
IPhotograph by Kirrilie Rowe, 2004

Warburton River in flood

4 Surface Water

A defining characteristic of the SAAL region is the cyclical nature of surface water flows. All rivers are ephemeral and flow intermittently, with often years between flows. In the Far North many of the larger flows are a result of rainfall in Queensland. In other areas flows are a result of intense localised rainfall.

A description of the surface drainage of the area and the type of surface flows which occur is presented in Section 4.1. An account of the main studies which have been undertaken in the area, and current available information, is presented in Section 4.2. Management boundaries have been defined by government bodies. These are discussed in Section 4.3, and where possible include information on water availability and use.

Information on surface water usage is scarce, and has been roughly estimated based on stocking rates. It is possible to gain an idea of the use of surface water compared to groundwater in each of the areas from the drillhole information presented in Figures 3.7 to 3.12, and the dam, and spring and waterhole information presented in Figures 4.6 and Figure 4.7.

4.1 Physical Description

4.1.1 Drainage Basins

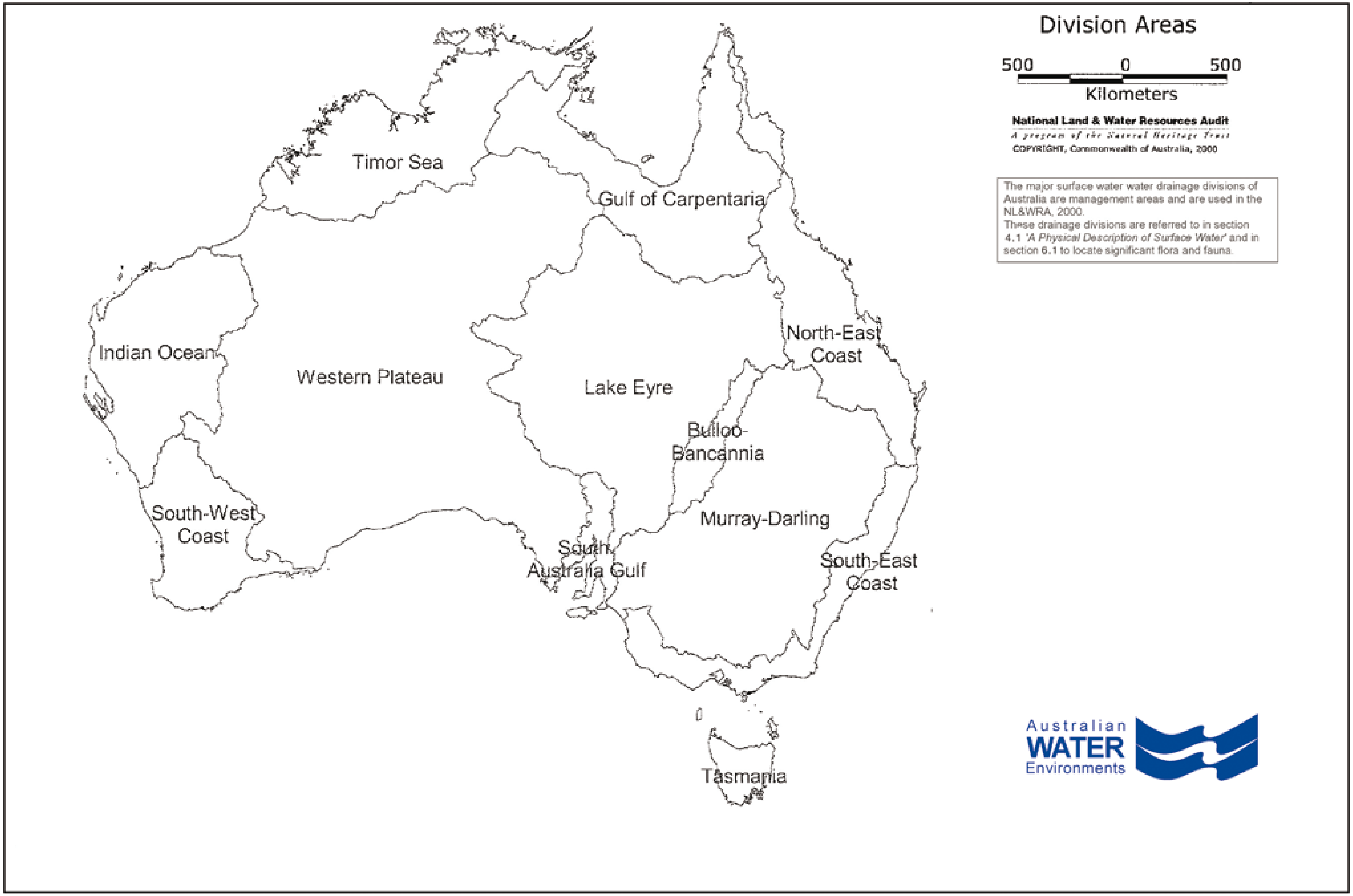
Three major surface drainage divisions cover the study area, namely the Lake Eyre Drainage Division, the Western Plateau Drainage Division and the South Australian Gulf Drainage Division (National Land and Water Audit, 2000). These are shown in Figure 4.1.

Drainage in the Lake Eyre Drainage Division ultimately ends at the playa lake, Lake Eyre. Playa lakes act as collection areas for surface water flows, and discharge zones for groundwater flows.

Current major rivers which drain the Lake Eyre Basin from the west are the Macumba, the Arckaringa and the Neales. These are normally dry yet are capable of carrying large volumes of water in times of flood, and have dissected the country west of Lake Eyre to form the tableland or breakaway country. Semi-permanent waterholes are supplied from flood events. Rivers more likely to fill Lake Eyre lie to the east and drain a vast area extending to the highlands of central Queensland. These are the Warburton (from the Diamantina River) and Cooper Creek. In South Australia, these river systems approach Lake Eyre through the interconnected river courses of the Channel Country. Annual run-off from the Great Dividing Range and the Barkley Tablelands of Queensland into the river systems fills some waterholes close to the borders, which are considered permanent. A discontinuous shallow aquifer system is also associated with the surface water drainage of the Lake Eyre Basin.

The Western Plateau Drainage Division is vast, covering large portions of Western Australia, Northern Territory and South Australia. It is divided into nine basins, of which only one (the Gairdner Basin) lies within the study area. There are no true riverine systems within the Gairdner Basin, resulting in many large salinas.

Figure 4.1 Major Surface Water Drainage Divisions



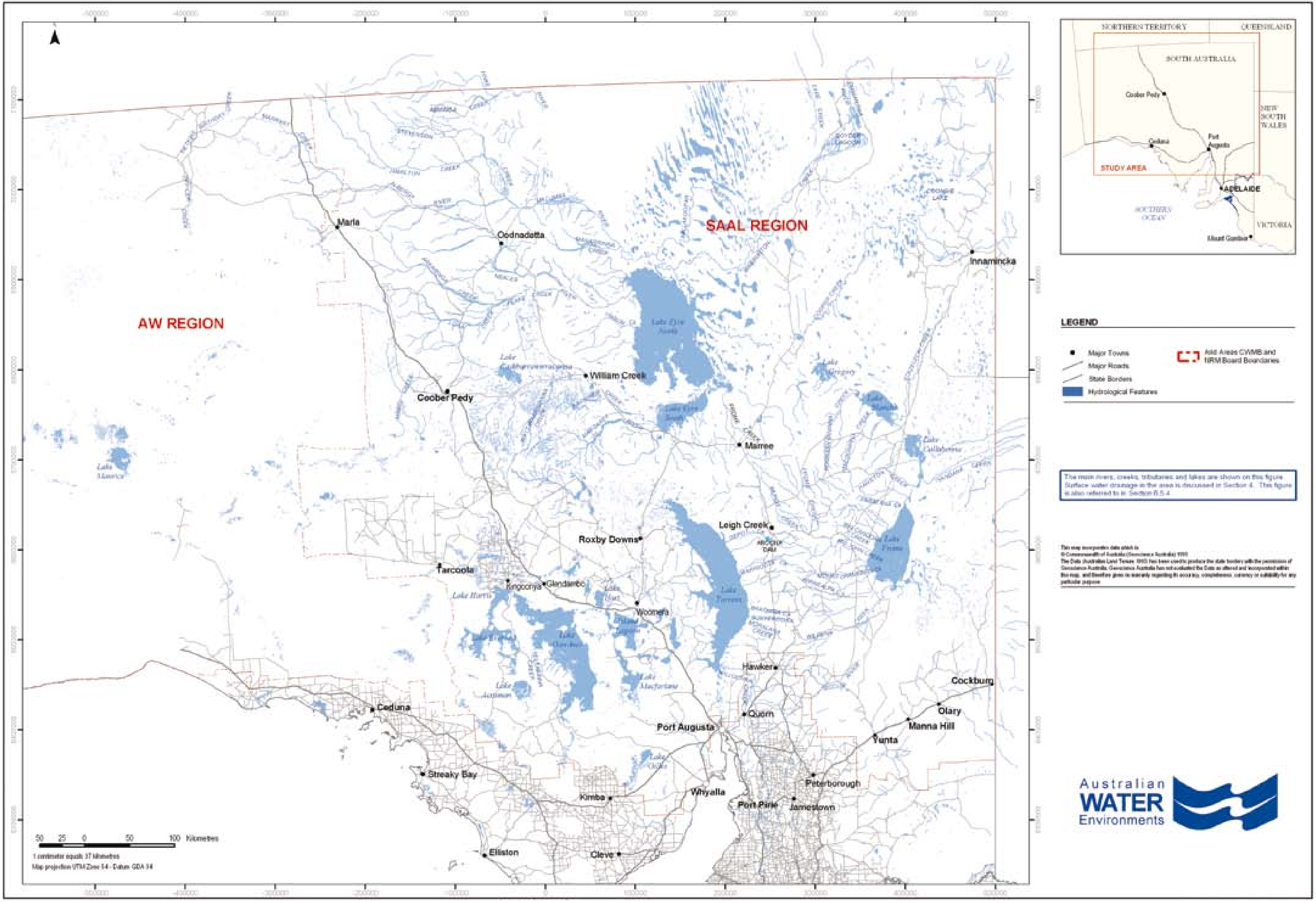


Figure 4.2 Major Rivers and Natural Wetlands

Lake Gairdner is the largest salina in the sub-basin, being 8,884 square kilometres, and is an alluviated river valley covered by a halite crust.

The South Australian Gulf Drainage Division is divided into 13 basins of which two, namely the Mambray Coast Basin and the Torrens Basin, lie within the study area. Drainage in the Torrens Basin is directed towards Lake Torrens mostly from the western flank of the northern Flinders Ranges, however there are numerous unconnected catchments in the region and great hydrological variability.

The major rivers and natural wetlands systems are presented in Figure 4.2.

4.1.2 Surface Flows

The arid zone is typified by infrequent but large flood events which punctuate an otherwise dry landscape and climate. In arid central Australia, 15 to 20 millimetres of rain of moderate intensity can cause a flow in minor streams that lasts for an hour or two. Such a flow can occur as often as five times a year. However, around twice this amount is needed before major streams begin to flow. Such falls can be expected less frequently than once a year. Major floods in the Lake Eyre Basin result from annual rainfalls which exceed 500 millimetres (Kotwicki, 2002 *website*).

Gypsum rich mud and surface salt crusts characterize the salinas across the study area except for Lake Torrens, which has no salt crust. Salt leached from rocks within the drainage basin is carried in solution and deposited into the lakes in times of flooding. Each time the lakes fill and evaporate, due to cycles of flooding and drying, a layer of salt is left behind. The layer of salt in Lake Eyre from the 1950 flood reached a thickness of 300 millimetres. Another source of salt in the interior of Australia is cyclic salt, evaporated from the ocean and brought inland by the wind and deposited with rain over the inland area over thousands of years. Shallow groundwater systems are also a source of surface salt.

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). To highlight this fact, stream flow data for the Cooper Creek has been used to calculate an annual average flow of 1,120,000 megalitres per year (NLWRA, 2000). However, Figure 4.3 below presents the median, 25, 75 and 90 percentiles for stream flow data collected in the Cooper Creek over a 30-year period. This graph clearly shows that in all three decades, 75 per cent of the time the flow in the Cooper Creek was substantially less than the annual average, and for 25 per cent of the time, there was no flow.

The median (50 percentile) is a better representation of flow in these systems than annual averages. The median flow for Cooper Creek in the last decade is approximately 120,000 megalitres per year – an order of magnitude less than the mean. This means that out of the data that has been collected, 50 per cent of the values are less than 120,000 megalitres per year, and 50 per cent are above. If the data is collected every year, it means that 50 per cent of the time flow is below 120,000 megalitres per year and 50 per cent of the time flow is above 120,000 megalitres per year. This is very different to the idea that on average, flows in the Cooper Creek are around 1,120,000 megalitres per year. The average is highly skewed by the fact that, very occasionally, Cooper Creek contains enormous flows.

Figure 4.3 Cooper Creek Stream Flow Data – Percentiles

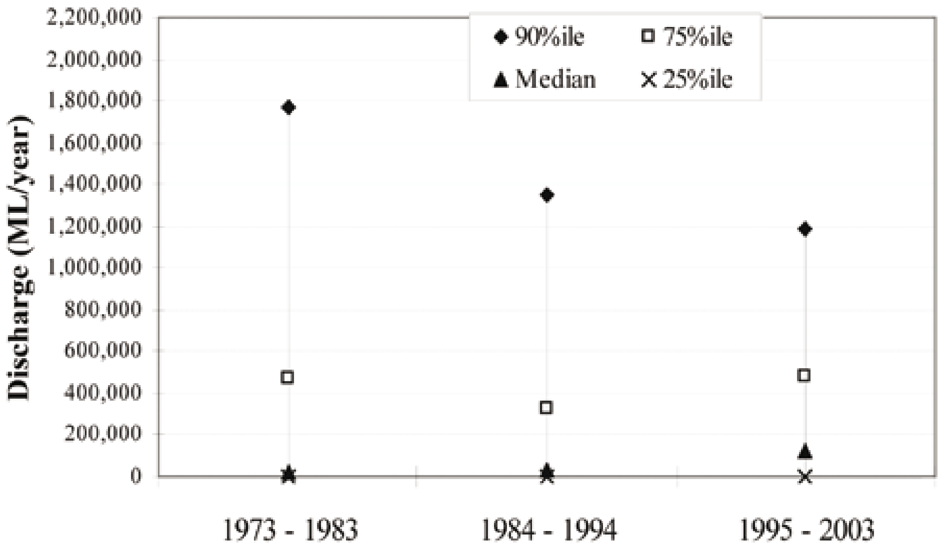


Table 4.1 provides a summary of stream flow data published by the Department of Water, Land and Biodiversity Conservation for stations with over five years of data in the SAAL region. The table highlights the extreme variability in stream flow from one year to the next. Median flows are typically less than a third of the mean, whilst minimum annual flows are all less than one per cent of the mean.

Table 4.1 DWLBC Published Stream Flow Data (megalitres per year)

Station Name	Region	Years of record	Max	Mean	Median	Min	Median as a proportion of the mean (%)
Diamantina River @ Birdsville	Far North	38	10990000	1332000	313400	6022	24
Cooper Creek @ Cullyamurra Water Hole	Far North	31	14340000	1574000	422700	17460	27
Mount Mckinlay Creek @ Wertaloona	North East & Finders	17	96680	8966	1200	15.2	13
Arcoona Creek @ Gammon Ranges National Park	North East & Finders	9	618.6	124.3	0	0	0
Aroona Creek @ Aroona Dam	North East & Finders	19	17020	2835	0	0	0
Warruwarldunha Hill Channel @ Hawker	North East & Finders	7	32.8	4.7	0	0	0
Windy Ck @ Maynards Well	North East & Finders	17	6483	909.2	340.7	10	37
Windy Ck @ Leigh Creek	North East & Finders	18	8846	2062	597.9	2	29
Emu Ck @ Leigh Creek	North East & Finders	18	37260	6484	2120	55.3	33

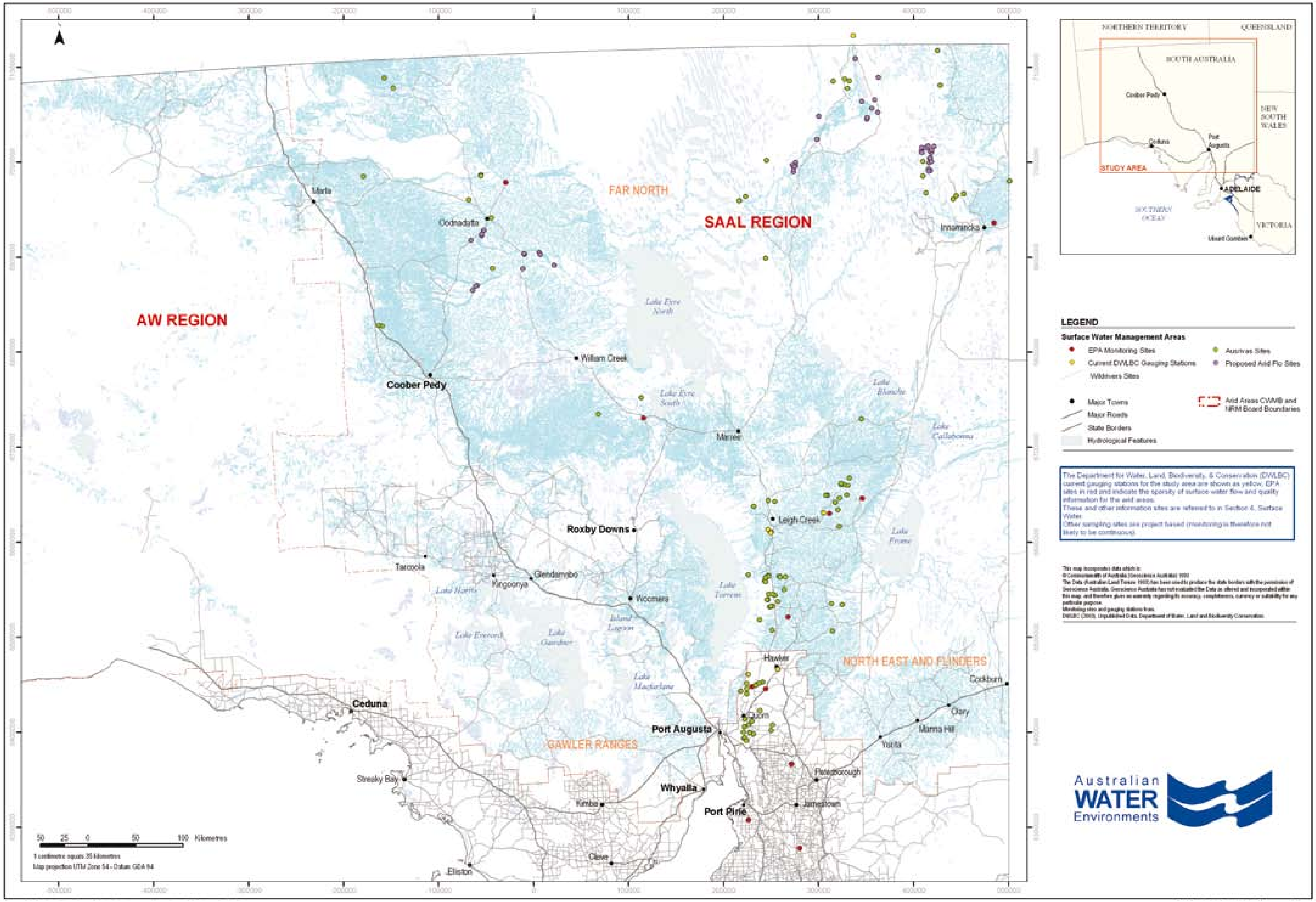


Figure 4.4 Surface Water Flow Gauging Stations and Locations of Previous Study Sites

4.1.3 Flooding

One of the defining characteristics of the arid areas is the 'boom and bust' phenomenon. All rain is important, as the environment has evolved to respond quickly to moisture. Vegetation and animals alike grow quickly and reproduce rapidly after rain. A local thunderstorm can produce a remarkable vegetation response in a few days, while the immediate surrounds remain parched.

Due to the unpredictable and highly variable rainfall, the wetting of the landscape and subsequent runoff into watercourses after some of the heavier rain events is also spasmodic and unpredictable. Mostly the rivers do not flow at all, and long dry periods are the norm. However, heavy rainfall events, either localised or interstate, can cause massive flooding and during these times the rivers in the Far North can carry at least five times the amount of water flowing in the River Murray. Massive flooding in the Far North is often caused by heavy rainfall events in Queensland.

Recent studies have demonstrated the importance of flooding to the health of the arid river systems. These studies have also shown how little we know about the significance of various flood events. The research studies to date have identified both high and low flows as having important ecological functions in the river systems. It is also clear the overall flow pattern, and not just individual floods, is important for maintaining the ecology of the rivers and wetlands in the Lake Eyre Basin. Series or clusters of floods also appear to be of major significance in influencing the successful breeding of many species. A critical question for floodplain habitats is whether enough regeneration continues to occur to maintain critical plant and animal populations, as this is also a time when grazing is heaviest. The value of a flood can be lost if land and water management is not co-ordinated to retain the water regime.

4.2 Previous Studies

A national Wild Rivers project commenced in 1993 to identify near pristine (that is, wild) rivers. The definition of a wild river considered only alterations to the natural processes affecting flow, and not issues relating to remoteness or aesthetic naturalness. The wild rivers are presented in Figure 4.4. More information on the methodologies used to assess the rivers is available at *www.environment.gov.au/heritage/anlr*.

An Australian River Assessment system was also undertaken on a national scale (AUSRIVAS). River health in the AUSRIVAS project was defined by the abundance and diversity of selected aquatic macroinvertebrates, and the degree of similarity between the aquatic macroinvertebrates found at each site and those predicted to occur at the site if it were not impacted. A series of reference sites were selected and sampled to provide information on the nominated condition of streams for each region in South Australia. Reference sites are minimally impacted and not significantly altered by human activities. The location of AUSRIVAS sampling sites are presented in Figure 4.4.

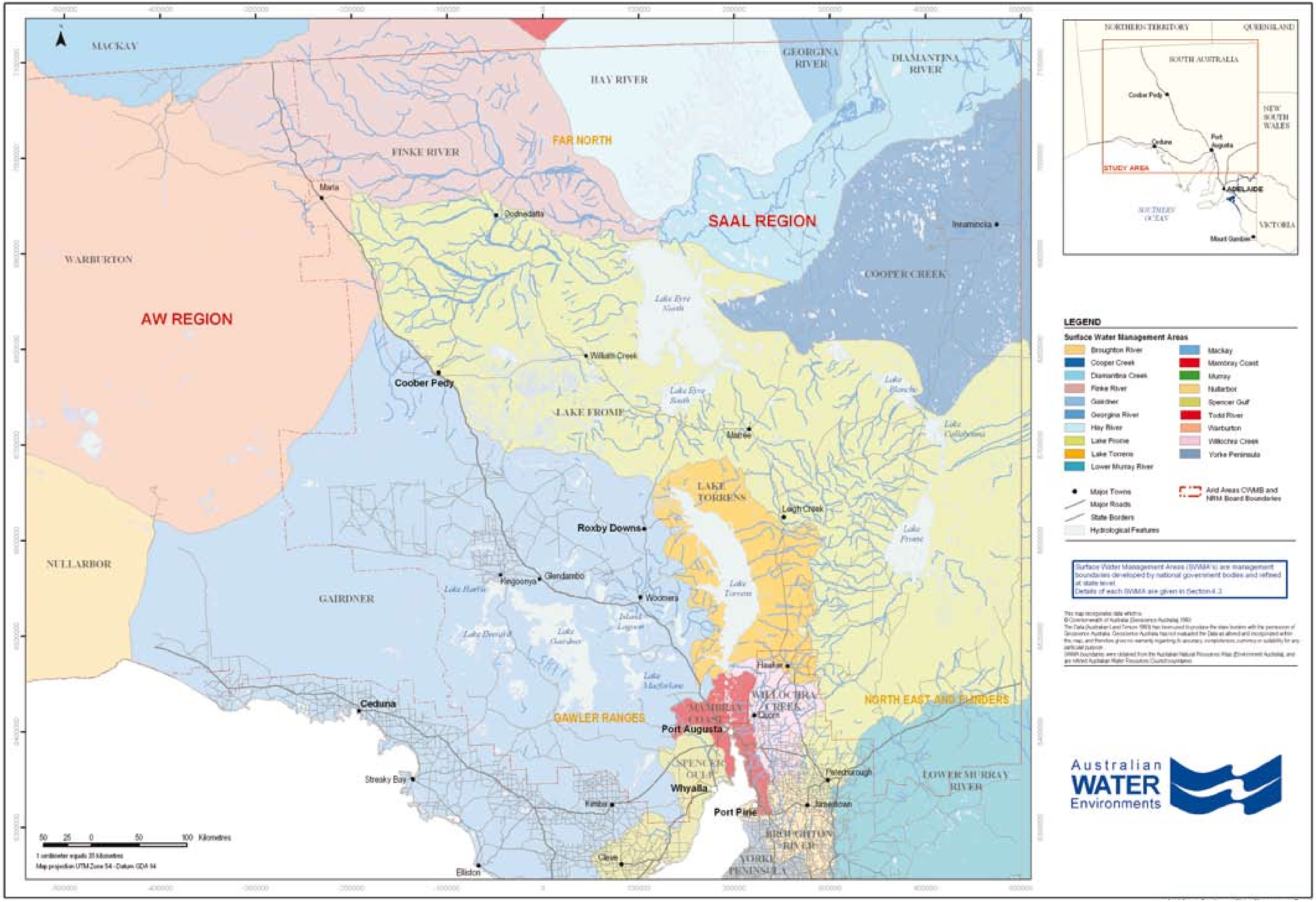


Figure 4.5 Surface Water Management Areas

A Natural Heritage Trust funded collaborative project named Aridflo has recently been undertaken by the Universities of Adelaide and Melbourne, CSIRO, CRC for Freshwater Ecology, CRC for Catchment Hydrology, DWLBC, Queensland EPA, Queensland P&WS and Queensland DNRM. The project provides more of an understanding of the ecosystem processes at work in the rivers of the Lake Eyre Basin. Little is known of the basic biology and hydrology of these systems. The aim of the project was to develop a generic model of relationships between flow regime, ecological processes and biodiversity for Australian arid flow rivers, and establish the basis for an environmental monitoring program on the Lake Eyre Basin rivers. Aridflo sampling sites were collected from five reaches distributed over three river systems, namely Cooper Creek, Diamantina River and the Neales River. Sampling locations are presented in Figure 4.4. Flow duration, magnitude, depths, geomorphology, physico-chemical characteristics and biotic assemblages were measured.

4.3 Surface Water Management Boundaries

Surface Water Management Areas (SWMAs) in Australia have been defined, initially on a national scale from Geoscience Australia's *Australia's River Basin* (1997) product. This product contains river basins and drainage division boundaries defined by the former Australian Water Resources Council. South Australia has split some of these basins into smaller areas to refine the SWMA boundaries. The SWMAs in South Australia are reported in the SA Technical Report titled *'Surface and Groundwater Management, Availability, Allocation and Efficiency of Use',* which was undertaken by Department of Water, Land and Biodiversity Conservation (DWLBC) as part of the National Land and Water Resources Audit (2000).

The SWMAs present in the arid areas are presented in Figure 4.5. The area is divided into the following SWMAs:

- Finke River (Far North area);
- Hay River (Far North area);
- Georgina River (Far North area);
- Diamantina River (Far North area);
- Cooper Creek (Far North area);
- Lake Frome (Far North and North East and Flinders area);
- Gairdner (Gawler Ranges area)
- Lake Torrens (Gawler Ranges and North East and Flinders area);
- (part of) Mambray Coast (Gawler Ranges area); and
- (part of) Spencer Gulf (Gawler Ranges area).

For the purposes of this study, the Lake Frome SWMA is further divided into two parts, namely the Lake Eyre and Lake Frome subdivisions of the Lake Frome SWMA.

Streamflow gauging station information was used in various ways in the SA Technical Report (depending on the availability and quality of the data) to provide an estimate of flow (National Land and Water Resources Audit, 2000). Stream gauging station locations are presented in Figure 4.4. Where gauging station information was not available, a computer model of the 'Catchment' was used. In the Far North there are significant losses between where water flow is generated and discharged, and in most cases no gauging station information was available to define these losses. The mean annual outflow is therefore simply assumed to be the average annual volume measured at the best available gauging site. As described in Section 4.1.2, average (that is, mean) flows are generally not useful for the South Australian arid areas, because the average is strongly influenced by huge one in 25-year type flood events. Most of the flow is generated outside of the State.

A description of each SWMA and associated available information is presented below.

4.3.1 Finke River SWMA

The Finke River SWMA is located in the far north-west of the Far North, and extends across the State border into the Northern Territory. It contains the end of the Finke River, which drains into the Simpson Desert and the majority of the Macumba River. Most of the flow in the Finke River is generated outside of South Australia. The Alberga River joins the Hamilton and Currallulla creeks to form the Macumba River, which drains directly into Lake Eyre North.

There is a sparsity of reports, but considerable data for this area. The Finke flows along its complete length within the Northern Territory about once every 12 years, with short multiple flows often yearly off the hard rock catchments. These do not reach South Australia. The flow in February/March 2000 was the largest known since European settlement of the region, at least in the Horseshoe Bend New Crown sector of the River. The river at Apatula (and associated areas) is within a major recharge zone of the GAB. Little is documented for this area.

The Finke River SWMA has very limited recorded gauging data within the management area and requires significant interpolation to infill. There is no reliable measurement of current flow, so an estimation of the mean annual natural flow from computer modelling was used. An average annual yield of 42,000 megalitres per year has been published by the Government of South Australia (National Land and Water Resources Audit, 2000).

The Finke River SWMA also contains an area known as the Desert Rivers Region catchment area (that includes the Hay River SWMA), which is the most hydrologically isolated region of the Lake Eyre Basin. None of its streams contribute to Lake Eyre on a regular basis, but anecdotal evidence suggests that the Finke and Sandover Rivers can join the main system during periods of extremely intense flooding. It is thought that the Finke flowed into the Macumba in the first decade of the 20th Century, and the Sandover flowed into the Georgina River in the mid 1980s (Lake Eyre Basin Co-ordinating Group, 2004).

High transmission losses during times of flow mean that the volume of flow decreases significantly down the catchment. The processes by which water is lost are not well understood and so stream contributions to the groundwater system cannot be quantified.

For all rivers in the Far North of South Australia, large volumes of water can become available for relatively short periods of time on an infrequent basis. The Far North of South Australia is therefore highly sensitive and any water resource development could be expected to have significant environmental implications (Department for Water Resources, 2000) and potentially affect downstream users.

Five AUSRIVAS sites are located in this SWMA, two on Macumba River and three on its tributaries – namely Coongra Creek, Lindsay Creek and a tributary of Stevenson Creek. All of these sites, apart from the site located on Lindsay Creek, were reference sites, which are 'least disturbed' sites not significantly altered by human activities.

The site located on Lindsay Creek (a permanent pool) was rated as being significantly impaired.

4.3.2 Hay River SWMA

The Hay River SWMA is located in the far north-central part of the Far North, and extends across the State border into the Northern Territory. The South Australian part of the SWMA contains the Simpson Desert Regional Reserve, in which the Ephemeral Lakes are located. It does not contain any true riverine systems. There is extremely limited gauging within the management area. No sampling locations are present in this SWMA.

4.3.3 Georgina River SWMA

The Georgina River SWMA is located in the far north-eastern part of the Far North, and extends across the State border into Queensland. The southern tip only of the SWMA is located in South Australia, and contains the West Lake, waterholes and Eyre Creek, which is a tributary to Warburton Creek. The Georgina River rises in the north on the Barkly Tablelands, and joins the water of the Diamantina River which has travelled up to 800 kilometres from the north-east. The Diamantina River ultimately enters Goyders Lagoon, from where it continues heading south-west as Warburton Creek.

There is extremely limited gauging within the management area. One sampling point, undertaken as part of the arid flow project, is located at the end of Eyre Creek at a deep waterhole located around the tip of a dune on the Andrewilla flowpath. This waterbody is deep enough to withstand two years of no flow, and so represents significant refugia for this area.

4.3.4 Diamantina River SWMA

The Diamantina River SWMA is also located in the far north-eastern part of the Far North, and extends across the State border into Queensland. Due to the low gradients of the rivers in this area they disperse into multiple braided channels, floodplain, waterholes and wetlands in the Queensland channel country before flowing into Goyder Lagoon, then onto Lake Eyre via Warburton Creek. In large flood events, the Goyder Lagoon becomes an extensive wetland area of over 1,300 square kilometres.

There is a limited gauging network, but the available gauging stations are well positioned to give a measurement of flow (National Land and Water Resources Audit, 2000). Spatial variation of flow within the catchment, and a measured recording of flow leaving the basin, is relatively unknown. The average annual flow (that is, flow under current catchment conditions) was estimated as the recorded flow plus an estimated contribution from areas downstream of the gauge. The mean annual flow for the Diamantina River SWMA was estimated to be 953,000 megalitres per year (National Land and Water Resources Audit, 2000). However, as described in Section 4.1.2, average flows are generally not useful for the South Australian arid areas, because the average is strongly influenced by huge one in 25-year type flood events. Most of the flow is generated outside of the State.

Ten sampling locations for the AUSRIVAS project are present within the management area. Of these, seven are reference sites. Two of the sites were so unusual they were beyond the capacity of the current AUSRIVAS models to assess. One of the sites located on the Diamantina River system at the Koonchera waterhole was significantly impaired.

Fourteen sites were sampled in this SWMA (in the lower Diamantina River) for the Aridflo project. Three of the sites were identified as a refuge, namely the Yelapawaralinna (which has a cease-to-flow depth of 3.3 metres), the Yammakira and Andrewilla. Hypersaline levels were recorded at sites in the Lower Diamantina River, and most downstream waterbodies experience high water salinity levels after flow ceases. These areas are restricted to the channel section of the Warburton River. Following flood events, saline seeps were observed near the base of banks. However, the zones of saline seepage are quite patchy along the channel, therefore salinity of waterbodies in the Warburton are also highly variable.

4.3.5 Cooper Creek SWMA

The Cooper Creek SWMA is located in the north-east of the Far North, and extends across the State border into Queensland. Cooper Creek stems from the Great Dividing Range, and enters South Australia from Queensland at Innamincka. Shortly after entering the State, the Cooper Creek system spreads into an enormous area of braided channel, which forms part of the Channel Country. If rainfall has been high enough, flows will eventually reach Lake Eyre, but this can take nine or ten months after the rain.

The wetlands within the region are diverse, ranging from what are considered to be permanent wetlands such as Coongie Lakes, to the semi-permanent wetlands of the Strezlecki Creek wetland system.

There is a limited gauging network, but the available gauging stations are well positioned to give a measurement of flow (National Land and Water Resources Audit, 2000). Spatial variation of flow within the catchment, and a measured recording of flow leaving the Basin, is relatively unknown. The average annual flow for the Cooper Creek SWMA is estimated to be 1,120,000 megalitres per year (National Land and Water Resources Audit, 2000). As described in Section 4.1.2, average flows are generally not useful for the South Australian arid areas, because the average is strongly influenced by huge one in 25-year type flood events. Most of the flow is generated outside of the State.

Seven sampling locations for the AUSRIVAS project are present within the management area. All of these are reference sites.

Thirteen sites were sampled in this SWMA for the Aridflo project. Five have been identified as refugia with a cease-to-flow depth greater than three metres, namely the Cullyamurra, Queerbiddie, Minke, Tirrawaara and Kudriemitchie waterholes. Cullyamurra is the deepest sampled at a cease-to-flow depth of 18.1 metres, and is never known to have dried out.

There are five official stream gauging stations in this SWMA, and one EPA water quality monitoring site.

4.3.6 Lake Eyre Subdivision of the Lake Frome SWMA

The Lake Eyre basin overlies the south-western margin of the GAB and is the world's largest internal drainage system. The drainage area was formed as a distinct basin of deposition during the mid-Tertiary age. Lake Eyre is a playa lake formed by earth movements and deflation, and at its deepest level is approximately 16 metres below sea level (at Lake Eyre itself).

By world standards, the rivers of the Lake Eyre Basin are considered to be relatively unregulated and retain much of their natural flow patterns (Reid and Puckridge, 2000).

The three major river systems which enter Lake Eyre are from the east, namely the Cooper, Georgina and Diamantina Rivers. These systems begin in the higher rainfall regions of the catchment in the north and east, and travel south and south-west through the arid regions of Queensland into South Australia. They originate in the biogeographic regions of the Mount Isa Inlier, the Desert Uplands and the Mitchell Grass Downs (Thackway and Cresswell, 1995), and move down into the Channel Country where, due to low topographic relief and low gradients, they disperse into huge numbers of anastomosing channels, waterholes, wetlands and floodplains. This Channel Country provides a vast, natural irrigation system. In times of very high flow the rivers may reach Lake Eyre and the Simpson-Strzelecki Dunefields - the Georgina and Diamantina Rivers meet at Goyders Lagoon and continue on from there as the Warburton River. The Cooper flows on from the wetlands of the Coongie Lakes. As these major rivers have their catchments in higher rainfall areas, they provide a moisture regime in arid regions of the Lake Eyre Basin that would not occur from local rainfall alone.

Increasing aridity towards Lake Eyre, the huge dispersal system, and high transmission losses, mean that the volume of flow decreases down the catchment. Although the Cooper is the largest of the rivers, it rarely flows into Lake Eyre, reaching it only eleven times since 1890. The Diamantina River contributes the majority of water to Lake Eyre. Every couple of years, the Diamantina River reaches the Lake, providing sufficient flow to cover a small portion of the Lake's bed (Badman *et al*, 1991). Inflows from the Cooper Creek are less reliable than the Diamantina River system as they firstly fill extensive floodplain areas such as channels, billabongs and lakes in its lower reaches.

The Western Rivers Region of the Lake Eyre Basin covers the catchments of the Macumba, Neales, Peake and others that occasionally flow into Lake Eyre from the west. The catchment lies almost entirely in South Australia, and contains the Stony Plains and Finke bio-regions. It also contains the world's largest cattle station (Anna Creek Station). The Western Rivers Region overlies the south-western extremities of the GAB, which is shown by the arc of artesian springs to the west of Lake Eyre. These springs are central to Aboriginal culture, and were the path that allowed European explorers to penetrate the arid centre of the continent.

The Lake Eyre Basin catchment has very high evaporation rates and extremely low run-off rates, and as a consequence the river systems have irregular flows. The rivers are ephemeral with streamflow highly variable and seasonal – generally short periods of flow following rain and extended periods of no flow. These rivers are also highly variable in both the time of flooding and the flood duration (Kotwicki, 2002). Major flooding of these river systems is associated with the El Nino Southern Oscillation (ENSO) (Puckridge *et al*, 1998) and large scale floods are typically associated with regional scale precipitation (University of Aberdeen, 2003).

The river systems typically contain a large number of waterholes that are deepened and widened reaches of the channel. The waterholes are mostly semi-permanent to temporary, holding water from a few months up to a few years. They range in size and shape but can be up to a few kilometres long within the main river channel. The channel and floodplain flowpaths of river systems on the western side of Lake Eyre are not as complex as the Cooper, Diamantina and Georgina River systems. In the Neales River system, in-channel waterholes range from shallow (one to 2.5 metres deep) to rarer, deeper waterholes (2.5 – 4.5 metres deep) that are near permanent (DWLBC, in prep).

Along the lower reaches of the Neales and Peake creeks, surface water becomes saline. Waterholes of the Neales River can be divided into those that are saline and flushed only during flow events (middle and lower reaches), and those that are mostly fresh, and which very slowly increase in salinity during periods of no flow (predominantly in the upper reaches). The salinity of waterholes has been recorded as 20,000 milligrams per litre Total Dissolved Solids in the Algebuckina and 100,000 milligrams per litre Total Dissolved Solids at the Peake Crossing waterhole. Salinity fluctuates dramatically over time in the waterholes. At the reach scale, saline waterholes show a marked spatial association with GAB springs, and are situated downstream of sub-catchments containing the springs.

Of the drainage area occurring west of Lake Eyre, less extensive creek systems occur in the west, which generally hold water for no longer than three to four months after a big rain. More extensive surface water systems are present in the north and east in this drainage area, where water holes/areas can hold water for up to 12 months after a good rain. Some waterholes are permanent, providing important refugia.

On average, a major flood to Lake Eyre occurs once every twenty years (Kotwicki, 2002) requiring inflows from at least two of its major tributaries (Kotwicki, 2002). In modern times Lake Eyre has been flooded four times – in 1945-50, in 1975 when the whole of Lake Eyre North was filled to a depth of five metres, in 1992, and in 2000. The highest recorded level in Lake Eyre was in 1974. In 2004, the Warburton Creek flooded and reached the northern end of Lake Eyre, however it only filled the Warburton Groove which runs down the centre of the lake.

Thirteen sites were sampled as part of the Aridflo study on the Neales River system (including tributaries), which was the smallest, most ephemeral unpredictable river system surveyed during the study. One site, the Algebuckina waterhole (Allandale), was identified as refugia, with a cease-to-flow depth of 4.5 metres. It does not appear to be significantly fed from groundwater.

Prior to the Aridflo study, no systematic hydrologic data had been collected on the Neale River system.

Within the Lake Eyre catchment, a large number of dams and off-stream storages have been built. These range in size, but average approximately seven megalitres. Due to the low runoff and relatively small catchment sizes of these dams, they do not constitute a large diversion of water, and during periods of flood they divert an almost negligible amount. Their impact may become more significant during low flow periods.

Waters are typically highly turbid, particularly after flood events, due to the deposition of natural materials and erosion and runoff from grazing lands. In a number of sites, there is nutrient enrichment through either elevated nitrogen or phosphorus. This has been attributed to stock activity as well as the release of nutrients from accumulated sediments during low flow periods (Bailey, 2001). In contrast to other surface water systems, the catchments draining to the Lake Eyre basin are considered relatively pristine (Environment Australia, 2000) but there are still localised impacts such as nutrient enrichment (Environment Protection Agency, 1998).

Wetlands within the region (such as Coongie Lakes and Lake Eyre which are recognised nationally and internationally) provide a major focus for tourism activity within the region.

4.3.7 Gairdner SWMA

The Gairdner SWMA is located in the Gawler Ranges area, and extends from Coober Pedy down to the coast, and from Woomera in the east to Ooldea in the west. The portion of the Gairdner SWMA which lies within the Gawler Ranges area does not contain any true riverine systems. There is extremely limited gauging and no water sampling within the area. The surface water resource is considered to be very limited and therefore no assessment of the resource has been made by governing bodies. However, upon inspection of properties in this area, it is apparent that the slopes of the Gawler Ranges are highly utilised at a local level to direct and collect surface run. Numerous small levees have been built to divert the surface runoff to dams during high rainfall events.

The Gawler Ranges form a massif of domes defined by fractures developed in Proterozoic volcanics. A sheet structure is well developed and is responsible for the rounded shape of the hills. Historically and currently, humans have used captured runoff from these granitic dome structures. Drainage is mostly impeded, resulting in many large salinas.

4.3.8 Mambray Coast SWMA

The north-west part only of the Mambray Coast SWMA lies within the SAAL Region and is situated in the Gawler Ranges area. It abuts the Lake Torrens SWMA to the north, and the Gairdner SWMA to the west. No values are given for the sustainable yield as the only estimates available are for the whole of the SWMA.

4.3.9 Spencer Gulf SWMA

The northern part of the Spencer Gulf SWMA is also situated in the Gawler Ranges area, and abuts the Mambray Coast SWMA to the north, and the Gairdner SWMA to the west. Surface water resources in this SWMA have not been assessed and are assumed to be zero. Rainfall and streamflow are highly variable.

4.3.10 Lake Torrens SWMA

The Lake Torrens SWMA contains Lake Torrens and has numerous unconnected catchments and considerable hydrological variation. A large proportion of the runoff is produced in relatively small regions. There is very limited gauging within the management area, and significant interpolation is required. The estimated mean annual flow is 63,000 megalitres per year. The estimated sustainable yield, taking into consideration environmental water requirements, has been estimated by DWLBC in the National Land and Water Resources Audit (2000) to be 8,500 megalitres per year. The diversion volume in this area in 1996 was 550 megalitres. As with the rest of the SAAL region, while large volumes may be available for relatively short periods on an infrequent basis, the Flinders Ranges is a highly sensitive area and any water resource development would likely have a significant impact on all users of that resource.

The majority of the catchment provides only low levels of runoff and therefore stock and domestic use is likely to remain the major demand for water, unless alternative water supply systems are developed. Should any major development occur, it is likely to be for mining or tourism industries.

There is potential to harvest the infrequent streamflows as an opportunistic water supply and to improve the reliability of water supplies through artificial recharge.

Existing monitoring in the Lake Torrens SWMA focuses on the operation of the Aroona Dam system. The available information is not well suited to decision-making on broader issues of resource sustainability and environmental conservation. Rainfall monitoring is sparse and there is a bias away from hydrologically significant regions of high elevation and steep topography, due to ease of data collection in areas of lower topography.

There is insufficient streamflow data available for the SWMA for a catchment-wide hydrological assessment to be made.

4.3.11 Lake Frome Subdivision - Lake Frome SWMA

The Lake Frome Region is centred on Lake Frome, and extends from east of Lake Eyre to near Broken Hill, and from Haddon Corner to south of Peterborough. The population is small and apart from the far southern fringe, very sparse. The eastern side of the Northern Flinders Ranges, along with the Olary Ranges, fall within the Lake Frome Catchment. The Lake Frome catchment contributes very little water to Lake Eyre itself. Lake Frome is 100 kilometres long and 40 kilometres wide, and linked at its northern end to Lake Callabonna via Salt Creek. Lake Frome rarely fills, due to the size of the lake compared to its catchment, and surrounding sand causing high losses through the ground. The lake overlies the south-eastern margin of the GAB, and GAB springs flank the lake's eastern shores.

Rivers and creeks in the region tend to flow episodically in response to occasional and irregular rains. There are three basic types of stream habitat in the Flinders Ranges:

- those fed by springs which are generally permanent;
- those that flow for a considerable length of time following winter rains and are thus seasonal in nature; and
- those which flow only briefly after rain and are therefore ephemeral (Environment Australia, 1994).

Many streams have springs which discharge near permanent water in their upper reaches but are temporary in their lower reaches (Environment Australia, 1994).

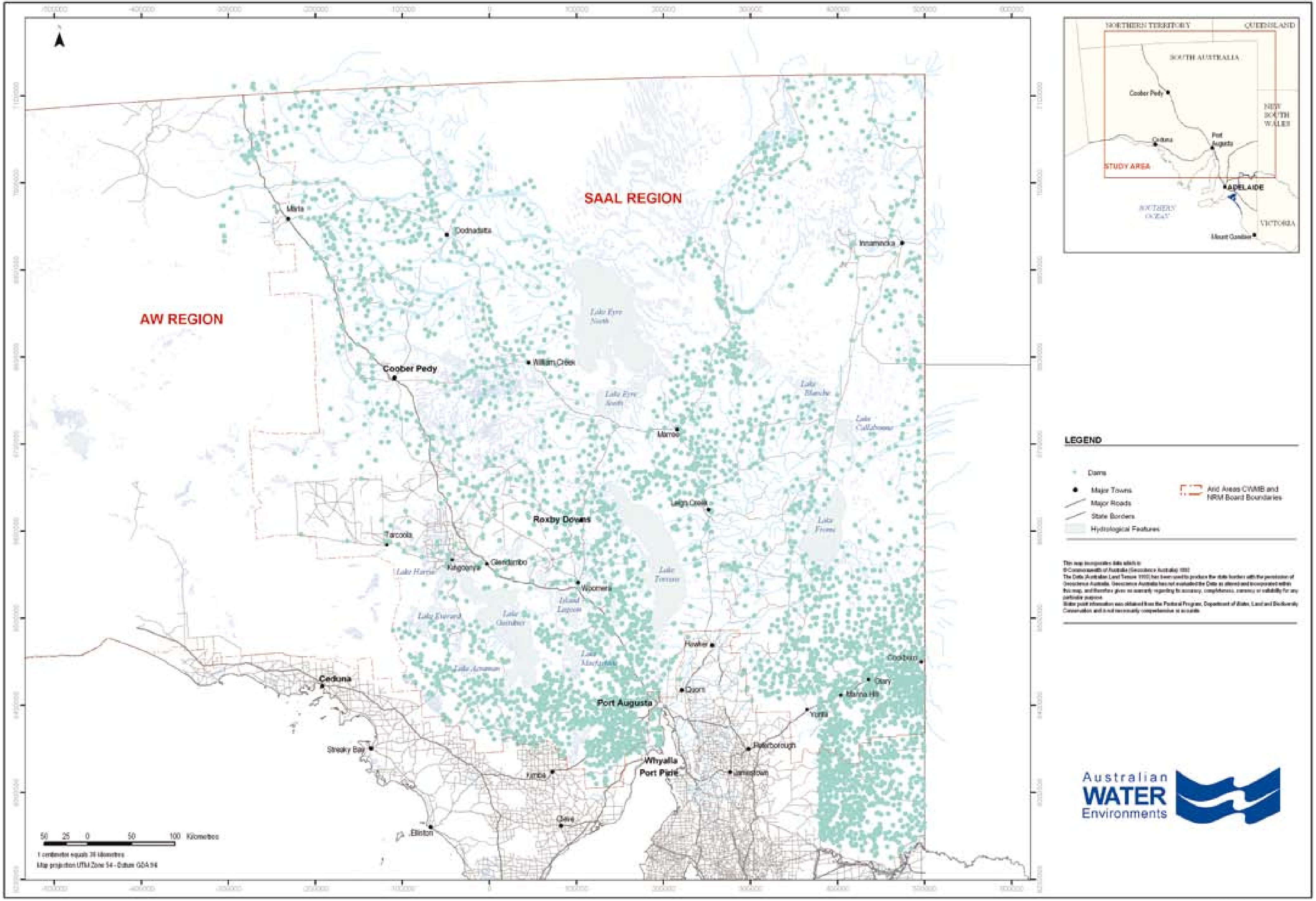
The Lake Frome catchment contains part of the Flinders Ranges, the Frome Embayment (to the east of the Flinders Ranges), and Lake Frome. The Ranges on the western side of the Frome Embayment are around 600 metres above sea level, and streams from the Ranges carry high sediment loads deposited as recent alluvium on the plain, and contributes detritus to fans on the western shore of Lake Frome. The high plains and the upper elevations of the low plains, with gibber/gilgai patterning, have brown cracking soils and stone gibber overlies a generally bare, silty clay soil (Heathgate Resources, 1998). Soils in slight depressions between the gibber in drier periods are cracked or puffy, and act as a sink during periods of heavy rain when water is shed from the adjacent, almost impermeable gibber-covered areas (Heathgate Resources, 1998). Initially, water is absorbed rapidly into the cracked soils but infiltration reduces as the clay swells. Some water erosion has occurred along the margins and old graded tracks of the High Plain, although it is not occurring as rapidly as some other gibber tableland areas in South Australia.

South of Lake Frome, and to the east of the Northern Flinders Ranges, is the Olary Spur. Surface water drainage runs off the Spur north towards Lake Frome. Streams from the Olary Spur do not reach the Lake but flood out at a small distance from the Upland. Between Lake Frome and the Flinders Ranges, ephemeral surface drainage dissects broad alluvial plains and drains either into, or towards, Lake Frome. On the eastern side of Lake Frome surface drainage is largely relict and choked by the sands of the dunefields of the Strzelecki desert.

To the south of the Olary Spur, drainage runs into the Lower Murray River SWMA (part of the Murray-Darling basin depression). The Lower Murray SWMA is not discussed here as the majority of it lies outside the study area.

There is insufficient streamflow data available for the Lake Frome SWMA for a catchment-wide hydrological assessment to be made. This shortcoming has been recognised by the Department of Water, Land and Biodiversity Conservation and the need for streamflow information is going to be addressed by the State Water Monitoring Review Project (National Land and Water Resources Audit, 2000).

Figure 4.6 Dams



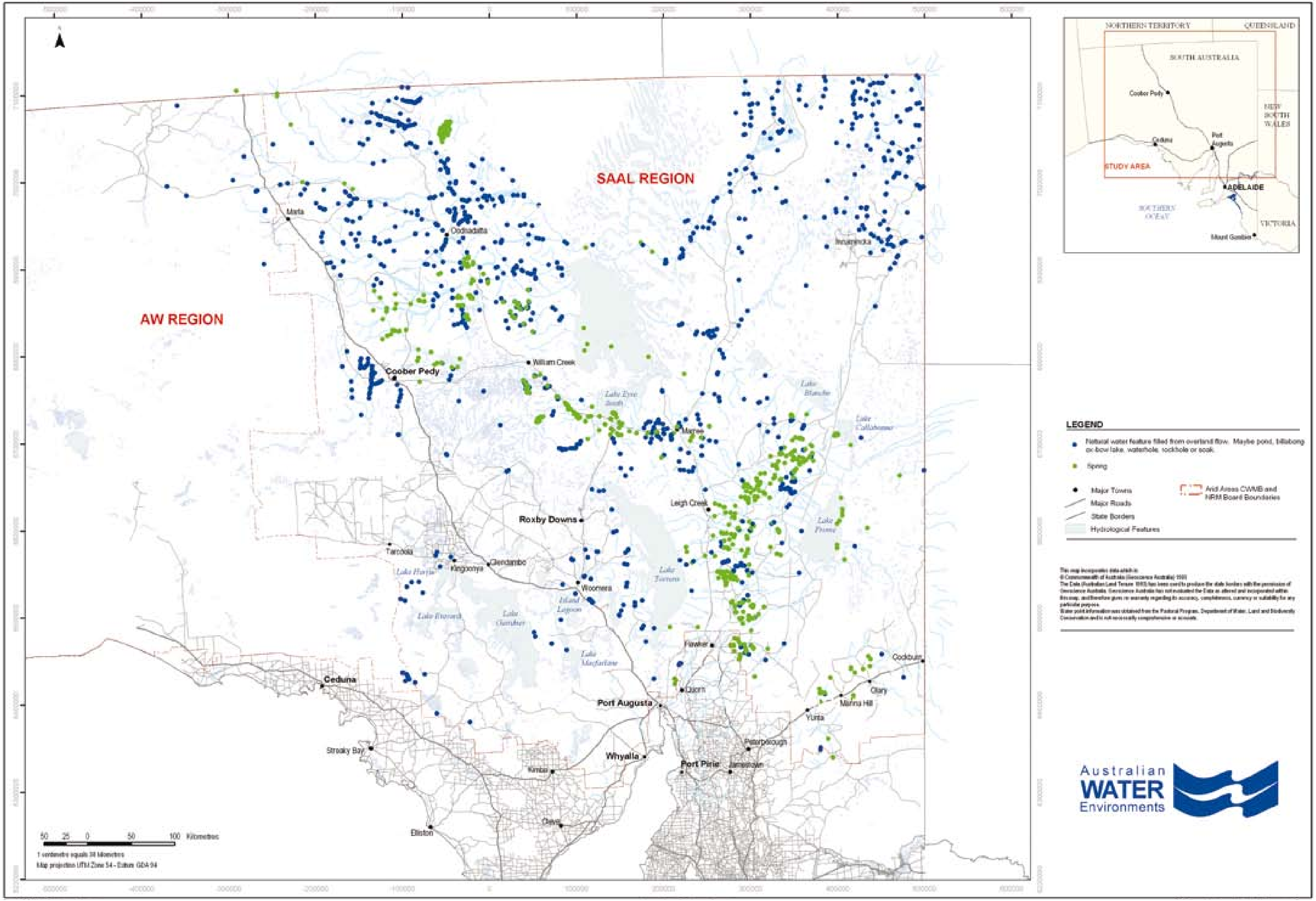


Figure 4.7 Waterholes and Springs

AACWMB Photo Library

Dry Creek bed on the Birdsville Track

During times of flooding, creeks fill and feed water into the underlying sands and gravels. Following floods, the reverse may occur, and groundwater flows back into the creek. This groundwater discharge is known as ‘base flow’. Eventually the base flow may diminish, and the creek bed becomes dry on the surface, however groundwater flow may continue underneath the creek bed. This subsurface (hyporheic) water may contain organisms, and be a refuge during dry periods. Very little is known about the hyporheic zone and the broader interactions between groundwater and surface water in the arid areas. The dependence of arid areas vegetation on groundwater is not well understood.

5 Groundwater/Surface Water Interaction

5.1 General

Natural surface water and groundwater systems are, in most cases, linked. Changes to one or the other of these systems will often affect both, and it is therefore prudent to manage them as one, instead of two separate systems. In the study area, shallow, freshwater aquifer systems are generally recharged by rainfall events and subsequent infiltration of ponded surface water into the ground. A deeper aquifer such as the GAB, is also recharged largely by surface water in Queensland. Deeper aquifers can recharge shallower aquifers through vertical upward leakage, which may in turn play a role in the presence of salinas or other surface water features.

The sustainability of freshwater aquifers is often therefore dependant on the volume and frequency of rainfall. As we know, in the arid areas, within our management timeframes, rain is not a reliable source of water.

Rain infiltrating into the ground to recharge the aquifers often does so via streams, creeks, lakes and rivers. Should the water be stopped from flowing down these drainage lines, the aquifers dependent on them will not recharge, and the cessation/reduction of flow will be to the detriment of users dependent not only on surface water downstream, but also on the users of groundwater (be they environmental, domestic or commercial users).

When managing the use of water the system must be looked at holistically.

5.2 Aquifer Recharge Enhancement and Recovery

Aquifer recharge enhancement is the enhanced recharge of surface waters to aquifers. It involves increasing the natural recharge processes so that more surface water becomes groundwater, which can be stored in the aquifer. Storage of water underground prevents water loss through evaporation, and can enhance water quality to some extent by filtration through the aquifer medium. The water can be extracted as the need arises, enabling the user to be less reliant on highly variable rainfall. Recharge of surface water into the aquifer is done by direct infiltration through bores, or infiltration through the ground. Often surface water storage prior to injection into the aquifer is required to improve water quality and to provide a balancing storage.

Any aquifer recharge enhancement and recovery project has the potential to affect a multitude of things in the surface or sub-surface, and harvesting of surface water may have an impact upon other users. Any aquifer recharge and recovery project should therefore be an integral part of an overall catchment/basin-wide water management strategy.

There are several methods for enhancing recharge to aquifers, the main ones being:

- basin infiltration whereby leakage from the basin enters an unconfined aquifer which is pumped (percolation through the unsaturated zone provides relatively rapid attenuation of some contaminants in comparison with passage through the aquifer);
- surface and sub-surface impoundments and dams in stream beds and wadis, designed to capture or slow down often sporadic runoff;
- rainwater harvesting from roof drainage, which is used to recharge aquifers via collection tanks or through sand filters;
- induced infiltration, or bank infiltration, by pumping of groundwater from aquifers that are hydraulically connected to lake or rivers (not particularly applicable to the arid zone)
- Aquifer Storage Recovery (ASR) which involves injecting water into a well and recovering it later from the same well; and
- injection and recovery from different wells, which has the advantage of filtration provided by the passage of the aquifer.

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

Due to the intermittent, ephemeral nature of flow in the arid areas, particularly in the Far North, surface water flow is often turbid and silty. This can be an impediment when transferring the surface water to an underground storage aquifer, as the silt decreases the permeability of the infiltrating beds. This can be overcome by storing the surface water initially in a large reservoir to allow the fines to settle, and then releasing the cleaner water in a controlled manner to infiltrate over designated sites. However in doing so the very high evaporation rates in the SAAL region will still cause significant water losses (unless the reservoir is covered).

The scarcity of freshwater in the arid areas also prompts the consideration of the re-use of wastewater.

Potential opportunities exist for the integration of surface water capture and underground storage throughout the study area. Managed aquifer recharge in arid regions such as Saudi Arabia, Oman, Kuwait and Egypt is recognised as a key element of water management strategies.

Near the study area, an Aquifer Storage and Recovery system has been investigated at Whyalla (AWE, 1999). Investigations have also been undertaken in areas around Hawker and Nepabunna with regard to enhanced aquifer recharge and recovery. Martin *et al*, 1998, highlighted an area having potential for enhanced groundwater recharge in the study region known as the Pirie-Torrens Basin (along the base of the Flinders Ranges). Although augmenting natural recharge in the arid areas is difficult due to the scarcity of surface water, if the demand was forthcoming (for example, around townships) such projects are not impossible. Alternatively, limited surface water injection into saline aquifers will result in an improvement in water quality, and desalination plants could then be used, resulting in some savings on the final water product, as the cost of desalinating water of 20,000 milligrams per litre is more economical than desalinating water of 40,000 milligrams per litre (Martin *et al*, 1998).

The success of an aquifer recharge and recovery project will depend to a large degree upon the scale of information provided for the area. Key geological features such as faults, folds, fractures or areally extensive coarse or fine-grained sedimentary units can exert dominant controls on a flow system. There have been numerous cases recorded whereupon a system has not behaved as expected due to the (previously unknown) presence of these controls.

Optimisation models and techniques can be used to identify the most efficient way to manage water resources, given a set of constraints put in place by water routing capabilities, volumes, economics, and off-site effects. Artificial recharge projects often form an integral part of these models.

Monitoring of hydraulic conditions is an essential part of any management plan, to provide information for adjustments to the system. Reduced uncertainties translate directly to increased confidence in management decisions.

5.3 Environment

For riparian trees of arid and semi-arid zones (for example, *Eucalyptus camaldulensis, Eucalyptus largifloren, Eucalyptus coolabah*), river flooding is the means of restoring soil water necessary for initiating seed germination and ensuring seed establishment. The environmental conditions required for germination, or for the survival of a seedling, are usually not the same as those required by an adult plant. Flooding events are required in many cases for seed germination, and also help to disperse seeds and other propagules. Following flood events, adult plants generally require a dry period, as water logging of their roots will starve them of oxygen. (Riparian vegetation, such as paperbark and river red gum, has developed adaptations to periods of flooding by developing adventitious roots. Floodplain vegetation has fewer adaptations.) The changes that result from flooding followed by flood recession provide a brief, but distinct, growing opportunity. Following flooding, vegetation has either adapted to long, dry periods by entering no-growth periods, or by having short life spans. However, some of the vegetation relies on storages of fresh groundwater to remain healthy.

It is common knowledge that vegetation along drainage lines and floodplains are dependent on rainfall and/or surface water flows (even if the flows are infrequent and irregular). The role of groundwater in supporting ecosystems across the continent is still poorly understood – yet is known in many cases to also be absolutely vital (Hutton, 1998). Many Australian rivers, which appear dry on the surface, continue to flow underground, and the trees, vegetation, bird and other animal life all depend on this (Hutton, 1998). During dry periods, underground flow in stream beds (that is, hyporheic flow) provides a refuge for aquatic insects and crustaceans, which in turn provide sustenance for species higher up the food chain.

Groundwater dependent ecosystems are often also dependent on the interaction of groundwater and surface water. There are five recognised classes of ecosystem dependency on groundwater:

- **ecosystems entirely dependant on groundwater**: only slight changes to key attributes would result in degradation of the ecosystem.
- **ecosystems highly dependant on groundwater**: ecosystems within this class utilise groundwater, surface water and soil water, with moderate changes to groundwater attributes resulting in degradation. Cessation of groundwater supply would result in substantial modification of the ecosystem.
- **ecosystems with proportional dependence on groundwater**: ecosystems of this nature experience a change proportional to the rate of change of the groundwater attribute.
- **ecosystems that make limited or opportunistic use of groundwater**: the use of groundwater in these ecosystems appears to be significant during dry periods such as drought and at the end of dry seasons. These ecosystems have the ability to survive without access to groundwater in the short-term, but will suffer and possibly collapse in the long-term if the situation is prolonged.

- **ecosystems which superficially appear to depend on groundwater**: these ecosystems may appear to be dependant on groundwater resources, but following further investigation are found to be dependant on rainfall or surface water flows only.

Recognition of groundwater dependent ecosystems as a distinct, important and diverse group has been relatively recent (Environment Australia, 2001). The level of dependency an ecosystem has on a groundwater source is dictated by a number of factors relating to the resource, primarily:

- flow (rate and volume);
- level (the depth below surface of the watertable in unconfined aquifers);
- pressure (of artesian flow), and
- quality (such as pH, salinity and/or nutrients and contaminants).

Ecosystems will respond in different ways to changes in these attributes. In the worse case scenario, an ecosystem may completely collapse if a certain attribute value is exceeded (Environment Australia, 2001). Less dramatic changes such as altered species composition, or a decline in health, can also occur. As described earlier, the level at which groundwater dependent ecosystems depend upon the groundwater varies, ranging from some entirely dependent on the groundwater, to some opportunistically dependent.

The interaction of groundwater and surface water in many areas is not fully understood, therefore classification of ecosystems is difficult. Examples include the Lignum (*Meuhlenbeckia cunninghamii*) shrublands of the stream and lake systems of southern and northern Australia, and the chenopod shrublands of the floodplain country in northern South Australia. These ecosystems are suspected of being groundwater dependant to a degree, but further investigation is required before this can be confirmed (Environment Australia, 2001).

Much native fauna is reliant on vegetation, and are therefore indirectly dependent on the surface water/groundwater interaction which is a requirement for many arid areas vegetation species.

Image courtesy of South Australian Tourism Commission

Pelicans on Lake Eyre

6 Ecology and Water Dependent Ecosystems

The general importance of inland aquatic areas to Australian biological diversity is very high. As areas of moisture in a generally arid continent, they are vital to many groups, notably birds, and many communities of floral and faunal species are specifically associated with them.

The arid climate and wet / dry cycle that drives ecological systems in the area has resulted in the SAAL region containing many unique organisms and a rich biodiversity significant on a global scale. For example, the salt lake communities, although restricted in the variety of species numbers, are noted for some distinctive and endemic brine shrimps. Only a limited number of organisms in the world have adapted to life in salt lakes, and many notable examples are in Australia (Mummery and Hardy, 1995). Many organisms have also evolved adaptations to cope with periods of drought, for example drought resistant eggs or larvae, burrowing, and life-cycle adaptations including opportunistic breeding after flooding (Mummery and Hardy, 1995). The Anaspidacea, an order of the crustacean superorder Syncarida, has most of its members confined to South Australia. This order is very interesting from an evolutionary point of view as it contains fossil and extant forms that are morphologically similar to the ancestors of the malacostracans, for example, crabs, lobsters and shrimps (William and Campbell, 1987 in Mummery and Hardy, 1995).

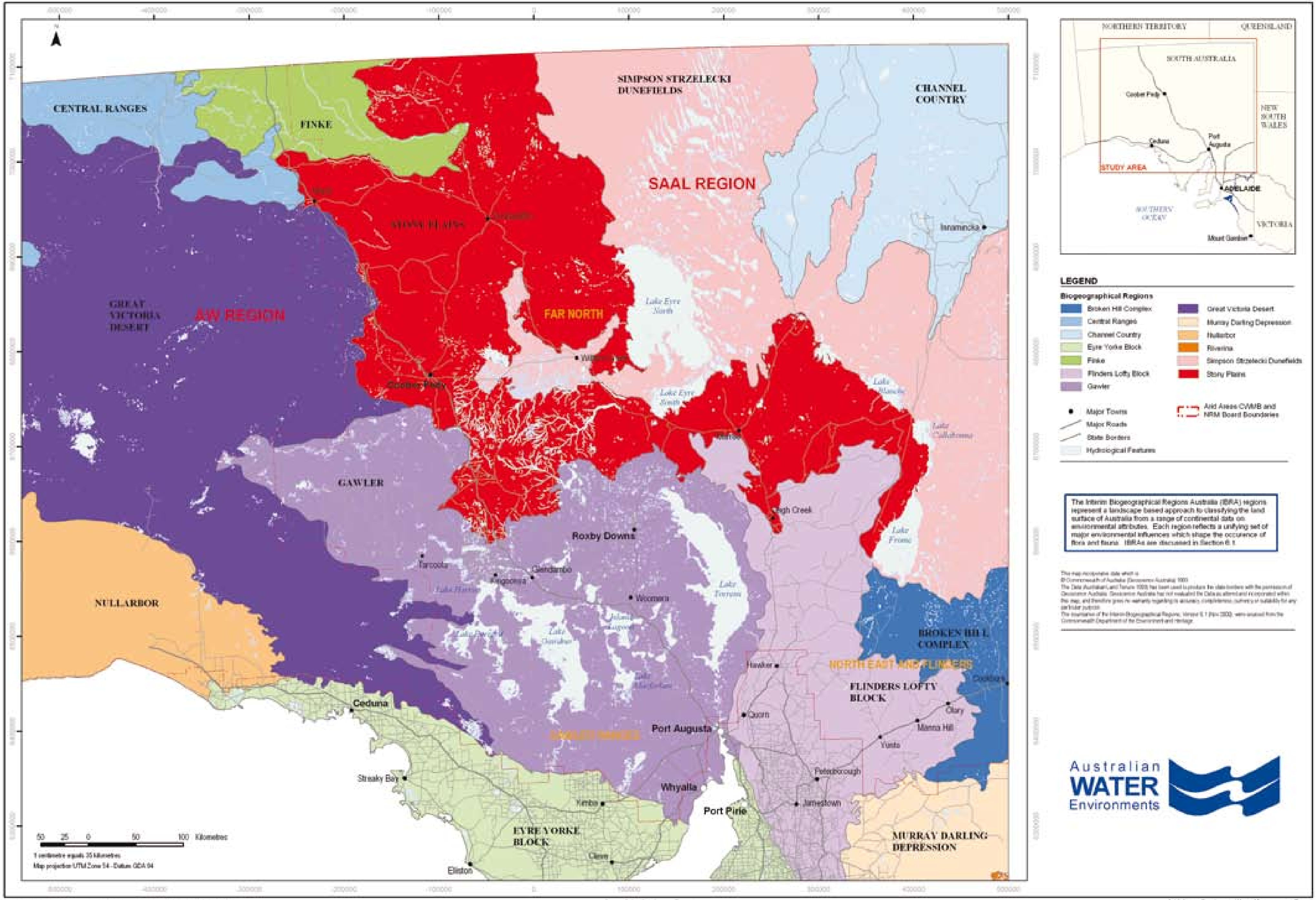
The insect order Odonata is of an ancient lineage, and it appears that Australia may have its most archaic member (Mummery and Hardy, 1995), which is a small green damselfly species, a rare insect which has probably been on the Australian landmass for at least 280 million years. It possesses a mixture of primitive and apparently reduced morphological features and is thought to be the sister taxon to the whole of the rest of the Odonata (Trueman *et al*, 1992, Watson and O'Farrell, 1991 in Mummery and Hardy, 1995). Damselflies live on plants, among stones or leaf litter at the bottom of ponds or slow-flowing rivers.

In a review of the refugia for biological diversity in arid Australia by the Australian Government (Mummery and Hardy, 1995), the Lower Cooper Wetlands (including the Coongie Lakes) was named as one of the unique wetland areas in Australia that deserves special consideration because it provides areas of significant moisture and a variety of habitats in an otherwise arid continent. The GAB springs are surface water expressions of a groundwater dependent ecosystem, and have also been identified in the same report as being of special significance. (These areas are discussed in more detail in Section 6.3 – Far North).

A set of nationwide ecological regions or boundaries (named bioregions) have been developed through input by various State, Territory and Commonwealth groups, to provide an integrated view of ecosystems across Australia. These boundaries are often used as the basis for ecological studies, and are described further below. A description of, including significant flora and fauna contained within, each bioregion is provided. A diagram showing the location of each bioregion in South Australia is presented in Figure 6.1.

The wet / dry cycle is a defining characteristic of the SAAL region, and the ecological importance of it is described in Section 6.2.

Figure 6.1 Interim Biogeographical Regions for South Australia Version 5.1



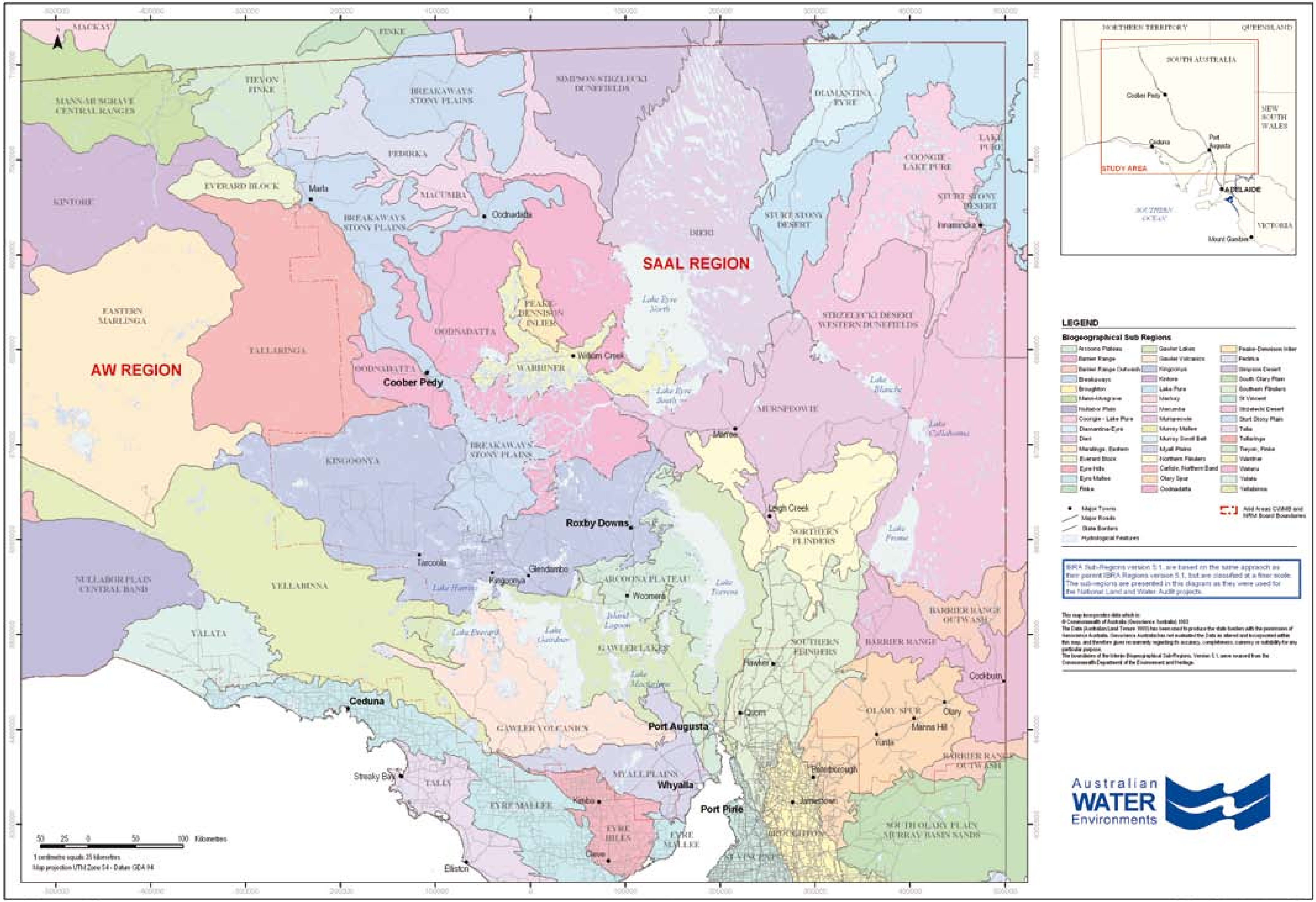


Figure 6.2 Biogeographical Sub-Regions

Groundwater and surface water dependent ecosystems for each area in the SAAL region are then detailed (that is, the Far North, Gawler Ranges, and Northern Flinders and East areas), although in many instances the description is fairly general due to a paucity of information.

6.1 Biogeographical Regions and Subregions in South Australia

The Interim Biogeographic Regionalisation for Australia (IBRA) was developed in 1993-94. This regionalisation built upon previous work by the Commonwealth, State and Territories to identify appropriate geographical regions, and to assess and plan for the protection of biological diversity. The nationally agreed regionalisation was published in Thackway and Creswell (1995), Version 4. Since then, most State agencies have refined and adopted new boundaries. These new boundaries have been formalised at a national level, creating IBRA Version 5.1.

Since their inception, the IBRA regions have been used for a myriad of analyses by States and Territories looking at a broad range of physical and biological values. They now represent the premier tool for nature conservation planning in particular (Environment Australia, 2000). The IBRA boundaries are based on the fact that it is the physical processes that drive ecological processes. The IBRA regions therefore represent a landscape-based approach to classifying the land surface – regional and continental scale data on climate, landform, lithology, surface and groundwater systems, and its characteristic flora and fauna, was combined with specialist ecological knowledge to define the biogeographic regions.

Given the paucity of biophysical data in some parts of the country, it was acknowledged that new information gained through time would modify our understanding of the regions, hence the term *Interim* is used in the title of IBRA.

This study uses the IBRA Version 5.1 boundaries to provide information on the processes occurring within, and potential threats to, ecosystems in the SAAL region.

The location of each biogeographical region in the SAAL region is presented in Figure 6.1 and their subregions in Figure 6.2. A description of each region follows.

6.1.1 Channel Country

The western portion of the Channel Country bioregion is present in the far north-eastern corner of South Australia, with the rest of the bioregion extending mainly into Queensland. It consists of low hills on Cretaceous sediments, forbfields (that is, areas of non-grass herbs), Mitchell grass downs, and intervening braided river systems of coolabah *E.coolabah,* woodlands and lignum/saltbush *Muehlenbeckia* sp./*Chenopodium* sp. shrublands (which includes small areas of sand plains). It also contains the internationally significant Coongie Lakes wetland, which was classified as a National Park in 2003 and is listed under the RAMSAR Convention, and the wetland systems of the Diamantina River and Strezlecki Creek (1,980,000 hectares). The Innamincka Regional Reserve lies within the

South Australian portion of the bioregion. The Innamincka area of South Australia has been declared a State Heritage Area. The main land uses in the bioregion are grazing by cattle, gasfields, conservation and tourism.

Subregions contained in the Channel Country biogeographical region are the Coongie – Lake Pure, Sturt Stony Desert and Diamantina – Eyre.

Significant Flora/Fauna

Species listed in the Australian/New Zealand Environment and Conservation Guidelines (ANZECC), which are present in this bioregion in South Australia, are:

- the mammal kowari *Dasyuroides byrnie* (endangered), which occurs at scattered localities such as at the Koonchera/Lake Goyder district in South Australia;
- the plains-wanderer bird *Pedionomus torquatus* (vulnerable) which occurs patchily in the region;
- the night parrot *Geopsittacus occidentalis* (endangered), sightings of which remain unconfirmed (McFarland, 1992, in Morton *et al*, 1995); and
- the plant *Frankenia plicata* (endangered), which occurs in the Coongie area.

Species that are reported as regionally endemic to this bioregion within South Australia, and presented in Morton *et al*, (1995) are:

- the grey grasswren, *Amytornis barbatus*, which occurs as isolated and taxonomically distinct forms in the Bulloo River, and in Goyder's Lagoon and other scattered localities northward along the Diamantina and Cooper Rovers into Queensland (it is confined to lignum *Muehlenbeckia cunninghamii*, or swamp canegrass *Eragrostis australasica*); and
- the Cooper Creek tortoise *Emydura* sp., which is endemic to the lower Cooper in South Australia.

Relict populations include the nationally threatened grass *Echinochloa inundata*, which is present in the backwaters of the north-west branch of the Cooper Creek (Reid and Gillen 1988, in Morton *et al*, 1995). Other species of concern in this vicinity include *Frankenia cupularis, Goodenia lobata,* and *Phlegmatospermum eremaeum* (Morton *et al*, 1995).

Waterholes and more permanent lakes provide drought refuge for the wide range of aquatic fauna when dry conditions persist for a year or more. Dense lignum beds adjacent lakes or channels are considered to provide a refuge for the long-haired rat, *Rattus villosissimus* (Reid and Gillen 1988 in Morton *et al*, 1995). Between plagues, the species shrinks to small pockets in perennially damp locations in the Channel Country. The Coongie Lakes wetlands are considered to provide habitat for two uncommon waterbirds, the white-winged tern *Chlidonias leucoptera*, and pectoral sandpiper *Calidris melanotos* (Reid and Gillen 1988 in Morton *et al*, 1995).

Species that characterise the bioregion in the South Australian portion are the Cooper Creek catfish (*Neosilurus* sp), Gilberts water dragon (*Gemmatopohora gilberti*) (which is restricted to South Australia only), an undescribed species of the frog *Cyclorana*, and an outlying population of the water rat *Hydromys chrysogaster*. In addition, the night parrot *Geopsittacus occidentalis* may be present in the Cooper Creek area, and the bush thick-knee *Burhinus grallarius* is definitely present (Reid and Gillen 1988 in Morton *et al*, 1995).

Other rare or localised reptile and mammal populations (presented in Morton *et al*, 1995) include:

- Forrests' mouse *Leggadina forresti* (rare in South Australia);
- the yellow-bellied sheath-tailed bat *Saccolaimus flaviventris* (rare in South Australia); and
- the skink *Lerista aericeps*.

Ten bird species of this bioregion in South Australia are classified as vulnerable (Morton *et al*, 1995). These are:

- Little egret *Egretta garzetta;*
- Freckled duck *Stctoneta naevosa;*
- Grey falcon *Falco hypoleucos;*
- Brolga *Grus rubicundus;*
- Australian bustard *Ardeotis kori;*
- Painted snipe *Rostratula benghalensis;*
- Latham's snipe *Gallinago hardwickii;*
- Blue winged parrot *Neophema chrysostoma;*
- Barking owl *Ninox connivens*; and
- Yellow chat *Ephthianura crocea*.

There are also endemic distinctive populations of red-rumped and mallee ring-necked parrots (*Psephotus haematonotus* and *Barnardius barnardi*) in the Innamincka area (Reid and Gillen 1988 in Morton *et al*, 1995). Grass owls *Tyto longimembris* occur sporadically in Goyders Lagoon.

The lower Diamantina and Cooper contain many hundreds of wetlands, including Goyders Lagoon, the Warburton, Lake Etaminbanie, Lake Coongie, and waterholes near Innamincka. When full, they can become a haven for waterfowl from southern areas. The Coongie Lake system is consequently listed under the Ramsar convention as a wetland of international importance to waterfowl. At least 20,000 waterfowl occupy the lakes all year, except after it rains, when there is significantly more (Morton *et al*, 1995).

Nine native and two exotic species of fish occur in the north-west branch of the Cooper. The native fish are:

- Bony bream (*Nematalosa erebi*);
- Callop (*Macquaria ambigua*);
- Smelt (*Retropinna semoni*);
- Western carp gudgeon (*Hypseleotris klunzingeri*);
- Desert rainbow fish (*Melanotaenia splendida tatei*);
- Cooper Creek tandan (*Neosilurus* sp.A);
- Yellow fin tandan (*Neosilurus* sp.B);
- Spangled perch (*Leiotherapon unicolour*); and
- Welch's grunter (*Bidyanus welchi*).

The two exotic fish species are the mosquito fish (*Gambusia affinis*) and the goldfish (*Carassius auratus*).

The Coongie Lakes and Goyders Lagoon are classed as refugia for biological diversity, according to the literature survey undertaken by the Australian Government *Department of the Environment and Heritage*, to identify the foci of biological diversity and determine the location of broad-scale refugia in Australia. This study is a starting point for further work and is not all-inclusive. On a smaller scale there would be many waterholes and other features which are also refugia for animals during long dry periods.

6.1.2 Simpson – Strzelecki Dunefields

The Simpson-Strzelecki Dunefields Bioregion is also in the north-east corner of the State, and consists of arid dunefields and sandplains, with sparse shrubland and spinifex hummock grassland, and cane grass on deep sands along dune crests. Large salt lakes and many clay plans are dispersed amongst the dunes. The Simpson-Strezlecki dunefields contain the wetlands of Lake Eyre and the inland saline lakes (1,798,000 hectares). Several significant arid rivers terminate at Lake Eyre (for example Cooper Creek and Warburton River), which are fringed with coolabah and redgum woodlands. This biogeographical region contains six parks/reserves, namely Simpson Desert Conservation Park, Simpson Desert Regional Reserve, Lake Frome Regional Reserve, Innamincka Regional Reserve (part), Strzelecki Regional Reserve, and Lake Eyre National Park. The main land uses in this bioregion are cattle and sheep grazing, Aboriginal land, conservation and tourism.

Subregions contained in the Simpson-Strzelecki Dunefields biogeographical region are the Simpson-Strzelecki Dunefields, Dieri, Warriner, and Strzelecki Desert Western Dunefields.

Significant Flora/Fauna

Species listed in the ANZECC, which are present in this bioregion in South Australia, are:

- Dusky hopping mouse *Notomys fuscus* (endangered), which occurs in sand dunes along the Strzelecki Creek in the vicinity of Lake Blanche (McFarland 1992 in Morton *et al*, 1995); and
- the endemic wattles *Acacia pickardii* and *Acacia peuce* (both vulnerable) are found at scattered localities (Morton *et al*, 1995).

Species that are reported as regionally endemic to this bioregion within South Australia, and presented in the Morton *et al*, 1995 are:

- the plant *Acacia nelsonii;*
- the Eyrean grasswren *Amytornis goyderi*, although it does not appear to be at risk; and
- the Lake Eyre dragon *Ctenophorus maculosus*, which is restricted to Lake Eyre and surrounding salt lakes.

The relict nature of *Acacia peuce* has been widely discussed (Chuk 1982, Boyland 1984, Purdie 1984, Neldner 1991 in Morton *et al*, 1995).

The plants *Dpteracanthus corynothecus, Glinus orygioides, Corchus elderi, Indigofera* sp.*, Bergia occultipetala, Ptilotus eichleranus, Eryngium supinum, Sclerolaena wilsonii, Teucrium albicaule, Zygophyllum humillimum* and *Eleocharis papillosa* are all rare species in the region (Purdie 1984, Gibson and Cole 1988 in Morton *et al*, 1995).

Invertebrates of Lake Eyre appear in the main to be widespread species, with at least one exception being the ostracod *Diacypris* sp (Williams 1990, in Morton *et al*, 1995). Similarly, the fishes of Lake Eyre appear to be widespread species. Five species occur in Lake Eyre, and three of these are rare.

Waterbirds can occupy the Lake Eyre in huge numbers (in excess of 300,000). There are generally at least 36 species in the assemblage, and several species breed on islands within the lake (Kingsford and Porter, 1993 in Morton *et al*, 1995).

Strzelecki Creek is an important distributory of Cooper Creek, and a major feeder of Lake Blanche, which is a shallow freshwater lake that increases in salinity as it dries out. When in flood, Strzelecki Creek also supports large numbers of waterbirds, including the freckled duck *Stictonetta naevosa* (Puckridge and Drewien 1992 in Morton *et al*, 1995).

Little is known of the biology of Lake Frome, which is a large, saline, relatively pristine playa lake.

Lake Frome, Lake Eyre, the Strzelecki Creek floodplain and Lake Blanche are all classed as refugia for biological diversity, according to the literature survey undertaken by the Australian Government, *Department of the Environment and Heritage,* to identify the foci of biological diversity and determine the location of broad scale refugia in Australia. This study is a starting point for further work and is not all-inclusive.

6.1.3 Stony Plains

The Stony Plains Bioregion is located in the middle and northern part of the State, and consists of arid, stony silcrete tablelands, gibber and gypsum plains with sparse low chenopod shrublands on duplex soils and calcareous earths, dissected by large arid drainage systems with coolabah and redgum on cracking clays along riverbanks of numerous creeks and valleys. The stony plains contain the majority of the GAB spring ecosystems (19,000 hectares). This biogeographical region contains one park/reserve, namely the Witjira National Park. The main land uses in this region are extensive pastoralism and mining.

Subregions contained in the Stony Plains biogeographical region are Murnpeowie, Oodnadatta, Peake-Denison inlier, Macumba, and Breakaways Stony Plains.

Significant Flora/Fauna

Species listed in the ANZECC, which are (or have recently been) present in this bioregion in South Australia, are:

- the black-footed rock wallaby *Petrogale lateralius* (vulnerable), was known to be present in the Davenport Ranges east of Coober Pedy until recently, when after two detailed surveys they are now presumed to be extinct (Eldridge *et al*, 1994 in Morton *et al*, 1995);
- the plains rat *Pseudomys australis* (vulnerable), which is now confined to the lower Finke and Oodnadatta area (Breed and Head, 1991 in Morton *et al*, 1995);
- the kowari (mammal) *Dasyuroides byrnie* (endangered) is recorded in the region, but its current status is unknown;
- the pygopodid (reptile) *Ophidiocephalus taeniatus* (vulnerable), which is markedly confined to watercourses lined with gidgee *Acacia cambagei* between Abminga and Coober Pedy (Ehmann 1992, Cogger *et al*, 1993 in Morton *et al*, 1995); and
- the plants *Eriocaulon carsonii, Atriplex kochiana*, and *Frankenia plicata*, which are all classified as endangered (Morton *et al*, 1995).

Species that are reported as regionally endemic to this bioregion and presented in Morton *et al*, (1995) are:

- the chestnut-breasted whiteface *Aphelocephala pectorals* bird (it is unusual for birds to be endemic to one region);
- the agamid lizard *Ctenophorus gibba*, which is endemic to the gibber plains of the bioregion;
- among invertebrates of the GAB springs, the endemic fauna is dominated by crustaceans and hydrobiid molluscs. Endemics include:
  - the isopod *Phreatomerus latipes;*
  - the ostracod *Ngarawa dirga;*
  - further undescribed ostracods;
  - a phreatic amphipod *Phreatochiltonia anophthalma;*
  - further species of the amphipod genus *Austrochiltonia;*
  - possibly endemic copepods;
  - a macrostomid flatworm; and
  - more than 20 taxa of snails (Hydrobiidae) have recently been found in GAB springs in both South Australia and parts of Queensland. Ten taxa are recognised in two endemic genera, namely *Fonscochlea* and *Trochidrobia* from springs between Marree and Oodnadatta.
- there are six species of endemic fishes in the bioregion, of which four (*Chlamydogobius* sp, *Neosilurus* sp, *Craterocephalus dalhousiensis*, and *C. gloveri*) are endemic to the Dalhousie Basin; and
- among 100 plant species recorded at Dalhousie, one is endemic to the spring complex (*Nicotiana burbidgeae*), one is the only record for central Australia (*Lemna disperma*), three constitute the only records for northern South Australia (*Baumea arthrophylla, Hydrocotyle verticillate* and *Polygonum salicifolia*), and five are uncommon species in South Australia.

Relict vegetation occurs at GAB springs. On active GAB springs at Dalhousie, there is fringing vegetation of *Melaleuca glomerate*, *Myoporum acuminatum*, *Typha domingensis*, *Phragmites australis* and *Cyperus gymnocaulos*. On drier slopes there is *Acacia salicina*. Great variation exists in vegetation between springs, and further investigations are likely to reveal more relict species (Morton *et al*, 1995).

Other significant populations in this bioregion are an apparently isolated population of the snake *Oxyuranus microlepidotus*, which occurs near Coober Pedy (Read 1994 in Morton *et al*, 1995), and reported rare plants *Hemichroa mesembryanthema*, and *Frankenia granulate* (Leigh *et al*, 1984 in Morton *et al*, 1995).

Apart from the GAB springs, a noted important wetland in this bioregion is Lake Phillipson, which lies south-west of Coober Pedy, and is the terminus of the Long and Mabel Creek drainages. It is a freshwater ephemeral lake which supports large numbers of water birds, including the freckled duck, *Stictinetta naevosa* (Morelli and Drewien 1993 in Morton *et al*, 1995).

Dalhousie Springs, the Lake Eyre mound springs and Lake Phillipson are classed as refugia for biological diversity, according to the literature survey undertaken by the Australian Government, *Department of the Environment and Heritage*, to identify the foci of biological diversity and determine the location of broad-scale refugia in Australia. This study is a starting point for further work and is not all-inclusive.

6.1.4 Finke

The Finke Bioregion does not cover much of South Australia, and is present only in the far north of the State, near the South Australian/Northern Territory boundary (the remainder of the bioregion extends into the Northern Territory). The bioregion consists of arid sandplains, dissected uplands and valleys formed from Pre-Cambrian volcanics with spinifex hummock grasslands and acacia shrub-lands on red earths and shallow sands. There are no reserves or parks in the Finke bioregion. The main land uses are grazing of cattle and Aboriginal lands.

Subregions contained in the Finke biogeographical region are the Pedirka and part of the Tieyon Finke.

Significant Flora/Fauna

Only one species is listed in ANZECC, which is the plains rat *Pseudomys Australis* (vulnerable), which was recorded in the mid 1970s by Corbett *et al*, 1975, and may still occur in the region.

The Finke River Basin has the greatest diversity of fishes of any central Australian river basin, with 18 species in ten families (Glover 1982 in Morton *et al*, 1995). Three of the species are endemic to the Lake Eyre and Western Plateau Drainage Divisions (see Figure 5.2 for Drainage Divisions), namely *Neosilurus argenteus, Chlamydogobius eremius*, and *Craterocephalus centralis*.

There is no available information on relict populations in the area. The Finke River channel and its tributaries provide habitat for a range of riverine birds, and presumably many other taxa.

6.1.5 Gawler

The Gawler Bioregion covers the Gawler Ranges in the centre of the State, Lake Gairdner and Lake Torrens and surrounds. It consists of semi-arid to arid, flat-topped to broadly-rounded hills of the Gawler Ranges Volcanics and Proterozoic sediments, low plateaux on sandstone and quartzite with an undulating surface of Aeolian sand or gibbers (broken duricrust) and rocky quartzite hills with colluvial footslopes, erosional and depositional plains and salt-encrusted lake beds, with black oak (belah) and myall low open woodlands, open mallee scrub, bluebush/saltbush open chenopod shrublands, and tall mulga shrublands on shallow loams, calcareous earths and hard red duplex soils. The main land uses in the bioregion are grazing for sheep and conservation. Three parks/reserves exist in this bioregion, namely the Lake Gairdner National Park, Gawler Ranges National Park and part of the Lake Gilles Conservation Park.

Subregions contained in the Gawler biogeographical region are the Kingoonya, Arcoona Plateau, Gawler Lakes, Gawler Volcanics and Myall Plains.

Significant Flora/Fauna

Species listed in the ANZECC, which are present in this bioregion in South Australia, are:

- the sandhill dunnarts, *Sminthopsis psammophila* (vulnerable), which were discovered in 1969 but have not been seen since (Aitken 1971 in Morton *et al*, 1995)
- the malleefowl, *Leipoa ocellate* (endangered)
- the night parrot *Geopsittacus occidentalis* (endangered). A large number of historical records exist of this parrot in this bioregion; and
- the plant *Brachycome Muelleri* (endangered).

Species that are reported as regionally endemic to this bioregion and presented in Morton *et al*, (1995) are:

- the gecko *Nephrurus deleani*, which is restricted (by apparently unsuitable surrounding habitat) to a small area in the vicinity of Pernatty Lagoon, between Island Lagoon and Lake Torrens. The gecko is vulnerable to grazing by rabbits, sheep, cattle, soil compaction and erosion, and trampling of burrows; and
- three plant species, namely crimson mallee (*Eucalyptus lansdowneana* ssp. *Lansdowneana*,) *Grevillea parallelinervis*, and the Gawler Range greenhood *Pterostylis ovata*.

Relict populations exist of a Gawler Ranges sub-species of the thick-billed grasswren, *Amytornis textiles myall.*

Other significant populations in the Gawler Ranges bioregion are four populations of yellow-footed rock wallabies at the western limit of this species in Australia, and the hairy-nosed wombat (*Lasiorhinus latifrons*), which are abundant in the western half of the Gawler Ranges (Robinson *et al*, 1988 in Morton *et al*, 1995).

Birds regarded as having conservation significance, are the slender-billed thornbill *Acanthiza iredalei*, the calamanthus *Sericornis capestris*, and the red throat *Sericornis brunneus*, which have all declined substantially over this century (Morton *et al*, 1995). Other rare species are the scarlet-chested parrot, *Neophema splendida*, the white browed tree-creepers *Climacteris affinis*, and the chestnut quail-thrush *Cinclosoma castonatum*, which have been recorded only once or not at all (Morton *et al*, 1995).

Five plant species in the bioregion are listed as significant because they are endemic to South Australia. These are: *Acacia tarculensis, Anthocercis anisantha collina, Grevillea aspera, Melaleuca oxyphylla*, and *Prostanthera florifera*.

Noted wetland sites of importance are Lakes Gairdner, Harris, Everard and Acraman, which lie to the south of Kingoonya, as part of a complex of saline lakes (which also includes Lakes Frome and Torrens) (Morton *et al*, 1995). Little is known of the biology of these lakes.

Lake Gairdner and the Gawler Ranges are classed as refugia for biological diversity, according to the literature survey undertaken by the Australian Government, *Department of the Environment and Heritage*, to identify the foci of biological diversity and determine the location of broad scale refugia in Australia. This study is a starting point for further work and is not all-inclusive.

6.1.6 Flinders Lofty Block

The Flinders Lofty Block Bioregion follows the Adelaide Geosyncline in the eastern part of the State (Figures 6.2 and 2.2). It consists of temperate to arid Proterozoic ranges, alluvial fans and plains, and some outcropping volcanics, with the semi-arid to arid north supporting native cypress, black oak (belah) and mallee open woodlands, Eremophila and Acacia shrublands, and bluebush/saltbush chenopod shrublands on shallow, well drained loams and moderately deep, well-drained duplex soils. The increase in rainfall to the south corresponds with an increase in low open woodlands of *Eucalypta obliqua* and *E. baaxteri* on deep lateritic soils, and *E. fasciculosa* and *E. cosmophylla* on shallower or sandy soils.

The main land uses in this bioregion are grazing of sheep, tourism and conservation. Five parks/reserves exist in this area, namely Flinders Ranges National Park, Gammon Ranges National Park, Mount Remarkable National Park, Telowie Gorge Conservation Park, and Lake Torrens Regional Reserve. Koonamore vegetation reserve, currently the responsibility of the University of Adelaide, is a 400 hectare-site located on the pastoral lands, which was fenced off from sheep by Professor Osborne nearly 80 years ago. The area has also been free of rabbits since 1981. It is one of the few longer term monitoring projects of its type in the world (Sinclair, 2002). Many questions about vegetation and impacts can only be answered from long-term studies.

Subregions contained in the Flinders Lofty Block biogeographical region are Northern Flinders, Southern Flinders and Olary Spur.

Significant Flora/Fauna

Species listed in the ANZECC which are present in this bioregion in South Australia are *Senecio megaglossus, Acacia araneosa,* and *Acacia menzelii* plants.

Species that are reported as regionally endemic to this bioregion and presented in the Biodiversity series, Morton *et al*, (1995) are:

- a pygopodid lizard *Aprasia pseudopulchella;*
- an agamid, *Ctenophorus vadnappa*; and
- a fish, the Flinders Ranges gudgeon *Mogurnda* sp, which is restricted to waterways in the Gammon Ranges National Park.

There are relict populations of the yellow-footed rock wallaby, which was formerly the most abundant of animals in the Flinders Ranges at the time of European settlement (Lim *et al*, 1987 in Morton *et al*, 1995). The population has greatly declined, but is still known from 180 sites. Population size is estimated at 10,000 – 20,000. The animals are widespread throughout the region and in some areas are locally common. Habitat does not appear to be seriously threatened (Morton *et al*, 1995).

Significant or rare plants which have been recorded in the bioregion, and which are presented in Morton *et al*, (1995), are as follows:

- *Senecio georgianus;*
- *Myoporum refractum;*
- *Acacia iteaphylla;*
- *Sclerolaena bicuspis;*
- *Calostemma luteum;*
- *Galium binnifolium;*
- *Grevillea huegelii;*
- *Enneapogon intermedius;*
- *Maireana erientha;*
- *Tephrosia sphaerospora;*
- *Gypsophila australis;*
- *Olearia calcarea;*
- *Asplenium flabellifolium;*
- *Doodia caudata;*
- *Pteris tremula;* and
- *Nicotiana occidentalis obliqua.*

The presence of rare plants at many locations throughout the Ranges provides evidence of the ecological diversity of the Ranges, and their conservation significance (Greenwood *et al*, 1989 in Morton *et al*, 1995).

Important wetland sites in this bioregion have been identified by Morelli and Drewien (1993) and reported in the Morton *et al*, 1995. They are:

- Lake Torrens, which is a large saline playa supporting large breeding colonies of the branded stilts, *Cladorhynchus leacocephalus;* and
- the Flinders Ranges creeks Bunyeroo, Brachina, Wilpena, Parachilna and Oratunga, which run out through gorges from the Ranges, and are sources of freshwater and therefore very important in the arid/semi-arid area. They also harbour the Flinders Ranges gudgeon.

Lake Torrens and the northern Flinders Ranges are classed as refugia for biological diversity, according to the literature survey undertaken by the Australian Government, *Department of the Environment and Heritage*, to identify the foci of biological diversity and determine the location of broad scale refugia in Australia. This study is a starting point for further work and is not all-inclusive.

6.1.7 Broken Hill Complex

The western portion of the Broken Hill Complex covers a small part of eastern South Australia, and extends across the South Australian/Victorian boundary. It consists of hills and colluvial fans on Proterozoic rocks, desert loams and red clays, lithosols and calcareous red earths, supporting chenopod shrublands *Maireana* spp. – *Atriplex* spp. shrublands, and mulga open shrublands *Acaia aneura*. In South Australia, the main land uses are sheep grazing and tourism. There are no parks or reserves in the South Australian part of the bioregion, although the South Australian Government has recently purchased Bimbowrie station for future dedication as a National Parks and Wildlife reserve.

Subregions contained in the Broken Hill Complex biogeographical region are the Barrier Range and Barrier Range Outwash.

Significant Flora/Fauna

Species listed in the ANZECC, which are present in this bioregion (and assumedly within the South Australian portion), are:

- the wattle *Acacia carnei* (vulnerable), which is at risk through depredation of young plants by rabbits;
- the plant *Lepidium monoplocoides* (endangered);
- the plant *Eleocharis obicis* (vulnerable); and
- the plant *Raphidospora bonneyana* (vulnerable).

There is no information about species that may be regionally endemic. The greater long-eared bat, *Nyctophilus timoriensis,* and the yellow-bellied sheath-tailed bat, *Saccolaimus flaviventris,* are considered to be sparse and at risk, because their tree-roosting behaviour exposed them to a loss of habitat and predation by cats (Dickman *et al*, 1993 in Morton *et al*, 1995).

The following remaining populations of birds are considered to be at risk by Smith and Smith 1994 (presented in Morton *et al*, 1995):

- the letter-winged kites *Elanus scriptus;*
- the black breasted buzzards *Hamirostra melanosternon*;
- the Australian bustards *Ardeotis kori;*
- the bush thick-knees *Burhinus grallarius*; and
- Bourkes' parrots *Neophema bourkii*.

The agamid reptile *Ctenophorus decresii* has a moderately restricted national range.

The following plants are considered to be rare (Bowen and Pressey 1993, in Morton *et al*, 1995):

- *Gahnia lanigera;*
- *Paspalidium clementii;*
- *Lxiochlamys nana;*
- *Pluchea baccaroides;*
- *Vittadinia arida;*
- *Atriplex lobativalvis;*
- *Atriplex morrisii;*
- *Euphorbia sarcostemmoides; and*
- *Goodenia berardiana.*

There is no information on wetlands in this bioregion, and no broad scale refugia for biological diversity have been identified by the Australian Government, *Department of the Environment and Heritage*, in a study undertaken on a national scale to identify the foci of biological diversity and determine the location of broad scale refugia in Australia. The study is a starting point for further work and is not all-inclusive.

6.2 Importance of the Water Cycle – Boom and Bust

The significance of the water cycle in the arid zone environment cannot be over-emphasised. Water is the primary ecological driving factor of arid land systems. The onset of wet conditions encourages regeneration of forage species, and stimulates breeding and migration of many bird, fish, amphibian and mammal species. Fauna populations that are isolated during drought are able to migrate, providing increased opportunity for the exchange of genetic material, ensuring species stay genetically robust.

In dryland rivers, the flow regime is so highly variable, that flow averages are virtually meaningless. Long, dry periods are the norm. Studies to date have identified both high and low flows as having important ecological functions in these river systems (Environment Australia, 2002). It is also clear that the overall flow pattern, and not just individual floods, is important for maintaining the ecology of the rivers and wetlands in the Basin, and series or clusters of floods appear to be of major significance in influencing the successful breeding of many species (Environment Australia, 2002).

The biota of the arid areas tolerate drought and respond to occasional floods that may have long enduring effects (riparian trees, for example, may live for centuries). All appear to be sensitive to the rates of rise and fall, the amplitude, duration and frequency of floods. Where flood pulses are erratic, species with opportunistic traits are likely to dominate. Many organisms have evolved adaptations to cope with periods of drought, for example, drought-resistant eggs or larvae, burrowing, and life-cycle adaptations including opportunistic breeding after flooding.

Studies of primary production in waterholes of the upper Cooper Creek suggest a bathtub ring or littoral layer of algal biofilm appeared to be responsible for most primary production in these waterholes (Bunn and Davies, 1999, Bunn *et al*, 2003 in DWLBC (in prep.)). However, primary production is also driven by the alternation of flooding and drying phases on the floodplain that allows the accumulation and decay of organic material (DWLBC, in prep.).

It is well known that in the ecological boom period due to flooding in the Far North, a huge number of species, and huge numbers of each species, utilise the surface waters in the arid areas. In the 1990 flood, when the Cooper Creek drained into Lake Eyre and overflowed into Strzelecki Creek to fill Lake Blanche, there were about 500,000 birds distributed between the Lower Cooper, Lake Eyre and Lake Blanche. Given underestimates of aerial surveys, there were conceivably one million waterbirds, making the area one of the most important for waterbirds in Australia (Kingsford *et al*, 1998). Two hundred and thirty species of birds have been reliably recorded in the South Australian part of the Lake Eyre Basin, covering the stony plains and tablelands, the vast floodplains of the Cooper and Warburton/Diamantina River and the extensive dunefields of the Simpson and Strzelecki (Brandle *et al*, 1998). Only a minority of these are considered to be resident in the area. The non-resident birds are either opportunists following productive seasons and water (moving into the area from adjacent regions) or are migratory species which pass through or into the region annually.

The Cooper Creek, Coongie Lakes, Warburton River and Lake Eyre provide an outstanding example of the evolution of aquatic, ecological and biological processes in an arid environment where variability is the key driving force behind the adaptations of biota. These drainages are among the most temporally variable systems in the world (Puckridge *et al*, 1998) and this together with their massive scale within the driest landscape in Australia, and the diversity of bird and fish fauna, represents an ecological boom and bust phenomenon with only one or two approximate counterparts elsewhere in the world (Morton *et al*, 1995). The site provides an outstanding example of fauna adapted to a degree of hydrological variability which is globally exceptional (Puckridge *et al*, 1998). Adaptations include pronounced mobility, high environmental tolerances and opportunistic breeding (Department of Environment and Heritage, 2004). Wetlands include diverse habitats that vary in the wet/dry cycle. The flora and fauna inhabiting them are notable for not only their diversity, but also the large fluctuations of abundance that can occur.

The irregular wetting and drying cycle may also provide a form of protection to native fish species, in that it inhibits the proliferation of the two introduced species of fish, as has occurred in regulated river systems.

For riparian trees of arid and semi-arid zones (for example, *Eucalyptus camaldulensis*, *Eucalyptus largifloren, Eucalyptus coolabah*), river flooding is the means of restoring soil water necessary for initiating seed germination and ensuring seed establishment. Successful regeneration of floodplain trees tends to follow major floods. Growing conditions for these plants alternate between mostly very dry and hot, and very wet, with the possibility of water logging or anoxia in the root zone. For established riparian trees, the critical aspects of the water regime are frequency and duration of flooding, the duration of dry periods between floods, and the variability of this. Australian riparian trees in the arid zone are adapted to this, with some capacity to survive extreme conditions of flood or drought. However, prescribing a watering regime based on extreme conditions is not good practice as, although it would be tolerated initially, it can be expected to have a cumulative effect that is negative (Roberts and Marston, 2000).

It should also be noted that any regeneration opportunity provided by flooding may be lost because of over-grazing by rabbits and livestock. Roberts (1993) investigated the population structure of coolabahs at two locations in the Cooper Creek region, and found that a coolabah population in a swale was from a regeneration event that could be attributed to a period of heavy flooding in 1974. However, the same flooding event was not the basis for regeneration in coolabah populations on the floodplain, even though aerial photographs show that the flooding was extensive over the floodplain areas. One explanation for this is grazing pressure – the most critical time for vegetation management in arid Australia is after episodic rainfall (Griffin and Friedel, 1985, in Roberts, 1993). The irony for arid areas riparian species is that the most favourable conditions for their regeneration is also the most favourable for explosions of rabbit populations and other herbivores, which in turn creates unfavourable conditions for the successful growth of plant species. Regeneration can therefore only be successful in protected places (such as areas hard to reach for animals), or if herbivores are few (Roberts, 1993).

A critical question for floodplain trees is whether regeneration is currently occurring often enough and widely enough to maintain whole populations (Roberts and Marston, 2000). The value of a flood can be lost if land management is not co-ordinated with the water regime.

Since 1995 the effects of rabbit calicivirus has been observed, and continues to significantly suppress rabbit numbers, especially in parts of the Far North and Flinders regions. The potential for increased regeneration of revegetation therefore exists in these areas. The opportunity also exists to severely affect the rabbit population by other means while rabbit numbers are down.

Image courtesy of South Australian Tourism Commission, 1997

Lake Gairdner in flood

Photograph by Kirrilie Rowe, 2003

Lake Gairdner dry salt bed

6.3 Far North

In the Far North, apart from GAB springs which are discussed separately, flooding is the most crucial factor in shaping the life history patterns of aquatic biota and dependent fauna in the region. Waterbirds move between the lakes to capitalise on habitat and fish populations respond in various ways. Juvenile fish undertake downstream colonising migrations, and adults of most species spawn during floods. Some, such as the Lake Eyre Basin callop, spawn after upstream migrations. However, the breeding behaviours of most species are more flexible than their southern Australian counterparts (Mummery and Hardy, 1995). Biota have also evolved to survive the highly variable flooding regime separated by long dry periods. For example, in the Coongie Lakes crustaceans such as the shield shrimp, the clam shrimp and the fairy shrimp hatch from drought-resistant eggs, and live through an accelerated life-cycle (Mummery and Hardy, 1995). A species of inland crab survives long droughts by sealing itself in deep burrows (Reid and Puckridge, 1990 in Mummery and Hardy, 1995).

The Far North of South Australia is characterised by a diverse and dynamic range of ecosystems and land types. These are reflected in the number and descriptions of the bioregions present, namely the Channel Country, the Simpson-Strzelecki Dunefields, the Stony Plains, and the Finke. The area includes the extensive floodplains of the Cooper Creek and Warburton/Diamantina River.

The aquatic and terrestrial habitats support a variety of plant and animal species that have evolved to survive in often adverse and highly variable conditions. The aridity and remoteness of the rangelands have prevented the widespread colonisation and intensive land use that has been experienced in the wetter coastal regions of Australia. This factor has largely contributed to the preservation of extensive tracts of land in near pristine condition. Consequently these areas, and their associated water resources, have been identified as extremely significant ecological assets.

There is a paucity of detailed information on the ecology of aquatic ecosystems in the Far North of South Australia. In the Lake Eyre Basin, studies have focused around the Coongie Lakes, Lake Eyre and the GAB springs.

In recent times attention has been focused on the extraction of water from arid zone rivers. Despite the lack of detailed information on the ecological and hydrological processes of arid zone rivers, it is understood that the biota dependent on these systems have evolved to survive under highly variable conditions. Any alteration to the natural flow regimes may have detrimental impacts on both aquatic and terrestrial species.

The environmental assets of the Far North are discussed in the following sections, and where possible are grouped into those that are dependent mainly on surface water, those that are dependent mainly on groundwater, and those dependent similarly on both resources.

6.3.1 Great Artesian Basin springs – Groundwater Dependent Ecosystems

The highly unique natural springs and surface water seepages of the GAB hold great ecological, social and economic value. Formerly referred to as mound springs, the GAB springs are found within the Queensland, New South Wales and South Australian portions of the GAB and are the only permanent source of naturally occurring water in arid South Australia. The springs are considered to be an ecosystem which is entirely dependent on groundwater.

The isolated nature of the GAB springs has resulted in the preservation of many endemic, rare and relict species of great ecological, evolutionary and biogeographical significance. These include species of ostracods, amphipods, isopods, hydrobiids, fish and plants, with great variability in species composition noted between springs (Mudd, 1998). The springs also provide important refuge to many terrestrial and avian species during drought.

The vegetation of the GAB springs consists of both dryland and wetland species. Aquatic species such as *Phragmites australis* and *Typha domengensis* are common at many springs. Of particular significance is the Salt Pipewort (*Eriocaulon carsonii*) (endangered) and *Fimbristylis sieberana*, which is known only to occur at mound springs (Badman, 1999). Approximately 259 vascular plant taxa have been recorded at GAB springs in South Australia.

The community of native species dependent on the natural discharge of the GAB have been recognised as an endangered ecosystem under the national Environment Protection and Biodiversity Conservation Act, 1999, and they are also listed as endangered under the South Australian National Parks and Wildlife Act, 1972 (Neagle, 2002). They are considered threatened because of their contraction in range due to declines in artesian pressure and their ongoing vulnerability due to their limited distribution, and human-related activity.

The GAB springs of South Australia have been relatively well studied, particularly over the last 20 years (Badman, 1999). A number of large reports were compiled on the GAB springs during the late 1970s and 1980s and were followed by reports which focused on individual biological groups or spring complexes in later years (Badman, 1999).

Individual springs form part of larger groups of springs, referred to as groups, complexes and supergroups (Habermehl 1982, in Social and Ecological Assessment, 1986). There are 11 spring supergroups located across the entire GAB, with three of those found within South Australia, namely Dalhousie, Lake Eyre and Lake Frome. These three supergroups comprise 23 complexes, which in turn are made up of 146 groups and greater than 1,000 springs (Badman, 1999). The springs are generally found along the margins of the GAB, with the exception of a few, such as Dalhousie Springs, which are located within the GAB. The Lake Eyre supergroup contains the largest concentration of active and unique springs (Mudd, 1998).

GAB springs are highly dynamic systems that vary in hydrology, geomorphology, ecology and size. True mound springs (those which have been formed by the accumulation and cementation of sand, silt and clay) are commonly perceived as representative examples of GAB springs as a whole. In reality, the springs vary from large mounds which can reach eight metres in height and 30 metres in diameter, to small, inconspicuous seeps in the ground. The mound springs are often characterised by a central pool which is surrounded by a rim of reeds, and an overflow channel which may drain into a wetland area. The area of the wetland is directly proportional to the flow rate from the spring (Mudd, 1998).

Natural discharge in 1999 was estimated at approximately 24 gigalitres per year (Fatchen, 1999). The flow rates from individual springs varies greatly, from near zero to 14 megalitres per day, however, the majority are under 0.5 megalitres per day (Mudd, 1998). Approximately 62 per cent of all natural artesian spring flows are attributable to those found in South Australia, with the Dalhousie Group accounting for an estimated 90 per cent of all natural artesian discharge in South Australia (Fatchen, 1999).

The results of a survey undertaken by Niejalke and Kovac (2003) of the flow status of artesian springs in northern South Australia are presented in Table 6.1.

Table 6.1 Flow status of Artesian Spring Groups in South Australia

Supergroup	Complex	Active	Inactive	Unknown	Total Groups
Dalhousie	Dalhousie	8	0	0	8
Lake Eyre	Beresford Hill	2	1	0	3
	Billa Kalina	1	0	0	1
	Coward	12	0	0	12
	Francis Swamp	3	0	0	3
	Hermit Hill	9	2	0	11
	Lake Cadibarrawirracanna	3	0	1	4
	Lake Eyre North	1	0	6	7
	Lake Eyre South	7	2	2	11
	Marree	4	5	0	9
	Mount Denison	5	5	0	10
	Mount Dutton	6	0	0	6
	Mount Margaret	2	0	1	3
	Mount Toondina	1	0	0	1
	Neales River	12	1	0	13
	Peake Creek	9	3	2	14
	Strangways	1	0	0	1
	Wangianna	3	0	0	3
Lake Frome	Lake Blanche	1	0	0	1
	Lake Callabonna	5	0	4	9
	Lake Frome	0	5	4	9
	Mount Hopeless	4	1	0	5
TOTAL Groups		99	25	20	144

The water quality of GAB springs is characteristically alkaline and saline with high concentrations of dissolved solids such as carbonates, sulphates and chlorides (Fatchen, 1999). Parameters such as salinity and temperature are highly variable between springs. The known ranges of salinity and pH of GAB springs in South Australia are presented below in Table 6.2.

Table 6.2 Approximate Water Quality Parameters of Vent Water from GAB springs in South Australia

Water quality Parameter	Maximum	Minimum	Median
Salinity (TDS)	33,000	900	3,000
pH	10.8	3.9	7.99

Significant Spring Complexes

Twenty species of hydrobiid snails in three genera have been described to date from GAB springs in Queensland and in the Lake Eyre Supergroup of South Australia (Ponder *et al*, 1989 in Mummery and Hardy, 1995). The distribution of several of these appear to be highly localised, and in some cases restricted to single springs or small, tightly grouped springs (Ponder et al 1989, Ponder and Clark 1990 in Mummery and Hardy, 1995). Up to five species of hydrobiids can be found in any one spring, sometimes in enormous numbers – more than one million snails and other invertebrates per square metre can be found in the most favoured areas.

At least one of the fish inhabiting the GAB springs (the spangled grunter) is widespread (Mummery and Hardy, 1995). As more information comes to light, an increasing number of fish species appear to be restricted to particular groups of springs. The desert goby was originally thought to be widespread, but is now believed to be six different species, five of which occur in desert areas (including the Dalhousie goby at Dalhousie Springs).

A number of springs in South Australia have been recognised for their ecological and social value by various registers, consultant reports, and as part of the South Australian Government Mound Spring Fencing Program. The following paragraphs discuss the values associated with these springs.

Dalhousie Springs Complex

The Dalhousie Spring Complex consists of eight active spring groups, one of which is the Dalhousie Spring Group which contains 80 active springs (Mummery and Hardy, 1995) representing some of the largest examples of artesian springs in Australia. The springs range in size and composition, with the largest pool 50 metres in length and 10 metres deep. Springs found within this complex include Missionary, Mount Jessie, Earwanyera, Warrarrinna and Dalhousie Springs Proper. This group of springs accounts for approximately 90 per cent of total natural artesian discharge in South Australia (Fatchen, 1999).

The springs support a significant endemic invertebrate and fish fauna, including several which are considered relicts of a once wetter climate in inland Australia. Notable plant species include: *Nicotiana burbidgeae* (native tobacco) which is endemic to the springs area but is a dryland plant and as such is not dependent on the springs' flows, *Lemna disperma* (duckweed) the only known record for Central Australia, and the sedges *Eleocharis geniculata* and *Fimbristylis ferruginea* which are found only at the springs (Australian Heritage Council, 2004).

The Dalhousie Spring Group is a refuge for six species of fish (three of which are probably endemic to these springs) and 90 species of terrestrial and semi-aquatic vascular plants, including several species rare amongst mound springs (Zeidler and Ponder 1989, Ponder and Clark 1990 in Mummery and Hardy, 1995). At least three new species and one new genus of hydrobiid snails are described from the Dalhousie Springs.

The Dalhousie hardyhead and the Dalhousie catfish appear to be narrow endemics. The Dalhousie goby also occurs at Dalhousie Springs.

The aesthetic beauty, oasis-like nature and cultural heritage of the springs have made them a popular destination for tourists and an important site for scientists across many disciplines. The springs have been listed on the Register of the National Estate reflecting their national significance.

Coward Springs Complex

This spring complex contains 12 spring groups, including the well-known Blanche Cup and Bubbler springs. Blanche Cup is considered to be an excellent example of the typical mound spring structure, and has been one of the most visited and publicised of all the springs behind Dalhousie. The Bubbler, as the name suggests, is of interest due to its bubbling behaviour (Australian Heritage Council, 2004). The springs support unique crustaceans and gastropods. The Blanche Cup Springs Area has been listed on the Register of the National Estate in recognition of its ecological and social value.

Photograph by Travis Gotch, 1994

Blanch Cup looking out at Hamilton Hill

Hermit Hill Spring Complex

The Hermit Hill Spring Complex contains 11 spring groups, including a number of springs which are considered to be of conservation significance. These include Old Finniss, West Finniss, Bopeechee and Hermit Springs. Hydrobiid snails, amphipods, ostracod, isopod and fish species have been recorded from springs in this complex. The rare plant, Salt Pipewort (*Eriocaulan carsonii*), which is present at Old Finnis, Northwest, Hermit Springs and West Finnis Springs has only been recorded at one other spring complex within South Australia (Australian Heritage Council, 2004). Finnis, Old Woman, Lake Eyre South, Mount Hopeless and West Finniss Springs have been listed on the Register of the National Estate.

Neales River Spring Complex

The Neales River Spring Complex contains a number of notable springs, particularly Hawker, 12 Mile, Big Perry and the Fountain. Also noted as important are Freeling, Frances Swamp and Billa Kalina. There are a total of 13 spring groups within this complex. A number of endemic invertebrates have been recorded from the springs, including a gastropod which is restricted to Big Perry, the Fountain and Freeling Springs.

Management of Great Artesian Basin springs

There was little interest in the conservation of GAB springs before the early 1980s. At this time there were calls for their conservation (Harris, 1981) and a major step forward was the declaration of Witjira National Park, one of the main driving factors being the protection of Dalhousie Springs. Additional stimulus also occurred when the WMCR undertook detailed investigations of the springs to fulfil environmental impact assessment requirements for the Olympic Dam mine and Roxby Downs Township (Fatchen, 1999). This work highlighted their unique characteristics and prompted further investigation from State government agencies and a number of other parties.

Based on the information gained from the various investigations, a number of springs were protected from the impact of stock through the South Australian Government Mound Spring Fencing Program. The protection of artesian springs in conservation areas is a relatively recent phenomenon (Niejalke and Kovac, 2003). There are currently 42 spring groups that are fenced to exclude domestic stock (these include conservation reserves and management initiatives by the Aboriginal Lands Trust and pastoral lease holders). The land tenure of the spring groups is presented below in Table 6.3, and is taken from Niejalke and Kovac (2003).

Table 6.3 Land Tenure of Active Artesian Springs in South Australia (Niejalke and Kovac, 2003)

Tenure	Number of Groups
Conservation Reserve	**20**
Aboriginal Lands Trust	**11**
Fossil Reserve	3
Pastoral Lease – Unfenced	54
Pastoral Lease – Fenced	**11#**
TOTAL NUMBER ACTIVE GROUPS	99

Note: Items shown in bold are currently protected from grazing by domestic stock.
In eight of these groups only part of the group is fenced

However, in many cases, conservation tenure has been biased towards larger spring groups (Niejalke and Kovac, 2003). Also, those GAB springs characterised by small, muddy seepages and generally low flows have barely been represented within the fencing programs, despite being the most common type of GAB spring in the region (Fatchen, 2000). The conservation of these sites is considered important as they potentially harbour significant features and are an important component of the general GAB spring system. It is likely that the smaller, more isolated, spring groups support the most isolated populations of rare species. Data collected by Niejalke and Kovac (2003) indicate that these spring groups are also the most susceptible to stock impacts.

Ongoing monitoring, in the form of photopoint analysis, plant species records and transects, has been undertaken at all springs protected by the government fencing program. The monitoring has revealed that stock exclusion poses management challenges of its own in the form of dramatic increases in the biomass of *Phragmites australis* and *Typha domengensis*. These species have the potential to decrease spring biodiversity through competitive exclusion of other species and, in some cases, reduces the available wetland area with consequent impacts on aquatic fauna.

In 2004, through Natural Heritage Trust funding, the AACWMB and Department for Environment and Heritage employed a full time GAB Spring Officer to collate all existing information relating to GAB Springs in South Australia, and identify data gaps and threats. It is recommended this position continue to be funded to ensure proper management of the GAB Springs.

Photograph courtesy of the South Australian Tourism Commission, 2001

Coward Bore

6.3.2 Boredrain Wetlands – Groundwater Dependent Ecosystems

Boredrain wetlands are artificial habitats resulting from the uncontrolled flow of artesian bores. The physical nature of these wetlands is variable, with many forming in natural depressions and drainage lines. Despite being of a relatively recent nature (less than 100 years old) some boredrains have developed ecological and social values of notable significance. Others are considered to have stock watering value only.

The wetlands associated with boredrains are most notably of significance to bird species, including migratory waterbirds, some of which are listed on international treaties. Boredrain wetlands contain relatively high bird populations in comparison to other wetlands within the region. 170 bird species have been recorded at boredrains, compared with 230 in the entire North East of the State.
In the larger wetlands, up to 2,000 birds have been recorded at one time (Social and Ecological Assessment Pty Ltd, 1984). Despite this fact, many of the birds which utilise the wetlands are common dryland species, and the boredrains are not considered to be an obligate habitat for any bird species (Kinhill, 1998).

The boredrain wetlands are not known to provide unique habitat for any rare or endangered plants or animals, with the majority of species associated with the wetlands being common native or introduced dryland species (Kinhill, 1998). Considering these factors, the ecological value of the artificial wetlands as a whole can be generally considered as less than GAB springs. However, a number of boredrains have developed ecological attributes, which are considered worthy of conservation by members of the community, in addition to having high social values. The value of these habitats may become increasingly important as natural wetland habitats continue to be degraded throughout the world (Kinhill, 1998).

By the turn of the 20th century more than 1,000 uncapped bores had been drilled into the entire Basin, continuously dumping millions of litres of water into thousands of kilometres of open boredrains.

Inadequate control over the extraction of this groundwater from the Basin was recognised early in the century. In 1913, the first interstate Conference on artesian water was held to address legislative control of groundwater use. Between 1913 and 1929, five Interstate Conferences on Artesian waters were held.

In 1939 an Interstate Conference recognised that the wastage of water from free-flowing bores was a major problem. This report was completed in 1945, however it was not until 1954 that the Artesian Waters Investigations Committee provided a report that was published and addressed the problems separately in each State. At that time there were more than 1500 flowing bores discharging more than 1200ML/day into an estimated 34000km of open bore drains across the Basin. Well over 90% of this water was being wasted.

Some gains were made over the first half of the last century but in many regions pressures continued to diminish and many bores ceased to flow. Inadequate knowledge of the Basin, too little legislative control over water extraction, and ineffective infrastructure technology and management practices meant that valuable water resources continued to be wasted.

Improvements in technology, management practice and legislation over the past several decades resulted in some incremental improvements, but lasting solutions for Basin-wide problems proved difficult. The SA bore rehabilitation project commenced in 1977. In 1989, the Commonwealth and State Governments initiated the Great Artesian Basin Rehabilitation Program, with work in Queensland, NSW and SA. The program shared the cost of capping bores between land managers and the Commonwealth and State Governments.

By the mid 1990's more than two-thirds of the water extracted from the GAB was still being wasted and the artesian pressure was still falling in the Basin. The rate of investment and control from governments and landholders was not sufficient and a more concerted and coordinated effort was required. Even after more than eighty years, the core problem was still the continued waste of water into open boredrains, and the continued decline in artesian pressures.

The Great Artesian Basin Consultative Council (GABCC) was established in 1998 in response to long-standing concern from the water users and governments about the need to control flowing bores and eliminate the waste of water in the GAB. A Strategic Management Plan for the Great Artesian Basin was developed under the auspices of the Council and signed off by State and Australian Government Ministers and released in 2000. The Plan provides a comprehensive fifteen-year strategy to improve the water delivery infrastructure and management of the Basin.

At the time the plan was released in 2000, State and Commonwealth Governments negotiated with the GABCC and landholders on a five-year $100m funding package called the Great Artesian Basin Sustainability Initiative (GABSI). This aims to reduce water loss by accelerating the bore infrastructure rehabilitation process and eliminating bore drains. The results of the first GABSI has been to raise the awareness of the GAB in the community, to convince water users of the need to rehabilitate bores, and to rehabilitate almost a third of the flowing bores in the Basin. Governments and water users negotiated the second five-year GABSI funding package in 2004 to begin in 2005.

In March 2003, the Far North Prescribed Wells area was defined in South Australia under the *Water Resource Act* 1997. A Water Allocation Plan has subsequently been developed and forms Volume 3 of the Catchment Water Management Plan. The Water Allocation Plan states that boredrains are no longer an acceptable method to deliver water to stock and requires all water users to have a licence to take water from the GAB.

Approximately 146 bore drains have been recorded in South Australia. The University of South Australia, in conjunction with the AACWMB, has developed a Great Artesian Basin Boredrain Assessment Tool, to help determine the fate of the boredrain wetlands under the GABSI program.

A number of descriptors have been developed to compare the boredrain wetlands. These descriptors have been developed with the aim of being applicable to all flow rates, being feasible in terms of associated time and costs, being understandable to all stakeholders (including those with no scientific background), scientifically robust and subject to continuous improvement (Brake and Williams, 2000). The ecosystem attributes which will be considered include:

- location and spatial pattern;
- adjacent land use systems;
- boredrain morphology;
- water flow and quality;
- habitat types and vegetation parameters;
- bird species present;
- other fauna present; and
- aspects of land use and management

The process of selecting those boredrain wetlands that warrant the continued allocation of GAB water is undertaken through the Water Allocation Plan for the Far North Prescribed Wells Area (Volume 3 of the CWMP). Water users with existing wetlands that have amenity values will need to negotiate with the SAAL NRM Board to:

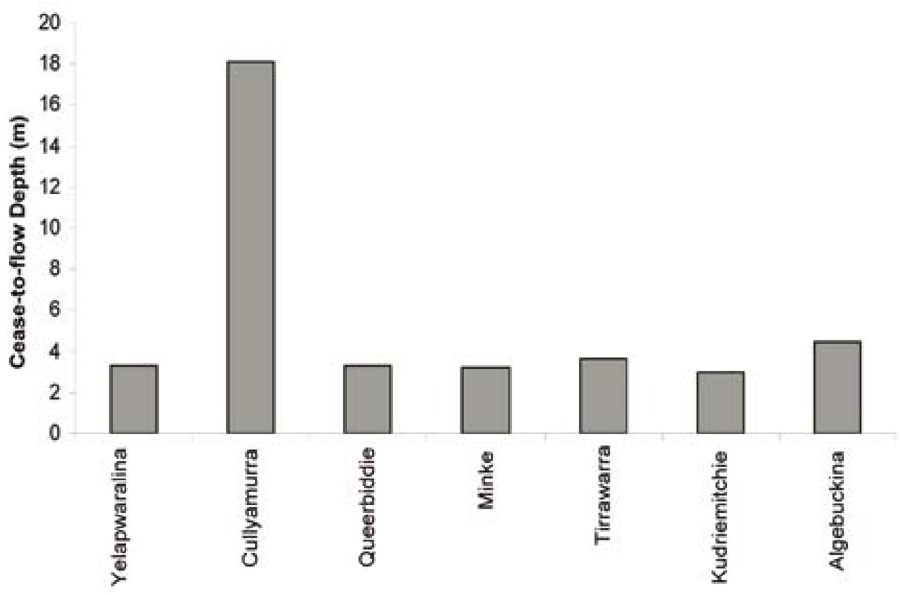
- clearly define the values of the wetlands and who benefits from the maintenance of it;
- decide if the values of the wetlands are sufficient to justify the continued allocation of water, and how much water is required to maintain those values;
- assess the best way to manage negative impacts that the wetlands may have on the landscape; and
- determine ongoing management for the wetlands to ensure that the values of the wetlands are maintained and enhanced where appropriate.

An adaptive management approach is proposed for the determination of the appropriate wetland flow.

6.3.3 Waterholes – Groundwater and/or Surface Water Dependent Ecosystems

The majority of pools within the Cooper Creek system are of a shallow and temporary nature, but a small number are considered to be permanent and consequently have great value as drought refuges. Refuge waterholes are generally characterised by cease-to-flow depths of greater than three metres, are generally larger, deeper, have a greater hydrological persistence and possess higher micro-habitat complexity than other aquatic habitats (DWLBC, in preparation). Examples of refuge waterholes include Cullyamurra, Queerbiddie, Kudrimitchie, Tirrawarra and Minke. A comparison of the depth of selected refuge waterholes within each system is provided in Figure 6.3. This table provides a comparison of the values of refuge waterholes from a hydrological persistence perspective (the actual value will be influenced by other factors such as degree of disturbance and water quality parameters).

Figure 6.3 Comparison of Cease-to-Flow Depths for Selected Drought Refuge Waterholes (DWLBC, 2003)



Drought refuge in the Georgina/Diamantina system is provided in the form of a number of permanent waterholes, including Andrewilla and Yelapawaralinna. The Strzelecki Creek wetlands area is characterised by temporary waterholes.

The Neales River is an ephemeral, unpredictable system that provides important drought refuge to the local biota through the provision of a limited number of waterholes. Most waterholes are shallow and ephemeral, with the exception of Algebuckina Waterhole, a major drought refuge which fills annually and, according to anecdotal evidence, has never dried up in living memory (DWLBC, in preparation). Other important sites include Stewart and Mathieson waterholes (Neagle, 2002).

Relatively large freshwater internal drainage systems such as Lake Phillipson and Millers Creek and many smaller lakes and swamps can supply water for up to four years (although they rarely catch water), and many natural waterholes have been enlarged or banked in these areas to increase capacity for stock and domestic use.

The relative dependence of each waterhole on surface water or groundwater is currently unknown.

6.3.4 Rivers, Creeks and Associated Wetlands – Surface Water and/or Ground Water Dependent Ecosystems

The Far North is characterised by a number of surface water-dependent ecosystems associated with different aquatic habitats, which primarily are:

- temporary streams;
- semi-permanent creeks and small rivers;
- large lowland rivers and associated wetlands; and
- ephemeral lakes (including salt lakes).

These ecosystems may also depend to some extent on groundwater. They are diverse and generally of high conservation significance. The locations of the main drainage lines, wetlands and lakes are presented in Figure 4.1.

The rivers and creeks of the Far North have remained in a relatively intact state in the absence of regulation, over extraction, exotic fish dominance and intensive land use. Consequently, these systems are of high conservation significance and are considered one of the last wild river systems in the world (Environment Australia, 2003).

The flora and fauna of the area are highly unique, having evolved to adapt to an extremely variable environment, where river flow and rainfall are highly irregular and unpredictable. This variability is the driving factor for the boom and bust responses of ecosystems, many of which have adopted life history strategies that enable rapid responses to opportunistic conditions.

The range of aquatic habitats associated with major drainage lines is also very diverse, attributed to the array of differences in land-form and water retention capabilities. These habitats include vast floodplains, inter-dune channels, deep main channels, refuge water holes, swamps and lakes. Extensive waterbird populations utilise these areas after flood events, while the permanent waterholes support both aquatic and terrestrial species during extended dry periods.

There is a lack of information about processes underpinning wetlands. Those on the eastern side of Lake Eyre (eg Coongie Lakes) have been studied more than other areas, such as the western rivers region. A major contribution to the understanding of arid zone river hydrology/ecology interactions has been the AridFlo study which has focused on the Cooper Creek, Diamantina and Neales River systems.

Vegetation

On a regional scale, wetland and floodplain ecosystems have not been comprehensively mapped, however a number of distinctive wetland and floodplain types are commonly found. On the larger streams/rivers River red-gum *Eucalyptus camuldulensis* woodlands are commonly found bordering watercourses. On smaller streams and flood-outs Coolabah *Eucalyptus coolabah*, River Cooba and Broughton Willows *Acacia salicina* are more common (Neagle, 2002).

Floodplains characteristically have a greater diversity of ecosystem types than in-stream areas. Common ecosystems include Coolabah woodland or tall shrubland of Broughton willow or prickly wattle (Neagle, 2002). Old man saltbush (*Atriplex nummularia*) and scattered coolabah, are often found in floodplains which are only occasionally flooded. Groundcover species, such as Golden Goosefoot *(Chenopodium auricomum*), grow rapidly on the floodplains following rain (Neagle, 2002).

In-stream vegetation has not been comprehensively surveyed across the region either. However, it is known that aquatic herbs and sedges, such as Common Reed (*Phragmites australis*), Bulrush (*Typha* spp.), common spike rush (*Eleocharis acuta*), milfoils (*Myriopyllum* species) and nardoo (*Marsilea drummondii*) occur in some areas (Neagle, 2002).

Cooper Creek System

The South Australian portion of the Cooper Creek system is characterised by an extensive array of freshwater lakes, wetlands and floodplains. The Lower Cooper wetlands floodplain extends for 20,000 square kilometres into the longitudinal sand dunes of the Strzelecki Desert. These areas provide important habitat for a range of species, and are of particular significance for waterbirds. The national and international significance of the wetland systems of the Lower Cooper Creek have been recognised through the listing of a number of sites under the Convention on the Wise Use of Wetlands (formerly Ramsar Convention), the Directory of Important Wetlands in Australia, and on the Register of the National Estate.

The unpredictable flow regime and spatially complex environment has created a distinctive ecology, based upon the opportunistic use of pulses of resources, scattered in space and time (Puckeridge *et al,* in Mummery and Hardy, 1995). A rich aquatic biota exists characterised by spectacular fluctuations in abundance, high dispersal and colonising capabilities, tolerance of extreme conditions, and flexible and opportunistic life histories.

The floodplain habitats are believed to support in excess of 500 plant species, 180 bird species, 25 mammal species, 47 reptile species and 16 fish species, many of which would not exist in the absence of freshwater (Australian Heritage Council, 2004). The area is known to support diverse frog fauna (Environment Australia, 2001a). It is not only the diversity of some species which is notable in this region, but also the abundance. The floodplains regularly support 20,000 waterfowl, with numbers reaching the hundreds of thousands during optimal conditions.

Wetlands of notable significance in this region include Coongie Lakes, a wetland system of international significance and which now is a National Park, and the Strzelecki Creek Wetlands, which are recognised as being of national significance (Environment Australia, 1996).

The Strzelecki Creek wetlands area is characterised by temporary waterholes, swamps, channels, low sand dunes and plains, and encompasses Lakes Blanche and Gregory and the Strzelecki Creek floodplain. Areas of particular ecological significance include Lake Blanche and the mouth of the Strzelecki Creek, which are utilised by a variety of waterbird species, including a number which are considered threatened. The creek system also supports a density and diversity of raptors amongst the highest in Australia.

The Coongie Lakes area is extensive, incorporating Lakes Coongie, Marroocoolcannie, Marooculchanie, Toontoowaranie, Goyder, Marra Dibba Dibba, Apanburra and Hope and a portion of the Cooper Creek floodplain. The diversity of aquatic habitats supports the most diverse plant and animal population of the North East area. An endemic species of freshwater tortoise found in the wetlands is also of notable significance.

The Coongie Lakes support a diverse and often extremely abundant bird population. Over 205 species have been reliably recorded (Mummery and Hardy, 1995). The region has a high bird species diversity including 24 species classified as rare, vulnerable or endangered in South Australia (for example, the endangered bush thick-knee and the vulnerable freckled duck which is one of the ten rarest waterfowl in the world).

The lakes also support an exceptional number of zooplankton species, attributable in part to an overlap of tropical and temperate faunas. Eight species of frog are known in the Coongie region, including an undescribed species of water-holding frog (Reid and Gillen, 1988 in Mummery and Hardy, 1995). The fish fauna is unusual for a large river system in that it only contains two exotics, the goldfish and the mosquito fish, neither of which is dominant in the fish community. At least one fish species in the Coongie region is endemic to the Cooper, namely the eel-tailed catfish (Puckridge, 1994 in Mummery and Hardy, 1995).

The Coongie Lakes community essentially retains its original composition and ecological cycles and may serve as a benchmark by which to gauge the effects of alterations to other inland aquatic systems.

Georgina/Diamantina System

The Georgina/Diamantina system (including the Warburton River) is associated with extensive floodout areas that provide a diverse array of habitat types which are of major significance to arid zone biota and local pastoral enterprises alike (DWLBC, in preparation). The wetlands of this system, like others within the Lake Eyre Basin, are relatively free of exotic fish species and considered to be in a near-pristine state.

The water of the Diamantina River comes from up to 800 kilometres from the north-east, enters South Australia from Queensland, and flows into Goyders Lagoon. The river and associated systems have very low gradients and disperse into multiple braided channels, floodplains, waterholes and wetlands of the south-west Queensland and north-east South Australian channel country before flowing into Goyder Lagoon, from which it then flows on to Lake Eyre via Warburton Creek.

The water often takes many months to travel from the higher rainfall areas of the north to Goyders Lagoon. In large flood events, Goyders Lagoon becomes an extensive wetland area of over 1,300 square kilometres. It is a long-lived wetland providing habitat for a variety of aquatic and terrestrial organisms in an otherwise arid and waterless environment. A distinctive race of the grey grasswren, *Amytornis barbatus diamantina*, is only found in Goyders Lagoon and in a few other isolated pockets in far western Queensland. The endangered kowari *Dasycercus byrnei,* and grass owls also occur in the vicinity (Morton *et al*, 1995).

Desert Rivers Region

A small portion of the Desert Rivers Region falls within South Australia, primarily the catchment of the Finke River. This region is very isolated in a hydrological sense, with flows only contributing to the main Lake Eyre drainage system on rare occasions.

Western Rivers Region

This drainage system encompasses the catchments of the Macumba, Alberga, Peake and Neales Rivers, on the western side of Lake Eyre. These areas have generally lacked detailed ecological study, but some important work has been undertaken on the Neales River as part of the AridFlo project.

Current Management

The majority of small rivers/creeks are found on pastoral leases, with very few conserved within the reserve system. The Coongie Lakes, and part of the Strzelecki Creek, are contained within the Innamincka Regional Reserve and Lake Blanche is contained within the Strezlecki Regional Reserve. A large portion of the Finke floodplain has also been included within Witjira National Park. The remaining areas are under the management of pastoral leasees and are subject to varying levels of stock grazing.

Environmental Water Requirements

Variability is the defining characteristic of arid zone watercourses, and is an essential component in maintaining ecological health of surface water dependant ecosystems. The importance of the wet/dry cycle is discussed in Section 6.2. Maintaining variability in the following attributes is of great importance:

- flood pulse timing and frequency;
- flood duration;
- flow magnitude (including multi-annual variability); and
- periods of no flow/drought.

Natural variability of attributes such as flood height, duration and rate of rise and fall is essential in maintaining processes such as floodplain recharge, fish migration and habitat complexity.

The Currareva Irrigation Proposal in 1995 highlighted the issues associated with water extraction. The scheme proposed an annual extraction of 42,000 megaltires from the headwaters of the Cooper Creek each summer and the construction of two off-stream storages with a total capacity of 15,000 megalitres for periods of low flow. This quantity of water equates to 2.5 per cent of the median annual flow, which due to the extreme variability of the system, may be the entire flow in any one year (Sheldon, 1999).

Proposed developments will need to take into account the impacts that are likely to occur to the high conservation value wetland complexes at the terminal points of the major drainage systems. These areas provide vital resources to a range of biotic groups, as well as pastoral and tourism industries, and any alterations may have dramatic consequences.

6.3.5 Salt Lake Ecosystems

The ecology of salt lake ecosystems in the Far North is not fully understood. Despite this fact, a number of these environments have been listed on the Directory of Important Wetlands in Australia in recognition of the vast areas of important habitat they provide for waterbirds during floods, including migratory waders. These systems have remained in a relatively pristine condition, and have been well conserved within the national parks system in South Australia.

Only a limited number of organisms in the world have adapted to life in salt lakes, and Australia has some notable examples, including a number of endemic brine shrimps.

There are many values associated with salt lake ecosystems. From an ecological perspective, the salt lakes of the Far North provide a diverse range of habitats with a variety of hydrologic regimes. The value to waterbirds during flood events is well noted, but these habitats are also significant in supporting a number of terrestrial invertebrates, including many which are endemic to salt lakes and to South Australia, during dry periods (Sheldon, 1999). The conservation value of these systems is therefore considered to be high.

Lake Eyre

Lake Eyre is an ephemeral salt lake spanning over 969,000 hectares, consisting of two basins – Lake Eyre South and Lake Eyre North. The Georgina, Diamantina and Cooper Creek provide the majority of inflow to the lake via a number of small rivers and creeks.

During periods of inundation, the Lake supports vast numbers of fish and waterbirds, and provides conditions suitable for waterbird breeding. Several threatened species have been recorded there including Freckled Duck (*Stictonetta naevosa*), Musk Duck (*Biziura lobata*) and Australasian Shoveler (*Anas rhynchotis*). A total of 41 waterbird species, including eight listed under treaties have been recorded there (Environment Australia, 1996). Five species of fish, an endemic ostracod, and several zooplankton species which are restricted in range have also been recorded from the lake (Sheldon, 1999). The breeding of Banded Stilts has been observed in Lake Eyre – nationally there are very few records of this although they have also been observed breeding in Lake Torrens.

Lakes Frome and Callabonna

Lakes Frome and Callabonna have also been listed under the Directory of Important Wetlands in Australia due to the habitat they provide for waders during flood events. Thirty waterbird species, including five listed under treaties, have been recorded utilising the habitat provided by the lakes, including the threatened Little Egret (*Egretta garzetta*). Lake Callabonna is also significant as it is one of the few arid zone areas where Banded Stilts (*Cladorhynchus leucocephalus*) breed in large numbers. Lake Callabonna is renowned for its fossil deposits, and is consequently an important scientific site.

Current Management

Salt lakes are well represented within the reserve system in South Australia. The beds of Lake Eyre North and South have been conserved within the Lake Eyre National Park and the Hunt Peninsula (at the southern end of Lake Eyre North) is protected within the Elliot Price Conservation Park. The areas surrounding the lake are managed as pastoral leases.

Lake Callabonna has been conserved within the unfenced Lake Callabonna Fossil Reserve, under the jurisdiction of the South Australian Museum. Lake Frome is conserved within the Lake Frome Regional Reserve.

Environmental Water Requirements

The environmental flow requirements of salt lake ecosystems in the Far North have not been quantified to date. The impacts of altered hydrology on salt lakes in other parts of the world provide some insight into the possible consequences of actions such as water extraction and river regulation in the catchments which supply water to these systems.

The Aral Sea in Uzebekistan and Kazakhastan is one such example. The sea is an endorheic system which has been affected by the diversion of water for irrigation in its upstream catchment. The area previously covered approximately 68,000 square kilometres. During a thirty-year period of water extraction, the area covered by the sea reduced to 33,500 square kilometres, 20 out of 24 fish species became extinct, only eight out of 200 macro-invertebrate species survive, 168 of 319 bird species still nest, and salinity has increased three-fold (Sheldon, 1999). In addition, 20,000 kilometres of previously arable land has become desert and groundwater supplies are contaminated.

This example is an extreme case, but highlights the way in which valuable salt lake ecosystems can be severely modified by water extraction. The value of salt lake ecosystems in the Far North are likely to be influenced by the maintenance of variability of the following attributes:

- frequency and duration of lake bed inundation;
- depth of flooding;
- source of water;
- flood timing; and
- dry phases.

The lack of understanding of salt lake ecology in the Far North makes it difficult to quantify the impacts of surface or underground flow diversions. However, it is reasonable to assume that as flood events result in high productivity, alterations to frequency or duration of flood events would result in lower productivity, and therefore impact on waterbird populations (Sheldon, 1999). Preservation of the above-mentioned characteristics will be vital in maintaining the ecological health of these important systems.

6.4 Gawler Ranges Region

The Gawler Ranges is an area naturally devoid of significant surface water resources, and has groundwater resources that are generally limited in quality. Despite this fact, a unique and significant flora and fauna have evolved in this important transitional area between the harsh arid climate of the north and the moister, temperate environment to the south. The Gawler Ranges are considered to be in the top 22 biological refugia in the arid and semi-arid areas of Australia (Morton *et al*, 1995).

The variety and complexity of available habitats provides suitable conditions for a range of fauna, including rare and endangered mammals and birds. The western ranges are of particular significance, as this area supports high species diversity and the greatest concentration of important plant species in the region, due to the higher rainfall it receives (Department for Environment and Heritage, 2003c).

There have been few studies undertaken in this region, particularly in the area of water-dependant ecosystems. Broadscale studies have been limited to the 1988 biological survey, with a number of smaller, species specific studies also undertaken across various parts of the region.

The environmental assets of the Gawler Ranges are discussed below.

6.4.1 Groundwater Dependent Ecosystems

The groundwater dependent ecosystems of the Gawler Ranges region have been poorly studied, and as such, little is known of the nature and subsequent water requirements of such ecosystems. In a region that is characterised by so few water resources, it would seem reasonable to conclude that the existing natural water resources are an extremely important feature within the landscape.

Groundwater resources within the Gawler Ranges are characteristically highly saline in most areas, with the exception of a number of springs in the Saltia Landsystem (Figure 2.6) that are known to have a water quality of approximately 700 ppm (Gawler Ranges Soil Conservation Board, 1996). These springs, namely South Creek, B-Spring, Depot Creek and Yadlamulka Spring, are utilised for stock water, but the nature of water dependent ecosystems at these springs is undocumented.

The permanency of springs in the region has not been recorded, therefore it is not known if these springs play an important role as drought refuge sites for aquatic and some terrestrial species.

A number of freshwater soaks are known to occur on the surface of Lake Gairdner. These soaks may be an important resource for the numerous species of introduced vertebrates which have been recorded on the islands, and possibly native species.

Current Management

Lake Gairdner has been protected within Lake Gairdner National Park, and consequently, the freshwater springs on the surface of the lake are subject to conservative land management practices.

Environmental Water Requirements

The water requirements for groundwater dependent ecosystems in the Gawler Ranges region are currently unknown.

6.4.2 Surface Water Dependent Ecosystems

The natural surface water resources of the Gawler Ranges are extremely restricted, with no significant permanent water sources present. Ephemeral drainage lines provide water during storm events, and numerous rockholes and soil pockets catch and store rainfall for varying lengths of time. In the southern ranges, Mallee Box (*Eucalyptus porosa*) dominates drainage lines, with Brown Head Samphire (*Halosarcia indica ssp leiostachya*) found around salt lakes and in small depressions (Department for Environment and Heritage, 2003c).

Similarly with groundwater dependent ecosystems in this region, little work has been undertaken to understand the nature and extent of surface water dependent ecosystems.

The majority of watercourses in the Gawler Ranges are ephemeral, flowing into the numerous salt lakes following rainfall events (Sheldon, 1999). Drainage lines tend to be dominated by *Maireana sedifolia* shrublands, *Halosarcia indica* or *Atriplex acutibractea* shrublands, with *Meuhlenbeckia cunninghamii* shrubland dominating temporary swamps (Robinson *et al*, 1988).

The coolabah (*Eucalyptus coolabah* ssp. *arida*) woodlands that are found on the levees and channel banks of regularly inundated floodplains (such as those found on the Arcoona Plateau and draining from the Stuart Range) are classified as ‘of concern’ at a State level (Neagle, 2002).

The Flinders Ranges Wattle (*Acacia iteaphylla*), found in valleys along creek banks, was a species of interest identified in the Gawler Ranges Biological Survey (Robinson *et al*, 1988).

Little detail has been provided about the aquatic ecosystems of the region, and as such little is known about the ecological processes.

Highly mobile waterbird species have always utilised the region opportunistically following rain events. The lack of surface water has limited the movement of many species, but it is believed that following the development of permanent water sources for the pastoral industry, the incidence of waterbirds and all birds in general, may have increased slightly (Robinson *et al*, 1988).

Table 6.4 Land Management Issues in Floodplain Areas by Landsystem[1] (Department for Environment and Heritage, 2003c)

Landsystem	Gully Erosion	Salinity	Rabbits	Degraded Perennial Vegetation near Water Points	Scalding
Gawler Ranges	Severe with storms	Spread is significant	Moderate numbers	Yes	
Moonaree	Slightly Prone		Moderate numbers	Yes	Slightly Prone
Glyde Hill	Moderately prone during high intensity rainfall		Low numbers	Yes	Yes

Table 6.5 Land Management Issues in Watercourse Areas by Landsystem[1] (GRSCB, 2003)

Landsystem	Water Erosion	Salinity	Goats	Rabbits	Degraded Perennial Vegetation Around Water Points
Middleback	Prone to streambank erosion during flash floods	Spreading		Yes	
Pandurra	Moderately prone to gully erosion during high intensity rain storms			High numbers in small areas	Yes

1 Locations of Landsystems are presented in Figure 2.6.

Current Management

The ephemeral water courses of the Gawler Ranges are primarily within pastoral leases, with the exception of those found within the Gawler Ranges and Lake Gairdner National Parks.

Environmental Water Requirements

The environmental water requirements of ephemeral watercourses in the Gawler Ranges have been unquantified to date. However, Sheldon (1999) identified a number of factors requiring consideration in relation to environmental water requirements of temporary streams within the entire Spencer region. Those factors that apply to the Gawler Ranges region include:

- maintenance of flow variability; and
- the importance of high velocity floods as a natural ecological function.

As more data becomes available, the environmental water requirements of these systems will become clearer and management actions will be able to focus on these needs.


Photograph by Pat Katnich

Algebuckina Waterhole

6.4.3 Waterholes

The entrapments of rainfall run-off in the rocky ranges provide an important water source for many species of birds, reptiles and mammals. It has been observed that many of the species that rely on this type of habitat have persisted in the area, despite other changes in habitat (Ehmann and Tynan, 1997). This reinforces the important role of these habitats in the maintenance of biological integrity and diversity.

Granite waterholes have been identified as key fauna habitat areas due to the important drought refuge function they provide (Ehmann and Tynan, 1997). These areas are also known to support diverse plant species and provide ideal habitat for Yellow-Footed Rock Wallabies (*Petrogale xanthopus*). The nationally endangered night parrot (*Geopsittacus occidentalis*) was sighted in the late 1800s near Murnea Rockhole (Australian Heritage Council, 2004). A large number of historical records of the species in the general area was documented in the late 1800s, but very few since. (A number of reports in the 1960s and early 1970s could not be confirmed until 1979, when a South Australian Museum team found several birds in far north-western South Australia (Australian Museum, 2004) and in 1990, Walter Boles found a body of a night parrot on the side of the road in south-west Queensland). If the parrot does still persist in the area, the significance of rockhole (or any other) water sources for its survival is unknown.

Rockholes are known to exist in water courses and creeks in this region, with isolated occurrences occurring in the west, however very little has been documented about these.

Current Management

Although it is known that rockholes occur in the southern and western parts of the Gawler Ranges region, exact locations have not been documented. It is therefore difficult to ascertain their current status, their sustainability, how they fit in to the ecosystems of the area, and the land management practices these environments are exposed to.

6.4.4 Salt Lakes

The large salt lakes that are found in the region are arguably some of the most striking and spectacular features of the Gawler Ranges. Such lakes include Harris, Acraman, Gairdner and the Gawler Lakes complex consisting of Lake Macfarlane and Island Lagoon. As for most salt lake ecosystems in the northern regions of South Australia, little is known about the processes that drive the ecology of these unique environments. However, it is known that during times of flooding, the great expanses of lake become an important opportunistic habitat for a range of waterbirds, fish and invertebrates.

Lake Gairdner

Lake Gairdner is the third largest salt lake in Australia (after Lakes Eyre and Torrens) and is part of one of the largest salt lake complexes in the country (Australian Heritage Council, 2004). The surface of the lake is approximately 5,500 square kilometres and contains 315 islands with varying sizes and vegetation communities, the largest having an area of 45 square kilometres.

The small quantities of water that flow into the lake from localised drainage do not supply salt to the lakes. Evaporation is responsible for the accumulation of salt on the lake surface, which is transported via saline groundwater (Department for Environment and Heritage, 2003d).

The numerous islands found on the lakes are characterised by a great diversity of plant communities and notable species. The differences in vegetation composition between islands that share similar physical structure, and which are in close proximity to each other, is also an interesting feature of the area.

Lakes Harris, Everard and Acraman

Lakes Harris, Everard and Acraman are located to the west of Lake Gairdner. Little information is available on these lakes, but it would be reasonable to assume that they would play a similar role to the other salt lakes in the region, as opportunistic waterbird habitat during flood events.

Current Management

Salt lake ecosystems have been well represented within the State's reserve system. Lakes Gairdner, Everard and Harris are conserved within the Lake Gairdner National Park, and as such are subject to conservative land management practices. Land use immediately adjacent to the lakes edges is primarily pastoralism. Feral animals are present on all of the islands within the lakes, and as such would have substantially altered the native fauna assemblage.

6.5 North East and Flinders Region

The North-East and Flinders area is one of the most environmentally diverse regions in South Australia. It includes mountainous areas, grasslands, salt bush, alluvial plains, sandy dune/swale systems and water courses lined with river red gums and melaleucas.

The natural features of the Northern Flinders Ranges are regarded as some of the most scenic and spectacular in South Australia. The diverse and unique assemblage of flora and fauna complement a similarly distinct geological and cultural vista, making this region a major tourist destination within the State. The ranges are an important transitional area between the harsh climate of the northern pastoral lands and the moister environments to the south. The northern portion of the ranges is of particular significance, and has been identified as the most important biological refugia in semi-arid and arid South Australia (Morton *et al*, 1995). It is important to note that there is considerable underground flow in many streams in the Flinders Ranges, which at times of low rainfall, is an important refuge for many aquatic insects and crustaceans (Environment Australia, 1994). There is very little information available relating to the area to the east of the Flinders Ranges.

Mammals have suffered severe declines in the region following European settlement, with many becoming regionally extinct. Reptiles and amphibians have been able to maintain a rich and diverse assemblage (Department for Environment and Heritage, 2003a).

The ecosystems of the region are dynamic, reflecting the often harsh and unpredictable terrain in which they have evolved. Flow regimes influence the nature of aquatic ecosystems, while permanent waterholes and springs provide vital drought refuge to aquatic and terrestrial organisms alike.

The distinction between those ecosystems which are groundwater dependent and those which are surface water dependent is often unclear, as many ecosystems have an apparent dependence on both water sources, with the degree of dependency on each not well understood. The water dependent assets of the North East and Flinders Ranges areas are discussed here in the two distinct groups, based on the best available knowledge.

6.5.1 Groundwater Dependent Ecosystems

The watercourses of the Flinders Ranges are characterised by many springs and waterholes which are of a permanent or semi-permanent nature. These areas support an array of organisms, but are of particular significance to fish and other aquatic organisms. A notable example is the Flinders Ranges Purple Spotted Gudgeon (*Mogurnda clivicola*), a fish species which is classified as vulnerable at a national level.

A number of springs found within the Gammon Ranges National Park are of particular significance due to the important drought refuge function they provide, particularly to amphibians (Sheldon, 1999). Important drought refuge sites in the Gammon Ranges National Park are (Source: Department for Environment and Heritage, 2003b):

- McKinlay Spring;
- Bitter Spring;
- Reedy Spring;
- Peach Spring;
- Worturpa Spring; and
- Donkey Spring.

Environmental Flow Requirements

There have been no assessments of environmental water requirements for groundwater dependent ecosystems undertaken for the North East and Flinders area. In particular, the way in which groundwater influences spring hydrology, and the interaction of groundwater, sub-surface and surface water requires further clarification (Sheldon, 1999).

6.5.2 Surface Water Dependent Ecosystems

Many of the watercourses of the region are characterised by permanent or semi-permanent headwaters which become increasingly ephemeral towards the lower reaches. River red gum (*Eucalyptus camaldulensis*) woodlands are found along creek lines and fringing waterholes. Populations of ferns are also found in the moist environments of Bunyip Chasm and at Junction waterhole.

Within the Flinders Ranges National Park alone, 32 per cent of all plants of conservation significance are found in association with creeklines and nine per cent are found in moist areas, including floodplains and claypans (Department for Environment and Heritage, 2003a). Two conservation listed ecosystems are found within this region. The river red gum woodlands (*Eucalyptus camaldulensis*) of levees and banks of drainage lines (in semi-arid areas) and freshwater wetlands (including herblands and sedgelands) have been identified as 'vulnerable' and 'endangered' respectively at a State level (Neagle, 2002). The river red gum systems are found along almost all major drainage lines which flow from the Flinders Ranges, and in isolated patches along creeklines emanating from the Olary Spur.

The water-related assets of the region will be discussed here in relation to two areas, namely the northern Flinders Ranges, and the North East pastoral area (which is bordered to the east by the New South Wales/South Australian border, to the north by the dingo fence, and to the west by the Flinders Ranges).

Northern Flinders Ranges

A number of fish species have been recorded in the watercourses of the region, including the Flinders Ranges Gudgeon (*Mogurnda* sp), which is only found in the Gammon Ranges National Park. Unique hyporheic invertebrate fauna species (that is, species that live beneath the riverbed) have also been collected from a number of streams in the Flinders Ranges (Sheldon, 1999). The hyporheic zone appears to be an important drought refuge for benthic invertebrates, with 18 out of 31 taxa collected in one study found to use the hyporheos on occasions (Sheldon, 1999).

The ephemeral streams of the northern Flinders Ranges are considered to be extremely important drought refuges (Sheldon, 1999). Even though there are no nominated wetlands of national significance in the region, the creeks and streams of the Flinders Ranges National Park have been included in a supplementary list of potential areas for future nomination.

Results from the AUSRIVAS study (Environment Australia, 1994) indicate that moderately to severely impacted creeks (including water quality) include Wilpena (possible impacts from tourism), Aroona (impacts from Aroona Dam), Arcoona (impacts from stock), Crows Nest (high nitrogen concentrations and turbidity) and Arkoona (limited habitat, high nutrients). Most other creeks sampled were in good condition, such as Parachilna, Brachina, Bunyeroo and Spring creeks.


Major Mitchell Cockatoo


Blue winged parrot


Australian bustard

Images courtesy of www.ozbirds.com


Pied honey eater


Brolga

North East Pastoral

The North East has generally not had the same level of examination as the Northern Flinders Ranges. The surface drainage is dominated by the higher topography of the Olary Spur, which runs in a north-easterly direction through the district. To the north, drainage runs into the Frome Drainage Basin, with streams flowing north towards Lake Frome. To the south is the Murray-Darling Basin.

A total of 125 bird species were recorded in the Northern Olary Plains biological survey, (Playfair and Robinson, 1997), some of which are of national significance (the Plains Wanderer, Freckled Duck and Scarlet Chested Parrot). Thirteen species were found to be rated as vulnerable or endangered in South Australia, namely:

- Grey Falcon;
- Bush Thick-knee;
- Major Mitchell;
- Blue-winged Parrot;
- Chestnut Quail Thrush;
- Australian Bustard;
- Pied Honeyeater;
- Brolga;
- Letter-winged Kite;
- Banded White-face;
- Apostlebird;
- Australasian Shoveler; and
- Hardhead.

Forty-six species of mammal were known or thought to have existed in the region (Playfair and Robinson, 1997). Since European occupation, 13 are now thought to be extinct in South Australia, three are endangered, three are vulnerable, and six are rare. The 1997 biological survey confirmed 22 existing species.

The presence of these rated species, and the biogeographical location of the North Olary Plains at a major ecotone where species of limited distribution often exist, suggest that some serious conservation effort is required in this area. The loss of habitat throughout most of the range of these species is a problem, due to total grazing pressure by stock and feral animals (Playfair and Robinson, 1997).

Environmental Water Requirements

The environmental water requirements of surface water dependant ecosystems in the Flinders Ranges/North East study area are largely unknown. However, the following are considered to be important features of the natural hydrology, and therefore require preservation:

- natural variability of floods and droughts;
- natural frequency and magnitude of high velocity flash floods; and
- maintenance of natural hyporheic flows (that is, flows beneath riverbeds).

A number of major creeks flow through the Flinders Ranges National Park and the Gammon Ranges National Park, including:

- Wilpena;
- Edeowie;
- Wilcolo;
- Bunyeroo;
- Brachina;
- Aroona;
- Enorama;
- Oraparinna;
- Mount Billy;
- Moodlatana;
- Etina;
- Weetootla;
- Arcoona;
- Balcanoona; and
- Big John.

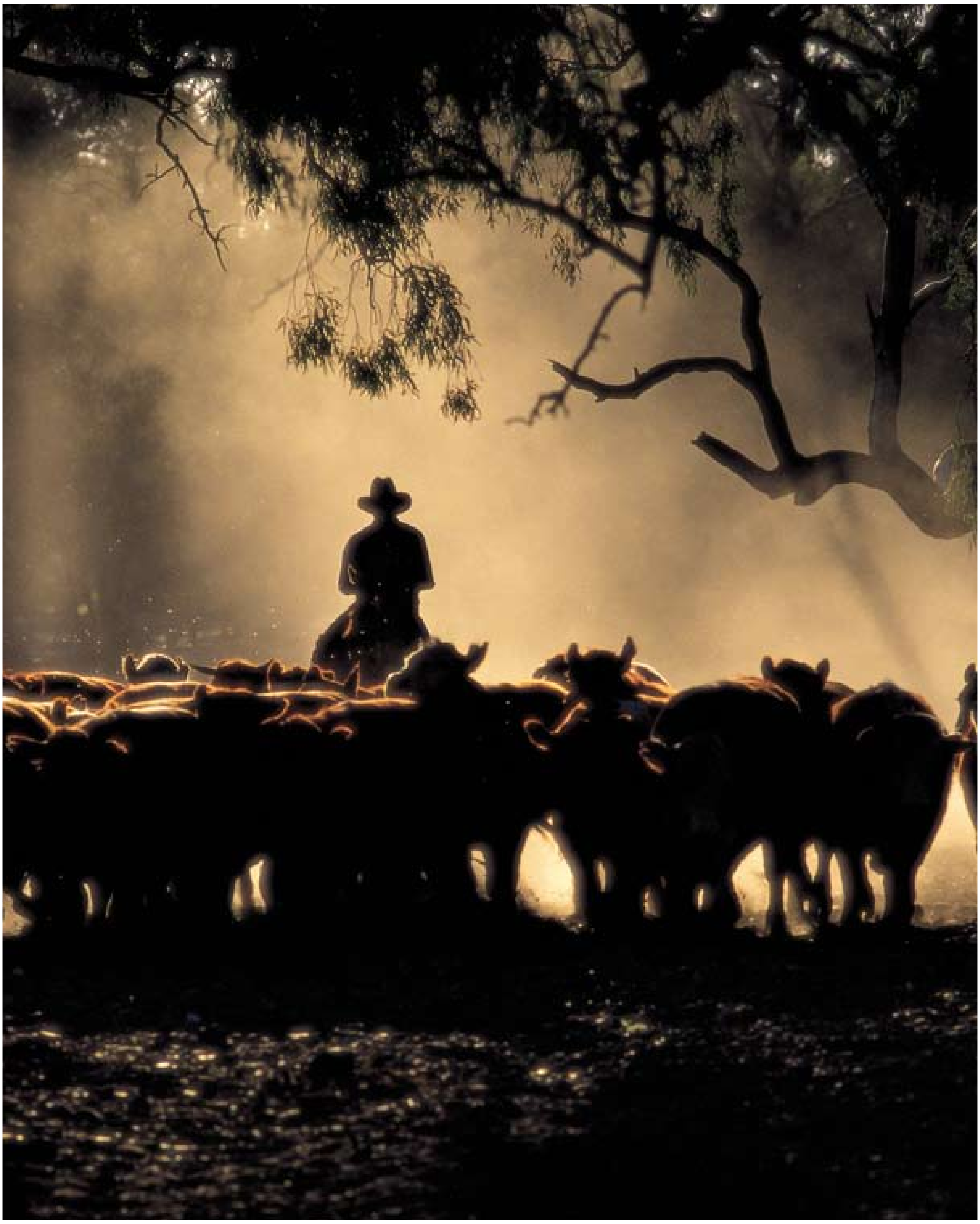


Image courtesy of South Australian Tourism Commission

Outback cattle drives have become a tourist activity

7

Social History of Water Use – Far North Region

7.1 Pastoral Expansion

In the 1850s, explorations, mineral discoveries and a more conciliatory colonial government policy toward grazing tenures for pastoral purposes combined to give further impetus to the northward and outward expansion of European pastoral occupation of what was later to become known as the Lake Eyre Basin and the area now formally known as the Far North Prescribed Wells Area.

From 1857 through 1859 separate expeditions under the command of AC Gregory, BH Babbage, PE Warburton and John McDouall Stuart all found ways through what had been regarded as a ring of impenetrable salt lakes north of the Flinders Ranges following their identification as such by Edward Eyre in the 1840s. These breakthrough discoveries, involving routes along the western shores of Lake Torrens, were made during a flurry of exploratory activity that followed the discovery of copper in the Flinders Ranges. Both government and privately-sponsored exploration parties pushed outward in the hope of finding further mineral deposits and suitable grazing lands.

Earlier in 1851, the first 14-year pastoral leases were introduced in the State's northern wastelands, offering pastoralists for the first time some security of tenure and an opportunity for lease renewal if the land was not required for other purposes. Prior to that time, as a direct result of a strict adherence to the Wakefield approach of systematic colonisation, pastoralists held occupation licenses only, to prevent land at the outer edge of agricultural expansion from being locked up.

With pastoral expansion following almost on the heels of the explorers, the ring of mound springs that was later understood to mark the southern and western outflows of the GAB, were progressively discovered by Peter Warburton's 1858 expedition and then by John McDouall Stuart. Between 1859 and 1860, Stuart used the GAB springs as a springboard for his push into the Finke River and MacDonnell Ranges districts of Central Australia. Ten years later, Sir Charles Todd was to use an identical route for the Overland Telegraph Line constructed during the 1870s.

Of the two major resources, land and water, it is clear that in the initial take up of pastoral lands in these areas, the incoming graziers were interested primarily in the grazing potential of the land and whatever limited natural waters this land contained. Water to supplement this very limited natural occurrence was going to have to be found, tapped, trapped and collected. Initially this did not appear to be seen as a particular limitation – an attitude that in large part reflected the wide lack of understanding of the natural aridity of the country being taken up, its real potential and its crippling disposition to drought.

This initial emphasis on the land resource was in sharp contrast to what was to happen much later at the end of pastoral development in the Far North. Almost 70 years later, before the Second World War, much of the undeveloped pastoral lands at the eastern end of the Musgrave Ranges were originally taken up by single operators holding permits to search for water, issued under the then current pastoral legislation.

The process involved a cash reward of $400 and a grazing permit for up to 100 square miles around any located underground water supply of 4,000 gallons per day, or better, of stock-quality water. The wells had to be proved to the satisfaction of the Pastoral Board and the responsible State Minister before a grazing permit would be issued. Some of the bitter lessons of the past relating to the absolutely critical importance of reliable water supplies to the grazing industry in these areas had by then been learnt.

The country that pastoralism expanded into in the last three decades of the 19th Century did contain natural surface waters in addition to the GAB springs. Most of the South Australian section of the Lake Eyre Basin lay then, as now, within the southern extent of the monsoonal intrusions that could intermittently cause heavy flood rains. In addition, it was to be learnt that the Cooper and Diamantina/Warburton systems in the north-east and the Macumba, Alberga and Peake River systems of the north-west supplied a number of semi-permanent waterholes. In the case of the Cooper and Diamantina systems, annual run-off from the Great Dividing Range and the Barkley Tablelands of Queensland provided annual freshette flows into South Australia that virtually assured supplies in some waterholes close to the borders.

Photograph by Pat Katnich, 2004

Anna Creek Station cattle

As the name suggests, the natural waterholes were holes of varying length and depth in the watercourses and drainage lines that spasmodically flowed in response to heavy local and upstream catchment rains. Flood flows in these systems are impressive and dramatic events that could refill these holes with a two-year or more supply. The depth of some of the holes was such that even isolated from flow they remained as semi-permanent or permanent supplies.

However, the presence of these waterholes, and what was to become known as the Desert Rivers systems, did not in any way isolate the pastoralists from the ravages of drought. Before the tapping of the GAB gave reliability to the waters along stock routes like the Birdsville Track, drought effectively isolated large numbers of stock on the runs ensuring their demise. Even naturally well-watered runs like Innamincka were not immune. When what flow there was in the Cooper stayed within its channels, the Innamincka and Coongie runs suffered drought as well, with only the cattle considered ready and strong enough being walked south. Over the years it has been estimated that almost five full-breeding herds died along the Cooper in drought. This would equate to at least 25,000 head of cattle.

As more country was leased for grazing, there were early attempts both by the Government and pastoralists to replicate the natural waterholes with the construction of dams and earth tanks wherever there was thought to be reasonable catchment. As the Government began to provide waters for travelling stock and public use – mainly in the Far North along the stock routes that successive administrations formally designated between 1896 and 1905 – the reservoirs, as they were optimistically labelled, formed part of the supply line. However, they were a relatively minor component compared with the effort that was to go into sinking wells.

Many of the Government earth tanks and dams in the north were some of the first waters to fall into disrepair. They lost water rapidly from massive evaporation that could be measured in feet against precipitation measured in inches. They tended to collect wind-driven sand deposits and when it did rain they were prone to siltation from uncontrolled stormwater collection.

The tanks and dams were also prone to extreme levels of trummeling from the hooves of the mobs of cattle, horses and sometimes sheep that in most cases drank directly from them. This loosened the surfaces of the banks and the land immediately surrounding the dams and exacerbated the siltation processes already underway. Later attempts to fence out at least the Government dams and wells to try and control numbers of stock using them at any one time were not successful. The fences were short-lived and, where they did survive, the small reserve enclosures were often used as bullock or horse-holding paddocks, which totally defeated their purpose.

Away from the main river systems, the slow but steady disappearance and abandonment of some of the man-made waterholes and dams was sometimes paralleled by the natural waterholes. This is now thought to have been substantially caused by the accumulative effects of large numbers of stock watering on them over a period of years. There is evidence that some natural waterholes in the Lake Eyre South region lost both capacity and longevity in the late 1800s and early 1900s. In some cases they silted up, lost their coolabah fringes and almost disappeared from the landscape.

The physical effort expended by pastoralists and Government on digging and excavating wells and reservoirs in the Far North was remarkable. It was a frustrating task given the high failure rate both at excavation and sometimes very soon afterward.

Capped bore at Mungerannie

A number of Government wells and reservoirs were dug in the period from 1883 to 1888 at a time when water administration in South Australia was headed by a Conservator of Water who reported to the Commissioner of Crown Lands. The first Conservator, JW Jones, was charged with the responsibility of developing a network of water wells and to this end he formed a Government well-sinking party. By 1888, 125 wells and 138 reservoirs had been developed or improved in both the surveyed and out-of-Hundreds areas of the State. Given the failure rate in the northern areas the number of excavations begun and abandoned could easily have matched the number where suitable supply was found.

An indication of the failure rate with wells can be gauged from reports provided to Parliament and to the 1898 Pastoral Lands Commission. In 1898 the Engineer-in-Chief reported to the House of Assembly that of 87 bores and wells drilled and dug by the Government in the out-of-Hundreds areas, 54 had been failures. Giving evidence to the Pastoral Lands Commission in the same year, John Hogarth, the manager of Anna Creek Station south and west of Lake Eyre, told of sinking 84 wells on the run and ‘out of these we have 27 we can put stock on’.

Uncapped Cowarie bore

Well-sinking was also an expensive business. Estimates provided to the 1898 Pastoral Lands Commission indicated that sinking a well cost ‘one pound per foot in earth and two in rock’. There was no standard dimension to the hole, but it had to accommodate one or two diggers and, eventually, the dimensions of whatever water-lifting equipment that was going to be used. The maximum depth to which they could be hand-dug was about 150 feet. From 140 feet downward, the air became increasingly foul and greater depths were not possible without artificial air supply.

Well failure was usually from a total absence of water, a limited and diminishing supply or a supply of saline water only.

The failures were not always immediately apparent. Supply sometimes diminished with use or the water became saline because of lateral feed of salty water into the small aquifer that supplied the well. Sometimes the wells were dug through a small, fresh supply, only to strike salty water at the greater depth. To avoid this, horizontal drives were sometimes dug into the fresh supply to increase both capacity and the well’s ability to make water.

Before the advent of windmills and mechanical lifting mechanisms, water was lifted by hand, or horse and hand, via a windless, a steel rope and a 10 to 40 or more gallon bucket. The labour requirement was intense and there were obvious limitations to the number of stock that could be watered at any one time.

In many cases, water lifters were employed by the various stations to live at the wells and draw water as required both for the station itself and for any travelling mobs on the move through.

Some of the bigger wells were equipped with large-capacity lifting devices called 'whips' and 'whims'. For instance, a whip consisted typically of an iron 'poppet head' which worked two 20-gallon buckets positioned on an endless cable. As one came up, the other bucket went down. The lifting impetus was supplied by a horse or camel walking up and down a tow path. It was at least a two-person job but the mechanism was capable of substantial output if the supply was there. Properly worked, whips were capable of a supply output at least equal to that of an average windmill.

In the 1880s, windmills and steam-driven pumps began to be used at the wells and tanks, beginning the mechanism trend that was to evolve further as bores began to be drilled seeking larger and more assured supplies. As a method of obtaining stock water supply drilling received considerable impetus following the discovery that much, of the State's northern and north-east pastoral lands overlay significant, deeper underground water supplies.

7.2 A Deeper Assured Supply

In 1878, five years after the GAB was first tapped south-west of Bourke, New South Wales, the first bore in South Australia struck the Basin aquifer at Tarkaninna, 56 kilometres north east of Marree. Former Department of Mines records indicate that the artesian supply at Tarkaninna was struck at 1,220 feet and the water gushed to 20 feet above the ground.

There is some anecdotal evidence to suggest that the Basin in South Australia may have been struck earlier in 1882 on what is now Anna Creek Station. There are even reports of a strike in that area as early as 1873. It is not totally clear when the connection was made between the GAB and the GAB springs, but it did not take long, with the Government concentrating its drilling along the arc of springs to support the Great Northern railway, then under construction between Marree and Oodnadatta.

The implications for the fledgling pastoral industry of the Lake Eyre Basin were profound not the least being the potential ability to drought-proof the designated travelling stock routes that were used to walk stock south toward markets in and near Adelaide.

There were four stock routes that traversed the Basin, as it was later delineated, for their entire lengths. However, easily the biggest beneficiary of the new water source was the Birdsville to Hergott route (better known as the Birdsville Track) that catered particularly for cattle travelling from Queensland's channel country to the Marree (Hergott) railway yards. Starting in 1890 with a bore at Lake Harry, 19 miles north/north east of Marree, 10 bores were drilled into the GAB aquifers, all at about two to three days cattle-walking distances. By 1916, these were all operational. They complemented the semi-permanent water holes on the Diamantina and Warburton Rivers south of Birdsville, and the base supply at the Marree bore. This ensured that the Birdsville Track was of primary importance among the State's designated stock routes.

These bores were all free-flowing and initially formed their own waterholes. The ponds and waterholes also acted as cooling tanks – a necessary initial stage given that the temperature of the waters flowing out of the bore heads was anywhere between 110 deg F and 190 deg F.

To the west of Lake Eyre, and along the western perimeter of the Basin, bores were drilled where supply was adequate but the pressure was usually not sufficient for free-flow. These Government bores, and those drilled into more localised aquifers west of Oodnadatta, were equipped with pumps and engines.

7.3 The Aboriginal Waters

In the early search for potential well sites, before the discovery of the GAB, the pastoralists of the Far North appeared to pay little heed to any knowledge held by the Aboriginal language groups of the area, as to where water could be found. Today there is still very little if any documented detail, even though groups like the Arabana, Wangkangurra, Thirrari and Dieri (Diyari) resided semi-permanently in the Simpson, Tirari and Sturt Stony Deserts.

Various reports have, for instance, indicated that there were at least 18 wells used by the Wangkangurru people who resided in the Simpson Desert. The locations of some of these were rediscovered in the early 1980s and some have been GPS-fixed. However, there is no documentation on supply, quality and ability to make water.

Given the hunter-gatherer lifestyle of the language groups, and the fact that they did not herd any livestock, their requirements of these wells and soaks would have been for drinking water only and the supplies were probably limited. It is known that the Wankangurra prolonged the effects of episodic rain by building dams across the deeper clay pans in the Simpson Desert and only fell back on the permanent waters to the east at the end of extreme dry phases. They also fell back onto Dalhousie Springs in the west in very dry times.

There was an important Aboriginal trade route along the eastern side of Lake Eyre linking Boulia in Queensland with a particularly valuable ochre mine near Parachilna. This traversed through Beltana and Lake Kopperamanna on the Cooper. A further route connected Lake Kopperamanna with Innamincka and south-west Queensland. While the trading centres on this and other routes were on more or less permanent water, the routes between were not and it is known that Aboriginals did not carry water. They would have known where water could be found but there is no evidence that this knowledge was ever sought in a formal sense.

The items traded along this route included pituri (a sought-after drug), ochre, shell and wooden and stone implements. Some of the items travelled a very long way. At Lake Kopperamanna, for instance, melo shell has been found that could only have come from eastern Cape York in Queensland.

7.4 Land Use

Today the dominant and almost totally exclusive grazing activity in the Lake Eyre Basin involves cattle – but this wasn't always the case.

A surprising number of the larger runs of the north began with sheep and continued to maintain some sheep numbers until well after the Second World War.

In the far north-east corner of South Australia, the Beltana Pastoral Company ran sheep at Cordillo Downs and at the extensive Murnpeowie run at the southern end of the Strzelecki Track. The immense Anna Creek run, operated by S Kidman and Co and being, in area, the largest, contiguous cattle run in Australia, ran sheep until 1918. In the Far North and west, sheep were grazed at Ernabella and Indulkana in the Musgrave Ranges, and at Kulgera across the border into Northern Territory.

Further south, a number of stations in the Oodnadatta district carried sheep. The last shearing at De Rose Hill Station on the Stuart Highway, just south of the Northern Territory border, took place in 1958 and on Evelyn Downs, Arkaringa and Mount Barry runs, north of Coober Pedy, sheep were still present in 1965.

Generally the more ephemeral sand hill country of the far north is better suited to cattle that are able to make stronger economic advantage from the pulse of forage growth that follows rainfall events. They are also better suited to the flood-out and watercourse country both in their ability to utilise feed and their capacity to handle wet, humid and boggy conditions.

There remain today some significant areas of perennial bush country in the Far North. This is country suited to sheep and is the main grazing support for the pastoral sheep industry further south.

There is little argument now that the main impetus to the dominance of cattle in the Lake Eyre Basin is down to the crippling potential losses that can occur with sheep subject to predation by dingos. Hindsight now makes it abundantly clear that, along with a failure to grasp the sustainable grazing capacity limitations of the northern country, the other knowledge gap that was to prove most chronically costly to the industry was the havoc that native dingo could cause among sheep flocks.

There are still many derelict sets of sheep yards to be found in the Lake Eyre Basin – a testimony to the time when labour was more plentiful and the sheep were shepherded during the day and yarded at night in an attempt to minimise losses to dingos. Some of the yards contained small watchboxes where shepherds would sometimes sleep among the yarded sheep as a protection against night attack.

There are anecdotal reports of some mobs of sale sheep walking in to rail from the northern stations but the general dearth of other reports of sheep being overlanded in the Far North suggests that when shepherding largely stopped and the sheep began to be contained in paddocks, the level of losses due to drought and dingo predation was such that there were no worthwhile numbers of cull and sale sheep to send off. The sheep survived or perished on the runs at a rate that usually meant that the numbers bred were all used as replacement stock only.

In many areas, sheep were run as cattle numbers built up. This change in commercial stock emphasis also coincided with labour shortages occasioned particularly by the Second World War. From the late 19th Century, Aboriginal labour was used extensively and as Philip Gee notes in his History of Pastoralism in the Lake Eyre South Drainage Basin, it has been generally recognised that without the availability of Aboriginal labour the occupation of the pastoral lands could not have taken place, yet in the process they (the Aboriginals) quickly became detached from their land and culture.

Much of the early shepherding and well-management was done by Aboriginals. They also made up the majority numbers in the mustering teams on most stations as cattle numbers increased. The arrangements under which they were employed varied but it was not uncommon for an Aboriginal employee to receive about half the wage of other workers but to also receive double rations. The price the pastoral industry paid for this cheap labour was to accommodate the extended families of Aboriginal stock workers on their properties.

It was not until 1968 – as an eventual flow-on from industrial agitation that began at Wave Hill Station in the Northern Territory – that the Australian Conciliation and Arbitration Commission granted equal pay rights to Aboriginal stock workers. When this happened, previous industry tolerance of non-productive family members on properties, in many cases, ceased.

The unrelenting losses that dingos are capable of inflicting on smaller domestic grazing animals led in 1946 to the passage by State Parliament of the Dog Fence Act, which provided for the establishment of a continuous dog-proof barrier across the northern parts of the State. Today it follows along the southern edges of the Lake Eyre Basin and across South Australia it extends over 2,178 kilometres from the Head of the Bight to the New South Wales border. It links with the New South Wales Border Fence and the Queensland Barrier Fence to make the longest man-made structure in the world.

It is a control line backed up by buffer baiting over a 35-kilometre strip outside the Fence. It makes conventional sheep grazing management inside the Fence possible and while there are cattle grazing inside the Fence, there are now no sheep outside the Fence. Ironically, it also marks a line of official status change for the dingo itself. Outside the fence, the dingo, which is thought to have come into Australia with Asian seafarers between 3,000 and 4,000 years ago, is a native animal. Inside the Fence it is a prescribed pest under the State's Animal and Plant Control legislation.

Diversification

There has been a recent trend within the pastoral industry – and within the Lake Eyre Basin – to look at diversification opportunities where these can be pursued on stations without adverse environmental effects or undesirable impacts on existing livestock practices. The trend has been driven variously by fluctuating commodity prices, concerns about property viability and the drift away of younger people toward more settled areas where employment opportunities are better.

Eco-tourism and regulated camping are the main options that present themselves in the area under discussion. This can involve paid camping at set-aside spots and the use of unoccupied station living quarters.

In the Far North, formal homestead stays involving insights into the daily working life of the property, have not yet caught on as it has further south – mainly because of distances.

The South Australian Pastoral Board, in keeping with some of the tenets of its legislative charter, has been supportive of diversification and has been prepared to consider applications relating to more diametrically different land uses. These have included the harvest of native fauna, camel trekking and opportunity commercial fishing of the watercourses.

There is also escalating tourist interest from people with the vehicles and equipment to access pastoral lands off-road. The State's Pastoral Act provides for consent access onto pastoral leases and for the establishment, and formal gazettal, of public access routes as adjuncts to existing maintained roads.

The exploration and expansion of the Cooper Basin gas fields (the Moomba and Gidgealpa gas fields) created ready road access to the Far North-east, facilitating tourism and the re-emergence of the Innamincka township. The gas field remains a specialist operation, with fly-in/fly-out crews at the base and on the exploration rigs.

The expansion and the infrastructure and transport requirements did, however, have a considerable impact on Gidgealpa Station. It was estimated that the loss of effective grazing on the lease totalled in excess of 220 square kilometres but as an offset to this relatively minor impost, the Gidgealpa run was left with a developed stock water system, access to electricity and vastly improved internal roads and tracks. The Station ceased being an ephemeral 'fattener's block' when there was flow in the Cooper system, and became a viable, stand-alone pastoral operation.

7.5 Towns and Settlements

The six recognised towns and settlements within the Far North Prescribed Wells Area were established in response to differing imperatives.

7.5.1 Coober Pedy

Coober Pedy was established following the discovery of opal in the Stuart Range. Marree, William Creek, Oodnadatta and Marla were established in support of rail or road transport corridors and Innamincka was surveyed around a police and tax-collecting presence.

Coober Pedy had its genesis in 1915 with the discovery of opal in the Stuart Range but it was not until the 1960s that the development of the town and the exploitation of the opal fields were formally recognised as being of lasting significance. In 1972, the Government resumed the Mount Clarence Station lease, on which the diggings took place, and gazetted a Precious Stones Field. The balance of the lease was re-offered for grazing but it was not until 1983 that it was re-allotted as a pastoral lease. Coober Pedy today has a population of about 3,500 people and is the only urban settlement in the area under discussion to be administered by a council. It became a local government area in 1981.

7.5.2 Marree

Marree was laid out and proclaimed in 1883, one year ahead of the extending narrow-gauge Great Northern Railway which reached there in 1884 and then swung north-west along the arc of the GAB springs to follow the water-safe route taken earlier by the Overland Telegraph line to Darwin and the Herrgott to Charlotte Waters stock route. This left Marree as the nearest South Australian railhead to the Far North-east of the State and the channel country of south-west Queensland. It was later to become a major railhead for cattle walked down from these areas along the legendary Birdsville Track stock route.

Despite its formal proclamation Marree was, for many years, known as Herrgott – a name derived from the nearby Hergott Springs that were discovered in 1859 by a member of John McDouall Stuart's second expedition through the area. All the residents of the town referred to it as Herrgott and it was not until 1918 that the Herrgott Springs sign at the railway station was replaced with Marree.

Even after road transport replaced the overlanding of cattle to rail, Marree retained a strong railway connection as a gauge-change stop on the Ghan railway line to Alice Springs. This ceased in 1980, when the new standard-gauge line through Tarcoola was opened.

Marree is also strongly and closely associated with camels and the Afghan cameleers. When the railhead moved north from Farina to Hergott in 1884, many of the Afghan camel drivers and their teams came too. They were the outgoing and incoming goods and mail connections between the remote north-east stations (and the Luthern missions at Lakes Killalpaninna and Kopperamanna on the Cooper) and the railway towns. They plied their trade until the 1920s and 1930s when motor trucks driven by legendary mailmen like Harry Ding and Tom Kruse began regular mail and goods runs up and down the Birdsville Track.

Today Marree's European and Aboriginal population of about 150 still includes a smattering of people of Afghan descent.

7.5.3 Oodnadatta

Oodnadatta, on the Neales River, was surveyed in 1890, one year after work on the Warrina to Angle Pole section of the Great Northern railway line reached there, and then went no further for a long time. Initially, work was suspended there following discussions in the new Parliament of 1889 and a decision to discharge 600 men to help the southern wheat harvest of that year.

The Great Northern railway terminated at Oodnadatta until 1929 when it was extended on to Alice Springs by the Commonwealth Government. This 39-year period ensured Oodnadatta's prominence as a major railhead for cattle walked down the stock route from Charlotte Waters, just over the Northern Territory border, and from the Musgrave and Everard Ranges to the north-west. The termination of the rail there also meant that travellers and freight moving on to Central Australia had to be carried by camel – a journey then of between eight and ten days. By 1893 there were some 50 Afghans based at Oodnadatta working 400 camels in every direction from the town.

Oodnadatta remained a railway service and stopover station while the narrow gauge Ghan line to Alice Springs was in use. With the lines closure in 1980 the town quietened, and is currently a major social and service centre for indigenous people, and a pastoral station and tourist service centre.

With a mixed Aboriginal and European population of about 160, Oodnadatta is arguably the most isolated surveyed town in the Far North. There is no all-weather road access and, beyond a twice-weekly mail run from Coober Pedy, no regular public transport. The town is sometimes isolated after heavy, episodic storm rain. All this makes Oodnadatta redolent of authenticity and with its wide main street, its iron and stone buildings with wide verandahs and its well preserved railway museum, it is a popular destination for serious outback travellers.

7.5.4 William Creek

The tiny settlement of William Creek was established as a railway service and watering point on the narrow-gauge Great Northern railway when it reached there in 1885.

The site had already been named in 1859 by explorer John McDouall Stuart after the second son of John Chambers, a pioneer pastoralist and a staunch supporter of Stuart's explorations. Situated effectively half way between Marree and Oodnadatta, William Creek has always been a small settlement. Even at its peak, before the Ghan line was moved further west in 1980, there were only ever a few cottages, a small school and a hotel/store.

With the closure of the hotel at Tarcoola, the legendary William Creek Hotel is now the only iron hotel left trading in South Australia.

7.5.5 Marla

Marla, or Marla Bore as it is sometimes called, was surveyed and established by the State Government in 1981 as a service point on the re-aligned and sealed Stuart Highway. It is located at a point where the Highway parallels the new standard gauge railway line to Alice Springs and now Darwin. The township also now marks the termination of the Oodnadatta Track from Marree via William Creek and Oodnadatta.

The town was laid out and designed to provide accommodation, fuel and services to road travellers and to locate police and some Government services at the nearest point on the Stuart Highway to the Pitjantjatjara Aboriginal lands of the north-west. With a population of about 140, it still provides these services while also acting as a jumping-off point to the Mintabie Opal Fields to the west and the developing Seven Waterholes opal mining camp on Lambina Station to the north-east.

7.5.6 Innamincka

Innamincka township was originally surveyed in 1890, but there had been a store and a police station there on Cooper Creek since 1884. The police presence persisted for many years and, up until Federation in 1901, the station, among other things, administered the collection of an introduced stock tax on cattle moving down the Cooper system toward the Strzelecki and Birdsville stock routes.

The original hotel at Innamincka served a large and thirsty area and counted among its regulars teams of shearers travelling by bicycle between stations like Cordillo Downs, Nappa Merrie (in Queensland) and Blanchewater (now part of Murnpeowie). The bottle pile outside the hotel was a regional feature. An inland mission hospital was established at Innamincka and served the Far North-east and parts of the Queensland channel country for many years. In the early 1990s, it was restored and refurbished as a headquarters and information centre for National Parks and Wildlife South Australia. The township is surrounded by the Innamincka Regional Reserve, as it used to be by S Kidman and Company's Innamincka Station.

The channels of Cooper Creek around Innamincka, and the permanent Nappacoonie, Callyamurra and Queerbidie Waterholes, have very strong historical connections with the ill-fated Burke and Wills expedition. Within easy reach of these features are Will's Grave, King's Marker, Burke's Memorial and the Dig Tree across the border in Queensland.

7.5.7 Other Services

There are two single-family or company service stops within the area under discussion; one at Cadney Homestead on the Stuart Highway between Coober Pedy and Marla and the other at the Mungeranie Roadhouse/Hotel halfway north along the Birdsville Track. Santos Ltd maintains a large service infrastructure and camp at Moomba in the gas fields but this is a closed, company settlement, staffed on a fly-in, fly-out roster basis.

7.6 Administration

The Far North lies outside the State's surveyed Hundreds and, with the exception of the island of local government that is Coober Pedy, lies also within the unincorporated areas of South Australia.

State planning and health legislation apply throughout the area and public road maintenance is carried out by Transport SA – a service that extends to maintaining access roads into homesteads and in some cases stockyards.

The Outback Areas Community Development Trust, established by legislation in 1978, provides elements of local government to the small, scattered settlements of the area by facilitating advice and financial assistance to the incorporated progress associations within each community.

As with other areas of the State's pastoral lands, land and water resource management are currently principally supported by the Pastoral Land Management and Conservation Act 1989, the Soil Conservation and Landcare Act of the same year and the Water Resources Act 1997.

Pastoral Legislation and the SA Pastoral Board

In South Australia's rangelands, a pastoral lease is the only form of tenure that can be issued over Crown land that is to be used for long-term grazing purposes. The administration of these 42-year leases and the advice required by the State Minister responsible for the pastoral grazing lands, is the responsibility of the State's Pastoral Board which has existed continuously now since 1893. It is one of the oldest, active statutory authorities in Australia.

The first Board of 1893 was the result of a recommendation from the 1891 Pastoral Lands Commission and was the outcome of some heavy, early financial losses in the face of drought, by pastoralists who had taken up the first 15-year leases of the wastelands from 1851 onward.

The work emphasis of current Pastoral Boards had its beginning in the 1930s when the sustainability of the grazing practices of the day was beginning to be questioned. The Pastoral Act of 1936 introduced stocking controls on leases for the first time and inspectors began to focus on land condition.

Today, sustainability of the pastoral lands subject to grazing and the monitoring of the condition of these lands, remain pivotal components of the work of the SA Pastoral Board.

Over the many years of its operations, Board members and pastoral inspection staff provided often the only regular link pastoralists had with Government and a number of other services. It was not uncommon for visiting Board members and staff to carry mail and supplies, witness documents, assist with staff replacement, locate city accommodation opportunities and help find governesses.

7.6.1 Water Resource Administration

As a consequence of the proclamation of the State's first Water Resources Act in 1976, a significant component of the advice to Government on the management of the underground and surface waters of the Far North was provided by successive Arid Areas Water Resource Committees (AAWRC) that were established pursuant to that Act. This advice was usually proffered through the State's Water Resources Council and focused particularly on the management of the artesian wells of the South Australia section of the GAB and on the resource itself.

This basic function has continued with the AACWMB appointed pursuant to the revised 1997 Water Resources Act but is accompanied now by a more strategic role for the Board which includes the preparation and implementation of a catchment water management plan.

The advice provided by successive arid areas committees and boards has generally complemented the more technically-focused drilling, bore-rehabilitation, bore-logging and pressure-monitoring role carried out by the groundwater groups of the old Department of Mines and Energy, its successor, Primary Industry and Resources SA and the supply function provided by SA Water.

The SA Pastoral Board has also considered a number of issues relating to artesian bore maintenance and responsibility – both before and since the 1976 water resource legislation. Before 1976, the SA Pastoral Board had a legislative mandate under the 1936 Pastoral Act for artesian bores and this related to their maintenance, licensing and shared use when 'conveniently located' in relation to adjoining leases.

Although these latter responsibilities were subsumed by the provisions of the 1976 Water Resources Act, the SA Pastoral Board's continuing interest was recognised in a consultative way, particularly following the instigation of the Bore Rehabilitation Program. This advisory collaboration was assisted by common memberships. The first Chair of the AAWRC was also the Presiding Member of the SA Pastoral Board.

The other committee appointed pursuant to the 1976 Water Resources Act that took an ongoing, but less direct, interest in the region's artesian bores was the Well Drillers Examination Committee which was primarily responsible for licensing well drillers and monitoring their activities. Only the highest grade of driller's license issued by the Committee would allow the holder to 'sink wells which would extend into the aquifer of the Great Artesian Basin'.

As with the SA Pastoral Board, there was frequently common membership between the Well Drillers Examination Committee and the AAWRC while the original Water Resources Act was in force.

7.6.2 Pastoral Soil Conservation Boards

The Pastoral Board works in close collaboration with pastoral district soil conservation boards that have been appointed since 1989 in all pastoral districts. Information from lease and district reports is made available by the Pastoral Board to the soil boards while field days and seminars relevant to the district are usually facilitated by the soil boards. The State's Soil Conservator, who works closely with the district boards, is also a member of the Pastoral Board.

7.6.3 Other Legislation

The lease tenures issued pursuant to the current Pastoral Act require all lessees to comply with other nominated pieces of natural resource legislation. In addition to the Water Resources Act, these include the Animal and Plant Control Act and the Native Vegetation Act.

The administration, maintenance and financing of the State Dog Fence are mandated by the Dog Fence Act 1946. This act empowers the Dog Fence Board and makes provision for the appointment of Local Dog Fence Boards to inspect and administer prescribed lengths of the barrier Fence. There are four such Boards while considerable stretches of the western Fence, and some smaller lengths of the eastern Fence, are maintained by private arrangements with adjoining landholders.

The national parks, regional reserves and conservation reserves within the far north are administered under the auspices of the State's National Parks and Wildlife Act.

Photograph by Kirrilie Rowe, 2003

Surface water flowing on granite outcrop, near Gawler Ranges.

8

Social History of Water Use – Gawler Ranges Region

In the following text separate reference is made to the Gawler Ranges and the North West. This recognizes that these two areas were explored and occupied as different regions, with the Gawler Ranges generally being taken up before the North West. In that context, reference to the Gawler Ranges in historical terms refers to the pastoral country south of a line from Port Augusta west to Lake Everard, down to the present boundary of the pastoral and farming lands on northern Eyre Peninsula, and west to the north–south section of the Dog Fence below Wilgena.

Similarly, reference to the north-west refers to the pastoral country west of Lake Torrens and north of a line Port Augusta to Lake Gairdner to Kingoonya up to about the latitude of Coober Pedy.

8.1 Early attitudes to land use

As mentioned in the preamble to the Flinders Ranges and North East region, the general view in the early years of the colony mistakenly assumed that all land would be similarly productive, and that agriculture would be the prevailing land use throughout. Pastoralism was seen merely as an interim step until agricultural pursuits could be put in place. The policies which initially limited pastoral tenure to grazing licenses only in the marginal lands, so as to preserve options to subdivide the land for agricultural purposes later, and the associated unsustainable minimum stocking rates that were applied to leases when they were eventually introduced, devastated many of these more arid areas. Some have never recovered.

While some of these attitudes persisted well into the 20th Century, it appears that by the time occupation of the Gawler Ranges and the North West began in the late 1850s, some lessons had been learned from earlier inappropriate policies and misconceptions. For the most part these two regions were not subject to the same pressures to convert them to smaller holdings and farming activities.

It is possible that decisions to allow ongoing use of these lands for pastoral purposes rather than farming were also influenced by the accounts and gruelling experiences of the early explorers and by their often daunting descriptions of the country through which they passed, including the scarcity and unreliability of water. Whatever the reason, pastoral grazing was from the earliest times the land use selected for the Gawler Ranges. Nevertheless, many stations had their cultivation paddocks near the homestead where small scale cropping and hay growing was attempted. In some places in the Gawler Ranges this practice continued until quite recently. For example, at Pondana north of Paney, there are reports that some form of cropping continued intermittently until the 1970s.

In the country north of Port Augusta, there seems from the outset to have been an acceptance that pastoral grazing, whether sheep or cattle, was the only practical and economic land use that could be applied to this region. However, the urge to subdivide to form small living areas had not disappeared entirely, and in 1893 land to the west of Port Augusta was subdivided to form 36 to 60 square mile living areas that were auctioned in Adelaide. Most were later abandoned and amalgamated to form holdings large enough to be economic.

8.2 Exploration and Pastoral expansion

8.2.1 Gawler Ranges

The earliest recorded exploration of the Gawler Ranges region occurred in September 1839 when Eyre's party travelled from Streaky Bay to the head of Spencer Gulf through the southern part of the Gawler Ranges. Eyre noted on arriving at the head of Spencer Gulf that he would have failed to complete this arduous 300 kilometre journey if not for the fortuitous local downpours that filled rockholes, for he had found not a drop of permanent fresh water or a single spring even though he had passed through the ranges themselves.

Just 12 months later, in September 1840, part of Eyre's party under Baxter returned on the same route from near Iron Knob to Streaky Bay, in the early stages of Eyre's epic exploration journey across the Bight from Port Lincoln to Albany in Western Australia. It seems the country between the head of the Gulf and Streaky Bay did not impress, with Eyre describing the section of the Gawler Ranges that he passed through in 1839 as having no watercourses and no timber and as being 'barren, rocky and naked in the extreme'.

Little further interest was shown in permanent settlement in the Gawler Ranges until about 1857 when the Government set up an expedition under the leadership of Stephen Hack to explore the north-west interior of the State. During his return from Streaky Bay to Adelaide, Hack explored extensively in the western Gawlers, and in his journal speaks highly of its potential for pastoralism, in sharp contrast to Eyre's comments 17 years prior.

However, Warburton, Commissioner of Police, was also familiar with the Gawler Ranges and was in fact inspecting the area around Lake Gairdner in 1857, at the same time that Hack was exploring further west. They did not meet, but Warburton's assessment of the country he saw was much more circumspect and with hindsight probably more accurate than Hack's. He noted that surface water was confined to rock holes that filled only after rain and did not last very long, and commented on the lack of decent watercourses and permanent water holes. Commenting somewhat scathingly on Hack's statement that the western Gawlers contained 4,500 square miles of country capable of carrying up to 225,000 sheep, Warburton suggested that if this figure was cut by 220,000 it might just be possible to provide the remaining 5,000 with sufficient water to carry them through the summer.

By 1857, only three years after the establishment of Port Augusta, leases at Lincoln Gap, Point Lowly and Wartaka had been taken up, and in 1862, on the basis of Hack's reports, J Harris Browne (Sturt's expedition doctor during his 1844-45 expedition into Central Australia) took up a preferential option for 1,800 square miles of country around Lake Gairdner. He later relinquished this claim after receiving unfavourable reports on its pastoral potential from Bonnin who he sent to inspect the area. However, this country including Yardea, Paney, and Pondana was taken up soon after 1862.

Occupation of the Gawler Ranges was certainly well underway by the early to mid-1860s, with the whole of the Gawler Ranges from Uno and Siam across to Kondoolka and north to Moonarie taken up by pastoral leases over the next few years (for example, Yardea and Yartoo in 1862, Pondana, Cacuppa [adjacent Mount Ive] and Tank Hill [Pandurra] in 1863, Nonning, Kolendo, Mount Ive and Paney in 1864, Coralbignie in 1865, Hiltaba and Lake Everard in 1868, and Kondoolka 1870).

For some time, Yardea was the only permanent station on the western side of the Gawlers, with many other leases being used for winter pasture for stock from stations on the West Coast, or as 'depots' for stock travelling from the West Coast to Port Augusta or other holdings in the Flinders Ranges. Since the mid 1840s, following the occupation of the coastal country between Port Lincoln and Fowlers Bay, there had been regular seasonal movement of stock from the large coastal holdings such as Talia, Bramfield and Lake Hamilton to the Gawler Ranges where sheep were shepherded over-winter, grazing on the saltbush and bluebush in the Ranges and watering from rockholes.

Early leases for pastoral lands, referred to as wastelands of the Crown, were issued under the Crown Lands Act 1851 for a period of 14 years. Land was classified in one of three classes based on its quality (at that time one would think a highly subjective assessment), and rents set accordingly: one pound for first class, 15/- for second, and 10/- for third, all payable in advance. In addition, minimum stocking rates were applied at the rate of 100 sheep or 16 cattle per square mile. In 1857, amendments to the occupation of the so-called wastelands specified that lessees run a minimum of eight cattle or 50 sheep per square mile within 12 months of the start of the lease and keep it stocked at that level for the duration.

Rents were clearly high for the three classes of land, and this was one of several significant factors that resulted in most of the early leases being abandoned during the late 1800s when many of the 21-year leases issued from 1867 expired.

In evidence to the 1897 Royal Commission into the pastoral lands, WB Sells, lessee of Yardea for many years, said that a combination of low wool prices, excessive rents and losses to wild dogs were in his view the main factors that rendered permanent pastoral activity uneconomic in the Gawler Ranges. He asserted that the three essential prerequisites for successful pastoral occupation in the Gawler Ranges were affordable rents (he had previously been negotiating unsuccessfully to reduce Yardea rents from 18/- to 7/- per square mile), large holdings, and vermin proof fencing to control the dingo problem. Surprisingly, he did not nominate water as one of these critical factors.

8.2.2 The North West

In 1860, very little was known of the country north of Port Augusta between and beyond Lake Torrens and Lake Gairdner. The little that was known was drawn from the limited accounts of the explorers Horrocks (1846), Babbage (1857) and Oakden and Hulkes (1859).

The country north and north-west of Port Augusta up to about the latitude of present day Woomera and west to Coondambo was explored, leased and settled progressively from around 1862. Most of this exploration and settlement was from the south (Port Augusta). Further north, the country including Mount Eba, Parakylia, Mount Vivian and Millers Creek, was initially taken up following investigation of this area by John Ross in 1873, exploring on behalf of Price Maurice. Unlike most previous exploration parties, Ross did not come from Port Augusta up the western shores of Lake Torrens, but instead travelled via Leigh Creek and Marree (Hergott Springs), and around the top of Lake Torrens.

Occupation North West of Port Augusta commenced in 1862 at Maslin's Paddock and Tent Hill, both within 17 miles of Port Augusta. Although some exploration took place further north in 1857-59, (Oakden and Hulkes, Babbage, Warburton) and discontinuous leases were established up to 200 kilometres north of Port Augusta by 1869, the northern extent of occupation in 1870 remained at Euro Bluff and Yudnapinna only 80 miles from Port Augusta.

Although 1857 and 1858 must have been good years, with reports from Babbage and others of 'permanent' fresh-water lakes and running streams (Pernatty Lagoon and Pernatty and Elizabeth Creeks), Pernatty was not leased until 1868, and not stocked until 1871. In 1859, Oakden and Hulkes had pushed out to the Oakden Hills area and for a time held the first lease over Oakden Hills but soon relinquished it when surface water disappeared.

In 1868, the Pernatty lease was taken up, and by 1869 GB Richardson had taken 100 square mile leases over sections further north including the Elizabeth and Philip's Ponds (both later part of Arcoona), and Lake Campbell, the latter around 140 miles (220 kilometres) north-west of Port Augusta.

In the early 1870s, Coondambo was established. Shortly after, the Wirraminna lease commenced. By 1880, Richardson (1925) notes that well-sinking, dam-sinking, hut building and fencing was widespread in the north-west, and a few stations had already been fenced.

In contrast to Eyre's relatively uneventful crossings of the southern Gawlers, Ernest Giles' 1875 journey from Fowler's Bay via Youldeh (Ooldea) and Wynbring Rockhole to Finniss Springs very nearly ended in disaster for the party of three. Giles had to endure eight days and over 200 miles (320 kilometres) from Wynbring Rockhole to near the top of Lake Torrens, without finding water, perishing both his horses in the process and nearly costing the whole party their lives. While his route east of present Tarcoola took him through country that was in the process of occupation in the mid-1870s (Wilgena, Parakylia, the various leases comprising Mount Eba and Andamooka), the near fatal outcome was a grim reminder of the risks associated with attempts to cross and occupy this country.

In 1873, two years before Giles' eventful journey, John Ross had come around the top of Lake Torrens from Leigh Creek and Hergott Springs (Marree) and had taken up leases, on behalf of Price Maurice, of 1,000 square miles near present Millers Creek and Mount Eba stations. By 1880, most of the country west of the top of Lake Torrens was taken up, some of it as huge holdings with multiple leases. Price Maurice's Mount Eba is a good example: it included eight separate leases totalling nearly 4,000 square miles (8,800 square kilometres), and ran between 50,000 and 60,000 sheep at its peak.

As with much of the country taken up under the 21-year 1872 lease arrangements, Mount Eba was later abandoned at the expiration of those leases in 1896. Between the late 1890s and about 1910, much of this country stood idle, and in spite of the Government installing caretakers on many of the abandoned leases, maintenance of equipment and infrastructure was neglected and much of it fell into disrepair.

The impact of the expiration and abandonment of many of the first 21-year leases in the north-west country can be gauged in part by the decline of the wool trade passing through Port Augusta. In 1888, 48,000 bales were shipped from Port Augusta but in 1891 this had reducesd to 12,400. This is reportedly mainly due to the abandonment of leases after 1888, including Pernatty, Wirraminna, Andamooka, Whittata, South Gap, Kingoonya, Mount Eba, McDouall Peak and later Wilgena. While all these leases were re-offered to the public, the costs of reinstating improvements together with rents that were considered prohibitive meant that the majority of these leases remained unoccupied, some for many years.

The period from the late 1890s right through to around 1920 seems to have been a time when the term wasteland may truly have been applied to vast areas of the country north-west of Port Augusta. Only Yudnapinna and Coondambo were leased continuously throughout this period. When finally reoccupied, the scene had changed forever, with leases issued to new occupants at greatly reduced rates, and with many of the old stations that had been worked as single leases now combined to form larger holdings.

8.3 Mining

To a large extent, mineral discoveries and mining activities in the Flinders Ranges from the 1860s onwards stimulated the establishment and development of townships and communities such as Blinman, Sliding Rock, and Beltana, and infrastructure such as roads and railways. The impact of mining on township and infrastructure development in the Gawler Ranges and north-west may have been less obvious, especially in the period 1860 to 1900, but it is notable that three of the five townships established by 1930 had their genesis in mining (Tarcoola, Andamooka and Iron Knob). Today of course, mining is solely responsible for the establishment and development of Roxby Downs, the largest town north of Port Augusta.

Gold was discovered at Tarcoola and Glenloth (60 kilometres south of Tarcoola) in 1893. Mining began at Tarcoola in 1900 and the mine became the State's major gold producer, with 2,400 kilograms of gold being recovered between 1900 and 1955. The smaller Glenloth mines were established in 1901 and produced 315 kilograms of gold between 1901 and 1955.

In 1995, following renewed interest in the mineral potential of the Gawler Craton, a major gold deposit was discovered 120 kilometres north-west of Tarcoola, and in 2002 the open-cut Challenger mine commenced production with an estimated Stage 1 life of two years. Recoverable gold was estimated at 105,000 ounces (approximately 3,000 kilograms) and the operator Dominion Mining is currently assessing the feasibility of underground operations to extend the life of the mine.

In 1875, copper was discovered at Mount Gunson, 130 kilometres north of Port Augusta and near the northern end of Pernatty Lagoon. The deposit has been mined intermittently since then. Open cut operations took place at four ore-bodies but the bulk of production occurred between 1974 and 1986 from the Cattle Grid ore body. Since 1987, the Adelaide Chemical Co has been heap-leaching oxidized ore to produce copper cement (approximately 60 per cent copper) which is used for the production of specialty copper chemicals at a plant in Burra.

Opal was discovered on Andamooka station in 1930 when station workers picked up floaters (surface opal). Mining has taken place since, often as one man or small-scale operations involving shafts bored to opal level with opal-bearing material extracted by winches or, more often today, blowers. Today, as at the larger Coober Pedy field, bulldozers are also used to excavate relatively shallow pits to expose the opal-bearing rock.

Iron ore was discovered at Iron Knob in 1880 and for the next 16 years the Mount Minden Mining Co extracted iron ore from the area. In 1896, BHP Ltd took over the leases, and mined the ore from 1899, originally supplying ironstone as a flux for their Port Pirie silver-lead smelters. In 1915, BHP Ltd established the Iron Knob open-cut iron ore mine, the first major iron ore mine in Australia and the main supplier for the Australian iron and steel industry from 1915 to 1965. Favourable extraction costs together with the proximity to the port of Whyalla led BHP Ltd to construct an integrated steel works in the city in 1964.

Since the divestment by BHP Ltd of its steel operations in 1999, the steelworks and Middleback iron ore mines have been operated by Onesteel Ltd.

In 1975, WMCR discovered the enormous Olympic Dam copper/uranium deposit on Roxby Downs station, 80 kilometres north east of Woomera. This deposit, one of the world's largest known accumulations of metals, lies about 300 metres below the surface. The Olympic Dam deposit has proven reserves of around 580 million tonnes of ore containing 12 million tonnes of copper, 350,000 tonnes of uranium, 350 tonnes of gold and 2800 tonnes of silver. Underground mining commenced at Olympic Dam in 1986, with a major expansion of the plant completed in 1998. The mine is serviced by Roxby Downs, a modern purpose-built town of over 4,000 people located ten kilometres from the Olympic Dam site.

The Gawler Craton, which underlies 440,000 square kilometres of central South Australia including the whole of the Gawler Ranges region, is highly prospective for many minerals. With promising new data available from the results of extensive airborne geophysical surveys conducted over the last few years as part of the State Government's South Australian Exploration Initiative (SAEI), large areas have recently been taken up with mineral exploration licences.


Western Mining Crorporation

Casting copper anodes in the Olympic Dam smelter

8.4 Water

Water or lack of it, presented serious problems for the early explorers of the Gawler Ranges and the north-west. In contrast, those who followed closely in the footsteps of the explorers were more interested in the grazing potential of the land and did not, at the outset, seem particularly concerned by the very limited natural waters in this region. As mentioned elsewhere, this attitude probably reflects the general lack of understanding at that time of the arid Australian environment, its resources and its limitations including the almost total lack of surface water in most locations and its predisposition to devastating droughts.

In contrast to the Far North, where the discoveries of the GAB springs at the western and southern margins of the GAB provided a springboard for further exploration and pastoral settlement, and where the Desert Rivers system provided intermittent but sometimes quite extensive surface water supplies, surface and groundwater in the Gawler Ranges was singularly lacking.

In 1839 Eyre, who had found no springs or permanent waters at all in his crossing from Streaky Bay, also remarked on the lack of watercourses in the Gawler Ranges. From the earliest times, pastoralists had to rely on the few transient rock holes for stock water and much effort and cost was expended in the construction of wells and later large earth tanks in an effort to secure better water supplies. Groundwater was particularly elusive and few reliable and abundant supplies were found. During dry times, stock in increasing numbers were forced back onto the few permanent water supplies, whether wells or ground tanks, often with devastating impacts on the surrounding vegetation. While these impacts did not go unnoticed by the more astute pastoralists, there was usually little opportunity to move stock during drought due to a general the lack of water throughout the country, including along stock routes.

It has been estimated that there are currently only about a dozen wells in the whole of the Gawler Ranges that have sufficient supplies of stock quality water capable of being piped to other locations, and that many properties have little or no useable underground water.

The lack of natural surface catchments and the paucity of groundwater supplies had two significant impacts on the development of water infrastructure in the Gawler Ranges. One was the development of a large number of earth tanks or dams on leases. These dams were typically situated in natural depression or within shallow watercourses, often with a network of catch drains radiating from them to augment catchment potential. Today it is estimated that there are over 1,000 dams on pastoral leases within the Gawler Ranges Soil Conservation District but only about 100 bores. These numbers provide striking evidence of the paucity of underground water supplies in the Gawler Ranges.

The other response to the lack of surface or groundwater was the development by the Government of a series of water tanks or reservoirs along the network of Stock Routes that ran across and through the Gawler Ranges and north-west country. On Stock Route 11, the 240 kilometre-long main stock route which ran westwards through the Gawler Ranges from Port Augusta, the Government constructed 14 tanks or catchments, generally spaced so that travelling stock did not have to go more than two days without water. This route ran almost due west from Iron Knob to Hiltaba, and from there to Murat Bay. Interestingly, today's main road through the Gawler Ranges from Iron Knob to Hiltaba via Nonning, Mount Ive and Yardea follows almost exactly the route of Stock Route 11.

Similar water catchments were constructed along three other stock routes that connected with Route 11 in the Gawler Ranges. These were Route 15, which ran 150 kilometres from Hiltaba to Kingoonya; Route 17, from Nonning running 110 kilometres south west past Coralbignie and Buckleboo tank to the mallee country between Wudinna Hill and Kyancutta; and Route 18 which started near Corunna and ran south-west for 75 kilometres to the edge of the farming country east of Kimba.

These stock routes and associated water supply points were mainly intended to service stock travelling either to the stock holding reserves at Port Augusta, or between the Gawler Ranges and the developing farming country of Eyre Peninsula.

The Government tanks in the Gawler Ranges were basically of two types: iron rainsheds (catchment roofs) that supplied above ground galvanized iron tanks; or masonry underground tanks that were sometimes roofed and fed from man-made surface drains via a smaller catch tank that acted as a silt trap.

In the north-west, the lack of surface water presented similar problems for early pastoral expansion. However, there was more success in finding groundwater, and many wells and later bores were successfully completed throughout the area north and north-west of Port Augusta. Depths to groundwater ranged from five metres to more than 150 metres with very variable salinity. Many were used for stock water purposes.

Stock routes were also a feature of the north-west, with the 400 kilometre-long Route 9 stretching from Port Augusta to Tarcoola via Kingoonya. This route ran east of Lake McFarlane and then swung to the west, north of Island lagoon and Lake Gairdner. As in the Gawler Ranges, the Government provided waters along this route, however the better availability of groundwater meant that there was less dependence on roofed tanks or drain fed underground tanks, with more than half of the 14 locations supplied with water from wells or reservoirs.

Surface water is generally more plentiful in the east and north east, and several large creeks contain waterholes that were very important during the early years of exploration and settlement. These included Pernatty Creek and the Elizabeth (the latter the depot for several exploration parties including those of Babbage, Warburton and Stuart), and ephemeral lakes to the north including Lake Richardson, Lake Campbell and Lake Koolymilka. When filled, in good years, these were capable of holding water for up to two years. The floodout of Millers Creek also provides large areas of canegrass swamps on Parakylia and Roxby Downs that become inundated to shallow depths after infrequent heavy rainfall events.

8.5 Transport and Communications

From the 1860s onwards, transport movement from the Gawler Ranges was principally eastwards to Port Augusta, mainly due to the difficulties involved in crossing the wide strip of sand and mallee country to the south and west of the Gawler Ranges. While stock were walked into the Gawler Ranges from stations on the west coast from the 1840s for winter grazing, regular movement of goods by wagon and team was very much to the east, along what was considered one of the best natural roads in the back country. Today the main public road access through the Gawler Ranges from Iron Knob through to Hiltaba follows closely the original alignment.

In the 1870s, four tracks led south from the western Gawler Ranges to Streaky Bay and Venus Bay on the West Coast. All these tracks had to traverse the 30 mile strip of mallee and sand that separates the Gawler Ranges from the West Coast country, and teams were only able to tackle them with very light loads. Teams were dependent on rock holes for water, and when these dried during summer or at times of drought, all these tracks were impassable and wheeled traffic from the western Gawler Ranges had no alternative but to use the Yardea to Port Augusta road.

Mail contracts into the Gawler Ranges commenced from Port Augusta in 1864, with initial horse mails going as far as Coralbignie, 160 kilometres west. In about 1870, the mail run was extended to Yardea, and in 1876 the first mail coach worked the Yardea mail run. In the 1890s, a branch service from Thurlga to Moonarie was established to service properties west of Lake Gairdner. In 1907, the first motor mails into the Gawler Ranges commenced, signalling the beginning of the end of the horse-drawn mail coaches.

The first official mail run into the country north of Port Augusta commenced in 1876, initially using horses but soon converting to a light coach. This mail followed the established route via Euro Bluff, Whittata, and Pernatty Stations to the Elizabeth Creek, about 180 kilometres north of Port Augusta. In 1879, the mail was extended from the Elizabeth to Coondambo, with another branch to Andamooka, and in 1884 the main mail run was further extended from Coondambo to Kingoonya. The discovery of gold at Tarcoola in 1890 resulted in a large influx of miners and in 1901 the first coach mail arrived at Tarcoola.

By 1878, bullock teams were carting fencing and other gear north from Port Augusta to stations all over the north-west. At that time, the track north was still via Pernatty and the Elizabeth, very much following the route taken during initial exploration of the country 20 years previously. In 1885, the government constructed a new route from Tent Hill north of Port Augusta directly north to a point near Pimba, cutting over 40 miles (65 kilometres) from the journey, and establishing the route still largely followed by today's Stuart Highway.

Completion of the Great Northern Railway from Port Augusta to Oodnadatta in 1891 provided a valuable, though expensive, transport link for the more northerly pastoral stations such as Mount Eba, Parakylia and McDouall Peak. Prices of £5 per ton for wool cartage from Mount Eba to the rail at Coward Springs applied in the 1890s, with rail freight to Port Augusta still to be added.

The erection of a telephone line from Port Augusta to Tarcoola in 1904, and the construction of the Transcontinental Railway from Port Augusta to Kalgoorlie in 1915-17, transformed freight and communications links for the towns and pastoral communities along the route of the new railway. The ability to send stock and wool to market by rail would have had profound positive benefits to a pastoral industry still recovering from the devastating years of the late 1890s and early 1900s. The social benefits provided by a telephone connection both within the north-west community and to the outside world, and the ability for people living and working in the north-west, to at last travel relatively quickly and safely by rail across this daunting landscape would have been enormous.

8.6 Towns and Settlements

There are eight towns and settlements in the Gawler Ranges Planning area. Four of these were established to support nearby mining operations, two as railway service centres, one to support the defence industry and one principally as a tourism and road traffic service centre.

8.6.1 Pimba

Pimba, six kilometres south of Woomera and at the junction of the Stuart Highway and road to Roxby Downs and Andamooka, was established originally as a workers' camp during the construction of the Transcontinental railway from Port Augusta to Kalgoorlie between 1915 and 1917. It was also used for accommodation for workers during the construction of Woomera in the 1950s. It remained a railway settlement and service centre with around a dozen houses until the 1960s when the railway operations closed. In the mid-1960s, the site of Pimba was finally excised from Arcoona station, and pegged as a potential township. Today Pimba is a tourist stop on the Stuart Highway, with the main attraction being Spud's Roadhouse, established in about 1970.

8.6.2 Andamooka

Andamooka developed following the discovery of opal by Andamooka station workers in 1930. It became a supply and service centre for the many miners' camps that were scattered over a wide area, and is well known for its many colourful characters and unconventional lifestyles. The township is located 32 kilometres east of Roxby Downs. With a floating population of up to 600 people, Andamooka is now the largest out-of Council settlement in South Australia. Due to its proximity to Roxby Downs and the dramatic growth of outback and four-wheel-drive-based tourism over the last few years, the provision of tourism services is becoming an increasingly important economic factor for Andamooka.

8.6.3 Glendambo

Glendambo was established in 1981 as a new tourism service centre on the realigned Stuart Highway, replacing Kingoonya which was bypassed by the new highway. At 600 kilometres from Adelaide, 300 kilometres from Port Augusta and 250 kilometres from Coober Pedy, it is well situated to provide a fuel, food and rest stop for transport operators and tourists. The township has a population of approximately 30 people who are mostly employed at the hotel-motel complex, one of the two roadhouses or the caravan park.

8.6.4 Kingoonya

The township of Kingoonya was established in the early 1900s as a railway construction support town during the development of the Transcontinental railway. Kingoonya is located midway between Coober Pedy and Port Augusta on the route of the original Stuart Highway. At this point, the old highway swung north to Coober Pedy and Alice Springs, while other roads ran west to Tarcoola, and south through the Gawler Ranges to the Eyre Peninsula and the West Coast. During the days of the notorious unsealed Stuart Highway, Kingoonya was a very welcome 'rest and revive' stop for travellers and truck drivers, and a popular venue for local pastoralists. The population never exceeded about 20 people, but the town boasted a post office and well-stocked store, a school and golf course, a railway station and cattle trucking yards, and an excellent hotel in the Outback style. Today, the township is intact but practically deserted.

8.6.5 Tarcoola

Tarcoola was originally surveyed and laid out into 330 allotments following the discovery of gold at the Tarcoola and Glenloth goldfields in 1893. Tarcoola serviced the goldfields and later the remote sheep stations of the north-west (Mulgathing, Commonwealth Hill, Bulgunnia) as they developed. With the completion of the Transcontinental railway in 1917, Tarcoola became an important service and refuelling point, originally for steam and later diesel locomotives, and a crew change location.

Tarcoola received a new lease of life during the late 1970s with the construction of the new standard gauge Alice Springs railway line which left the Perth line just west of the township. Tarcoola became the base for construction operations on this line, with a revitalized school, hospital, church, community hall and police station. By 1998 railway operations were transferred to Port Augusta, and Tarcoola was progressively closed down. Today, only a couple of people live permanently in the town, and even the old Wilgena Hotel has closed.

8.6.6 Woomera

The Woomera Village, as it was known, was established in about 1950 to accommodate and support scientists, technicians and workers who came to the Woomera Rocket Range following its development as a joint Australian and British (later European) rocket and weapons testing facility. Woomera had the luxury of a grid power connection from Port Augusta and an abundant water supply sourced from the Morgan-Whyalla pipeline. With a relative abundance of good water, Woomera was able to develop and maintain extensive amenity and shelter plantings and many grassed recreation areas within the township.

During Woomera's heyday in the mid 1960s, its population swelled to around 5,000 people, with an influx of people from the UK, Australia, Germany, Italy and France as part of the multi-country ELDO partnership which sought to develop and launch the Europa satellite launch vehicle. Later, Woomera was the accommodation and support base for the nearby Narrungar tracking station operated by the US Government. This facility closed in 2000, and today Woomera's population has declined to under 200. Until 1982 Woomera was a restricted town, but is now open to the public. Facilities are still at an impressive level, and today Woomera's unique history, facilities and rocket museum attracts many visitors.

8.6.7 Iron Knob

The township of Iron Knob was surveyed and established to support the iron ore mining that began there in 1880. Until 1896, the mines were operated by the Mount Minden Mining Co but in 1896 were taken over by the BHP Co and the township grew progressively as a company town, with a peak population of over 2,000 people. Mining has now ceased at Iron Knob and the nearby Iron Monarch, and much of the town's infrastructure has been removed. Administration of the town has been handed back to the small resident population of about 200 people.

8.6.8 Roxby Downs

The town of Roxby Downs was established as a greenfield development in 1987 to provide permanent accommodation and all modern town facilities for the staff and workers employed at the nearby Olympic Dam copper/uranium mine. The town is 80 kilometres from Woomera and was established as a fully planned facility from the start. WMCR, the operator of the mine, effectively built the majority of the township, with the State Government providing all of the community facilities. With a population of over 4,000 people, Roxby Downs is now the largest town in South Australia north of Port Augusta.

Roxby Downs has facilities common to most large modern towns, including an Area school, an integrated Health Service (Hospital), modern shopping, hotel, motel and restaurant facilities, and a $10 million cultural precinct. The recently completed $2 billion expansion of Olympic Dam included a major expansion of Roxby Downs township with over 400 additional houses being built.

Under the terms of the Roxby Downs (Indenture Ratification) Act 1982, the town was created as a municipality with an Administrator. The original intent was that Roxby Downs would eventually have sufficient population (originally envisaged to grow to 9,000 people) to financially sustain a fully independent Local Government operation. Current population is approximately 4,200 people, and due to a number of factors including improved mining technology, it is now unlikely that the original population estimates will be reached in the medium term. With the provision of municipal services operating at an annual loss of up to $950,000 (subsidized equally by WMCR and the State Government), it is unlikely that the town will be financially able to make the transition to an independent Local Government operation in the short-term.