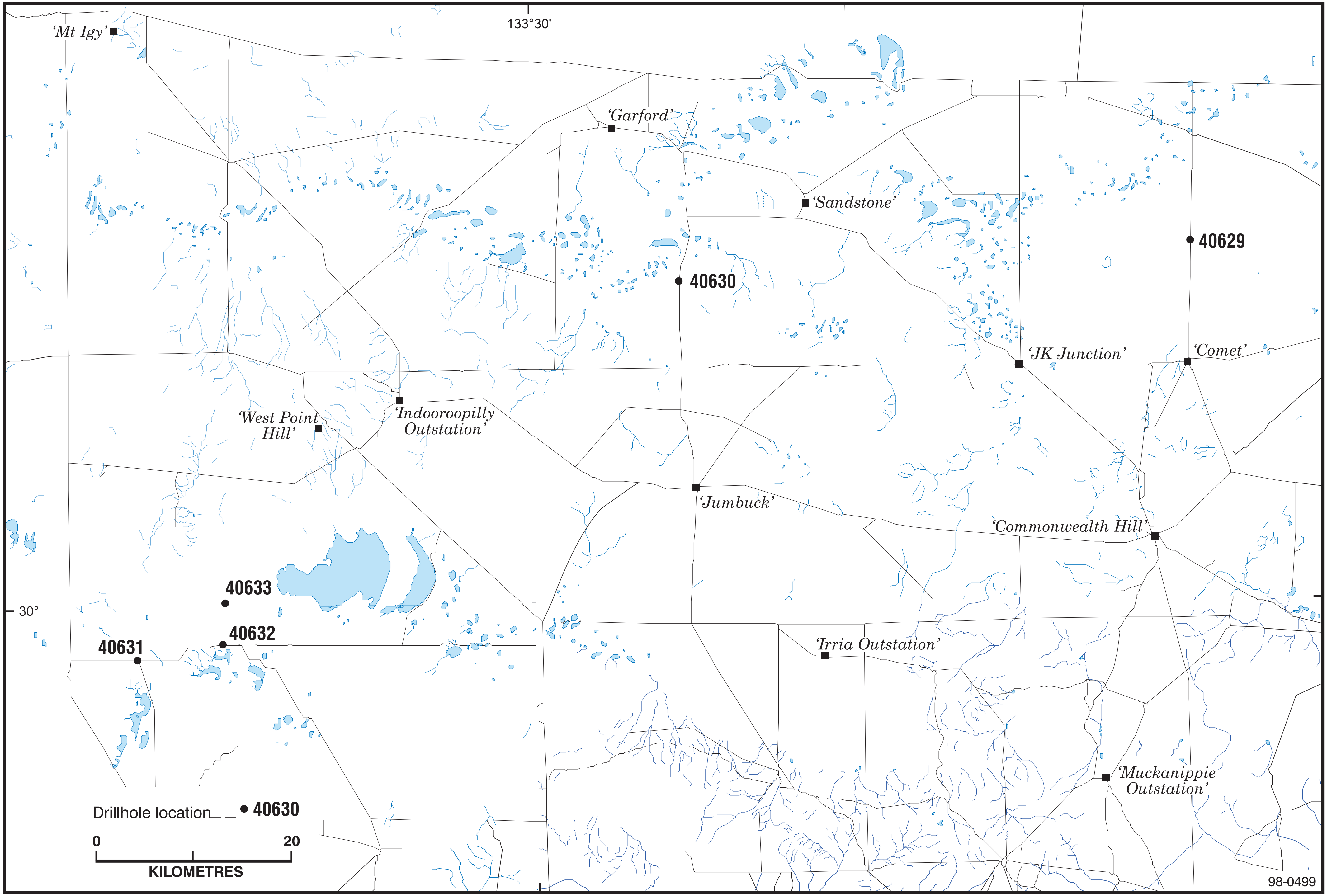


Fig. A3-1 Drilling locations of Gawler Craton area.

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MINES AND ENERGY – SOUTH AUSTRALIA
GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97–0857

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary, Percussion
CIRCULATION Mud, Air
MUD RESISTIVITY/TYPE
START 23/04/97 FINISH 25/04/97
TOTAL DEPTH 75.6 m

	mm	From (m)	To (m)
HOLE DIAMETER	251	0	6
	203	6	55
	142	55	75.6
CASING DIAMETER (Cemented)	209	0	5.5
	145	0	54
OPEN HOLE (Uncemented)	OH	54	75.6
SCREEN DETAILS			

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD		TOTAL DISSOLVED SOLIDS	
		m³/day	Method of Test	mg/litre	Analysis W No.
	19.7		Airlift	71 902	

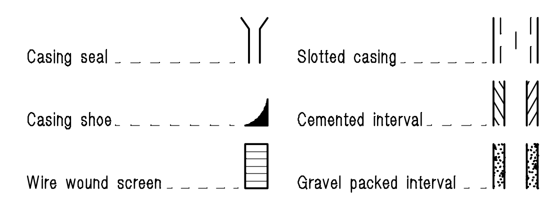
REMARKS

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 40629
LOCATION Easting 421731
Northing 6717027
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 25/04/97

GEOPHYSICS

TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res				
DATE OF RUN	9/5/97	9/5/97	9/5/97	9/5/97				
FIRST READING (m)	75.95	75.95	75.95	75.95				
LAST READING (m)	0.0	0.0	0.0	0.0				
RECORDED BY	DBF	DBF	DBF	DBF				

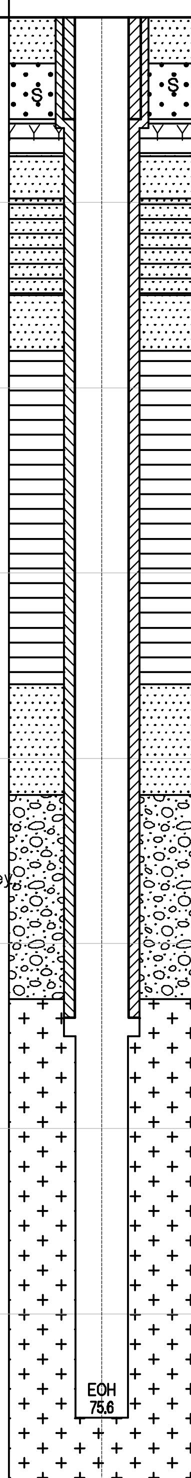
WELL SYMBOLS



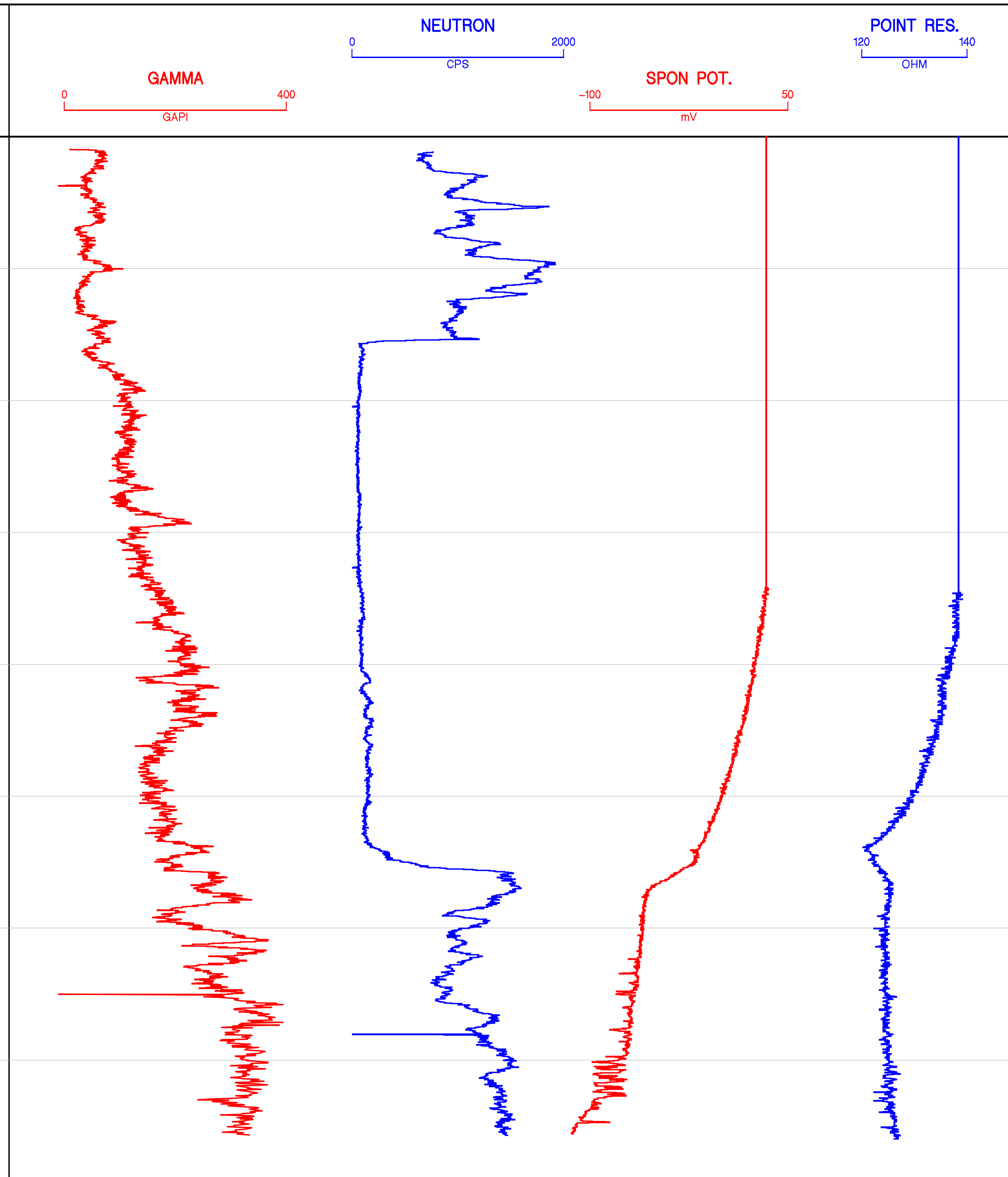
LITHOLOGY

DEPTH (m)	AGE	UNIT	DESCRIPTION
0			0–2.5 SAND dark red, quartz. Poorly sorted, fine to coarse grained, subangular to subrounded. Calcareous.
			2.5–5.5 SILCRETE interbedded hard and soft bars. Pale grey, medium to coarse grains cemented by fine cement.
			5.5–7.5 SILTY CLAY light grey, white, sticky, a few medium to coarse quartz grains throughout. With gypsum beds.
			7.5–9.8 SAND light pale grey, quartz, medium to coarse, with silcrete beds.
20			9.8–15 CLAYEY SAND grey to white (kaolinitic?), quartz, fine to coarse grained, some gravel grains throughout. Subangular to subrounded. Becoming greyish white in colour with depth.
			15–18 SAND quartz, brownish grey, grey. Mainly coarse, subangular. Some ironstained beds. Clayey at the bottom.
			18–36 CLAY interbedded dark grey, grey, bluish grey, brownish grey, grey–brown, with greenish grey beds. Plastic. Laminated. Sticky. With some thin beds of black to dark brown carbonaceous clay.
40			36–42 SAND Quartz, slightly clayey, grey in colour, mainly coarse grained, some gravel content, max. grain size up to 5mm with mica flakes (muscovite) up to 3mm in diam. some black mineral grains. Angular to subangular.
			42–53 SANDY GRAVEL greenish grey quartz, angular. With clayey sand beds greenish grey in colour. Mica content increasing with depth. From 44.0m with grey granite fragments. From 45.0 with milky-white feldspars fragments, from 47.5m with kaolinitic clay beds.
60			53–75.6 GRANITE hard grey, coarse grained. Comprises mainly off-white to milky quartz, rose and milky white feldspars. Black and off-white mica black and light green to olive-green mineral inclusion. Rare pyrite crystals 0.5mm in diam. With black, hard, fine grained gneiss beds (thickness is up to 1.5 m). From 73.0 fractured zone, thickness 15–20cm

CONSTRUCTION and LITHO. LOG



HYDRO DATA



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MINES AND ENERGY – SOUTH AUSTRALIA

GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97–0858

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary
CIRCULATION Mud
MUD RESISTIVITY/TYPE
START 27/04/97 FINISH 01/05/97
TOTAL DEPTH 180.5 m

	mm	From (m)	To (m)
HOLE DIAMETER	251	0	6
	203	6	180.5
CASING DIAMETER (Cemented)	209	0	6
CASING DIAMETER (Uncemented)	145	0	132
	145	156	168
SLOTTED CASING	145	132	156

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD m³/day	YIELD Method of Test	TOTAL DISSOLVED SOLIDS mg/litre	TOTAL DISSOLVED SOLIDS Analysis W No.
	17.25	302.4	Airlift	116 848	
		561.6	Pump	135 378	

REMARKS

GEOPHYSICS

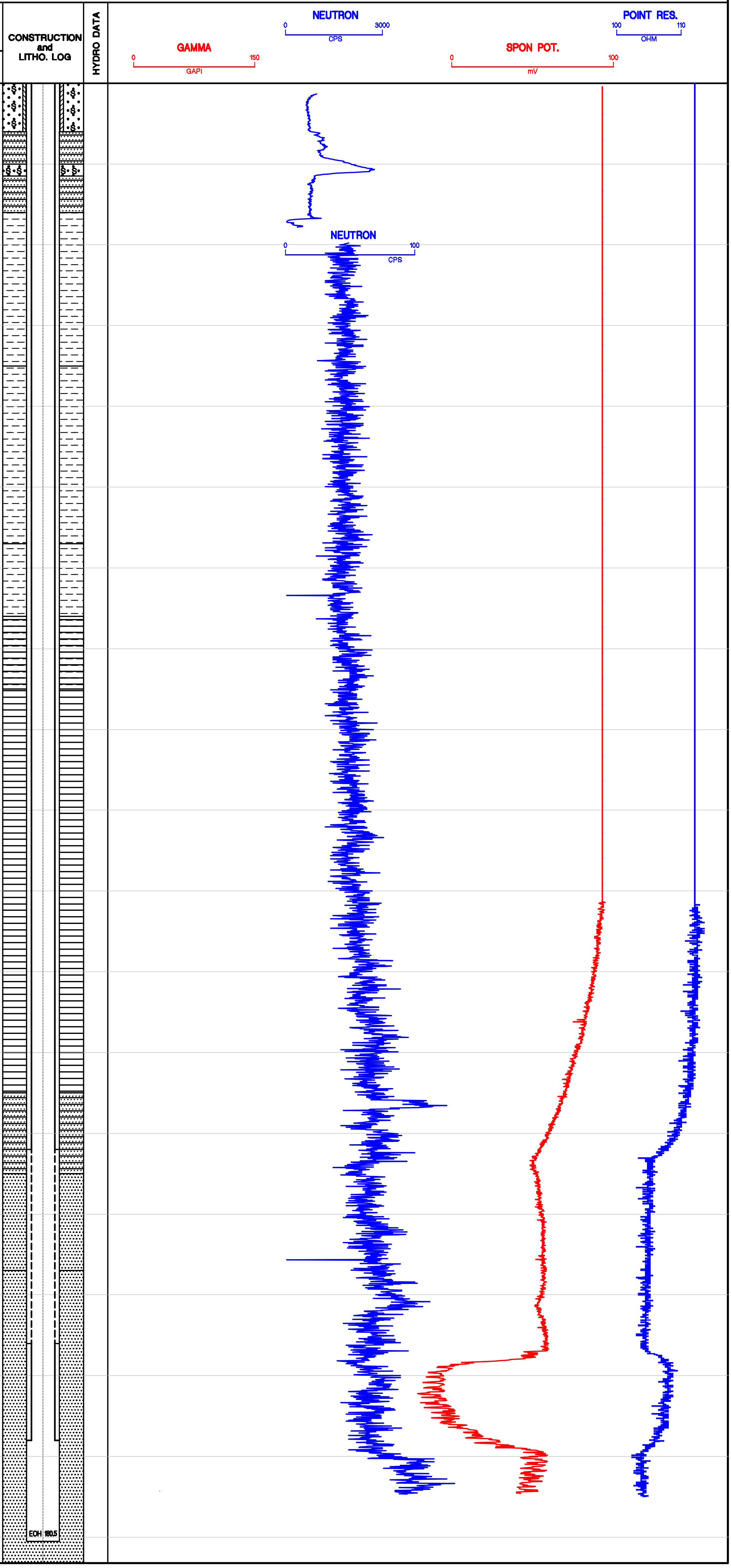
TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res
DATE OF RUN	9/5/97	9/5/97	9/5/97	9/5/97
FIRST READING (m)	174.95	174.95	174.95	174.95
LAST READING (m)	0.0	0.0	0.0	0.0
RECORDED BY	DBF	DBF	DBF	DBF

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 40630
LOCATION Easting 369786
Northing 6712828
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 01/05/97

WELL SYMBOLS

Casing seal — Slotted casing — Casing shoe — Cemented interval — Wire wound screen — Gravel packed interval

DEPTH (m)	AGE	UNIT	LITHOLOGY – DESCRIPTION
0			0–6 SAND, SILCRETE pinkish red, quartz, dry, poorly sorted, fine to coarse grained, subrounded to subangular. Calcareous. With interbedding of very hard and soft silcrete, fine grained.
			6–10 CLAY, CLAYEY SAND interbedded greyish white clay and clayey sand. Clay–plastic, sticky. Clayey sand–mainly medium grained, subrounded.
			10–11.5 SILCRETE, SAND as 0–6 m .
			11.5–16 SANDY CLAYpinkish grey , light grey to grey, plastic when wet, laminated. Up to 50% fine sand and silt content. With beds of greenish light yellow sand, subangular.
20			16–39 CLAYEY SILT dark brownish grey, greyish brown, dark grey to black, stiff to hard, sticky, plastic when wet, laminated, with crystals of pyrite (0.5mm in diam.), and pyrite nodules up to 5cm length and 2–3cm wide and a few white solid grains up to 1mm in diam., a few mica flakes up to 1mm in diam.
40			39–57CLAYEY SILTa/a, but thinly laminated. From 56.0– with thin beds of grey silty clay.
60			57–66 CLAYEY SILT as 16 – 39m, but from 60 to 63– with thin beds of grey silty clay.
			66–75 CLAYEY SILT, SILTY CLAY interbedded black clayey silt as 16–39 and grey silty clay, stiff, plastic when wet, laminated, with pyrite crystals and mica flakes. From 73 m. with thin beds of yellowish grey hard siltstone and pyritic beds (1mm thick).
80			75–125 SILTY CLAY grey to bluish grey, stiff to hard, plastic when wet, laminated, with pyrite crystals 0.5mm in diam., and mica flakes 0.7mm in diam. With beds of black clayey silt as 18.5–39.0m. From 108m–with beds of stiff to hard black to blue–grey shale thickness 2–4cm, and from 114m.–with beds of grey, hard sandstone well cemented, fine to medium grained, subrounded to rounded quartz grains, max. thickness 30cm (117.0–117.3m).
100			
120			125–135 CLAYEY SANDgreyish white, grey, quartz, mainly fine grained, about 10% of medium grained, subrounded to rounded, some coarse quartz grains and a few black grains up to 1.5mm in diam. A few red grains up to 1.5mm in diam., some of them–red rock fragments.
140			135–147 SAND grey, quartz, slightly clayey, fine to medium grained, subrounded to well rounded, well sorted, a few coarse quartz grains. some red and black grains up to 1.5mm in diam.
160			147–180.5 SAND grey, quartz, mainly medium grained, subrounded. Increasing content of coarse quartz grains up to 30%, subangular to angular. 10% of red granite fragments up to 1.5cm in diam., some of them very angular, some subrounded. Black, greenish and yellowish granules throughout, also a few bluish. From 159 m.– increasing amount of angular granite fragments. From 177 m.– loosing circulation
180			



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MINES AND ENERGY – SOUTH AUSTRALIA

GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97–0859

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary
CIRCULATION Air
MUD RESISTIVITY/TYPE
START 03/05/97 FINISH 04/05/97
TOTAL DEPTH 70.6 m

	mm	From (m)	To (m)
HOLE DIAMETER	251	0	6
	201	6	70.6
CASING DIAMETER (Cemented)	206	0	5.8
CASING DIAMETER (Uncemented)	142	0	29
SLOTTED CASING	142	29	41

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD m³/day	YIELD Method of Test	TOTAL DISSOLVED SOLIDS mg/litre	TOTAL DISSOLVED SOLIDS Analysis W No.
31	22.1	43.2	Airlift	36680	

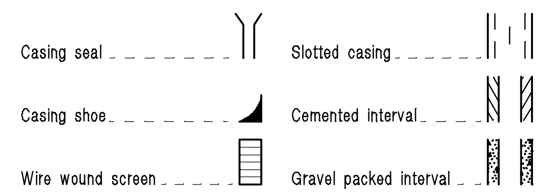
REMARKS

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 40631
LOCATION Easting 314793
Northing 6674358
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 04/05/97

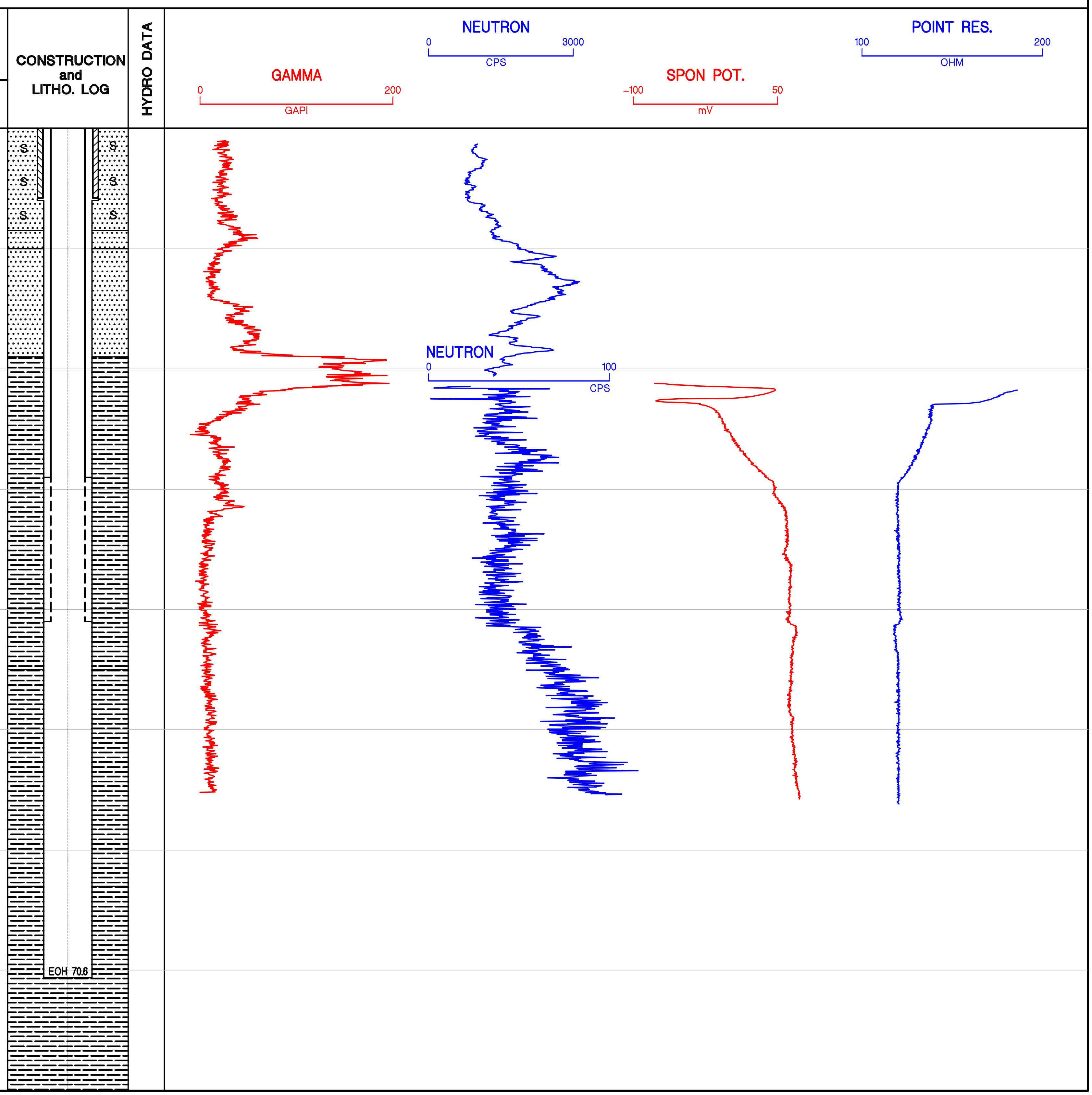
GEOPHYSICS

TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res
DATE OF RUN	10/5/97	10/5/97	10/5/97	10/5/97
FIRST READING (m)	56.2	56.2	56.2	56.2
LAST READING (m)	0.0	0.0	0.0	0.0
RECORDED BY	DBF	DBF	DBF	DBF

WELL SYMBOLS



DEPTH (m)	AGE	UNIT	LITHOLOGY – DESCRIPTION
0			0–8.5 SAND dark red, quartz, poorly sorted, fine to coarse grained, subangular to angular, calcareous. From 3.0m–non–calcareous. With silcrete beds, hard, well cemented, from 5 to 30 cm thick.
			8.5–10 SAND grey, quartz, fine to medium grained, mainly subangular.
			10–19 SAND orange–red, pink to yellow, quartz, mainly fine to medium grained, mainly subangular. With a few yellow hard sandstone beds, medium grained, well cemented, max thickness 2–3cm. From 12m.– dark red to greyish white, fine to medium grained sandstone, well to poorly cemented. From 15m– with a few beds of greyish white very clayey sand.
20			19–45 LIGNITE dark brown to black, sandy, sand content, quartz, fine to medium grained. With pyrite crystals 0.5mm to 1mm in diam. Dark brown variety contains 5–7% of pins 2–3mm in length (sponge spicules?) up to depth 27m. From 21m. with pyrite nodules up to 4 mm in diam. From 31m. with hard white oolites? (up to 4 mm in diam., no reaction with HCl) and with very thin (thickness is about 1mm) fine grained, rounded, sand beds with abundant pyrite crystals.
40			45–63 CLAYEY LIGNITE with some pyrite nodules 2x5cm.
60			63–70.6 LIGNITE a/a, but less clay content. From 66.0 – a few quartz grains coarse sand–sized, subrounded



100801AS.DTA

MINES AND ENERGY – SOUTH AUSTRALIA

GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97–0860

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary Percussion
CIRCULATION Mud, Air
MUD RESISTIVITY/TYPE
START 05/05/97 FINISH 07/05/97
TOTAL DEPTH 57.4 m

	mm	From (m)	To (m)
HOLE DIAMETER	251	0	6
	201	6	38
	139	38	57.4
CASING DIAMETER (Cemented)	206	0	5.2
	142	0	35.7
CASING DIAMETER (Uncemented)			
OPEN HOLE	OH	36	57.4

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD		TOTAL DISSOLVED SOLIDS	
		m³/day	Method of Test	mg/litre	Analysis W No.
	15.5	86.4	Airlift	83081	

REMARKS

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 40632
LOCATION Easting 323650
Northing 6676045
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 07/05/97

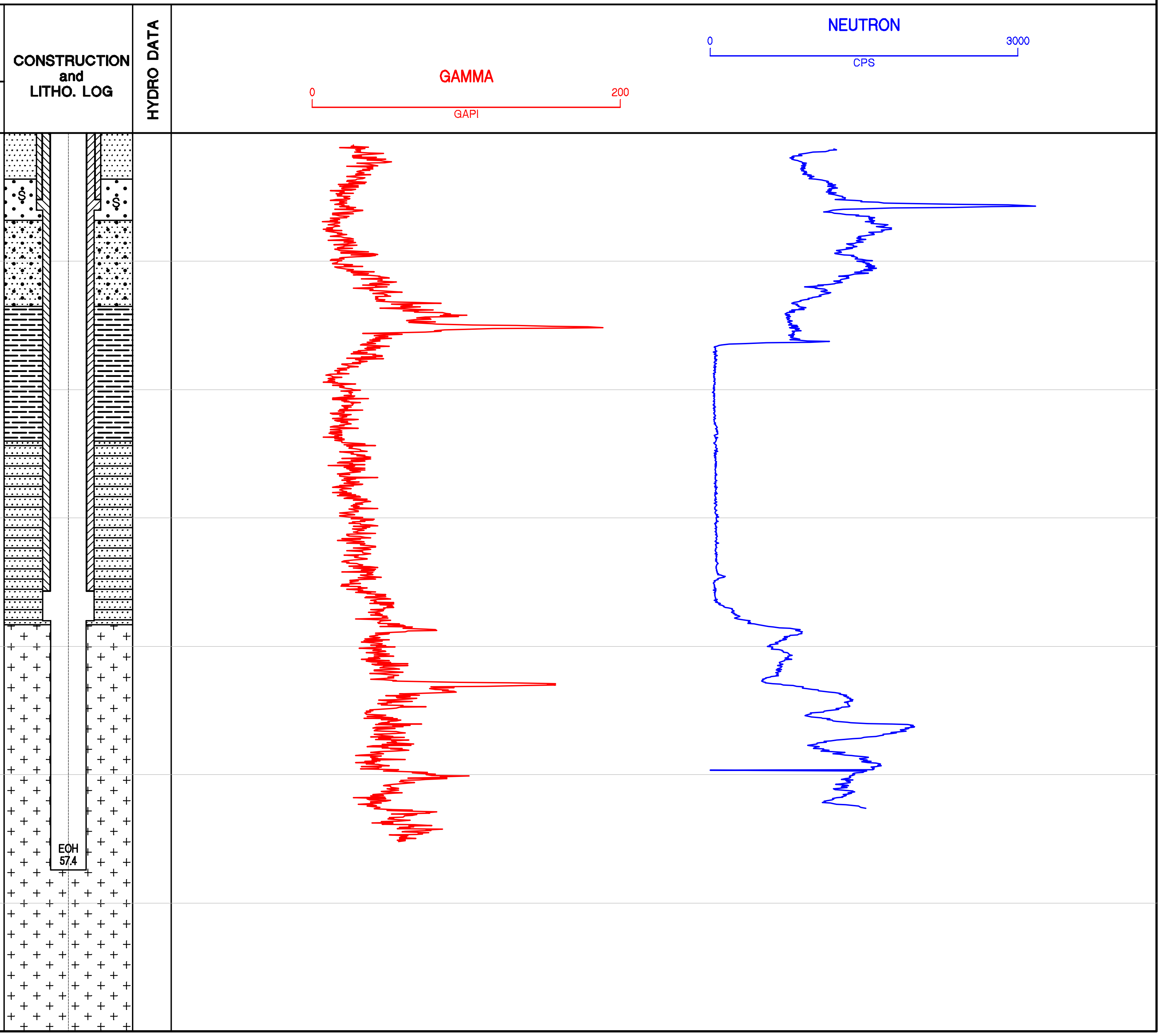
GEOPHYSICS

TYPE OF LOG	Gamma	Neutron					
DATE OF RUN	10/5/97	10/5/97					
FIRST READING (m)	55.25	52.8					
LAST READING (m)	0.0	0.0					
RECORDED BY	DBF	DBF					

WELL SYMBOLS

Casing seal
Slotted casing
Casing shoe
Cemented interval
Wire wound screen
Gravel packed interval

DEPTH (m)	AGE	UNIT	LITHOLOGY – DESCRIPTION
0			0–3.6 SAND pink–red to orange, quartz, poorly sorted, medium to coarse grained, subrounded to angular, calcareous.
			3.6–6.8 SILCRETE very hard, orange–red to greyish white, well cemented.
			6.8–13.5 SANDSTONE, SAND dark red (ironstained) and yellow sandstone, medium to coarse grained, poorly to well cemented interbedded with yellow to orange–red, clayey sand, fine to medium grained, subangular. Non–calcareous.
			13.5–24 SILTY LIGNITE dark chocolate to black, laminated, plastic when wet, with pyrite crystals (0.5mm) throughout. At the bottom of interval with sand content and a few coarse sand–sized quartz grains throughout.
20			24–38.3CLAYEY SANDlight brown to pale grey, with greyish blue mottling, gravelly, subangular to angular, quartz, gravel content up to 10%. Micaceous, mica flakes up to 1mm in diam. Increasing coarse grains content with the depth. Max. grain size up to 1.5cm in diam., angular. From 33m. with fragments of light grey to grey granite and abundant quartz grains up to 1.5cm.
40			38.3–57.4 GRANITE hard, coarse grained, top of interval is fractured. Mainly quartz, black and pink mineral grains present. Some crystals of sulphide minerals and mica. Decreasing pyrite crystals and pink mineral content with depth
60			



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MINES AND ENERGY - SOUTH AUSTRALIA
GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97-0861

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD: Rotary Percussion
CIRCULATION: Mud, Air
MUD RESISTIVITY/TYPE: 08/05/97
START FINISH 10/05/97
TOTAL DEPTH 55.7 m

	mm	From (m)	To (m)
HOLE DIAMETER	251	0	6
	201	6	36
	137	36	55.7
CASING DIAMETER (Cemented)	206	0	5.5
	142	0	35.6
CASING DIAMETER (Uncemented)			
OPEN HOLE	OH	35.6	55.7

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD m³/day	YIELD Method of Test	TOTAL DISSOLVED SOLIDS mg/litre	TOTAL DISSOLVED SOLIDS Analysis W No.
	17.0	43.2	Airlift	34155	

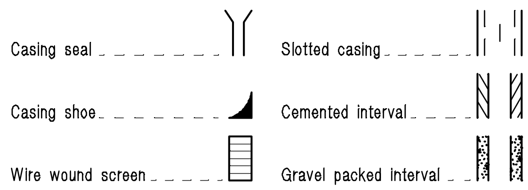
REMARKS

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 40633
LOCATION Easting 323820
Northing 6680217
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 10/05/97

GEOPHYSICS

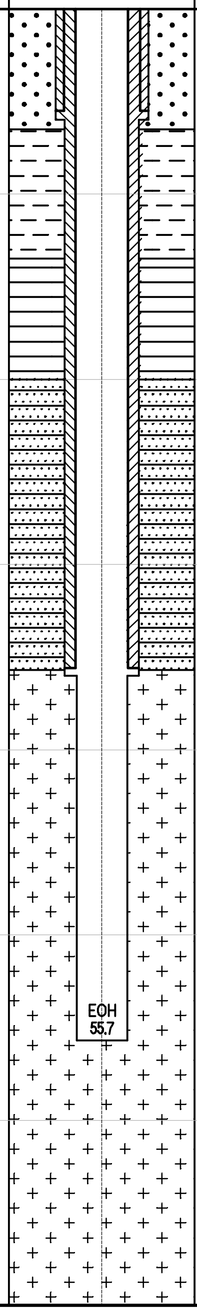
TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res	Density	Caliper		
DATE OF RUN	10/5/97	10/5/97	10/5/97	10/5/97	10/5/97	10/5/97		
FIRST READING (m)	56.0	56.0	56.0	56.0	56.0	56.0		
LAST READING (m)	0.0	0.0	0.0	0.0	0.0	0.0		
RECORDED BY	DBF	DBF	DBF	DBF	DBF	DBF		

WELL SYMBOLS

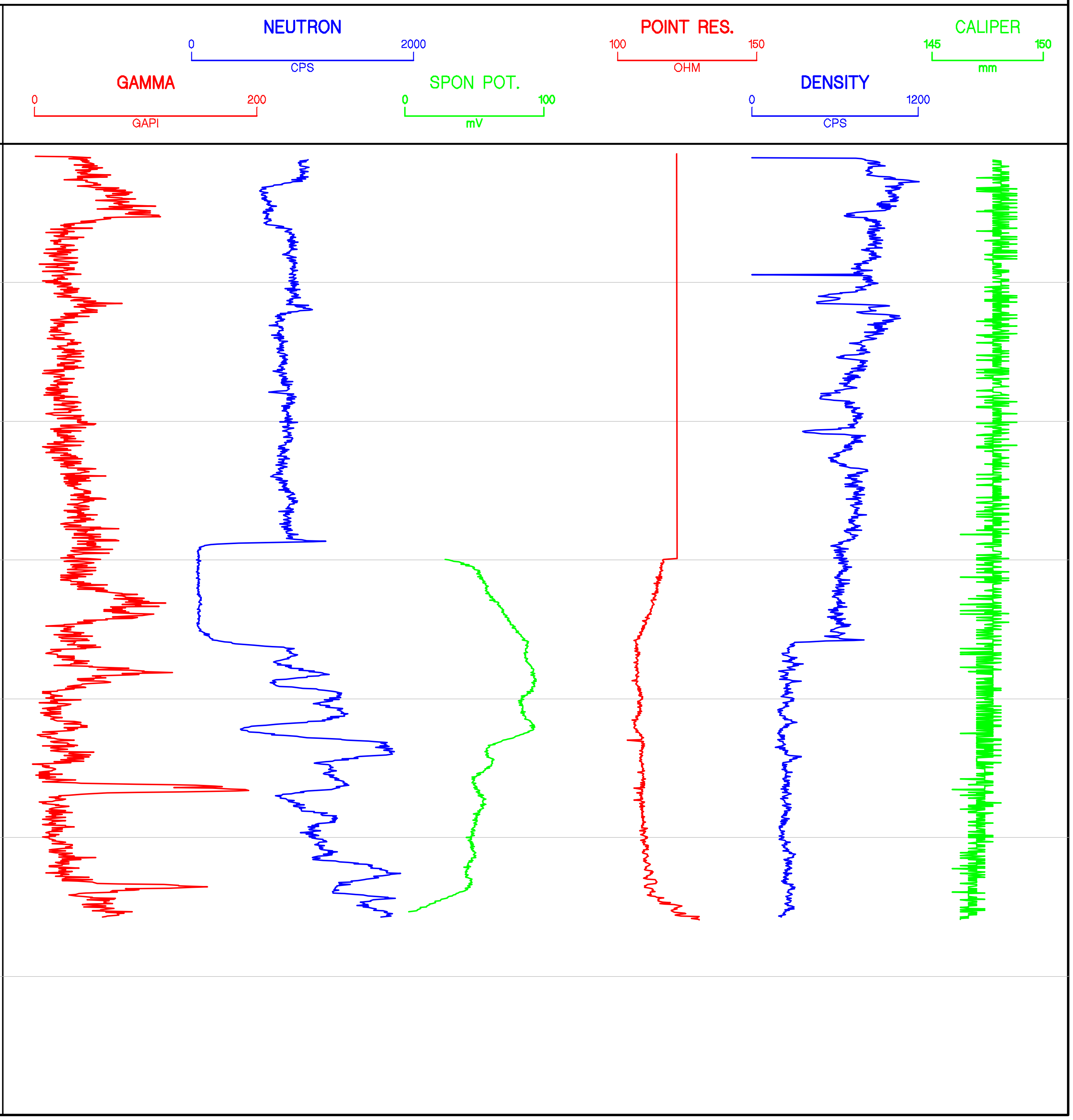


DEPTH (m)	AGE	UNIT	LITHOLOGY – DESCRIPTION
0			0-6.5 SANDSTONE (SILCRETE) dark red to pale grey, well cemented, fine to medium grained, ironstained, calcareous to slightly calcareous.
			6.5-13.5 CLAYEY SANDY SILT white, with pink to dark red mottling, stiff to hard, plastic when wet. 20-30% sand content, mainly medium grained, subangular to angular. With sandstone fragments (as 0-6.5m.). From 9.0 - loosing circulation. Non-calcareous.
			13.5-20 SILTY CLAY white, milky chocolate, reddish brown, yellow, pinkish red, mottled. Stiff to hard, up to 15% sand content, with sandstone fragments. Abundant black minerals grains, medium sand-sized. Loosing circulation.
20			20-35.7 SANDY CLAY Pinkish grey to white, bluish grey, yellow in part mottled, stiff to hard, plastic when wet., very fine grained, slightly micaceous. Sand content quartz, fine to medium grained, some coarse grains, angular to very angular, a few grains up to 3cm in diam. Abundant fine black grains 0.1mm in diam. With hard sandstone beds and fragments dark red in colour. At the end of interval some quartz pebbles up to 4cm in diam and grey granite fragments.
40			35.7-55.7 GRANITE dark grey, hard, coarse grained, mainly quartz, mica, feldspars pinkish white, milky white to off-white in colour, some greenish grey and black mineral granules. From 48m. with a few chips of chlorite and pyrite crystals in quartz up to 1mm in diam
60			

CONSTRUCTION and LITHO. LOG



HYDRO DATA



PROJECT: North Spencer Gulf

LOCATION OR COORDS:
421731 (Easting); 6717027 (Northing)

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION:

PERMIT NO: 40629

UNIT NO:

Hundred: WOORONG Sec:

El.Surface (m): El.Ref.Point (m): Datum:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	l/sec	Test length	Method	mg/ltr	Analysis No:
		19.7	54	75.6			Airlift	88 134	Field analysis

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	2.5		SAND	Brownish red to dark red quartz sand. Poorly sorted, fine to coarse grained, loose, subangular to subrounded. Dry. Calcareous.			209 145	0 0	5.2 54.0
2.5	5.5		SAND, SILCRETE	Interbedded hard silcrete, soft silcrete and sand. Sand: as 0–2.5 m, but pinkish red when dry, dark red when wet, a few black grains 0.5 mm in diam. throughout. Non-calcareous. Silcrete interbedded very hard and soft beds. Pale grey to reddish grey in colour. Very hard silcrete, very well cemented, conglomerate structure, subrounded quartz grains, medium to coarse sand-sized cemented by very fine grained cement. Soft silcrete same description a/a, but poorly cemented. Top part of interval contains a few gypsum crystals up to 2 cm in diam.					
5.5	6.5		SILTSTONE	Grey siltstone, slightly clayey, poorly cemented, some ironstained bars. With grey clay beds up to 0.5 cm thick and thin black beds and patches up to 3 mm in diam., (poss. MnO?). Non-calcareous.					

REMARKS: Drilling water salinity was 1664 mg/l. Casing was pressure cemented from 30.0 to 54.0 m. Open hole from 54.0 to 75.6 m.

DRILL TYPE: Rotary, Percussion

COMPLETED: 25/04/1997

CIRCULATION: Mud, air.

LOGGED BY: A. Sereda

DATE: 23/04/1997

SHEET 1 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40629

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
6.5	7.0		CLAY	White clay (second. kaolin?) slightly silty, sticky, plastic when wet, easily friable when dry, a few black grains up to 0.4 mm in diam. throughout. Non-calcareous.					
7.0	7.5		SILTY CLAY	Light grey silty clay, sticky, a few quartz grains medium to coarse sand-sized throughout. With beds of gypsum crystals 2–3 cm thick. Non-calcareous.					
7.5	9.2		SAND	Light pale grey quartz sand. Slightly clayey. Poorly sorted, medium to very coarse grained, some fine gravel-sized quartz grains. Subangular to subrounded. Some ironstained patches. Non-calcareous.					
9.2	9.6		SILCRETE	Two beds of very hard, firm silcrete, pale grey in colour, conglomerate structure, well cemented with subrounded quartz grains, coarse sand-sized. Thickness of each bed about 20–25 cm, soft bed between them (poss. sand).					
9.6	9.8		SANDY CLAY	Pinkish grey sandy clay, plastic when wet. Abundant quartz coarse sand-sized grains, a few fine gravel-sized grains, subangular. Non-calcareous.					
9.8	15.0		CLAYEY SAND	White (kaolinitic?) clayey sand, quartz, poorly sorted, fine to coarse grained, some gravel grains throughout. Subangular to subrounded. Becoming greyish white in colour with depth.					
15.0	17.5		SAND	Quartz sand, brownish grey in colour. Mainly coarse, some quartz grains up to 3 mm in diam., subangular. Some ironstained beds.					
17.5	18.0		SANDY CLAY	Grey, dark grey, brownish grey sandy clay. Plastic when wet. Sand content about 30%, medium to coarse grained, subangular to subrounded. Non-calcareous.					

SHEET 2 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40629

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK / SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
18.0	21.0		CLAY	Clay, interbedded dark grey, brownish grey, grey-brown. Plastic. Laminated. Sticky. With some thin beds of black to dark brown carbonaceous clay.					
21.0	24.0		CLAY	a/a, but grey in colour and rare thin carbonaceous beds.					
24.0	27.0		CLAY	a/a, bluish grey in colour.					
27.0	30.0		CLAY	a/a, but light bluish grey in colour.					
30.0	35.7		CLAY	a/a, but with several greenish grey beds of clay.					
35.7	39.0		SAND	Quartz sand, slightly clayey, grey in colour, mainly coarse grained, some gravel content, max grain size up to 5 mm. Angular to subangular.					
39.0	42.0		SAND	a/a, but with mica flakes (muscovite) up to 3 mm in diam. some black mineral grains ~1.5 mm in diam. and a few green and dark green grains ~1 mm in diam. Some greenish grey beds of clayey sand, fine to medium grained, angular. Non-calcareous.					
42.0	45.0		SANDY GRAVEL	Greenish grey sandy gravel, quartz, angular. With clayey sand beds greenish grey in colour. Mica content increasing with depth. From 44.0 m with grey granite fragments.					
45.0	53.0		SANDY GRAVEL	a/a, but with some fragments of white, milky white feldspars (plagioclase?). From 47.5 m with kaolinitic clay beds, white and greyish white in colour, abundant black solid grains up to 0.3 mm in diam.					
53.0	53.9		GRANITE	Hard grey granite, coarse grained. Mainly quartz, rose and milky white feldspars.					

SHEET 3 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40629

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
53.9	55.0		GNEISS	Black hard gneiss, fine grained (poss. schist). Becoming harder with depth. With thin quartz beds.					
55.0	57.0		GRANITE	Hard granite, coarse grained, mainly off-white quartz, white and rose feldspars, black mica (biotite?), black and light green mineral inclusion.					
57.0	58.0		GNEISS	Black gneiss as 53.9–55.0.					
58.0	62.0		GRANITE	Rose granite, coarse grained, comprises quartz, rose feldspars (microcline), mica (biotite or muscovite), grains of black minerals. Rare white feldspars. Rare pyrite crystals 0.5 mm in diam.					
62.0	64.5		GNEISS	Black gneiss with quartz beds as 53.9–55.0					
64.5	75.6		GRANITE	Granite coarse grained, comprises off-white quartz, milky-white feldspars, some olive-green and black minerals and mica (muscovite?). From 73.0 fractured zone, thickness 15–20 cm.					
				End of bore - 75.6 m					

SHEET 4 of 4

PROJECT: North Spencer Gulf

LOCATION OR COORDS:
369786(Easting); 6712828(Northing)

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION

PERMIT NO: 40630

UNIT NO:

Hundred: JUMBUCK Sec:

El.Surface (m): El.Ref.Point (m): Datum:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m) From	INTERVAL (m) To	SUPPLY l/sec	SUPPLY Test length	SUPPLY Method	TOTAL DISSOLVED SOLIDS mg/ltr	TOTAL DISSOLVED SOLIDS Analysis No:
	132.0-156.0	17.25	132.0	156.0	3.5	120 min.	Airlift	>150 000	Field analyses

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	6.3		SAND, SILCRETE	Pinkish red, quartz sand, dry, poorly sorted, fine to coarse grained, subrounded to subangular. Calcareous. With beds of very hard and soft silcrete, fine grained.			209 145	0 0	6.0 168
6.3	6.4		CLAY	White clay (second. kaolin), silty, a few quartz grains throughout, subrounded, mainly medium sand-sized. Plastic when wet, non-calcareous.					
6.4	10.2		CLAY, CLAYEY SAND	Interbedded greyish white clay and clayey sand. Clay-plastic, sticky, a few quartz grains throughout. Clayey sand-mainly medium grained, subrounded, with ironstained beds.					
10.2	11.5		SILCRETE, CLAYEY SAND	Interbedded very hard silcrete and clayey sand. Silcrete-yellow-brown to light grey in colour, very well cemented. Conglomerate structure with subrounded, various sizes quartz grains and very fine cement. Clayey sand, quartz, poorly sorted, fine to coarse grained, some gravel content, subangular.					

REMARKS: Drilling water salinity was 28561 mg/l. Casing was cemented 0–6.0 m. Slotted casing 132.0–156.0 m. Blank casing 156.0–168.0 m

DRILL TYPE: Rotary

COMPLETED: 1/5/1997

CIRCULATION: Mud

LOGGED BY: A.Sereda

DATE: 27/4/1997

SHEET 1 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40630

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
11.5	15.5		SANDY CLAY	Very sandy, silty clay, light grey to grey in colour, plastic when wet, laminated. Up to 50% fine sand and silt content. From 12.0 m with ironstained beds.					
15.5	16.0		SANDY CLAY	Pinkish grey sandy clay, plastic when wet. Contains up to 50% fine sand and silt. With beds of greenish light yellow sand mainly fine, coarse grained sand content ~15% (max 3 mm in diam.), subangular to angular, ironstained in patch.					
16.0	18.5		CLAYEY SILT	Dark brownish grey to greyish brown clayey silt, stiff to hard, sticky, laminated with crystals of pyrite (0.5 mm in diam.), and a few white solid grains up to 1 mm in diam., a few mica flakes up to 0.8 mm in diam.					
18.5	39.0		CLAYEY SILT	Dark grey to black clayey silt, stiff, plastic when wet, pyrite crystals throughout, and pyrite nodules up to 5 cm length and 2–3 cm wide, a few mica flakes up to 1 mm in diam.					
39.0	56.0		CLAYEY SILT	a/a, but thinly laminated.					
56.0	57.0		CLAYEY SILT	a/a, but with thin beds of grey silty clay, laminated, with pyrite crystals 0.5 mm in diam. and mica flakes up to 0.7 mm in diam.					
57.0	60.0		CLAYEY SILT	as 18.5–39.0 m					
60.0	63.0		CLAYEY SILT	as 56.0–57.0 m.					
63.0	66.0		CLAYEY SILT	as 18.5–39.0					
66.0	73.0		CLAYEY SILT, SILTY CLAY	Interbedded black clayey silt as 18.5–39.0 and grey silty clay stiff, plastic when wet, laminated, with pyrite crystals and mica flakes.					

SHEET 2 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40630

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
73.0	75.0		CLAYEY SILT, SILTY CLAY	a/a, but with thin beds of yellowish grey hard siltstone and pyritic beds (~1 mm thick).					
75.0	85.0		SILTY CLAY	Grey silty clay, stiff, plastic when wet, laminated, with pyrite crystals 0.5 mm in diam., and mica flakes ~0.7 mm in diam. With beds of black clayey silt as 18.5–39.0 m.					
85.0	108.0		SILTY CLAY	Bluish grey silty clay, stiff to hard (hard to drill), laminated, non-calcareous. To 88.5 m a few pyrite crystals and mica flakes.					
108.0	111.0		SILTY CLAY	a/a, but with beds of stiff to hard black shale (stiff when wet), at 109.5 m and 110.5 m.					
111.0	114.0		SILTY CLAY	as 85.0–108.0 m.					
114.0	125.0		SILTY CLAY	Bluish grey silty clay stiff to hard, laminated. With beds of grey, hard sandstone and blue-grey shale. Sandstone - well cemented, fine to medium grained, subrounded to rounded quartz grains, max. thickness ~30 cm (117.0–117.3 m). Shale hard, laminated thickness ~2–4 cm.					
125.0	129.0		CLAYEY SAND	Greyish white clayey sand, quartz, mainly fine grained, subrounded to rounded, a few coarse quartz grains and a few black and red grains up to 1.5 mm in diam.					
129.0	135.0		CLAYEY SAND	Grey clayey sand, quartz, mainly fine grained, rounded, about 10% of medium grained, some coarse quartz grains. A few grains of black minerals, and a few red grains up to 1.5 mm in diam., some of them-red rock fragments.					
135.0	147.0		SAND	Grey quartz sand, slightly clayey, fine to medium grained, subrounded to well rounded, well sorted, a few coarse quartz grains. Some red and black grains up to 1.5 mm in diam. (washed river sand).					

SHEET 3 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40630

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
147.0	159.0		SAND	Grey quartz sand, mainly medium grained, subrounded. Increasing content of coarse quartz grains up to 30%, subangular to angular. ~10% of red granite fragments up to 1.5cm in diam., some of them very angular, some subrounded. Black, greenish and yellowish granules throughout, also a few bluish.					
159.0	177.0		SAND	a/a, but increasing amount of angular granite fragments.					
177.0	180.5		SAND	a/a but losing circulation					
				End of hole 180.5 m					

SHEET 4 of 4

PROJECT: North Spencer Gulf	DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA **WATER WELL LOG** GROUNDWATER DIVISION	**PERMIT NO: 40631**
LOCATION OR COORDS: 314793(Easting); 6674358(Northing)		UNIT NO:
	El.Surface (m): El.Ref.Point (m): Datum:	Hundred: MOBELLA Sec:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	l/sec	Test length	Method	mg/ltr	Analysis No:
	31.0	22.1	29.0	41.0	0.5	60 min.	Airlift	26 024	Field analyses

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	0.2		SAND	Dark red quartz sand, poorly sorted, fine to coarse grained, subangular to angular, calcareous.			206 142	0 0	5.8 41
0.2	0.5		SILCRETE	Silcrete, hard, well cemented, very fine grained with quartz and black mineral grains up to 2 mm in diam. (conglomerate structure). Calcareous.					
0.5	3.0		SAND	Sand as 0 - 0.2m with silcrete beds as 0.2–0.5 m - ~5 cm thick. Calcareous.					
3.0	8.5		SAND	a/a, but non-calcareous.					
8.5	10.0		SAND	Grey sand, quartz, fine to medium grained, poorly sorted, a few coarse quartz grains throughout, mainly subangular. Contains a few beds of yellow sand with ironstained grains. Non-calcareous.					

REMARKS: Drilling water salinity – 2783 mg/l. Casing cemented 0–8.0 m. Slotted casing 29.0–41.0 m	DRILL TYPE: Rotary	COMPLETED: 4/5/1997
	CIRCULATION: Air.	LOGGED BY: A.Sereda
	DATE: 3/5/1997	**SHEET 1 of 3**

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
10.0	12.0		CLAYEY SAND	Orange-red clayey quartz sand, fine to medium grained, mainly subangular. With a few yellow hard sandstone beds, medium grained, well cemented, max thickness 2–3 cm. Non-calcareous.					
12.0	15.0		SAND, SANDSTONE	Interbedded pink sand, well to poorly cemented sandstone and hard sandstone. Pink sand, quartz, mainly fine grained, loose, subangular, non-calcareous. Dark red fine to medium grained sandstone, ironstained. Hard greyish white sandstone, very fine grained, very well cemented.					
15.0	18.0		SAND, SANDSTONE, CLAYEY SAND	a/a, but with a few beds of greyish white very clayey sand, quartz, fine grained, non-calcareous.					
18.0	18.5		CLAYEY SAND	Pink-red clayey sand, quartz, mainly fine grained, subangular, non-calcareous.					
18.5	19.0		CLAYEY SAND	a/a, but yellow in colour.					
19.0	20.0		LIGNITE	Dark brown sandy clayey lignite, with 5–7% of pins 2–3 mm in length (sponge spicules?) and pyrite crystals 0.5 mm in diam.					
20.0	21.0		LIGNITE	Black sandy lignite with fine to medium, subrounded quartz grains and a few crystals of pyrite up to 1 mm in diam.					
21.0	24.0		LIGNITE	a/a, but slightly clayey with pyrite nodules up to 4 mm in diam.					
2.40	2.70		LIGNITE	Interbedded dark brown and black sandy lignite. Dark brown or chocolate lignite, sandy, partly cemented, with pyrite crystals and nodules throughout, with thin pins up to 3 mm in length (sponge spicules?). Black sandy lignite, slightly clayey with pyrite crystals up to 1mm in diam, and pyrite nodules up to 4 mm in diam.					

SHEET 2 of 3

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
27.0	31.5		LIGNITE	Black sandy lignite with pyrite crystals up to 0.6 mm in diam. and with fine grained sand content, slightly clayey.					
31.5	36.0		LIGNITE	a/a but with hard white oolites? up to 4 mm in diam. (no reaction with HCl) throughout. With very thin (thickness is about 1 mm) fine grained, rounded, sand beds. Pyrite crystals throughout, particularly abundant pyrite crystals in sand beds.					
36.0	39.0		LIGNITE	a/a but with pyrite nodules.					
39.0	45.0		LIGNITE	a/a but less amount of white oolites.					
45.0	63.0		CLAYEY LIGNITE	a/a with some pyrite nodules 2x5 cm, clayey.					
63.0	70.6		LIGNITE	a/a, but less clay content. From 66.0 - a few quartz grains coarse sand size, subrounded.					
				End of bore - 70.6 m.					

SHEET 3 of 3

PROJECT: North Spencer Gulf

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION

PERMIT NO: 40632

LOCATION OR COORDS:
323650 (Easting); 6676045 (Northing)

UNIT NO:

Hundred: MOBELLA Sec:

El.Surface (m): El.Ref.Point (m): Datum:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m) From	INTERVAL (m) To	SUPPLY l/sec	SUPPLY Test length	SUPPLY Method	TOTAL DISSOLVED SOLIDS mg/ltr	TOTAL DISSOLVED SOLIDS Analysis No:
	<37.0	13.0							
	41.0-43.0	15.52	38.3	57.4	~1–1.5		Airlift	98 624	Field analyses

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	3.0		SAND	Pink-red sand, quartz, poorly sorted, mainly medium to coarse grained, subrounded to angular, calcareous. With beds of silcrete (or sandstone), dark red-brown in colour, conglomeratic structure with subrounded to subangular various sizes quartz grains finely cemented. Ironstained in part.			206 142	0 0	5.2 35.7
3.0	3.6		SAND	a/a but orange-red in colour and slightly calcareous.					
3.6	4.5		SILCRETE	Very hard silcrete, orange-red in colour, well cemented, description as for 0–3 m interval.					
4.5	4.9		SAND	As for 3–3.6 m					
4.9	6.8		SILCRETE	Greyish white hard silcrete as 3.6–4.5 m.					

REMARKS: Drilling water salinity 2783 mg/l. Casing was pressure cemented 8–36.0 m. Cement plug- 36–38.3 m. Open hole 38.3–57.4 m.

DRILL TYPE: Rotary, Percussion

COMPLETED: 7/05/1997

CIRCULATION: Mud, Air

LOGGED BY: A.Sereda

DATE: 5/05/1997

SHEET 1 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
6.8	8.0		SANDSTONE	Interbedded dark red (ironstained) and yellow sandstone. Medium to coarse grained, poorly to well cemented. Abundant subrounded to rounded quartz grains up to 5 mm in diam. Non-calcareous.					
8.0	9.0		SAND	Sand, yellow to yellowish-red in colour, quartz, fine grained, subrounded, a few coarse quartz grains. With ironstained sandstone fragments. Non-calcareous.					
9.0	10.0		SAND	Red quartz sand, poorly sorted, mainly medium grained, subangular to angular.					
10.0	10.5		SANDSTONE	as 6.8–8.0 m.					
10.5	11.6		SAND	Orange-red sand, quartz, fine to medium grained, subangular. With a few black mineral grains medium sand-sized.					
11.6	13.5		CLAYEY SAND	Light grey clayey sand, quartz, coarse grained, subangular, some grains up to 3 mm in diam., interbedded with yellow clayey quartz sand, mainly fine grained, ironstained in part. Non-calcareous.					
13.5	14.7		CLAYEY SILT	Light grey to dark chocolate clayey silt (colour becoming darker with the depth), plastic, non-calcareous. With a few pyrite crystals up to 0.5 mm in diam.					
14.7	18.4		SILTY LIGNITE	Black silty lignite with pyrite crystals (~0.5 mm). At the bottom of interval thin (about 1 mm in thick) brown sand beds, finegrained, with pyrite crystals.					
18.4	23.0		SILTY LIGNITE	Dark brown silty lignite, laminated, plastic when wet, pyrite crystals throughout, up to 0.5 mm in diam.					

SHEET 2 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
23.0	23.8		SILTY LIGNITE	a/a but with sand content and a few coarse sand-sized quartz grains throughout.					
23.8	26.5		CLAYEY SAND	Light brown to pale grey, bluish in part gravelly clayey sand subangular to angular, quartz, gravel content up to 10%. Micaceous, mica flakes up to 1 mm in diam. Becoming more clayey with the depth.					
26.5	33.0		SANDY CLAY	Pale grey with greyish blue mottling sandy clay, plastic when wet, micaceous, soapy. Sand content up to 50%, mainly medium grained, coarse grains ~10%, quartz, subangular to angular. Increasing coarse grains content with the depth. Max. grain size up to 1.5 cm in diam., angular.					
33.0	36.0		SANDY CLAY	a/a but with fragments of light grey to grey granite up to 0.5 cm in diam.					
36.0	38.3		SANDY CLAY	a/a but abundant quartz grains up to 1.5 cm in diam and granite fragments up to 1 cm in diam.					
38.3	45.0		GRANITE	Hard granite, fractured. Mainly quartz, black and pink mineral grains present. Some crystals of sulphide minerals and mica. At the end of interval a few thin beds of black gneiss?.					
45.0	48.0		GRANITE	Very hard granite a/a, but more content of black minerals: mica (biotite?), poss. tourmaline? etc., pink mineral grains. Less content of sulphide minerals (pyrite, etc).					

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
48.0	51.0		GRANITE	a/a but more content of pyrite crystals.					
51.0	54.0		GRANITE	a/a, but no pink minerals.					
54.0	57.4		GRANITE	a/a, but less amount of pyrite crystals.					
				End of bore 57.4 m.					

SHEET 4 of 4

PROJECT: North Spencer Gulf

LOCATION OR COORDS:
323820 (Easting): 6680217 (Northing)

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION

PERMIT NO: 40633

UNIT NO:

Hundred: MOBELLA Sec:

El.Surface (m): El.Ref.Point (m): Datum:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m) From	INTERVAL (m) To	SUPPLY l/sec	SUPPLY Test length	SUPPLY Method	TOTAL DISSOLVED SOLIDS mg/ltr	TOTAL DISSOLVED SOLIDS Analysis No:
	<21.0	9.6							
	36.0-55.7	~17.0	36.0	55.7	0.5	30 min.	Airlift	37 598	Field analyses

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	0.2		SAND	Dark red sand, quartz, poorly sorted, mainly medium grained, subangular to angular, slightly ironstained, calcareous.			206 142	0 0	5.5 35.6
0.2	3.0		SANDSTONE (SILCRETE)	Sandstone (silcrete?), dark red to pale grey, well cemented, medium grained, ironstained, calcareous.					
3.0	6.5		SANDSTONE (SILCRETE)	a/a, but with a few bars of dark brown sandstone fine to medium grained well cemented, slightly calcareous.					
6.5	8.0		CLAYEY SANDY SILT	Sandy clayey silt, white to light pink in colour, plastic when wet. Up to 30% sand content, mainly medium grained, subangular to angular, becoming white and stiffy with the depth. Non-calcareous.					
8.0	9.0		CLAYEY SANDY SILT	a/a, but with dark pink mottling and sandstone fragments up to 3 cm in diam. Sandstone medium grained, well cemented. Non-calcareous.					

REMARKS: Drilling water salinity – 2783 mg/l. Casing was pressure cemented 11–35.6 m. Open hole from 35.6 to 55.7 m.

DRILL TYPE: Rotary, Percussion

COMPLETED: 10/05/1997

CIRCULATION: Mud, air.

LOGGED BY: A. Sereda

DATE: 8/05/1997

SHEET 1 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
9.0	11.5		SILTY SANDY CLAY	White silty sandy clay , dark pink mottled, stiff, compact, plastic when wet, ironstained in part. Sand content ~20% medium grained, quartz, a few coarse grains, subrounded. With sandstone fragments as 8–9 m. Non-calcareous. Loosing circulation of drilling mud.					
11.5	13.5		SILTY SANDY CLAY	Dark red to red sandy silty clay a/a, 12-12.2 hard sandstone bar, medium grained, well cemented with pyrite? nodules. Non-calcareous.					
13.5	17.0		SILTY CLAY	White silty clay, greyish mottled in part, stiff, plastic when wet, sandy (up to 15% sand content) with abundant grains of black minerals, medium sand-sized. With clayey sand beds, ochres-yellow in colour, quartz, fine to medium grained, with sandstone fragments, ironstained. Non-calcareous.					
17.0	18.5		SILTY CLAY	a/a, but milky chocolate, reddish brown, yellow, pinkish red, brownish red mottled. Becoming very stiff to hard with the depth, increasing sand content with depth.					
18.5	19.0		SANDY SILT	Red-brown sandy silt, stiff to hard, plastic when wet, with sandstone fragments, medium grained, well cemented, ironstained.					
19.0	20.0		SILTY CLAY	as 13.5–17.0 m. Still loosing circulation of drilling mud.					
20.0	21.0		CLAYEY SAND	Pinkish grey clayey sand, very fine grained, slightly micaceous, with fine grains of black minerals.					
21.0	21.4		SANDSTONE	Dark red to red-brown hard sandstone, medium grained, well cemented.					

SHEET 2 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
21.4	22.0		CLAYEY SILT	Clayey silt, slightly sandy, brown to yellow, becoming brownish grey to yellow-grey with yellow mottling at the end of interval, stiff to hard, plastic when wet.					
22.0	24.0		SILTY CLAY	Pink-grey to bluish grey silty clay, stiff to hard, plastic when wet, micaceous, (soapstone?). Abundant black mineral grains <0.1 mm in diam. Non-calcareous. With clayey sand beds, pinkish grey in colour, fine grained.					
24.0	25.5		SANDY SILTY CLAY	Light grey to white sandy silty clay (kaolin?), bluish grey mottled, with yellow patches and pinkish mottled in part. Stiff to hard, plastic when wet, laminated, micaceous, (soapstone?). Non-calcareous. Abundant black minerals grains <0.1 mm in diam. With thin ironstained beds.					
25.5	28.5		SANDY SILTY CLAY	a/a but more sandy and with hard sandstone fragments dark red in colour.					
28.5	31.0		CLAYEY SAND	Grey-white with pinkish grey beds clayey sand, quartz, fine to medium grained, some coarse grains, angular to very angular, a few grains up to 3 cm in diam. Abundant fine black grains ~0.1 mm in diam.					
31.0	32.2		SILTY SANDY CLAY	Silty, sandy clay as 24.0–25.5 m.					
32.2	34.5		SILTY SANDY CLAY	a/a, but mainly bluish grey in colour, sand content increasing with the depth up to 30%, quartz fine to medium grained angular to very angular, a few quartz pebbles up to 4 cm in diam.					
34.5	35.0		SANDY CLAY	Sandy clay, description a/a, but with dark grey and greenish grey beds. Increased quartz pebble content. Becoming clayey sand with the depth.					

SHEET 3 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 40631

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
35.0	35.7		CLAYEY SAND	Clayey sand, pale grey, light grey, grey to dark grey in colour, quartz, fine to medium grained, poorly sorted, subangular to angular, some subrounded grains. With fragments of grey granite and quartz pebbles.					
35.7	39.0		GRANITE	Dark grey granite, hard, coarse grained, mainly quartz, mica (biotite), greenish grey and black mineral granules.					
39.0	45.0		GRANITE	a/a but a few pyrite crystals and pink feldspars granules.					
45.0	48.0		GRANITE	Hard granite, coarse grained, mainly quartz, feldspars pinkish white, milky white to off-white in colour, mica (biotite) and black mineral grains.					
48.0	51.0		GRANITE	a/a but with a few chips of chlorite.					
51.0	55.7		GRANITE, GNEISS	Hard granite composes quartz, pink feldspars (microcline) black and greyish white mica (biotite and muscovite), pyrite crystals in quartz up to 1 mm in diam. With beds of gneiss? black in colour, hard, micaceous with chlorite chips.					
				End of bore - 55.7 m.					

SHEET 4 of 4

APPENDIX 4

ADDITIONAL DRILLING IN THE PIRIE–TORRENS BASIN

ADDITIONAL PIRIE–TORRENS DRILLING

1. INTRODUCTION

Primary Industries and Resources of South Australia undertook an investigation in Pirie–Torrens Basin for groundwater potential of the Tertiary sands in the north-east and south-east of the Port Pirie area between South Flinders Rangers and Spencer Gulf coast line (Fig. A1-1). The programme carried out by PIRSA, involved:

- drilling and completing 2 appraisal/ monitoring wells;
- estimating groundwater quality and yield of Tertiary aquifer;

2. RESULTS OF DRILLING

Drilling of the two appraisal/monitoring wells commenced on 5 November 1997 and was concluded on 21 November 1997. Three sites were initially selected from a ground survey adjacent to creeks along the roadside verge. All three sites proved unsatisfactory once the driller had surveyed the sites. Accessibility for the size of the drill rig and OH&S concerns (adjacent frequently travelled roads) were cited as the primary reasons for the unsuitability of these sites.

Two other sites were selected, one adjacent to the BP Roadhouse along the eastern boundary of the truckstop area and the other well was located on private property adjacent to Telowie Creek (Fig A3-1). The site adjacent to the creek was selected because of its favourable position for harvesting of excess stream flows and recharging the aquifer. This would only be carried out if the Spencer Regions Economic Development Board wished to pursue the study further and demonstrate the feasibility of ASR from catchment runoff in this area.

Well information and geological logs are contained on pages 87 through 97 of this report. Both wells are artesian.

The first well (P/N 43080) was drilled to a total depth of 132.6 m using rotary mud drilling up to Precambrian fractured rock and stoped there. Cuttings were collected at three metre intervals over the entire penetrated depth. The well was completed using 142 mm ID PVC casing with the 6.17 m length and 0.35 mm aperture stainless steel screen installed from 88.7 to 94.87 m and sump set at interval from 94.87 to 104.7 m. The casing was pressure cemented over the interval 0 to 88.5 m and remaining section of the well from the bottom of sump to the bore bottom was blocked by setting a cement plug.

The flowing rate of the top aquifer interval from ~57 to 61 m was 0.63 L/s on 6 November and a water sample was obtained. The field Electrical Conductivity of 5300 µS/cm inferred a Total Dissolved Solids (TDS) content of 2950 mg/L. The screen interval was jetted during 4 hours and the well was developed by airlifting with rate of about 3.0 L/s and duration was 5.0 hours. The second water sample was obtained and sent for full chemical analysis on 24 November 1997. The field Electrical Conductivity of 5100 µS/cm inferred a Total Dissolved Solids (TDS) content of 2850 mg/L. After completion of development the flowing rate of the screened interval was 0.76 L/s on 14 November 1997.

The second well (P/N 43079) was drilled to a total depth of 153.1 m using rotary mud drilling and stoped in the Tertiary lignitic sand. Cuttings were collected at three metre intervals over the entire penetrated depth. The well was completed using 142 mm ID PVC casing. The casing was pressure cemented over the interval 0 to 138 m. The 6.1 m and 0.35 mm aperture stainless screen was installed from 138.8 to 144.9 m with a sump set from 144.9 to 153.1 m (bottom of the hole).

The well screen was jetted for 3 hours and developed by airlifting with rate of about 10 L/sec for a duration of 3 hours. After completion of airlifting the flowing rate was measured at 0.9 L/sec and water sample was obtained. The field Electrical Conductivity of 5100 µS/cm inferred a Total Dissolved Solids (TDS) content of 2850 mg/L.

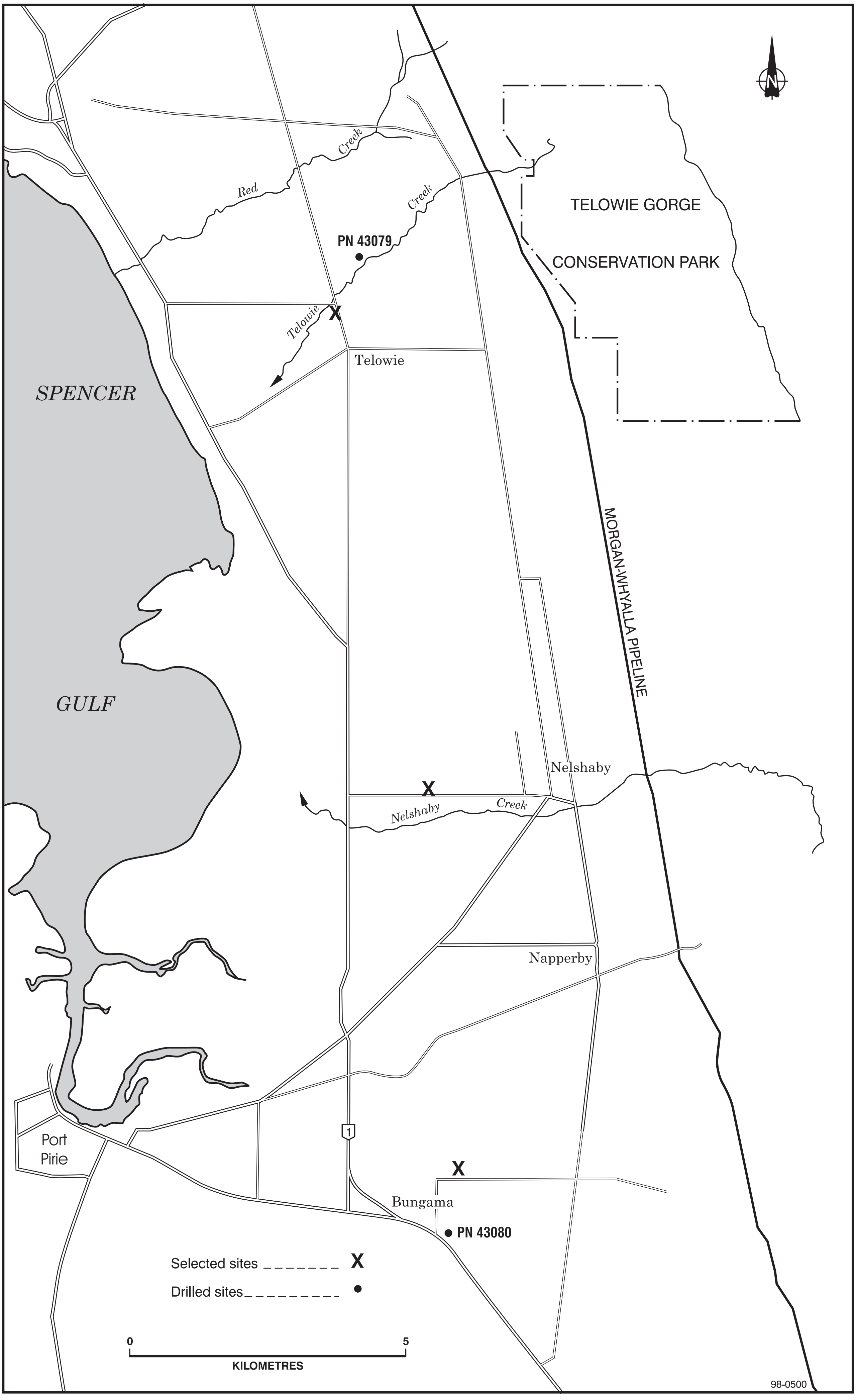


Fig. A4-1 Pirie-Torrens Basins showing drill sites.

QD6 101067

PLAN No. 97–1272

MINES AND ENERGY – SOUTH AUSTRALIA
GROUNDWATER AND ENVIRONMENTAL SERVICES

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary
CIRCULATION Mud
MUD RESISTIVITY/TYPE
START 14/11/97 FINISH 21/11/97
TOTAL DEPTH 153.1 m

		mm	From (m)	To (m)
HOLE DIAMETER		305	0	5.5
		225	5.5	153.1
CASING DIAMETER (Cemented)		236	0	5.5
		142	0	138
CASING DIAMETER (Uncemented)				
SCREEN DETAILS	Blank casing	110	136.5	138.8
	screen	110	138.8	144.9
	sump	110	144.9	153.1

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD		TOTAL DISSOLVED SOLIDS	
		m³/day	Method of Test	mg/litre	Analysis W No.
	Flow	78		2852	
	Flow	864	Airlift	2852	

REMARKS

GEOPHYSICS

TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res	Density	Caliper		
DATE OF RUN	18/11/97	18/11/97	18/11/97	18/11/97	18/11/97	18/11/97		
FIRST READING (m)	0.8	3.0	0.5	0.5	1.1	1.8		
LAST READING (m)	151	153.1	150.7	150.7	153.1	153.1		
RECORDED BY	DBF	DBF	DBF	DBF	DBF	DBF		

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 43079
LOCATION Latitude 33°2.707'
Longitude 138°3.967'
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 21/11/97

WELL SYMBOLS

Casing seal
Slotted casing
Casing shoe
Cemented interval
Wire wound screen
Gravel packed interval

DEPTH (m) | LITHOLOGY: AGE | UNIT | DESCRIPTION | CONSTRUCTION and LITHO. LOG | HYDRO DATA

0–7 SAND dark brown to red brown, quartz, fine to medium grained subangular to subrounded. Poorly sorted. Calcareous.

7–10 SANDY CLAY light grey, to red–brown, hard, laminated. Non–calcareous.

10–13 CLAYEY SAND grey to red–brown, quartz, mainly medium grained. Becoming coarser with depth. Non–calcareous.

13–15 SANDY GRAVEL loose, slightly clayey. Grain size graded from coarse sand to coarse gravel.

15–25 CLAYEY SAND interbedded light grey, grey and red–brown. Quartz, mainly medium grained, some fine and coarse grains, subrounded to rounded. Non–calcareous. With some calcareous sand beds.

25–27 SANDY GRAVEL as 13–15 m.

27–30 CLAYEY SAND as 15–25 m.

30–34 SANDY CLAY red–brown witha few grey beds. Hard. Non–calcareous. With a few calcareous patches up to 1 cm in diam.

34–36 CLAYEY SAND red–brown withgrey beds. Quartz, medium to coarse grained.

36–38 GRAVEL sandy, clayey. Grain size up to 4 cm in diam.

38–61 CLAYEY SAND, SANDY CLAY interbedded. Clayey sand red–brown with some grey beds, quartz, mainly medium grained. Sandy clay brown–red to grey, hard. Some gravel beds fine to coarse grained.

61–78 SAND, CLAYEY SAND, SANDY CLAY light grey to grey with dark red, brown–red and yellowish brown mottling. Sand, clayey sand –quartz, medium to coarse grained, compacted. Sandy clay, brown–red, stiff to hard. Some fine to coarse grained gravel beds.

78–101 CLAYEY SAND dark red and grey, quartz, mainly medium grained, compacted. From 88 to 101 mainly grey in colour. With gravel beds a/a.

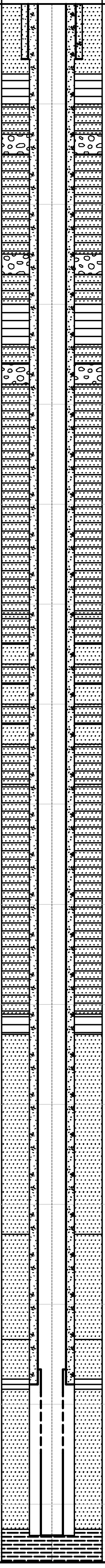
101–103 SANDY CLAY grey, hard.

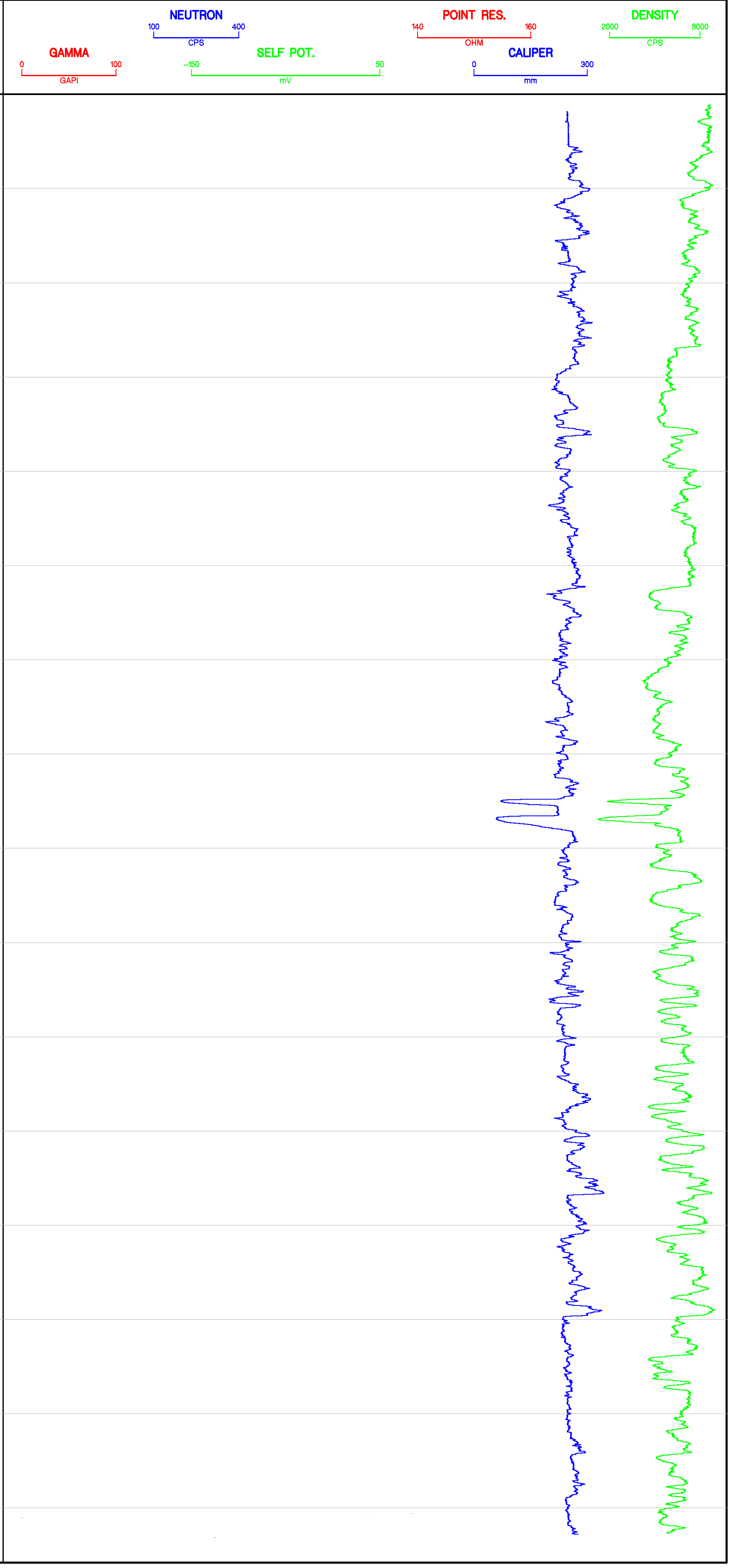
103–123 SAND light grey, greenish grey and dark pink–grey, quartz, medium to coarse grained, mainly subangular. Compacted. With fine grained gravel beds and gravelly sand beds.
Some thin beds of pinkish dark grey silty clay.

123–133.5 SAND greenish grey to greyish green, slightly clayey, mainly medium grained, quartz, some gravelly sand beds and thin bluish grey clay beds..

133.5–137 SAND White, silty, fine to medium grained, with pyrite nodules and silty clay beds.
137–138.5 CLAY bluish grey, hard, with pyrite.
138.5–152.5 SAND white and pinkish white, quartz, mainly fine grained, subrounded to rounded. Some pyrite nodules throughout. From 146 to 152.5 with abundant pyrite nodules and with some gravel and very coarse sand.

152.5–153.1 LIGNITIC SAND brown, dark brown to black, fine to medium grained, subrounded





QD6 101067

MINES AND ENERGY – SOUTH AUSTRALIA

GROUNDWATER AND ENVIRONMENTAL SERVICES

PLAN No. 97–1273

COMPOSITE WELL LOG

CONSTRUCTION DETAILS

DRILLING METHOD Rotary
CIRCULATION Mud
MUD RESISTIVITY/TYPE
START 5/11/97 FINISH 14/11/97
TOTAL DEPTH 132.6 m

		mm	From (m)	To (m)
HOLE DIAMETER		251	0	5.5
		201	5.5	132.6
CASING DIAMETER (Cemented)		209	0	5.5
		145	0	88.5
CASING DIAMETER (Uncemented)				
SCREEN DETAILS	Blank casing	100	86.8	88.7
	Screen	100	88.7	94.87
	Sump	100	94.87	104.07

GROUNDWATER ANALYSES

DEPTH TO WATER CUT (m)	DEPTH TO SWL (m)	YIELD		TOTAL DISSOLVED SOLIDS	
		m³/day	Method of Test	mg/litre	Analysis W No.
	Flow	65.4		2852	
	Flow	259.2	Airlift	2852	

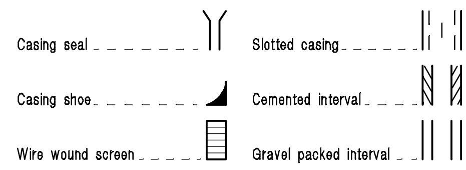
REMARKS

GEOPHYSICS

TYPE OF LOG	Gamma	Neutron	Spon Pot	Point Res.	Caliper	Density	Later	
DATE OF RUN	8/11/97	8/11/97	8/11/97	8/11/97	8/11/97	8/11/97	8/11/97	
FIRST READING (m)	0.8	2.9	0.4	0.4	1.8	1.0	1.3	
LAST READING (m)	130.2	130.2	129.7	129.7	132.5	131.9	130.4	
RECORDED BY	DBF	DBF	DBF	DBF	DBF	DBF	DBF	

PROJECT North Spencer Gulf
FIELD No. UNIT No. PERMIT No. 43080
LOCATION Latitude 32°12.067'
Longitude 138°5.102'
REF. ELEV. m SURFACE ELEV. m DATUM
LOGGED BY A Sereda DATE 14/11/97

WELL SYMBOLS



DEPTH (m) | LITHOLOGY: AGE | UNIT | DESCRIPTION | CONSTRUCTION and LITHO. LOG | HYDRO DATA

0–6 CLAYEY SAND pinkish red to brownish red, quartz, fine to medium grained, subrounded. Poorly sorted. Calcareous.

6–16 SANDY CLAY light grey with red–brown mottling, stiff to hard, laminated. Sticky. Non–calcareous. With some milky white calcareous patches. From 12 to 16 mainly red–brown.

16–21 CLAYEY SAND red–brown, quartz, fine to medium grained, subrounded. Non–calcareous.

21–35 SANDY CLAY light grey with red–brown mottling, stiff to hard. From 27 to 35 becoming harder. With thin black MnO2 veins (1–2mm thick). From 32 to 35 with some fine grained sandstone beds.

35–42 SAND (no description) with beds of grey sandy clay.

42–57 CLAYEY SAND, SANDY CLAY interbedded. Clayey sand, quartz, mainly fine grained. Sandy clay– grey with yellow, dark brown and black (MnO2) mottling, hard, sticky. With pieces of well cemented dark brown sandstone.

57–63 SAND fine to medium grained, some coarse grains. Subrounded to rounded. With some sandy clay beds.

63–75 SANDY SILTSTONE grey with red–brown to yellow–brown mottling. Hard. Non–calcareous. With some clayey sand beds. A few pyrite nodules.

75–84 SILTSTONE, SANDY CLAY, CLAYEY SAND interbedded. Light grey to pale grey and brownish grey. Siltstone a/a. Clayey sand mainly fine grained. Sandy clay, hard. With quartz chips and a few pyrite nodules.

84–98 SAND, SILTSTONE interbedded. Siltstone light grey to pale grey with a little brownish yellow mottling. Hard, non–calcareous. Sand grey to bluish grey, quartz, fine grained, well sorted. Compacted, rounded. With pyrite nodules, abundant at the bottom of interval.

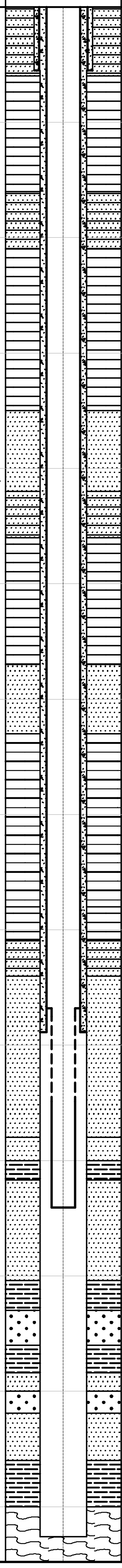
98–113 LIGNITIC SAND dark grey to black, mainly fine grained, with a few coarse grains, quartz. Subangular to subrounded, well sorted. Some pyrite nodules. With beds of well cemented quartz sandstone.

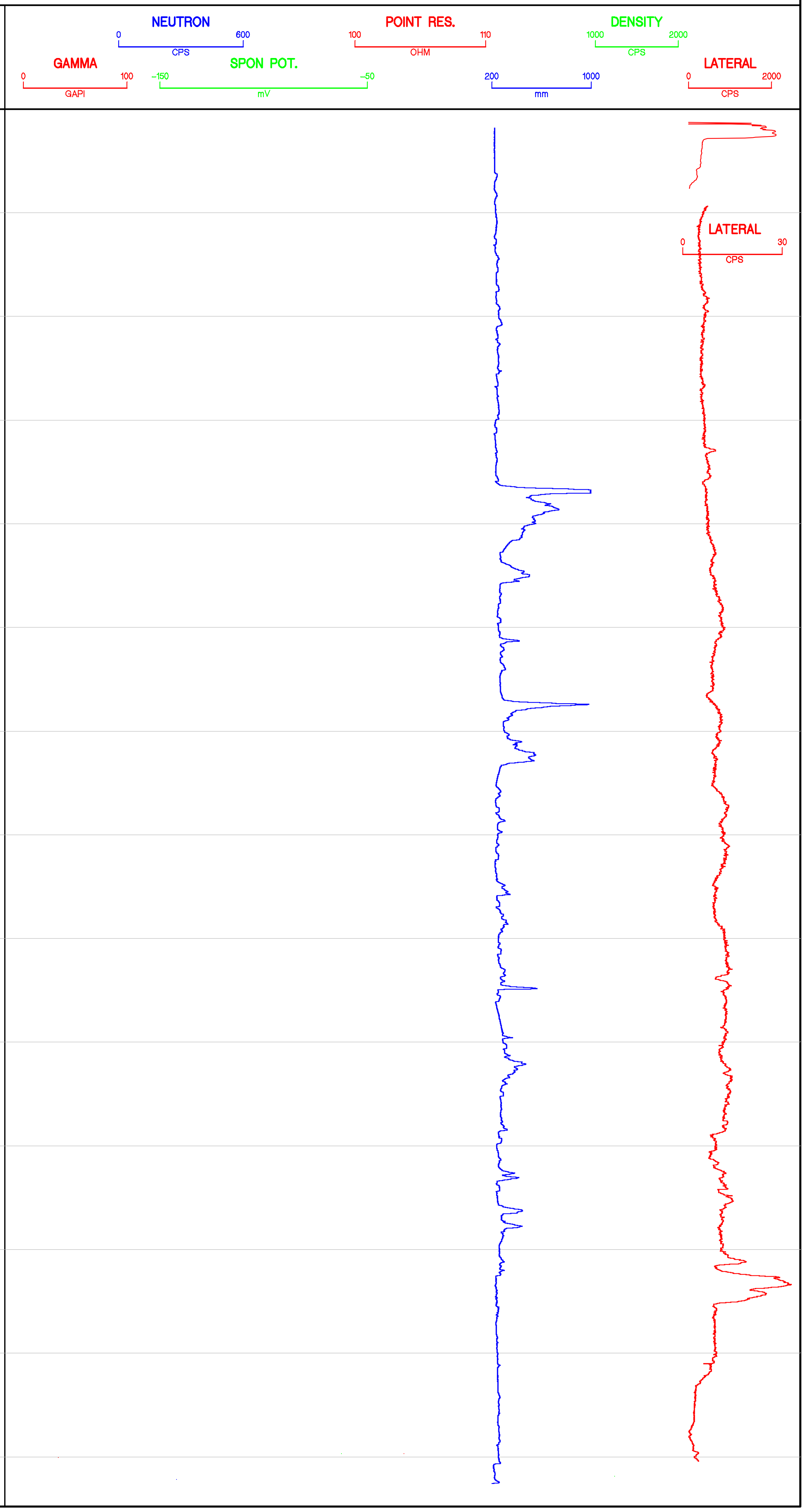
113–116 SANDSTONE medium grained, well cemented, with clayey sand and sandy clay beds.

116–126 LIGNITIC CLAYEY SAND, SANDY CLAY interbedded, all black in colour. Clayey sand fine grained, subrounded to subangular. Sandy clay stiff to hard. Some pyrite nodules.

126–130 LIGNITIC SANDY CLAY brownish black, stiff to hard. Some chips of sandstone and some quartz gravel grains.

130–132.6 SLATE black, fine to very fine grained, some pyrite crystals 1mm in diam





PROJECT: North Spencer Gulf

LOCATION OR COORDS:
Latitude-33°2.707' Longtitude-138°3.967'

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION

El.Surface (m): El.Ref.Point (m): Datum:

PERMIT NO: 43079

UNIT NO:

Hundred: Telowie Sec: 27

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	l/sec	Test length	Method	mg/ltr	Analysis No:
	138.5	Flow	138.8	144.9	0.9 ~10.0	3 hrs	Flowing Airlift	2852	Field analysis

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	1		SAND	Dark brown sand, fine to medium grained, with some coarse grains. Quartz, poorly sorted, subangular to subrounded. Dry. Calcareous with some pinkish white calcareous nodules up to 1 cm in diam.			236 142	0 0	5.5 138
1	7		SAND	Red-brown sand a/a. with some sandy clay beds 3–5 cm thick. Dry. Calcareous.					
7	10		SANDY CLAY	Light grey to red-brown sandy clay. Hard, plastic when wet, sticky, laminated. With a few clayey sand beds mainly medium grained. Non-calcareous. With some white calcareous patches up to 1.5 cm in diam.					
10	13		CLAYEY SAND	Grey to red-brown clayey sand, quartz, mainly medium grained, poorly sorted, subrounded. Becoming more coarse with depth. Non-calcareous.					
13	15		SANDY GRAVEL	Sandy gravel loose, slightly clayey. Grain size graded from coarse sand to coarse gravel, represents quartz, quartzite, sandstone, brown to black bedrock pieces up to 3 cm in diam, mainly subrounded.					

REMARKS: Casing was pressure cemented 0–138.0 m. Stainless screen - 138.8–144.9 m. Sump - 144.9–153.1 m.

DRILL TYPE: Rotary | COMPLETED: 153.1 m.

CIRCULATION: Mud | LOGGED BY: A. Sereda

DATE: 21/11/97 | **SHEET 1 of 5**

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
15	25		CLAYEY SAND	Interbedded light grey, grey and red brown clayey sand. Quartz, mainly medium grained, some fine and coarse grains. Subrounded to rounded. With some sandy clay beds. A few MnO2 veins and ironstained patches. From 21.0 to 25.0 m with a few white calcareous patches and light grey calcareous sand beds.					
25	27		SANDY GRAVEL	Sandy gravel as 13.0–15.0 m interval.					
27	30		CLAYEY SAND	Clayey sand as 15.0–25.0 m interval.					
30	34.3		SANDY CLAY	Red-brown with a few grey beds sandy clay, hard, plastic when wet. Non-calcareous. Sand content ~25%, quartz, mainly medium grained with a few coarse sand grains, subrounded. A few white calcareous patches up to 1 cm in diam. and some calcareous nodules 2–3 mm in diam.					
34.3	36		CLAYEY SAND	Red-brown with grey beds clayey sand, quartz, medium to coarse grained, some gravelly sand at the bottom.					
36	38		GRAVEL	Sandy, clayey gravel , grain size up to 4 cm in diam., mainly sandstone and quartzite.					
38	61		CLAYEY SAND, SANDY CLAY	Interbedded clayey sand and sandy clay. Clayey sand brown-red in colour from 45.0 m to 61.0 m with some grey beds. Quartz, mainly medium grained, some coarse grains, with ~20% of clay content. Sandy clay brown-red to grey, hard, plastic when wet. With beds of considerable amount of fine to coarse gravel (red, yellowish red, greyish red well cemented sandstone) subrounded to rounded.					

SHEET 2 of 5

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING		
From	To						Dia (mm)	From (m)	To (m)
61	74		SAND, CLAYEY SAND, SANDY CLAY	Interbedded sand, clayey sand and sandy clay beds. Light grey, grey with dark red, brown-red and yellowish brown mottling. Sand, clayey sand - quartz, medium to coarse grained, ironstained in part, non-calcareous, compacted. Sandy clay- stiff to hard, high sand content in part (up to 50%), non-calcareous. Some fine to coarse grained gravel beds. Compose of pink sandstone, quartz and black chert, subrounded.					
74	78		SAND, CLAYEY SAND, SANDY CLAY	A/a, but more sandy clay and gravelly beds.					
78	88		CLAYEY SAND	Interbedded dark red and grey clayey sand, quartz, mainly medium grained, non-calcareous, compacted. with gravel beds a/a. From 84.0 to 88.0 m predominantly grey in colour with some yellowish-greenish grey beds.					
88	101		CLAYEY SAND	Grey clayey sand a/a.					
101	103		SANDY CLAY	Light grey to grey sandy clay hard, with some greenish grey clayey sand beds a/a.					
103	112		SAND	Interbedded light grey silty sand mainly medium grained and greenish grey slightly clayey sand medium to coarse grained. Quartz. Compacted. Non-calcareous. With gravel beds fine grained (up to 1 cm in diam).					
112	123		SAND	Interbedded light grey silty sand a/a and dark pink-grey sand medium to coarse grained, mainly subangular. Some yellow-brown ironstained patches. Some gravelly sand beds. With a few up to 1cm thick pinkish dark grey silty clay. All non-calcareous.					

SHEET 3 of 5

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
123	126		SAND	Greenish grey to greyish green slightly clayey sand, mainly medium grained with ~10% of coarse and <10% fine sand grains. Quartz. Some gravelly sand beds (up to 3 mm in diam. quartz grains). With 2 mm thick bluish grey clay beds and a few beds of brownish green sandy silt up to 1 cm thick. All non-calcareous.					
126	133.5		SAND	Interbedded beds as 112.0–123.0 and as 123.0–126.0 m intervals.					
133.5	137		SAND	White silty sand fine to medium grained, quartz, subrounded to rounded. With a few pyrite nodules up to 2–3 mm in diam. Some rounded quartz fine gravel grains and granules of white medium grained sandstone. With beds of dark grey to bluish grey silty clay, hard, slightly sandy. Some thin beds of white silt and brownish green sandy clay. From 135.0 to 137.0 m some beds of dark grey clayey sand medium grained.					
137	138.5		CLAY	Bluish grey clay, hard, plastic when wet, abundant pyrite nodules bars throughout and pyrite crystals ~ 0.5 mm in diam.					
138.5	140		SAND	Interbedded white, light grey and pinkish white sand mainly fine grained, with some dark grey silty sand beds mainly medium grained. Some pyrite nodules, several have spherical shape 3–4 mm in diam. All non-calcareous.					
140	146		SAND	White to pinkish white sand, quartz, fine to medium grained (~50% fine grains), subrounded to rounded. Less than 5% of coarse sand to fine gravel grains subangular to rounded, represent quartz and pink sandstone granules and some pyrite nodules throughout. With a few thin beds of pinkish white very fine silty sand and bluish grey silty clay (thickness <1 cm).					

SHEET 4 of 5

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
146	152.5		SAND	Sand a/a with abundant pyrite nodules up to 1 cm in diam. and ~10% of gravel and a very coarse sand.					
152.5	153.1		LIGNITIC SAND	Lignitic clayey sand, brown, dark brown to black, fine to medium grained, quartz, subrounded with some coarse quartz grains.					
				End of Hole - 153.1 m.					

SHEET 5 of 5

PROJECT: North Spencer Gulf

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
WATER WELL LOG
GROUNDWATER DIVISION

PERMIT NO: 43080

LOCATION OR COORDS:
Latitude 33°12.067’ Longitude 138°5.102’

UNIT NO:

Hundred: Napperby Sec: 130

El.Surface (m): El.Ref.Point (m): Datum:

AQUIFER SUMMARY:	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m) From	INTERVAL (m) To	SUPPLY l/sec	SUPPLY Test length	SUPPLY Method	TOTAL DISSOLVED SOLIDS mg/ltr	TOTAL DISSOLVED SOLIDS Analysis No:
	~57.0	Flowing	57.0	61.6	0.063			3092	
		Flowing	88.5	93.0	1.0			2852	Field
		Flowing	88.7	94.87	~3.0	5 h.	Airlift	2852	Field

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	1		SANDY CLAY	Dark brown sandy clay, stiff, dry. Sand content ~20%. With plant roots. Non-calcareous.			209 145	0 0	5.5 88.5
1	6		CLAYEY SAND	Pinkish red to brownish red (orange-red when wet) clayey sand. Quartz, poorly sorted. Fine to medium grained, a few coarse sand grains up to 1mm in diam. Subrounded. With pieces of light pink calcrete ~ 1 cm in diam., well cemented (very fine calcareous cement with medium sand-sized quartz grains). Clay content ~30%. Very calcareous.					
6	16		SANDY CLAY	Light grey with red-brown mottling sandy clay. Stiff to hard, plastic when wet, sticky. Laminated. Sand content 30–35%, mainly medium grained, quartz subrounded. With a few yellow clayey sand beds or lenses up to 2 cm thick, ironstained. With milky white calcareous patches 1.5–2.0 cm in diam. and a few black subrounded grains medium sand-sized. Grey clay matrix- non-calcareous, red-brown mottled-slightly calcareous in part. From 12.0 to 16.0 mainly red-brown in colour.					

REMARKS: Cement plug - 104.07 m. Casing was pressure cemented 0–88.5 m. Screen interval 88.7–94.87 m. Sump 94.87–104.07 m.

DRILL TYPE: Rotary

COMPLETED: 132.6 m

CIRCULATION: Mud

LOGGED BY: A. Sereda

DATE: 14/11/97

SHEET 1 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
16	21		CLAYEY SAND	Red-brown clayey sand. Quartz, fine to medium grained. Subrounded, non-calcareous. With a few patches of calcareous silty clay, pinkish white in colour. From 19.0 m with some pieces of light pink calcareous sandstone, well cemented, fine to medium grained.					
21	30		SANDY CLAY	Light grey with red-brown mottling sandy clay. Stiff to hard. Sand content ~20%. With a few sand beds and chips of calcareous sandstone a/a. With thin veins of MnO_2 1–2 mm thick. From 27.0 to 35.0 becoming hard to very hard, increasing amount of MnO_2 veins.					
30	35		SANDY CLAY	Slightly pinkish grey sandy clay with light to pale brown mottling. Non-calcareous. Sand content ~20%, quartz, mainly medium grained, some coarse grains, subrounded. From 32.0 to 35.0 with some fine grained, well cemented calcareous sandstone beds.					
35	42		SAND	Sand (no description, washed out by drilling mud). With beds of hard sandy clay, mainly grey, brownish red mottled and light red patches. Some MnO_2 veins. Non calcareous.					
42	57		CLAYEY SAND, SANDY CLAY	Interbedded grey to red-brown clayey sand and sandy clay. Clayey sand, quartz mainly fine grained with some medium and a few coarse grains. Sandy clay, hard, plastic when wet, sticky. With yellow, dark brown and black (MnO_2) mottling. With pieces of well cemented dark brown non-calcareous sandstone.					
57	63		SAND	Sand, quartz, slightly clayey. Fine to medium grained, some coarse grains, well sorted, subrounded to rounded. With some sandy clay beds, light grey with red-brown mottling, hard plastic when wet, sticky. From 62.0–63.0 with a few hard (poss. sandstone) beds.					

SHEET 2 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
63	67		SILTSTONE	Sandy siltstone, hard, light grey to grey with yellow brown, brown, red-brown mottling. With a few shale beds black in colour. And MnO2 veins and dendrites. Non-calcareous. With some sand beds, fine to medium grained, subrounded to rounded.					
67	75		SANDY SILTSTONE	Very sandy siltstone, light grey, red, yellow with some black shaly beds. With some sandy clay and clayey sand beds 2–5 cm thick. Clayey sand ironstained in part mainly fine grained. With some coarse quartz and dark red iron cemented medium grained sandstone pieces ~1 cm in diam. A few pyrite nodules 1–2 cm length. Non-calcareous.					
75	84		SILTSTONE, CLAYEY SAND, SANDY CLAY	Interbedded clayey sand, sandy clay and siltstone. Light grey to pale grey and brownish yellow in colour. Sandy clay hard, plastic when wet. With quartz chips up to 2 cm in diam. A few pyrite nodules and glauconitic grains ~0.5 mm in diam. With MnO2 veins and dendrites.					
84	98		SAND, SILTSTONE	Interbedded siltstone and sand. Siltstone light grey to pale grey with a little brownish yellow mottling. Hard. Non-calcareous. Sand, light grey, grey, bluish grey in colour, quartz, fine grained, well sorted, compacted. Rounded. Non-calcareous. With pyrite nodules up to 1 cm in diam., abundant at the bottom of interval. And some pieces of poorly cemented medium grained sandstone, dark red in colour.					
98	113		LIGNITIC SAND	Dark grey to black lignitic clayey sand, mainly fine grained, with a few coarse grains, quartz, subangular to subrounded, well sorted. Some beds of brownish black slightly clayey lignitic sand. With pyrite nodules different shaped (some as a tree branch ~2 cm length). With very well cemented quartz sandstone at 101.5, 108 and 110.5. Medium grained, dark grey to pink-grey.					

SHEET 3 of 4

GROUNDWATER DIVISION

DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA

WATER WELL LOG

CONTINUATION SHEET

PERMIT NO: 43079

UNIT NO:

DME

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	DEPTH CORE SAMPLE	CASING Dia (mm)	CASING From (m)	CASING To (m)
113	116		SANDSTONE	Dark grey sandstone. Quartz, mainly medium grained, very well cemented. With some beds of lignitic quartz clayey sand and sandy clay.					
116	126		LIGNITIC SANDY CLAY, CLAYEY SAND	Interbedded black lignitic clay, sandy clay and clayey sand. Clayey sand fine grained subangular to subrounded, well sorted. Clay and sandy clay stiff to hard, plastic when wet. Some pyrite nodules. Quartz and sandstone chips and pieces angular shaped.					
126	130		LIGNITIC SANDY CLAY	Brownish black sandy clay, stiff to hard, plastic when wet, sand content ~30%, fine grained, quartz, (poss. with some lignitic sand beds). Some chips of sandstone a/a and some quartz gravel grains. With thin beds of black coal with pyrite crystals 1–2 mm in diam. Some pyrite nodules up to 1 cm in diam.					
130	132.6		SLATE	Very well cemented black slate, fine to very fine grained with some amount of pyrite crystals ~1 mm in diam. Fractured zone 131–132.3.					

SHEET 4 of 4