TECHNICAL REPORT

NON-PRESCRIBED GROUNDWATER RESOURCES ASSESSMENT – SOUTH AUSTRALIAN ARID LANDS NATURAL RESOURCES MANAGEMENT REGION

PHASE 1 – LITERATURE AND DATA REVIEW

2012/01

Government of South Australia
Department for Water

NON-PRESCRIBED GROUNDWATER RESOURCES ASSESSMENT – SOUTH AUSTRALIAN ARID LANDS NATURAL RESOURCES MANAGEMENT REGION

PHASE 1 – LITERATURE AND DATA REVIEW

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FOREWORD

South Australia's Department for Water leads the management of our most valuable resource—water.

Water is fundamental to our health, our way of life and our environment. It underpins growth in population and our economy—and these are critical to South Australia's future prosperity.

High quality science and monitoring of our State's natural water resources is central to the work that we do. This will ensure we have a better understanding of our surface and groundwater resources so that there is sustainable allocation of water between communities, industry and the environment.

Department for Water scientific and technical staff continue to expand their knowledge of our water resources through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT FOR WATER

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1. INTRODUCTION

In its *Water for Good* plan, the Government of South Australia (2009) states that resource assessment, monitoring and management of non-prescribed groundwater resources are crucial and necessary elements that will assist in achieving sustainable use of the resource. The Department for Water has lead agency responsibility for ensuring the sustainable management of groundwater resources of the state of South Australia (the State) and has developed the *Groundwater Program* to fulfil responsibilities under the *Natural Resources Management Act 2004* and in response to water security issues facing the State. This report presents findings of the sub-program *Non-prescribed groundwater resource assessments – South Australian Arid Lands Natural Resources Management Region*.

In an environment where water resources are increasingly scarce, a better understanding of both potable and non-potable water resources capacity and a more proactive approach to management is required. *Water for Good* identifies that the State's non-prescribed water resources require monitoring and management to enhance sustainable development opportunities and avoid them being over exploited. *Water for Good* supports this through an action to expand monitoring networks and increase the regularity of assessments and reporting.

There is only limited understanding of groundwater resources in most non-prescribed regions across the State. Current knowledge gaps regarding the occurrence, storage and quality of groundwater resources present significant barriers to the management and future development of many groundwater systems. Addressing these gaps is especially important due to anticipated increases in demand for water, changes in land use and potential impacts associated with a changing climate.

The pressure to access new water resources will also increase. The water-related impacts of land use change, such as mining and energy operations, may go undetected unless suitable monitoring and assessment is in place (Government of South Australia 2009). New pressures are likely to be realised for non-potable resources that traditionally have not been utilised or managed. Baseline information is important to allow appropriate planning to avoid unsustainable extraction and detrimental resource decline.

Through the Department for Water's *Groundwater Program*, an opportunity exists to deliver an improved understanding of the State's groundwater resources and to better understand the potential for further groundwater development. Benefits to stakeholders include a better understanding of the potential for groundwater to support South Australia's social and economic development and the identification of resources that require a strong focus on detailed scientific investigation and effective monitoring.

1.1. OBJECTIVES

The objective of this project is to improve the understanding of non-prescribed groundwater resources in the South Australian Arid Lands Natural Resources Management Region (SAAL NRM Region). Water resources are important for sustaining pastoral activities, mining, environmental and cultural assets and communities, but non-prescribed regions have traditionally been poorly understood due to limited monitoring and investigation programs. A better understanding of the potential for groundwater development will benefit a broad range of stakeholders and assist to identify areas that require further investigation and effective monitoring.

The aim of this report is to integrate and describe the existing data and knowledge about the non-prescribed groundwater resources in the SAAL NRM Region. This assessment aims to compile geological and hydrogeological data, giving particular attention to the identification of major hydrogeological units and related groundwater information. Based on the available information, discussions on groundwater salinity, level and yield are supported by a selection of map products. The report identifies further steps required to identify priority areas for further assessment and to address the knowledge gaps that may exist.

2. SOUTH AUSTRALIAN ARID LANDS NRM REGION

The study area is contained by the SAAL NRM Region boundary and the boundary of the Far North Prescribed Wells Area (PWA) (Fig. 1). The total area of the SAAL NRM Region is greater than 520 000 km^2 representing more than 50% of the State. The Far North PWA has an area of approximately 315 000 km^2 (SAALNRMB 2009), leaving a non-prescribed region of around 212 000 km^2.

The South Australian Arid Lands take their name from the distinctive arid landscapes that cover the north of the State. There are few reliable permanent fresh surface water resources within the Arid Lands, with a number of ephemeral salt lakes scattered across the landscape. Sandy and gibber stone deserts dominate the Far North, with the rounded ranges and volcanic outcrops of the Gawler Ranges in the south and the mountainous Flinders Ranges in the east.

Aboriginal people have a strong connection with this region and there are many sites that have high cultural and spiritual importance. The SAAL NRM Region, along with the Alinytjara Wilurara NRM Region, is distinctive in that broad-scale clearance for agricultural development has not occurred (SAALNRMB 2010). Despite this, the majority of the region’s land is now used for pastoralism, with native vegetation forming the feed stock for cattle and sheep production (SAALNRMB 2010). Large proportions of land are recognised as Aboriginal Managed Lands, or set aside for conservation purposes under the *National Parks and Wildlife Act 1972*.

The economic prosperity of the SAAL NRM Region relies heavily on mining, energy production, pastoralism and tourism. Other industries, such as building and construction, are also significant in several localities in the region (SAALNRMB 2010).

There are only a few townships within the Arid Lands and the human population is small but generally increasing, although for some towns, such as Coober Pedy and Marree, the population is in decline (Table 1).

Table 1. Human population of towns and communities within the SAAL NRM Region (SAALNRMB 2010)

Far North			Gawler Ranges			Flinders and North East		
Town	**2006**	**2001**	**Town**	**2006**	**2001**	**Town**	**2006**	**2001**
Oodnadatta	277	160	Andamooka	528	600	Beltana	83	~20
William Creek	~10		Glendambo	77	30	Blinman	151	~25
Marla	72	140	Tarcoola	38	~2	Cockburn	90	~38
Innamincka	131	~15	Woomera	295	<200	Copley	104	~100
Coober Pedy	1472	3500	Iron Knob	199	~200	Hawker	361	~300
Marree	70	150	Roxby Downs	4055	4200	Leigh Creek	548	~300
						Lyndhurst		~20
						Yunta	104	~70

Figure 1. The SAAL NRM Region

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Due to low rainfall and the lack of surface water, water quality and supply is a critical issue for the region (SAALNRMB 2010). Transporting water over vast distances to the major towns and communities is currently uneconomical (AACWMB 2006a), thus promoting the need to use local water resources for drinking and domestic supplies. This reliance on local water resources can place pressure on supplies in some towns, particularly between April and September when large numbers of tourists visit the region (AACWMB 2006a).

2.1. CLIMATE

Rainfall is generally less than 250 mm per year, however, rainfall in the arid areas of the State is unpredictable and consequently, averages can be misleading. Rainfall occurrence and intensity is episodic, sometimes without significant rainfall for years while intense rainfall can deliver annual rainfalls in a single event. Average annual evaporation can be around 3500 mm, resulting in the rapid evaporation of surface water runoff.

Summers are hot, with mean maximum temperatures in the Arid Lands averaging 30–39°C. Maximum mean temperatures for winter average 16–24°C, while minimum temperatures can drop below zero (BoM 2011). Temperatures are cooler in the Flinders Ranges and hotter in the sand hills, rising to above 50°C in summer (SAALNRMB 2010).

Table 2. Monthly climate statistics for the non-prescribed area of the SAAL NRM Region (BoM 2011)

Locality	Mean annual maximum temp (°C)	Mean annual minimum temp (°C)	Mean summer maximum temp (°C)	Mean summer minimum temp (°C)	Mean winter maximum temp (°C)	Mean winter minimum temp (°C)	Period of record
Tarcoola	27.2	11.6	34.8	18.1	19.3	5.0	1922–2011
Andamooka	27.5	13.7	35.5	20.5	19.2	6.7	1969–2011
Kimba	23.5	10.3	30.6	15.2	16.2	5.5	1967–2011
Arkaroola	25.6	11.6	33.3	19.0	17.4	4.2	1977–2011
Yunta	24.3	9.2	32.1	15.1	16.2	3.6	1951–2011

Locality	Mean annual rainfall (mm)	Mean summer rainfall (mm)	Highest summer rainfall (mm)	Lowest summer rainfall (mm)	Mean winter rainfall (mm)	Highest winter rainfall (mm)	Lowest winter rainfall (mm)	Period of record
Tarcoola	183.9	18.9	167.4	0	13.8	81.8	0	1904–2011
Andamooka	196.1	20.7	231.1	0	13.7	79.9	0	1965–2011
Kimba	346.3	17.9	162.9	0	41.0	129.6	1.3	1920–2011
Arkaroola	255.1	31.8	403.8	0	14.7	138.0	0	1938–2011
Yunta	220.4	20.7	176.5	0	16.6	71.9	0	1888–2011

2.2. LAND USE

There are a number of different land uses within the SAAL NRM Region (Fig. 2):

- Pastoral enterprises on pastoral leases constituted under the *Pastoral Land Management and Conservation Act 1989*
- Mineral and energy exploration and development under the *Mining Act 1971* and *Petroleum Act 2000*
- Conservation through parks and reserves under the *National Parks and Wildlife Act 1972*
- Conservation through other reserves and areas under private management, including areas under the custody and control of Aboriginal people and pastoral leases managed for conservation purposes
- A mixture of land uses on Aboriginal Managed Lands (SAALNRMB 2010)

Spatially, pastoralism is the dominant land use, covering 409 000 km^2 (SAALNRMB 2010). The Department of Environment and Natural Resources manages a number of parks and reserves throughout the region for biodiversity conservation. Some of these areas are co-managed with Aboriginal groups and there are also privately-held conservation areas. Aboriginal Managed Lands include pastoral leases, protected areas and other smaller properties. The mining and energy industries have become an increasingly significant land use in the region (SAALNRMB 2010).

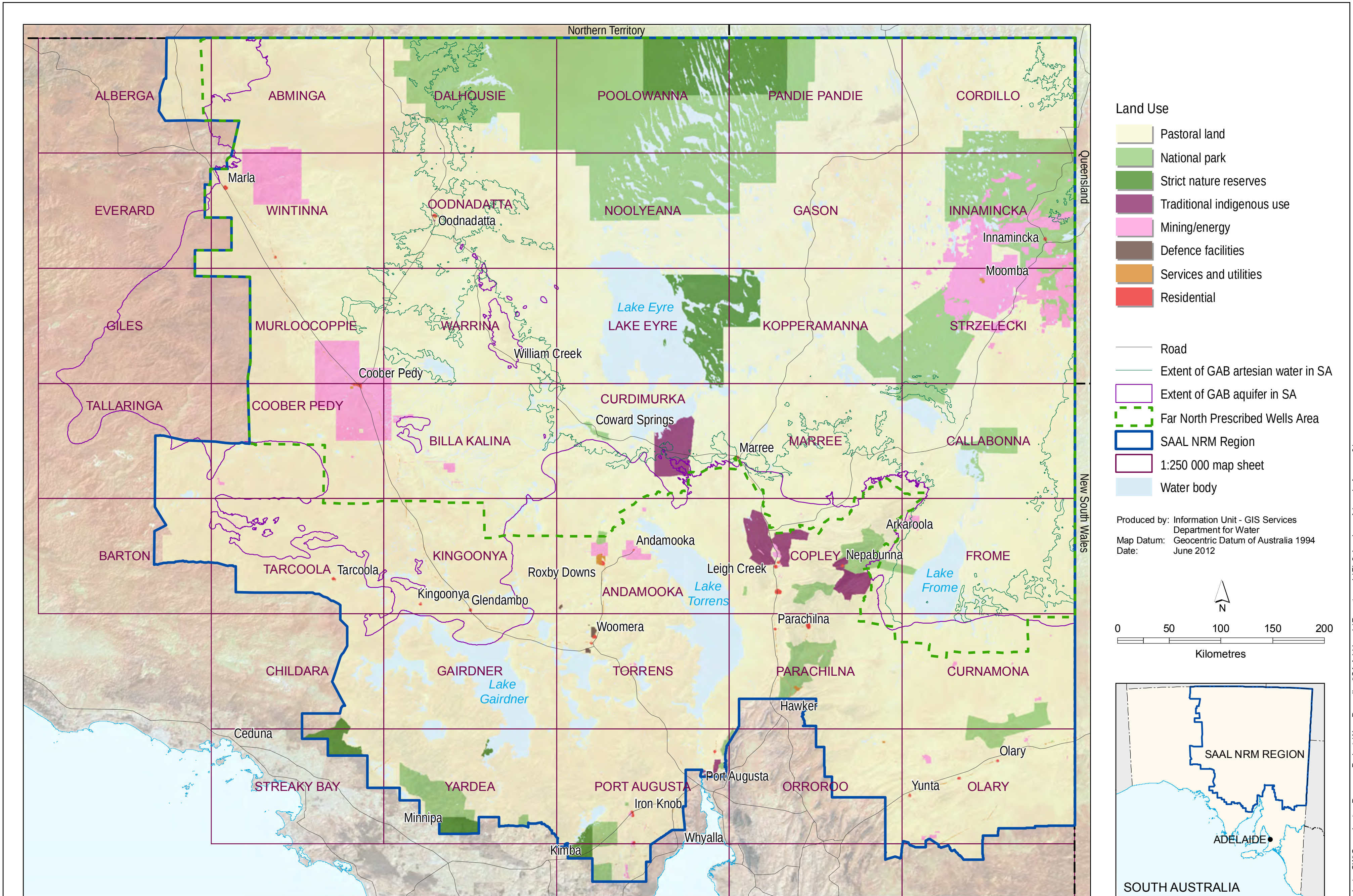

Figure 2. Aggregated land use categories within the SAAL NRM Region

2.3. WATER RESOURCES

As there is no regional reticulated water system and few reliable permanent surface water resources, locally supplied groundwater resources are the key source of water upon which the SAAL NRM Region relies. Surface water is mainly used as a resource for pastoralism, town supplies and tourism, but has a much lower usage than groundwater supplies (AACWMB 2006b).

Aboriginal people have opportunistically used waterholes, streams, claypans and springs in the arid interior of Australia for tens of thousands of years, falling back onto more permanent water resources (such as Great Artesian Basin springs and large waterholes in Lake Eyre Basin rivers) during times of drought (AACWMB 2006b).

Options have been explored for the integration of surface water capture and aquifer storage throughout the study area (AACWMB 2006b). Just outside the region at Whyalla, an Aquifer Storage and Recovery (ASR) system has been investigated (AWE 1999 in AACWMB 2006a). Investigations have also been undertaken in areas around Hawker and Nepabunna (AACWMB 2006a). Martin, Sereda and Clarke (1998) identified the Pirie-Torrens Basin (along the south-western margin of the Flinders Ranges) as an area having the potential for enhanced groundwater recharge.

2.3.1. COMMUNITY WATER SUPPLIES

Information about community water supplies within the SAAL NRM Region is taken from Volume two of the State of the Catchment Report by the former Arid Areas Catchment Water Management Board (AACWMB 2006a).

Far North townships mostly rely on groundwater to meet potable and domestic needs. In the Far North PWA, groundwater from the Great Artesian Basin (GAB) supplies Coober Pedy and Roxby Downs (SAALNRMB 2010). Oodnadatta and Marree also obtain their water from the GAB, with supplies managed by SA Water. Innamincka extracts surface water from a permanent water hole (Queerbiddie Waterhole) on the Cooper Creek, while River Murray water is imported via a branch of the Morgan to Whyalla pipeline to supply Woomera and the nearby town of Pimba.

SA Water is also responsible for the Marla, Parachilna, Blinman, Cockburn, Mannahill, Yunta and Olary town water supplies, which source shallow aquifers outside the GAB (SAALNRMB 2010) or divert water from creeks into settling dams for supply. Self-managed wells and rainwater provide for other towns. Stock on pastoral land are supported by dams, tanks and wells (SAALNRMB 2010).

Development in the Gawler Ranges has been restricted by the available water supply. No true riverine systems are found in the region, so local populations opportunistically use the topography of the land to collect surface water runoff in dams, or generally use rainwater collected from man-made structures. Surface water runoff is captured from the granite dome-shaped outcrops that form the rounded ranges.

The township of Kingoonya obtains its water from the Kingoonya Palaeovalley aquifer, which is a relatively reliable source of water, although there have been some salinity issues. Annual consumption is approximately one megalitre per year.

Glendambo’s town water supply is from a production well screened within unconfined GAB sediments. At the time of drilling in 1986, the salinity was 1640 mg/L. As the well is located very close to the township it is at risk of pollution and salinisation and pastoral homesteads generally rely on rainwater for human consumption (Cowley & Martin 1991). In 2004, the salinity had risen to 2114 mg/L.

Small towns in the western Flinders Ranges rely on groundwater and surface water runoff. The Arcoona Dam captures runoff from a large catchment in the ranges and provides water for the townships of

Leigh Creek and Lyndhurst, the Leigh Creek coalfields and some pastoral properties. The Blinman town water supply is pumped from the old copper mine to storage tanks and piped to houses, but as with many outback towns, there are problems with supply during the peak tourism season. Copley pumps water from a dam to storage tanks, while Parachilna has recently been upgraded with a new production well to supplement existing supplies. Prior to 2005, the town utilised surface water from the Parachilna Creek, but now relies on groundwater sourced from a sedimentary aquifer (Costar & Howles 2011). The Nepabunna community has also recently been upgraded with a new supply well, which at 300 m is three times as deep as the previous supply well; however, the water quality is marginal and needs to be managed (Costar, Kruger & Howles 2010).

In the east of the study area, the fractured rock aquifers of the Olary Ranges provide groundwater suitable for stock in the district. Outside of this, dams are the major water supply. The supply and quality of groundwater beneath the plains to the north and south of the Olary Ranges are poor with respect to stock requirements and is used to supplement supplies in dry seasons, although some usable stock water can be obtained from palaeovalleys in the area.

2.3.2. GROUNDWATER USAGE

Aside from mining operations there are no definitive data for groundwater usage within the non-prescribed area of the SAAL NRM Region. Information on groundwater usage within the Far North PWA is available from the Water Allocation Plan for the Far North PWA by the SAAL NRM Board (SAALNRMB 2009).

2.3.3. SURFACE WATER

Information about the surface water resources of the Arid Lands is taken from the Catchment Water Management Plan for the SAAL Region by the former Arid Areas Catchment Water Management Board (AACWMB 2006b) and the Regional Natural Resources Management Plan by the South Australian Arid Lands Natural Resources Management Board (SAALNRMB 2010). A report on the surface water resources of the SAAL NRM Region is currently in preparation by DFW.

The arid zone is typified by infrequent but large flood events in an otherwise dry landscape and climate. Sustainability of the use of surface water systems in the area relies heavily on the scale and frequency of rainfall events. Annual average flows are not a reliable indicator of resource availability either temporally (due to variability in flow) or spatially (due to high transmission losses in arid areas streams). Mostly the rivers do not flow at all and long dry periods are the norm, although heavy rainfall events, particularly from events in Queensland or north-western NSW, can cause massive flooding.

In the Gawler Ranges area there are no true riverine systems and the surface water resource is considered to be very limited. Drainage is mostly impeded, resulting in many large salinas, Lake Gairdner being the largest at 8884 km^2. The slopes of the Gawler Ranges are utilised at a local level to direct and collect surface runoff, dams having been built upon pockets of clay, with the largest having long pipeline systems radiating from them. Natural waterholes occur in watercourses and creeks, but none are a source of permanent stock water. Relatively large freshwater internal drainage systems such as Lake Phillipson and Millers Creek, and smaller swamps and lakes, can supply water for up to four years but are unreliable as they rarely catch water.

On the western side of the northern Flinders Ranges, drainage is directed towards Lake Torrens, however, there are numerous unconnected catchments in the region and great hydrological variability. In the northern Flinders Ranges area, rivers and creeks tend to flow episodically in response to occasional and irregular rains. Dams are a significant part of the water supply network for domestic use in the Northern Flinders, however, between 60 and 90 per cent of water stored in dams is usually lost by evaporation annually. On the eastern side of the northern Flinders Ranges, drainage is directed into the Frome Embayment.

There a very few reliable permanent natural sources of surface water in the east. The hard rock areas of the Olary Ranges provide the catchment and storage for most groundwater suitable for stock in the district and outside of this, dams are the major water supply, although often an unreliable water source with silting and high water losses due to evaporation.

2.4. DEMAND AND SUPPLY

A key commitment in *Water for Good* is the development of Regional Demand and Supply Statements to ensure that long-term water security solutions for each region are based on a thorough understanding of the state of all local water resources, the demand for these resources and likely future pressures (DFW 2011).

The Demand and Supply Statements provide demand and supply projections for the scenarios of high and low population growth and high and low greenhouse gas emissions. Two projection sets address the demand and supply for (1) drinking quality water only; and (2) for all water sources and human demands.

Access to reliable water supplies has been the major limiting factor in the development of industries and settlement in the arid areas over the past 200 years (AACWMB 2006a). Today, major industries in the Far North are highly dependent on GAB water and include mining, pastoralism and tourism. Mining industries that utilise the water resources of the area include oil and gas extraction and refining, coal extraction and mineral ore extraction and refining (AACWMB 2006a). It is important that associated water resource demands are considered, planned for and managed to support this development, while balancing this against environmental and social requirements.

The Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) has indicated that there will be significant growth in the mining industry over the next 40 years and beyond (Government of South Australia 2007; RESIC 2010). Mining operations require significant volumes of water, but can typically be of a lower quality than is required for stock or irrigation. The Resources and Energy Sector Infrastructure Council's 2011 study of exploration and mining development activity reported that the water demand for 'weighted' projects across the State's resource sector will increase from approximately 40 GL/y in 2011 to 170 GL/y in 20177 (RESIC 2011). Of this water demand, approximately 80% of the water quality required is non-potable. Desalinated groundwater will be the primary water source for weighted projects at approximately 45% followed by desalinated seawater (~30%).

2.4.1. MINING

The SAAL NRM Region currently accounts for 70% of South Australia's mining outputs. The Leigh Creek coal mine has been a major industrial activity and economic driver in the region for more than three decades. Gas and oil production and exploration, centring on the Cooper and Eromanga Basins, is expanding with investment in exploration increasing considerably in recent times. There has also been a rapid rise in interest in geothermal energy in the east of the region (Planning SA 2008 in SAALNRMB 2010).

The Olympic Dam mine and Roxby Downs township are currently the largest individual groundwater users in the Far North area. The primary water supply for the existing Olympic Dam operation is groundwater extracted from Wellfields A and B located in the GAB (in the Far North PWA) about 120 and 200 km north of Olympic Dam, respectively. The proposed Olympic Dam expansion would require an additional 183 ML/d (peak requirement). The primary water supply for the expansion is a proposed desalination plant located at Point Lowly, not groundwater from the GAB. A supplementary, low-quality water supply, primarily for dust suppression, would be sourced from saline aquifers close to the current operation (BHP Billiton 2009).

Although the level of activity can vary quickly, there are currently 518 exploration licences, 211 mineral exploration licence applications, 195 petroleum production licences, 40 petroleum explorations licences, 33 petroleum exploration licence applications, 184 geothermal exploration licences and 21 geothermal exploration licence applications held within the SAAL NRM Region. The RESIC (2010) study identified that operation in the Gawler Craton, western Eromanga Basin and underlying Arckaringa Basin and the Curnamona Province are expected to experience a significant increase in demand for water use). Although mining operations require significant volumes of water, the quality of the water is typically of less importance. Depending on the type of mine, highly saline water can be used for processing and auxiliary uses. On-site reverse osmosis produces potable water for camp supply.

Dewatering of mines and supply wellfields can cause the development of considerable cones of depression within the targeted aquifer (AGT 2010). This has the potential to affect the water supply for communities in close proximity to the mine if they are accessing water from the same aquifer. Guidelines from the *Mining Act 1971* and DMITRE require any new mining project to assess the risks to the environment and stakeholders. For example, if significant drawdown effects occurred at community supply wells due to mining, the company would be responsible for supplying the town with potable water from the mine dewatering or its own potable supply (AGT 2010).

3. HYDROGEOLOGY

There are numerous geological provinces and basins within the SAAL NRM Region. The major provinces within the non-prescribed area include the Gawler Craton, Curnamona Province, Stuart Shelf, Adelaide Geosyncline, Eromanga Basin, Torrens Basin and Lake Eyre Basin. The region's major stratigraphic units have been summarised in Table 18 (Section 5).

3.1. GEOMORPHOLOGY

The SAAL NRM Region includes a variety of different landforms including dunefields, gibber plains, tablelands, sand plains, volcanic dome-shaped exposures and ranges of Precambrian rock (Fig. 3). The following description of the topography and geomorphology of the SAAL NRM Region is taken from Volume two of the former Arid Areas Catchment Water Management Board's State of the Catchment Report (AACWMB 2006a).

The Adelaide Geosyncline originated as a long, narrow trough developed below sea level that over millions of years collected marine sediments until tectonic movement caused the trough to compress and uplift, producing the present day highland chain of the Mount Lofty and Flinders Ranges.

West of the Flinders Ranges, in a region known today as the Stuart Shelf, sediments were deposited on a relatively stable region west of Lake Torrens. Further west of the shelf are the Gawler Ranges, the peaks of the Gawler Craton—an ancient stable land mass extending from the Fleurieu Peninsula to Marla and including some of the oldest rocks in the State.

Early Cambrian sedimentation commenced unconformably over the Adelaide Geosyncline in the Arrowie Basin. Between 230 and 280 million years ago, the Arckaringa Basin was formed. From about 180 million years ago, sediments of the Eromanga Basin were deposited in a shallow continental sea around 180 to 65 million years ago.

East of the northern Flinders Ranges, the south-eastern margin of the Eromanga Basin underlies the Frome Embayment. The Lake Eyre Basin is a thin sedimentary blanket extending in age from 55 million years to the present overlying most of the Eromanga Basin. Between 50 and 60 million years ago the Murray Basin began to subside and the Torrens Basin was formed.

The gibber deserts of the Far North are broken and weathered duricrust that cap and protect an underlying softer surface that is highly susceptible to erosion. West of Lake Eyre, the duricrust has been dissected by stream erosion to form the breakaway country located in the Arckaringa Hills and around Coober Pedy.

The large central desert salt pans of northern South Australia are significant features in the landscape. In a wetter past climate these formed freshwater lakes, with Lake Eyre an extensive inland sea. Currently, the Lake forms the terminus of an extensive area of surface drainage, with no outlet to the sea.

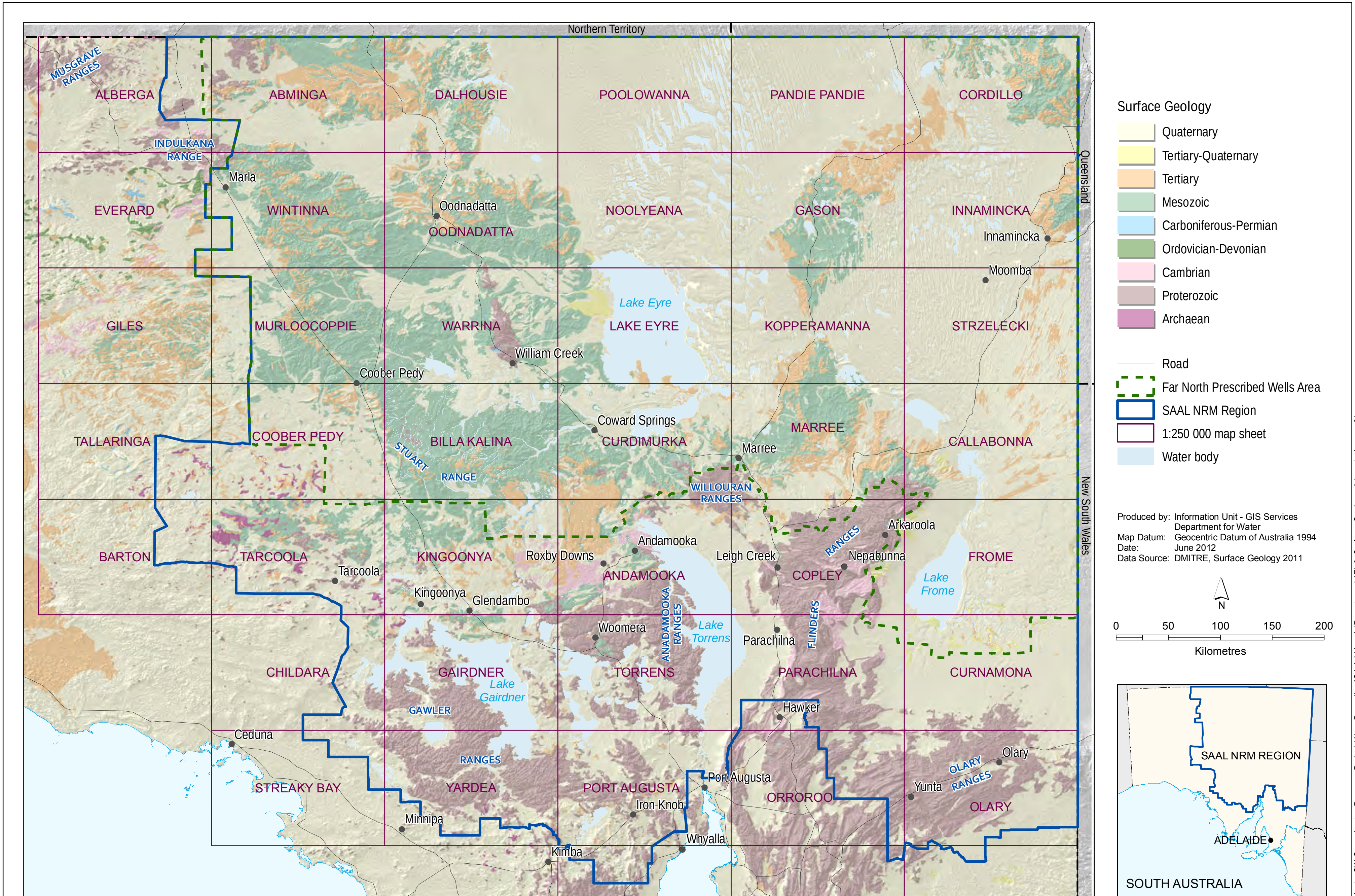

Figure 3. Surface geology of the SAAL NRM Region

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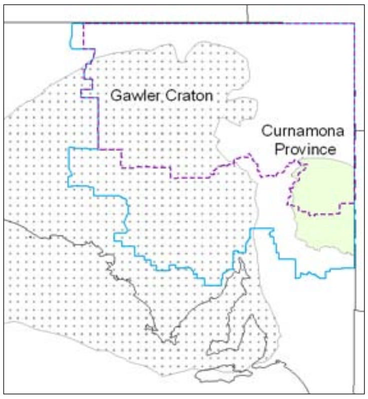
3.2. ARCHAEAN TO EARLY MESOPROTEROZOIC



3.2.1. GAWLER CRATON

The Gawler Craton geological province encompasses approximately 440 000 km^2 of central South Australia (Fig. 4). The craton is a stable crystalline basement province comprising Archaean to Mesoproterozoic rocks of gneiss, schist, granite and banded iron formations, with the Mulgathing Complex the dominant rock unit within the study area (Lewis *et al.* 2010). Weathering may occur to a depth of as much as 50 m; overlying Permian clays are generally restricted to narrow east–west trending troughs. Late Proterozoic to early Palaeozoic sediments of the Officer Basin overlie the Craton to the north-west. Late Palaeozoic to early Mesozoic sediments of the Arckaringa Basin and Late Mesozoic sequences of the Eromanga Basin onlap the older rocks of the craton to the north-east (Dodds 1996). An extensive region of palaeodrainage exists over the Gawler Craton, terminating along the margins of the Eucla Basin (Fig. 6). These palaeorivers drained the Musgrave Block, Stuart Range and Gawler Ranges. Mesozoic and Tertiary age sediments infill the widely distributed palaeovalleys incised into the older rocks and cover the craton at the surface along with a thin cover of Quaternary dune sands, calcrete and colluvium (Benbow, Lindsay & Alley 1995).

At the regional scale, groundwater within the Gawler Craton generally occurs in fractured rock aquifers within the Precambrian basement rocks and Tertiary sediment-filled incised palaeovalleys (AGT 2010). Supplies have also been obtained from Permian troughs; the best known of these features is the Mulgathing Trough although yields are small (Martin, Sereda & Clarke 1998).

3.2.2. CURNAMONA PROVINCE

The Curnamona Province extends from central-eastern South Australia into western New South Wales (Fig. 4). The province is separated from the Archaean to Mesoproterozoic Gawler Craton to the east by the Neoproterozoic to Cambrian Adelaide Geosyncline (Fairclough, Hore & Birt 2007). The province contains two known sets of rocks: the older set consists of the Willyama Supergroup, a deformed sequence of metasediments and metavolcanics of late Palaeoproterozoic age; the younger set comprises granitoid intrusives of early Mesoproterozoic age together with less deformed or undeformed volcanics and sediments (Tonkin 2009).

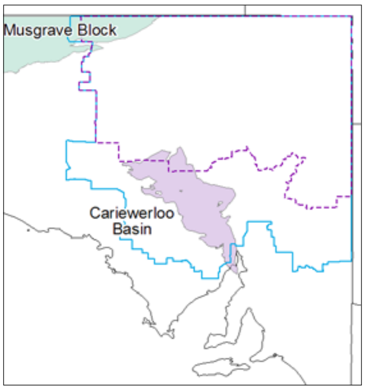
Exposures of the Curnamona Province are limited to the Mount Painter and Mount Babbage Inliers to the north-west and the Willyama Inliers to the south-east (Tonkin 2009). The Willyama Supergroup is divided into the Olary and Broken Hill Domains; the Olary Domain (OLD) falling mostly within South Australia. The OLD extends to the north along the north–south trending Benagerie Ridge that is dominated by the flat-lying sheet of Mesoproterozoic Benagerie Volcanics (Conor 2004; Burtt, Conor & Robertson 2004). Cambrian and Adelaidean age rocks are found either side of the ridge (Conor 2004). The Neoproterozoic age Burra and Umberatana Groups unconformably overlie, or are faulted against, Palaeoproterozoic rocks in the Olary Domain to the west, south and, to a limited extent, the north (Conor 2004). Cainozoic sediments dominate cover over the Curnamona Province away from areas of outcrop.

The western and eastern parts of the Curnamona Province are obscured by the Neoproterozoic to Cambrian aged Moorowie and Yalkalpo Sub-basins, which are separated by the Benagerie Ridge (Tonkin

2009). Excluding outcrop, basement rocks and the overlying Neoproterozoic and Cambrian sub-basins are covered by shallow to moderately thick Mesozoic and Cainozoic sediments (Burtt *et al.* 2005).

Within the Curnamona Province, groundwater occurs within fractured rocks of Palaeoproterozoic and Neoproterozoic age. However, the primary aquifer in the region coincident with the Curnamona Province occurs within overlying Eromanga Basin sediments. Smaller localised aquifers occur in alluvial and fluvial sands within Cainozoic sediments (Fabris *et al.* 2008). Areas of maximum groundwater flow are located along the eastern edge of the Flinders Ranges (Fabris *et al.* 2008). There is a paucity of information north of the Olary Ranges, though the area over the Benagerie Ridge is known to be lacking in groundwater (Shepherd 1960 in Callen 1975).

3.3. *MID TO LATE MESOPROTEROZOIC*



3.3.1. CARIEWERLOO BASIN

Information on the Cariewerloo Basin is taken from Cowley (1991; 1993). A tectonic subdomain of the Gawler Craton, the Cariewerloo Basin is a 120 km-wide, north–west trending intracratonic basin (Fig. 4). Erosion of the Gawler Ranges resulted in continental sedimentation of the Pandurra Formation within the Cariewerloo Basin. The Pandurra Formation is a thick unit of unmetamorphosed, flat-lying, sandy sediments and typically comprises a medium to coarse-grained sandstone, but also includes very fine to medium-grained sandstone, pebble conglomerate and shale.

The Pandurra Formation overlies Gawler Range Volcanics and the Hiltaba Suite and is intruded by the Gairdner Dolerite. It is exposed in a north–west trending belt from Whyalla to areas west and south-east of Woomera. The formation is continuous in the subsurface between these exposures, and extends significantly to the northwest.

The thickest intersection of the Pandurra Formation obtained to date is 1180 m, from a drillhole in the north-west of the basin about 110 km due north of Glendambo. Anderson (1978) interpreted aeromagnetic data to suggest a maximum thickness of 1500 to 2000 m in the north of the KINGOONYA 1:250 000 map sheet. Read & Beal (1988) and Kellet *et al.* (1999) have documented groundwater occurring within the Pandurra Formation.

3.3.2. MUSGRAVE BLOCK

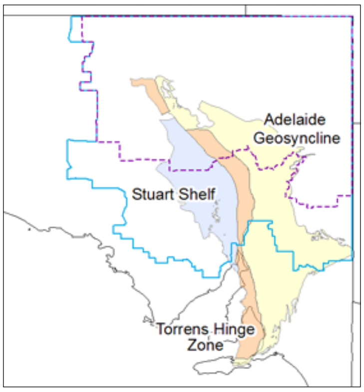
The Musgrave Block is a Palaeoproterozoic to Mesoproterozoic aged crystalline basement craton that extends into Western Australia and the Northern Territory (Fig. 4). The craton is bounded to the east by the Eromanga Basin, to the south and west by the Officer Basin and to the north by the Amadeus Basin (Major & Conor 1993).

The Musgrave Block is separated into two tectonic subdomains by the south-dipping Woodroffe Thrust (Lewis *et al.* 2010). The Mulga Park Subdomain, containing amphibolite facies of the Olia Gneiss, is found to the north (Major & Conor 1993). The major portion of the block within South Australia, the Fregon Subdomain, containing granulite facies of the Birksgate Complex, is to the south of the thrust (Major & Conor 1993).

Pliocene to Pleistocene sediments consisting of unconsolidated clays with sands and limestone, were deposited into the extensive network of palaeovalleys that incised the Musgrave Block (Lewis *et al.* 2010). These sediments have undergone deep weathering that led to the development of ferricrete and silcrete (Magee 2009). In the absence of basement outcrop, Quaternary sand dunes of the Great Victoria Desert blanket the region and include Pleistocene calcrete and Holocene alluvial, fluvial and aeolian deposits that are generally unconsolidated and consist of gravel, sands and clays with some thin limestone (Lewis *et al.* 2010; Fig. 5).

Groundwater occurs within the Precambrian basement rocks of the Musgrave Block and shallow, poorly consolidated Tertiary sediments infilling palaeovalleys incised into these rocks. Small localised freshwater aquifers may also be found in shallower Quaternary alluvium, sand or calcrete deposits in streambeds and adjacent to basement outcrop where recharge occurs by direct infiltration from rainfall (Rowe *et al.* 2006).

3.4. NEOPROTEROZOIC



3.4.1. ADELAIDE GEOSYNCLINE

The complex of basins of thick Neoproterozoic sedimentary sequences in central-eastern South Australia is known as the Adelaide Geosyncline (Parker 1993; Fig. 4). It encompasses the entire length of the Mount Lofty and Flinders Ranges, the Olary region and Kangaroo Island. The western margin is defined as the Torrens Hinge Zone, which represents both the edge of the Gawler Craton and the transitional zone between thick, folded Neoproterozoic sediments of the geosyncline and very thin, flat-lying platformal counterparts of the Stuart Shelf (Sprigg 1952 in Parker 1993).

It is likely that a late Palaeoproterozoic precursor basin, distinct from the Archaean to Mesoproterozoic Gawler Craton, forms the basement beneath the Adelaide Geosyncline (Preiss 1999). Two supergroups encompass all sediments of the Adelaide Geosyncline (Preiss 1999): the Warrina Supergroup comprises the early rift sequences of the Callanna and Burra Groups and the Heysen Supergroup comprises the glacial, interglacial and post-glacial sediments of the Umberatana and Wilpena Groups.

Nearly all groundwater in the Flinders Ranges occurs in weathered and fractured indurated sedimentary rock aquifers (Read 1987). Some limestone layers have dissolution cavities that can supply high yields (AACWMB 2006a). Minor aquifers also occur in unconsolidated sand and gravel sediments of Quaternary age at the base of the ranges (AACWMB 2006a). In the hard rock areas of the Olary Ranges, groundwater occurs in fractured rock aquifers, with larger supplies obtainable from the harder and brittle sandstones compared to the softer shales (NFRSCB 2004). Groundwater can also be obtained from sediment-filled watercourses and valleys where the surface water collects and infiltrates (NFRSCB 2004).

3.4.2. STUART SHELF

The Stuart Shelf is a thinner and flat-lying extension of Adelaide Geosyncline sedimentation on the eastern portion of the Gawler Craton to the west of the Spencer Gulf, extending from Whyalla towards Cooper Pedy (Fig. 4). The sedimentary sequence on the Stuart Shelf is undeformed and is separated from the Adelaide Geosyncline by the Torrens Hinge Zone (Curtis 2007). Only the glacial, interglacial and post-glacial sediments of the Umberatana and Wilpena Groups of the Heysen Supergroup are present on the shelf.

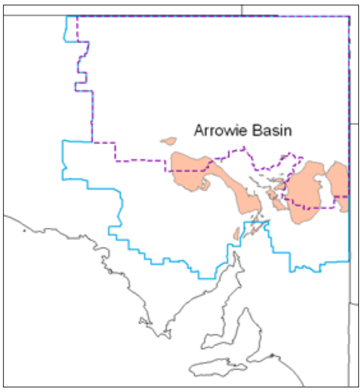
In the Stuart Shelf province, the most significant sedimentary rocks are the Wilpena Group's Tent Hill Formation, which comprises the Arcoona Quartzite, Corraberra Sandstone and Tregolana Shale

Members (BHP Billiton 2009a). The lower parts of the Arcoona Quartzite and the Corraberra Sandstone Members form an extensive aquifer over the southern portion of the Stuart Shelf (BHP Billiton 2009a).

3.4.3. TORRENS HINGE ZONE

The Torrens Hinge Zone (THZ) cuts across the Gawler Craton and is a mainly north–south trending transitional belt 20 to 30 km wide (Parker & Fanning 1998; Fig. 4). The zone represents both the edge of the Gawler Craton and the transitional zone between thick, folded Neoproterozoic sediments of the Adelaide Geosyncline and very thin, flat-lying platformal counterparts of the Stuart Shelf (Sprigg 1952 in Parker 1993). It is also the locus of the Cainozoic aged Torrens, Pirie and St Vincent Basins (Parker 1993).

3.5. CAMBRIAN TO LATE CARBONIFEROUS



3.5.1. ARROWIE BASIN

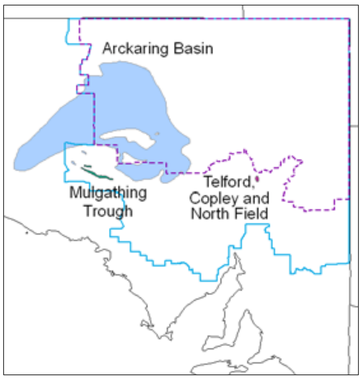
In the Arrowie Basin (Fig. 5), Early Cambrian sedimentation commenced unconformably over Neoproterozoic strata (Wilpena Group) of the Adelaide Geosyncline after a widespread hiatus (Gatehouse & Gravestock 1990; Parker 1993). The basin extends across the Torrens Hinge Zone onto the Stuart Shelf with deposition likely to have ceased by the Middle to Late Cambrian (Gatehouse & Gravestock 1990).

Sediments were deposited in the Arrowie Basin on the eastern seaboard of the Gawler Craton in two contrasting but conformable thick sedimentary packages: the lower package (Hawker Group) is Early Cambrian in age and is carbonate dominated; the upper package (Lake Frome Group) of early Middle to Late Cambrian age consists primarily of siliciclastics (Gatehouse & Gravestock 1990).

The Andamooka Limestone is one of the most important sedimentary rocks of the Arrowie Basin as it forms an aquifer over the Stuart Shelf region. The base of the Andamooka Limestone dips gently to the north and north-east and reaches its maximum thickness of 160 m at the northern end of Lake Torrens, where it continues below the bed of Lake Torrens (Kellett *et al.* 1999). In some areas where the limestone is near the surface and exhibits dissolution features, local perched aquifers have formed after major rain events (AACWMB 2006a). At the northern extent of the Stuart Shelf, where these rocks dip beneath Mesozoic cover, the Andamooka Limestone has been identified as a highly transmissive, karstic unit with the potential to yield large amounts of saline groundwater (BHP Billiton 2009a).

Previous groundwater investigations for town water supplies for Nepabunna and Leigh Creek have identified Cambrian limestones, other carbonates and tillites as good or potential aquifers (Read 1984a; 1984b). Recent town water supply well drilling at Nepabunna targeted the Wilkawillina Limestone (Costar, Howles & Kruger 2010).

3.6. LATE CARBONIFEROUS TO TRIASSIC



3.6.1. ARCKARINGA BASIN

The Arckaringa Basin is a Late Palaeozoic, predominantly marine to marginal marine intracratonic basin of about 80 000 km^2 in central-northern South Australia underlying the Eromanga Basin (Hibburt 1995; Fig. 5). It consists of diamictite of the Late Carboniferous to Early Permian Boorthanna Formation overlain in most parts of the basin by Early Permian marine shale with minor mudstone, siltstone and sandstone of the Stuart Range Formation (AGT 2010). The Mount Toondina Formation is the uppermost unit of the Arckaringa Basin, overlying the Stuart Range Formation. Toward the north, the formation may directly overlie the Boorthanna Formation (AGT 2010). The Mount Toondina Formation comprises siltstone and sandstone interbedded with shale and sometimes carbonate and coal seams (AGT 2010).

The Permian sediments infilling the Arckaringa Basin comprise two main aquifer systems. North-west of Coober Pedy, the upper portion of the Mount Toondina formation is known to comprise some sandy units and may act as a permeable aquifer (AGT 2010). The Boorthanna aquifer often occurs as several zones within the Boorthanna Formation separated by significant thicknesses of low-permeability sediments and has been significantly developed as a water supply for the Prominent Hill copper mine (SKM 2009). Where it occurs, the Stuart Range Formation forms an effective aquitard between the two aquifers (AGT 2010).

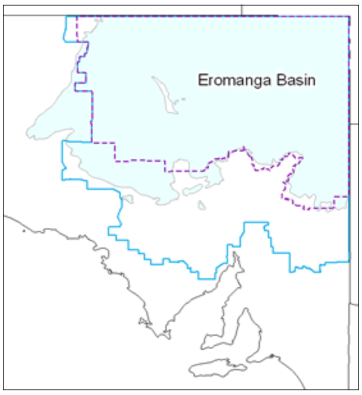
3.6.2. MULGATHING TROUGH

The Mulgathing Trough is a north-westerly orientated narrow structure measuring 4 x 90 km within the Gawler Craton, 100 km south of the Arckaringa Basin (Hibburt 1995; Fig. 5). Seismic data indicate that at least 800 m of Permian sediments overlie crystalline basement and in turn, are overlain by up to 100 m of Mesozoic and Cainozoic sediments (Nelson 1976). Permian sediments are correlated with the Boorthanna and Stuart Range Formations of the Arckaringa Basin, but differ in that they appear to be non-marine (Hibburt 1995). The lower unit generally comprises a pale grey gritty claystone and sandstone, whereas the upper consists of grey to black mudstone, shale and siltstone. Groundwater supplies have been obtained from the Mulgathing Trough, although yields are small (Martin, Sereda & Clarke 1998).

3.6.3. TELFORD, COPLEY AND NORTH FIELD BASINS

The Leigh Creek Coalfield was originally defined as comprising four separate intramontane basins, the North Field (2 lobes), Telford and Copley Basins, the largest of which is the north–west trending Telford Basin. The basins are aligned north to south over about 20 km (Fig. 5). The Late Triassic sequence, designated as the Leigh Creek Coal Measures, occurs in all basins, ranging in thickness from 120 m in North Field to over 1500 m in the Telford Basin. Grey carbonaceous mudstone is dominant, with coal, sandstone and siltstone present in lesser and varying proportions (Kwitko 1995).

3.7. JURASSIC TO CRETACEOUS



3.7.1. EROMANGA BASIN

The Eromanga Basin is the largest and most central of three epicontinental depressions that together comprise the Great Artesian Basin, a non-marine and marine Jurassic–Cretaceous superbasin that covers approximately one-fifth of the Australian continent (Krieg, Alexander & Rogers 1995; Fig. 5). Only the southwestern third of the Eromanga Basin occurs in South Australia and extends as an almost continuous blanket over the northeast of the State from where it laps onto the older basement blocks and basins to the west and south-west (Krieg, Alexander & Rogers 1995).

In South Australia, the GAB is composed entirely of Eromanga Basin sediments whose thickness varies from less than 100 m on the margins of the basin, to over 3000 m in the deeper parts (Martin, Sereda & Clarke 1998).

The following description of the Eromanga Basin sequences is taken from Martin, Sereda and Clarke (1998). The Jurassic Algebuckina Sandstone reaches a maximum recorded thickness of 750 m and consists of a fine to coarse-grained quartzose sandstone with granule and pebble layers, with shale interclasts common in the coarser beds. The Cretaceous Cadna-owie Formation is typically 10 to 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 formation is mainly a thick-bedded sequence of pale grey siltstone and very fine to fine-grained sandstone, with medium to very coarse-grained sandstone interbeds and minor carbonaceous claystone intervals, and records the transition from terrestrial-freshwater to marine conditions (Krieg & Rogers 1995). The Cretaceous Bulldog Shale forms an effective confining bed between the lower and upper aquifers and has a maximum known thickness of about 340 m in north-eastern South Australia, thinning to less than 200 m in the Oodnadatta and Marree regions. The unit 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.

Within the non-prescribed area of the SAAL NRM Region, the Algebuckina Sandstone and Cadna-owie Formation (often referred to as the J-K aquifer) form the major water-bearing aquifer system (Love *et al.* 2000). Where present, the overlying Bulldog Shale confines the J-K aquifer.

The J-K aquifer is artesian throughout much of the Eromanga Basin, including large areas of South Australia; within the non-prescribed area of the SAAL NRM Region, the aquifer is non-artesian. In this area, groundwater generally flows to the east from the western recharge zone and to the south-east around the Flinders Ranges.

To the south-west of the basin, the Algebuckina aquifer is generally semi to unconfined, and is recharged by rainfall. The Algebuckina aquifer reaches a thickness of approximately 50 m at Kingoonya, but is absent beneath the Kingoonya Palaeovalley (AAWMCB 2006a).

A number of other stratigraphic units comprise the Eromanga Basin but as they are found within the Far North PWA and not the non-prescribed area, they are not included in this report.

3.7.1.1. Frome Embayment

East of the northern Flinders Ranges, a small lobe of the Eromanga Basin extending beneath Lake Frome is known as the Frome Embayment (Krieg, Alexander & Rogers 1995). The Frome Embayment contains shallow marine and non-marine sandstones and shales of upper Jurassic and Cretaceous age, overlain by Tertiary and Quaternary terrestrial sediments. North of Olary, the recent Tertiary sediments are just over 120 m thick. In the southern portion of the embayment, the Palaeocene to Eocene sands and clays of the Eyre Formation are found within distinct palaeovalleys incised into the older sediments and sometimes the basement rocks. They are blanketed by lacustrine silts and clays of the Miocene Namba Formation that are overlain by Quaternary sands and clays (Waterhouse & Beal 1978).

3.8. CAINOZOIC

3.8.1. TORRENS BASIN

The Torrens Basin is a north–south trending structural depression bound to the west by the Torrens Hinge Zone and to the east by the Flinders Ranges (Alley & Benbow 1995). The basin extends north of Port Augusta, is around 400 km long and varies in width from 0.8 to 40 km, with a total area of approximately 10 000 km^2 (Shepherd 1978; Fig. 6). The Basin contains fluvio-lacustrine sediments of Eocene and Miocene age and overlies Precambrian and Cambrian rocks. In the east where the basin is deepest and abuts the Flinders Ranges, the basin is underlain by Mesozoic sediments (Alley & Benbow 1995).

Martin, Sereda and Clarke (1998) provide a comprehensive description of the basin sequences. Tertiary sediments within the Torrens Basin occur at a minimum depth of about 80 m to a maximum of about 270 m. The fluvio-lacustrine Cotabena Formation contains partly carbonaceous, fine to coarse-grained sand, silt, and sandstones with occasional thin carbonaceous clay beds. The overlying Neuroodla Formation is commonly about 100 m thick, although up to about 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 Torrens Basin, this unit forms a confining bed to the deeper Tertiary aquifers of the Cotabena Formation (Alley & Benbow 1995).

Quaternary sediments overlying the 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 up to 180 m has been recorded in places. An unnamed sandy gravel outwash alluvium occurs along the eastern margin of the Torrens Basin between Lake Torrens and the Flinders Ranges.

Groundwater within the Torrens Basin is mainly sourced from the Cotabena Formation, which is thickest along the base of the Flinders Ranges (AACWMB 2006a). In the northern part of the Torrens Basin, the Neuroodla Formation forms a confining bed to the Cotabena Formation (Alley & Benbow 1995).

3.8.2. LAKE EYRE BASIN

During the Late Palaeocene, tectonic subsidence in north-eastern South Australia produced the large, shallow Lake Eyre Basin in which episodic fluvial and lacustrine sedimentation has taken place until present (Callen, Alley & Greenwood 1995). The basin is divided into the north-western Tirari sub-basin and southern Callabonna sub-basin by the Birdsville Track Ridge (Fig. 6). Like the underlying Eromanga Basin, the Lake Eyre Basin consists of a thick sedimentary succession in a north-eastern depocentre and a south-western part where the sediments are significantly thinner and discontinuous (Callen, Alley & Greenwood 1995). In the non-prescribed SAAL NRM Region, the basin is bound to the west by the Flinders Ranges, to the south by the Olary Ranges and to the east by the Barrier Ranges.

Deposition in the Lake Eyre Basin occurred in three phases. In the first phase (latest Palaeocene to the Middle Eocene) deposition included sandstone, carbonaceous clastics and conglomerate of the Eyre Formation and Mount Sarah Sandstone. The second phase may have commenced in the Oligocene and extended through to the Pliocene; sediments deposited include grey, green and white clay fine-grained sand and carbonate with minor conglomerate, of the Etadunna Formation and its correlative Namba Formation. The third phase, during the Pliocene to Quaternary, was characterised by deposition of red and yellow-brown sand and sandy clay and development of gypsum and carbonate palaeosols (Krieg *et al.* 1990). These units are commonly covered by Quaternary sediments.

The Eyre Formation has been identified as comprising a highly transmissive aquifer of approximately 70 m thickness in the Callabonna Sub-basin (URS 2009). Directly east of the northern Flinders Ranges at Beverley, the Namba Formation contains interbedded sands and hosts a confined aquifer (Heathgate 1998).

3.8.3. MURRAY BASIN

The epicratonic Murray Basin, of Palaeocene to Quaternary age, covers an area of 300 000 km^2 in south-eastern South Australia, south-western New South Wales and north-western Victoria (Fig. 6). The basin is described by Rogers *et al.* (1995) and is up to 600 m thick, with the thickest part occurring between Renmark and north-western Victoria. Within the study area, the Tertiary succession rests unconformably on Neoproterozoic to early Palaeozoic basement and can be divided into three sequence sets: Late Palaeocene to Early Oligocene non-marine and marginal marine sediments of the Renmark Group, Late Eocene to Middle Miocene transgressive marine sediments of the Murray Group and Late Miocene to Late Pliocene marine, coastal and non-marine sediments.

There are four aquifer systems within the Murray Basin: the Lower Renmark Group confined aquifer, the Murray Group Limestone aquifer, the Upper Renmark Group aquifer and the Pliocene Sands aquifer (Barnett 1994). The Lower Renmark Group confined sand aquifer occurs at the base of the Tertiary succession over most of the basin and consists of the Olney Formation within the study area. The Murray Group Limestone aquifer, which is the most productive aquifer elsewhere in the Murray Basin, is not present within the study area. The Lower Renmark Group is separated from the overlying Upper Renmark Group aquifer by the glauconitic marl of the Geera Clay confining layer. Within the study area, the Upper Renmark Group is blanketed by the Loxton and Parilla Sands. These two units form the Pliocene Sands aquifer, which is unsaturated within the study area.

3.8.4. BILLA KALINA BASIN

The Billa Kalina Basin is separated from the Lake Eyre Basin to the northeast by the Denison–Willouran divide and Norwest Fault, bounded to the west by high country along an extension of the Stuart Range and the Lake Torrens Basin to the southeast by the Torrens Hinge Zone (Rogers & Zang 2006; Fig. 6).

The Billa Kalina Basin contains a thin, flat-lying succession of early Tertiary to possibly Pliocene age, including the Willalinchina Sandstone, Watchie Sandstone and Mirikata Formation (Callen & Cowley 1995). These sequences commonly overlie the Bulldog Shale and occasionally the Neoproterozoic ABC Range Quartzite and Early Cambrian Andamooka Limestone (Rogers & Zang 2006).

There are no recorded occurrences of groundwater within the Billa Kalina Basin. Geological mapping indicates stratigraphic units of the basin are thin and disconnected, suggesting groundwater resources may be limited to localised aquifer systems.

3.8.5. PALAEOVALLEYS

Throughout much of the early to middle Cainozoic, palaeorivers draining to the south-west from the Musgrave Block, Stuart Range and Gawler Ranges deposited into the Eucla Basin (Lewis *et al.* 2010). In the study area, palaeovalleys are generally found in the Gawler Ranges and east of the Flinders Ranges in the Curnamona Province (Fig. 6). Palaeovalleys have the potential to contain large quantities of groundwater, although often saline. Significant compositional variations can occur over relatively short distances due to depositional and erosional channel processes, resulting in significant differences in the thickness and hydraulic properties of aquifers and confining layers. In some places direct connection between aquifer units occurs. Except where otherwise referenced, information on the hydrogeology of the palaeovalleys within the non-prescribed area of the SAAL NRM Region is taken from Magee (2009).

An extensive network of river channels carried sediments across the Curnamona Province during Palaeogene and Early Neogene times. These palaeovalley deposits host significant uranium mineralisation originally sourced from uranium-rich rocks in the Curnamona Province, forming economic accumulations at several sites including the Beverley and Honeymoon mines.

The Yarramba and Billeroo Palaeovalleys host the Honeymoon, East Kalkaroo and Gould’s Dam uranium prospects. The Yarramba Palaeovalley extends for more than 100 km and is filled with up to 55 m of the Eyre Formation overlain by 60 to 70 m of Tertiary and Quaternary clays and silts with minor sands and gravels (Waterhouse & Beal 1978). The Billeroo Palaeovalley is similar to the Yarramba and extends northwards for at least 80 km, where it joins the Curnamona Palaeovalley. It is up to 10 km wide and occurs at an average depth of 90 m, with about 50 m of valley-fill sediments. The Namba Formation and undifferentiated Quaternary sediments, similar in thickness and composition to the Yarramba Palaeovalley, overlie the Eyre Formation in the Billeroo Palaeovalley.

Recent drilling by Uranium One at its Honeymoon deposit has identified two sand aquifer units, the Upper Sand and Basal Sand of the Eyre Formation, that are separated by a semi-confining clay aquitard. The water quality within the Eyre Formation Sands aquifers at Honeymoon is generally poor, with salinity and sulphate levels exceeding both drinking water and stock watering guidelines.. Uranium and radium-226 levels in the two aquifers are also elevated (Uranium One 2011).

In the Honeymoon–East Kalkaroo area, palaeovalley sands are recharged by a combination of rainfall infiltration in the Olary Ranges, lateral inflow from fractured and weathered basement rocks and throughflow from tributary palaeovalleys. The regional groundwater flow direction is towards the north, in the direction of extensive Eyre Formation sediments in the Callabonna Sub-basin.

The Billeroo Palaeovalley about 70 km north of Honeymoon is similar to the Yarramba Palaeovalley, although the detailed stratigraphic architecture is less constrained. There are three semi-confined sand aquifers separated by significant clayey aquitards.

A number of other, smaller palaeovalleys are found in the area (Fabris 2004). The north-trending Erudina Palaeovalley is 3 to 7 km wide and 140 to 160 m deep and contains 15 to 30 m of Eyre Formation sands. The Stickhole Palaeovalley contains two 10 to 20 m thick reduced sand seams at a depth of 80 to 100 m and down to 150 m. The Curnamona and Wyambana Palaeovalleys have also been identified but specific stratigraphic information is not available.

Heathgate’s Beverley Uranium deposit is located further north of the Honeymoon deposit, around 30 km north-east of Arkaroola, in a north–south trending palaeovalley (the Beverley aquifer). The deposit occurs in the Tertiary age Namba Formation sediments that overlie Cretaceous sediments of the GAB. The GAB aquifer is separated from the base of the Beverley aquifer by at least 100 m of dense plastic clay (Alpha Mudstone) that is underlain by a thin sequence of Bulldog Shale (Howles 2000).

Found in the north-west of the study area, the Kingoonya Palaeovalley is defined on the surface by a chain of playa lakes that overlie channel-fill deposits and fluvio-lacustrine sediments of Tertiary age (AACWMB 2006a). The deposits are around 25 m thick and are overlain by about 5 to 10 m-thick playa lake deposits of halite, gypsum, clays and silts (AACWMB 2006a). The Kingoonya Palaeovalley has a large tributary network that develops into a complex mouth near the western margin of the Tarcoola 1:250 000 map sheet. Smaller distributary palaeovalleys, Wynbring and Tolmer, are found in the lower reaches. Within the Kingoonya Palaeovalley and its tributaries, sediments consist primarily of Pidinga Formation overlain by the Kingoonya Member of the Garford Formation (Hou *et al.* 2003).

The Garford Palaeovalley occurs in the north-western Gawler Craton and trends east to west linking with the Tallaringa Palaeovalley near its mouth at the boundary of the SAAL NRM Region. The Garford Palaeovalley has an extensive tributary network with the Anthony Palaeovalley extending into the SAAL NRM Region at its south-western extent. Further to the south, a small proportion of the Narlaby Palaeovalley extends into the SAAL NRM Region.

In the west of the study area, the extent of the Garford Palaeovalley is reasonably well known and drilling has indicated a 10 to 15 m thick sand aquifer. The Tallaringa Palaeovalley on the north-western margin of the Gawler Craton contains a considerable thickness of sand containing water. Similar palaeovalleys occur to the southwest of Tarcoola and south of the Gawler Range Volcanics (Martin, Sereda & Clarke 1998).

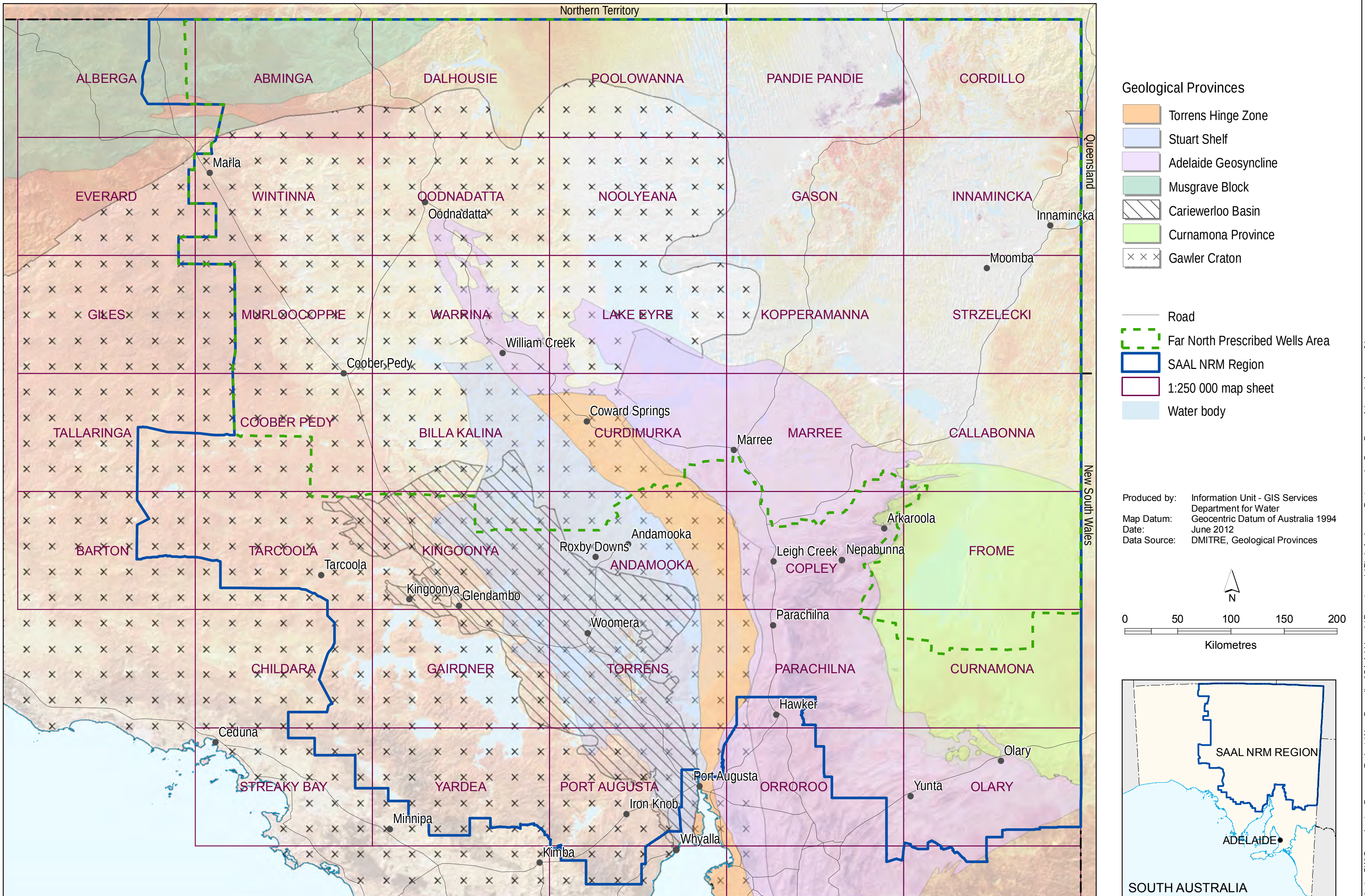


Figure 4. Archaean to Proterozoic-aged geological provinces of the SAAL NRM Region

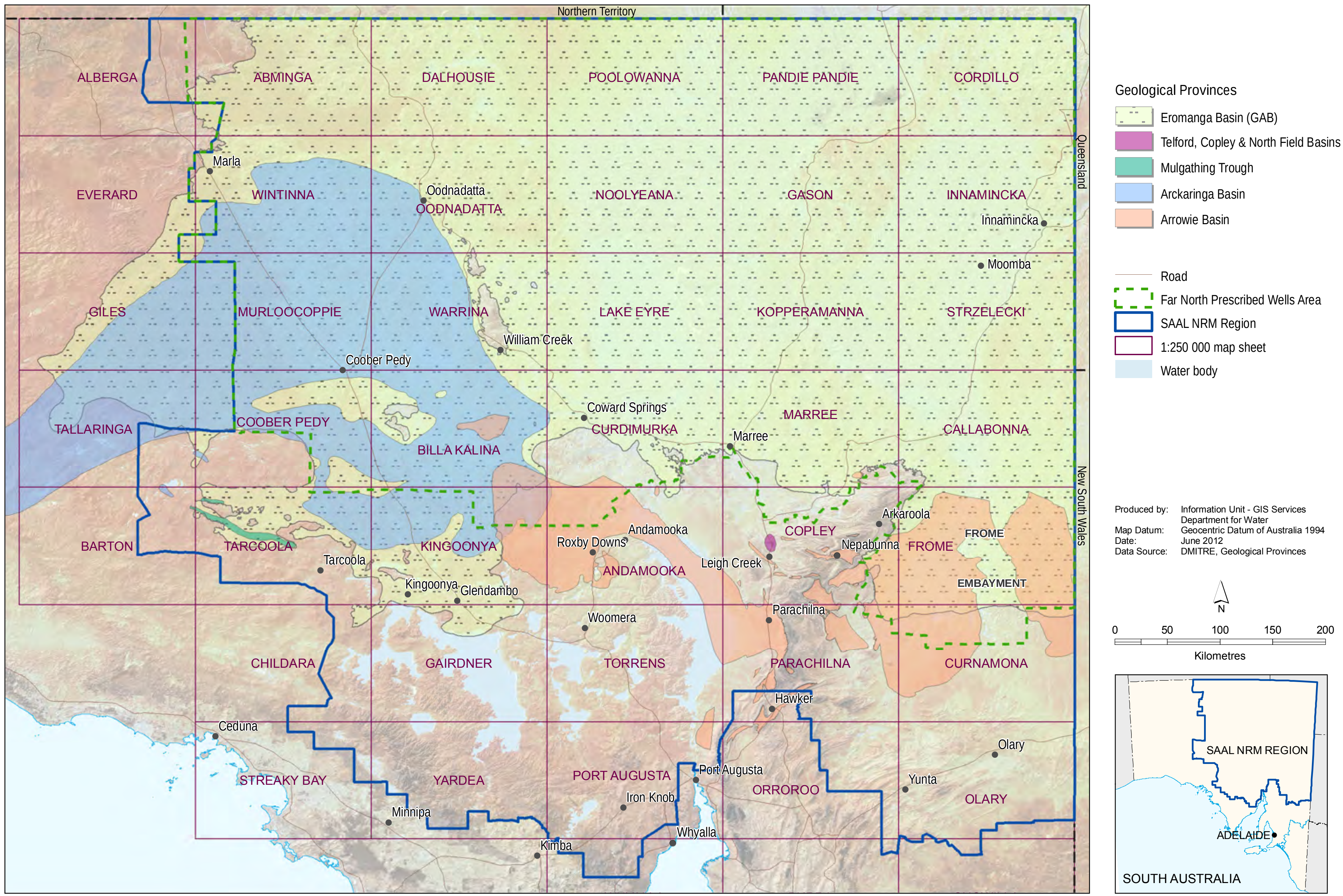


Figure 5. Palaeozoic and Mesozoic-aged geological provinces of the SAAL NRM Region

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Figure6. Cainozoic-aged geological basins of the SAAL NRM Region

4. GROUNDWATER DATA

4.1. DATA

Data used in the production of this report have been sourced principally from the South Australian hydrogeological geodatabase (SA Geodata), which is administered by the Department for Water (DFW) and DMITRE. Whilst every effort is made to present information from the database as accurately as possible, there will be limitations on data accuracy in relation to data being up-to-date, validated or complete. Other sources of information accessed in support of these assessments include available literature and publicly available state and national geoservers – namely, DMITRE's South Australian Resources Information Geoserver (*SARIG*) and Geoscience Australia's (GA) geoserver.

Recent water level and salinity data are available for current active groundwater observation networks. These data can be accessed via the groundwater information database on the DFW's *WaterConnect* website. In areas that are not currently monitored, it is common to find that only a few groundwater parameters (e.g. salinity and water level) have been sporadically recorded since 1999. Table 3 highlights the low availability of recent (2000–11) groundwater data, which represents only 10% and 12% of the 'latest' salinity and water level observations respectively. A large proportion of the data for both parameters predates 1980. Most wells have only a single water salinity and/or level observation collected at the time of drilling.

Table 3. Groundwater data summary showing the periods over which water quality and water level data have been collected

Period of record	Total Dissolved Solids		Standing Water Level		Yield	
	Drillholes	%	Drillholes	%	Drillholes	%
pre–1960	708	18	511	13	610	20
1960–79	1773	46	1557	40	914	30
1980–99	908	24	1222	32	934	31
2000–11	387	10	471	12	451	15
No date recorded	88	2	125	3	120	4
Total	**3865**	**100**	**3832**	**100**	**3030**	**100**

Intuitively, exploration for new groundwater resources that are suitable for domestic and stock purposes is focused in regions where salinity is known to be low. For this reason, drillhole data are likely to be clustered around these areas. Information regarding relatively saline groundwater is likely to be sparse, as demand for this resource has traditionally been low.

Although there can be a great number of wells for which water quality data exists, a common constraint is the lack of associated well construction and production zone details. This limits the ability to assign groundwater observations to a specific hydrogeological formation. Of the nearly 52 000 drillholes in the non-prescribed region of the SAAL NRM Region, around 14 000 wells have stratigraphic information and about 6600 are classed as water wells. Of these water wells, around 470 have stratigraphic information, but only about 260 have an 'aquifer monitored' assigned – i.e. identification of which aquifer(s) the well is screened within for the purpose of groundwater abstraction or monitoring. To build on this very limited knowledge, a desktop assessment identified wells that have both stratigraphic information and production zone information. For the study area, this assessment identified 50 water wells that may have suitable information to identify or infer the aquifer that is monitored, aiding in the ability to provide discussion around groundwater resources.

4.1.1. MONITORING

Limited groundwater monitoring has occurred in the SAAL NRM Region as historically, there has been no large development within the area. Historical establisment of monitoring networks have been focussed in other regions of the state regarded as higher priorities at the time.

There are five 'current' State observation wells within the non-prescribed area of the SAAL NRM Region. These wells are monitored for standing water level (SWL) and are part of larger State monitoring networks. Three are part of the Murray Basin Northern Region monitoring network and two, at the township of Nepabunna, are part of the Aboriginal Communities monitoring network (Table 4; Fig. 1).

At Nepabunna, a third well was drilled in 2009 to augment the exsiting two water supply wells. All three wells are telemetered and monitored with data loggers for yield, flow, accumulated flow and water level. The data are downloaded and the water levels measured manually every six months by DFW. The original two wells at Nepabunna have been monitored since 2000. Periodic monitoring has also occurred at the townships of Glendambo and Tarcoola, but these wells are not monitored as part of a specific observation network.

Table 4. Monitoring networks within the SAAL NRM Region

Network	Current Sites		Monitoring Frequency		Formations Monitored
	SWL	Salinity	SWL	Salinity	
GAB	41	0	continuous to six monthly	-	Cadna-owie Formation and Algebuckina Sandstone
Marla	6	0	six monthly	-	Cadna-owie Formation and Algebuckina Sandstone
Nepabunna	2	0	six monthly	-	Wilkawillina Limestone
Murray Basin – Northern Region	3*	0	yearly	-	Pliocene Sands, Geera Clay and Upper Renmark Group

*Only a subset of the total 40 observation wells within the Murray Basin – Northern Region monitoring network

4.1.2. REGIONAL GROUNDWATER SALINITY

Across the non-prescribed portion of the SAAL NRM Region, groundwater salinity observation records exist for 3865 drillholes (Table 3). Only 10% of these wells have salinity observations recorded within the past 11 years. Just over 700 wells (18%) have salinity observations recorded prior to 1960 and a total of 1773 wells, or just under half (46%), have salinity observations recorded prior to 1980.

Salinity data density appears fairly uniform except for areas in and around ephemeral salt pan water bodies, where a paucity of salinity data is likely due to high salinity of groundwater within the underlying aquifers. Groundwater salinity is generally very high, with the exception of in and around the Flinders Ranges where groundwater salinities are typically less than 1500 mg/L (Fig. 7).

Other occurrences of low-salinity groundwater appears limited to fractured rock environments and along creek lines. These low salinity records are likely to reflect recharge from rainfall occurring either directly to outcrop or subcrop of hard rock material, or indirectly via stream bed recharge.

4.1.3. REGIONAL WATER LEVELS

There are 3832 wells within the SAAL NRM Region with records detailing the depth to groundwater. While 471 water wells (12%) have standing water level recorded within the past 11 years, over 2000 wells (53%) have standing water level observations recorded prior to 1980.

The spatial density and areal distribution of standing water level data (Fig. 8) closely matches that of salinity data as numerous parameters are commonly recorded at the time of measurement (often at the time of drilling). Across the non-prescribed area, groundwater is most commonly encountered between 20 and 50 m below ground surface (34%), followed closely by 10 to 20 m (27%). Wells showing shallow depths to groundwater (<10 m) are found throughout the area but are most commonly found in and around the Flinders and Olary Ranges. Wells recording large depths to groundwater (50 m or more) are common north and south of the Olary Ranges, immediately north of Roxby Downs near the Olympic Dam mine and along the Far North PWA border north of Kingoonya.

4.1.4. REGIONAL WELL YIELDS

Records for well yield are available for 3030 wells. Typically, well yields are recorded at the time of drilling. Consequently, well yield data from 1524 of 3030 water wells (50%) have been recorded prior to 1980, while only 451 wells (15%) have well yield recorded within the past eleven years.

Across the region, well yields are predominantly less than 1 L/s (Fig. 9) and the reported purpose relating to groundwater use is variable. Groundwater is the principal source of water for the numerous mine sites throughout the study area as well as for town water supply. Higher-yielding wells are reported at these locations where the demand requires appropriately specified, designed and constructed well infrastructure. Beyond these areas, groundwater is used mainly for watering livestock via windmill-operated wells and the full supply potential of the aquifers is not likely to have been tested.

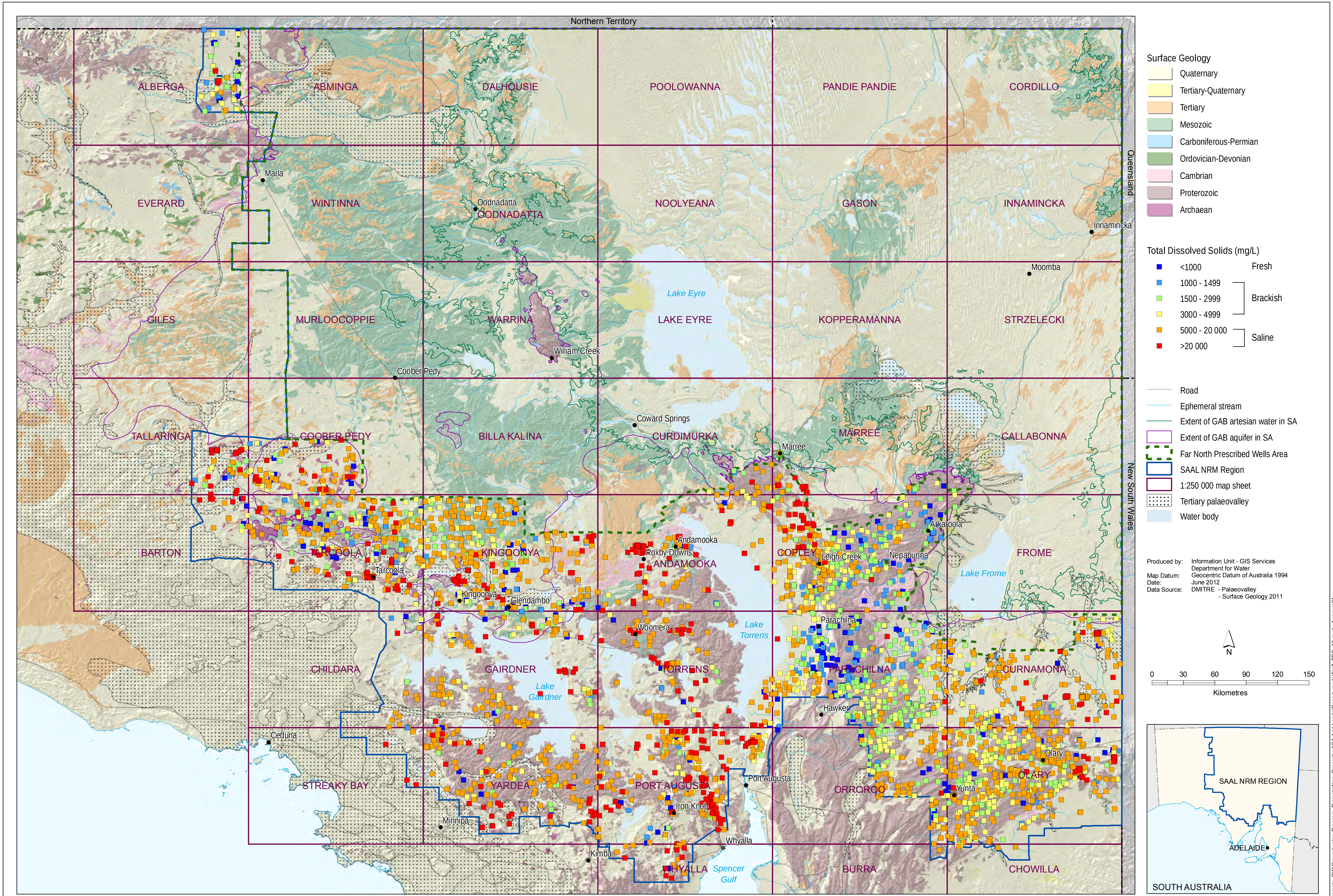

Figure 7. Regional distribution of groundwater salinity in the non-prescribed areas of the SAAL NRM Region

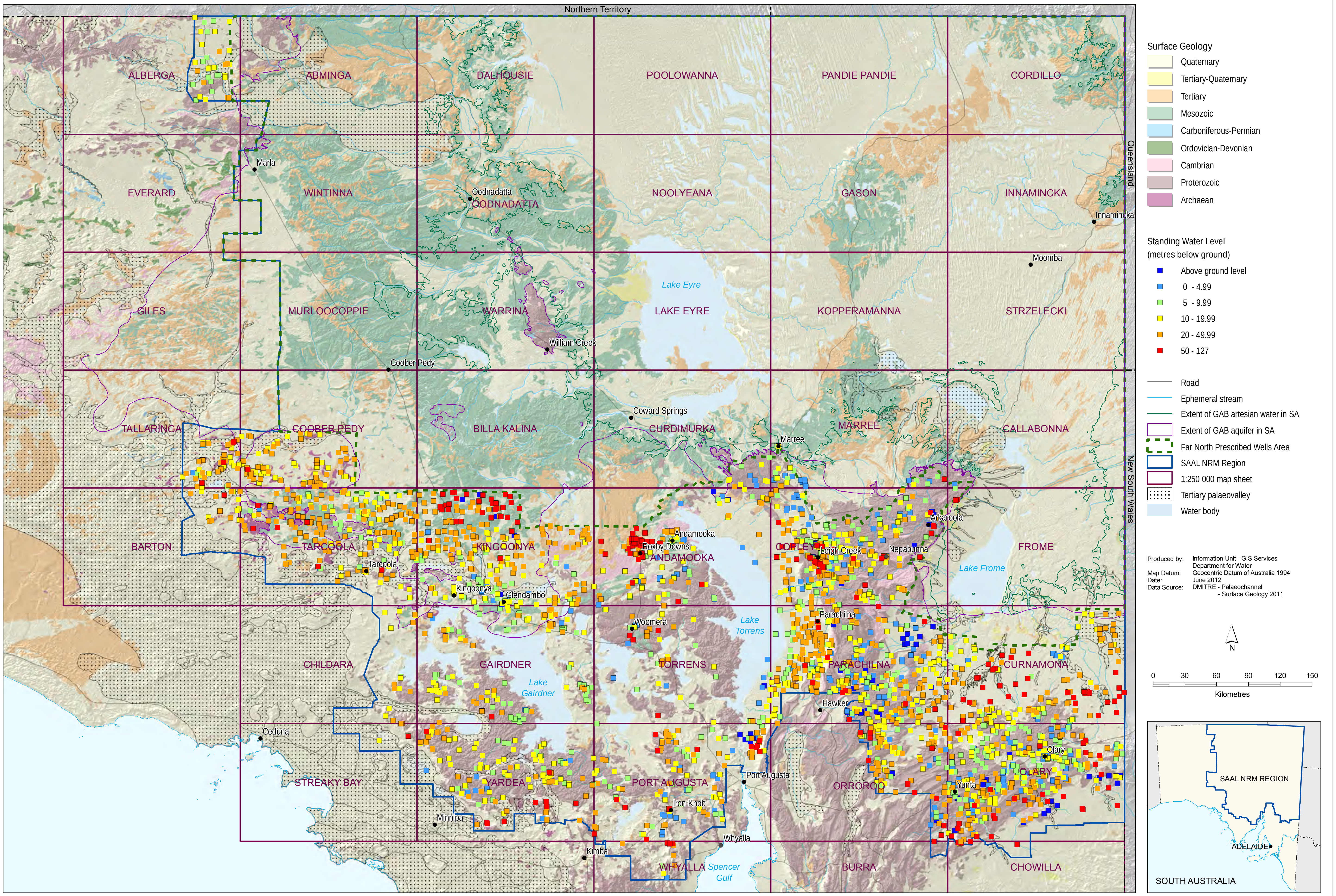

Figure 8. Regional distribution of groundwater standing water levels in the non-prescribed areas of the SAAL NRM Region

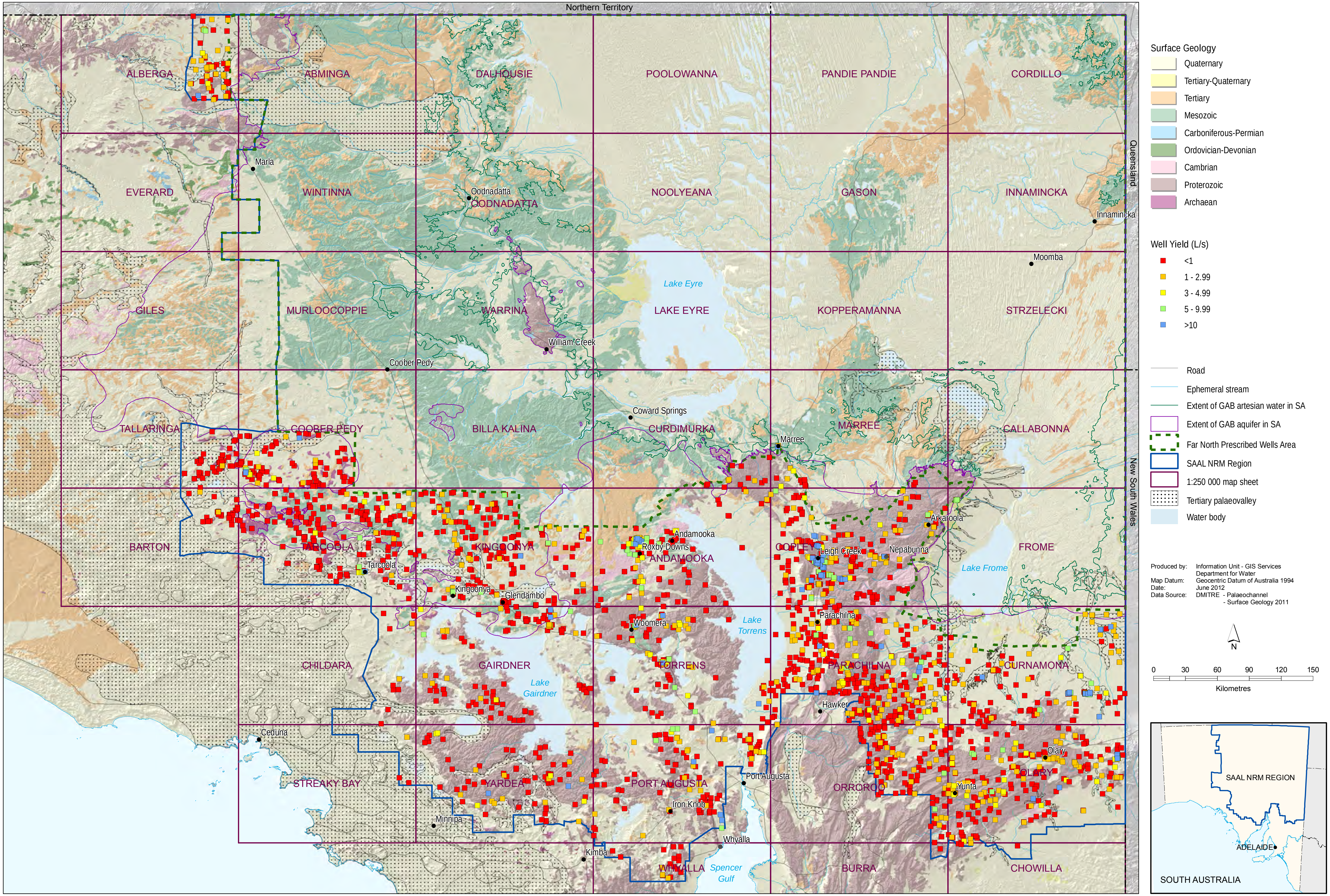

Figure 9. Regional distribution of groundwater well yields in the non-prescribed areas of the SAAL NRM Region

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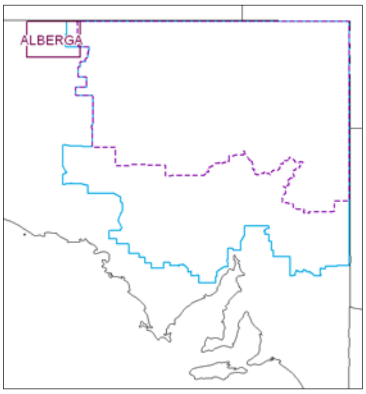
4.2. 1:250 000 MAP SHEET DATA

This report has compiled groundwater data available from within the SA Geodata database for the non-prescribed wells area of the SAAL NRM Region. Information on groundwater salinity, standing water level, yields and data age are tabulated by 1:250 000 map sheets and where applicable, information on associated water cuts and maximum well depth are included.

Stratigraphic information sourced from SA Geodata is also included in the data summaries to give a general representation of the location and thickness of potential aquifer units. The median thickness of a stratigraphic unit is calculated using only samples inferred to be fully-penetrating, that is, when the entire thickness of a unit is intercepted.

For consistency, the reference to map sheet areas will follow a uniform naming convention. For example, the ALBERGA 1:250 000 map sheet area will be referred to in this report as ALBERGA.

4.2.1. ALBERGA



Only a small section of ALBERGA is included in the SAAL NRM Region. Tributaries of the large Hamilton Basin Palaeovalley cross the southern half of the map sheet, either side of De Rose Hill (Fig. 6). Land is used for grazing of the natural vegetation and the De Rose Hill pastoral station is subject to native title (Fig. 2).

Surface Geology

The surface geology of the north-east portion of ALBERGA within the study area is dominated by red sand of Pleistocene age, the Delisser Formation. A sizeable outcrop of the Wataru Gneiss of the Birksgate Complex occurs in the south in the form of De Rose Hill (Fig. 3).

Stratigraphy

Stratigraphic data are sparse for ALBERGA. Within the small section contained within the SAAL NRM Region, there are numerous wells located in the north-west and several in the south-east. Mesoproterozoic rocks of the Musgrave Block are predominantly Birksgate Complex, with occurrences of the Pitjantjatjara Supersuite and dykes of Gairdner Dolerite. The depth to these basement rocks is quite shallow (1–9 m), with a median of 3 m. The Quaternary sands of the Delisser and Wintrena Formations of the Great Victoria Desert cover the basement rocks.

Groundwater Data

The shallowest water cut depth is 6 m, which suggests that most groundwater wells are intercepting basement rocks. Over the period of record from 1974–2004, groundwater salinity has varied greatly (520–89 000 mg/L), although the median and the most recent (2003–04) salinity observations are less than 2000 mg/L (1959 mg/L and 1322–1973 mg/L, respectively). True to the complex and variable nature of fractured rock environments, there is no correlation to be found between salinity and the water cut depth (Table 5). A number of the highly saline records are located within the mapped extent of the Hamilton Basin Palaeovalley (Fig. 7). No other spatial pattern is apparent.

Standing water levels are between 6 and 32 m below the surface with a median of 11 m (Fig. 8). Water cut depths have been reported between 6 and 78 m. Twelve wells have both water cut and SWL records; all bar one well have a water cut depth greater than the SWL, a common observation in fractured rock environments. Yields are generally low (0.006–10 L/s, median 0.81 L/s) with 92% of the

80 wells with yield data supplying groundwater at less than 3 L/s; just over half return yields of less than 1 L/s (Table 5; Fig. 9).

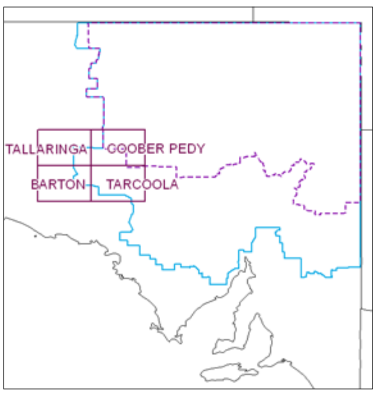
Table 5. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for ALBERGA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(64)	19 (12)	15 (10)	25 (16)	20 (13)	11 (7)	2 (1)	8 (5)
SWL (m)	(34)	15 (2)	10 (9)	9 (15)	9 (6)	11.3 (2)	-	-
Water cut (m)	(37)	15 (9)	12.8 (5)	16 (5)	15 (5)	22 (7)	18 (1)	7 (5)
Yield (L/s)	(54)	0.93 (11)	1.27 (8)	0.9 (10)	0.87 (12)	0.6 (7)	0.75 (1)	1.2 (5)
Max well depth (m)	(63)	49 (12)	20.8 (10)	22 (16)	23.3 (12)	34.3 (7)	103 (1)	39 (5)
Year of observation		1982	1980	1980	1980	1984	1984	1984

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(50)	-	44 (22)	38 (19)	12 (6)	6 (3)	-	-
Water cut (m)	(14)	-	11.3 (3)	25 (10)	64 (1)	-	-	-
Max well depth (m)	(50)	-	16.4 (22)	25 (19)	34.8 (6)	46.7 (3)	-	-
Year of observation		-	1980	1980	1980	1980	-	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(80)	56 (45)	36 (29)	4 (3)	3 (2)	1 (1)
Water cut (m)	(47)	22 (25)	13.5 (17)	10 (3)	9 (1)	15 (1)
Max well depth (m)	(79)	37.5 (44)	32 (29)	62 (3)	36.7 (2)	26 (1)
Year of observation		1980	1980	1984	1961	2003

4.2.2. TARCOOLA, COOBER PEDY, TALLARINGA AND BARTON



The TARCOOLA summary includes sections of COOBER PEDY, TALLARINGA and BARTON that are within the non-prescribed area of the SAAL NRM Region. The Garford Palaeovalley falls mostly within the non-prescribed portion of COOBER PEDY with an east–west orientation (Fig. 6). The Kingoonya Palaeovalley runs across the bottom half of TARCOOLA and the Anthony Palaeovalley straddles the TALLARINGA–BARTON border, converging with the Garford Palaeovalley (Fig. 6). The Challenger gold mine is located in the south-west corner of COOBER PEDY with the remaining land use classified as grazing of natural vegetation (Fig. 2). Lake Anthony and Half Moon Lake are located in the south-eastern corner of TALLARINGA and there some small water bodies east of Tarcoola (Fig. 1).

Surface Geology

Rocks of the Gawler Craton, namely the Mulgathing Complex, but also including the Hiltaba Suite, crop out over all sections of the four map sheets within the study area (Fig. 3). The Algebuckina Sandstone crops out over the northern half of TARCOOLA while the Bulldog Shale is present in the north-east of the same map. Possible Ilkina Formation equivalents are scattered throughout the area. Undifferentiated Quaternary aeolian sediments surround outcrops of older material.

Stratigraphy

A varied and complex stratigraphy occurs on TARCOOLA. The Gawler Craton forms the basement of all four map sheets (Fig. 4) and consists predominantly of the Mulgathing Complex. Other units include the Hiltaba, Tunkillia and Muckanippie Suites, Tarcoola Formation, Mount Woods Complex and Gawler Range Volcanics. Excluding outcrop, depths to basement range up to 380 m with a median of 7 m.

The Cariewerloo Basin is found in the north-east of TARCOOLA (Fig. 4) at depths of 38 to 331 m below the surface (median of 62 m). It contains sediments of the Pandurra Formation, through which three wells have fully penetrated and recorded thicknesses of 14, 49 and 71 m.

The Arckaringa Basin contains the Boorthanna, Stuart Range and Mount Toondina Formations. It is found in north-eastern TARCOOLA and TALLARINGA and COOBER PEDY along the border of the SAAL NRM Region and the Far North PWA throughout TARCOOLA (Fig. 5). Other occurrences are found within the Mulgathing Trough that stretches from north-western to central TARCOOLA (Fig. 5). The depth to the Boorthanna Formation is between 1.5 and 210 m with a median of 34 m. Its thickness ranges from 2 to 225 m with a median of 31 m. The top of the Stuart Range Formation confining layer is up to 96 m below the surface, with a median depth of 38 m. Thickness ranges from 1.5 to 410 m with a median of 32 m. Where present, the Mount Toondina Formation starts from 20 m to 52 m below ground with a median depth of 51 m. It is between 6 and 45 m thick with a median thickness of 15 m.

The Eromanga Basin is found extensively throughout TARCOOLA and COOBER PEDY and is also present in the south-eastern corner of TALLARINGA that is included in the study area (Fig. 5). The Cadna-owie Formation and Algebuckina Sandstone are encountered in outcrop. Excluding outcrop, depth to the units is up to 113 m with a median of 4 m. They have a combined thickness of between 2 and 114 m with a median thickness of 18 m. The Bulldog Shale has been intercepted in 14 wells, primarily in the north-east of TARCOOLA, from up to 11.5 m below the surface and has a thickness of between 2 and 61 m (median of 12 m).

The Hampton Sandstone and Pidinga and Garford Formations and are found within the palaeovalleys incised into the basement rocks (Fig. 6). The Pidinga Formation crops out in the Anthony Palaeovalley in the south-east of TALLARINGA and north-east of BARTON and the Garford Formation crops out in the Ealbara Palaeovalley in the south-west of TARCOOLA. Aside from small areas of outcrop, the depth to these sequences is up to 72 m with a median of 4 m. Where present, the Garford Formation overlies the Pidinga Formation. The Garford Formation has a thickness of up to 63 m with a median of 8 m. The Pidinga Formation has a thickness of between 2 and 88 m with a median of 28 m. One well recorded an 81 m thick sequence of Hampton Sandstone and another recorded 20 m of Munjena Formation. Undifferentiated Tertiary sediments crop out throughout the four map sheets; elsewhere they have a maximum depth of 28 m with a median of 2 m. Thickness of the unnamed Tertiary sequences is up to 155 m with a median of 7 m.

Quaternary sediments have not been differentiated in stratigraphic logs but are likely to consist of the Wintrena and Delisser Formations and other unnamed units. Their thickness ranges from 0.2 to 46 m with a median of just 2 m.

Groundwater Data

There are six mostly shallow wells (3.6–39 m) in central TARCOOLA that have a recorded salinity of less than 200 mg/L (in 1977) and if reliable, would indicate localised rainfall recharge. Elsewhere, salinity is mostly brackish (median value of 5768 mg/L) but extremely variable, ranging from 214 to 205 000 mg/L. Low and high-salinity groundwater is found throughout the area (Fig. 7). Highly-saline groundwater is commonly found within the mapped extent of the palaeovalleys (Fig. 7) although no production zone data are available. Occasional instances of low-salinity groundwater are also correlated within the mapped extent of the palaeovalleys (Fig. 7).

Depth to groundwater is between 0.5 and 94 m below the surface with a median of 21 m (Fig. 8). Two hundred and thirty-eight wells from a total of 307 have a SWL at a higher elevation than the water cut depth, indicating confined conditions. These are found throughout all areas of the four map sheets within the study area.

Well yields are typically very low with a median of 0.25 L/s and 90% of wells returning a yield of less than 1 L/s (Table 6, Fig. 9). Three wells within one metre of each other recorded yields of 10, 12.5 and 13 L/s in 2001. They are found in the south-west corner of COOBER PEDY. Two of the wells have a maximum depth greater than 200 m recorded, but no stratigraphic or production zone details are available for the three wells. Nearby stratigraphic logs indicate either 50 m deep, low-yielding drillholes within fractured rock (overlain by Quaternary regolith material), or deeper drillholes that intersect Tertiary units between 96 and 255 m depth. This may suggest the higher-yielding wells are accessing the Tertiary sediments, which at such great depths are thought to be within a palaeovalley. These wells are not located within a mapped extent of any palaeovalley, which may indicate the nearby palaeovalleys may extend further than currently known, or the presence of an unmapped palaeovalley.

A well located in south-western central COOBER PEDY has a recorded yield of 14.5 L/s and a depth of 32 m. No production zone or stratigraphic data are available, but a cluster of nearby wells intercepts basement rock from a depth of about 5 m, suggesting the well to be within a fractured rock aquifer.

Moderately high yields of mostly between 3 and 5 L/s (but up to 11.5 L/s) have been reported in the south-east corner of TARCOOLA near the old gold-mining town of Tarcoola. These wells do not have production zone or stratigraphic data, but nearby information indicates the wells are likely to be accessing basement rocks that also crop out in the area. One well north-west of Tarcoola located within the mapped extent of the Kingoonya Palaeovalley has a well yield of 5 L/s. Production zone details are not available, but the stratigraphic log indicates Tertiary sediments from 9 to 37 m (EOH).

On TARCOOLA and the included sections of COOBER PEDY, TALLARINA and BARTON, there are 57 wells that have an aquifer unit assigned to them. There are also a few wells that have groundwater quality data as well as associated production zone and stratigraphic data so the aquifer unit can be correlated to groundwater information. Wells are identified to be open to the Mulgathing Complex or undifferentiated basement rocks of the Gawler Craton have salinities ranging from 2500 to 62 500 mg/L, with a median of 11 200 mg/L. The SWL is between 5 and 37 m and yields are between 0.0008 and 2 L/s. Four wells identified as open to Permian aquifer units record salinities of between 720 and 8100 mg/L, a SWL of 19 m and yields of 0.5 to 0.9 L/s. Wells open to the non-artesian Eromanga Basin units recorded salinities of 500 to 28 000 mg/L, SWLs of between 9 and 33 m and yields of 0.001 and 6.7 L/s.

Five wells are known to be open to Tertiary units. One is screened in the Pidinga Formation at a depth of 9 m with a salinity of 38 626 mg/L and a yield of 7.6 L/s. An undifferentiated Tertiary unit at a depth of 10 m has a salinity of 1160 mg/L and a yield of 0.27 L/s. Another well has a yield of 2.2 L/s and water cut depth of 183 m but no other data. The remaining two wells have standing water levels of nearly 30 m but no other data.

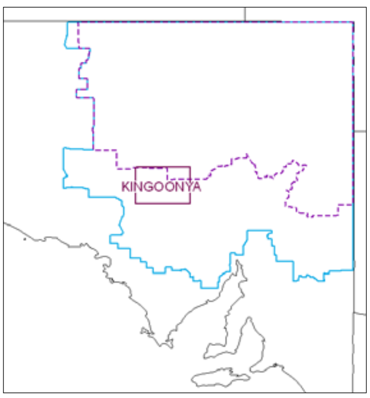
Table 6. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for TARCOOLA and the included sections of COOBER PEDY, TALLARINGA and BARTON

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(519)	13 (67)	5 (28)	12 (62)	15 (76)	23 (117)	16 (85)	16 (84)
SWL (m)	(393)	20 (61)	22.3 (23)	21 (58)	22.1 (61)	24.1 (92)	24.2 (58)	16.6 (40)
Water cut (m)	(304)	26.1 (40)	27.4 (15)	28 (34)	27.4 (39)	28 (70)	28 (59)	36 (47)
Yield (L/s)	(340)	0.17 (48)	0.27 (23)	0.23 (51)	0.3 (58)	0.38 (84)	0.26 (45)	2.55 (31)
Max well depth (m)	(508)	31.7 (65)	36.6 (27)	34.4 (61)	38.3 (74)	35 (113)	36.1 (85)	54 (83)
Year of observation		1977	1977	1977	1977	1977	1959	1979

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(565)	3 (14)	10 (56)	31 (177)	32 (181)	21 (123)	3 (14)	-
Water cut (m)	(310)	18 (3)	13.1 (15)	19 (105)	26.8 (97)	36.9 (81)	65.5 (9)	-
Max well depth (m)	(552)	7.2 (14)	11.4 (56)	29 (172)	35 (174)	42 (122)	70.7 (14)	-
Year of observation		1983	1997	1977	1977	1977	1978	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(536)	91 (485)	5 (29)	2 (9)	1 (6)	1 (7)
Water cut (m)	(408)	28 (374)	27.2 (16)	66 (8)	23.2 (6)	40 (4)
Max well depth (m)	(528)	38.1 (478)	43.9 (29)	97.5 (9)	70.3 (6)	81 (6)
Year of observation		1961	1982	1997	1976	2001

4.2.3. KINGOONYA



The townships of Glendambo and Kingoonya are found in the south and south-west of KINGOONYA (Fig. 1). The Kingoonya Palaeovalley runs east–west across southern KINGOONYA with a number of small lakes at the surface (Fig. 6).

Surface Geology

Basement rocks of the Gawler Craton, including but not limited to the Mulgathing Complex, Hiltaba Suite and Gawler Range Volcanics, appear as scattered outcrop in the south-west corner of KINGOONYA. The Wilpena Group of the Stuart Shelf crops out in the south-east corner of the map sheet. Undifferentiated rocks from the Moralana Supergroup of the Arrowie Basin are found in outcrop in eastern KINGOONYA. Small outcrops of Arckaringa Basin rocks are scattered across the north-east corner of the map sheet. The Bulldog Shale of the Eromanga Basin crops out in the south-east of KINGOONYA and extensively in the north and north-west and the Algebuckina Sandstone crops out in southern and south-western KINGOONYA (Fig. 3). Tertiary and Quaternary sediments are found at the surface throughout KINGOONYA, particularly the southern and eastern halves. Quaternary lacustrine playa sediments and gypsiferous lunettes form most of KINGOONYA's lake beds and are found along the mapped extent of the Kingoonya Palaeovalley. Elsewhere, Quaternary sediments are found at the surface over most of the map sheet; alluvial/fluvial sediments in the west and north and aeolian sediments in the east and south of KINGOONYA.

Stratigraphy

The Gawler Craton forms the basement of KINGOONYA (Fig. 4). The Gawler Range Volcanics dominate with smaller occurrences of the Mulgathing and Mount Woods Complexes, Hiltaba Suite and the Eba, Tarcoola and Labyrinth Formations also present (Appendix Table B2). Excluding outcrop, depth to the craton is up to 98 m with a median of 18 m. Despite the Cariewerloo Basin overlying the Gawler Craton over much of KINGOONYA (Fig. 4), only 34 wells have intercepted the Pandurra Formation. Three of these wells have fully penetrated the formation with thicknesses of 6, 46 and 257 m. The depth to the top of the basin ranges from 6 to 294 m with a median of 35 m.

Overlying the Cariewerloo Basin in the north and over the eastern third of KINGOONYA is the Stuart Shelf (Fig. 4). Consisting of the Seacliff Sandstone, Nuccaleena and Tent Hill Formations and Yarloo Shale, the shelf has a thickness ranging from 7 to 252 m with a median of 26 m. The top of the shelf sits from as little as one metre below the surface in the south-east of KINGOONYA, to up to 140 m in the north. The Arrowie Basin overlies the Stuart Shelf in the east and north-east of KINGOONYA (Fig. 5). The top of the basin's Andamooka Limestone has been encountered at depths of 1 to 50 m with a median of 12 m and has a thickness of between 4 to 80 m with a median of 15 m.

The Arckaringa Basin overlies the Cariewerloo Basin, Stuart Shelf and Arrowie Basin across the northern half of KINGOONYA (Fig. 5). The depth to the Boorthanna Formation is between 1 to 140 m with a median of 51 m. It has a thickness of between 2 and 110 m with a median of 24 m. The overlying Stuart Range Formation that acts as an aquitard has a thickness of between 1 and 81 m with a median of 24 m. The Mount Toondina Formation has not been positively identified on KINGOONYA.

Absent only along the eastern third of KINGOONYA, the sequences of the Eromanga Basin are widespread and are commonly found in outcrop (Figs. 3 & 5). Excluding outcrop, the maximum recorded depth to the Bulldog Shale is 12 m with a median of just 2 m. Here at the basin margins, the Bulldog Shale has a thickness of between 1 and 65 m with a median of 16 m. It overlies the combined aquifer of the Cadna-owie Formation and Algebuckina Sandstone, although it is absent in areas where the Algebuckina Sandstone is found in outcrop. Excluding outcrop, the depth to the two units is up to 45 m with a median of 7 m. The Cadna-owie Formation overlies the Algebuckina Sandstone but it is often absent. The aquifer has a combined thickness of 2 to 49 m with a median of 27 m.

The Billa Kalina Basin is found in north-eastern and eastern KINGOONYA and to a lesser extent the south-east (Fig. 6). The basin sequences, predominantly the Mirikata Formation but also the Watchie Sandstone, are found in outcrop; away from outcrop, the maximum depth to the basin units is 8 m with a median of 3 m. They have a thickness of up to 20 m with a median of 7 m. The Kingoonya Palaeovalley contains the Pidinga and Garford Formations, although these units have not been differentiated in stratigraphic logs. Other Tertiary and undifferentiated Tertiary–Quaternary sediments are found throughout KINGOONYA and range in thickness from 1 metre to 94 m with a median of 7 m. Quaternary sediments are also undifferentiated and have a maximum thickness of 39 m but a median of 3 m.

Groundwater Data

Groundwater salinity is highly variable, ranging from just 170 mg/L to 168 000 mg/L, but is generally brackish with a median of 6200 mg/L. Nineteen wells with salinities of over 100 000 mg/L are found within the south-west corner of KINGOONYA, all bar two are within the mapped extent of the Kingoonya

Palaeovalley. Pockets of low-salinity groundwater are found throughout the map sheet, particularly through the centre and along the southern border (Fig. 7).

In central KINGOONYA, fifteen wells recorded a salinity of less than 1500 mg/L and eleven between 1500 and 3000 mg/L. No production zone data are available for these wells but some have stratigraphic logs as do other wells nearby. These logs suggest the Cadna-owie Formation and Algebuckina Sandstone as the likely aquifer being accessed.

Across KINGOONYA, the maximum depth to groundwater is 88 m below the surface with a median of 22 m. All bar two of the 38 wells with a depth to water greater than 50 m are found in the north/north-west of KINGOONYA (Fig. 8). The majority of wells with shallow depths to water (within 10 m of the surface) are concentrated in the south but there are others throughout the map sheet (Fig. 8).

Well yields are typically very low with a median of 0.4 L/s and 84% less than 1 L/s (Table 7). A yield of 15 L/s was reported in 2008 for a new supply well in central KINGOONYA. There are no production zone or stratigraphic data available but the previous supply well nearby was screened in the Arckaringa Basin at a similar depth. Generally, based on nearby stratigraphic information, wells with reasonable yields in southern KINGOONYA are likely to be within palaeovalley deposits, largely being mapped within the extents of the Kingoonya Palaeovalley (Fig. 9). Wells with yields between 5 and 10 L/s are also found in the south-west, north and north-east but there is not enough data to make any correlations between possible stratigraphic units.

On KINGOONYA there are only a small number of wells that have groundwater quality data as well as associated production zone and stratigraphic data. However, there are 52 wells with an aquifer unit assigned to them. Three wells are identified to be open to the Andamooka Limestone of the Arrowie Basin. The salinity values are 1278, 6341 and 17 136 mg/L and standing water levels are 29, 22 and 32 m respectively. The two lower-salinity wells had a yield of 1.3 and 0.9 L/s with all data recorded prior to 1978.

Four wells are identified to be screened in the Boorthanna Formation of the Arckaringa Basin. Salinity is between 3300 and 8710 mg/L, SWL between 30 and 50 m below the surface and yields are from 0.3 to 1.5 L/s.

Forty-eight wells are indicated to be open to the Algebuckina Sandstone of the Eromanga Basin. Salinity is highly variable, ranging between 240 and 22 000 mg/L. Yields are between 0.5 and 1 L/s and SWL is between 32 and 45 m.

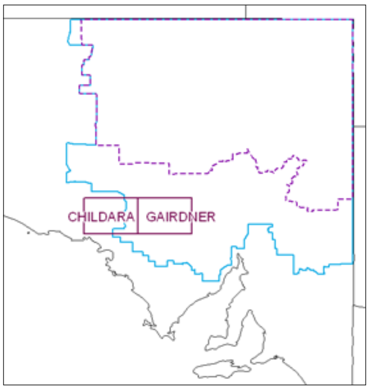
Table 7. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for KINGOONYA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(387)	8 (33)	7 (26)	12 (46)	15 (58)	33 (129)	15 (58)	10 (37)
SWL (m)	(282)	12.2 (28)	14.7 (24)	17.2 (38)	24.5 (48)	34.2 (95)	22.6 (33)	12.2 (16)
Water cut (m)	(99)	16.8 (4)	22.1 (6)	24.4 (14)	37.3 (14)	48 (40)	46.8 (12)	15.9 (9)
Yield (L/s)	(189)	0.16 (9)	0.25 (13)	0.27 (24)	0.38 (35)	0.5 (72)	0.32 (23)	1.52 (13)
Max well depth (m)	(367)	19.8 (29)	25.7 (25)	27 (42)	32.8 (56)	45 (125)	39.9 (56)	35.9 (34)
Year of observation		1978	1978	1978	1978	1978	1962	2007

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(335)	6 (20)	15 (49)	28 (94)	16 (54)	24 (80)	11 (38)	-
Water cut (m)	(80)	47.9 (6)	15.2 (7)	18.3 (12)	29 (9)	44.5 (26)	66.5 (20)	-
Max well depth (m)	(330)	19.8 (19)	15.7 (48)	19.6 (93)	30.8 (53)	46 (79)	69.3 (38)	-
Year of observation		1978	1978	1978	1978	1978	1978	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(238)	83.6 (199)	11 (27)	2 (4)	3 (7)	0.4 (1)
Water cut (m)	(82)	36.3 (67)	54.5 (8)	13 (3)	37 (3)	72 (1)
Max well depth (m)	(230)	42 (192)	41.1 (26)	21 (4)	26 (7)	74 (1)
Year of observation		1978	1980	1981	1964	2008

4.2.4. GAIRDNER AND CHILDARA



This summary of GAIRDNER includes the eastern section of CHILDARA that lies within the non-prescribed section of the SAAL NRM Region. The Gawler Ranges dominate GAIRDNER along with Lake Gairdner, one of the largest lakes in South Australia (Fig. 3). There are a number of smaller lakes in the north-east of GAIRDNER and the larger Lake Harris and Lake Everard in the north-west and west. Other significant features include the Lake Acraman 'impact' crater, and the prominent linear west to north-west corridor of dune sand that passes to the north (Davies 2005). A palaeovalley surrounds Lake Acraman and runs west to converge with the extensive network of palaeodrainage fringing the Eucla Basin (Fig. 6).

Surface Geology

Gawler Range Volcanics of the Gawler Craton crop out extensively west of Lake Gairdner to form the Gawler Ranges (Fig. 3). The Pandurra Formation crops out as low hills east of Lake Gairdner. Stuart Shelf rocks, the Wilpena Group, crop out in the north-west corner of GAIRDNER. The Algebuckina Sandstone of the Eromanga Basin crops out in the north of GAIRDNER and the north-east of CHILDARA. Tertiary—Quaternary silicified and ferruginised alluvial, colluvial and regolithic clastic sediments are scattered throughout eastern and northern GAIRDNER and cross over into CHILDARA. Quaternary alluvial and fluvial sediments surround outcrop of older rocks across the northern and southern thirds of GAIRDNER and extend into CHILDARA. Quaternary lacustrine playa sediments form most of the lake beds and are often flanked by gypsiferous lunettes. Quaternary aeolian sediments are prolific across the Eyre Peninsula and cross from CHILDARA into GAIRDNER in the west and south-west, north of Lake Everard and Lake Acraman and are also found east of Lake Gairdner.

Stratigraphy

The Gawler Craton forms the basement of KINGOONYA (Fig. 4). The Gawler Range Volcanics dominate with smaller occurrences of the Mulgathing Complex, Hiltaba and St Peter Suites and the Tunkillia Suite and equivalents also present. Excluding outcrop, depths to basement range up to 119 m with a median of 14 m.

The Cariewerloo Basin occupies GAIRDNER to the north and east of Lake Gairdner, cropping out in the east (Fig. 4). Excluding outcrop, the depth to the Pandurra Formation is as much as 95 m with a median of 26 m. From six wells, it has a thickness of 7 to 197 m and a median of 105 m.

The Tent Hill Formation of the Stuart Shelf is found in the north-east part of GAIRDNER where it crops out (Fig. 4). Where it does not, the depth to the unit is up to 30 m below the surface and it is between 4 and 65 m thick with a median thickness of 39 m.

Of the Eromanga Basin sequences, only the Algebuckina Sandstone has been identified in stratigraphic logs on GAIRDNER, found to the north of Lake Gairdner. The top of the unit begins from a depth of 2 to 32 m with a median of 4 m and has a thickness of between 2 and 50 m with a median of 14 m.

The Garford and Pidinga Formations are found in the Eucla Basin along the boundary of the SAAL NRM Region in the south of CHILDARA (Fig. 6). The Garford Formation has also been found between Lake Harris and Clucas Hill. Depth to the Garford Formation is up to 19 m with a median of 4 m. It has a thickness of between 7 and 113 m with a median of 48 m. Depth to the underlying Pidinga Formation is between 60 and 107 m with a median of 87 m. It has a thickness of up to 60 m with a median of 17 m. Undifferentiated Tertiary sediments are found in outcrop, elsewhere they have a depth to of up to 40 m and a median of 2 m with a thickness of up to 47 m (median of 6 m).

Quaternary sequences include the Moornaba Sand and Pooraka Formation and likely sands of the Wintrena and Delisser Formations. The Moornaba Sand is between 2 and 40 m thick with a median of 18 m. The Pooraka Formation has a thickness of up to 8 m with a median of 2 m. Undifferentiated Quaternary units have a combined thickness of up to 38 m with a median of 3 m.

Groundwater Data

Salinity is highly variable (187–315 280 mg/L, median 5109 mg/L). Two very low values of 187 and 190 mg/L were recorded in 1977 and are located in the north-east of GAIRDNER, west and south-west of Lake Hanson. There are no wells with groundwater quality data on GAIRDNER and the included section of CHILDARA that also have associated production zone and stratigraphic data. This limits the ability to assign groundwater observations to a specific hydrogeological formation. However, stratigraphic data from wells nearby indicate it may be within Quaternary sediments, which would indicate localised recharge.

Salinities of more than 20 000 mg/L are found across northern GAIRDNER and in the east. However, low-salinity groundwater is also found in these areas as well as north-eastern CHILDARA and southern GAIRDNER (Fig. 7). In north-eastern CHILDARA, stratigraphic data from surrounding wells indicate that low salinity wells may be accessing fractured rock aquifers. The well with the maximum recorded salinity value of 315 280 mg/L is located within Lake Gairdner in shallow Quaternary sediments within 10 m of the surface and illustrates the process of groundwater discharge through evaporation that occurs in most ephemeral lakes within arid areas.

Across GAIRDNER, standing water levels are between 2 and 50 m below the surface with a median of 12 m. Twenty-three wells have both a SWL and water cut depth measurement, 19 of these have the SWL above the water cut depth, ranging from 1 m above to a maximum of 41 m above. Most of the wells with water levels above the water cut depths are found within the Gawler Ranges, which is common within fractured rock aquifers.

Well yields are up to 19 L/s but the median is just 0.3 L/s with 79% below 1 L/s (Table 8). The two wells of higher yields (15 and 19 L/s) are located in north-eastern GAIRDNER (Fig. 9). These two wells had a salinity of 7433 and 187 mg/L recorded in 1977. Unfortunately no aquifer unit, production zone or stratigraphic data are available so a hydrogeological formation can not be related to the data.

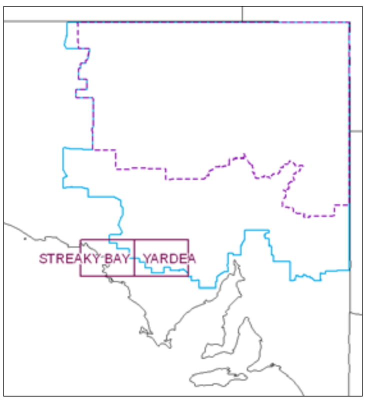
Table 8. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for GAIRDNER and the included section of CHILDARA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(201)	8 (16)	7 (13)	11 (22)	20 (40)	34 (68)	9 (19)	11 (23)
SWL (m)	(169)	9.3 (14)	13.7 (13)	6.6 (18)	11.8 (38)	10 (59)	26.5 (15)	12.5 (12)
Water cut (m)	(24)	12 (1)	24 (2)	13 (3)	25 (5)	36 (7)	30.5 (5)	15 (1)
Yield (L/s)	(108)	0.2 (6)	0.36 (12)	0.23 (12)	0.32 (23)	0.35 (36)	0.7 (12)	0.47 (7)
Max well depth (m)	(198)	15.1 (16)	26 (13)	15.5 (21)	25.4 (40)	19.8 (68)	40.5 (18)	33.4 (22)
Year of observation		1977	1977	1977	1977	1977	1977	1977

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(200)	8 (16)	35.5 (71)	30 (60)	17 (34)	9 (18)	0.5 (1)	-
Water cut (m)	(23)	-	13 (1)	22.5 (10)	36 (7)	30 (5)	-	-
Max well depth (m)	(200)	7.4 (16)	12.2 (71)	24.2 (60)	32.7 (34)	43.1 (18)	56.3 (1)	-
Year of observation		1977	1977	1977	1977	1979	1977	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(133)	79 (106)	15 (21)	2 (2)	2 (2)	2 (2)
Water cut (m)	(27)	28 (21)	24.4 (5)	36 (1)	-	-
Max well depth (m)	(133)	26 (106)	29.6 (21)	34.7 (2)	18.3 (2)	28.3 (2)
Year of observation		1977	1977	1987	1967	1977

4.2.5. YARDEA AND STREAKY BAY



This YARDEA summary includes the small area of north-eastern STREAKY BAY that lies within the non-prescribed section of the SAAL NRM Region. The southern Gawler Ranges dominate YARDEA with the Lake Acraman crater in the north-west (Fig. 3). The only major township within the area is Minnipa, which is located south of the SAAL NRM Region boundary in the south-west. The palaeovalley surrounding Lake Acraman drains from east to west through a valley in the Gawler Ranges onto the plain west of the ranges (Fig. 6). The Narlaby Palaeovalley runs along the south-western edge of the SAAL NRM Region boundary.

Surface Geology

The surface geology of YARDEA is dominated by the Gawler Range Volcanics that crop out extensively to form the Gawler Ranges. Only minor occurrences of Tertiary sequences appear at the surface. Quaternary sequences are found both in and around the outcrops of the Gawler Ranges (Pooraka Formation) and outside of the ranges (Wiabuna Formation and Moornaba Sand).

Stratigraphy

Basement rocks of YARDEA and STREAKY BAY are composed of the Gawler Craton (Fig. 4). YARDEA is dominated by the Gawler Range Volcanics, while STREAKY BAY consists primarily of the St Peter Suite. Other units include the Hutchison Group, found in south-eastern YARDEA, and the Hiltaba Suite, found across southern YARDEA and along the two map sheets shared border where the Sleaford Complex is also found. Excluding outcrop, depths to basement can be as great as 146 m although the median depth to basement is just 21 m.

Small outcrops of Tertiary sequences are found along the southern flank of the Gawler Ranges as well as in the north-east corner of YARDEA. Otherwise, the median depth to undifferentiated Tertiary sequences is 2 m below the surface with a maximum of 40 m. The Pidinga and Garford Formations are limited to the Narlaby Palaeovalley, other palaeovalleys and the adjoining Eucla Basin (Fig. 6). Depth to the Garford Formation is up to 19 m below the surface with a median of 4 m. Depth to the Pidinga Formation is between 60 and 107 m below the surface and the median is 86 m. The Pidinga Formation has a thickness of between 2 and 78 m with a median of 40 m, while the overlying Garford Formation is up to 114 m thick with a median thickness of 53 m. Undifferentiated Tertiary sequences have a combined median thickness of 18 m with a maximum of 96 m. The thicker sequences are most likely palaeovalley deposits.

Undifferentiated Quaternary units have a combined median thickness of 4 m but can reach up to 40 m. The Pooraka Formation has a combined thickness of up to 24 m with a median of 3 m. The Moornaba Sand is between 3 and 16 m thick with a median of 6 m.

Groundwater Data

None of the wells on YARDEA and the included section of STREAKY BAY have an aquifer unit assigned to them and there are no wells with groundwater quality data that also have associated production zone and stratigraphic data. This limits the ability to assign groundwater observations to a specific hydrogeological formation. Groundwater salinity is extremely variable with a minimum of 600 mg/L and a maximum of 86 000 mg/L recorded, but is generally brackish, with a median salinity of nearly 9000 mg/L. Six wells with low salinity are within the Gawler Ranges and most likely to be open to fractured rock aquifers (Fig. 7).

Standing water levels are also quite variable, with some close to the surface (0.4 m below) and others at depth (78 m below). Generally, depth to groundwater is relatively shallow (median of 14 m; Fig. 8). Fifty-one wells have an associated water cut depth. Forty-three of these wells record a water level from 1 to over 100 m above the water cut depth and are located within the areas of basement outcrop of the Gawler Ranges. Six wells have the SWL at the surface, three of which are on a creek line. The majority of deep groundwater levels (over 50 m below the surface) are found across southern YARDEA (Fig. 8).

Well yields also vary substantially, from a low of 0.0001 L/s to as much as 18 L/s, although typically, yields are poor with a median of 0.3 L/s and 75% of wells supplying less than 1 L/s (Table 9). No stratigraphic or production zone data are available for the two wells with high yields but, based on the surface geology, are suggested to be within fractured rock aquifers (Fig. 9).

Table 9. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for YARDEA and the included section of STREAKY BAY

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(179)	4 (7)	4 (7)	5 (10)	9 (16)	31 (55)	26 (47)	21 (37)
SWL (m)	(128)	21.6 (4)	15.2 (5)	22 (10)	10.3 (13)	13.2 (48)	14.6 (31)	20 (17)
Water cut (m)	(59)	22.9 (2)	-	56 (4)	14.4 (8)	25.9 (13)	21.3 (17)	26.2 (15)
Yield (L/s)	(65)	0.32 (2)	-	0.34 (4)	0.37 (8)	0.39 (22)	0.23 (19)	0.35 (10)
Max well depth (m)	(165)	58.5 (5)	27.4 (6)	52.3 (10)	29.7 (16)	32 (52)	36.7 (40)	45.4 (36)
Year of observation		1963	1977	1978	1978	1978	1978	1999

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(146)	5 (8)	21 (31)	42 (61)	10 (14)	14 (21)	8 (11)	-
Water cut (m)	(51)	21.5 (2)	8.1 (12)	24 (16)	31.1 (6)	44.5 (8)	64 (7)	-
Max well depth (m)	(145)	14.9 (8)	16.7 (30)	30.5 (61)	41.6 (14)	52.4 (21)	75 (11)	-
Year of observation		1978	1978	1978	1978	1999	1999	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(76)	75 (57)	16 (12)	6 (5)	-	3 (2)
Water cut (m)	(57)	32 (41)	54 (10)	53 (4)	-	27.8 (2)
Max well depth (m)	(76)	41.5 (57)	57.4 (12)	47 (5)	-	29.9 (2)
Year of observation		1969	2003	2003	-	1992

4.2.6. ANDAMOOKA AND CURDIMURKA

This summary of ANDAMOOKA includes the small part of south-eastern CURDIMURKA that falls within the non-prescribed section of the SAAL NRM Region. Andamooka and Roxby Downs are the two major towns within ANDAMOOKA. The Olympic Dam Cu–Ag–Au–U mine is located north of Roxby Downs (Fig. 1). The northern section of Lake Torrens occupies the eastern half of ANDAMOOKA and like all ephemeral lakes within the arid areas is typically dry with a layer of halite crust. The Andamooka Ranges are within the southern areas of ANDAMOOKA and the Willouran Ranges are found in the north-east corner, stretching into south-eastern CURDIMURKA (Fig. 3).

Surface Geology

The Burra and Callanna Groups crop out as the Willouran Ranges in the north-east of ANDAMOOKA, continuing into the south-east of CURDIMURKA (Fig. 3). The Umberatana Group also crops out in this area as well as northern ANDAMOOKA. The Wilpena Group also has minor outcrop in the north and north-east but crops out extensively in central and southern ANDAMOOKA in the form of the Andamooka Ranges (Fig. 3).

Outcrop of the Arrowie Basin occurs in the south-west and north of ANDAMOOKA. The Bulldog Shale of the Eromanga Basin crops out throughout the western two-thirds of ANDAMOOKA. Small outcrops of the Algebuckina Sandstone are found in central ANDAMOOKA and in the north. The Willalinchina Sandstone of the Billa Kalina Basin forms a linear outcrop from south-western ANDAMOOKA towards the centre where it meets Lake Torrens and the Watchie Sandstone crops out extensively in the north-west region of ANDAMOOKA.

Tertiary–Quaternary silicified and ferruginised alluvial, colluvial and regolithic clastic sediments are found in outcrop in the north-east corner of ANDAMOOKA. Quaternary lacustrine/playa sediments form the lake bed of Lake Torrens and aeolian sediments are found elsewhere. Small occurrences of alluvial and fluvial sediments are found in central, northern and north-eastern ANDAMOOKA.

Stratigraphy

The stratigraphy of ANDAMOOKA is quite complex as it covers a large number of geological provinces and basins: the Gawler Craton, Cariewerloo Basin, Adelaide Geosyncline, Stuart Shelf and Torrens Hinge Zone (Fig. 4), the Arrowie and Eromanga Basins (Fig. 5) and the Billa Kalina and Torrens Basins (Fig. 6).

The Mulgathing Complex is found under the western third of ANDAMOOKA, the Hutchison Group in the north-west, the Donington Suite throughout the central third of ANDAMOOKA, the Broadview Schist in the south-west quadrant of the map sheet, the Gawler Range Volcanics occur in the south-western quadrant of ANDAMOOKA and the Hiltaba Suite is found in central and north-western ANDAMOOKA. Due to the large number of basins overlying the Gawler Craton, few drillholes have penetrated basement where it lies at great depth and as such, depth to basement rocks of the Gawler Craton is taken from only 32 wells. The depth ranges from 87 to 1133 m with a median of 560 m.

Depth to the Pandurra Formation of the Cariewerloo Basin is between 118 to 840 m below the surface with a median of 432 m. It overlies the Gawler Craton in the east and across southern ANDAMOOKA and has a thickness of 6 to 950 m with a median of 207 m.

The Torrens Hinge Zone separates the Stuart Shelf from the Adelaide Geosyncline, the latter of which is only present in the very north-eastern corner of ANDAMOOKA. The Callanna, Burra and Umberatana Groups occur within the Torrens Hinge Zone and the Adelaide Geosyncline, while the Wilpena Group is present in all three provinces. Depth to Neoproterozoic units is up to 244 m with a median of 36 m; thickness is up to 1177 m with a median of 387 m.

The Arrowie Basin occurs over most of the eastern third of ANDAMOOKA and runs from the north to the south-east and contains units from the Hawker and Lake Frome Groups, particularly the Andamooka Limestone. The depth to the Arrowie Basin units is up to 26 m with a median of 4 m; the thickness of the basin varies from 7 to 200 m with a median of 37 m.

The Eromanga Basin covers most of the north-western quadrant and central ANDAMOOKA. There is also a lens in the south-west. The Bulldog Shale crops out throughout these areas and elsewhere is found at very shallow depths (0.3–6 m, median 0.6 m). It has a thickness of between 3 and 70 m with a median of 17 m. In eastern ANDAMOOKA, east of Lake Torrens, one well has intercepted Bulldog Shale at a depth of 174 m below the surface. The underlying top of the Algebuckina Sandstone and Cadna-owie Formation are found from a depth of 8 to 20 m. One well has fully penetrated the Algebuckina Sandstone, recording a thickness of 5 m.

The Billa Kalina Basin covers much of the western third of ANDAMOOKA from the north to the south-west. Within ANDAMOOKA, the basin contains the Willalinchina Sandstone and Watchie Sandstone. The

Torrens Basin is present over the eastern third of ANDAMOOKA and contains the Cotabena and Neuroodla Formations. Tertiary sequences from stratigraphic wells located within ANDAMOOKA have not been differentiated, but based on the mapped extent of the basins' margins, the depth to the Billa Kalina Basin is up to 4 m below the surface and the units are thin, with a thickness of 2 to 6 m and a median of 2 m. Depth to the Torrens Basin units is up to 28 m, with thickness varying from 8 to 174 m with a median of 72 m.

Stratigraphic logs do not differentiate between Quaternary sequences. They have a combined thickness of up to 36 m with a median of 2 m.

Groundwater Data

There are 36 wells on ANDAMOOKA and the included section of CURDIMURKA that have been assigned an aquifer unit. There are no wells with groundwater quality data that also have associated production zone and stratigraphic data. There are likely to be wells with this level of information associated with the Olympic Dam operations, however, this information is yet to be entered into the digital database.

Groundwater salinity is extremely variable with a minimum of 100 mg/L and a maximum of 222 000 mg/L recorded. Generally, groundwater is saline with a median of nearly 15 000 mg/L. The well with the maximum recorded salinity value of 222 000 mg/L is located within Lake Torrens in shallow Quaternary sediments within 2 m of the surface. Again, this illustrates the process of groundwater discharge through evaporation.

Low salinity groundwater is found in the north-east of ANDAMOOKA and along a creek line within the town of Andamooka. Within ANDAMOOKA, most of the low salinity wells appear to be within the Eromanga Basin sediments based on the surface geology map, with one to the west within fractured rock (Fig. 7). Low salinities have also been recorded in wells located along creek lines in areas of Neoproterozoic outcrop west of Andamooka and in the south-east and south-west of ANDAMOOKA. Elsewhere, salinity is generally over 5000 mg/L with many over 20 000 mg/L. Some wells with salinity between 1000 to 3000 mg/L have been recorded in the north-east corner of ANDAMOOKA and south-eastern CURDIMURKA, again along creek lines in areas of Neoproterozoic outcrop.

Wells positively identified as open to the Neoproterozoic aged Burra and Wilpena Groups record salinities ranging from as low as 297 mg/L up to 95 200 mg/L. The Cambrian aged Andamooka Limestone has salinities of between 22 645 mg/L and nearly 50 000 mg/L. Two wells in undifferentiated Tertiary units record similar salinities (19 381–53 200 mg/L).

Standing water levels are also highly variable, ranging from artesian conditions recorded in one well (1 m above the surface) to a maximum depth to groundwater of 116 m. Generally, groundwater is found around 25 m below the surface (median 24.4 m). The SWL value above the ground surface was recorded in the late 1800s from a well more than 400 m deep and is found in the north–north-east of ANDAMOOKA. There is a good spread of wells with the SWL within 5 m of the surface from the south-west through to the north-east and into CURDIMURKA. The surface geology indicates many of these wells are located in areas of Neoproterozoic outcrop (Fig. 8).

The wells identified as Neoproterozoic aged aquifer units record a wide range of SWLs, from as low as zero (ground surface) to nearly 100 m below the surface. This highlights the variable nature of fractured rock environments. Water levels in the Andamooka Limestone are between 31 and 60 m. Tertiary and Quaternary wells record water levels within 3 m of the ground surface.

There is a large cluster of wells with the SWL at 20 to 50 m or more in the west of ANDAMOOKA in and around the location of the Olympic Dam site. These are likely to be the observation or dewatering wells associated with the mining operation. As some of the wells are used for dewatering, the SWL recorded may not be a true representation of the current standing water level in the aquifers. BHP Billiton (2009a) report that depth to the watertable within the Andamooka Limestone of the Arrowie Basin is typically about 50 m in the area of the mine. The underlying aquifer within the Tent Hill Formation (Wilpena Group) of the Stuart Shelf typically occurs 160–200 m below ground level (BHP Billiton 2009a).

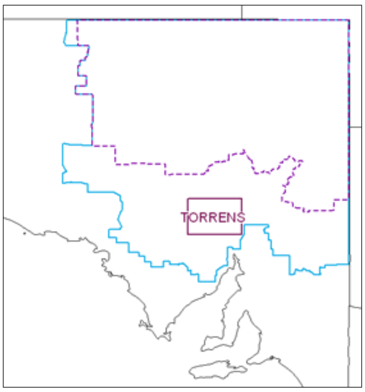
Well yields vary from very low (0.001 L/s) to high (25 L/s) but are typically low (median of 1 L/s) with low yields (1–3 L/s) common across ANDAMOOKA and into CURDIMURKA (Fig. 9). Due to specific well constructions, the wells located at the Olympic Dam site are capable of high yields. The wells are open to either the Andamooka Limestone or the underlying Tent Hill Formation. Other wells open to the Andamooka Limestone record yields of 0.2 to 0.5 L/s. Wells in other Neoproterozoic aged units return yields of between 0.02 and 2 L/s.

Table 10. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for ANDAMOOKA and the included section of CURDIMURKA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(154)	7 (11)	3 (4)	6 (9)	10 (15)	17 (26)	25 (39)	32 (50)
SWL (m)	(115)	3.6 (9)	7.4 (2)	8.1 (7)	17.5 (8)	17.5 (17)	15.2 (33)	25.6 (39)
Water cut (m)	(18)	-	-	-	58 (2)	27.4 (3)	45.1 (4)	170 (9)
Yield (L/s)	(88)	0.03 (6)	0.03 (3)	0.13 (5)	0.32 (8)	0.63 (13)	0.13 (20)	1.1 (33)
Max well depth (m)	(142)	18.3 (9)	13.9 (3)	21.3 (9)	31.7 (13)	27.8 (23)	43.4 (36)	80 (49)
Year of observation		1956	1971	1964	1970	1968	1960	1987
Associated median well data	**Total number of wells**	**Standing Water Level (metres below ground)**						
		<5	**5–9.99**	**10–19.99**	**20–29.99**	**30–49.99**	**50–99.99**	**≥100**
%	(237)	16 (38)	13 (30)	15.6 (37)	7 (17)	24 (57)	24 (57)	0.4 (1)
Water cut (m)	(31)	-	10.6 (2)	22.1 (2)	35 (2)	67 (7)	70 (17)	176 (1)
Max well depth (m)	(235)	14.1 (38)	18.3 (29)	28.8 (37)	38.7 (17)	66 (57)	124 (56)	234 (1)
Year of observation		1979	1979	1978	1964	1997	1997	2011

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(193)	51 (99)	22 (42)	10 (20)	10 (19)	7 (13)
Water cut (m)	(45)	57 (22)	57.8 (6)	170 (5)	167 (10)	195 (2)
Max well depth (m)	(191)	36.6 (98)	293 (41)	231 (20)	208 (19)	234 (13)
Year of observation		1967	1982	1986	2007	1984

4.2.7. TORRENS



The township of Woomera is located in the north-west of TORRENS with the Woomera Prohibited Area covering that area (Fig. 1). Lake Torrens is found along the east of TORRENS and flanks the Andamooka Ranges (Fig. 3). A number of other ephemeral lakes of various sizes are found throughout TORRENS, west and south of the ranges and associated hills.

Surface Geology

The Mesoproterozoic Pandurra Formation of the Cariewerloo Basin is the oldest unit found at the surface of TORRENS. It crops out through the centre from north to south and is also found along the south-western border. The Umberatana and Wilpena Groups that form the Stuart Shelf crop out extensively throughout TORRENS in the form of the Andamooka Ranges. The Bulldog Shale of the Eromanga Basin is found atop these rocks in the north-west. Quaternary aeolian sediments dominate the low-lying areas with lacustrine and playa sediments within the various lakes and lagoons found throughout TORRENS.

Stratigraphy

The Gawler Craton forms the basement of TORRENS (Fig. 4). The Gawler Range Volcanics dominate with the Donington Suite found in the north to north-east and central areas and the Broadview Schist present throughout the central third of TORRENS. Depth to basement rocks of the Gawler Craton ranges from 48 m in the south-west, to nearly 1400 m in the southern Andamooka Ranges. The median depth to basement is 520 m.

The Cariewerloo Basin overlies the Gawler Craton over much of TORRENS, but is absent in the eastern third of the map sheet (Fig. 4). Excluding outcrop, the depth to the Pandurra Formation can reach up to 802 m below the surface in the north, with a median depth to the Cariewerloo Basin of 80 m. The Pandurra Formation has a thickness of between 10 and 819 m with a median of 312 m.

A roughly 25 km-wide strip of the Torrens Hinge Zone is present along the eastern border of TORRENS (Fig. 4). The Stuart Shelf is found to the west of the zone, covering the rest of TORRENS but is absent where the Cariewerloo Basin crops out (Fig. 4). Neoproterozoic sequences of the Callanna, Burra, Umberatana and Wilpena Groups are found throughout the Torrens Hinge Zone (THZ) with the Umberatana and Wilpena Groups also found across the Stuart Shelf. As Neoproterozoic rocks crop out extensively over TORRENS, depth to units is typically shallow (median of 7 m) but can reach up to 375 m. Thickness of Neoproterozoic units can vary greatly, from 1 m near outcrops of the Pandurra Formation, to nearly 1400 m in the Andamooka Ranges. The median thickness is 74 m.

Small sections of the Cambrian age Arrowie Basin can be found in the north-east and south-east parts of TORRENS (Fig. 5) but no stratigraphic data are available. A small, isolated remnant of the Eromanga Basin is found in the Woomera area (Fig. 5). Two wells intercept Cretaceous sequences of the basin at a depth of 4 m; one well intercepted a 38 m thick sequence of Bulldog Shale, the other a 24 m thick undifferentiated Cretaceous unit.

The Torrens Basin overlies the THZ along the eastern border of TORRENS (Fig. 6) but no stratigraphic data are available. The Neuroodla Formation can be found around 50 m below the surface with a similar thickness (Alley & Benbow 1995). The Cotabena Formation is absent in the shallower western parts of the basin and may have limited occurrences on TORRENS.

Quaternary sequences covering most of TORRENS are undifferentiated dune sand and may belong to the Great Victoria Desert. The Avondale Clay and Pooraka Formation are found east of the Andamooka Ranges overlying the Torrens Basin and may be up to 170 m thick. In general, Quaternary units are up to 50 m thick with a median of 7 m.

Groundwater Data

There are no wells on TORRENS that have been assigned an aquifer unit, nor are there any wells with groundwater quality data that also have associated production zone and stratigraphic data. This limits the ability to assign groundwater observations to a specific hydrogeological formation. Groundwater salinity is extremely variable, ranging from fresh (158 mg/L) to hypersaline (175 000 mg/L), but is generally saline (median of 14 200 mg/L). There are three wells with salinities of less than 200 mg/L that were recorded in the late 1940s to early 1950s. One well is found within a large area of Neoproterozoic outcrop in the north-west of the map sheet, within 1 km of a creek line. Another is also in an area of Neoproterozoic outcrop in the west of TORRENS and the last one is in the south-east, also on a creek line. The other eight wells with low-salinity groundwater (<1500 mg/L) were also recorded in the same time period. There are wells with stratigraphic data located near some of these wells and these indicate that the wells may be accessing groundwater held within Tertiary to Quaternary sediments of sand and calcrete. These low salinities suggest local recharge processes.

Standing water levels are up to 72 m below the surface with a median of 10 m. Shallow depths to water are found throughout TORRENS in areas of both Neoproterozoic outcrop and Quaternary sedimentary cover (Fig. 8). There are two wells with the water level recorded at the surface; both are located close to creek lines.

Twenty-one wells have corresponding water cut depths. Most have a water level above the water cut depth of between 1 and 60 m indicating confined conditions in many areas of the map sheet.

Three wells with water levels of between 65 and 73 m below the surface are found within areas of Neoproterozoic outcrop south and east of Woomera. One well with a SWL of just over 50 m is found in the south of TORRENS. Based on nearby stratigraphic data, it has recorded the water level in either the Pandurra Formation of the Cariewerloo Basin or the Tapley Hill Formation of the Umberatana Group within the Stuart Shelf.

Well yields are typically low with a median of 0.4 L/s and 67% of wells suppling less than 1 L/s (Table 11) but some good yields have been recorded (up to 19 L/s; Fig. 9). Three wells with yields between 7 and 19 L/s are found in the north/north-west of TORRENS around Woomera. The wells are in an area of Neoproterozoic outcrop and appear to be located on parallel north-east lineaments that may define significant fracture zones within the Arcoona Quartzite aquifer at depth (Kellett *et al.* 1999).

Two wells within central TORRENS have recorded yields of 7 and 11 L/s but there is not enough information to determine which aquifer they are accessing. One well in south-eastern TORRENS has recorded yield of 13 L/s at a maximum drilled depth of 11 m. Stratigraphic records within a 20 km radius indicate thick Quaternary sediments in the area. One well in southern central TORRENS has a recorded yield of 6 L/s at a water cut depth of 48 m and is most likely accessing the Pandurra Formation, while a well in the south has a recorded yield of 5 L/s at a water cut depth of 87 m and is most likely within the Tapley Hill Formation.

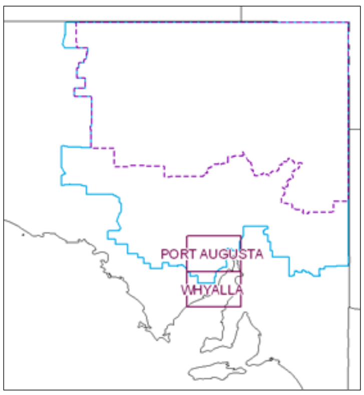
Table 11. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for TORRENS

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(121)	7 (9)	2 (2)	3 (3)	11 (13)	15 (20)	35 (42)	26 (32)
SWL (m)	(52)	12 (7)	12.2 (2)	15.2 (3)	6.9 (6)	9 (13)	10.7 (11)	7.3 (10)
Water cut (m)	(50)	32 (2)	-	11.4 (2)	16 (3)	23.5 (6)	37.5 (25)	30.9 (12)
Yield (L/s)	(80)	0.26 (6)	0.11 (2)	0.25 (2)	0.11 (6)	0.55 (14)	0.5 (29)	1.3 (21)
Max well depth (m)	(115)	21.3 (7)	24.4 (2)	15.2 (2)	18.3 (11)	55.3 (20)	65.5 (41)	109 (32)
Year of observation		1948	1947	1948	1961	1951	1972	1975

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(82)	27 (22)	23 (19)	28 (23)	5 (4)	12 (10)	5 (4)	-
Water cut (m)	(21)	28 (3)	11 (8)	24.7 (6)	25.3 (2)	-	93.4 (2)	-
Max well depth (m)	(79)	10.4 (22)	12 (19)	24.4 (22)	36.6 (4)	64.9 (8)	111.6 (4)	-
Year of observation		1964	1969	1947	1947	1976	1978	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(112)	67 (76)	16 (18)	9 (10)	4 (4)	4 (4)
Water cut (m)	(52)	31.8 (39)	25.6 (7)	44.8 (3)	67.5 (2)	28 (1)
Max well depth (m)	(112)	52.4 (76)	109 (18)	78 (10)	48.3 (4)	69.6 (4)
Year of observation		1955	1975	1977	1978	1975

4.2.8. PORT AUGUSTA AND WHYALLA



This summary of PORT AUGUSTA includes the small section of northern WHYALLA within the non-prescribed section of the SAAL NRM Region. PORT AUGUSTA covers the north-eastern part of the Eyre Peninsula and the northern Spencer Gulf. The main townships are the city of Port Augusta and Iron Knob. The region is largely occupied by numerous pastoral leases used predominantly for sheep grazing (Curtis 2007) and there are a number of iron and sand mines through both map sheets (Fig. 2). The eastern part of the Gawler Ranges occupies the north-western part of PORT AUGUSTA and the Baxter Range lies to the north-east of the Gawler Ranges.

Surface Geology

Basement rocks of the Gawler Craton crop out extensively throughout western, southern and central PORT AUGUSTA and throughout WHYALLA in the form of the Gawler Ranges, other smaller ranges and hills. The Pandurra Formation crops out in central northern PORT AUGUSTA as the Baxter Range and continues down to the coast at Whyalla. The Umberatana and Wilpena Groups of the Stuart Shelf crop out through the eastern half of PORT AUGUSTA. Small outcrops of Tertiary–Quaternary sediments are scattered throughout PORT AUGUSTA. Quaternary alluvial and fluvial sediments blanket areas in and around outcrop. Quaternary lacustrine and playa sediments and gypsiferous lunettes are found in and around the lakes and minor water bodies. Quaternary aeolian sediments cover much of PORT AUGUSTA across the north, the east and the south-west where it stretches into WHYALLA.

Stratigraphy

The Gawler Craton forms the basement of PORT AUGUSTA and WHYALLA (Fig. 4). The Gawler Range Volcanics dominate followed by the Donington Suite in the south-west and the Broadview Schist in southern and along eastern PORT AUGUSTA. The Hutchison Group is found in the south-west corner and the Hiltaba Suite in the south-east. Small occurrences of the Corunna Conglomerate and the Moonabie Formation also occur. Basement rocks crop out extensively across PORT AUGUSTA and WHYALLA in the form of the Gawler Ranges and other smaller ranges and as such, the median depth to basement is shallow (10 m). Excluding outcrop, depth to basement can be as much as 337 m.

The Cariewerloo Basin overlies the Gawler Craton over much of northern PORT AUGUSTA (Fig. 4) where it crops out and stretches down to the coast between Cariewerloo Station and Port Augusta to Whyalla, also cropping out between Roopena Station and Whyalla. Excluding outcrop, depth to the Pandurra Formation is up to 320 m with a median of 38 m. The formation ranges in thickness from 17 to 172 m and has a median of 49 m.

The THZ runs down north-eastern PORT AUGUSTA with a thin strip of the Adelaide Geosyncline to the east (Fig. 4). The Stuart Shelf lies between the THZ and the Baxter Range on the west, down to Whyalla on the coast and consists of the Umberatana and Wilpena Groups. Excluding outcrop, depth to Neoproterozoic units is up to 412 m but the median is just 8 m. The thickness of Neoproterozoic rocks is between 3 and 837 m with a median of 51 m.

The Arrowie Basin occurs as an isolated occurrence overlying the THZ in the north-east corner of PORT AUGUSTA (Fig. 5). It contains the Parachilna Formation, Woodendinna Dolomite and the Wilkawillina Limestone. The top of the basin is intercepted between 134 and 187 m below the surface, is between 101 and 271 m thick and has a median thickness of 223 m based on the four wells that fully penetrate Cambrian units.

The Torrens Basin overlies a larger area of the same location as the Arrowie Basin and slightly overlies the edge of the Stuart Shelf (Fig. 6). The basin contains the Cotabena and Neuroodla Formations, with these units positively identified in one well. The Neuroodla Formation was recorded from 24 to 88 m, overlying the Cotabena Formation from 88 to 146 m below the surface.

Elsewhere, there are scattered outcrops of undifferentiated Tertiary sequences throughout PORT AUGUSTA. Excluding outcrop, depth to Tertiary sequences is as much as 70 m but is generally shallow with a median of 6 m. The Tertiary sequences have a thickness of up to 145 m but are typically thin (median 4 m).

Quaternary sequences range in thickness from less than 0.5 metre to up to 82 m but have a median of just 4 m. They consist mainly of Pleistocene-age alluvial/fluvial sediments and aeolian sediments. Aeolian sediments in ten wells have been identified as the Moornaba Sand. The unit is between 2 and 8 m thick. Lacustrine/playa sediments are found in the lake beds and in the north-east and gypsiferous dunes/lunettes are found along the southern banks of the lakes.

Groundwater Data

Groundwater is generally saline (median of 15 000 mg/L) but records range from fresh (265 mg/L) to hypersaline (159 000 mg/L). Wells with high to very high salinity are found in all areas of PORT AUGUSTA and the included part of WHYALLA and at varying water cut depths, from 3 to nearly 150 m. Occurrences of low-salinity groundwater have been found in most areas of PORT AUGUSTA (Fig. 7). A well located within the Middleback Range in northern WHYALLA recorded a salinity of 866 mg/L in 1957. Based on its mapped location and the surface geology, it is most likely within the Hutchison Group of the Gawler Craton.

Low to medium-salinity groundwater was recorded in a number of wells in the south–south-west of PORT AUGUSTA between the mid-1950s and 70s. No production zone data are available and stratigraphic data from nearby wells is unable to clarify if the groundwater is coming from either Tertiary–Quaternary sediments or Palaeoproterozoic basement material of the Gawler Craton. Three wells recorded salinities between 440 and 1010 mg/L, two of them in 2003, within the Gawler Range Volcanics cropping out as the Uno Range in western PORT AUGUSTA. A number of wells recorded low to medium salinities between 1939 and 1976 in central PORT AUGUSTA around Iron Knob and to the north and north-west of the town. Basement material of the Gawler Craton crops out extensively throughout this area and may be the source of this groundwater as overlying Quaternary sediments are relatively thin in this area.

Wells with low to medium salinity groundwater records are also found in northern PORT AUGUSTA along the eastern flank of a large outcrop of the Pandurra Formation where an edge of the Stuart Shelf is located. No production zone data are available and based on stratigraphic information, it is difficult to determine if the groundwater is coming from the Pandurra Formation or the overlying rocks of the Stuart Shelf.

Two wells identified as open to the Pandurra Formation record salinities of 4369 and 12 765 mg/L. One well identified as accessing undifferentiated Tertiary and Quaternary sediments recorded a salinity of 23 900 mg/L in 1965. Three wells with production zone and stratigraphic data record a salinity of 17 357 mg/L in Neoproterozoic sediments, 41 164 mg/L in the Cambrian aged Wilkawillina Limestone and 61 289 mg/L in Tertiary sediments.

Depth to groundwater for this region is up to 93 m below the surface, but it is commonly at shallow depths (median of 13 m). Six wells have recorded artesian conditions, they are all found in the north-east corner of PORT AUGUSTA and their maximum drilled depths are between 80 and 360 m. One of these wells has been positively identified as open to the Wilkawillina Limestone. There are six wells in the same area that have stratigraphic information; up to 150 m of Tertiary sediments of the Torrens Basin, the Neuroodla and Cotabena Formations, are found in this area and are underlain by the Wilkawillina Limestone, Parachilna Formation and Woodendinna Dolomite of the Arrowie Basin. Only one of these wells fully penetrates the Arrowie Basin sediments and records nearly 300 m of thickness. Neoproterozoic rocks of the Torrens Hinge Zone underlie the Arrowie Basin in this area.

Shallow water levels (<10 m) are found throughout the map sheet and adjacent to the Middleback Range in the north of WHYALLA (Fig. 8). Stratigraphic information indicates that many shallow water levels are found in areas of relatively thick Tertiary and Quaternary sediments but the lack of production zone data makes it difficult to determine if these water levels are recording groundwater held within these sediments or the underlying fractured rock aquifers.

Well yields vary from extremely low (0.001 L/s) to high (>10 L/s) but are generally low (median of 0.5 L/s). One high-yielding well (300 L/s) was drilled in 2005 as the new supply well for Cariewerloo Station. The driller’s log recorded white clay with creek gravel at the screen interval (13–22 m).

A well with a yield of 12.5 L/s recorded in 1975 is found in northern PORT AUGUSTA. It is screened within Neoproterozoic rocks of the Stuart Shelf. No water cut depth is recorded, the maximum drilled depth is 227 m but the groundwater is only 0.3 m below the surface. The salinity is over 50 000 mg/L.

Three wells with yields of 6, 19 and 13 L/s are found in south-eastern PORT AUGUSTA within 2 km of a creek line between two areas of outcrop. Their stratigraphic logs indicate there is Neoproterozoic rocks underlying 14 to 40 m of Tertiary–Quaternary sediments. No production zone data are available but water cut depths suggest the groundwater is within the younger sediments.

Four wells with yields of 4 to 6 L/s are found in northern PORT AUGUSTA. Water cut depths of three of the wells indicate fractured rocks of the Stuart Shelf as the likely aquifer. The other well is found in a large area of outcrop of the Pandurra Formation.

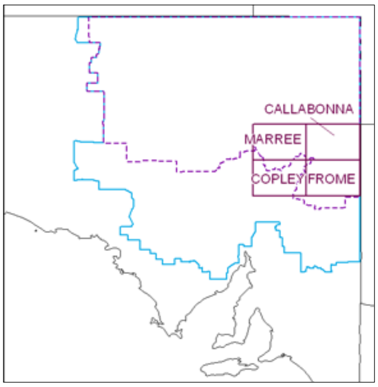
Table 12. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for PORT AUGUSTA and the included section of WHYALLA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(289)	6 (16)	2 (6)	6 (16)	11 (33)	16 (46)	21 (61)	38 (111)
SWL (m)	(126)	11.3 (8)	20.6 (6)	28.9 (14)	13.9 (24)	12 (28)	27.1 (23)	8.3 (23)
Water cut (m)	(106)	45.7 (2)	82 (1)	-	49 (10)	31 (13)	24 (22)	33.3 (58)
Yield (L/s)	(113)	0.21 (4)	0.16 (4)	0.3 (5)	0.76 (14)	0.63 (18)	0.31 (28)	0.59 (40)
Max well depth (m)	(263)	38.1 (11)	42.3 (6)	56.4 (15)	46.5 (30)	49 (44)	50.1 (56)	79 (101)
Year of observation		1975	1975	1966	1976	1976	1975	1975

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(198)	28 (54)	17 (34)	15 (30)	13 (26)	19 (38)	8 (16)	-
Water cut (m)	(32)	4.1 (4)	14 (6)	20 (11)	26 (5)	52.9 (4)	83 (2)	-
Max well depth (m)	(195)	5.3 (54)	25.9 (32)	44.8 (30)	48.4 (26)	72 (37)	87 (16)	-
Year of observation		1977	1975	1976	1975	1966	1965	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(143)	73 (105)	20 (28)	1 (2)	3 (4)	3 (4)
Water cut (m)	(77)	31 (54)	40.5 (16)	34 (2)	21 (3)	14.9 (2)
Max well depth (m)	(140)	50.3 (103)	63 (27)	44 (2)	64 (4)	221.2 (4)
Year of observation		1975	1975	1986	1974	1975

4.2.9. COPLEY, MARREE, CALLABONNA AND FROME



This summary of COPLEY includes the small sections of south-western and south-eastern MARREE and north-western FROME that occurs within the non-prescribed section of the SAAL NRM Region. COPLEY covers the northern Flinders Ranges and includes the Arkaroola Wilderness Area and the Gammon Ranges in the north-east. The township of Leigh Creek and the coal mines of the same name are found in the west. The Beltana Zinc Zn–Pb mine and the Mountain of Light, Paltridge South and Rossmann East copper mines are also operating in the area. The Beverley uranium mine is located outside of the study area to the north-east of Arkaroola. Nepabunna in south-eastern central COPLEY is the major Aboriginal settlement in the area and hosts two monitoring wells (Fig. 1).

Surface Geology

Basement rocks of the Curnamona Province crop out along the north-east tip of the northern Flinders Ranges in the north-east corner of COPLEY and stretching into the corners of FROME, CALLABONNA and MARREE. The Adelaide Geosyncline crops out extensively across COPLEY as the Flinders Ranges. Arrowie Basin units overlie the Adelaide Geosyncline rocks through the southern areas. Tertiary–Quaternary silicified and ferruginised alluvial, colluvial and regolithic clastic sediments are found in outcrop in the north-west corner of COPLEY and the Willawortina Formation is found east of the ranges. Quaternary alluvial and fluvial sediments cover most of the areas either side of the ranges, with aeolian sediments along the western border.

Stratigraphy

As COPLEY covers the northern Flinders Ranges, the majority of the geology and stratigraphy is made up of Neoproterozoic (Adelaidean) rocks of the Adelaide Geosyncline (Figs. 3 & 4). There are some Palaeoproterozoic and Mesoproterozoic basement rocks present as well as some Cambrian-aged outcrops overlying the Neoproterozoic rocks. From 20 wells, depth to basement rocks excluding areas of outcrop is up to 248 m with a median of 4 m. As to be expected when the majority of the map area is covered in outcrop, depth to Neoproterozoic rocks is typically quite shallow (87% of records are less than 20 m below the surface; median of 8 m), but thick units of Quaternary sediments have been recorded in the south-west of COPLEY, where the basement is 307 m below the surface. Where Neoproterozoic rocks overlie older basement rocks, their thickness is between 2 and 298 m with a median of 48 m.

Arrowie Basin sequences are from the Moralana Supergroup and include the Lake Frome and Hawker Groups, the Mernmerna Formation and the Kulpara Formation and overlie Neoproterozoic units throughout the southern half of COPLEY (Fig. 5). Again, due to extensive outcrop, depth to Cambrian units is shallow, with a median of 6 m below the surface but is as great as 304 m in the south-west of COPLEY. The thickness of Cambrian units ranges from 7 to 306 m with a median of 71 m.

The Cotabena and Neuroodla Formations of the Torrens Basin are found in the west and south-west of COPLEY (Fig. 6). Three wells have intercepted the formations with the depth to the Neuroodla Formation between 130 and 145 m below the surface. It has a recorded thickness of 80 to 92 m. The Cotabena Formation has a similar recorded thickness.

Depth to undifferentiated Tertiary sequences is typically relatively shallow (median 30 m) but it is up to 247 m in the south-west. Tertiary sequences have a combined thickness of between 3 and 115 m with a median of 24 m. No wells are located within the mapped extent of the Lake Eyre Basin.

The Willawortina Formation was deposited in fans to the east and west of the northern Flinders Ranges. The formation crops out to the east but no stratigraphic wells are located in the area. The formation is intercepted in three wells to the west of the ranges and is found at depths of 28, 33 and 52 m and has recorded thicknesses of around 100 m.

The Avondale Clay, Telford Gravel and Pooraka Formation form alluvial fans on both sides of the Flinders Ranges. The Telford Gravel is underlain by Avondale Clay and basement rocks in the ranges and by Tertiary sediments elsewhere. Five wells have intercepted up to 11 m of the unit. Eight wells have intercepted the Avondale Clay at a thickness of between 9 and 36 m. One well has a recorded thickness of 244 m in the Ediacara Range in the south-west of COPLEY. Undifferentiated Quaternary units have a combined thickness of up to 52 m but a median thickness of 3 m. One well that is located in the west of COPLEY near Mount Parry has a recorded thickness of 122 m.

Groundwater Data

Groundwater salinity ranges from low (428 mg/L) to very high (92 000 mg/L) but is generally brackish (median of 2755 mg/L). Low-salinity groundwater is found throughout rocks of the Adelaide Geosyncline and Arrowie Basin that crop out as the northern Flinders Ranges through much of COPLEY (Fig. 7). Wells with salinity records of more than 20 000 mg/L are generally found to the west of the ranges and in the south-western corner of MARREE. Wells with salinity between 5000 and 20 000 mg/L are found throughout COPLEY and south-western MARREE. There are also a small number of wells in south-western MARREE that are identified as either GAB sediments or undifferentiated basement rocks that have salinities of between 1000 and 3000 mg/L.

Depth to groundwater is up to 127 m below the surface but is generally shallow (median of 11 m). Twenty-four wells have the water level at the surface. A number of these are within the Telford Basin at Leigh Creek. Three are found north of Mount Stuart. A number of springs are identified in this area and north and south of Arkaroola where a number of other wells also recorded water levels at the surface.

Shallow water levels are common throughout COPLEY and the included parts of the adjoining map sheets (Fig. 8). Many wells with deep water levels are found in western COPLEY, particularly along a strip of the Arrowie Basin south of Leigh Creek. Others are also found through central, southern and eastern COPLEY.

Well yields can be high (65 L/s) but are typically low (median is 1 L/s). Low yields are found all throughout COPLEY and the southern corners of MARREE. A large number of wells with high yields are concentrated in and around Leigh Creek in both Neoproterozoic and Cambrian rocks (Fig. 9). High yields are also found in the Arrowie Basin near Nepabunna. A high yield of 32 L/s is recorded from a town water supply well in Marree that is accessing the GAB aquifer. Many of the other wells with high yields are town water supply or mining operation wells, implying that favourable yields are possible with specifically constructed wells. A small number of wells with reasonable yields are also found north of Arkaroola and in the north-west corner of FROME in Palaeoproterozoic to Mesoproterozoic-aged outcrop.

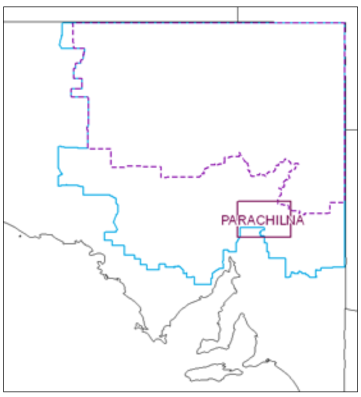
Table 13. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for COPLEY and the included sections of MARREE and FROME

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(505)	7 (37)	15 (78)	30 (153)	18 (90)	17 (84)	6 (30)	7 (33)
SWL (m)	(345)	18.3 (23)	15.2 (47)	11 (114)	9.1 (58)	15 (59)	10.7 (20)	4.1 (24)
Water cut (m)	(65)	29 (5)	61 (14)	28 (28)	14 (9)	19.5 (2)	58 (1)	33 (6)
Yield (L/s)	(264)	0.83 (19)	1.05 (34)	0.62 (89)	1 (51)	0.63 (37)	0.75 (11)	0.5 (23)
Max well depth (m)	(428)	73.2 (27)	48.1 (56)	31 (137)	33.5 (73)	36.6 (76)	40.5 (27)	52.5 (32)
Year of observation		1973	1966	1979	1970	1969	1980	1980

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(725)	23 (163)	23 (169)	24 (177)	9 (65)	9 (65)	11.6 (83)	0.4 (3)
Water cut (m)	(124)	4 (48)	6.5 (30)	22 (23)	45 (4)	42 (9)	83 (8)	92.5 (2)
Max well depth (m)	(717)	13 (160)	17 (166)	60 (175)	74.7 (65)	68.6 (65)	234 (83)	156 (3)
Year of observation		1985	1983	1984	1983	1982	2010	1992

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(459)	46 (212)	20 (92)	14 (65)	8 (38)	12 (52)
Water cut (m)	(76)	25.6 (31)	26 (33)	67 (3)	30 (5)	69 (4)
Max well depth (m)	(454)	44.3 (207)	71 (92)	240 (65)	122 (38)	108 (52)
Year of observation		1980	1983	2010	1983	1983

4.2.10. PARACHILNA



PARACHILNA covers the central Flinders Ranges and includes Wilpena Pound. Major townships include Parachilna in the north-west and Hawker in the south-west (outside the SAAL NRM Region). There are numerous pastoral properties in the area.

Surface Geology

PARACHILNA is dominated by the Adelaide Geosyncline, which is generally well exposed in the Flinders Ranges. They include units from the Burra, Callanna, Umberatana and Wilpena Groups. Some of these rocks are overlain by Arrowie Basin sediments including the Mernmerna and Kulpara Formations and rocks of the Hawker and Lake Frome Groups. Quaternary alluvial and fluvial sediments of the Pooraka Formation and the Avondale Clay blanket the low-lying areas either side of the ranges. Quaternary lacustrine playa sediments are found in Lake Torrens in the north-west of PARACHILNA with a thick band of Quaternary aeolian sediments found to the east of the lake.

Stratigraphy

The Adelaide Geosyncline forms the basement of the majority of PARACHILNA and crops out extensively in the form of the Flinders Ranges (Figs. 3 & 4). Numerous formations of the Callanna, Burra, Umberatana and Wilpena Groups form the basement material. The Curnamona Province bounds the ADELAIDE GEOSYNCLINE along the eastern border of PARACHILNA and the THZ bounds the ADELAIDE GEOSYNCLINE along the western border (Fig. 4). Excluding outcrop or beneath overlying Cambrian sequences, depth to Neoproterozoic basement rocks is up to 249 m with a median of just 12 m.

The Arrowie Basin contains the Hawker and Lake Frome Groups and overlies Neoproterozoic rocks in some areas (Fig. 5). Excluding outcrop, depth to Cambrian sequences is up to 192 m below the surface with a median of 17 m. The thickness of Cambrian units is highly variable, ranging from just 1 m up to 296 m, with a median of 49 m.

The Torrens Basin units, the Cotabena and Neuroodla Formations, are found to the west of the Flinders Ranges, particularly in the north-west of PARACHILNA (Fig. 6). The depth to the basin is between 18 and 300 m below the surface with a median of 35 m. The thickness of the Neuroodla Formation is taken from five wells and is between 18 and 167 m with a median of 145 m. Only two wells have penetrated the full thickness of the Cotabena Formation and recorded a thickness of 95 and 155 m.

The Lake Eyre Basin units, the Namba and Lake Eyre Formations, are found east of the ranges but are absent in the south-east corner of PARACHILNA (Fig. 6). Depth to the Namba Formation is between 4 and 92 m below the surface with a median 32 m and has a thickness of between 12 and 175 m with a median of 71 m. Ten wells fully penetrated the underlying Lake Eyre Formation and recorded a thickness of between 14 and 67 m with a median of 30 m.

The Willawortina Formation is found at the surface in eastern PARACHILNA and has a median thickness of 16 m, but is known to range between 4 and 56 m. Undifferentiated Tertiary and Tertiary–Quaternary-age sequences are found between 2 and 133 m below the surface.

Quaternary sequences are dominated by Pleistocene alluvial/fluvial sediments (Pooraka Formation and Avondale Clay) and Holocene alluvial/fluvial sediments. Pleistocene to Holocene lacustrine/playa sediments are found within Lake Torrens with Pleistocene to Holocene aeolian sediments along the lake’s eastern flank. The thickness of Quaternary sequences is known to range from 0.5 to 146 m with a median of 9 m.

Groundwater Data

Groundwater salinity is quite variable (214–51 850 mg/L) but is generally relatively low (median of ~2100 mg/L). Wells with salinities below 1000 mg/L are generally found through the centre of PARACHILNA in the Flinders Ranges, along its western flank and to the east in the north of the map sheet (Fig. 7). Salinities of varying quality are found throughout PARACHILNA, although there are only three of 447 wells with salinity greater than 20 000 mg/L (Table 14). Quaternary and Tertiary sediments are quite thick to the east and west of the ranges and may be receiving recharge from rainfall runoff as the salinity tends to increase with distance from the ranges. All wells with very low salinity (<400 mg/L) are found within 2 km of a stream and may suggest connectivity of the surface water and groundwater systems.

Depth to groundwater is up to 86 m below the surface but the median is 15 m. Shallow levels are mainly found within the ranges and to their east in the north-east of the map sheet (Fig. 8). Thirty-three wells have a water level at the ground surface. Most of these are either in southern or north-eastern PARACHILNA. Just thirteen of 463 wells have a SWL of more than 50 m below the surface (Table 14). They can be found west of the ranges and across southern and northern PARACHILNA.

Well yields are generally very low (median of 0.5 L/s). There is a well returning a yield of an estimated 30 L/s that is located at a spring in the bed of the Wilpena Creek in eastern PARACHILNA. Of the four other wells with yields greater than 10 L/s, three are located within 1 km of a creek. Wells with yields between 5 and 10 L/s are typically found in areas of Neoproterozoic outcrop (Fig. 9).

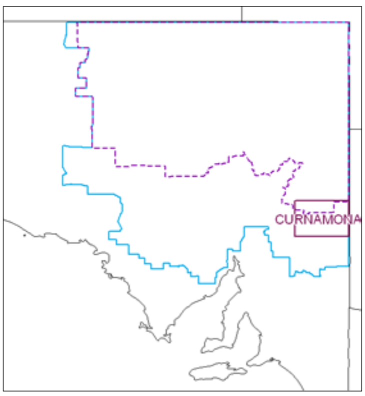
Table 14. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for PARACHILNA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(447)	13 (61)	19 (86)	34 (152)	18 (80)	12 (53)	3 (12)	1 (3)
SWL (m)	(364)	11.1 (42)	12.1 (76)	14 (122)	17.3 (66)	15 (45)	12.8 (10)	18.3 (3)
Water cut (m)	(72)	29 (10)	38 (12)	29 (25)	42 (15)	36.5 (10)	-	-
Yield (L/s)	(325)	0.63 (44)	0.54 (58)	0.5 (120)	0.5 (58)	0.63 (36)	0.51 (7)	0.59 (2)
Max well depth (m)	(375)	49.3 (44)	42.1 (72)	41 (132)	42.8 (68)	47.2 (46)	41.9 (10)	144.8 (3)
Year of observation		1979	1979	1980	1980	1980	1968	1962

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(463)	19 (87)	17 (77)	28 (130)	18 (85)	15 (71)	3 (13)	-
Water cut (m)	(70)	5 (2)	30 (7)	24 (27)	33 (16)	50 (17)	87 (1)	-
Max well depth (m)	(416)	17.1 (68)	27.2 (72)	36 (122)	43.6 (74)	57.4 (68)	76.3 (12)	-
Year of observation		1979	1979	1981	1980	1980	1980	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(398)	73 (291)	20 (80)	3 (13)	3 (9)	1 (5)
Water cut (m)	(84)	33.5 (42)	30 (37)	27 (1)	28 (3)	31 (1)
Max well depth (m)	(366)	43.4 (266)	45.7 (75)	58.5 (12)	44.3 (9)	34.1 (4)
Year of observation		1980	1991	1980	1983	1951

4.2.11. CURNAMONA



The Honeymoon uranium mine is located in the south-east of CURNAMONA within the Yarramba Palaeovalley (Fig. 1). There are a number of other palaeovalleys within CURNAMONA including the Billeroo, Curnamona and Wyambana Palaeovalleys (Fig. 6). The southern extent of Lake Frome sits just inside the northern border of CURNAMONA but is inside the Far North Prescribed Wells Area, as are a number of small lakes to its east.

Surface Geology

The Curnamona Province crops out along the southern border of CURNAMONA. The Willawortina Formation is found in scattered outcrop in the north-west of CURNAMONA. Undifferentiated Tertiary and Tertiary–Quaternary sediments are found throughout northern CURNAMONA. Quaternary alluvial and fluvial sediments (possibly the Pooraka Formation and Avondale Clay) cover most of the southern half of CURNAMONA and some of the north-west. Quaternary aeolian sediments cover the remaining northern areas of CURNAMONA.

Stratigraphy

The Curnamona Province forms the basement of CURNAMONA (Fig. 4). The majority of the Curnamona province within CURNAMONA is comprised of units from the Willyama Supergroup in the Olary Domain. The Ninnerie Supersuite also occurs throughout the domain. In the north of CURNAMONA lies the Benagerie Ridge that consists of Mesoproterozoic-aged sandstone, quartzite and felsic and mafic volcanics (Robertson *et al*. 1998). Excluding outcrop, depth to basement rocks of the Curnamona Province is up to 778 m below the surface with a median of 55 m. On either side of the Benagerie Ridge lies a sub-basin containing undifferentiated Neoproterozoic and Cambrian sediments, the Moorowie Sub-basin to the west and the Yalkalpo Sub-basin to the east (Tonkin 2009). Depth to the rocks within these basins is between 2 and 207 m with a median of 70 m.

The Arrowie Basin occupies the west–north-west and north-east of CURNAMONA (Fig. 5). The basin contains units from the Moralana Supergroup, including the Lake Frome and Hawker Groups. The depth to these units is between 41 and 159 m below the surface with a median of 127 m. Four wells have fully penetrated the basin and recorded thicknesses of up to 100 m.

The Marree Subgroup has been identified throughout the eastern half of CURNAMONA, particularly the north-east. The depth to the unit is between 15 and 150 m below the surface with a median depth to of 94 m. It has a median thickness of 20 m but can be up to 86 m thick.

The Willawortina Formation is found in the south-west, east and south-east of CURNAMONA, often at the surface. Excluding outcrop, the depth to the formation is up to 22 m with a median of 5 m. It varies in thickness from 2 to 74 m and has a median thickness of 21 m.

The Lake Eyre Basin is present across most of CURNAMONA (Fig. 6). Occasionally cropping out, the depth to the basin is up to 100 m below the surface with a median depth to of 15 m. The Namba Formation is up to 130 m thick with a median thickness of 50 m. The underlying Lake Eyre Formation has a median thickness of 30 m but can reach 104 m.

Undifferentiated Tertiary and Tertiary–Quaternary sequences are sometimes found in outcrop but this is predominantly across the northern third of CURNAMONA that is not within the study area. Depth to these sequences is up to 37 m below the surface with the median depth 8 m. The sequences are between 2 and 132 m thick with a median of 44 m.

The Eurinilla Formation is the only Quaternary unit that has been positively identified in stratigraphic logs from CURNAMONA, although the Millyera and Coonarbine Formations have been identified in the CURNAMONA 1:250 000 Geological Explanatory Notes by Callen (1990). The Eurinilla Formation has a thickness of between 2 and 78 m with a median of 18 m. Undifferentiated Quaternary sediments are up to 172 m thick with a median of 9 m.

Groundwater Data

Groundwater salinity within CURNAMONA is extremely variable, ranging between just 243 mg/L to over 200 000 mg/L. Generally, the groundwater is brackish to saline with a median salinity of just over 10 000 mg/L.

Low-salinity groundwater is found in south-western CURNAMONA where basement rocks of the Curnamona Province crop out (Fig. 7). It is also recorded in eastern central CURNAMONA but as no other well data are available it can not be positively linked to a specific hydrogeological unit. In lower north-eastern CURNAMONA a salinity of 622 mg/L was recorded in 1977 from a poor-yielding well (0.06 L/s). No production zone data, water cut depth or stratigraphic log is available but the well has a maximum drilled depth of 122 m. A well with stratigraphic data located 20 m from the well intercepted 90 m of Lake Eyre Basin sediments (Namba and Eyre Formations) overlying 23 m of Cambrian sediments of the Arrowie Basin.

In western CURNAMONA a shallow well (7 m) recorded a salinity of 243 mg/L in 1961. It is located around 30 m from a creek. A deep well (113 m) within 3 km upstream of this well recorded a salinity of 10 800 mg/L in 1928. A well located on the opposite side of the creek between these two wells intercepted 15 m of Quaternary sediments underlain by over 100 m of the Tertiary Namba Formation and Cambrian sediments of the Arrowie Basin. This may suggest the Quaternary sediments are being recharged via rainfall either directly or via stream connectivity.

Three other occurrences of reasonable quality groundwater (1000–1500 mg/L) are found in western CURNAMONA. Quaternary sediments in the area are from 9 to 56 m thick and are underlain by Lake Eyre Basin sediments that have a thickness of between 60 and 100 m. These overlie Arrowie Basin sediments. Unfortunately, the lack of production zone data limits interpretation but it appears Quaternary and deeper sedimentary basins may provide reasonable-quality groundwater. However, recharge and lower-salinity groundwater is location dependent as highly-saline groundwater is found in north-eastern CURNAMONA within the mapped extent of the Yarramba Palaeovalley.

Stratigraphic wells in north-eastern CURNAMONA record thin Quaternary sediments overlying up to 100 m of Lake Eyre Basin sediments underlain by Cretaceous mudstone and clay of the Marree Subgroup. Two wells north of the well identified as open to the Eyre Formation record salinities of nearly 5000 and 17 200 mg/L, with one of theses wells returning a yield of over 11 L/s. Two wells in the same area identified as open to the Cadna-owie Formation have salinities of around 2000 mg/L and yields of about 1 L/s.

A cluster of wells with high salinity found in south-eastern CURNAMONA is likely to be from the Willyama Supergroup of the Curnamona Province. Four wells within this cluster return yields of 8 to 10 L/s. Four wells in this area are screened over the Eyre Formation at depths of 90 to 106 m and record salinities of between 1334 to 11 112 mg/L and yields of 0.5 to 3.75 L/s. Another cluster of wells further east at the Honeymoon uranium deposit is within a mapped extent of the Yarramba Palaeovalley and are accessing the Eyre Formation. Here, the Eyre Formation contains widespread low grade uranium mineralisation (Waterhouse & Beal 1978) and is the focus of the Honeymoon mining operations..

Depth to groundwater can be either very shallow (0.05 m) or quite deep (98 m) but is generally around 40 m below the surface (median depth of 38 m). Shallow depths to groundwater (<10 m) are found in central CURNAMONA towards the north-east, western CURNAMONA and southern CURNAMONA in areas of outcrop of the Curnamona Province (Fig. 8). Deeper levels (>50 m) are found across southern CURNAMONA away from areas of outcrop and central CURNAMONA including within the mapped extents of the Billeroo Palaeovalley. Deep levels are also found in the cluster of wells within the Yarramba Palaeovalley at the Honeymoon site.

Well yields are variable (0.001–28 L/s) but are generally quite low (median of 1.5 L/s). Low yields are found in every area of the map sheet (Fig. 9). Many of the wells at the Honeymoon site return a yield of 5 L/s or more, including the maximum for the map sheet of 28 L/s. Good yields of high-salinity groundwater were also recorded from six wells in the north-east of CURNAMONA located within the mapped extent of the Lake Charles/Yarramba Palaeovalley. Here, yields of between 10 and 20 L/s were recorded in 2009 and 2010 from wells around 100 m deep, where thin Quaternary sediments overlie up to 100 m of the Lake Eyre Basin sediments underlain by the Marree Subgroup.

A well that recorded a yield of 10 L/s in 2008 is located in western CURNAMONA within the mapped extent of the Billeroo Palaeovalley but useful stratigraphic data are not available.

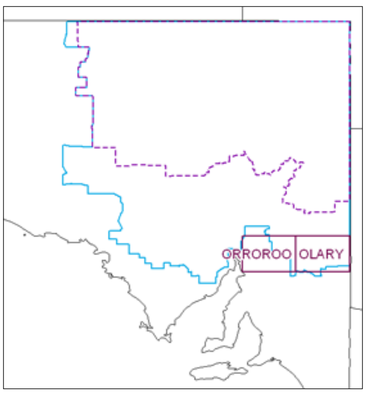
Table 15. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for CURNAMONA

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(331)	2 (7)	3 (10)	8 (27)	10 (34)	26 (86)	41 (136)	10 (31)
SWL (m)	(215)	9.8 (6)	13.8 (8)	11.8 (24)	25.6 (24)	39 (54)	49 (86)	49 (13)
Water cut (m)	(108)	15.5 (2)	57.2 (2)	17.4 (6)	50 (4)	74 (25)	82 (55)	95 (14)
Yield (L/s)	(177)	0.12 (3)	0.73 (4)	0.53 (15)	0.51 (20)	0.63 (45)	2.5 (79)	7 (11)
Max well depth (m)	(314)	30 (6)	34.4 (9)	30.9 (26)	57.8 (32)	91.4 (81)	117(129)	108 (31)
Year of observation		1977	1961	1977	1977	1986	1999	2009

Associated median well data	Total number of wells	Standing Water Level (metres below ground)						
		<5	5–9.99	10–19.99	20–29.99	30–49.99	50–99.99	≥100
%	(264)	6 (15)	9 (24)	18 (49)	12 (31)	28 (74)	27 (71)	-
Water cut (m)	(113)	14.5 (3)	11.9 (3)	31 (15)	58.9 (10)	93.3 (46)	78.6 (36)	-
Max well depth (m)	(256)	64 (15)	17.3 (23)	58.3 (48)	90.8 (31)	119 (74)	116 (65)	-
Year of observation		1986	1977	1977	1980	1998	1988	-

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(291)	36 (106)	29 (83)	16 (46)	13 (39)	6 (17)
Water cut (m)	(119)	56 (53)	79 (23)	83 (13)	94.9 (24)	119.8 (6)
Max well depth (m)	(291)	90.6 (106)	116 (83)	124.5 (46)	125.8 (39)	118 (17)
Year of observation		1979	2001	2009	1999	2008

4.2.12. OLARY AND ORROROO



This summary of OLARY includes the eastern section of ORROROO within the SAAL NRM Region. The small townships of Olary and Yunta are found in the north and west, respectively. The Murray Plain lies south of the Olary Ranges that dominate the map sheets. The White Dam gold mine is located in the north–north-east of OLARY.

Surface Geology

Basement rocks (Willyama Supergroup) of the Curnamona Province crop out through northern OLARY. The Burra, Callanna, Umberatana and Wilpena Groups of the Adelaide Geosyncline crop out extensively throughout OLARY and the adjacent part of ORROROO included in the study area as the Olary Ranges. Small outcrops of the Anabama Granite are found in southern OLARY. Minor outcrops of Tertiary–Quaternary sediments are found in north-eastern OLARY and the Loxton and Parilla Sands are found in the south-east corner of OLARY. Quaternary alluvial and fluvial sediments (possibly the Pooraka Formation and the Avondale Clay) cover most of the low-lying areas of both map sheets with small occurrences of calcrete and lacustrine, playa and aeolian sediments also present.

Stratigraphy

The Curnamona Province forms the basement of OLARY across most of the northern third of the map sheet where it crops out extensively (Fig. 4). Excluding outcrop, the depth to Palaeoproterozoic to Mesoproterozoic basement, primarily the Willyama Supergroup, is generally shallow (2 m) but can be up to 105 m. The basement for the rest of OLARY and all of ORROROO is formed by the Adelaide Geosyncline, which onlaps part of the Curnamona Province where they meet. Depth to basement is as deep as 146 m with a median of 3 m.

The Ordovician age Anabama Granite is found in outcrop in southern OLARY. Excluding outcrop, the known depth to the unit is up to 64 m, with a median of 6 m.

The Murray Basin occupies the south-east corner of OLARY, from the south to the east of the map sheet (Fig. 6). Tertiary sequences of the basin include the Olney Formation, Geera Clay, Bookpurnong Formation and the Parilla and Loxton Sands and are unconformably overlain by the Quaternary Blanchetown Clay. The depth to the Blanchetown Clay is between 2 and 41 m below the surface with a median of 15 m andit is between 5 and 88 m thick with a median of 48 m. The Loxton and Parilla Sands are between 4 and 68 m thick with a median thickness of 29 m. The top of the sands is between 14 and 86 m below the surface with a median depth to of 60 m. The Loxton and Parilla Sands are typically underlain by the Bookpurnong Formation, which ranges between 20 and 77 m in thickness, with a median of 58 m. Depth to the unit is between 39 and 82 m with a median of 51 m. The Geera Clay of the Murray Group typically underlies the Bookpurnong Formation. It has a thickness of between 2 and 87 m with a median of 15 m. The depth to the Murray Group units is between 45 and 135 m below the surface with a median of 95 m. The Murray Group units typically overlie sequences from the Renmark Group, which in OLARY is likely to include the Olney Formation (Rogers *et al.* 1995), although this unit has not been differentiated in stratigraphic records. Renmark Group sequences have a recorded thickness of between 8 and 70 m with a median of 48 m. Depth to the Renmark group is between 56 and 125 m with a median of 70 m.

Outside of the Murray Basin, undifferentiated Tertiary and Quaternary sediments have a median thickness of 9 m but are known to range from 0.2 to 56 m thick. The depth to these sediments can reach 100 m but the median is just 7 m. The Quaternary Pooraka Formation is up to 54 m thick with a median thickness of 10 m. The Eurinilla Formation and the Telford Gravel have also been identified in three wells. Undifferentiated Quaternary sediments have a combined thickness of up to 114 m with a median of just 2 m.

Groundwater Data

Groundwater quality ranges from fresh (117 mg/L) to saline (42 000 mg/L) but is generally brackish (median is nearly 5000 mg/L). Wells with salinity records of more than 20 000 mg/L are found in north-eastern and eastern ORROROO and western, central and eastern OLARY. Salinities of 1500 to 20 000 mg/L are found in all areas of OLARY and the adjoining part of ORROROO included in the study area. Salinities of 1000 to 1500 mg/L are scattered throughout the two map sheets and wells with salinities of less than 1000 mg/L are only common throughout the ranges (Fig. 7).

There is one well in eastern ORROROO that recorded a salinity of 117 mg/L in 1973. No stratigraphic log is available but it is located in an expansive area of Neoproterozoic outcrop of the Adelaide Geosyncline and intercepted groundwater at a depth of 6 m. Stratigraphic wells along a nearby creek recorded 2 to 3 m of Quaternary sediments overlying the Neoproterozoic rocks, thus it is likely to be a fractured rock aquifer within the Neoproterozoic basement material. Anecdotal evidence from a 1973 driller's report states that the water quality from this well is good even in summer.

There are a number of wells with salinities below 1500 mg/L within the Olary Ranges in central and eastern OLARY and western ORROROO. Low-salinity groundwater is also found in the predominantly Palaeoproterozoic to Mesoproterozoic outcrop of the Curnamona Province in northern and eastern OLARY. Neoproterozoic rocks of the Flinders Ranges in northern ORROROO also contain low-salinity groundwater. There are also a number of wells with high salinity within the Curnamona Province outcrop in eastern OLARY.

A number of wells screened over Neoproterozoic sediments record salinities ranging from nearly 1700 mg/L up to 28 300 mg/L. Water levels are quite variable (4–70 m) and yields are low (0.04–1.5 L/s).

There are 24 wells that have recorded groundwater at the surface. These are found throughout the Olary Ranges. Overall, the maximum depth to groundwater is 102 m while the median is 13 m. Shallow water depths (<5 m) are found throughout OLARY and most of ORROROO (Fig. 8). Deep water levels (>50 m) are also found within the ranges but generally along the southern extent and in the east.

High well yields have been recorded (18 L/s) although the majority are poor (median of 0.5 L/s) with low yields found throughout both map sheets. High yields are found in a number of wells in close proximity within eastern OLARY (Fig. 9). The wells are between 60 and 150 m deep with the Palaeoproterozoic Willyama Supergroup of the Curnamona Province overlain by thin Quaternary sediments in this area. Two wells with yields of 10 and 18 L/s are located in central OLARY and are likely to be open to the Neoproterozoic Burra Group.

Table 16. Summary of salinity, standing water level and yield data and the associated median values (with number of data points in brackets) for OLARY and the included section of ORROROO

Associated median well data	Total number of wells	Salinity (mg/L)						
		<1000	1000–1499	1500–2999	3000–4999	5000–9999	10 000–19 999	≥20 000
%	(667)	5 (32)	3 (18)	19 (128)	26 (177)	32 (212)	12 (77)	3 (23)
SWL (m)	(486)	8.8 (24)	7.1 (16)	13.8 (92)	14 (133)	12 (155)	13.2 (52)	26.7 (14)
Water cut (m)	(59)	75 (1)	40 (1)	36 (13)	26 (15)	36.5 (20)	59 (4)	48 (5)
Yield (L/s)	(323)	0.45 (13)	0.45 (7)	0.5 (58)	0.63 (84)	0.5 (110)	0.57 (37)	1.58 (14)
Max well depth (m)	(554)	21.6 (24)	30.9 (16)	35 (100)	34 (142)	36 (184)	39.6 (68)	67 (20)
Year of observation		1977	1977	1977	1977	1977	1976	1982
Associated median well data	**Total number of wells**	**Standing Water Level (metres below ground)**						
		<5	**5–9.99**	**10–19.99**	**20–29.99**	**30–49.99**	**50–99.99**	**≥100**
%	(567)	20 (115)	22 (124)	26 (147)	15 (86)	8.8 (50)	8 (44)	0.2 (1)
Water cut (m)	(55)	25 (4)	14.3 (5)	20 (17)	39 (18)	53 (4)	71 (6)	140 (1)
Max well depth (m)	(523)	16 (104)	19 (114)	30 (135)	46 (80)	56.3 (47)	78.2 (42)	169 (1)
Year of observation		1977	1977	1977	1980	1979	1980	1992

Associated median well data	Total number of wells	Yield (L/s)				
		<1	1–2.99	3–4.99	5–9.99	≥10
%	(383)	65 (250)	27 (102)	5 (17)	2 (9)	1 (5)
Water cut (m)	(65)	38 (37)	23.5 (21)	32 (5)	28.5 (2)	-
Max well depth (m)	(376)	42.4 (246)	35 (99)	45.7 (17)	68 (9)	106 (5)
Year of observation		1979	1983	1986	1987	1983

5. GROUNDWATER RESOURCES

Groundwater resources of the non-prescribed SAAL NRM Region are found in Quaternary, Tertiary, Mesozoic and Palaeozoic sediments, as well as weathered and unweathered fractured rock aquifers of Precambrian age. There are four main aquifer types present in the study area: sedimentary basins, fractured rock, palaeovalleys and surficial aquifers of unconsolidated material generally not exceeding 150 m (AACWMCB 2006b). The region's major stratigraphic units have been summarised in Table 17. Particular attention is paid to stratigraphic units of hydrogeological significance with more detailed descriptions presented in Appendix A.

The density of groundwater data is fairly evenly spread throughout the non-prescribed region, excluding the data poor locations of the major ephemeral lakes and their surrounding areas. The arid lake regions typically represent zones of saline groundwater discharge, where high evaporation rates form dry salt lakes that only fill infrequently.

Although the spatial occurrence of potential aquifers can be derived from stratigraphic logs, groundwater data relating to specific aquifers are often uncertain due to a lack of well construction information such as production zone intervals.

Occurrences of groundwater with salinity of less than 3000 mg/L are predominantly found within the Flinders and Olary Ranges. Moderate salinities are also found in the north-west area of the non-prescribed region north of Lake Gairdner and probably coincide with the south-western extent of the Eromanga Basin of the GAB.

Regional standing water levels indicate that groundwater can be intersected at shallow depth throughout much of the region; however, the depth to groundwater within fractured rock aquifers in the highlands is variable. It can be expected where favourable groundwater resources are encountered at shallow depths, limited drilling to greater depths often results in sparse information and knowledge of deeper aquifer formations.

Wells throughout the study region show yields are predominately less than 1 L/s, which is not likely to accommodate the needs of high-volume groundwater users. However, considerable uncertainty surrounds the estimates of well yields and improved well siting and construction could result in greater yields. This is highlighted by the fact that high-yielding wells can usually be achieved for town water supply or mining operations where attention to well design and construction is of a higher technical standard.

5.1. GAWLER CRATON

Groundwater within the Gawler Craton province occurs in weathered and fractured Precambrian basement rocks. These groundwater resources are not highly utilised and not well understood, with well yields not well reported (AGT 2010). Groundwater salinities range from fresh to hyper-saline but the majority of groundwater in these fractured rock aquifer systems is highly saline. They are characterised by high spatial variability in hydraulic conductivity and there are currently no reliable methods for estimating their sustainable yield. Outside areas of specific investigation by mining companies, little is known about the fractured rock aquifers that tend to be structurally (fault) controlled and spatially variable (AGT 2010).

Where limited exposures exist, recharge to the fractured basement rock and Tertiary palaeovalley aquifers is likely to occur via infiltration of rainfall (GHD 2009); however, recharge is assumed to be minimal because of the highly variable and often infrequent rainfall and high potential evapotranspiration (Martin, Sereda & Clarke 1998).

Groundwater discharge from the Precambrian basement rocks of the Gawler Craton is poorly understood but is likely to occur to the surrounding Tertiary palaeovalley aquifers that, in turn, discharge to the Eucla Basin (Hou *et al.* 2003).

5.2. CURNAMONA PROVINCE

Groundwater supplies in the Curnamona geological province are poorly understood (AGT 2010). Hydrogeological investigations in the area have concentrated on the overlying Lake Eyre Basin sediments, particularly where these infill palaeovalleys incised into basement rock (AGT 2010).

Both low and high-salinity groundwater has been found in the southern Curnamona Province where the Palaeoproterozoic Willyama Supergroup crops out at the surface. Well yields of 8 to 10 L/s have also been found in this area.

Overall, the high salinities and minimal groundwater in the region reflect low rainfall, high evaporation and limited recharge. Recharge occurs during rare high rainfall events and in areas where ponding of significant runoff coincides with effective connection to aquifers (Fabris *et al.* 2008).

5.3. CARIEWERLOO BASIN

Generally, all groundwater in the Pandurra Formation aquifer is too saline for stock supplies. Many wells have been abandoned due to pumping-induced salinity increases from deeper groundwater (Kellet *et al.* 1999). Wells with low to medium-salinity groundwater have been located in northern PORT AUGUSTA along the eastern flank of a large outcrop of the Pandurra Formation at the edge of the Stuart Shelf. However, no production zone data are available and it is unclear whether the groundwater is coming from the Pandurra Formation or the overlying Neoproterozoic rocks of the Stuart Shelf. A yield of 6 L/s was recorded in a well in this area of large outcrop of the Pandurra Formation.

Kellet *et al.* (1999) cites low well yields from the Pandurra Formation, with observations of higher well yields with increasing depth (up to 150 m). However, one of the highest yielding wells (6 L/s), most likely screened in the Pandurra Formation, has a water cut depth of 48 m and is located in central TORRENS where the Pandurra Formation has been intensively silicified and consequently more competent. This may have affected its fracture characteristics (Kellet *et al.* 1999).The Pandurra Formation is likely to be recharged at the southern part of the Stuart Shelf where the unit sub-crops or crops out (BHP Billiton 2009b).

5.4. ADELAIDE GEOSYNCLINE

The quality and quantity of groundwater in the fractured rock of the Adelaide Geosyncline depends on a number of factors, the most important being the degree and extent of joints and fractures, lithology, recharge and the extent of weathering (Martin, Sereda & Clarke 1998). Groundwater is used mainly for stock and for water supplies at Arkaroola, Hawker and Wilpena as well as providing baseflow to waterholes or springs – an important source during dry periods when water is scarce (AACWMB 2006a).

Nearly all groundwaters are suitable for sheep and while potable groundwater exists in most parts of the Flinders Ranges, volumes are generally insufficient for large-scale development (Read 1987). Good quality groundwater is generally more common in the southern, higher rainfall areas (Read 1987). Elsewhere, salinities are generally over 5000 mg/L with many records over 20 000 mg/L.

The best supplies of groundwater within the Ranges occur in porous sandstones such as the ABC Range Quartzite and Elatina Formation and also in limestones such as the Balcanoona Formation (Coats 1973). The ABC Range Quartzite at Mount Bayley Range south of Leigh Creek is capable of yielding 5 to 10 L/s (Read 1984a). In the Northern Flinders Ranges, the highest yields are obtained near faults where most springs occur (AACWMB 2006a); however, the majority of wells are sited in valleys underlain by easily erodible slates and shales and are of shallow depth with low yields that are usually adequate for stock but give little indication of the yields that might be obtained by deeper drilling in more favourable rocks (Read 1987). Some of the best yields have been encountered by deeper mineral exploration drilling but supplies vary widely depending on the number and size of fractures intersected, rock type as well as structural setting. Generally, high yields (~30 L/s) are obtained from limestones and the lowest (<0.1 L/s) from shales and siltstones (Read 1987).

Groundwater within the fractured rock aquifers of the Olary Ranges is relatively fresh and is the main source of water for stock. Groundwater of less than 5000 mg/L can be obtained from sediment-filled watercourses and valleys where the surface water collects and percolates (AACWMB 2006a).

Natural recharge to groundwater within fractured basement rock may occur regionally or along creek lines, however, it is very difficult to predict the quantity of recharge occurring within this type of environment (Martin, Sereda & Clarke 1998).

Discharge most likely also occurs by deeper groundwater flow into the sediments of the Frome Embayment to the east or the Torrens Basin to the west, where sediments overlie the fractured rock aquifers (AGT 2010).

5.5. STUART SHELF

The extensive Tent Hill aquifer forms the main aquifer system over the southern portion of the Stuart Shelf where the overlying Andamooka Limestone aquifer is either absent or very thin (BHP Billiton 2009a). It includes the lower parts of the Arcoona Quartzite and the Corraberra Sandstone members of the Tent Hill Formation (BHP Billiton 2009a). In the Woomera–Arcoona–Andamooka area, the aquifer is unconfined, however, further north-west in the Billa Kalina area, it is confined by the Andamooka Limestone (Kellett *et al.* 1999).

Like all fractured rock aquifers, yields from the Tent Hill aquifer are structurally controlled and highly variable. High well yields have been discovered around Woomera and appear to be located on parallel north-east lineaments that may define significant fracture zones at depth (AAWCMB 2006a). High yields in the vicinity of Olympic Dam are consistent with the inferred alignment of a major structural zone locally referred to as Mashers Fault (BHP Billiton 2009a). Yields from pastoral wells in the Andamooka region are typically less than 0.2 L/s irrespective of depth, but this is likely due to infrastructure differences as most pastoral wells are windmill driven.

Groundwater salinity in the Tent Hill aquifer ranges between 35 000 to more than 100 000 mg/L in the vicinity of Olympic Dam, reaching up to 200 000 mg/L closer to Lake Torrens (BHP Billiton 2009a).

5.6. ARROWIE BASIN

Cambrian limestones have widely-varying permeabilities but good yields can be obtained by deep drilling in zones with well-developed fissuring (Read 1984a). Yields in the Ajax Limestone are known to vary from 30 L/s to 0.5 L/s over a distance of a few kilometres, illustrating how fractured rock aquifers are structurally controlled and spatially variable, (Read 1987).

South-east of Leigh Creek, a Cambrian limestone recorded well yields of 30 L/s from depths of 150 to 200 m (Read 1984a). South of Leigh Creek, high yields were obtained from Cambrian limestones at the western end of a syncline directly east of the Mount Bayley Range. Elsewhere in the syncline only low to moderate yields were obtained. Further south, high yields were obtained from both Cambrian limestones and sandstone at the base of the Parachilna Formation. High yields have also been recorded near Nepabunna.

As part of the Environmental Impact Statement for the proposed Olympic Dam mine expansion, BHP Billiton (2009a) provided groundwater information for the Andamooka Limestone. The formation forms the regional unconfined aquifer to the north of Olympic Dam. It covers an area of approximately 14 500 km^2, extending from around 50 km south and 80 km north-west of Olympic Dam, to around 35 km north of the top of Lake Torrens. South of Olympic Dam the base of the Andamooka Limestone becomes shallower and the aquifer becomes unsaturated. To the north of Olympic Dam the Andamooka Limestone aquifer has a high secondary porosity and permeability that is associated with dissolution features. Recent investigations undertaken by BHP Billiton show high transmissivity and groundwater yields from wells drilled in this area.

Groundwater salinity generally ranges between 20 000 and 60 000 mg/L, increasing to as much as 200 000 mg/L closer to Lake Torrens.

Ultimately, all easterly-flowing groundwater from the southern area of BILLA KALINA discharges into the Andamooka Limestone aquifer, which transmits flow into the two major sinks of the area, Lake Torrens and Olympic Dam. A prominent groundwater divide exists between Andamooka and the Olympic Dam site. Prior to the mine opening, groundwater flowing from the west and south to the area would likely have been deflected at the groundwater divide and discharged into northern Lake Torrens but is currently being intercepted at Olympic Dam (AACWMB 2006a).

5.7. ARCKARINGA BASIN

The Arckaringa Basin aquifers are structurally controlled and discontinuous and are only well understood in areas of specific investigation by mining companies. Beyond these areas, the groundwater supply capacity of the basin is completely untested and no estimates of sustainable yield are available (AGT 2010).

Oz Minerals (2009) observed salinities from the Boorthanna Formation ranging from brackish (~5000 mg/L) to saline (>30,000 mg/L) and currently extractgroundwater at a rate of 17 ML/d.

Inferred groundwater flow in the Boorthanna Formation is to the east with discharge via evaporation west of the GAB springs zone (AGT 2010). A component of flow is believed to move south to discharge to transmissive units of the Stuart Shelf (Oz Minerals 2009; BHP Billiton 2009a).

5.8. EROMANGA BASIN

The entire artesian component of the Eromanga Basin is within the Far North Prescribed Wells Area. Information about the non-artesian aquifers of the GAB is not well documented and is generally limited to specific mining projects. The Department for Water (2012) has reviewed the monitoring needs of the non-artesian section of the basin in response to recent artesian-well capping, mining developments, stock and domestic use and investigation of recharge and groundwater flow.

Groundwater quality in the J-K aquifer is generally good, with salinities ranging between 700 mg/L in the north and north-east to more than 40 000 mg/L in the southwest, but generally between 1000 and 5000 mg/L (Sampson 1996). Groundwater of salinity less than 3000 mg/L occurs in the unconfined Algebuckina Sandstone aquifer around Kingoonya and Glendambo. North of these towns, large parts of the Algebuckina Sandstone contain groundwater between 3000 and 7000 mg/L. The Cadna-owie Formation also contains groundwater of salinity less than 3000 mg/L north of Glendambo. In the

Kingoonya area, groundwater discharges into the Kingoonya Palaeovalley and Lake Harris, where it evaporates or moves westward (Martin, Sereda & Clarke 1998).

The Cadna-owie Formation crops out at Andamooka and provides a small but locally important source of potable groundwater (AACWMB 2006a). Permeability and porosity of the Cadna-owie Formation generally decrease with depth in this area (AACWMB 2006a).

In the south-west of the basin, groundwater is too saline for stock although fresher groundwater can occur after recharge from rainfall as the system is semi-confined to unconfined in this area. However, the saturated thickness of the Algebuckina Sandstone is typically less than 10 m and evapotranspiration can occur from shallow watertables, resulting in salinity increases in poorly flushed sections of the aquifer (SAALNRMB 2009).

The yield and quality of groundwater can vary seasonally because recharge of the aquifer is dependent on episodic rainfall events with groundwater quality and availability falling dramatically during periods of drought (AACWMB 2006a).

Recharge occurs by direct infiltration of rainfall through aquifer outcrop in the Great Dividing Range in central Queensland and lateral flow into the South Australian part of the basin has been estimated at 425 ML/day (Martin, Sereda & Clarke 1998). Minor recharge also occurs around the southern and western margins. The Frome Embayment is recognised as a discharge area for the Eromanga Basin (AACWMB 2006a).

5.9. TORRENS BASIN

The Torrens Basin aquifer is thickest along the flanks of the Flinders and Willouran Ranges south of Parachilna where most of the recharge occurs and groundwater is freshest here (Read 1987; AACWMB 2006a). Salinities within the Torrens Basin range from 800 mg/L near the ranges to 30 000 mg/L near Lake Torrens (AGT 2010). Well yields are variable but generally lie between 0.5 and 2 L/s, although they can be as high as 22 L/s (AACWMB 2006a). Artesian saline groundwater was obtained from the Cotabena Formation at a test well drilled on the eastern shore of Lake Torrens (AGT 2010).

Inferred groundwater flow is from recharge areas in the Flinders Ranges and Stuart Shelf converging to discharge via upward leakage beneath Lake Torrens (AGT 2010).

Martin, Sereda and Clarke (1998) estimated the sustainable yield to be 3600 ML/y from the combined Pirie-Torrens Basin (the Pirie Basin is to the south of Port Augusta, outside the study area). A rough estimate of sustainable yield for the Torrens basin might be 1800 ML/y (AGT 2010). Large supplies of poor quality groundwater may be available from the deeper Cotabena Formation, however, well yields and groundwater quality is largely unknown and the basin’s potential for large volume, poor quality groundwater supplies is untested (AGT 2010).

5.10. LAKE EYRE BASIN

Investigations in the Callabonna Sub-basin of the Lake Eyre Basin by URS (2009) have identified the Eyre Formation as able to yield supplies of moderately saline to very saline groundwater depending on the proximity to recharge sources in adjacent ranges. Well yields range from less than 1 L/s to around 10 L/s (AGT 2010). The salinity close to the Flinders Ranges is around 2500 mg/L (URS 2009) and increases with distance from recharge sources.

The Eyre Formation is also the host aquifer for sedimentary uranium deposits such as Honeymoon, within palaeovalleys in the southern portion of the Callabonna Sub-basin. Salinities between 3000 and 10 000 mg/L have been recorded from wells in the Lake Frome area (Heathgate Resources 1998).

The Lower Namba Formation unit (Alpha Mudstone) is widespread and comprises black clays that confine the Eyre Formation regionally and the Cadna-owie Formation where the Eyre Formation is absent (Heathgate Resources 1998). The Namba Formation is not generally considered a significant aquifer and accordingly, there is no regional quantitative assessment of its hydraulic properties (Heathgate 1998).

Groundwater suitable for stock watering has been intersected in the Tertiary–Quaternary age Willawortina Formation overlying the Namba Formation (Heathgate 1998). Weathered Precambrian metamorphic rocks underlying the Tertiary sequences are not thought to contain groundwater of usable quality or quantity (Waterhouse & Beal 1978).

Discharge from these aquifers is believed to occur via evaporation from salt pans such as Lake Frome and Lake Eyre. The potential for large, poor quality groundwater supplies from the Eyre Basin is untested (AGT 2010).

5.11. MURRAY BASIN

To the south of the Olary Ranges, groundwater can be found in the sediments of the Murray Basin at a depth of about 100 m below ground (AACWMB 2006a). The Lower Renmark Group confined sand aquifer has been developed for stock and domestic supplies only around the basin margin, where it is relatively shallow and contains groundwater that is usually fresher than the sometimes saline groundwater in the overlying limestone aquifer (Rogers *et al.* 1995). Recharge occurs from higher rainfall areas around the basin margin such as the northern Mount Lofty Ranges. Groundwater flows under low hydraulic gradients to the Murray River, which acts as a drain for all three aquifer systems. Salinity increases downgradient, from less than 1000 mg/L in the recharge areas to more than 20 000 mg/L adjacent to the river.

5.12. PALAEOVALLEYS

Palaeovalleys are present in the north-east, north-west and west of the region and have the potential to contain large quantities of often saline groundwater. 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 palaeovalley aquifers, however, the palaeovalley aquifers are not always geographically associated with salt lakes (Martin, Sereda & Clarke 1998).

In the Gawler Ranges region, palaeovalleys could provide a significant source of saline groundwater for use in the mining industry (Martin, Sereda & Clarke 1998). Kingoonya has one of the few satisfactory water supplies in the area, which is derived from a palaeovalley with a salinity of 3010 mg/L (AACWMB 2006a). The Garford Palaeovalley contains saline groundwater with potentially up to 300 000 ML in storage. The Tallaringa Palaeovalley contains an estimated 900 000 ML of groundwater in storage. No estimates of storage have been made for the Narlaby and Thurlga Palaeovalleys to the south. Groundwater quality ranges from around 5000 mg/L to more than 100 000 mg/L and yields are not well known. Anecdotal reports have indicated that some of these groundwaters may be artesian (Martin, Sereda & Clarke 1998).

Over the central and western Frome Embayment margins, the Eyre Formation contains groundwater with salinities of 3000 to 10 000 mg/L that is often used by pastoralists (AACWMB 2006a). At the Honeymoon deposit, which is contained within a palaeochannel between the Olary Ranges and the southern part of the Frome Embayment, the groundwater within the Yarramba palaeovalley deposits is saline and naturally radioactive (Uranium One 2011).

The following overview of recharge to palaeovalley aquifers is largely referenced from a review of palaeovalley groundwater resources in arid and semi-arid Australia (Magee 2009). Direct recharge to palaeovalley aquifers within the SAAL NRM Region is generally regarded as minimal. The Oligocene to Miocene fine-grained lacustrine upper sequence is typically ubiquitous and occupies a larger area of the palaeovalley than the underlying palaeovalley aquifers and as such, direct recharge via rainfall is prevented. Despite the absence of the upper confining unit from most palaeovalleys' upper reaches, unconfined conditions are present along only a small fraction of total palaeovalley length and direct recharge via rainfall is subsequently only a small proportion of total aquifer recharge. The majority of recharge to palaeovalley aquifers is therefore likely to be predominantly via slow vertical and lateral leakage from surrounding saturated weathered bedrock and the overlying upper sequence. Direct rainfall recharge does occur to unconfined palaeovalley calcrete aquifers as they often extend over considerable areas of the palaeovalley and are usually exposed at the ground surface or buried by thin unconsolidated surficial sediments.

5.13. QUATERNARY

Fresh groundwater can be found in shallower unconsolidated sediments such as alluvial fans or stream beds and are generally recharged by localised rainfall. In areas of low rainfall, such as the Gawler Ranges region, there are few such aquifers, but in areas of relatively higher rainfall, such as in the Flinders Ranges, these aquifers are recharged more often and are used extensively by pastoralists in the region (AACWMB 2006b).

Aquifers contained in the Quaternary sediments overlying the Torrens Basin are generally unconfined or semiconfined. As these aquifers are contained within the outwash alluvium along old drainage courses, they are limited in areal extent and groundwater quality is variable with increases from less than 1000 mg/L near the foothills, to more than 40 000 mg/L near Lake TorrensYields from these aquifers vary widely, with yields typically between 0.6 and 2 L/s, however, they can reach 12 L/s where the aquifer is more permeable (Martin, Sereda & Clarke 1998).

In general, there is a poor understanding of recharge to the shallow aquifers and their extent. Most shallow aquifers are recharged by heavy episodic rainfall events, which are infrequent in the arid areas, and excessive use of the aquifers may cause depletion or an increase in salinity (AACWMB 2006b). Local recharge rates are estimated to be up to 5 mm/y in the Kingoonya–Glendambo area and decrease significantly northward, to between 0.1 and 0.3 mm/y in central to northern KINGOONYA (Kellett *et al*. 1999).

Playa lakes act as discharge zones for shallow groundwater flow systems. Groundwater in these shallow systems can be evaporated if the watertable is close enough to the surface, causing them to become highly saline (AACWMB 2006a).

Table 17. Major geological formations of the non-prescribed area of the SAAL NRM Region and their hydrogeological significance

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	Moornaba Sand (Qhem)	Red-orange to pale orange quartz sand, clayey sand; yellow to orange-brown quartz sands; siliceous, off-white sand, grades down into yellow to orange quartz sand, often vertical carbonate pipes; red-brown sandy clay	Overlies: Wintrena and Pooraka Formations, Tertiary sediments and eroded older rocks		KINGOONYA, YARDEA, GAIRDNER, TARCOOLA
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Unconsolidated red-brown clayey sand, silty clay, occasional gravel lenses, carbonate earth, capped in general by soft powdery carbonate and/or nodular calcrete; yellow to reddish brown fluviatile clay-sand; angular cobbles and pebbles; reddish alluvial clay and gravel, calcareous mottling	Overlies: Avondale Clay and Tertiary sediments	Can contain localised shallow aquifers	TARCOOLA, KINGOONYA, GAIRDNER, CHILDARA, YARDEA, ANDAMOOKA, PORT AUGUSTA, WHYALLA, COPLEY, PARACHILNA, OLARY, ORROROO
Cainozoic	Quaternary	Pleistocene	Wintrena Formation (Qpei)	Red-brown, orange-brown, fine to coarse grained sands, clayey and silty in part; often capped by carbonate palaeosol that includes mottled, indurated, massive and nodular calcrete	Overlies: Delisser Formation, Tertiary sediments and basement rocks	Can contain localised shallow aquifers	Great Victoria Desert: ALBERGA, TARCOOLA, BARTON, TALLARINGA, COOBER PEDY, KINGOONYA
Cainozoic	Quaternary	Pleistocene	Avondale Clay (Qpav)	Green to grey clay, ferruginous (red-brown) mottling; sandy clay; locally gypsiferous	Underlies: Pooraka Formation Overlies: Tertiary sediments	Aquitard	ANDAMOOKA, COPLEY, PARACHILNA
Cainozoic	Quaternary	Pleistocene	Delisser Formation (Qped)	Weakly indurated, dull to bright red-brown sand; varying clay, silt and sandy mud; deep reddened calcrete cemented sandstone	Underlies: Wintrena Formation Overlies: Tertiary sediments and basement rocks	Can contain localised shallow aquifers	Great Victoria Desert: ALBERGA, TARCOOLA, TALLARINGA, BARTON, KINGOONYA
Cainozoic	Tertiary	Pliocene	Parilla Sand (Tpp) or Loxton Sand (Tpl)	Pale grey, yellow, brown, orange or pinkish sand, mainly medium grained, varying from fine grained to over 1 mm; conglomerate contains angular fragments of metamorphic and igneous rocks	Underlies: Blanchetown Clay Overlies: Geera Clay	Unsaturated	Murray Basin: south-eastern and southern OLARY
Cainozoic	Tertiary	Miocene	Willawortina Formation (TpQaw)	Sandy mud; silty dolomite, lacustrine, floodplain; coarse framework supported gravel, braided flow origin and matrix supported clayey gravels	Underlies: Quaternary sediments Overlies: Cambrian sediments	Aquifer	COPLEY, PARACHILNA, CURNAMONA
Cainozoic	Tertiary	Miocene	Mirikata Formation (Tmpm)	Dolomite or dolomitic limestone, dolomitic clay; yellow to olive-green and grey clay; fine to coarse-grained sand, usually ferruginised and silicified	Underlies: Quaternary sediments Overlies: Watchie Sandstone	Untested	Billa Kalina Basin: KINGOONYA, ANDAMOOKA
Cainozoic	Tertiary	Miocene	Watchie Sandstone (Tmw)	Basal conglomerate, sand lenses, lower silt to fine-grained sand, upward-coarsening sand; sandstone, quartz and silcrete granules	Underlies: Quaternary sediments Overlies: Willalinchina Formation	Untested	Billa Kalina Basin: KINGOONYA, ANDAMOOKA
Cainozoic	Tertiary	Miocene	Mangatitja Formation (TmQlm)	Limestone, red bed facies, sand, grit, and flood-plain to fan clay	Underlies: Garford Formation Overlies: Pidinga Formation	Palaeovalley aquifer	Hamilton Basin Palaeovalley: eastern ALBERGA
Cainozoic	Tertiary	Miocene	Garford Formation (Tig)	Mudstone, carbonate, stromatolitic, oncolitic and oolitic, gastropods, minor sandstone horizons; vari-coloured well-laminated clay, silt, sand; dolomitic clay; dolostone, limestone; carbonaceous, lignitic	Underlies: Quaternary sediments Overlies: Mangatitja Limestone and Pidinga Formation	Palaeovalley aquifer	Hamilton Basin, Garford, Anthony, Kingoonya and Narlaby Palaeovalleys, eastern BARTON
Cainozoic	Tertiary	Miocene	Namba Formation (Topn)	Sand, silt and clay, thin dolomite and limy, often oolitic, dolomite interbeds; smectite-dominated clay, illite, kaolinite; fine clastics	Underlies: Willawortina Formation Overlies: Eyre Formation	Aquifer	Lake Eyre Basin: PARACHILNA, CURNAMONA Palaeovalleys: CURNAMONA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Tertiary	Oligocene	Neuroodla Formation (Topu)	Green-grey to black, argillaceous claystone and white calcareous mudstone; basal shelly, carbonaceous clay; quartz gravel and pebble layers near the Flinders Ranges	Underlies: Quaternary sediments Overlies: Cotabena Formation, Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: ANDAMOOKA, TORRENS, PORT AUGUSTA, COPLEY, PARACHILNA
			Geera Clay (Tyg)	Clay, variously sandy, silty, pyritic, carbonaceous, micaceous; fossiliferous marine marl in lower part contains calcite, glauconite, fossil fragments	Underlies: Pliocene sands Overlies: Olney Formation	Aquitard	Murray Basin: south-eastern and southern OLARY
		Eocene	Olney Formation (Tro)	Greyish, medium-grained, cross-laminated, clayey sand; contains carbonaceous and clay laminae	Underlies: Geera Clay Overlies: Neoproterozoic rocks	Aquifer	Murray Basin: south-eastern and southern OLARY
			Pidinga Formation (Tbp)	Clayey sands, gravelly sands, quartz sands, silt, clay, silty to sandy clay, siltstone, quartz/pebbly/clayey sandstone, lignite; carbonaceous, gypsiferous and pyritic in parts	Underlies: Garford Formation and Mangatitja Formation Overlies: Basement rocks	Palaeovalley aquifer	Hamilton Basin, Garford, Anthony and Kingoonya Palaeovalleys, topographic lows, TARCOOLA, BARTON, YARDEA
			Cotabena Formation (Teoo)	Partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite; finely laminated silt and carbonaceous mudstone; white clay horizons near base	Underlies: Neuroodla Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: COPLEY, PARACHILNA, PORT AUGUSTA, ANDAMOOKA
		Palaeocene	Eyre Formation (Taee)	Carbonaceous sand with minor clay lenses, fine to very coarse, moderately sorted, sub-rounded to sub-angular, irregularly-shaped grains; pyrite and beds of lignite and clay are common, uranium may be present; polished gravel in basal horizons, pebbles of basement rock in some localities	Underlies: Namba Formation Overlies: Bulldog Shale	Aquifer	Lake Eyre Basin: PARACHILNA, CURNAMONA Palaeovalleys: CURNAMONA
Mesozoic	Cretaceous	Barremian	Bulldog Shale (Kmb)	Dark grey, bioturbated, fossiliferous shaly mudstone or siltstone, slate, micaceous silt to very fine-grained sandstone intervals, carbonaceous matter, pyrite; organic-rich dark shale; micaceous, carbonaceous clay	Underlies: Billa Kalina Basin and Quaternary sediments Overlies: Cadna-owie Formation	Aquitard	Eromanga Basin: TARCOOLA, TALLARINGA, COOBER PEDY, KINGOONYA, ANDAMOOKA, CURNAMONA
		Valanginian	Cadna-owie Formation (Knc)	Siltstone, sandstone, carbonaceous claystone intervals; diamictites, breccia, pebbly layers; calcareous sandstone to shaly mudstone; micaceous siltstone, feldspar grains, quartz granules; hornfels of low-grade basement, porphyry or Cambrian shale and limestone; lonestones around basin margin	Underlies: Bulldog Shale Overlies: Algebuckina Sandstone	Aquifer	Eromanga Basin: KINGOONYA, ANDAMOOKA, CURNAMONA
	Jurassic	Toarcian	Algebuckina Sandstone (JK-a)	Quartzose sandstone, granule and pebble layers with shale intraclasts; gritty or pebbly sandstone with distinctive white kaolinitic matrix, interbeds of finer sandstone, micaceous siltstone and massive mudstone	Underlies: Cadna-owie Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Eromanga Basin: TARCOOLA, TALLARINGA, COOBER PEDY, KINGOONYA, GAIRDNER, ANDAMOOKA
Palaeozoic	Permian	Asselian	Mount Toondina Formation (P-t)	Sandstone; pale grey, friable, fine-grained, micaceous; interbedded with grey, sandy, micaceous mudstone and siltstone with abundant plant fossils; thin coal layers	Overlies: Stuart Range Formation Underlies: Algebuckina Sandstone	Aquifer	Arckaringa Basin: TARCOOLA
			Stuart Range Formation (P-s)	Grey to black carbonaceous mudstone, silty mudstone, commonly altered to green or yellow; occasional siltstone, rare sandstone interbeds; micaceous partings; pyrite	Underlies: Eromanga Basin Overlies: Boorthanna Formation	Aquitard	Arckaringa Basin: TARCOOLA, KINGOONYA Mulgathing Trough: TARCOOLA
			Boorthanna Formation (CP-b)	Quartz sandstone, mostly weakly indurated; silty mudstone to mudstone; pebbles of quartzite, granite, acid volcanics and chert; locally pyritic, silty to sandy claystone; siltstone and sandstone interbeds	Underlies: Stuart Range Formation Overlies: Stuart Shelf, Arrowie and Cariewerloo Basins	Aquifer	Arckaringa Basin: TARCOOLA, KINGOONYA Mulgathing Trough: TARCOOLA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Palaeozoic	Cambrian	Early	Lake Frome Group (Ef)	Sandstone; siltstone; shale; limestone; conglomerate. Includes the Billy Creek Formation, Wirrealpa Limestone, Balcoracana, Pantapinna Sandstone, Grindstone Range Sandstone, Aroona Creek Limestone and Moodlatana Formation	Underlies: Billa Kalina and Eromanga Basin sediments Overlies: Hawker Group	Weathered and fractured rock aquifer	Arrowie Basin: ANDAMOOKA, TORRENS, COPLEY, PARACHILNA, CURNAMONA
Palaeozoic	Cambrian	Early	Hawker Group (Eh)	Limestone, siltstone, shale; lesser sandstone, greywacke, sandstone. Includes the Parachilna Formation, Mernmerna Formation, Woodendinna Dolomite, Ajax Limestone, Andamooka Limestone, Wilkawillina Limestone, Bunkers Sandstone, Moorowie Formation, Midwerta Shale, Nepabunna Siltstone, Narina Greywacke, Wirrapowie Limestone, Bendieuta Formation and Orapinna Shale	Underlies: Lake Frome Group Overlies: Wilpena Group	Weathered and fractured rock aquifer	Arrowie Basin: KINGOONYA, ANDAMOOKA, TORRENS, PORT AUGUSTA, COPLEY, PARACHILNA, CURNAMONA
Proterozoic	Neoproterozoic (Adelaidean)	Marinoan	Wilpena Group (Nw)	Quartzite; siltstone; shale; calcareous in part. Includes the Sandison Subgroup (Brachina Formation, Seacliff Sandstone, Nuccaleena Formation, ABC Range Quartzite), Aruhna Subgroup (Bunyeroo Formation), Pound Subgroup (Bonney Sandstone, Rawnsley Quartzite) and Tent Hill Formation, Uratanna Formation, Wonoka Formation, Ulupa Siltstone, Billy Springs Formation and Yarloo Shale	Underlies: Torrens Basin sediments and Hawker Group Overlies: Umberatana Group, Pandurra Formation and Gawler Craton	Weathered and fractured rock aquifer	Stuart Shelf, Torrens Hinge Zone, Adelaide Geosyncline, platform over Curnamona Province: KINGOONYA, GAIRDNER, OLARY, ANDAMOOKA, CURDIMURKA, TORRENS, PORT AUGUSTA, COPLEY, MARREE, PARACHILNA, CURNAMONA, ORROROO
Proterozoic	Neoproterozoic (Adelaidean)	Sturtian	Umberatana Group (Nu)	Tillite; sandstone; siltstone; arkose; dolomite; quartzite; conglomerate; shale; greywacke. Includes the Yudnamutana Subgroup (Appila, Bolla Bollana and Pualco Tillites, Brighton Limestone, Benda Siltstone, Wilyerpa, Fitton and Lyndhurst Formations, Holowilena Ironstone), Upalinna Subgroup (Angepena, Amberoona, Etina, Sunderland, Wilmington, Yaltipena and Trezona Formations, Enorama Shale, Tarcowie Siltstone), Yerelina Subgroup (Whyalla and Balparana Sandstones, Elatina and Fortress Hill Formations, Pepuarta and Mount Curtis Tillites, Grampus Quartzite, Gumbowie Arkose) and Balcanoona and Tapley Hill Formations	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Stuart Shelf, Torrens Hinge Zone, Adelaide Geosyncline, platform over Curnamona Province: ANDAMOOKA, CURDIMURKA, TORRENS, PORT AUGUSTA, COPLEY, MARREE, PARACHILNA, CURNAMONA, OLARY, ORROROO
Proterozoic	Neoproterozoic (Adelaidean)	Torrensian	Burra Group (Nb)	Siltstone, laminated; shale; sandstone, heavy mineral lamination, quartzose to feldspathic, cross bedding; dolomite, blue-grey to pale pink, lenticular. Includes the Emeroo Subgroup (Humanity Seat and Opaminda Formations, Copley, Yednalue and Wortupa Quartzites, Blue Mine Conglomerate, Rhynie Sandstone, Wirreanda Dolonite Beds, Boucaut Volcanics, Woodnamoka Phyllite), Bungarider Subgroup (Saddleworth and Myrtle Springs Formations), Mundallio Subgroup (Skillogalee Dolomite) and Belair Subgroup	Underlies: Umberatana Group Overlies: Callanna Group	Weathered and fractured rock aquifer	Torrens Hinge Zone, Adelaide Geosyncline, platform over Curnamona Province: ANDAMOOKA, CURDIMURKA, TORRENS, COPLEY, MARREE, PARACHILNA, CURNAMONA, OLARY, ORROROO
Proterozoic	Neoproterozoic (Adelaidean)	Willouran	Callanna Group (Nc)	Siltstone, locally carbonaceous; sandstone, locally stromatolitic, ripple marks, halite casts, heavy mineral lamination; carbonates; evaporites; basalt, minor volcanics. Includes the Arkaroola Subgroup (Wooltana Volcanics, Cutana beds, Wywyana Formation, Paralana Quartzite) and Curdimurka Subgroup (Wirrawilka, Arkaba Hill and Niggly Gap Beds, Kirwan Siltstone, Waraco Limestone, Worumba Dolomite Beds)	Underlies: Burra Group Overlies: Gawler Craton	Weathered and fractured rock aquifer	Torrens Hinge Zone, Adelaide Geosyncline: ANDAMOOKA, CURDIMURKA, TORRENS, COPLEY, MARREE, PARACHILNA, OLARY, ORROROO

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Mesoproterozoic	Stenian	Pitjantjatjara Supersuite (Mp)	Adamellite; alkali granite; diorite, often porphyritic, foliated or even massive	Basement rocks of the Musgrave Block	Weathered and fractured rock aquifer	Musgrave Block: northern ALBERGA
		Calymmian	Birksgate Complex (Mr)	Granite gneiss, granulite and amphibolite facies; altered adjacent to dyke	Basement rocks of the Musgrave Block	Weathered and fractured rock aquifer	Musgrave Block: southern ALBERGA
			Pandurra Formation (M-p)	Arenaceous red bed sediments; medium to coarse-grained, poorly-sorted, sub-angular quartz and lithic sandstone; moderately well-sorted, very fine to medium-grained sandstone, pebble conglomerate and shale	Underlies: Wilpena Group Overlies: Gawler Craton	Weathered and fractured rock aquifer	Cariewerloo Basin: TARCOOLA, KINGOONYA, GAIRDNER, ANDAMOOKA, TORRENS, PORT AUGUSTA
			Hiltaba Suite (Mh)	Massive anorogenic granitoids forming large batholiths and smaller plutons; hornblende-bearing quartz monzodiorite, quartz monzonite and granodiorite; massive dioritic and gabbroic intrusives	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: TARCOOLA, KINGOONYA, GAIRDNER, CHILDARA, YARDEA, STREAKY BAY, ANDAMOOKA
			Gawler Range Volcanics (Ma)	Basalt and andesite to dacite, rhyodacite and rhyolite, variable silica gap between the tholeiitic basalt-andesite series and the felsic series; massive porphyritic dacite and rhyodacite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: TARCOOLA, KINGOONYA, GAIRDNER, CHILDARA, YARDEA, STREAKY BAY, ANDAMOOKA, TORRENS, PORT AUGUSTA
	Palaeoproterozoic	Statherian	Broadview Schist (Lyb) and Myola Volcanics (Lym)	Deformed schist, slaty to phyllitic quartzite, interlayered amphibolites Porphyritic rhyolite and rhyodacite, gneisses and amphibolite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: ANDAMOOKA, TORRENS, PORT AUGUSTA
			Willyama Supergroup (Lw)	Deformed schists and gneisses and minor 'lode' rocks. Includes Ethiudna and Wiperaminga Subgroups of the Curnamona Group and the Saltbush and Mount Howden Subgroups of the Strathearn Group	Basement rocks of the Curnamona Province	Weathered and fractured rock aquifer	Curnamona Province: all of CURNAMONA, northern and north-eastern OLARY
		Orosirian	Donington Suite (Ld)	Quartz gabbronorite, megacrystic granite gneiss, charnockite, granodiorite gneiss, granite gneiss; deformed granite; felsic granite, pegmatite; tonalite, gabbroic anorthosite, granodiorite and quartz monzonite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: ANDAMOOKA, TORRENS, PORT AUGUSTA
			Hutchison Group (Lh)	Massive to flaggy quartzite containing local pelitic schist interbeds; variably graphitic dolomitic marble, banded calcsilicate, recrystallised cherty banded iron formation and pelitic to semi-pelitic schist; interlayered, deformed and recrystallised rhyodacites and calcsilicate gneisses; banded iron formation	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: YARDEA, STREAKY BAY, ANDAMOOKA, PORT AUGUSTA
Archaean			Sleaford Complex (ALs)	Compositionally-banded metasediments, sheets of tholeiitic metabasalt; foliated, medium to coarse-grained granodiorite, mafic xenoliths of hornblende, plagioclase; tabular, perthitic K-feldspar, microcline phenocrysts	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: most of western and southern YARDEA, eastern border of STREAKY BAY
			Mulgathing Complex (ALm)	Granite, gneiss, granodiorite, metasediment and basic dykes	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Gawler Craton: TARCOOLA, COOBER PEDY, BARTON, TALLARINGA, KINGOONYA, GAIRDNER, CHILDARA, ANDAMOOKA

5.14. GROUNDWATER POTENTIAL

Across South Australia, few assessments have addressed regional groundwater storage volumes. The Spencer Region Strategic Water Management Study (Martin, Sereda & Clarke 1998) provided first-order assessments of groundwater storage for a number of geological and groundwater provinces. The available knowledge of shallow groundwater salinity was also used to group groundwater storages by salinity class.

The provinces assessed, which included the Pirie-Torrens and Great Artesian Basins, Gawler Craton, Adelaide Geosyncline and palaeovalley resources (Table 18), do not cover all areas of South Australia and large regions remain devoid of information suitable to conduct a meaningful assessment.

To determine the total storage estimates in the Spencer Region study, data were interpreted from limited drillhole information within each of the individual provinces. Where suitable data were available, the saturated aquifer thickness was determined, providing a representative value to extrapolate for each province. An effective porosity of 10% was used to determine a total resource volume. It is important to recognise that the estimates are only first-order approximations and that more detailed and targeted assessments will be required to refine the estimates of the total resource (Martin, Sereda & Clarke 1998).

These preliminary estimates of total groundwater storages within each province could potentially be an over-estimate and it is likely that they are based on data that lacks a high degree of validation. Additionally, the ability to improve estimates of resource volumes is dependent upon local scale issues including land access, drillhole specification and well and aquifer efficiency. Any estimates should be treated with caution until a more detailed and reliable assessment of groundwater resources can be addressed in subsequent investigations. Should future demand occur within these regions, it is recommended that groundwater resources be evaluated locally in more detail for their supply potential.

Groundwater is available in most locations but is highly variable in quality and quantity. Improved estimates of resource potential should be made based on revised and more detailed knowledge of aquifer formations, their hydrogeological properties and associated water levels.

Sedimentary sequence information (e.g. mean thickness and areal extent) within Quaternary, Tertiary, Mesozoic, Palaeozoic and Proterozoic sequences, can be calculated for a defined region (e.g. 1:100 000 map sheet), or geological feature (e.g. palaeovalleys). As a preliminary assumption, locations of greater sedimentary thickness may have a potential for larger volumes of groundwater storage. However, it is important that this assumption is coupled with the knowledge of groundwater levels to determine saturated thicknesses before estimates of saturated sedimentary thickness and groundwater volume can be derived.

Fractured rock aquifers are far more complex than sedimentary sequences and consequently estimating the capacity of groundwater resources in fractured rock environments requires many simplifying assumptions about porosity and the degree of and depth to which water-bearing fractures extend.

The use of groundwater in non-prescribed regions can be difficult to quantify beyond the knowledge of town water supply volumes. Landowner surveys, land-use maps and satellite imagery can be used to investigate land use practise and estimate the levels of groundwater-dependent irrigation.

Table 18. Summary of total groundwater resources and estimated use (after Martin, Sereda & Clarke 1998)

Groundwater province	Total GW resource* (GL)	Estimated GW use (GL/y)	Comments and additional information
Pirie-Torrens Basin			EP, NY and SAAL NRM Regions. Considers Tertiary and Quaternary sequences only. Potential aquifer sequences include the Tertiary age Kanaka Beds, Melton Limestone, Gibbon Beds and Neuroodla and Cotabena Formation and the Quaternary-age Hindmarsh Clay, Telford Gravel and Pooraka Formation.
Fresh (0–1500 mg/L)	3425	1.4	
Brackish (1500–7 000 mg/L)	9500	0.3	
Saline (>7 000 mg/L)	45 250	-	
Adelaide Geosyncline			SAAL, MLR and NY NRM Regions. Aquifers consist of Neoproterozoic (Adelaidean) metasediments, including the ABC Range Quartzite, Elatina and Balcanoona Formations, overlain by Cambrian limestones and dolomites of the Arrowie Basin. Due to the variable nature of hard/fractured rock aquifers, estimates may be a gross over-estimate.
Fresh (0–1500 mg/L)	200 000	20	
Brackish (1500–7 000 mg/L)	462 500		
Saline (>7 000 mg/L)	650 000		
Palaeovalleys			EP, AW, NY and SAAL NRM Regions. An extensive region of palaeodrainage that drained the Musgrave Block, Stuart and Gawler Ranges exist within the Gawler Craton, Far West and Mid North of the state. They have the potential to contain large quantities of water (albeit of high salinity) and can be of vital importance to the mining industry. Estimates presented in this table are for the whole State.
Fresh (0–1500 mg/L)	-	-	
Brackish (1500–7 000 mg/L)	-	-	
Saline (>7 000 mg/L)	6 000	-	
Great Artesian Basin			The total resource of the GAB is extremely large and estimates vary depending on the number of basins and sub-basins included. A volume of water in storage estimate of 64.9 x 10^6 GL(Far North PWA WAP) is for major, basin-wide GAB aquifers. The South Australian GAB region (comprising entirely Eromanga Basin sediments) is largely within the Far North PWA. The limited occurrence within the non-prescribed areas of the AW and SAAL NRM Regions are at the basin margins where thinner non-artesian aquifers occur; the most significant aquifer is the Algebuckina Sandstone and Cadna-owie Formation, where water quality is generally good.
Fresh (0–1500 mg/L)	4 3500 000	155	
Brackish (1500–7 000 mg/L)	unknown		
Saline (>7 000 mg/L)	unknown		

* Based on a matrix porosity of 0.1.

5.15. *POTENTIAL CLIMATE CHANGE IMPACTS*

Water resources are climate dependent and climate changes may pose future limitations on groundwater resources in the SAAL NRM Region. Climate change impacts and the understanding of its implications will vary across the State; regional water demand and supply plans will undertake regional scale assessments of the impact of climate change where this has not already occurred (Government of South Australia 2009).

Regional climate change scenarios for the SAAL NRM Region have been developed based on statewide climate modelling conducted by the CSIRO Marine and Atmospheric Research Group (Suppiah *et al.* 2006). Projections include:

- an increase in the mean annual temperature of between 0.6–1.5 °C by 2030 and 1.2–4.7 °C by 2070
- changes in mean annual rainfall of between -9 and +1% by 2030 and between -25 and +4% by 2070
- an increase in mean annual evaporation of 1.2–5.8 mm/y, based on data obtained from Woomera
- if CO_2 emissions stabilise, the predicted warming effects and rainfall changes are reduced.

Impacts to the hydrology due to climate change include a reduction in the volume of surface water runoff and groundwater recharge. This problem is likely to be compounded by an enhanced unpredictability in temporal and spatial distribution of rainfall. Predictions of decreased rainfall and increased evapotranspiration due to rising temperatures are expected to impact the groundwater resources by an increase in demand and a reduction in supply source.

The Department for Water is undertaking assessments of groundwater resources that are vulnerable to the impacts of climate change through the *Impacts of Climate Change on Water Resources* (ICCWR) project. Detailed modelling of groundwater resources under various CO_2 emission scenarios is currently being conducted and forecasts made of potential climate change impacts on the rate of rainfall recharge.

6. RECOMMENDED FURTHER INVESTIGATIONS

This initial investigation has collated groundwater information for the SAAL NRM Region and presents a regional description of the non-prescribed groundwater resources. Geological and hydrogeological data have been compiled with particular attention given to the identification of major hydrogeological units and related groundwater information.

Additional assessment of non-prescribed groundwater resources will be addressed in a prioritised manner and structured to allow stakeholders an opportunity to provide feedback on their priority groundwater needs. The 'Phase 2' assessments will be developed to advance the understanding of groundwater resources for areas within the SAAL NRM Region deemed to have a greater short term need for improved knowledge. Areas for further and more detailed assessments in Phase 2 will be defined based on criteria including importance of and proximity to, proposed and projected development activities (e.g. mining or other industrial economic developments), as well as population growth needs. It is anticipated that Phase 2 assessments will involve more detailed desktop analysis of the available information but may need to be supported by targeted field activities to fill information gaps.

The following recommendations are made with a view to guide project planning for future non-prescribed groundwater assessments. Identified key knowledge gaps include groundwater storage volumes, sustainable yield estimates, rates and volumes of groundwater abstraction and processes of groundwater recharge. Better knowledge of these parameters is fundamental to formulating strategies for sustainable groundwater use.

6.1. DATA CAPTURE AND DATA VALIDATION – SA GEODATA

It is recommended that greater attention be focused on groundwater data capture and validation and ensuring that all available historical groundwater data (e.g. microfiche and exploration files) are available via the State geodatabase, SA Geodata. Salinity or water level data that are many decades old may be valuable for analyses of trends in the condition of the groundwater resource. Also, any lengthy time series are useful in calibrating and validating numerical groundwater models. Importantly, archived data not yet entered into SA Geodata may include well construction details that are invaluable as it enables a more robust assessment of groundwater resources by identifying the specific aquifer(s) from which groundwater samples have been taken.

DMITRE's Plan for Accelerated Exploration (PACE 2020) aims to improve the knowledge of groundwater occurrence and water quality by supporting exploration companies through co-funding drilling grants. It is expected that where suitable exploration methods are used, well yield, water cuts and standing water level are recorded and groundwater samples are collected. Following the relinquishment of Mineral Exploration Licenses, DMITRE captures stratigraphic information for inclusion into SA Geodata. A process needs to be implemented to ensure that all drillhole data from mineral exploration activities are captured, which could include groundwater levels, salinity, chemistry, well yields and lithological logs.

6.2. GROUNDWATER MONITORING

Groundwater levels provide important information on the relationships between recharge, discharge, storage and flow directions of groundwater systems. Long term monitoring is essential in the development of groundwater models and to design, implement and monitor the effectiveness of groundwater management programs (Wen 2005).

There are only limited dedicated monitoring well networks established within the non-prescribed SAAL NRM region. Beyond these networks, available regional water well data for most areas (i.e. water level, salinity and yield) are often several decades old. The lack of recent groundwater information does not allow an accurate appraisal of the current groundwater condition and hampers the assessment of the resource potential. Groundwater assessments or investigations that utilise historical data may not always be reliable.

Historically the establishment of groundwater monitoring networks has been to monitor potable water resources. However, the emergence of non-potable groundwater use highlights the importance to understand and monitor these resources so that they can be equitably managed for all potential users.

Other private groups across the region (e.g. mining ventures) may manage networks or groups of wells that actively observe groundwater, but are not under a formal arrangement to have data included into the State database.

In a review of the monitoring requirements for water resources in the Arid Lands, Sibenaler (2010) recommended that a new regional groundwater monitoring network be established for all different geological regions, with at least two wells located in each of the following geological regions: a) the Gawler Craton, b) the Adelaide Geosyncline (Northern Finders Ranges) and c) the Torrens Basin. The establishment of localised networks in groundwater-dependent communities, such as Coober Pedy and Glendambo, to provide baseline information on water level and salinity was also suggested. The small communities of Glendambo and Tarcoola have had historical groundwater investigation wells completed and may have suitable infrastructure to facilitate ongoing monitoring.

Further to this, it is recommended that a regional monitoring program be developed, particularly for non-prescribed areas with a high probability of future development, to enable review of the status of both potable and non-potable groundwater resource. A suitable approach may target a broad network of operational wells for which stratigraphic and production zone information exists.

Recommendations and activities that relate to groundwater monitoring and associated infrastructure requirements will be closely linked with the *Groundwater Program's* Statewide Groundwater and Water Monitoring System project. This is a project that aims to deliver a reliable 'fit for purpose' state groundwater monitoring network that is under regular review with respect to current suitability and future needs.

6.2.1. MONITORED AQUIFERS

As part of this project, the occurrence of individual stratigraphic units of hydrogeological significance were examined and used to develop a hydrogeological discussion around the available groundwater data. For a limited number of suitable wells, available well production zone information was correlated with the associated stratigraphic intervals to indicate the geological interval(s) to which the well is open.

Knowledge of the open-aquifer interval would allow for a more robust analysis of the available groundwater data. Further interpretation of lithological logs to hydrostratigraphic intervals coupled with validation of well production zones would allow an aquifer monitored description to be linked to a greater amount of groundwater observations.

6.3. AQUIFER EXTENT

To determine volumetric estimates of groundwater storages, better definition of the vertical and areal extents of hydrostratigraphic units is required. Refined estimates of aquifer extent would aid in 3-D mapping of groundwater systems (Section 7.9.1.). Furthermore, refining the hydrogeological significance of various geological units could be achieved via the generation of stratigraphic logs from existing lithological logs. However, large areas can be devoid of drillhole information (e.g. within the Officer Basin) and drilling programs would best define the likely areal extent of groundwater resources. Drilling programs are extremely resource intensive and geophysical methods may be favoured where budgetary constraints restrict drilling programs.

6.4. GEOPHYSICAL DATA

Geophysical datasets often provide valuable interpretation of hydrostratigraphic information that could not otherwise be obtained without expensive conventional groundwater investigations. Where paucity of data presents barriers to defining aquifer extent, geophysical methods (e.g. gravity, electromagnetic, shallow seismic) may be the most cost-effective option for filling data gaps. Airborne geophysical techniques can acquire vast amounts of data within a short time frame over complex terrain.

The SAAL NRM Region has numerous existing geophysical datasets collected for mineral exploration and there is a potential to revisit these data and reinterpret from a groundwater perspective. High priority areas for groundwater development may benefit from the use of geophysical surveying to provide an improved knowledge of aquifer formations extents and groundwater salinity distribution.

Magnetic Resonance Sounding provides a qualitative evaluation of sub-surface water content and although in the early stages of application in Australia, this approach promises to be a valuable geophysical tool to aid in groundwater status assessments.

6.5. AQUIFER HYDRAULIC PROPERTIES

Hydraulic properties of an aquifer, such as transmissivity and storage (specific yield or specific storage), can be determined by conducting aquifer tests. Tests targeted at specific hydrostratigraphic units would result in a more robust understanding of groundwater conditions across the SAAL NRM Region. Aquifer testing could be focused on areas where demand for groundwater is likely to be greatest, however, it should be noted that good quality data from aquifer tests are contingent on meeting numerous assumptions, two of which are: (1) The aquifer of interest is the only aquifer that is pumped/observed and (2) the well(s) from which data are collected are screened across the entire thickness of the aquifer. Appropriately constructed wells can indicate the capacity of a groundwater system to supply water in the long term and in a sustainable manner.

6.6. PALAEOVALLEYS

Palaeovalleys are considered to be an important source of groundwater. Such resources already provide supplies to the Honeymoon uranium mine in the region’s east. The lateral extent of palaeovalleys in the SAAL NRM Region has been progressively updated, but very limited groundwater information has been reported. Geoscience Australia’s *Palaeovalley Groundwater Resources in Arid and Semi-Arid Australia* project (Palaeovalley Project), funded by the National Water Commission, has applied and researched new methodologies to investigate these resources, providing an improved basis for evaluating their capacity. Techniques applied to date include aerial and ground geophysical datasets, targeted groundwater sampling and aquifer testing, digital elevation model manipulations and remote sensing imagery to differentiate thermal mass, soil moisture and vegetation indexes. The use of ESRI’s Arc Hydro® groundwater tools have also been adopted, particularly for three-dimensional representations of areas with a high density of data.

The palaeovalleys of the Gawler Craton were included in the Palaeovalley Project conducted by Geoscience Australia. The use of these investigation methods should be considered for the remaining SAAL NRM Region to improve the understanding of these potentially high volume groundwater resources. Initially, additional assessments of existing available data could be completed for the palaeovalleys and first order groundwater resource potential estimates calculated. On ground works, including water sampling, hydrochemical analysis and the pump testing of suitable wells would facilitate a more accurate appraisal.

6.7. FRACTURED ROCK AQUIFERS

Basement or fractured rock aquifers are utilised in a number of areas across the SAAL NRM Region. They are important to the overall groundwater resource capacity of the region but a large knowledge gap exists with regard to their development potential. Little reliable data are available due the existence of shallower resources that limits the drilling of the deeper water wells.

An investigation targeting bedrock aquifers in key areas that includes a field sampling component, would allow greater certainty in the potential of these groundwater resources. The use of hydrochemical data would be important in defining the origin of groundwater and connectivity with other aquifer formations.

6.7.1. BASEMENT INTERPRETATION

A regional definition of depth to basement is a valuable product in the estimation of sedimentary thickness and groundwater storage volumes. A basement map utilising geophysical data including shallow seismic, regional gravity and magnetic data is recommended for the development of more accurate resource assessments.

A valuable related product would be a map of saturated sedimentary thickness. Such a spatial product could be coupled with a distribution map of salinity and a well capacity rating, based on the knowledge of the formation type and well yields. Such a product would require detailed well and groundwater data validation and a program of aquifer testing.

6.8. GROUNDWATER RECHARGE

Recharge to the groundwater system is an important component to the water budget and estimates of recharge are essential to define a resource's capacity to sustain supply over a given time period. Further investigation is required to better understand the magnitude and processes of natural groundwater recharge in non-prescribed areas.

In order to better estimate recharge to unconfined aquifers, the feasibility of regional modelling of recharge using such packages as the WAVES model as used in the Murray-Darling Basin modelling project (Crosbie *et al.* 2008) should be investigated. Estimating rates of rainfall recharge within fractured rock environments is especially challenging. Numerical modelling and/or water balance studies may aid in constraining estimated ranges of recharge to fractured rock aquifers.

CSIRO and Geoscience Australia have recently developed a framework for a nationally consistent approach to estimating recharge and discharge in data poor areas (CSIRO 2011). To generate estimates of recharge, two stand-alone tools required users to populate key inputs fields including rainfall, soil and regolith texture, bedrock type and vegetation. The tools are in the Microsoft Excel® spreadsheet format and recharge and discharge estimates are based on simple approximations with data that are readily available or accessible.

Extending the scope of the Department for Water's *Impacts of Climate Change on Water Resources* project may aid in estimating future recharge rates of the non-prescribed groundwater resources across the SAAL NRM Region, in addition to facilitating the evaluation of climate change impacts on recharge into the future.

6.9. PRODUCTS

To enable easier interpretation of groundwater data, a number of mapping products have been generated by this study. These mapping products will also improve accessibility to groundwater information for key stakeholders and the public. At the conclusion of this study, additional mapping products have been identified that could potentially augment the new products presented here. Also, optimal technologies by which they might be delivered have been explored.

6.9.1. 3-D MAPPING

The petroleum and mining industries are well advanced in using 3-D mapping and visualisation techniques to aid in the assessment of potential reserves of oil or ore. Hydrogeologists in Australia are beginning to take advantage of these technologies to aid in the development of conceptual hydrogeologic models within a virtual 3-D environment. Manipulating and evaluating data within a 3-D environment enables volumetric assessment (e.g. groundwater storage) of the resource in addition to state-of-the-art static visualisation and animation.

6.9.1.1. Arc Hydro®

Arc Hydro® is a geodatabase design and incorporates a suite of accompanying tools tailored for support of water resource assessment applications within ESRI’s ArcGIS® (Geographic Information System, or GIS) environment. Arc Hydro® is compatible with Microsoft Access® and ArcGIS® thereby providing an interface between the State’s stratigraphic database and GIS software. It is expected that the main benefits will be improvements in the way that groundwater data are queried, superior reporting products, 3-D visualisation and capabilities including the calculation of stratigraphic geo-volumes that can be used to develop estimates of groundwater storage.

6.9.2. ONLINE PDF MAPS

The most recent available datasets of groundwater and aquifer formations could be arranged and presented (for download) as high-quality Portable Document Format (PDF) map products. These would deliver the functional advantages of spatial software through a layered information structure. Users (such as industry and community) would be able to toggle layers and annotations on and off, zoom in and out and query groundwater related layers and labels. Such a product could be delivered to the wider audience via the internet and current freeware (Adobe Reader). Any new data or knowledge generated and incorporated into the database can be updated to the PDF products in later iterations of data map productions.

7. CONCLUSION

Surface water and groundwater resources are essential in maintaining the social fabric and economic viability of the SAAL NRM Region. Many townships, pastoral leases and homesteads rely heavily on groundwater for stock and domestic water supplies. The mining industry is also a major user of groundwater within the region and demand is forecast to increase. In response, it has become necessary to improve the knowledge of groundwater resources to improve resource management. The assessments in this report have collated data on hydrogeological formations and groundwater resources to consolidate current knowledge, identify key knowledge gaps, explore the need for further investigations and improve the ability to advise on groundwater development opportunities.

At the regional scale, the SAAL NRM Board predicts drivers of increasing demand for groundwater will be mining activity, livestock numbers and tourism. Changes in the long-term sustainability of groundwater supplies are likely to be influenced by climate change. Based on modelling conducted by CSIRO, impacts of climate change are likely to include increasing temperatures (leading to increasing rates of evaporation) and decreasing rates of rainfall.

Although a discussion of the available groundwater data is presented herein, this body of work does not explicitly identify any new viable resources without further assessment being required. The occurrence of individual stratigraphic units of hydrogeological significance are examined and used to develop a hydrogeological discussion around the available groundwater data. However, much of the groundwater data, due to a lack of supporting well construction information, are unable to be confidently allocated to an aquifer formation. An additional limitation that often precludes confident assessment is data age, which is often numerous decades old. The scarcity of available recent information limits the ability to make reliable estimates.

Groundwater within the Gawler Craton occurs in fractured and weathered Precambrian basement rocks. These groundwater resources are not heavily utilised and not well understood.

Groundwater supplies in the Curnamona geological province are poorly understood. Hydrogeological investigations in the area have concentrated on the overlying Tertiary Lake Eyre Basin sediments, particularly where these infill palaeovalleys incised into basement rock.

Generally, all groundwater in the Pandurra Formation aquifer is too saline for watering livestock but reasonable yields have been reported. This may indicate the Cariewerloo Basin may be more appropriate for supplying mining operations but the hydrogeology of the basin is not well understood.

The major aquifer within the Stuart Shelf province is the Tent Hill aquifer. High well yields have been discovered around Woomera and reasonable yields of saline groundwater have been recorded in fractured rock aquifers underlying the Arcoona Quartzite Member. However, yields are generally low and unpredictable.

The quality and quantity of groundwater in the fractured rock aquifers of the Adelaide Geosyncline depends on a number of factors, the most important being the degree and extent of joints and fractures, lithology, recharge and the extent of weathering. Nearly all groundwater is suitable for sheep and while potable groundwater exists in most parts of the Flinders Ranges, volumes are generally insufficient for large-scale development. Good quality groundwater is generally more common in the southern, higher-rainfall areas or in wells located along creek lines in the northern part of the ranges. Limestones, such as the Balcanoona Formation, commonly supply good quality groundwater. There are also a number of wells with low salinity within the Olary Ranges. Generally, high yields are obtained from limestones and the lowest from shales and siltstones. Best supplies of groundwater within the ranges occur in porous sandstones such as the ABC Range Quartzite and Elatina Formation. The highest yields are obtained near faults where most springs occur, however, wells are mostly sited in valleys underlain by easily erodible slates and shales and are of shallow depth. The low yields obtained by these wells give little indication of the yields that might be obtained by deeper drilling in more favourable rocks.

Low salinity groundwater is found throughout the Cambrian Arrowie Basin that crops out in the northern Flinders Ranges. The Cambrian limestones have widely varying permeabilities with yields known to vary widely over a distance of a few kilometres, although good yields can be obtained by deep drilling in zones with well-developed fissures. The Andamooka Limestone forms an important aquifer in the Olympic Dam area and wells drilled to the north show high transmissivity and yields.

The Arckaringa Basin aquifers are only well understood in areas of specific investigation by mining companies. Beyond these areas, the groundwater supply capacity of the basin is completely untested. Salinities range from brackish to saline with current extraction from the Boorthanna Formation estimated at 17 ML/day.

In the southern Frome Embayment, no groundwater has been intersected in the Quaternary and Tertiary sediments overlying the Eyre Formation and groundwater resources within the weathered Precambrian rocks are considered insignificant. The Eyre Formation is the host aquifer for sedimentary uranium deposits such as Honeymoon, within palaeovalleys in the southern portion of the Frome Embayment. Groundwater in the Eyre Formation is generally of poor quality and the Namba Formation is generally not considered as a significant aquifer. Groundwater with a salinity of less than 10 000 mg/L is mainly restricted to zones of local recharge near the Flinders Ranges and to the Eromanga Basin aquifers.

Groundwater salinities within the Torrens Basin vary from 800 mg/L near the Flinders Ranges to 30 000 mg/L near Lake Torrens. Well yields are variable but generally lie between 0.5 and 2 L/s but can be as high as 22 L/s. An estimate of sustainable yield for the Torrens Basin might be 1800 ML/y of fresh groundwater, however, the basin's potential for large volume, poor-quality groundwater supplies is untested (AGT 2010).

The Eyre Formation in the Lake Eyre Basin can yield supplies of brackish to very saline groundwater depending on the proximity to recharge sources in adjacent ranges. Well yields range from less than 1 L/s to around 10 L/s.

The Lower Renmark Group confined sand aquifer of the Murray Basin is relatively shallow around the basin margins where it contains groundwater that is usually fresher than the sometimes saline groundwater in the overlying limestone aquifer. The Murray Group Limestone is generally unconfined and has been developed for stock, domestic, irrigation and town water supplies because it contains low-salinity groundwater over large areas. The Loxton and Parilla Sands aquifer contains highly saline groundwater. Salinity increases downgradient, from less than 1000 mg/L in the recharge areas such as the Mount Lofty Ranges, to more than 20 000 mg/L adjacent to the River Murray.

Palaeovalleys are present in the north-east, north-west and west of the region and have the potential to contain large quantities of saline groundwater.

Low salinity groundwater can be found in shallower unconsolidated Quaternary sediments such as alluvial fans or stream beds. In areas of low rainfall, such as the Gawler Ranges region, there are few such aquifers, but in areas of relatively higher rainfall, such as in the Flinders Ranges, these aquifers are recharged more often and are used extensively by pastoralists in the region.

This report has identified key knowledge gaps including groundwater storage volumes, sustainable yield, rates and volumes of groundwater abstraction and processes of groundwater recharge. Better knowledge of these parameters is fundamental to formulating strategies for sustainable water use. Consideration of stakeholders needs for groundwater resources and criteria including importance of and proximity to proposed and projected development activities will prioritise areas for further assessment.

APPENDICES

A. SAAL NRM REGION GEOLOGICAL FORMATIONS SUMMARY

More detailed descriptions of the geological formations summarised in Table 18 are presented in this section. Much of the material is extracted from The Geology of South Australia, Bulletin 54, Volumes 1 and 2 (Drexel, Preiss & Parker 1993; Drexel & Preiss 1995) with additional information taken from Callen (1975; 1977), Morris (1977), Morton *et al*. (1984), Flint, Rankin and Fanning (1988), Rankin, Flint and Fanning (1988), Gatehouse and Gravestock (1990), Cowley (1991), Robertson *et al*. (1993), Dodds (1996), Preiss (1999), Conor (2004), Fabris (2004), Rogers and Zang (2006), Chalmers (2007), Curtis (2007), Fabris *et al*. (2008) and Tonkin (2009).

ARCHAEAN TO PALAEOPROTEROZOIC

Mulgathing Complex (ALm)

The Archaean to Palaeoproterozoic Mulgathing Complex occurs on the central and northern Gawler Craton. Outcrop is poor, discontinuous and structurally complex but exceeds 6000 km^2 and is predominantly banded iron formation and quartz and feldspar rich ortho- and paragneisses. The extent of basic and ultrabasic rocks is unknown but believed to be subordinate. The complex contains 11 rock units:

- Christie Gneiss — Archaean to Palaeoproterozoic gneiss with migmatitic layers, paragneiss, carbonate, calcsilicate and quartzite; some banded iron formation
- Kenella Gneiss — Archaean to Palaeoproterozoic gneiss with local pegmatitic separations and possible metavolcanics. Concordant with Christie Gneiss
- Hopeful Hill Basalt — Archaean to Palaeoproterozoic medium to fine-grained metatholeiitic basalt with plagioclase, hornblende and diopside
- South Lake Gabbro — Archaean to Palaeoproterozoic metagabbro with plagioclase and pyroxene
- Lake Harris Komatiite — Archaean to Palaeoproterozoic bright green, illite-tremolite-chlorite-serpentine metabasic rock; green-grey komatiite
- Blackfellow Hill Pyroxenite — Archaean to Palaeoproterozoic gabbro and norite
- Aristarchus Peridotite — Archaean peridotite; pyroxenite; norite and gabbro cumulate. Intruded by tonalite and granodiorite
- Mobella Tonalite — Archaean to Palaeoproterozoic grey, coarse-grained, poorly foliated, plagioclase-quartz-biotite tonalite
- Devils Playground Volcanics — Archaean low metamorphic grade, weakly deformed rhyodacite, andesite and basalt
- Glenloth Granite — Archaean to Palaeoproterozoic pink-brown to grey granite and granodiorite with quartz, microcline and plagioclase and remnants of gneiss and biotite and hornblende schlieren

- Paxton Granite — Palaeoproterozoic coarse-grained slightly K-feldspar porphyritic monzogranite consisting of subequal amounts of quartz and K-feldspar; plagioclase, lesser biotite, hornblende and titanite with accessory magnetite, apatite, zircon and allanite.

Sleaford Complex (ALs)

The Sleaford Complex is composed of the granulite-facies Carnot Gneisses and the mildly deformed, late orogenic Dutton Suite. The Carnot Gneisses are divided into compositionally-banded metasediments, concordant sheets of tholeiitic metabasalt that are interpreted as either volcanic flows, or intrusive sills or dykes tectonically transposed into parallelism with the regional foliation and synorogenic intrusives. The Dutton Suite consists of Coulta Granodiorite, Kiana Granite and other granitoids. The Coulta Granodiorite is grey, foliated, medium to coarse-grained and contains abundant, variably assimilated mafic xenoliths up to 1 m of hornblende and plagioclase with subordinate biotite and quartz. The Kiana Granite is characterised by abundant, tabular, perthitic K-feldspar and microcline phenocrysts up to 50 mm in size.

PALAEOPROTEROZOIC

Hutchison Group (Lh)

The Hutchinson Group is an extensive sequence of shallow clastic and chemical marine sediments, with minor acid and mafic volcanics. A grey, migmatitic granite gneiss, the Miltalie Gneiss, was intruded into the Sleaford Complex and together they form the base of the Hutchison Group. The Hutchison Group has been differentiated into a basal Warrow Quartzite, the Bosanquet Formation, Wilgena Hill Jaspilite and the Middleback Subgroup, which comprises the Burrawing Amphibolite, Katunga Dolomite, Cook Gap Schist and Yadnarie Schist. The most complete sequence of the Hutchison Group occurs in the southern Middleback Range. On YARDEA, the Hutchison Group consists of the Warrow Quartzite overlain by the Middleback Subgroup.

The Warrow Quartzite is a massive to flaggy quartzite containing local pelitic schist interbeds. It is generally massive and feldspathic at its base and grades into micaceous flaggy quartzite and flaggy to massive quartzite interbedded with pelitic schist.

The Middleback Subgroup is a variably graphitic dolomitic marble, banded calcsilicate, recrystallised cherty banded iron formation and pelitic to semi-pelitic schist. The Katunga Dolomite is a white to pale bluish-grey dolomitic marble. It generally grades from a pure dolomite to dolomite interbedded with chert, banded chert interbedded with dolomite. The Yadnarie Schist comprises quartz-veined quartz–feldspar–mica (garnet) schist. The Cook Gap Schist consists of interbanded pelitic and semi-pelitic quartz-veined quartz–feldspar–mica (garnet–sillimanite) schist and gneiss that grade into migmatitic quartz–feldspar–biotite–garnet–sillimanite gneiss. The Burrawing Amphibolite is fine to medium-grained hornblende–plagioclase amphibolite interbedded with banded diopside–hornblende-rich calcsilicate gneiss, with minor calcite, epidote and tremolite.

The Bosanquet Formation is a sequence of interlayered, deformed and recrystallised rhyodacites and calcsilicate gneisses lying structurally above the Middleback Subgroup of the eastern Gawler Craton. The Bosanquet Formation consists of megacrystic, recrystallised and deformed rhyodacite containing relic phenocrysts of coarse-grained microcline and medium-grained, subequant, bluish quartz, with a recrystallised matrix of fine-grained quartz + feldspar + biotite (± muscovite, sphene and zircon). Banded grey-green, medium to coarse grained, granoblastic to granoblastic-elongate calcsilicate gneisses are interlayered with the rhyodacites in bands varying from 0.2 to 20 m thick.

The Wilgena Hill Jaspilite is an extremely fine-grained banded iron formation consisting of very thin laminae or microbands of dark grey to black iron oxide, now predominantly hematite, interlayered with very thin laminae of red chert or jasper. The iron oxide and chert laminae may occur either as individual laminae or as components of variable thickness in predominantly iron-rich or cherty mesobands, commonly 10 to 50 mm thick. The mesobanding produced is variable and strikingly red and black.

Donington Suite (Ld)

In the southern Gawler Craton the Donington Suite intrudes the Hutchison Group. Quartz gabbronorite, megacrystic granite gneiss, charnockite, granodiorite gneiss and granite gneiss are common lithologies within this suite. In addition to a coarse-grained, deformed granite, there are two other distinct lithological groups within the Donington Suite: 1) felsic, medium-grained, equigranular granite and pegmatite and 2) intermediate to mafic lithologies including tonalite, gabbroic anorthosite, granodiorite and quartz monzonite.

St Peter Suite (Lp)

The St Peter Suite consists of a complex of comagmatic intrusive rock types. Five main phases are evident, although their composition and texture greatly vary within isolated exposures and from one exposure to the next (Flint, Rankin & Fanning 1990):

- Pink, fine to medium-grained granite and adamellite grading through to a medium to coarse-grained pink to red granite. Pink to red microcline (<20 mm) is conspicuous.
- Fine to medium-grained and equigranular adamellite to granodiorite commonly is present as dykes. Varieties may contain up to 10% hornblende, enclaves of dolerite/diorite are common, and magmatic banding is conspicuous along the margins of some dykes.
- Medium-grained, porphyritic adamellite to granodiorite with abundant orthoclase and plagioclase phenocrysts. Enclaves of dolerite/diorite are common.
- Dolerite, diorite and amphibolite are fine to medium-grained and chiefly consist of pyroxene, hornblende and plagioclase. Lamprophyre dykes that contain euhedral hornblende crystals (<15 mm) are present.
- Pink medium-grained porphyritic granite containing conspicuous pale pink microcline phenocrysts up to 15 mm.

Tunkillia Suite (Ln)

The Tunkillia Suite represents a suite of comagmatic late Palaeoproterozoic, I-type intrusives and rhyolite, mafic and aplite dykes. Six main lithologies have been delineated:

- Orthogneiss (Ln1) – variety of coarse-grained, megacrystic granites to augen gneisses ranging in composition from granite (K–feldspar dominant) to quartz syenite
- Granite (Ln2) – variably deformed, grey to pink, medium to coarse-grained, adamellite, quartz syenite to granodiorite with K-feldspar and plagioclase common
- Mylonite (Ln3) – narrow (up to 3 m wide) mylonite zones are observed within precursor granitoids, aplite and rhyolite dykes
- Mafic dykes (Ln4) – thin (<10 m wide) dykes of fine to coarse-grained amphibolite intrude units Ln1 and Ln2; the rock has a characteristic dark green crystalline appearance
- Rhyolite, rhyodacite dykes (Ln5) – deformed, porphyritic rhyolite dykes intrude granite gneiss (Ln2) southwest of Childara Outstation

- Aplite Dykes (Ln6) – north of Fyne Dam, narrow (up to 0.2 m wide) aplite dykes comprising quartz and feldspar with minor muscovite, intrude coarse-grained augen gneiss and granite (Ln1 and Ln2); off-white, felsic crystalline rock with a moderately strong foliation occurs as scattered float.

Myola Volcanics (Lym) and Broadview Schist (Lyb)

These units crop out east of the Middleback Range and consist of deformed acid volcanics and fine-grained gneisses, schists and quartzites metamorphosed to upper greenschist to lower amphibolite facies. Stratigraphic relationships between the schists and acid volcanics are unknown since there are no exposed contacts or reliable sedimentary structures; the volcanics may overlie, underlie or be interbedded with the metasediments.

At their type locality, the Myola Volcanics comprise interbanded porphyritic rhyolite, rhyodacitc, fine-grained felsic and hornblende-bearing gneisses and fine-grained amphibolite. Between exposures of Myola Volcanics and the southern Middleback Range, the Broadview Schist comprises fine-grained slaty to phyllitic quartz-muscovite schist, thin-bedded fine-grained quartzite and amphibolite.

Mount Painter Inlier

The Mount Painter Inlier consists of a thick (at least 6100 m) metasedimentary sequence, the Radium Creek Metamorphics. The units comprising the Radium Creek Metamorphics on COPLEY are the Mount Adams Quartzite, Pepegoona Porphyry, Brindana Schist and Freeling Heights Quartzite. The uppermost unit, the Freeling Heights Quartzite, is a largely arenaceous sequence consisting of upper and lower unnamed quartzite members separated by arenaceous, mica and corundum schists of the Corundum Creek Schist Member.

Willyama Supergroup (Lw)

The late Palaeoproterozoic metasedimentary and metavolcanic rocks of the Willyama Supergroup of the southern Curnamona Province are the remnants of a basin of unknown original extent. The lower parts of the Willyama Supergroup are psammite to psammopelite dominated, and the upper parts are more pelitic. The Olary Domain (OLD) and the Broken Hill Domain (BHD) are the two major components of the Curnamona Province. In the Olary Domain the Willyama Supergroup is divided into the lower Curnamona Group and upper Strathearn Group.

The Curnamona Group are the oldest known rocks of the Willyama Supergroup and is currently subdivided into the lower Wiperaminga Subgroup and the upper Ethiudna Subgroup. The Wiperaminga Subgroup is comprised of quartzofeldspathic rocks, schistose metasediments and migmatites. It can be broadly subdivided into albitised and non-albitised metasediment-dominated assemblages that have been named the George Mine Formation and Tommie Wattie Formation, respectively. A third unit is the Mooleugore Formation.

The George Mine Formation is characterised by numerous layers of leucocratic, foliated or massive to thickly layered albite–quartz granofels that is generally interlayered with migmatitic schist. The George Mine Formation is distinguished from the Tommie Wattie and Mooleugore Formations by high component of quartz-albitite layers.

The Tommie Wattie Formation comprises a thick, fining-upwards metasedimentary succession. Dark grey to brown psammopelites show well defined sedimentary layering, and clean pale brown metasandstones locally exhibit well preserved sedimentary structures that include graded bedding, cross-bedding, ripples, ball and pillow structures, and water escape structures.

The Mooleugore Formation underlies the calcareous metasediments assigned to the Ethiudna Subgroup in the Telechie Valley area. The package typically comprises dark grey, fine-grained, biotite-bearing psammopelitic metasediments containing distinct clean, fine-grained quartzites, which locally grade into quartz-albitite. Where unaltered, the quartzites locally preserve cross-bedding, and are sporadically epidote-bearing.

The Ethiudna Subgroup overlies the Wiperaminga Subgroup and though lithologically diverse, is characterised by calc-silicate minerals and local pyrite-dominated mineralisation. The Ethiudna Subgroup includes the Peryhumuck, Whey-Whey and Bimba Formation, extrusive units of the Basso Suite as well as volcaniclastic metasediments and possibly sub-volcanic granite intrusives.

The Peryhumuck Formation is dark grey, well laminated, rather fine-grained, albite–quartz metasediment. Shallow water, sedimentary structures such as ripples, ripple crossbeds and flaser bedding are locally preserved.

The largely pelitic facies of the Ethiudna Subgroup west of Olary is referred to as the Whey-Whey Formation. Here the basal unit of the Ethiudna Subgroup is a discontinuous calc-silicate comprising a lower psammopelite-psammite unit and an upper bedded pelite. A psammitic unit of the Bimba Formation overlies the Whey-Whey Formation, which is about 200 m thick.

The Bimba Formation is the basal unit of the Saltbush Group, which apparently lies unconformably upon the Curnamona Group. The Bimba Formation ranges from 1 to 50 m thick and, although dominantly psammitic, is characterised by carbonate and calc-silicate rich sections showing obvious bedding. The unit is anomalous in base metals and typically pyrite-pyrrhotite rich, locally containing lenses of massive sulphide up to a few metres thick.

The Basso Suite is believed to have mantle affinities, comprises felsic intrusives and volcanics and possibly coeval mafic volcanics and is contemporary with Curnamona Group sedimentation. The Ameroo Subsuite contains metagranites that are coarsely crystalline and commonly occur as thick sills. The Abminga Subsuite contains extrusives, possible thin volcanic sills and proximal volcaniclastics. The Lady Louise Suite is represented by partly differentiated amphibolite-granite sills.

The Strathearn Group is widely distributed in the Olary Domain, especially in the northern part of the outcropping region and bordering the Benagerie Ridge. It is judged to be several hundred metres in thickness in the northern Curnamona Province. The base of the Strathearn Group is here taken as the top of the Bimba Formation as explained by Conor (2004).

Overlying the Bimba Formation at the top of the Curnamona Group is a thin volcaniclastic unit called the Plumbago Formation. The Plumbago Formation is friable, medium to dark grey and fine-grained. It primarily consists of biotite–quartz–feldspar, but with minor graphite and accessory zircon. The Plumbago Formation appears to grade upwards from fine-grained psammopelite to merge into the basal graphite-rich aluminous pelite units of the overlying Saltbush and Mount Howden Subgroups. The Plumbago Formation has been observed to vary from 5 to 40 m thick, although its top is gradational and somewhat arbitrary.

The Oonartra Creek Formation of the Saltbush Subgroup includes all Broken Hill Group-type lithological packages above the Plumbago Formation. The base of the Oonartra Creek Formation in the northern Olary Ranges area is distinctly graphitic and grades downwards into a thin graphitic psammitic unit that is equated with the Plumbago Formation, and this overlies calc-silicates of the Bimba Formation.

The main lithology of the Saltbush Subgroup’s Walparuta Formation is bedded pelite to psammopelite with variable distribution of generally thin psammite layers. Calc-silicate nodules have been observed locally and fibrolite and andalusite are both locally common, as is tourmaline. Fe–Mn garnet is a common accessory mineral, especially in the more psammitic parts.

The Mount Howden Subgroup is the youngest of the Curnamona Group and includes the Alconie, Mooleulooloo and Dayanna Formations. The Alconie Formation comprises a lower aluminous pelite unit and an upper dark grey, fine-grained, graphitic psammopelite. The basal unit is andalusite-rich and famous for large chiastolite porphyroblasts (howdenite or "priests' turds"). Where the Alconie Formation has been observed, its interface with the underlying Plumbago Formation is gradational. Poor outcrop prevents description of a dark grey calc-silicate lens, but it appears to be within the upper psammopelite. The Mooleulooloo Formation is a thinly interlayered albitic psammites and brown mica schist. The psammites are commonly cross-bedded. Locally there are siliceous concretions. The Dayanna Formation is a pale grey silky, andalusite and staurolite-bearing schist.

MESOPROTEROZOIC

Gawler Range Volcanics (Ma)

The GRV consist predominantly of felsic dacite-rhyodacite-rhyolite assemblages of pyroclastic rocks. Two main subdivisions of the GRV are recognised. The lower GRV consist of variable assemblages ranging in composition from basalt and andesite to dacite, rhyodacite and rhyolite with a variable silica gap between the tholeiitic basalt-andesite series and the felsic series. These rocks are overlain by the upper GRV, represented by flat-lying sheets of massive porphyritic dacite and rhyodacite that are very extensive in the central portion of the province. The lower GRV show significant regional variations in lithological associations. The layered volcanics were intruded by co-magmatic felsic dykes, and by later granites and adamellites of the Hiltaba Suite.

Hiltaba Suite (Mh)

Massive anorogenic granitoids forming large batholiths and smaller plutons in the Gawler Craton are collectively termed the Hiltaba Suite. Included within the suite are the Charleston Granite, Tickera Granite, Calca Granite, Roxby Downs Granite, Balta Granite and numerous unnamed granites. Compositionally, granites predominate but the suite is bimodal. Mafic lithologies, for example, hornblende-bearing quartz monzodiorite, quartz monzonite and granodiorite, occur in the Olympic Dam, Andamooka and Kingoonya areas. Massive dioritic and gabbroic intrusives occur elsewhere. Felsic lithologies are chiefly granite and lesser adamellite, aplite and pegmatite. Granite in the Gawler Ranges in north-western YARDEA is typical for much of the Hiltaba Suite. Its colour is a distinctive red due to abundant minute iron oxide inclusions within plagioclase and K-feldspars. Perthitic orthoclase and microcline are abundant and exhibit a well-developed granophyric texture with quartz. Plagioclase is a relatively minor constituent while chloritised biotite, apatite and fluorite are common accessory minerals. Miarolitic cavities contain quartz, haematite and feldspar.

Pandurra Formation (M-p)

The Pandurra Formation is a thick, monotonous unit of unmetamorphosed, flat-lying, arenaceous red bed sediments. It is younger than the underlying GRV and Hiltaba Suite granitoids and is intruded by the Neoproterozoic-aged Gairdner Dolerite. The formation is typically a medium to coarse-grained, poorly sorted, sub-angular quartz and lithic sandstone but also includes moderately well-sorted, very fine to medium-grained sandstone, pebble conglomerate and shale. The red, red-brown or purple matrix of kaolinite, ochreous haematite and minor illite has generally undergone some reduction of the ferric iron content and displays spotting or mottling in grey or white. Interbeds of laminated, red-brown or purple shale and siltstone (with yellow or green reduction spots) occur mainly in the lower part of the formation. The framework of the Pandurra is remarkably consistent basin wide and comprises sub-rounded to sub-angular quartz. With minor to common amounts of altered K-feldspar, chert, ferruginous chert, ironstone, muscovite and acid volcanics indicating derivation largely from the GRV.

Pitjantjatjara Supersuite (Mp)

The Pitjantjatjara Supersuite includes widespread felsic, mainly adamellitic, plutons emplaced dominantly in the Fregon Subdomain and range greatly in composition from alkali granite to diorite. The hydrous and oxidation states vary so that orthopyroxene, clinopyroxene, hornblende or biotite may be locally dominant.

Birksgate Complex (Mr)

Rocks of the Birksgate Complex are dominant throughout the Fregon Subdomain of the Musgrave Block and are predominantly made up of Mesoproterozoic gneisses. Although the contribution of the various minerals varies greatly in different areas and lithologies, a broad regional pattern has emerged. The Tomkinson, Mann and Musgrave Ranges form a core characterised by granulite-facies rocks that pass southwards and eastwards into lower grade amphibolite-facies rocks. Hornblende-bearing granulites are distributed across the central and southern portions of the subdomain.

NEOPROTEROZOIC

Warrina Supergroup

Callanna Group (Nc)

The Callanna Group contains the oldest (Willouran age) rocks of the Adelaide Geosyncline, which have been subdivided into the Arkaroola and Curdimurka Subgroups. Much of the Callanna Group occurs in a disrupted state in the Flinders and Willouran Ranges, commonly within diapiric structures. The Callanna Group consists of partially to wholly disrupted sedimentary and minor volcanic rocks preserved in diapirs and anticlinal cores. The Arkaroola Subgroup unconformably overlies pre-Adelaidean basement in the Mount Painter region and in the Peake and Denison Inliers (within the Far North PWA).

The Arkaroola Subgroup comprises basal clastics, a middle carbonate unit and mafic volcanics at the top. Units present within the study area include the Cutana Beds, Paralana Quartzite (and Shanahan Conglomerate Member), Wywyana Formation, Wooltana Volcanics, Black Knob Marble and Noranda Volcanics. The Curdimurka Subgroup is inferred to overlie the Arkaroola Subgroup and consists of a very thick (up to 6 km), mixed clastic-carbonate evaporitic unit. Sequences within this unit in the study area include the Doe Sandstone, Rook Tuff, Dunns Mine Limestone, Wirrawilka Beds, Recovery Formation, Niggly Gap Beds, Cooranna Formation, Hogan Dolomite, Arkaba Hill Beds, Boorloo Siltstone, Kirwan Siltstone, Waraco Limestone, and Worumba Dolomite Beds.

The Burra Group (Nb)

The Burra Group is the first major sedimentary succession that is widely preserved and exposed in the Adelaide Geosyncline and has an area of deposition greater than the Callanna Group. The Burra Group oversteps the Callanna Group onto basement in the Adelaide and Olary regions. The Emeroo Subgroup is a clastic-dominated sequence at the base of the Burra Group. In the northeastern Flinders Ranges, the Emeroo Subgroup comprises, at the base, pebbly quartzite with halite casts and heavy mineral laminations of the Humanity Seat Formation, interfingering with the Woodnamoka Phyllite west of the Paralana Fault. These units are overlain by the arkosic Blue Mine Conglomerate, followed by dolomitic and silty Opaminda Formation and the Wortupa Quartzite. The Mundallio Subgroup, comprising the Skillogalee Dolomite and equivalent formations, is a carbonate-dominated sequence characterised by sedimentary magnesite. The uppermost part of the Burra Group is the Belair Subgroup.

Heysen Supergroup

The glacial, interglacial and post-glacial sediments of the Umberatana and Wilpena Groups of the Heysen Supergroup are present on the Stuart Shelf

Umberatana Group (Nu)

In many sections of the Umberatana Group, diamictite dominates but a number of other facies are present, including well-sorted quartzose sandstone, lithic and feldspathic sandstone, conglomerate and laminated siltstone. The oldest beds, occurring in the north-eastern Flinders Ranges, are the Fitton Formation and its basal granite conglomerate Hamilton Creek Member. The Fitton Formation is mostly a bedded dropstone-bearing metasiltstone and minor metasandstone and calc-silicate, and passes up into massive diamictite of the Bolla Bollana Tillite. Equivalent diamictite units are the thick Pualco Tillite south of Lake Frome and thinner shelf successions such as the Appila and Sturt Tillites.

In the Baratta Trough, the Pualco Tillite passes up into the laminated Benda Siltstone, a unit apparently not represented in the shelf environments. The magnetitic Braemar Ironstone facies is characteristic of the Benda Siltstone and Pualco Tillite, and has an equivalent in the haematitic siltstone of the Holowilena Ironstone. The Wilyerpa Formation is separated from the Benda Siltstone and Pualco Tillite by a disconformity to angular unconformity, and constitutes a separate sequence. However, the Wilyerpa Formation gradationally overlies and partly intertongues with the Appila Tillite in a more condensed stratigraphy of the shelf regions.

The Nepouie Subgroup is of late Sturtian age and contains the laminated, carbonaceous and calcareous siltstone of the Tapley Hill Formation that is one of the most persistent facies in the Adelaide Geosyncline. The Brighton Limestone represents the culmination of upward shallowing at the top of the Nepouie Subgroup and comprises high-energy ooid grainstone with interfingering stromatolitic bioherms.

The Upalinna Subgroup is of earliest Marinoan age. In the shallow-water western marginal zone, the basal transgressive unit is a tepee-bearing dolomite, previously considered as the upper member of the Brighton Limestone, that grades upward into rippled and mudcracked red siltstone and sandstone of the Angepena Formation. In the deeper basin to the east, the base is marked by the basal Cox Sandstone Member of the flaser-bedded Tarcowie Siltstone. In the Central Flinders Zone, the sandy, oolitic and stromatolitic limestones of the Etina Formation intertongue with Angepena Formation to the west and Tarcowie siltstone to the southeast. The Etina Formation also gradationally overlies laminated siltstone of the Sunderland Formation. The upper Upalinna Subgroup includes the Enorama Shale, Waukaringa Siltstone and Amberoona Formation. The Enorama Shale shallows up into stromatolitic and intraclastic carbonates of the Trezona Formation and then, locally in the Central Flinders Zone, the clastic Yaltipena Formation.

The Yerelina Subgroup is mostly glaciomarine. The sandstone-dominated Elatina Formation consists largely of glacial outwash with local lenses of diamictite. The deeper basin areas of the Nackara Arc and North Flinders Zone contain marine laminated siltstone of the Fortress Hill Formation, culminating in sparsely pebbly diamictite of the Mount Curtis and Pepuarta Tillites and a return to dropstone facies in the Ketchowla Siltstone.

Wilpena Group (Nw)

The Wilpena Group is the youngest subdivision of the Adelaide Geosyncline and consists of two major overall upward-shallowing sedimentary cycles. The Sandison Subgroup records the major mid-Marinoan post-glacial transgression. The Nuccaleena Formation is the “cap dolomite” generally found at the base of the Wilpena Group, overlying a disconformity to very low angle unconformity. The deepest level of erosion on this sequence boundary is in the northern Flinders Ranges, where any Ketchowla Siltstone that may have been deposited has been completely removed, and the dolomite directly overlies sandstone or diamictite. Incised valleys are filled with arenaceous and silty sediments of the Seacliff Sandstone, which interfingers with the Nuccaleena Formation. A thin, very fine-grained shale commonly found at the top of the formation grades up into the Brachina Formation, commencing with siltstone with thin event bed sandstones (Moolooloo Siltstone Member) followed by rippled and cross-laminated silts and sands of the Moorillah Siltstone Member. The Bayley Range Siltstone Member records a slight deepening and finally shallowing into the clean sandstones with cross-beds, ripples and mudcracks of the ABC Range Quartzite. The upper of the two major upward shallowing cycles of the Wilpena Group is separated from the Sandison Subgroup by a persistent erosional surface. The sequence-set includes at its top the Pound Subgroup overlying the Bunyeroo and Wonoka Formations. The Bunyeroo Formation commences with poorly sorted gritty sandstone of the Wilcolo Sandstone Member. The sandstone rapidly grades up to or is sharply overlain by deepwater red mudstone with minor green and dark grey organic-rich intercalations. The approximately 700 m thick Wonoka Formation consists of calcareous siltstone, silty and fine sandy limestone and minor sandstone; it abruptly but conformably overlies the Bunyeroo Formation.

The Pound Subgroup comprises the Bonney Sandstone and Rawnsley Quartzite. The Bonney Sandstone consists of cyclic, mostly red, fine to medium-grained silty sandstone and siltstone. The Rawnsley Quartzite is largely white, well-washed medium-grained sandstone. The basal Chace Quartzite Member sharply overlies the Bonney Sandstone and is itself cut by large erosional channels filled with a transgressive-regressive marine sequence, the Ediacara Member, famous for its contained metazoan fossil assemblage.

CAMBRIAN

Moralana Supergroup (Eo)

Cambrian sedimentation in the Adelaide Geosyncline is referred to two separate preservational basins – the Stansbury Basin in the south and Arrowie Basin in the north, although some interconnection during sedimentation is likely. The Moralana Supergroup encompasses all Cambrian sediments of the Adelaide Geosyncline; in the Arrowie Basin this comprises the Early Cambrian Hawker Group and two ungrouped formations, and the mostly Middle Cambrian Lake Frome Group.

Uratanna Formation (Eot)

The Uratanna Formation disconformably overlies Rawnsley Quartzite as erosional channel-fill up to 100 m thick southwest and west of the Wirrealpa Hill Hinge (WHH; Fig. 5). It comprises mudclast-rich, medium-grained to pebbly quartz sandstone. More widespread green siltstone and shale with thin, mud-cracked sandstone and limestone interbeds comprise middle and upper members up to 500 m thick north of the WHH. Where Uratanna Formation is absent, siliciclastics of the Parachilna Formation disconformably overlie Rawnsley Quartzite and, in the absence of both units, younger carbonates onlap elevated Pound Subgroup locally, south of the WHH.

Hawker Group (Eh)

The Hawker Group is a carbonate-dominated succession of three depositional sequences of Early Cambrian age that overlies a major disconformity surface above the Wilpena Group throughout the Flinders Ranges. The Parachilna Formation is widespread and has a maximum known thickness of 570 m at the top of the central Flinders zone. The formation is an upward-fining suite of sandstone and siltstone with minor carbonate interbeds. 'Pipe rock' typifies basal units due to numerous U-shaped worm burrows. Ripple marks, thin brown shale laminae and desiccation cracks are common in the lower, bioturbated beds.

The Ajax and Wilkawillina Limestones conformably overlie the Parachilna Formation south of the WHH, commencing a phase of extensive carbonate sedimentation. Basal beds, 25 to 100 m thick, are stromatolitic and oolitic with stringers of coarse-grained quartz sand. The equivalent Ajax Limestone is dolomitised but also comprises skeletal calcarenite with associated oolite.

Stromatolites, oolite, mud-cracked dolomitic shale and abundant quartz-sand interbeds comprise the laterally equivalent Woodendinna Dolomite. Quartz sand interbeds persist in the lower part. This unit, which is usually 90 to 180 m thick, exceeds 400 m in actively-subsiding grabens, but thins to zero north of the WHH. The overlying 210 m thick Wirrapowie Limestone is dark grey, laminated to mottled micritic limestone with ooid grainstone tongues, stromatolites, thrombolites and bioherms. Storm breccias are common but mud cracks and siliciclastics are rare. The Wirrapowie Limestone overlies Parachilna Formation in the northern central Flinders zone beyond the northern depositional limit of the Woodendinna Dolomite. In this area, the Wirrapowie and Wilkawillina Limestones intertongue, while the Wilkawillina and Ajax Limestones dominate on the shallow shelf. However, Wirrapowie Limestone is also predominant in the south-western Arrowie Basin. The lower Ajax and Wilkawillina Limestone transgressive deposits are lime mudstone, immature sandstone and isolated bioherms. In northern synclines the transgressive deposits also include the Wirrapowie Limestone and basal Mernmerna Formation. The name Mernmerna Formation replaces Parara Limestone in the Arrowie Basin, the Parara Limestone now being restricted to the western Stansbury Basin.

The lower Wilkawillina Limestone is overlain disconformably by either lower Mernmema Formation or upper Wilkawillina Limestone immediately south of the WHH. In north-eastern PARACHILNA, the lower Wilkawillina Limestone is overlain disconformably by the Bendieuta Formation. Between central and northern PARACHILNA and at Balcoracana Creek, the Edeowie Limestone Member of the Oraparinna Shale onlaps exposed lower Wilkawillina Limestone.

Transgressive deposits on the carbonate shelf are condensed sections in the mid-Ajax and Wilkawillina Limestones. Sediments are red and glauconitic (Ajax) or grey (Wilkawillina), thinly bedded, abundantly fossiliferous calcarenite and immature sandstone. Localised thicker Ajax Limestone in the Mount Scout Range is grey, sparsely fossiliferous immature sandstone.

Lower Mernmerna Formation intertongues with adjacent platform bioherm complexes at Ten Mile Creek. South of the WHH along the Heysen Range, condensed Mernmerna Formation partly onlaps the carbonate shelf. In contrast, the lower Mernmerna Formation conformably overlies bioherms or mottled Wirrapowie Limestone at 'Mernmerna', near Mount Aleck and in the Chace Range. In this part of the Arrowie Basin, the Mernmerna Formation is unusually thick (up to 600 m). Flaggy lower Mernmerna Formation, 300 to 650 m thick north of the WHH and at Wilkawillina Gorge, comprises turbidite couplets of lime silt and mud. Lower Mernmerna Formation turbidites in the northern synclines (Angepena, Nepabunna, Arrowie) conformably overlie Wirrapowie Limestone and intertongue with the Midwerta Shale and Nepabunna Siltstone. These latter units are green-grey to black, argillaceous, pyritic, manganiferous limestones.

The base of the Cambrian on the Stuart Shelf is locally disconformable but is regionally a low-angle unconformity. Due to slight tilting and erosion of the Adelaidean succession, the Cambrian Andamooka Limestone rests on Yarloo Shale in the north, then on successively older members of the Tent Hill Formation. Basal beds of the Andamooka Limestone are fine to coarse-grained, locally bouldery siliciclastics and carbonates that pass up rapidly into widespread ooid grainstones.

In the eastern Flinders Ranges, the Bendieuta Formation conformably overlies lower Mernmerna Formation between Mount Frome and Mount Chambers Mine, but disconformably overlies lower

Wilkawillina Limestone at Reaphook Hill to the south. The up to 238 m thick Bendieuta Formation is coarse-grained, sparingly fossiliferous quartz sandstone, ooidpeloid grainstone and fenestral limestone. Intensively burrowed calcareous sandstones form distinctive marker beds in the middle part of the formation. Fossiliferous ooid-peloid calcarenite of the Bendieuta Formation comprises the basal 16 m of the Cambrian succession in the southern Moorowie Sub-basin.

The Bunkers Sandstone thins from 200 m adjacent to the carbonate shelf at Wilkawillina Gorge to 15 m in the Arrowie Syncline. The basal Bunkers Sandstone is flat to ripple-laminated, silty, fine-grained quartz sandstone that overlies the Mernmerna Formation with a sharp, locally disconformable contact. The overlying unit, restricted to Wilkawillina Gorge and comprising the main part of the formation, is planar to trough cross-bedded quartz sandstone. Flat to cross-bedded silty, fine-grained sandstone predominates in the Donkey Bore and Arrowie Synclines.

The Curdlawidny Siltstone Member of the Andamooka Limestone crops out near 'Parakylia' on the Stuart Shelf. The member is up to 22 m thick, comprising planar and ripple-bedded siltstone and fine-grained sandstone, locally with shale clasts and mud cracks; lower parts of the unit are dolomitic. Boundary relationships with the enclosing Andamooka Limestone are not clear.

The lower Oraparinna Shale was deposited conformably on Bunkers Sandstone at Ten Mile Creek. To the north at Bunkers Range, it overstepped Bunkers Sandstone and lapped onto the lower Mernmema Formation. The lower Oraparinna Shale is khaki, sparingly fossiliferous and silty with common limestone concretions. It is thickest at Wilkawillina Gorge (~200 m) but thins rapidly away from that locality. The thickness of the upper Mernmerna Formation varies from 190 m in Donkey Bore Syncline to 700 m or more in the Arrowie Syncline. The upper Mernmerna Formation overlies Bunkers Sandstone conformably in these regions, but intertongues with, and is replaced by, Oraparinna Shale at Wilkawillina Gorge.

In the eastern Flinders Ranges, the upper Mernmerna Formation, up to 60 m thick, onlapped the Bendieuta Formation from north to south with a sharp basal contact, but did not reach Reaphook Hill. The unit is fossiliferous dark grey, flaggy to mottled argillaceous limestone with common coarse-grained quartz sand and occasional dolomitised pebbles near the base.

The upper Andamooka Limestone on the Stuart Shelf was initially mud-cracked and bioclastic limestone overlain by bioherms that crop out on the north shore of Lake Torrens as low, flat-topped 'biscuits' 10 to 80 m in diameter. The bioherms are overlain sharply by buff, dolomitised stromatolites at the top of the Andamooka Limestone. In the Mount Scott Range, 60 m of dolomitised, peritidal, platy algal boundstone and stromatolites of the upper Ajax Limestone overlie syntectonic breccia and conglomerate.

The Moorowie Formation in the eastern Flinders Ranges outcrops between Mount Frome and Chambers Gorge to form a complex of near-shore shale and siltstone, shelf margin oolite and reef limestone, all breached by high-energy erosional channels. Carbonates of the uppermost Mernmerna Formation underlie the Moorowie Formation and overlie transgressive, flaggy, silty limestone at Chambers Gorge. Elsewhere, the Mernmerna Formation is replaced by calcareous upper Oraparinna Shale that becomes less limy and increasingly silty north of the WHH. The youngest unit in this region is the Narina Greywacke that is 540 m thick at its type locality. Due to faulting, nowhere is its contact with overlying units seen in outcrop, and no subsurface occurrences are known. The Narina Greywacke intertongues with the Oraparinna Shale over a passage of 100 m and comprises khaki, flat to ripple-laminated, silty to medium-grained feldspathic sandstone. Several distinct olive-green units contain coarse-grained quartz phenocrysts reworked from crystal tuff.

The calcareous upper Oraparinna Shale is widespread south and south-west of the WHH, where the Narina Greywacke was not deposited, but is very thin (<20 m) or even absent in the Bunkers Range and near Brachina Gorge.

The Yarrawurta Shale, the youngest Cambrian unit preserved on the Stuart Shelf, abruptly overlies upper Andamooka Limestone stromatolites. Maximum preserved thickness is 90 m but higher levels have been eroded. The unit comprises red-green shale and siltstone with tuff recorded near Andamooka. The Warragee Member of the Billy Creek Formation in the Mount Scott Range and at Wirrealpa Mine likewise rests sharply on upper Ajax and upper Wilkawillina Limestone stromatolites. In other outcrops the basal Billy Creek Formation is conformable on the Edeowie Limestone Member of the Oraparinna Shale but at Ten Mile Creek it overlies a tongue of Wilkawillina Limestone. The Warragee Member is evenly to ripple- laminated shale and siltstone up to 370 m thick. Desiccation cracks and salt casts are uncommon except in carbonate beds that cap poorly defined cycles above red, green and grey shale.

The 265 m of Billy Creek Formation in the Yalkalpo Sub-basin is red and green shale and siltstone with common sandstone interbeds, rare tuff bands near the base, and no carbonate. The formation is incomplete, upper levels having been eroded. The only drillhole to have fully penetrated the Billy Creek Formation in the Moorowie Sub-basin recorded 332 m.

The Aroona Creek Limestone crops out in the Mount Scott Range and only the basal 10 m of the 70 m thick unit are sub-tidal skeletal-peloid calcarenite. The remainder is principally fenestral and cryptalgal-laminated dolomite mudstone. The Wirrealpa Limestone is remarkably consistent in thickness (105–135 m) across the Flinders Ranges and into the Moorowie Sub-basin, but it is not recorded in the Yalkalpo Sub-basin. Trilobites, brachiopods and numerous other skeletal remains occur in the basal Aroona Creek and lower Wirrealpa Limestone.

Lake Frome Group (Ef)

The apparently conformable succession of Lake Frome Group red-beds and sandstones is locally up to 2700 m thick but erosion has removed younger units, leaving progressively less outcrop towards the northern Flinders Ranges. Drillholes have intersected Lake Frome Group west of the ranges and in the Moorowie Sub-basin but not in the Yalkalpo Sub-basin.

The Moodlatana Formation conformably overlies the Wirrealpa and Aroona Creek Limestones. The formation boundary is marked by abrupt appearance of red-brown micaceous siltstone or a passage through thin, mud-cracked, calcareous siltstone and fenestral to laminated limestone. The Moodlatana Formation consists of 170 to 590 m of micaceous siltstone, shale, arkosic fine to medium-grained sandstone and minor carbonate. Western outcrops are more sandy, usually tabular cross-bedded with occasional scour channels. The dominant siltstone lithology is planar to ripple-bedded with mud cracks, evaporate casts and trilobite tracks.

The 80 to 280 m thick Balcoracana Formation is repetitively bedded, very micaceous siltstone, shale and carbonate, deposited conformably above the Moodlatana Formation. Arkosic, fine-grained, trough cross-bedded sandstone is relatively common near Brachina Gorge but is a minor facies elsewhere. Red-green shale-carbonate cycles contain pencil-thin chalky limestone bands and laminated or stromatolitic carbonates 0.2 to 1 m thick. Ripples, mud cracks and halite casts are common.

The Pantapinna Sandstone is a 950 to 1300 m thick feldspathic sandstone with restricted outcrop and subcrop occurrences of the full unit. The basal beds lying conformably above the Balcoracana Formation are marine as they contain trilobite tracks, ooid grainstone and tidal channels, bioturbated beds and large ripple bedforms. The unit mainly comprises 0.5 to 1 m planar and trough cross-beds of red and white, fine to medium-grained sandstone with minor micaceous siltstone and shale.

The Grindstone Range Sandstone is the uppermost formation of the Lake Frome Group and is thickest (750 m) near 'Wirrealpa' although its top is not exposed anywhere. The formation is a mature quartz arenite with minor feldspar and upward-decreasing traces of volcanic lithic clasts. Well-rounded quartz-arenite pebbles and cobbles are concentrated in channels and down planar foreset beds in upper exposures near ‘Wirrealpa'. Trilobite tracks and mud cracks are found in basal sandstones.

ORDOVICIAN

Anabama Granite (EOda)

The Anabama Granite is an elliptical-shaped body, about 65 km long and 9 km wide, that lies along the southern margin of the Olary Ranges. Apart from the resistant greisen capped hills of Anabama and Netley Hills, the Anabama Granite has been deeply weathered since Tertiary times and is now almost completely concealed by Quaternary clays and gravels. It is described as a biotite granite, usually coarse grained, with anhedral microcline and some orthoclase intergrown with quartz and biotite, with up to 15% sodic plagioclase near oligoclase in composition. However, at Anabama Hill the unaltered granitic rock consists mainly of biotite granodiorite, with some adamellite, carrying up to 15% biotite and small amounts of muscovite. Microgranodiorites are interlayered with the main mass of biotite granodiorite and are presumably penecontemporaneous. Quartz porphyry or porphyritic microgranite forms dykes or sill-like masses cutting the main mass of granodiorite. A dacite porphyry dyke has also been noted.

CARBONIFEROUS TO PERMIAN

Alpana Formation (CP-a)

The Alpana Formation is a small isolated outlier of glacigene sediments that unconformably overlie the Neoproterozoic aged Callanna Group 3 km south of Blinman. The sediments are preserved in a palaeovalley eroded in bedrock and extend for 200 to 500 m along two west-bank tributaries to Blinman Creek. The formation comprises two facies, a weathered, grey diamictite overlain by a generally massive, buff coloured, fine to medium-grained sandstone. Collectively the facies reach a maximum of 20 m in thickness.

The diamictite measures up to at least 3 m in thickness and comprises a light grey to greenish-grey, moderately calcareous silty clay matrix enclosing numerous larger clasts up to 40 cm in diameter and varying in roundness from angular to well-rounded.

Overlying the diamictite at several sites is a very fine to medium grained, buff-weathering, well-sorted lithic sandstone. The grains are commonly well-rounded and consist of quartz, metamorphic rock fragments, microcline and minor garnet, tourmaline and zircon. Small pockets of pea-sized gravel and isolated pebbles occur sporadically throughout the sand. These clasts are similar in lithology to those found in the diamictite. The upper surface of the sandstone facies is weathered, eroded and overlain by non-glacigene friable buff-coloured sand of unknown age.

Boorthanna Formation (CP-b)

The Boorthanna Formation comprises two units including a basal facies dominated by diamictite with shale intercalations and an upper unit of rhythmically bedded coarse and fine clastics. The diamictite facies is a sandy to bouldery claystone that is often calcareous and sometimes dolomitic, interbedded with shale and occasionally thin sandstone or carbonate. This unit appears to be restricted to the Wallira and Phillipson Troughs and the southern part of the Boorthanna Trough. The rhythmically bedded facies is generally medium to coarse-grained sandstone but ranges from siltstone to boulder beds. In the southwestern portion of the Arckaringa Basin, diamictite and clastics are not confined to one stratigraphic level.

PERMIAN

Stuart Range Formation (P-s)

The Boorthanna Formation is conformably (occasionally disconformably) overlain by the Stuart Range Formation, although seismic evidence indicates that the relationship is unconformable in the Boorthanna Trough. The two units intertongue locally in the south-western Arckaringa Basin. The Stuart Range Formation, which directly overlies older rocks locally, is generally homogenous marine shale with minor siltstone and sandstone and pale to dark greyish shaly, poorly bedded mudstone.

Mount Toondina Formation (P-t)

Mount Toondina Formation overlies, usually conformably but occasionally disconformably, the Stuart Range Formation; in some parts of the basin it may unconformably overlie the Boorthanna Formation. Up to 170 m of Stuart Range Formation was eroded prior to deposition of the Mount Toondina Formation. The latter comprises siltstone and sandstone interbedded with coal, shale and rare carbonate; the coal is generally restricted to the upper part of the formation. Three units have been tentatively recognised and are mappable by seismic methods. The basal unit comprises marine shales and interbedded anoxic marine lacustrine shales. The middle unit is interpreted from seismic information and comprises westward-prograding deltaic sandstone and siltstone. The uppermost unit is dominantly lacustrine shale and minor fluvial clastics with intervals of coal formed in peat swamps.

TRIASSIC

Leigh Creek Coal Measures (RJ-l)

The Late Triassic sequence designated as the Leigh Creek Coal Measures occurs in the North Field, Telford and Copley Basins, ranging in thickness from 120 m in North Field to more than 1500 m in the Telford Basin. Grey carbonaceous mudstone is dominant, with coal, sandstone and siltstone present in lesser and varying proportions.

JURASSIC TO CRETACEOUS

Algebuckina Sandstone (JK-a)

The Early Jurassic to Early Cretaceous Algebuckina Sandstone reaches a maximum recorded thickness of 750 m near the South Australian border with the Northern Territory and Queensland. The unit is a fine to coarse-grained quartzose sandstone with granule and pebble layers; shale intraclasts 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. In outcrop at the top of the unit, secondary silicification, ferruginisation and carbonate cementation may be present, in some places preserving abundant plant remains as casts and moulds. Macrofossils along the exposed margin of the basin consist of leaves, stems, reproductive structures and pieces of wood up to 4 m long.

Cadna-owie Formation (Knc)

Underlying the Bulldog Shale and extending throughout the Eromanga Basin is the Cadna-owie Formation, a thin, mainly fine-grained Early Cretaceous sequence. It has a typical thickness of 10 to 20 m around the basin margin, increasing to 75 to 100 m in the deeper parts. The formation is a pale grey siltstone and very fine to fine-grained sandstone with laterally extensive or locally developed medium to very coarse sandstone interbeds and minor carbonaceous claystone intervals with the upper boundary marked by a sudden upward change from calcareous sandstone to shaly mudstone. Pebbly layers, diamictites and coarse breccia layers occur locally and large, rounded lonestones up to boulder size are widely distributed around the basin margin. Aside from quartz, the primary mineral components are mica, feldspar, heavy minerals, pyrite and glauconite. Extremely coarse calcite crystals, enclosing quartz grains, cement sandstone beds occurring regionally at or near the top of the unit. Intense ferruginisation in thin, distinct layers is also common and calcareous sandstone beds containing ooids form a minor constituent of the unit. In the central parts of the basin, the unit has been recorded as a single, uniform lithological unit coarsening upward from grey siltstone into fine to occasionally medium-grained calcareous sandstone.

Bulldog Shale (Kmb)

The Bulldog Shale forms a regional aquitard over much of the Eromanga Basin, the largest within the Great Artesian Basin (Love *et al.* 2000). The maximum known thickness is around 340 m in north-eastern South Australia, decreasing to less than 200 m in areas of outcrop in central South Australia where the unit has commonly undergone chemical alteration by weathering events. It thins further westwards with outlying remnants of Bulldog Shale recorded in Andamooka, Woomera and the northern Flinders Ranges. The Early Cretaceous unit comprises dark grey, bioturbated and fossiliferous shaly mudstone, with pale grey micaceous silt to very fine sand intervals. Carbonaceous matter and pyrite are also present. The sandy fraction mainly consists of detrital quartz, glauconite and feldspar. Organic-rich dark shale forms the basal 10 to 25 m of the unit that in marginal areas contains numerous rounded lonestones up to very large boulder size like those in the underlying Cadna-owie Formation.

TERTIARY

PALAEOCENE

Eyre Formation (Taee)

The Late Palaeocene to Middle Eocene Eyre Formation, basal unit of the Tertiary succession and widespread throughout the Lake Eyre Basin, incorporates the Macumba Sandstone and the Murnpeowie Formation. The Eyre Formation mostly disconformably overlies Mesozoic sediments, but locally oversteps onto Cambrian and Precambrian rocks; it is overlain unconformably by the middle to late Tertiary Etadunna and Namba Formations and Quaternary sediments. Upper exposed horizons are commonly silicified.

The Eyre Formation consists of mature, pyritic, carbonaceous sand, although the carbonaceous lithologies are often leached in outcrop. Grainsize varies from silt to gravel, with clasts up to small cobble size, sand grains usually being sub-angular to sub-rounded and polished. Beds of lignite and clay composed of montmorillonite and kaolinite with some illite, sometimes with root horizons, are common; a clay matrix is often present in sand around the basin margins. Polished gravel composed of resistant siliceous lithologies such as yellow, grey and milky quartz, black chert, red jasper, agate, fossil wood and buff and grey silcrete are a diagnostic feature of the basal horizons, with pebbles of basement rock in some localities.

EOCENE

Cotabena Formation (Teoo)

The Early Eocene age Cotabena Formation comprises fluvio-lacustrine, partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite with white clay horizons near the base of the succession. The formation overlies Precambrian and Cambrian rocks and, in deeper parts of the Torrens Basin adjacent to the Flinders Ranges, sediments of Mesozoic age; it is absent in the shallower western and northern parts of the basin. Thin, partly conglomeratic silicified sand that is widespread at a higher elevation in the north-eastern part of the basin may also be Cotabena Formation, as may be other sediments described as Eyre Formation at a similar elevation within the ranges.

Willalinchina Sandstone (Tmpw)

The Middle Eocene age Willalinchina Sandstone consists of a pebble conglomerate less than 0.5 m thick, overlain by 7 to 9 m of strongly silicified quartz sandstone. The unit has been cut by a series of 2 to 3 m thick brown-weathering, sandstone-filled palaeochannels, without basal pebble layers. The top of the succession comprises about 2 m of fine-grained sandstone silicified by 'reed-mould' silcrete. Medium-scale cross-bedding and rippled surfaces are common in the channel facies; other sandstones are thinly bedded. The basal conglomerate contains clasts of Wilpena Group quartzite, milky quartz, ferruginised Bulldog Shale and other Cretaceous sediments, silcrete (including 'reed-mould' type) and sandstone intraclasts.

Being a channel fill, the Willalinchina Sandstone is restricted to linear outcrops in central parts of palaeovalleys in the Stuart Creek Valley and Olympic Dam areas, where it disconformably overlies Adelaidean, Cambrian and Cretaceous sediments. The formation was deposited in meandering channels probably flowing to the north-east in the Stuart Creek area and to the south-west near Wirragilpina Dam.

Pidinga Formation (Tbp)

The Middle to Late Eocene age Pidinga Formation of palaeodrainage channels in the Eucla Basin commonly overlies deeply weathered Permian and older rocks. These terrigenous clastics, averaging 30 to 60 m in thickness, are generally carbonaceous and include poor quality lignite. Onshore they are mostly confined to topographically low settings such as palaeovalleys. The Pidinga Formation overlies the Mesozoic Bight Basin, Palaeozoic Officer Basin sediments and Precambrian basement. The basal sediments in the palaeovalleys are commonly coarse-grained sand and grit.

Hampton Sandstone (Tbh)

The lensoid to sheet-like marine, estuarine and fluvial Hampton Sandstone overlies the Pidinga Formation. Originally described from the central and western part of the Eucla Basin, these quartz-rich sands are widespread around the inner margin. The formation is partly clayey at the base and glauconitic and fossiliferous at the top. Over the central part of the Eucla Basin, the Hampton Sandstone is late Middle Eocene. However, a widespread younger, phase in the northern reaches is up to 50 m thick and bears siliceous sponge spicules in part.

Olney Formation (Tro)

The oldest sediments within the Murray Basin are the Renmark Group, comprising the Warina Sand and Olney Formation, together exceeding 330 m in thickness near Renmark. The Olney Formation overlies, and is more widespread than, the Warina Sand and extends into marginal areas of the basin where it rests on pre-Tertiary basement. Thinly-bedded carbonaceous sand, silt, clay and lignite were deposited in fluvial, lacustrine and swamp environments. The upper part of the Olney Formation is often marginal marine in the western Murray Basin. Although the Olney Formation ranges in age from Middle Eocene to Early Oligocene in the western part of the basin, deposition of lithologically identical sediments continued, probably with interruptions, into Middle Miocene time further east.

OLIGOCENE

Neuroodla Formation (Topu)

Overlying the Cotabena Formation, the Neuroodla Formation is a green, grey to black argillaceous and white calcareous mudstone correlated with the Etadunna Formation of the Lake Eyre Basin. The upper boundary of the formation cannot be determined because of weathering and erosion. The Neuroodla Formation is commonly 100 m thick although about 250 m may be present south of Parachilna. It is thickest along the western flank of the Flinders Ranges and similar sediments extend eastwards into the ranges, where the upper part may be equivalent to the Avondale Clay. Carbonaceous mud is locally present in lower parts of the Neuroodla Formation. In the central part of the basin, the lower clay beds contain montmorillonite, kaolin, illite and palygorskite. The mudstone is dolomicrite and the associated argillaceous clay is predominantly palygorskite and halloysite, the latter being the most common in the upper weathered part. Quartz gravel and pebble layers are locally major components near the ranges. Beneath Lake Torrens, the formation is overlain sharply and probably unconformably by undated gypsum and halite-bearing sediments. Eastwards toward the ranges the formation is overlain by Quaternary aeolian sand and conglomeratic alluvial sediments.

Namba Formation (Topn)

In the south-western Callabonna Sub-basin, the Namba Formation disconformably overlies Eyre Formation and averages 90 m in thickness but thickens towards the Barrier and Flinders Ranges and thins over the Benagerie Ridge. The unit is similar lithologically to the Etadunna Formation and comprises alternating fine to medium-grained, poorly-sorted, angular sand, silt and clay, with thin dolomite and limy, often oolitic, dolomite interbeds. The clay is black (due to ferrous iron and manganese), tough and bears fracture surfaces. Dolomite frequently contains rod-shaped ooliths and is affected by widespread bioturbation, intraformational brecciation and slump structures.

The Namba Formation is informally divided into a lower member characterised by smectite-dominated clay and cyclic deposition, and an upper member with illite and kaolinite. Carbonate facies of the Etadunna and Namba Formations contain abundant gastropods, ostracodes, algae, stromatolites and rare foraminifera. In the upper clayey parts of the succession, remains of fish, reptiles, birds and mammals are locally abundant. The age of the Namba Formation may range from Late Oligocene to Pliocene.

Geera Clay (Tyg)

The shallow marine carbonates of the Murray Group grade northwards to the progressively more marginal Winnambool Formation and Geera Clay. The Winnambool Formation comprises fossiliferous marl, glauconitic marly limestone and marly clay. Late Oligocene to Middle Miocene marginal marine and tidal sediments of the Geera Clay in the north-western Murray Basin are predominantly black to grey-green, carbonaceous, pyritic clay with minor glauconite and sparse marine fossils. At the northern margin of the Murray Basin, non-marine carbonaceous and pyritic sand, silt and clay with lignite overlie Geera Clay and Winnambool Formation. The non-marine unit may be a correlative with the Late Oligocene-Middle Miocene component of the Olney Formation, although alternatively it could be a carbonaceous facies of the Early Pliocene Loxton Sand.

MIOCENE

Garford Formation (Tig)

The Middle Miocene to Pliocene aged Garford Formation comprises extensive lacustrine carbonate, 10 to 20 m thick, between the Ooldea and Barton Ranges and in the Wilkinson Lakes region. These sediments include stromatolitic, oncolitic and oolitic mudstone with gastropods and minor sandstone horizons. There is an upward change from argillaceous mudstone to carbonate mudstone. The Garford Formation is similar to Etadunna Formation of the Lake Eyre Basin. Uplift and south-eastward tilting of the Eucla Basin sediments and regression followed in the Middle-Late Miocene. Deposition of a possibly younger phase of the Garford Formation resumed in the palaeovalleys around the basin, such as in the Tarcoola region and northern Eyre Peninsula. This part of the succession is up to 60 m thick and dominated by grey, green and cream to black mud, minor carbonate and local basal and interbedded carbonaceous sand and grit. Near the Gawler Ranges, the Garford Formation becomes sandy and locally contains clasts of acid volcanic rocks.

Watchie Sandstone (Tmw)

The Watchie Sandstone overlies Cretaceous or Cambrian rocks and, in the Stuart Creek area, is interpreted to overlie Willalinchina Sandstone although stratigraphic relationships here are ambiguous. The sandstone is 5 to 7 m thick and comprises a thin basal conglomerate with occasional sand lenses, a lower silt to fine-grained sand 2 to 3 m thick and an upper, upward-coarsening sand. Pebbles at the base of the formation are similar to those of the basal Eyre Formation, but also include Precambrian quartzite clasts derived directly from bedrock or via the Bulldog Shale, whereas pebbles near the top of the unit are mainly polished silcrete. Pebble beds often mark the sharp contact between the fine-grained unit and the upper sand.

Mirikata Formation (Tmpm)

The Mirikata Formation is a clay-dolomite succession up to 15 m thick and restricted to the central western part of the Billa Kalina Basin. It is divided into the thin basal Danae Conglomerate Member, Billa Kalina Clay Member and Millers Creek Dolomite Member.

The Danae Conglomerate Member, up to 3 m thick, comprises resistant clasts, some of silcrete and others reworked from Permian and Cretaceous sediments, in a matrix of fine to coarse-grained sand. The unit is usually ferruginised and silicified, forming thin sheets and lenses deposited in channels cut into Mesozoic sediments. The contact with the overlying Billa Kalina Clay Member is gradational.

The Billa Kalina Clay Member is a 4 to 6 m thick, yellow to olive-green and grey clay including magnesium-rich clay, palygorskite, and a mixture of montmorillonite and illite.

The Millers Creek Dolomite Member near 'Billa Kalina' is up to 10 m thick and comprises two dolomite or dolomitic limestone layers separated by dolomitic palygorskite clay. To the south, thicknesses of 1 to 5 m are more usual. Contact with the underlying Billa Kalina Clay Member is gradational. The dolomite is white or cream, aphanitic, commonly intraformationally brecciated, and locally includes sandy dolomite or calcareous sandstone. The Danae Conglomerate Member either intertongues with or underlies this unit. Outcrops are commonly silcreted or calcreted.

Mangatitja Limestone (TmQlm)

The Mangatitja Limestone was deposited in palaeovalleys adjacent to the Musgrave Ranges during the Miocene to Pliocene and is up to 30 m thick. The extensive limestone facies described contains oogonia of Characeae, ostracods and gastropods. Major alluvial red-bed facies occur, including sand, grit and flood-plain to fan clay.

PLIOCENE

Loxton Sand (Tpl)

Loxton Sand comprises glauconitic, micaceous and shelly fine sand, overlain by planar and cross-bedded fine to coarse-grained sand and fine gravel, and planar-bedded, calcareous, micaceous, medium to coarse-grained sandstone with abundant shell debris.

Willawortina Formation (TpQaw)

The Middle Miocene to Early Pleistocene Willawortina Formation south-east of Lake Eyre comprises two facies, one fine and one coarse, along the edge of the Flinders Ranges. The finer sequence of sandy mud and silty dolomite is present west of Lake Frome, where nine upward-fining cycles are recognisable. These sediments are of partly lacustrine and partly mudflow and flood-plain origin, and may be equivalent to the Avondale Clay. The top of the finer unit can be observed in creek exposures along the margins of the northern Flinders Ranges, where gravelly stream-channel sediments are interbedded with clay. Thick calcareous palaeosols are present.

The coarser facies is exemplified by drillholes around the Beverley uranium deposit, in which there are coarse, framework supported gravels of braided fan origin and matrix-supported clayey, poorly-sorted gravels interpreted as debris flows. The Willawortina Formation has also been recognised along the northern margin of the Olary Ranges. Drilling beneath Lake Frome has demonstrated intertonguing of fine and coarse facies. Just west of the Ediacara Range, about 100 m of gravel has been equated with the Willawortina Formation. Around the northern margins of the Flinders and Willouran Ranges, there are extensive fan and colluvial deposits that include equivalents of the Willawortina Formation and the coarser Telford Gravel. These are frequently preserved in dissected 'high plains' and are generally cemented with carbonate or gypsum, derived from saline sulphate and/or carbonate groundwaters percolating through the fans. Towards Port Augusta to the south, the Willawortina Formation equivalent merges with the Hindmarsh Clay.

Parilla Sand (Tpp)

The Loxton Sand is overlain by the Late Pliocene Parilla Sand, composed of unfossiliferous, non-marine, fine to medium-grained clayey quartz sand with thin beds of sandy clay. The formation was derived mainly from Loxton Sand by aeolian and fluvial reworking, and may include large transgressive dune complexes, as well as lacustrine and fluvial deposits laid down in depressions between stranded coastal ridges.

Blanchetown Clay (TpQlb)

The Blanchetown Clay, up to 20 m thick, was deposited in a large body of freshwater known as Lake Bungunnia that covered a large part of the western Murray Basin in the Late Pliocene to Early Pleistocene. The sediment consists of greenish-grey sandy clay with thin layers of limestone and quartz sand overlying red-brown and greenish-grey mottled sandy clay. The unit is commonly gypsiferous at the top, and often contains calcareous septarian nodules.

Ilkina Formation (TeQii)

The Ilkina Formation was deposited in the palaeovalleys during the Late Pliocene or Early Pleistocene and consists of laminated to thinly-bedded clay, silt and sand up to 5 m thick in the Narlaby Palaeovalley. It also forms the beds of playas such as Ifould Lake where it contains clasts of silcrete and ferricrete. The upper part of the formation is commonly gypseous and capped by a gypsum crust.

QUATERNARY

PLEISTOCENE

Avondale Clay (Qpav)

The Avondale Clay, which comprises green and grey clays, becoming red-brown when mottled, was probably deposited in a lacustrine environment. On COPLEY, this unit is locally gypsiferous, probably indicating mildly evaporitic environmental conditions. Exposures of the unit are mainly confined to plateau margins at Leigh Creek where it underlies the Telford Gravel. Approximately 161 m of possibly Avondale Clay are known from two wells immediately east of the Ediacara Range.

Coonarbine Formation (Qec)

Aeolian deposits of Late Pleistocene to Holocene age are represented by the Coonarbine Formation in the Strzelecki Desert and Simpson Sand in the Simpson Desert. The Coonarbine Formation includes older dune deposits in addition to the last glacial age dunes. The aeolian sands are formed in linear dunes typically 15 m high, with subdued transverse features in some areas and various 'tuning fork' junctions. They trend roughly north–south, oblique to the dominant transport direction and have migrated laterally to the east whilst extending their linear form northwards. The sand is disconformable on the Late Pleistocene alluvial and lacustrine sediments and consists of red-coated, frosted quartz grains, yellow to orange grains, clay pellets and gypsum flakes; aeolian cross-bedding is prominent. The older phases of the linear dunes are marked by calcareous palaeosols and are often paler than the overlying younger phases, as a result of the greater proportion of clay.

Delisser Formation (Qped)

The Delisser Formation appears to be the oldest widespread Quaternary aeolian sands, although dune forms have not been recognised. The weakly indurated, brick-red Pleistocene sand of the Delisser Formation is exposed around some playa lakes, including those to the west of Lake Anthony. Equivalent and possibly older, bioturbated yellow to orange-brown aeolian sand is found at Lake Anthony.

Wintrena Formation (Qpei)

The Pleistocene to Holocene Wintrena Formation of the Great Victoria Desert is a widespread sand unit that varies in colour but is commonly red-brown and orange-brown and up to 20 m in thickness. It is exposed around the margins of playa lakes near the Ooldea Range and is often capped by a major, variable carbonate palaeosol that includes mottled, indurated, massive and nodular calcrete up to 4 m thick. The oldest dunes of the Kwaterski Dune Field adjacent to the Gawler Ranges are weakly to moderately indurated and locally contain red-brown carbonate palaeosols. The youngest overlying sands are mobile and currently active. Gypsum and quartz sand lunettes are commonly present around playa lakes, including those around Ifould Lake.

Bridgewater Formation (Qpcb)

The Bridgewater Formation comprises fine to medium-grained calcareous aeolianites and minor calcareous silt. The unit is extensively developed along the western coastline of the Eyre Peninsula and extends well inland on the STREAKY BAY where it unconformably overlies both Archaean-Mesoproterozoic crystalline basement and Tertiary sediments. The thickness varies considerably, ranging from less than 1 m inland to over 90 m in local coastal sections.

On YARDEA, there is one isolated exposure of calcareous gritty sand with worm burrows and cocoons of *Leptopius duponti* that are common in coastal exposures of the upper Bridgewater Formation. The outcrop on the edge of a salina 8 km south-east of Mount Sturt is within the regional depression of the Narlaby Palaeochannel and represents the northeastern limit of the formerly coastal calcarenites.

Eurinilla Formation (Qpae)

A more complete succession of Late Pleistocene facies (alluvial, lacustrine, lacustrine-shoreline) is preserved to the south in the Strzelecki Desert and near Lake Frome. The Eurinilla Formation has a type section at Lake Moko to the east of Lake Frome. It consists of bright red-brown to yellow-brown sand and gravel of intermittent streams and their overbank deposits and is often cemented with gypcrete. The unit intertongues with playa-lacustrine deposits of the Millyera Formation and was deposited partly in palaeovalleys formed within the Willawortina Formation. West of Strzelecki Creek, coarse, poorly-sorted brown sand with angular grains forms a blanket deposit up to 50 m thick.

Pooraka Formation (Qpap)

The late Pleistocene age Pooraka Formation consists of unconsolidated silty clay, sand and carbonate deposits with occasional gravel lenses deposited in fans on both sides of the Flinders Ranges. In some parts of the ranges, this unit may be up to 50 000 years old. The Eurinilla Formation in the south-eastern Lake Eyre Basin is probably equivalent.

Wiabuna Formation (Qpew)

The eastern Nullarbor Plain is mantled in part by the late Pleistocene age Wiabuna Formation. It consists of orange-brown calcareous silt to fine-grained sand, pale brown quartz or shell sand with carbonate silt. The upper part contains carbonates of the Loveday Soil in most places. It locally thickens and is conglomeratic along the flanks of playas such as Ifould Lake. A weakly developed carbonate palaeosol has formed locally.

HOLOCENE

Moornaba Sand (Qhem)

The Moornaba Sand covers large tracts of both Eyre Peninsula and the central to northern Gawler Ranges. It is easily identified as vegetated, light-coloured, linear, siliceous seif dunes up to about 10 m high that trend north–west on northern Eyre Peninsula but east–west in the central Gawler Ranges. At the surface, Moornaba Sand is off-white in colour but it grades down with depth into a pale yellow to dark orange-brown quartz sand often with soft, vertical carbonate pipes. Interdunal corridors generally consist of red-brown sandy clay that grades laterally into the quartz sand.

B. SAAL NRM REGION GEOLOGICAL FORMATIONS TABLES

The following tables include the major geological formations found within each 1:250 000 maps covering the non-prescribed area of the SAAL NRM Region.

Table B1. Major geological formations of ALBERGA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Wintrena Formation (Qpei)	Red-brown, orange-brown, fine to coarse-grained sands, clayey and silty in part; often capped by carbonate palaeosol, includes mottled, indurated, massive and nodular calcrete	Overlies: Delisser Formation, Tertiary sediments and basement rocks	Can contain localised shallow aquifers	Great Victoria Desert: throughout ALBERGA
Cainozoic	Quaternary	Pleistocene	Delisser Formation (Qped)	Weakly indurated, brick-red sand; dull to bright red-brown sand, varying clay, silt and sandy mud	Underlies: Wintrena Formation Overlies: Tertiary sediments and basement rocks	Can contain localised shallow aquifers	Great Victoria Desert: throughout ALBERGA
Cainozoic	Tertiary	Miocene	Garford Formation (Tig)	Mudstone, carbonate, stromatolitic, oncolitic and oolitic, gastropods, minor sandstone horizons; upward change from argillaceous to carbonate mudstone	Underlies: Quaternary sediments Overlies: Mangatitja Limestone and Pidinga Formation	Palaeovalley aquifer	Hamilton Basin Palaeovalley: eastern ALBERGA
Cainozoic	Tertiary	Miocene	Mangatitja Limestone (TmQlm)	Limestone, red-bed facies, sand, grit, and flood-plain to fan clay	Underlies: Garford Formation Overlies: Pidinga Formation	Palaeovalley aquifer	Hamilton Basin Palaeovalley: eastern ALBERGA
Cainozoic	Tertiary	Eocene	Pidinga Formation (Tbp)	Clays and lignite, fluvial/estuarine channel sands, gravelly carbonaceous coarse sands; carbonaceous siltstone	Underlies: Garford Formation and Mangatitja Limestone Overlies: Basement rocks	Palaeovalley aquifer	Hamilton Basin Palaeovalley: eastern ALBERGA
Proterozoic	Mesoproterozoic	Stenian	Pitjantjatjara Supersuite (Mp)	Adamellite; alkali granite; diorite, often porphyritic, foliated or even massive	Basement rocks of the Musgrave Block	Weathered and fractured rock aquifer	Musgrave Block: northern ALBERGA
Proterozoic	Mesoproterozoic	Calymmian	Birksgate Complex (Mr)	Granite gneiss, granulite and amphibolite facies; altered adjacent to dyke	Basement rocks of the Musgrave Block	Weathered and fractured rock aquifer	Musgrave Block: southern ALBERGA

Table B2. Major geological formations of TARCOOLA and the included parts of BARTON, TALLARINGA and COOBER PEDY that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	Moornaba Sand (Qhem)	Red-orange to pale orange, fine to coarse-grained quartz sand and clayey sand	Overlies: Wintrena Formation, Tertiary sediments	Possible aquifer	Topographic depressions, playa lakes
		Pleistocene	Pooraka Formation (Qpap)	Reddish and orange gravel, sand, silt and clay; reddish brown, gravelly and gritty clayey sand, sandy clay and silty sand	Overlies: Tertiary sediments	Can contain localised shallow aquifers	Most of TARCOOLA
			Wintrena Formation (Qpei)	Red-brown to orange-brown, poorly-sorted, fine to coarse-grained sands, clayey and silty in part; clayey to silty sandstone	Underlies: Moornaba Sand Overlies & intertongues: Delisser Formation	Can contain localised shallow aquifers	Throughout TARCOOLA, BARTON, TALLARINGA and COOBER PEDY
			Delisser Formation (Qped)	Dull to bright red-brown sand, varying clay, silt and sandy mud; deep reddened calcrete cemented sandstone	Underlies & intertongues: Wintrena Formation Overlies: Tertiary sediments	Can contain localised shallow aquifers	Lake Anthony and lakes to the west
	Tertiary	Miocene	Garford Formation (Tig)	Mudstone, clayey, sandy at base, minor sandstone; dolomitic clay; dolostone, limestone, stromatolitic, oolitic, fossiliferous; clay and sand, carbonaceous, lignitic, carbonised wood and leaf fragments	Underlies: Quaternary sediments Overlies: Pidinga Formation	Palaeovalley aquifer	Garford, Anthony and Kingoonya Palaeovalleys; topographic lows; eastern BARTON
		Eocene	Pidinga Formation (Tbp)	Quartz sandstone, clayey, carbonaceous and pyritic in part; pebbly sandstone commonly at base; silty to sandy clay, carbonaceous and laminated in places; lignite	Underlies: Garford Formation Overlies: Algebuckina Sandstone, Boorthanna Formation, weathered basement rocks	Palaeovalley aquifer	Garford, Anthony and Kingoonya Palaeovalleys; topographic lows on TARCOOLA
Mesozoic	Cretaceous	Barremian	Bulldog Shale (Kmb)	Grey mudstone or siltstone, minor sandy siltstone, rare sandstone interbeds; locally bioturbated; quartzite pebbles in thin layers of pebbly sandy siltstone in basal part; deep weathering: bleaching (kaolinite), silicification (porcellanite), ferruginisation	Underlies: Cainozoic sediments Overlies: Algebuckina Sandstone	Aquitard	Eromanga Basin: northern half of TARCOOLA; COOBER PEDY; south-eastern TALLARINGA
	Jurassic	Toarcian	Algebuckina Sandstone (JK-a)	Gritty/pebbly sandstone; white kaolinitic matrix, quartz; interbeds of sandstone, micaceous siltstone, mudstone; pebble conglomerate; quartz/quartzite clasts; carbonaceous clayey and silty sand	Underlies: Bulldog Shale and Tertiary sediments Overlies: Arckaringa Basin and Gawler Craton	Aquifer	Eromanga Basin: northern half of TARCOOLA; COOBER PEDY; south-eastern TALLARINGA
Palaeozoic	Permian	Asselian	Mount Toondina Formation (P-t)	Sandstone; pale grey, friable, fine-grained, micaceous; interbedded with grey, sandy, micaceous mudstone and siltstone with abundant plant fossils; thin coal layers	Underlies: Algebuckina Sandstone Overlies: Stuart Range Formation	Aquifer	Arckaringa Basin: north-eastern TARCOOLA
			Stuart Range Formation (P-s)	Mudstone, silty mudstone; grey to black (carbonaceous), commonly altered to green or yellow; occasional siltstone and rare sandstone interbeds; micaceous partings; locally pyritic near base	Underlies: Mount Toondina Formation, Algebuckina Sandstone Overlies: Boorthanna Formation	Aquitard	Arckaringa Basin: north-eastern TARCOOLA; Mulgathing Trough: north-western TARCOOLA
			Boorthanna Formation (CP-b)	Silty mudstone, mudstone; quartz sandstone; pebbles of quartzite, granite, acid volcanics, chert, locally pyritic; silty to sandy claystone; siltstone and sandstone interbeds	Underlies: Stuart Range Formation, Algebuckina Sandstone or younger sediments Overlies: Gawler Craton & Pandurra Formation	Aquifer	Arckaringa Basin: north-eastern TARCOOLA; Mulgathing Trough: north-western TARCOOLA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Sandstone, shale and siltstone, arenaceous, red-beds	Underlies: Arckaringa Basin Overlies: Gawler Craton	Aquifer	Cariewerloo Basin: north-eastern TARCOOLA
			Gawler Range Volcanics (Ma)	Porphyritic rhyodacite/rhyolite, plagioclase, hornblende, biotite, chlorite, granophyric dacite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	North–north-eastern TARCOOLA
			Hiltaba Suite (Mh)	Granites to adamellites, generally fine to medium grained, quartz, potassium feldspar, plagioclase, biotite poor rocks typically with accessory sphene, zircon, apatite and occasionally fluorite. Includes Balta Granite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Most of TARCOOLA, absent in north-west
Archaean			Mulgathing Complex (ALm)	Microcline-plagioclase gneiss with biotite, garnet and layers of banded iron formation, marble, dolomite, quartzite, metabasics. Includes Glenloth Granite, Lake Harris Komatiite, Kenella Gneiss, Hopeful Hill Basalt, Blackfellow Hill Pyroxenite, Christie Gneiss	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Widespread over TARCOOLA and included parts of COOBER PEDY BARTON and TALLARINGA

Table B3. Major geological formations of KINGOONYA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	Moornaba Sand (Qhem)	Red-orange to pale-orange, fine to coarse-grained quartz sand and clayey sand	Overlies: Wintrena Formation, Tertiary sediments	Possible aquifer	Along eastern and southern KINGOONYA; topographic depressions
		Pleistocene	Wintrena Formation (Qpei)	Red-brown to orange-brown, very fine to medium-grained quartz sand, clayey and silty in part; moderately to well sorted with a coarse to very-coarse sand fraction; extensive carbonate palaeosols and calcrete	Underlies: Moornaba Sand Overlies & Intertongues: Delisser Formation	Can contain localised shallow aquifers	Along eastern and southern KINGOONYA
			Pooraka Formation (Qpap)	Reddish and orange gravel, sand, silt and clay; reddish brown, gravelly and gritty clayey sand, sandy clay and silty sand	Overlies: Tertiary sediments	Can contain localised shallow aquifers	Throughout KINGOONYA
			Delisser Formation (Qped)	Dull to bright red-brown weakly indurated sand; varying clay, silt and sandy mud	Underlies: Wintrena Formation Overlies: Tertiary sediments	Can contain localised shallow aquifers	Along eastern and southern KINGOONYA
	Tertiary	Miocene	Mirikata Formation (Tmpm)	Dolomite or dolomitic limestone, dolomitic clay; yellow to olive-green and grey clay; fine to coarse-grained sand, usually ferruginised and silicified	Underlies: Quaternary sediments Overlies: Mirikata Formation	Unknown	Eastern half of KINGOONYA including Billa Kalina Basin
			Watchie Sandstone (Tmw)	Off-white to pale-grey sandstone, quartz and silcrete granules; off-white to yellowish micaceous sandstone; pale grey, pale yellow, whitish sandstone	Underlies: Mirikata Formation Overlies: Arckaringa & Arrowie Basins	Unknown	Billa Kalina Basin: along eastern KINGOONYA
			Garford Formation (Tig)	White, fine-grained and cavernous limestone; green clay, partly oxidised to red-brown; compact, cream, crystalline limestone	Underlies: Quaternary sediments Overlies: Pidinga Formation	Aquifer	Kingoonya Palaeovalley: southern KINGOONYA
		Eocene	Pidinga Formation (Tbp)	Pale-green, grey, brown sandy clay often oxidised to red-brown colours, carbonaceous fragments, white to yellow-orange quartz sand, minor quartz pebbles, grey to black, gypsiferous or carbonaceous clay, sand	Underlies: Garford Formation Overlies: Eromanga and Arrowie Basins and Stuart Shelf	Aquifer	Kingoonya Palaeovalley: southern KINGOONYA
Mesozoic	Cretaceous	Barremian	Bulldog Shale (Kmb)	White shale of kaolinised mudstone or siltstone, minor sandy siltstone, rare fine to coarse-grained sandstone interbeds, often strongly calcreted; shale is dominantly massive, unstratified but bioturbation occurs locally; well rounded, pale quartzite pebbles and boulders locally near base	Underlies: Cainozoic sediments Overlies: Cadna-owie Formation, Algebuckina Sandstone, older units	Aquitard	Eromanga Basin: most of KINGOONYA
		Valanginian	Cadna-owie Formation (Knc)	Micaceous, white to yellowish siltstone, very fine to medium-grained sandstone, local feldspar grains, quartz granules, fine pebbles; thin interbeds of white, coarse-grained to granular sandstone are common; yellow and purple mottling in places	Underlies: Bulldog Shale, Cainozoic sediments Overlies: Algebuckina Sandstone, Arckaringa Basin	Aquifer	Eromanga Basin: north-western KINGOONYA
	Jurassic	Toarcian	Algebuckina Sandstone (JK-a)	Medium-grained to granular, gritty or pebbly sandstone, distinctive white kaolinitic matrix; sand is usually sub-angular milky or clear quartz, but iron -stained, bluish, smoky quartz grains do occur; some interbeds of fine to very fine-grained sandstone, micaceous siltstone and massive mudstone	Underlies: Bulldog Shale, Cadna-owie Formation, Cainozoic sediments Overlies: older basins	Aquifer	Eromanga Basin: western two-thirds of KINGOONYA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Palaeozoic	Permian	Asselian	Stuart Range Formation (P-s)	Grey to black carbonaceous mudstone, occasional siltstone, rare sandstone interbeds; commonly altered to green or yellow colours near overlying Mesozoic sediments; pyrite occurs locally near base	Underlies: Eromanga Basin Overlies: Boorthanna Formation	Aquitard	Arckaringa Basin: along northern KINGOONYA
			Boorthanna Formation (CP-b)	Fine to coarse-grained quartz sandstone, mostly weakly indurated, local calcareous or ferruginous cements; silty mudstone to mudstone; pebbles of quartzite, granite, acid volcanics and chert locally present in both sandstone and mudstone	Underlies: Stuart Range Formation Overlies: Stuart Shelf, Arrowie and Cariewerloo Basins	Aquifer	Arckaringa Basin: along northern KINGOONYA
Palaeozoic	Cambrian	Early	Hawker Group (Eh)	Andamooka Limestone: buff, grey and pink, massive to vuggy, sugary textured limestone to dolomite, locally oolitic or pyritic; algal laminations; stromatolites occur near base; limestone interbedded with massive and vuggy white, stylolitic limestone and grey-orange calcarenite and dolomitic siltstone	Underlies: Arckaringa & Eromanga Basins Overlies: Wilpena Group	Aquifer	Arrowie Basin; along eastern KINGOONYA
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes Seacliff Sandstone (red-brown sandstone; pink/whitish bleaching, red-brown shale flakes; red-brown, grey-green micaceous shale, siltstone interbeds), Nuccaleena Formation (pink/white dolomite, stylolites/vuggy dolomite), Tent Hill Formation (red-brown shale, siltstone, interbedded green-grey shale, siltstone; red, white micaceous sandstone beds) and Yarloo Shale (brown to red-orange, strongly micaceous, massive mudstone, silty mudstone, siltstone; brown, blue-green shale)	Underlies: Arrowie, Arckaringa and Eromanga Basins Overlies: Cariewerloo Basin	Aquifer	Stuart Shelf: most of eastern half of KINGOONYA
	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Fine-grained to pebbly sandstone with a mottled, red-brown, purple and white, haematitic and sericitic silty matrix containing occasional traces of pyrite; interbeds of red (rarely green), laminated, micaceous, haematitic and sericitic siltstone	Underlies: Stuart Shelf, Arckaringa and Eromanga Basins Overlies: Gawler Craton	Aquifer	Cariewerloo Basin: most of KINGOONYA
			Hiltaba Suite (Mh)	Red to pink quartz + plagioclase + microcline granite to adamellite, occasional hornblende or biotite usually altered to chlorite; pink, coarse-grained biotite adamellite containing phenocrysts of perthitic orthoclase and zoned plagioclase	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Western KINGOONYA
			Gawler Range Volcanics (Ma)	Includes Konkaby Basalt (amygdaloidal metabasalt, metabasaltic lapilli tuff, agglomerate; trachyandesite; andesite, basalt, amygdaloidal basalt) and Ealbara Rhyolite (pale-coloured, weakly welded pyroclastics and lava; red or brown ignimbrite)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Most of KINGOONYA
Archaean			Mulgathing Complex (ALm)	Includes Kenella Gneiss (red to orange, fine to coarse-grained quartz + microcline + plagioclase ± muscovite granitic gneiss, rare garnet or biotite), Christie Gneiss (quartzo-feldspathic gneiss with variable amounts of magnetite, garnet, sillimanite and pyrite, sericitic and chloritic alteration, and some mylonite development) and Glenloth Granite (pale reddish pink quartz + microcline + sericitised plagioclase granite)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	South-western, northern, north-eastern KINGOONYA

Table B4. Major geological formations of GAIRDNER and the included part of CHILDARA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	Moornaba Sand (Qho)	Seif dunes up to about 10 m high composed of aeolian quartz sand varying from pale yellow to dark orange-brown in colour stabilised by vegetation and supporting close stands of mallee and native pine	Overlies: Pooraka Formation and eroded older rocks	Possible aquifer	Most of GAIRDNER; eastern CHILDARA
		Pleistocene	Pooraka Formation (Qpap)	Yellowish brown to reddish brown sandy, gravelly clay & silty sand, overlain by dark yellow, orange, reddish-brown, gravelly, sandy clays with gibbers of silcrete and silicified quartzose sandstone, or by reddish brown sandy clay with fragments of yellowish-brown, reddish-brown mottled quartzose grit	Underlies: Moornaba Sand Overlies: Algebuckina Sandstone	Can contain localised shallow aquifers	Most of GAIRDNER; eastern CHILDARA
Mesozoic	Jurassic	Toarcian	Algebuckina Sandstone (JK-a)	Pale grey quartzose sandstone, pebbly grit, some granule and pebble conglomerate beds; clasts of milky quartz, clear quartz and some quartzite in gritty matrix, interstitial kaolin, stained yellowish-brown or reddish-brown	Underlies: Pooraka Formation Overlies: Tent Hill Formation, Pandurra Formation, Gawler Craton	Aquifer	Eromanga Basin: along northern GAIRDNER
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes Simmens Quartzite Member (pale grey and greenish-grey quartzose sandstone), Corraberra Sandstone Member (pale grey and cream sandstone and siltstone, bands of laminated purplish-brown, reddish-brown and greenish-grey silty and sandy shale) and the Tregolana Shale Member (purplish-brown, reddish-brown and greenish-grey shale) of the Tent Hill Formation	Underlies: Quaternary sediments and Algebuckina Sandstone Overlies: Pandurra Formation	Aquifer	Stuart Shelf: north-east GAIRDNER
	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Brown, reddish-brown and purplish-brown, medium to coarse-grained, cross-bedded, feldspathic sandstone and grit with minor intercalations of micaceous shale, siltstone and fine sandstone	Underlies: Quaternary sediments, Algebuckina Sandstone, Tent Hill Formation Overlies: Gawler Craton	Aquifer	Cariewerloo Basin: north–north-eastern and eastern–south-eastern GAIRDNER
			Gawler Range Volcanics (Ma)	Metabasalt, lapilli tuff, chert, dacite, rhyodacite and rhyolite. Includes Yardea Dacite, Gawler Hill Volcanic Complex, Chandabooka Dacite, Lake Gairdner Rhyolite and Chitanilga Volcanic Complex	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Most of GAIRDNER; eastern CHILDARA
			Hiltaba Suite (Mh)	Leucocratic unfoliated pink to reddish-brown, medium to coarse-grained potash granite grading to adamellite; scattered veins of microgranite and aplite; narrow, discontinuous zones of greisening	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	North-west GAIRDNER/north-east CHILDARA; south-west GAIRDNER/south-east CHILDARA; northern GAIRDNER
	Palaeoproterozoic	Statherian	St Peter Suite (Lp)	Granite; adamellite; granodiorite; dolerite; diorite; amphibolite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Most of CHILDARA
			Tunkillia Suite (Ln) and equivalents	Comagmatic, I-type intrusives and rhyolite, mafic and aplite dykes; orthogneiss; granite, mylonite; mafic dykes; rhyolite, Rhyodacite dykes; aplite dykes	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Along eastern and northern CHILDARA
Archaean			Mulgathing Complex (ALm)	Actinolite-chlorite schist, tremolite-chlorite schist, serpentinite, amphibolite; basaltic or spilitic pillow-lavas and calc-silicate hornfels. Includes Glenloth Granite (pinkish brown, grey to dark grey, leucocratic gneiss or gneissic granite, adamellite and granodiorite)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	North-west GAIRDNER; north-east CHILDARA

Table B5. Major geological formations of YARDEA and the included part of STREAKY BAY that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	Moornaba Sand (Qhem)	Vegetated, siliceous, off-white sand that grades down with depth into a pale yellow to orange quartz sand often with soft, vertical carbonate pipes; interdunal corridors generally consist of red-brown sandy clay that grades laterally into the quartz sand	Intertongues with Wiabuna Formation Overlies: older units	Possible aquifer	Linear seif dunes that trend east–west in the central Gawler Ranges
		Pleistocene	Wiabuna Formation (Qpew)	Thin yellowish brown to red-brown, often calcareous, clayey sand and silt, commonly contains soft biscuity to nodular carbonate overlying hard sheet calcrete	Overlies: older units	Possible aquifer	South-western YARDEA
			Pooraka Formation (Qpap)	Alluvial, red-brown, clayey sand and gravel, capped in general by soft powdery carbonate and/or nodular calcrete	Overlies: older units	Possible aquifer	Valleys and around margins of the Gawler Ranges
			Bridgewater Formation (Qpcb)	Pale yellow–cream calcareous gritty sandstone	Overlies: older units	Possible aquifer	Along SAAL NRM Region boundary
		Miocene	Garford Formation (Tig)	Variably-coloured, khaki to greenish grey to brown, well-laminated to locally flaggy clay, silt and sand	Underlies: silcrete Overlies: Pidinga Formation or weathered basement	Aquifer	Narlaby Palaeovalley
		Eocene	Pidinga Formation (Tbp)	Interbedded, well-sorted, fine to coarse-grained carbonaceous sand and silt with minor lignite; sand is generally well sorted, with rounded to well-rounded quartz grains; local pyrite	Underlies: Quaternary sediments and Garford Formation Overlies: weathered basement	Aquifer	Narlaby Palaeovalley and south-western YARDEA
Proterozoic	Mesoproterozoic	Calymmian	Hiltaba Suite (Mh)	Massive, medium to coarse-grained granite and adamellite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Southern and western thirds of YARDEA and eastern quarter of STREAKY BAY
			Gawler Range Volcanics (Ma)	Pinkish granite, xenoliths of gneiss and granodiorite; foliated biotite granite; massive cream-coloured leucogranite. Includes Yardea, Eucarro and Waganny Dacites, Paney and Bittali Rhyolites, Yannabie and Nonning Rhyodacites and Corunna Conglomerate	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Northern two-thirds of YARDEA, north-eastern STREAKY BAY
		Orosirian	Hutchison Group (Lh)	Includes Cook Gap Schist (quartzofeldspathic gneiss to quartz–muscovite–biotite schist), Katunga Dolomite (calcite marble; schist and amphibolite; ankeritic dolomite marble) and other Middleback Subgroup (interlayered banded iron formation (BIF), impure marble–calcsilicate), Warrow Quartzite (micaceous and feldspathic quartzite)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	South-eastern quadrant of YARDEA
Archaean			Sleaford Complex (ALs)	Foliated migmatitic quartz–feldspar–biotite (garnet) gneiss and augen gneiss; possible local banded iron formation	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Most of western and southern YARDEA, eastern border of STREAKY BAY

Table B6. Major geological formations of ANDAMOOKA and the included part of CURDIMURKA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Unconsolidated red-brown clayey sand, gravel, conglomerate, breccia; colluvial sheet wash, alluvial fan and residual lag	Overlies: Avondale Clay and Tertiary sediments	Possible aquifer	Adjacent Flinders Ranges
			Avondale Clay (Qpav)	Green to grey clay, ferruginous mottling	Underlies: Pooraka Formation Overlies: Tertiary sediments	Unknown	Adjacent Flinders Ranges
	Tertiary	Miocene	Watchie Sandstone (Tmw)	Basal conglomerate, occasional sand lenses, lower silt to fine-grained sand, upper, upward-coarsening sand; alternating silcrete and ferricrete horizons	Underlies: Quaternary sediments Overlies: Willalinchina Formation	Unknown	Billa Kalina Basin: western third of ANDAMOOKA
		Oligocene	Neuroodla Formation (Topu)	Green-grey to black, argillaceous claystone and white calcareous mudstone; basal carbonaceous clay; quartz gravel and pebble layers near the ranges	Underlies: Quaternary sediments Overlies: Cotabena Formation, Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: eastern third of ANDAMOOKA
		Eocene	Willalinchina Formation (Tmpw)	Channel fill; thin pebble conglomerate overlain by silicified quartz sandstone; cut by a series of sandstone-filled palaeochannels	Underlies: Watchie Formation Overlies: Eromanga and Arrowie Basin sediments	Untested	Billa Kalina Basin: western third of ANDAMOOKA
			Cotabena Formation (Teoo)	Partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite; finely laminated silt and carbonaceous mudstone; white clay horizons near base	Underlies: Neuroodla Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: absent in shallower western and northern parts of basin
Mesozoic	Cretaceous	Barremian	Bulldog Shale (Kmb)	Dark grey, bioturbated, fossiliferous shaly mudstone, micaceous silt to very fine sand intervals, carbonaceous matter, pyrite; organic-rich dark shale forms the basal 10–25 m	Underlies: Quaternary and Billa Kalina Basin sediments Overlies: Cadna-owie Formation	Aquitard	Eromanga Basin: north-western, central and south-western ANDAMOOKA
		Valanginian	Cadna-owie Formation (Knc)	Siltstone, sandstone, minor carbonaceous claystone intervals; calcareous sandstone to shaly mudstone; diamictites, breccia, pebbly layers; lonestones around basin margin	Underlies: Bulldog Shale Overlies: Algebuckina Sandstone	Aquifer	Eromanga Basin: north-western, central and south-western ANDAMOOKA
	Jurassic	Toarcian	Algebuckina Sandstone (JK-a)	Fine to coarse-grained quartzose sandstone, granule and pebble layers with shale intraclasts. Silicification, ferruginisation, carbonate cementation in some outcrop, occasional plant relics	Underlies: Cadna-owie Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Eromanga Basin: north-western, central and south-western ANDAMOOKA
Palaeozoic	Cambrian	Early	Lake Frome Group (Ef)	Sandstone; siltstone; shale; limestone; conglomerate. Includes the Billy Creek Formation, Wirrealpa Limestone and Moodlatana Formation	Underlies: Billa Kalina and Eromanga Basin sediments Overlies: Hawker Group	Weathered and fractured rock aquifer	Arrowie Basin: western and northern ANDAMOOKA through to south-east
			Hawker Group (Eh)	Limestone, siltstone, shale; lesser sandstone, greywacke, sandstone. Includes the Parachilna and Mernmerna Formations, Woodendinna Dolomite, Ajax, Andamooka and Wilkawillina Limestones, Bunkers Sandstone and Orapinna Shale	Underlies: Lake Frome Group Overlies: Wilpena Group	Weathered and fractured rock aquifer	Arrowie Basin: western and northern ANDAMOOKA through to south-east

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Neoproterozoic (Adelaidean)	Marinoan	Wilpena Group (Nw)	Quartzite; siltstone; shale; calcareous in part. Includes the Sandison Subgroup (Brachina and Nuccaleena Formations, ABC Range Quartzite), Aruhna Subgroup (Bunyeroo Formation), Pound Subgroup (Rawnsley Quartzite), Tent Hill, Uratanna and Wonoka Formations and Yarloo Shale	Underlies: Torrens Basin sediments and Hawker Group Overlies: Umberatana Group, Pandurra Formation, Gawler Craton	Weathered and fractured rock aquifer	Stuart Shelf and Torrens Hinge Zone: all of ANDAMOOKA
		Sturtian	Umberatana Group (Nu)	Tillite; sandstone; siltstone; arkose; dolomite; quartzite; conglomerate; shale; greywacke. Includes the Yudnamutana Subgroup (Appila Tillite, Brighton Limestone), Upalinna Subgroup (Angepena, Amberoona, Etina and Trezona Formations), Yerelina Subgroup (Whyalla Sandstone, Elatina Formation) and Tapley Hill Formation	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Stuart Shelf and Torrens Hinge Zone: all of ANDAMOOKA, south-eastern CURDIMURKA
		Torrensian	Burra Group (Nb)	Siltstone, laminated; shale; sandstone, heavy mineral lamination, quartzose to feldspathic, cross bedding; dolomite, blue-grey to pale pink, lenticular. Includes the Emeroo and Mundallio Subgroups	Underlies: Umberatana Group Overlies: Callanna Group	Weathered and fractured rock aquifer	Torrens Hinge Zone and Adelaide Geosyncline: eastern third and northern ANDAMOOKA, south-eastern CURDIMURKA
		Willouran	Callanna Group (Nc)	Siltstone, locally carbonaceous; sandstone, locally stromatolitic, ripple marks, halite casts, heavy mineral lamination; carbonates; evaporites; basalt, minor volcanics. Includes the Arkaroola and Curdimurka Subgroups	Underlies: Burra Group Overlies: Gawler Craton	Weathered and fractured rock aquifer	Torrens Hinge Zone and Adelaide Geosyncline: eastern third and northern ANDAMOOKA, south-eastern CURDIMURKA
	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Arenaceous red-beds; medium to coarse-grained, poorly sorted, sub-angular quartz and lithic sandstone; moderately well-sorted, very fine to medium-grained sandstone, pebble conglomerate and shale	Underlies: Wilpena Group Overlies: Gawler Craton	Weathered and fractured rock aquifer	Cariewerloo Basin: southern and western ANDAMOOKA
			Hiltaba Suite (Mh)	Massive, medium to coarse-grained granite and adamellite; hornblende-bearing quartz monzodiorite, quartz monzonite and granodiorite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Central, north-western ANDAMOOKA
			Gawler Range Volcanics (Ma)	Basalt and andesite to dacite, rhyodacite and rhyolite, variable silica gap between the tholeiitic basalt-andesite series and the felsic series; massive porphyritic dacite and rhyodacite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	South-western quadrant of ANDAMOOKA
	Palaeoproterozoic	Statherian	Broadview Schist (Lyb) and Myola Volcanics (Lym)	Deformed schist, slaty to phyllitic fine-grained quartzite, interlayered amphibolites Interbanded porphyritic rhyolite and rhyodacite, fine-grained felsic and hornblende-bearing gneisses and fine-grained amphibolite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Southern ANDAMOOKA
		Orosirian	Donington Suite (Ld)	Quartz gabbronorite, megacrystic granite gneiss, charnockite, granodiorite gneiss, granite gneiss; deformed granite; felsic granite, pegmatite; tonalite, gabbroic anorthosite, granodiorite and quartz monzonite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Throughout central third of ANDAAMOOKA
			Hutchison Group (Lh)	Quartzite, local pelitic schist interbeds; graphitic dolomitic marble, banded calcsilicate, recrystallised cherty BIF, pelitic to semi-pelitic schist; interlayered, deformed and recrystallised rhyodacites and calcsilicate gneisses; BIF	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	North-western ANDAMOOKA
Archaean			Mulgathing Complex (ALm)	Granite, gneiss, granodiorite, metasediment and basic dykes	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Western third of ANDAMOOKA

Table B7. Major geological formations of TORRENS that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Holocene	unnamed (Qha)	Alluvium, gravels and silts of major drainage channels; outwash floodplain deposits	Overlies: older units	Can contain localised shallow aquifers	Western flank of Andamooka Ranges, south-eastern TORRENS
			unnamed (Qhe)	Sand plains: sand dunes with claypans	Overlies: older units	Can contain localised shallow aquifers	Throughout TORRENS
			unnamed (Qhl)	Lakes: salt, gypsum, gypseous clays, silts and quartz sands	Overlies: older units	Can contain localised shallow aquifers	Lakes
	Tertiary	Oligocene	Neuroodla Formation (Topu)	Green-grey to black, argillaceous claystone and white calcareous mudstone; basal carbonaceous mud	Underlies: Quaternary sediments Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: along eastern border of TORRENS east of the Andamooka Ranges
Palaeozoic	Cambrian	Early	Lake Frome Group (Ef)	Sandstone; siltstone; shale; limestone; conglomerate. Includes Billy Creek Formation, Moodlatana and Balcoracana Formations, Pantapinna and Grindstone Range Sandstones and Wirrealpa and Aroona Creek Limestones	Underlies: Neuroodla Formation Overlies: Hawker Group	Aquifer	Arrowie Basin: north-eastern and south-eastern TORRENS
			Hawker Group (Eh)	Limestone, siltstone, shale; lesser sandstone, greywacke, sandstone. Includes the Parachilna and Mernmerna Formations, Woodendinna Dolomite, Ajax, Wilkawillina and Andamooka Limestones, Bunkers Sandstone, Orapinna Shale, Midwerta Shale, Narina Greywacke and Nepabunna Siltstone	Underlies: Lake Frome Group Overlies: Wilpena Group	Aquifer	Arrowie Basin: north-eastern and south-eastern TORRENS
Proterozoic	Neoproterozoic (Adelaidean)	Marinoan	Wilpena Group (Nw)	Quartzite; siltstone; shale; calcareous in part. Includes the Pound Subgroup, Wonoka, Bunyeroo, Brachina, Nuccaleena, Tent Hill and Uratanna Formations, ABC Range Quartzite and Yarloo Shale	Underlies: Quaternary sediments and Hawker Group Overlies: Umberatana Group	Weathered and fractured rock aquifer	Stuart Shelf and Torrens Hinge Zone: most of TORRENS
		Sturtian	Umberatana Group (Nu)	Tillite; sandstone; siltstone; arkose; dolomite; quartzite; conglomerate; shale. Includes Elatina, Trezona, Etina, Amberoona, Angepena and Tapley Hill Formations, Brighton Limestone, Whyalla Sandstone, Appila Tillite and Upalinna Subgroup	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Stuart Shelf and Torrens Hinge Zone: most of TORRENS
		Torrensian	Burra Group (Nb)	Siltstone, laminated; shale; sandstone, heavy mineral lamination, quartzose to feldspathic, cross bedding; dolomite, blue-grey to pale pink, lenticular. Includes the Myrtle Springs Formation, Skillogalee Dolomite and Rhynie Sandstone	Underlies: Umberatana Group Overlies: Callanna Group	Weathered and fractured rock aquifer	Torrens Hinge Zone: along eastern border of TORRENS east of the Andamooka Ranges
		Willouran	Callanna Group (Nc)	Siltstone, locally carbonaceous; sandstone, locally stromatolitic, ripple marks, halite casts, heavy mineral lamination; carbonates; evaporites; basalt, minor acid and intermediate volcanics. Includes Arkaroola and Curdimurka Subgroups	Underlies: Burra Group Overlies: Pandurra Formation, Gawler Craton	Weathered and fractured rock aquifer	Torrens Hinge Zone: along eastern border of TORRENS east of the Andamooka Ranges

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Arenaceous-red beds; quartz and lithic sandstone, pebble conglomerate and shale; red, red-brown or purple matrix of kaolinite, haematite and minor illite; grey or white spotting or mottling; laminated and siltstone interbeds	Underlies: Callanna Group Overlies: Gawler Craton	Weathered and fractured rock aquifer	Cariewerloo Basin: western three-quarters of TORRENS
			Gawler Range Volcanics (Ma)	Basalt and andesite to dacite, rhyodacite and rhyolite with a variable silica gap between the tholeiitic basalt-andesite series and the felsic series; massive porphyritic dacite and rhyodacite	Basement rocks of Gawler Craton	Weathered and fractured rock aquifer	Most of western two-thirds of TORRENS
Proterozoic	Palaeoproterozoic	Statherian	Broadview Schist (Lyb) and Myola Volcanics (Lym)	Deformed schist, slaty to phyllitic quartzite, interlayered amphibolites Porphyritic rhyolite/rhyodacite, felsic/hornblende-bearing gneisses, amphibolite	Basement rocks of Gawler Craton	Weathered and fractured rock aquifer	Northern, central and southern TORRENS
		Orosirian	Donington Suite (Ld)	Quartz-gabbronorite, hypersthene gneissic granite, syenogranite, monzogranite, granodiorite, tonalite, megacrystic granitoid gneiss	Basement rocks of Gawler Craton	Weathered and fractured rock aquifer	Central and north–north-eastern TORRENS

Table B8. Major geological formations of PORT AUGUSTA and the included part of WHYALLA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Unconsolidated silty clay, sand and carbonate earth with occasional gravel lenses	Overlies, Tertiary sediments and Cambrian and Proterozoic rocks	Can contain localised shallow aquifers	Throughout PORT AUGUSTA and WHYALLA
Cainozoic	Tertiary	Oligocene	Neuroodla Formation (Topu)	Green, grey to black argillaceous claystone and white calcareous mudstone; fauna include planorbid gastropods, a hydrobiid gastropod and a fish otolith	Underlies: Quaternary sediments Overlies: Cotabena Formation	Aquifer	Torrens Basin: north-eastern PORT AUGUSTA
Cainozoic	Tertiary	Eocene	Cotabena Formation (Teoo)	Fluvio-lacustrine, partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite	Underlies: Neuroodla Formation Overlies: Proterozoic rocks	Aquifer	Torrens Basin: north-eastern PORT AUGUSTA
Palaeozoic	Cambrian	Early	Hawker Group (Eh)	Includes the Wilkawillina Limestone (stromatolitic, oolitic limestone, quartz sand stringers; lime mudstone; fossiliferous calcarenite, sandstone), Woodendinna Dolomite (stromatolites, oolite, dolomitic shale, quartz-sand interbeds) and Parachilna Formation (sandstone and siltstone with minor carbonate interbeds)	Underlies: Cotabena Formation Overlies: Wilpena Group	Weathered and fractured rock aquifer	Arrowie Basin: north-eastern PORT AUGUSTA
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes Nuccaleena Formation (thin, laminated dolomite), Brachina Formation (calcitic siltstone, sandstone, minor shale), ABC Range Quartzite (quartzite, minor micaceous siltstone partings, some black heavy mineral laminations), Bunyeroo Formation (calcitic shale, siltstone; dolomite beds, limestone), Tent Hill Formation (quartzose sandstone; sandstone, siltstone, bands of silty shale, sandy shale; laminated shale), Wonoka Formation (limestone, siltstone, sandstone), Bonney Sandstone (silty feldspathic sandstone, interbedded siltstone, quartzite) and Rawnsley Quartzite (sandstone and quartzite)	Underlies: Hawker Group Overlies Umberatana Group	Weathered and fractured rock aquifer	Stuart Shelf, Torrens Hinge Zone and Adelaide Geosyncline: northern and eastern third of PORT AUGUSTA
Proterozoic	Neoproterozoic	Sturtian	Umberatana Group (Nu)	Includes Tapley Hill Formation (carbonaceous, dolomitic or calcareous pyritic silty shale, interbeds of micritic dolomites at base), Brighton Limestone (oolitic limestones, intraclasts of ooid grainstone, intertonguing stromatolite bioherms), Angepena Formation (micro-micaceous siltstone, interbedded dolomite), Wilmington Formation (arenaceous sandstone, quartzite, sandy siltstone, minor arkose and lenticular dolomite) and Etina Formation (often sandy oolitic, stromatolitic carbonates, interbedded shale and siltstone)	Underlies: Wilpena Group Overlies: Pandurra Formation	Weathered and fractured rock aquifer	Stuart Shelf, Torrens Hinge Zone and Adelaide Geosyncline: northern and most of eastern third of PORT AUGUSTA
Proterozoic	Mesoproterozoic	Calymmian	Pandurra Formation (M-p)	Quartz, lithic sandstone, very fine to medium-grained sandstone; framework of quartz with minor altered feldspar, chert, ferruginous chert, ironstone, muscovite, acid volcanics in red or purple matrix of kaolinite and haematite, interbeds of laminated shale and siltstone often intercalated with sandstone	Underlies: Stuart Shelf Overlies: Gawler Craton	Aquifer	Cariewerloo Basin: northern and most of eastern third of PORT AUGUSTA
Proterozoic	Mesoproterozoic	Calymmian	Gawler Range Volcanics (Ma)	Includes the Waganny Dacite (porphyritic dacite to rhyodacite, phenocrysts of plagioclase), Bittali Rhyolite (rhyolite, rhyodacite), Eucarro Rhyolite (rhyolite lava; generally plagioclase-rich, evenly porphyritic) and Yardea Dacite (dacite, porphyritic, phenocrysts of plagioclase, pyroxene)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Much of PORT AUGUSTA, particularly in the north and west

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Palaeoproterozoic	Statherian	Broadview Schist (Lyb) and Myola Volcanics (Lym)	Deformed schist, slaty to phyllitic fine-grained quartzite, interlayered amphibolites Interbanded porphyritic rhyolite and rhyodacite, fine-grained felsic and hornblende-bearing gneisses and fine-grained amphibolite	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	Northern through to southern PORT AUGUSTA/northern WHYALLA
		Orosirian	Donington Suite (Ld)	Variably deformed gneissic granite and granitic gneiss and gabbroic and amphibolite intrusives	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	South-eastern quadrant of PORT AUGUSTA into northern WHYALLA
			Hutchison Group (Lh)	Includes Warrow Quartzite (massive to flaggy quartzite containing local pelitic schist interbeds), Katunga Dolomite (dolomitic marble; dolomite, dolomite interbedded with chert, banded chert interbedded with dolomite, cherts of Middleback Jaspilite), Middleback Jaspilite (banded haematite and magnetite quartzite and chert grading into jaspilites, interbedded with lenticular altered schist)	Basement rocks of the Gawler Craton	Weathered and fractured rock aquifer	South-western PORT AUGUSTA, northern WHYALLA

Table B9. Major geological formations of COPLEY and the included parts of MARREE, CALLABONNA and FROME that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Yellow to reddish-brown fluviatile clay-sand; angular cobbles and pebbles	Overlies: Avondale Clay and Cambrian sediments	Can contain localised shallow aquifers	Western flank of Flinders Ranges
Cainozoic	Quaternary	Pleistocene	Avondale Clay (Qpav)	Green and grey clays, becoming red brown when mottled; locally gypsiferous	Underlies: Pooraka Formation Overlies: Cambrian sediments	Can contain localised shallow aquifers	Western flank of Flinders Ranges
Cainozoic	Tertiary	Miocene	Willawortina Formation (TpQaw)	One fine, one coarse facies; finer sequence of sandy mud and silty dolomite contains nine upward-fining cycles. Gravelly stream-channel sediments, interbedded clay; thick calcareous palaeosols	Overlies: Cambrian sediments	Can contain localised shallow aquifers	Eastern flank of Flinders Ranges
Cainozoic	Tertiary	Oligocene	Neuroodla Formation (Topu)	Green-grey to black, argillaceous and white calcareous mudstone; basal carbonaceous clay; quartz gravel and pebble layers near the ranges	Underlies: Quaternary sediments Overlies: Cotabena Formation, Cambrian and Neoproterozoic rocks	Aquitard	Torrens Basin: west of Flinders Ranges
Cainozoic	Tertiary	Eocene	Cotabena Formation (Teoo)	Partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite; finely laminated silt and carbonaceous mudstone; white clay horizons near base; lignitic quartz sand	Underlies: Neuroodla Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: west of Flinders Ranges
Mesozoic	Triassic	Late	Leigh Creek Coal Measures (RJ-l)	Basal conglomerate overlain by dark grey carbonaceous shales with brown coal seams and a thin, lenticular fine-grained sandstone	Underlies: Quaternary sediments Overlies: Umberatana Group		Three small infolded basins at Leigh Creek and Copley
Palaeozoic	Cambrian	Early	Lake Frome Group (Ef)	Includes the Billy Creek Formation (brown, minor green shales and sandstones; cherty limestone interbeds; halite casts), Moodlatana Formation (buff, brown sandstones), Balcoracana Formation (red, brown sandstones, siltstones, dolomite and chert beds), Pantapinna Sandstone (red, white feldspathic sandstones) and Grindstone Range Sandstone (white quartzites, minor red sandstone and quartzite conglomerate) and Wirrealpa and Aroona Creek Limestones (oolitic, pisolitic, marly limestones, fossils)	Underlies: Quaternary and Tertiary sediments Overlies: Hawker Group	Aquifer	Arrowie Basin: throughout southern two-thirds of COPLEY
Palaeozoic	Cambrian	Early	Hawker Group (Eh)	Includes the Parachilna Formation (arkosic, glauconitic sandstone, shales), Mernmerna Formation (limestone often in calcareous shale matrix), Moorowie Formation (clean to sandy limestones, siltstones, shales, fossils), Ajax Limestone (sandy, oolitic dolomites, limestones, fossiliferous limestones), Wilkawillina Limestone (dolomitic limestones, often oolitic, shale and sandstone interbeds; fossiliferous limestone), Midwerta Shale (calcareous shale), Orapinna Shale (thinly bedded silty shale), Nepabunna Siltstone (calcareous siltstone) and Narina Greywacke (greywacke sandstone)	Underlies: Lake Frome Group Overlies: Wilpena Group	Aquifer	Arrowie Basin: throughout southern two-thirds of COPLEY

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes the Nuccaleena Formation (purple shales, thin beds and lenses of cream dolomites), Brachina Formation (siltstones , minor shales and sandstones), Ulupa Siltstone (basal shale, outcropping siltstone-shale), ABC Range Quartzite (white quartzite, clay balls), Bunyeroo Formation (red-brown to purple shales), Wonoka Formation (green shales, sandy limestone, minor siltstone interbeds), Billy Springs Formation (lenticular breccia of dolomite, limestone, granite), Pound Subgroup (white quartzite; haematitic feldspathic sandstone)and Uratanna Formation (shales, siltstones, limestone nodules, sandstone lenses)	Underlies: Hawker Group Overlies: Umberatana Group	Aquifer	Adelaide Geosyncline: most of Copley; included parts of MARREE and CALLABONNA
		Sturtian	Umberatana Group (Nu)	Tillite; sandstone; siltstone; arkose; dolomite; quartzite; conglomerate; shale; greywacke. Includes the Fitton Formation (conglomerate; arkose, pebbly; quartzite, white, massive, interbedded with silty shale), Bolla Bollana Formation (schistose grey-green tillite), Lyndhurst Formation (blue-grey siltstone, quartzite interbeds), Angepena Formation (siltstone, interbeds of dolomite and minor shale; pisolitic and algal limestone), Elatina Formation (granule-bearing greywacke, sandstones), Tapley Hill Formation (blue-grey silty shales), Balcanoona Formation (fossiliferous, partly oolitic limestone and dolomite), Amberoona Formation (green and grey-green siltstones, shales), Enorama Shale (grey-green silty shales), Trezona Formation (breccia limestones or dolomites interbedded in silty and dolomitic shales), Fortress Hill Formation (laminated grey-green siltstones), Mount Curtis Tillite (massive, slightly dolomitic siltstone tillite) and Balparana Sandstone (well-bedded medium-grained light grey sandstones; lenses of quartz and red porphyry granules)	Underlies: Wilpena Group Overlies: Burra Group	Aquifer	Adelaide Geosyncline: most of Copley; included parts of MARREE and CALLABONNA
		Torrensian	Burra Group (Nb)	Siltstone, shale; sandstone; dolomite. Includes the Copley and Wortupa Quartzites, Skillogalee Dolomite (dolomitic siltstone; dolomites, magnesites), Myrtle Springs Formation (siltstones, feldspathic greywackes), Humanity Seat Formation (heavy mineral laminated quartzites, halite casts), Woodnamoka Phyllite (breccia-conglomerate of clasts of Callanna Group units), Blue Mines Conglomerate (potash feldspar and quartz; pebbles; porphyritic rhyolite) and Opaminda Formation (green siltstones, shales, bands of magnesian dolomite)	Underlies: Umberatana Group Overlies: Callanna Group	Aquifer	Adelaide Geosyncline: most of Copley; included parts of MARREE and CALLABONNA
		Willouran	Callanna Group (Nc)	Includes the Paralana Quartzite (quartzites, sandstones, basal conglomerate), Wywyana Formation (dolomitic, actinolitic marbles) and Wooltana Volcanics (altered basalts, minor rhyolite and andesite, quartzites, tuffs, calc-silicate metasediments)	Underlies: Burra Group Overlies: Mount Painter Inlier	Aquifer	Adelaide Geosyncline: most of Copley; included parts of MARREE and CALLABONNA
Proterozoic	Palaeoproterozoic	Statherian	Mount Painter Inlier	Includes the Radium Creek Metamorphics consisting of the Mount Adams Quartzite (feldspathic quartzite, minor phyllite), Pepegoona Porphyry (recrystallised rhyolite), Brindana Schist (muscovite schists, minor garnet schists) and Freeling Heights Quartzite (feldspathic quartzites, arenaceous schists, mica schists, minor corundum schists, quartz pebbles, conglomerates)	Underlies: Callanna Group	Unknown	Beneath Adelaide Geosyncline; north-eastern COPLEY, north-western FROME and south-western CALLABONNA

Table B10. Major geological formations of PARACHILNA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Unconsolidated red-brown poorly-sorted clayey sand, gravel, conglomerate, breccia; clay, sand and carbonate earth, silty with gravel lenses	Overlies: Tertiary sediments, Cambrian and Neoproterozoic rocks	Can contain localised shallow aquifers	Fans east and west of Flinders Ranges
			Avondale Clay (Qpav)	Green to grey clay, ferruginous mottling, sandy clay	Overlies: Tertiary sediments, Cambrian and Neoproterozoic rocks	Unknown	Fans east and west of Flinders Ranges
	Tertiary	Miocene	Willawortina Formation (TpQaw)	Calcareous, silty to sandy clay and medium-grained sand becoming bouldery near the Flinders Ranges	Underlies: Quaternary sediments Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Lake Eyre Basin: east of Flinders Ranges
		Oligocene	Namba Formation (Topn)	Fine to medium-grained, poorly sorted, angular sand, silt and clay, with thin dolomite and limy, often oolitic, dolomite interbeds; smectite-dominated clay, illite, kaolinite	Underlies: Quaternary sediments Overlies: Eyre Formation	Aquifer	Lake Eyre Basin: east of Flinders Ranges
			Neuroodla Formation (Topu)	Dark-grey to green claystone and white, calcareous mudstone with a basal shelly, carbonaceous clay	Underlies: Quaternary sediments Overlies: Cotabena Formation	Aquifer	Torrens Basin: west of Flinders Ranges
		Eocene	Cotabena Formation (Teoo)	Fluvio-lacustrine, partly carbonaceous, fine to coarse-grained sand, silt, clay and lignite	Underlies: Neuroodla Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Torrens Basin: west of Flinders Ranges
		Palaeocene	Eyre Formation (Taee)	Pyritic, carbonaceous sand, silt to gravel-size grains, clasts up to small cobble size; beds of lignite and clay are common; clay matrix often present in sand around basin margins; polished gravel in basal horizons, pebbles of basement rock in some localities	Underlies: Namba Formation Overlies: Cambrian and Neoproterozoic rocks	Aquifer	Lake Eyre Basin: east of Flinders Ranges
Palaeozoic	Carboniferous		Alpana Formation (CP-a)	Three-metre thick, glacigene basal lodgement till with faceted, striated and polished clasts and a till fabric indicating north-westerly ice movement, overlain by ~17 m of fine to medium-grained sandstone	Overlies: Callanna Group	Unknown	Palaeovalley incised in Blinman Diapir
	Cambrian	Early	Lake Frome Group (Ef)	Includes the Billy Creek Formation (red siltstone, shale), Wirrealpa Limestone (lime mudstone, limestone, fossils), Moodlatana Formation (micaceous siltstone, shale, arkosic sandstone), Balcoracana Formation (micaceous siltstone, shale, limestone bands, carbonate beds), Pantapinna Sandstone (sandstone, micaceous siltstone, shale, volcanic, lithic clasts) and Grindstone Range Sandstone (quartz sandstone, minor feldspar, volcanic clasts)	Underlies: Tertiary sediments Overlies: Hawker Group	Weathered and fractured rock aquifer	Arrowie Basin: northern half of PARACHILNA; south–south-western PARACHILNA
			Hawker Group (Eh)	Includes the Parachilna Formation (sandstone, siltstone, minor carbonate), Woodendinna Dolomite (oolitic, stromatolitic, quartz sand interbeds, local gravel trains), Wirrapowie Limestone (micritic limestone with fossils), Wilkawillina Limestone (lime mudstone, immature sandstone, shelly fossils), Mernmerna Formation (nodular to mottled, thinly bedded limestone), Midwerta Shale (partly calcareous, minor nodular limestone), Bendieuta Formation (quartz sandstone, oolitic, fenestral limestone), Bunkers Sandstone (quartzose, upward-coarsening sandstone), Orapinna Shale (silty shale, limestone concretions, fossil fragments), Moorowie Formation (shale, siltstone, oolitic, reef limestone) and Narina Greywacke (silty, feldspathic greywacke)	Underlies: Lake Frome Group Overlies: Wilpena Group	Weathered and fractured rock aquifers	Arrowie Basin: northern half of PARACHILNA; south–south-western PARACHILNA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes Nuccaleena Formation (laminated, pink-cream dolomite), Brachina Formation (siltstone, sandstone), ABC Range Quartzite (white quartzite), Bunyeroo Formation (red mudstone), Wonoka Formation (calcareous siltstone, silty, fine sandy limestone, minor sandstone), Bonney Sandstone (red, micaceous siltstone, sandstone), Rawnsley Quartzite (quartz-cemented sandstone)	Underlies: Hawker Group Overlies: Umberatana Group	Weathered and fractured rock aquifer	Adelaide Geosyncline: most of PARACHILNA
		Sturtian	Umberatana Group (Nu)	Includes Pualco Tillite (diamictite, gritty siltstone, minor sandstone, quartzite interbeds), Holowilena Ironstone (laminated haematitic siltstone, minor haematitic diamictite), Wilyerpa Formation (siltstone, occasional dropstones, interbedded lithic sandstone, minor conglomerate, diamictite), Tapley Hill Formation (carbonaceous siltstone, some sandstone interbeds) and Brighton Limestone (oolitic, intraclastic, stromatolitic limestone), Angepena Formation (red siltstone, sandstone bands), Wilmington Formation (sandstone, siltstone, minor sandy limestone), Sunderland Formation (laminated siltstone, sandstone interbeds; minor sandstone, oolitic limestone), Etina Formation (grey, oolitic, sandy, stromatolitic limestone, green siltstone), Tarcowie Siltstone (flaser bedding, sandy lenses, dark mud drapes), Enorama Shale (grey-green silty shale), Trezona Formation (calcareous siltstone, stromatolitic, intraclastic limestone), Yaltipena Formation (limestone, sandy beds, siltstone) and Elatina Formation (sandstone, granule trains, pebbles)	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Adelaide Geosyncline: most of PARACHILNA
		Torrensian	Burra Group (Nb)	Includes the Emeroo Subgroup (feldspathic sandstone, quartzite, minor siltstone), Wirreanda Dolomite Beds (dolomite, minor siltstone, magnesite conglomerate), Yednalue Quartzite (feldspathic quartzite, minor siltstone), Skillogalee Dolomite (dolomite, siltstone, sandstone; black chert, intraclasts, stromatolites, conglomerate interbeds) and Saddleworth Formation (dolomitic siltstone, dolomite, sandstone; feldspathic quartzite interbeds)	Underlies: Umberatana Group Overlies: Callanna Group	Weathered and fractured rock aquifer	Adelaide Geosyncline: most of PARACHILNA
		Willouran	Callanna Group (Nc)	Includes the Arkaroola Subgroup (basal clastics, a carbonate unit and mafic volcanics) and the Wirrawilka Beds (laminated siltstone overlain by laminated limestone and dolomite), Niggly Gap Beds (immature clastics with minor sandstone, siltstone) and Arkaba Beds (laminated and micaceous siltstone, sandstone, stromatolitic dolomite), Kirwan Siltstone (thinly laminated, carbonaceous siltstone), Waraco Limestone (stromatolitic limestone, chert, stromatolite beds, stromatolitic dolomite, laminated siltstone) and Worumba Dolomite Beds (dolomite with tepee structures) of the Curdimurka Subgroup	Basement rocks of the Adelaide Geosyncline	Weathered and fractured rock aquifer	Adelaide Geosyncline: most of PARACHILNA

Table B11. Major geological formations of CURNAMONA that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Coonarbine Formation (Qec)	Brown clayey sand, columnar jointing, calcareous palaeosols; sand may be gypsum, clay pellets or quartz, or mixtures of these	Overlies: Eurinilla Formation	Unsaturated	Leeside mounds and longitudinal dunes
			Eurinilla Formation (Qpae)	Bright red-brown to yellow-brown sand and gravel; red-brown to brown sand and clayey fine sand or silt	Underlies: Coonarbine Formation Overlies: Willawortina Formation	Unsaturated	Palaeovalleys in western CURNAMONA; claypans; northern Olary Ranges
	Tertiary	Miocene	Willawortina Formation (TeQpaw)	Brown, poorly sorted alluvial deposits with pink pedogenic carbonate nodules	Underlies: Eurinilla Formation Overlies: Namba Formation and Proterozoic rocks	Aquifer	Western and eastern CURNAMONA
			Namba Formation (Topn)	Fine clastics, mainly olive to grey-coloured clay, sandy clay and silt to fine sand, the sands being lighter and yellowish; three dolomite horizons	Underlies: Willawortina Formation Overlies: Eyre Formation	Aquifer	Palaeovalleys; Lake Eyre Basin: most of CURNAMONA, absent along southern quarter
		Palaeocene	Eyre Formation (Taee)	Carbonaceous sand with minor clay lenses, fine to very-coarse, moderately-sorted, sub-rounded to sub-angular, irregularly-shaped grains; pyrite common, uranium may be present	Underlies: Namba Formation Overlies: Bulldog Shale	Aquifer	Palaeovalleys; Lake Eyre Basin: most of CURNAMONA, absent along southern quarter
Mesozoic	Cretaceous	Barremian	Bulldog Shale (Kmb)	Black, blue-grey silty mudstone, mudstone, slate, shale; grey micaceous, carbonaceous clay	Underlies: Eyre Formation Overlies: Cadna-owie Formation	Aquitard	Eromanga Basin (Frome Embayment): north–north-eastern CURNAMONA
		Valanginian	Cadna-owie Formation (Knc)	Siltstone or hornfels of the low-grade basement, porphyry or grey Cambrian shale and limestone; fine sand; basal pebble bed	Underlies: Bulldog Shale Overlies: Cambrian and Proterozoic rocks	Aquifer	Eromanga Basin (Frome Embayment): north–north-eastern CURNAMONA
Palaeozoic	Cambrian	Early	Lake Frome Group (Ef)	Includes the Wirrealpa Limestone (medium grey micritic limestone; basal dolomite), Billy Creek Formation (siltstone, shale, dolomite, tuff beds), Moodlatana Formation (red-brown sandstone, minor calcareous siltstone and sandstone), Balcoracana Formation (micaceous siltstone, shale, carbonate cycles), Pantapinna Sandstone (feldspathic, sandstone, minor micaceous siltstone and shale) and Grindstone Range Sandstone (quartz arenite, minor feldspar and volcanic lithic clasts)	Underlies: Cadna-owie and Eyre Formations Overlies: Hawker Group	Weathered and fractured rock aquifer	Arrowie Basin (Moorowie and Yalkalpo Sub-basins):western and north-eastern CURNAMONA
			Hawker Group (Eh)	Includes the Wilkawillina Limestone (fossiliferous limestone, pelloidal grainstone), Mernmerna Formation (thin, fossil-rich red limestone) and Moorowie Formation (shale, siltstone, oolite and reef limestone; fossiliferous limestones; siltstones, shales fossils)	Underlies: Lake Frome Group Overlies: Wilpena Group	Weathered and fractured rock aquifer	Arrowie Basin (Moorowie and Yalkalpo Sub-basins); western and north-eastern CURNAMONA

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Neoproterozoic (Adelaidean)	Marinoan	Wilpena Group (Nw)	Grey-green laminated siltstone with laminated grey flaggy quartzite and brown-weathering dolomite, marble and sandy marble. Includes the Nuccaleena Formation (pinkish stromatolitic dolomite) and Brachina Formation (grey-green to reddish siltstone)	Underlies: Hawker Group Overlies: Umberatana Group	Weathered and fractured rock aquifer	Neoproterozoic Platform over Curnamona Province: central, western and north-eastern CURNAMONA
		Sturtian	Umberatana Group (Nu)	Includes the Pualco Tillite (clasts of brown carbonate and dark metasiltstone), Wilyerpa Formation (laminated black slate, siltstone, some tillite interbeds, several sandstone beds), Etina Formation (pink and grey stromatolitic limestone), Elatina Formation (diamictite, gritty siltstone bands), Brighton Limestone (stromatolitic carbonate) and Upalinna Subgroup	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Neoproterozoic Platform over Curnamona Province: central, southern, western and north-eastern CURNAMONA
		Torrensian	Burra Group (Nb)	Dark grey, laminated shale and siltstone; calc-silicates with gossanous horizons, pink siliceous breccia and magnetite-calcite-silica beds, interbedded with fine-grained, green to grey, laminated, occasionally graphitic slate	Underlies: Umberatana Group Overlies: Willyama Supergroup	Weathered and fractured rock aquifer	Neoproterozoic Platform over Curnamona Province: southern CURNAMONA
	Palaeoproterozoic	Statherian	Willyama Supergroup (Lw)	Deformed schists and gneisses and minor 'lode' rocks. Includes Ethiudna (Peryhumuck, Whey Whey and Bimba Formations) and Wiperaminga (George Mine, Tommie Wattie and Mooleugore Formations) Subgroups of the Curnamona Group and the Saltbush (Oonartra Creek and Walpurta Formations) and Mount Howden (Alconie, Mooleulooloo and Dayana Formations) Subgroups of the Strathearn Group	Basement rocks of the Curnamona Province	Weathered and fractured rock aquifer	Curnamona Province: all of CURNAMONA

Table B12. Major geological formations of OLARY and the included parts of ORROROO that are within the study area

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Cainozoic	Quaternary	Pleistocene	Pooraka Formation (Qpap)	Reddish alluvial clay and gravel, calcareous mottling; lenses of sub-angular quartz and quartzite boulders (up to 0.4 m) sometimes cemented by calcrete; sandy clay; argillaceous sandstone. The Callabonna Clay occasionally overlies the Loveday Soil as a thin reddish clay layer	Overlies: Blanchetown Clay and Proterozoic rocks	Can contain localised shallow aquifers	Throughout OLARY and ORROROO
	Tertiary	Pliocene	Blanchetown Clay (TpQlb)	Green, grey, brownish, yellowish or reddish sandy clay, commonly mottled, some silt, sand, sometimes gypsiferous; yellow and grey clay, strong red mottling; silt, sandstone, calcrete or gravel over partly pebbly, sandy clay	Underlies: Pooraka Formation Overlies: Pliocene sands	Aquitard	Murray Basin: southe-astern and southern OLARY
			Parilla Sand (Tpp) or Loxton Sand (Tpl)	Pale grey, yellow, brown, orange or pinkish, mainly medium-grained, varying from fine-grained to over 1 mm; conglomerate contains angular fragments of metamorphic and igneous rocks	Underlies: Blanchetown Clay Overlies: Geera Clay	Unsaturated	Murray Basin: southe-astern and southern OLARY
		Oligocene	Geera Clay (Tyg)	Light grey, black, brownish black to greenish black clay; variously sandy, silty, pyritic, carbonaceous; fossiliferous marine marl in lower part contains calcite, glauconite, fossil fragments; in upper part, clay contains interbedded partly carbonaceous, micaceous sand in places	Underlies: Pliocene sands Overlies: Olney Formation	Aquitard	Murray Basin: southe-astern and southern OLARY
		Eocene	Olney Formation (Tro)	Greyish, medium grained, cross-laminated, clayey sand; contains carbonaceous and clay laminae	Underlies: Geera Clay Overlies: Neoproterozoic rocks	Aquifer	Murray Basin: southe-astern and southern OLARY
Palaeozoic	Ordovician	Darriwilian	Anabama Granite (EOda)	Pale grey biotite granite, usually coarse-grained, with anhedral microcline and some orthoclase intergrown with quartz and biotite, up to 15% sodic plagioclase near oligoclase	Underlies: Quaternary sediments Overlies: Neoproterozoic rocks	Unknown	Along southern margin of Olary Ranges
Proterozoic	Neoproterozoic	Marinoan	Wilpena Group (Nw)	Includes Nuccaleena Formation (dolomite), Seacliff Sandstone (dolomite, siltstone, quartzite; sandstone), Ulupa Siltstone (partly pyritic siltstone, sandstone, quartzite) and Wonoka Formation (limestone, siltstone, shale, silty limestone, calcitic siltstone, pyritic calcareous siltstone, sandstone, sandy siltstone)	Underlies: Quaternary and Tertiary sediments Overlies: Umberatana Group	Weathered and fractured rock aquifer	Adelaide Geosyncline: central, western OLARY, eastern half of ORROROO
		Sturtian	Umberatana Group (Nu)	Includes Pualco Tillite (diamictite, quartzite, siltstone), Benda Siltstone (calcareous, laminated siltstone, silty limestone), Wilyerpa Formation (siltstone, sandy siltstone, quartzite), Tapley Hill Formation (grey laminated siltstone), Tarcowie Siltstone (siltstone, calcareous siltstone, dolomitic siltstone, quartzite, dolomite, sandy or silty dolomite, sandy limestone), Enorama Shale (siltstone. Calcitic siltstone, sandstone,minor limestone), Gumbowie Arkose (interbedded quartzite, sandstone, siltstone), Pepuarta Tillite (tillite with matrix of siltstone or sandstone) and Grampus Quartzite (feldspathic quartzite, quartz pebbles)	Underlies: Wilpena Group Overlies: Burra Group	Weathered and fractured rock aquifer	Adelaide Geosyncline: throughout OLARY and ORROROO

Age			Unit	Lithology	Stratigraphic position	Hydrostratigraphy	Known occurrence
Proterozoic	Neoproterozoic	Torrensian	Burra Group (Nb)	Includes Emeroo Subgroup (sandstone, black hematitic laminations), Skillogalee Dolomite (dolomite, siltstone, conglomerate, chert), Saddleworth Formation (partly laminated and pyritic siltstone, dolomitic siltstone. silty dolomite, dolomite rock, rare sandstone), Belair Subgroup (siltstone, siltstone, laminated dolomite, quartzite, micaceous phyllite, dolomitic siltstone, quartzite, silty dolomite) and Boucaut Volcanics (rhyolite, dacite, amygdaloidal andesite & basalt, biotitic schist)	Basement rocks of the Adelaide Geosyncline	Weathered and fractured rock aquifer	Adelaide Geosyncline: throughout OLARY and ORROROO
		Willouran	Callanna Group (Nc)	Quartzite, interbedded schist; calcareous sandstone, shale flakes, iron-rich sandstone to siltstone, amphibole schist. Includes Cutana beds and Curdimurka Group	Basement rocks of the Adelaide Geosyncline	Weathered and fractured rock aquifer	Adelaide Geosyncline: minor occurrences in NE and SW OLARY, SE and NE ORROROO
	Palaeoproterozoic	Statherian	Willyama Supergroup (Lw)	Deformed schists and gneisses and minor 'lode' rocks. Includes Ethiudna Subgroup (Peryhumuck, Whey Whey and Bimba Formations) and Wiperaminga Subgroup (George Mine, Tommie Wattie and Mooleugore Formations) of the Curnamona Group and the Saltbush Subgroup (Oonartra Creek and Walpurta Formations) and Mount Howden Subgroup (Alconie, Mooleulooloo and Dayana Formations) of the Strathearn Group	Basement rocks of the Curnamona Province	Weathered and fractured rock aquifer	Curnamona Province: northern and north-eastern OLARY

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
milligram	mg	10^{-3} g	mass
millimetre	mm	10^{-3} m	length
second	s	base unit	time interval
year	y	365 or 366 days	time interval

GLOSSARY

AACWMB – Arid Areas Catchment Water Management Board

Act (the) — in this document, refers to the *Natural Resources Management (SA) Act 2004,* which supersedes the *Water Resources (SA) Act 1997*

Aeolian — pertaining to or caused by wind

Age — (1) unit of geological time, shorter than an epoch, during which rocks of that period were formed; (2) the position of any feature relative to the geological time scale

Ag — the chemical symbol for silver

AGT — Australian Groundwater Technologies

AHD — Australian Height Datum; the geodetic datum for altitude measurement in Australia. In 1971 the mean sea level for 1966–1968 was assigned the value of zero on the Australian Height Datum at thirty tide gauges around the coast of the Australian continent.

Alluvial — composed of or pertaining to alluvium, or deposited by running water

Alluvial fan — an outspread mass of alluvium deposited by flowing water where it debouches from a steep narrow canyon on to a plain or valley floor. The abrupt change of gradient eventually reduces the transport of sediment by the issuing stream. Viewed from above, the deposits are usually fan-shaped; they are especially prominent in arid areas

Alluvium — general term for detrital deposits made by rivers or streams or found on alluvial fans, floodplains, etc. Alluvium consists of gravel, sand, silt and clay and often contains organic matter. It does not include the subaqueous sediments of lakes and seas

Ambient — the background level of an environmental parameter (e.g. a measure of water quality such as salinity)

Amphibole — important group of rock-forming minerals that occur in a wide range of igneous and metamorphic rocks whose molecular structure is based on silica tetrahedral linked to give double chains, $(Si_4O_{11})n$, in a lattice that gives scope for very extensive ionic substitution

Amphibolite — metamorphic rock consisting mainly of amphibole and plagioclase, little or no quartz and crystalloblastic texture

Anthropogenic — of, relating to, or resulting from the influence of human beings on nature

Aquifer — an underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer, confined — an aquifer in which the upper surface is impervious (see 'confining layer') and the water is held at greater than atmospheric pressure; water in a penetrating well will rise above the surface of the aquifer

Aquifer test — a hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resources available for development from the well

Aquifer, unconfined — an aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure

Aquitard — a layer in the geological profile that separates two aquifers and restricts the flow between them

ASR — Aquifer Storage and Recovery; involves the process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal; also known as aquifer storage and retrieval

Archaean — the eon of the Precambrian between 4000 Ma and 2500 Ma; the rocks that formed in that time

Arid lands — in South Australia, arid lands are usually considered to be areas with an average annual rainfall of less than 250 mm and support pastoral activities instead of broadacre cropping

GLOSSARY

Artesian aquifer — an aquifer in which the water surface is bounded by an impervious rock formation; the water surface is at greater than atmospheric pressure, and hence rises in any well which penetrates the overlying confining aquifer

Artificial recharge — the process of artificially diverting water from the surface to an aquifer; artificial recharge can reduce evaporation losses and increase aquifer yield; see also 'natural recharge', 'aquifer'

Au — the chemical symbol for gold

Banded iron formation — sedimentary rocks that are typically bedded or laminated and composed of at least 25% iron

Baseflow — the water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Basement — the surface beneath which sedimentary rocks are not found

Basin — the area drained by a major river and its tributaries

Bedded — arranged in layers

Biodiversity — (1) the number and variety of organisms found within a specified geographic region, (2) the variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

BoM — Bureau of Meteorology, Australia

Cainozoic — the ('recent life') era covering the last 66 Ma; it is subdivided into the Tertiary and Quaternary periods

Calcrete — a limestone precipitated as surface or near-surface crusts and nodules by the evaporation of soil moisture in semi-arid climates

Cambrian — the oldest of the Palaeozoic Era, having a duration of about 50 Ma and beginning about 544 Ma ago

Catchment — that area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

Catchment Water Management Board — a statutory body established under the Act whose prime function is to implement a catchment water management plan for its area

Catchment water management plan — the plan prepared by a CWMB and adopted by the Minister in accordance with the Act

Claypan — dense, clayey subsoil layer that is hard when dry but may be plastic when wet

CO_2 – carbon dioxide

Colluvium — unconsolidated material at the bottom of a cliff or slope, generally moved by gravity alone

Cone of depression — an inverted cone-shaped space within an aquifer caused by a rate of groundwater extraction that exceeds the rate of recharge; continuing extraction of water can extend the area and may affect the viability of adjacent wells, due to declining water levels or water quality

Confining layer — a rock unit impervious to water, which forms the upper bound of a confined aquifer; a body of impermeable material adjacent to an aquifer; see also 'aquifer, confined'

Consolidation — any process whereby soft or loose earth materials become firm

Craton — part of the continental crust that has been stable for at least 1000 Ma

Crystalline — having a regular atomic or molecular structure but without developing easily discernible crystal faces

CSIRO – Commonwealth Scientific and Industrial Research Organisation

Cu — the chemical symbol for copper

CWMB — Catchment Water Management Board

δD — hydrogen isotope composition, measured in parts per thousand ($^{o}/_{oo}$)

DEH — Department for Environment and Heritage (Government of South Australia)

DENR — Department of Environment and Natural Resources (Government of South Australia)

DES — Drillhole Enquiry System; a database of groundwater wells in South Australia, compiled by the South Australian Department of Water, Land and Biodiversity Conservation (DWLBC)

DFW — Department for Water (Government of South Australia)

Diamictite — a terrigenous sedimentary rock containing a mixture of particles

Discharge — groundwater discharge is the removal of water from the saturated zone across the watertable surface, together with the associated flow toward the watertable within the saturated zone

Domestic purpose — the taking of water for ordinary household purposes; includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares

Domestic wastewater — water used in the disposal of human waste, for personal washing, washing clothes or dishes, and swimming pools

Drillhole — *see* 'well'. A hole or passage made by a drill; usually made for exploratory purposes. Typically used in the mining industry

Dryland salinity — the process whereby salts stored below the surface of the ground are brought close to the surface by the rising watertable. The accumulation of salt degrades the upper soil profile, with impacts on agriculture, infrastructure and the environment

Dunefield —an area covered by extensive sand dunes

DWLBC — Department for Water, Land and Biodiversity Conservation (Government of South Australia)

Ecology — the study of the relationships between living organisms and their environment

Ecosystem — any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Environmental water requirements — the water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

Eocene — the middle epoch of the Tertiary period between the Palaeocene and Oligocene epochs

EOH — end of hole

Eon — a division of geological time, the longest time unit, next in order above era; the term is also used for an interval of 10^9 years

Ephemeral streams — those streams that usually contain water only on an occasional basis after rainfall events

Epoch — an interval of geological time longer than an age and shorter than a period during which the rocks of a particular series were formed

Equivalent — agreeing or corresponding in geological age or position within the stratigraphical profile

Era — a geological time unit one order of magnitude below eon

Erosion — natural breakdown and movement of soil and rock by water, wind or ice; the process may be accelerated by human activities

Evapotranspiration — the total loss of water as a result of transpiration from plants and evaporation from land, and surface water bodies

Exposure — an area where rocks can be seen free from the soil and vegetation cover

Facies — an assemblage or association of mineral, rock or fossil features reflecting the environment and conditions of the origin of the rock; it refers to the appearance and peculiarities that distinguish a rock unit from associated or adjacent units

Ferricrete — an amalgam of surface sand and gravel cemented into a mass by iron oxide

Filtration — numerous methods of filtering a water sample or supply to remove suspended sediment and the larger animal and plant life

Fissile — capable of being split or cleft or divided easily along close parallel planes of weakness

Floodplain — of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development (SA) Act 1993*; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow regime — the character of the timing and amount of flow in a stream

Fluvial — of or pertaining to rivers; produced by the action of a river or stream

Fossil water — groundwater that has remained sealed in an aquifer for a long period of time

Fossiliferous — (of rocks or strata) containing or bearing fossils

Fractured rock aquifer — aquifer in which groundwater flow occurs along fractures, faults and weathered zone (secondary porosity)

Fresh — a short duration, small volume pulse of streamflow generated by a rainfall event that temporarily, but noticeably, increases stream discharge above ambient levels

Fully-penetrating well — in theory this is a well hole that is screened throughout the full thickness of the target aquifer; in practice, any screen that is open to at least the mid 80% of a confined aquifer is regarded as fully-penetrating

GAB — Great Artesian Basin

Geological features — includes geological monuments, landscape amenity and the substrate of land systems and ecosystems

Geomorphic — related to the physical properties of the rock, soil and water in and around a stream

Geomorphology — the scientific study of the landforms on the Earth's surface and of the processes that have fashioned them

Gibber plain — a residual layer of wind-polished, closely concentrated rock fragments covering a desert surface because of the removal of loose silt and sand

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis

Gneiss — a foliated metamorphic rock formed under conditions of high-grade regional metamorphism

Granite — in the strict sense a coarse-grained alkali-rich plutonic igneous rock composed primarily of quartz and one or two feldspars

Granulite — a high-grade metamorphic rock composed of equal-sized, interlocking grains

Gravel — an unconsolidated accumulation consisting of particles larger than sand (diameter >2 mm), i.e. granules, pebbles, cobbles, boulders or any combination of these

Groundwater — water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Habitat — the natural place or type of site in which an animal or plant, or communities of plants and animals, live

Headwaters — small streams that make up the source and uppermost portion of a river or stream before the main tributaries join it

Heavy metal — any metal with a high atomic weight (usually, although not exclusively, greater than 100), for example mercury, lead and chromium. Heavy metals have widespread industrial uses, and many are released into the biosphere via air, water and solids pollution. Usually these metals are toxic at low concentrations to most plant and animal life.

Hydraulic conductivity (K) — a measure of the ease of flow through aquifer material: high K indicates low resistance, or high flow conditions; measured in metres per day

Hydrogeology — the study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also 'hydrology'

Hydrography — the discipline related to the measurement and recording of parameters associated with the hydrological cycle, both historic and real time

Hydrology — the study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

Hydstra — a time series data management system that stores continuously recorded water-related data such as water level, salinity and temperature; it provides a powerful data analysis, modelling and simulation system; contains details of site locations, setup and other supporting information

Hyporheic zone — the wetted zone among sediments below and alongside rivers; it is a refuge for some aquatic fauna

ICCWR – The Department for Water's Impacts of Climate Change on Water Resources project

Igneous rock — a rock that solidified from molten rock material (magma) that was generated deep within the Earth

Impact — a change in the chemical, physical, or biological quality or condition of a water body caused by external sources

Indigenous species — a species that occurs naturally in a region

Infiltration — the movement of a fluid into a solid substance through pores or cracks, in particular the movement of water into soil or porous rock

Infrastructure — artificial lakes; dams or reservoirs; embankments, walls, channels or other works; buildings or structures; or pipes, machinery or other equipment

Injection well — an artificial recharge well through which water is pumped or gravity-fed into the ground

Integrated catchment management — natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints

Intensive farming — a method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or mechanical means

Interdunal — between dunes

Irrigation — watering land by any means for the purpose of growing plants

Karst — a type of topography characterised by caves and sinkholes shaped by the dissolution of soluble bedrock, usually carbonate rock such as limestone

Lake — a natural lake, pond, lagoon, wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context

Land — whether under water or not, and includes an interest in land and any building or structure fixed to the land

Licence — a licence to take water in accordance with the Act; see also 'water licence'

Licensee — a person who holds a water licence

Limestone — a rock composed primarily of calcareous sediments consisting of calcium carbonate ($CaCO_3$)

Lunette — an arcuate dune formed on the lee side of a lake basin or river bed in semi-arid areas

m AHD — defines elevation in metres (m) according to the Australian Height Datum (AHD)

Ma — abbreviation for 10^6 years (one million years)

Marinoan — youngest chronostratigraphic unit of the Adelaidean period

Mesoproterozoic — middle era of the Proterozoic that occurred between 1600–1000 Ma

Mesozoic — era of geological time between 251 and 66 Ma

Metadata — information that describes the content, quality, condition, and other characteristics of data, maintained by the Federal Geographic Data Committee

Metamorphic rock — any of a class of rocks that are the result of partial or complete recrystallisation in the solid state of pre-existing rocks under conditions of temperature and pressure that are significantly different from those obtaining at the surface of the Earth

Miocene — the epoch of the Tertiary Period between the Oligocene and the Pliocene epochs from 23–5 Ma

Model — a conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off, assessing the impacts of dams or predicting ecological response to environmental change

Monitoring — (1) the repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things

Mudstone — a mud-supported carbonate sedimentary rock containing less than 10% particles of clay and fine silt size

Native species — any animal and plant species originally in Australia; see also ‘indigenous species’

Natural recharge — the infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc). See also recharge area, artificial recharge

Natural resources — soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

Neogene — the youngest of the Tertiary periods (23–2.6 Ma), subdivided into the Miocene and the Pliocene epochs

Neoproterozoic — the youngest era of the Proterozoic (1000–542 Ma)

NFRSCB – Northern Flinders Ranges Soil Conservation Board

Nodule — an irregular, spherical to ellipsoidal, flattened to cylindrical body, commonly composed of calcite, pyrite and chert

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively

δ^{18}O — oxygen isotope composition, measured in parts per thousand (‰)

Observation well — a narrow well or piezometer whose sole function is to permit water level measurements

Obswell — Observation Well Network

OLD – the Olary Domain of the Curnamona Province

Onlap — the successive increase in the area covered by beds in a sedimentary sequence. The term ‘overlap’ describes the relationship between beds in a sequence above an unconformity. The term ‘onlap’ refers to the process by which overlap is produced

Outcrop — an exposure of bedrock or superficial deposits at the surface of the Earth

Outwash — gravel and sand deposited by meltwater streams on land

Overthrust — when pressure pushes rock strata up until one side folds over onto the second side; this will cause younger rock layers to be located under older layers

PACE 2020 — Plan for Accelerated Exploration

Palaeochannel — ancient buried river channel formed by palaeorivers in arid areas of the state

Palaeochannel deposits — refer to the sediments that infill the palaeochannels

Palaeodrainage — refers to a network of palaeorivers

Palaeogene — the oldest of the Tertiary periods from 66–23 Ma; consists of the Palaeocene, Eocene and Oligocene epochs, from oldest to youngest

Palaeoproterozoic — the oldest of the Proterozoic Eon, from 2500–1600 Ma

Palaeoriver — refers to an ancient fluvial system responsible for a particular feature

Palaeovalleys — refers to the valleys incised by the palaeorivers

Palaeozoic — the era extending from about 542–251 Ma; the lower Palaeozoic includes the Cambrian, Ordovician and Silurian periods; the upper Palaeozoic includes the Devonian, Carboniferous and Permian periods. It was preceded by the Precambrian and followed by the Mesozoic

PB — Parsons Brinckerhoff

Pb — the chemical symbol for lead

Pasture — grassland used for the production of grazing animals such as sheep and cattle

Penetrating well — see 'fully-penetrating well'

Perennial streams — permanently inundated surface stream courses. Surface water flows throughout the year except in years of infrequent drought.

Permeable — allowing a gas or fluid to move through it at an appreciable rate

Permeability — a measure of the ease with which water flows through an aquifer or aquitard, measured in m^2/d

Permian — the period at the end of the Palaeozoic Era, from 299–251 Ma and is subdivided into the Cisuralian, Guadalupian and Lopingian epochs from oldest to youngest

Piezometer — a narrow tube, pipe or well; used for measuring moisture in soil, water levels in an aquifer, or pressure head in a tank, pipeline, etc

PIRSA — Primary Industries and Resources South Australia (Government of South Australia)

Plagioclase — a series of feldspars with compositions in the range of $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$

Playa — a flat, dry barren plain at the bottom of a desert basin, underlain by silt, clay and evaporates; it is often the bed of an ephemeral lake and may be covered with white salts

Playa lake — a shallow recurring lake that covers a playa after rains but disappears during a dry period

Pleistocene — the oldest epoch of the Quaternary Period

Pliocene — the youngest epoch of the Tertiary Period

Porosity — describes the fraction of void space in a porous medium (such as rock or sediment), where the void may contain, for example, air or water and is a fraction of the volume of voids over the total volume

Potable water — water suitable for human consumption such as drinking or cooking water

Potentiometric head — the potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer, measured in metres (m); also known as piezometric surface

Precambrian — the period of time from the formation of the Earth, 4600 Ma to about 542 Ma ago, during which the Earth's crust was formed and the first organisms appeared. The Precambrian is now used informally to describe the Hadean (4600–4000 Ma), Archaean (4000–2500 Ma) and Proterozoic (2500–542 Ma) eons

Precipitation — (1) the falling to earth of any form of water (rain or snow or hail or sleet or mist); (2) the formation of a solid in a solution or inside another solid during a chemical reaction or by diffusion in a solid

Prescribed water resource — a water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed well — a well declared to be a prescribed well under the Act

Production well — the pumped well in an aquifer test, as opposed to observation wells; a wide-hole well, fully developed and screened for water supply, drilled on the basis of previous exploration wells

Proterozoic — the last of the three major subdivisions of the Precambrian. The Proterozoic has been divided into three eras; the Palaeoproterozoic (2500–1600 Ma), Mesoproterozoic (1600–1000 Ma) and the Neoproterozoic (1000–542 Ma)

PWA — Prescribed Wells Area

PWRA — Prescribed Water Resources Area

Quaternary — the most recent period of geological time, a division of the Cainozoic

Radioactivity — a property of certain elements that spontaneously and constantly emit ionising and penetrating radiation

Recharge area — the area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. See also artificial recharge, natural recharge

RESIC – Resources and Energy Sector Infrastructure Council

Reticulated water — water supplied through a piped distribution system

Rockhole — a shallow, small depression in rock outcrops, often rounded in form and holding water after rains

Runoff — that part of precipitation that appears in or makes its way to surface streams

SAAL – South Australian Arid Lands

SAALNRMB – South Australian Arid Lands Natural Resources Management Board

SA Geodata — a collection of linked databases storing geological and hydrogeological data which the public can access through PIRSA. Custodianship of data related to minerals and petroleum, and groundwater, is vested in PIRSA and DFW, respectively. DFW should be contacted for database extracts related to groundwater

Salt lake — a body of water in an arid or semi-arid region having no outlet to the ocean and containing high concentration of salt

Sandstone — a sedimentary rock composed of sand-sized particles with varying amounts of a fine-grained matrix of clay or silt

SA Water — South Australian Water Corporation (Government of South Australia)

Schist — a metamorphic rock that is not defined by mineral composition but by the well-developed parallel orientation of more than 50% of the minerals present

Seasonal watercourses or wetlands — those watercourses or wetlands that contain water on a seasonal basis, usually over the winter–spring period, although there may be some flow or standing water at other times

Secondary porosity — subsequent or separate porosity system in a rock, often enhancing overall porosity of a rock. This can be a result of chemical leaching of minerals or the generation of a fracture system. This can replace the primary porosity or coexist with it

Sediment — solid material, organic or inorganic in origin, that has settled out from a state of suspension in a fluid and has been transported and deposited by wind, water or ice; loose sediment such as sand and mud may become consolidated and/or cemented to form coherent sedimentary rock

Sedimentary — containing sediment or formed by its deposition

Sedimentation — the process of depositing sediments

Shale — a fine-grained fissile sedimentary rock formed by the compaction of clay or silt; it is the most abundant of all sedimentary rocks

Silcrete — a hard surface deposit composed of sand and gravel cemented by opal, chert and quartz, formed by chemical weathering and water evaporation in semi-arid climates

Siliciclastic — a clastic rock whose clasts are predominantly of silicate minerals

Siltstone — a fine-grained sedimentary rock principally composed of silt-grade material

Sink hole — an approximately circular depression in limestone terrain into which water drains and collects

SKM – Sinclair Knight Merz

Soak — where good-quality or marginally saline groundwater is held in an aquifer close to the surface

Specific storage (S_s) — specific storativity; the amount of stored water realised from a unit volume of aquifer per unit decline in head; it is dimensionless

Specific yield (S_y) — the volume ratio of water that drains by gravity, to that of total volume of the porous medium. It is dimensionless

Spring — a natural flow of water from underground where the watertable intersects the ground surface

State Water Plan — policy document prepared by the Minister that sets the strategic direction for water resource management in the State and policies for achieving the objects of the *Natural Resources Management (SA) Act 2004*

Stock use — the taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act)

Stormwater — run-off in an urban area

Sub-catchment — the area of land determined by topographical features within which rainfall will contribute to run-off at a particular point

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Surficial — pertaining to or occurring on or near the Earth's surface

Sustainability — the ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time

SWL — depth to groundwater below the natural ground surface

TDS — total dissolved solids, measured in milligrams per litre (mg/L); a measure of water salinity

Tectonic — relating to structures of, or forces associated with, tectonics

Tectonics — branch of geology that deals with the geometry of rocks and the forces and movements that produced them

Tertiary — oldest geological period of the Cainozoic Era (66–2.6 Ma)

Tertiary aquifer — a term used to describe a water-bearing rock formation deposited in the Tertiary geological period

Terrigenous — see siliciclastic

THZ – Torrens Hinge Zone

Throughflow — the movement of water horizontally beneath the land surface

Thrust — a low-angle reverse fault

Transmissivity (T) — a parameter indicating the ease of groundwater flow through a metre width of aquifer section

Tributary — a river or creek that flows into a larger river

Turbidity — the cloudiness or haziness of water (or other fluid) caused by individual particles that are too small to be seen without magnification, thus being much like smoke in air; measured in Nephelometric Turbidity Units (NTU)

U — the chemical symbol for uranium

Underground water (groundwater) — water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

Volcanics — relating to a volcano

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Water affecting activities — activities referred to in Part 4, Division 1, s. 9 of the Act

Water allocation — (1) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence (2) in respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

Water allocation, area based — an allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water–use year

Water body — includes watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers

Watercourse — a river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

Water cut — the depth at which a water-bearing unit is intersected during the process of drilling a well

Water-dependent ecosystems — those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

Water hole — a depression where water collects

Water licence — a licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area; this grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water; a water licence confers a property right on the holder of the licence and this right is separate from land title

Water plans — the State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act

Water quality data — chemical, biological, and physical measurements or observations of the characteristics of surface and groundwaters, atmospheric deposition, potable water, treated effluents, and wastewater, and of the immediate environment in which the water exists

Water quality information — derived through analysis, interpretation, and presentation of water quality and ancillary data

Water quality monitoring — an integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses

Water resource monitoring — an integrated activity for evaluating the physical, chemical, and biological character of water resources, including (1) surface waters, groundwaters, estuaries, and near-coastal waters; and (2) associated aquatic communities and physical habitats, which include wetlands

WDE — water dependent ecosystem

Weathering — destructive natural processes by which rocks are altered with little or no transport of the fragmented or altered material

Weighted project — *see* Resources and Energy Sector Infrastructure Council 2011

Well — (1) an opening in the ground excavated for the purpose of obtaining access to underground water, (2) an opening in the ground excavated for some other purpose but that gives access to underground water and (3) a natural opening in the ground that gives access to underground water

WHH – Wirrealpa Hill Hinge

Wetlands — defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres

Zn — the chemical symbol for zinc

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