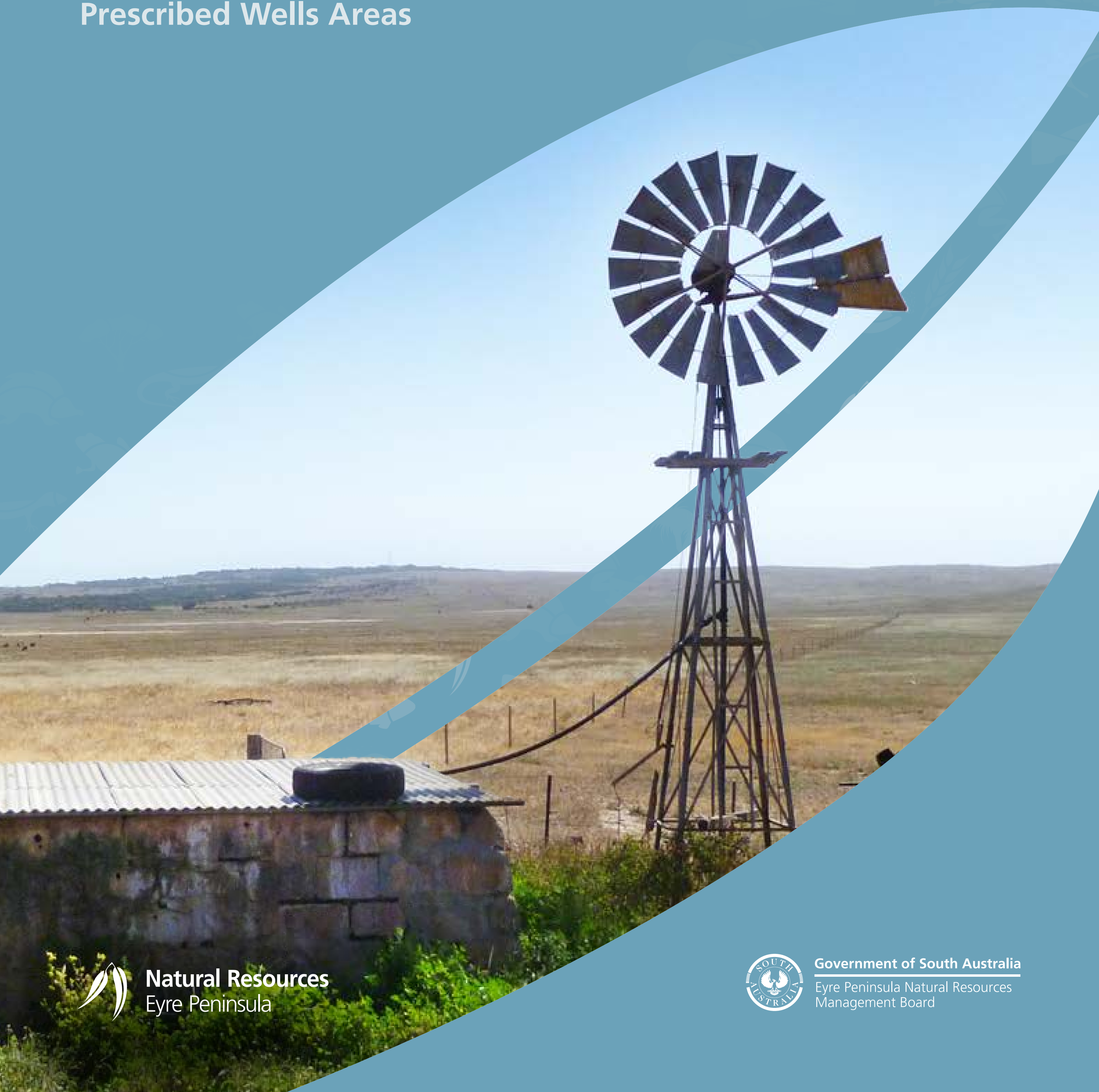
Water Allocation Plan

for the Southern Basins and Musgrave Prescribed Wells Areas



Natural Resources Eyre Peninsula

Government of South Australia
Eyre Peninsula Natural Resources Management Board

Produced by: Eyre Peninsula Natural Resources Management Board
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for the Southern Basins and Musgrave Prescribed Wells Areas

Natural Resources Management Act 2004

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for the
Southern Basins and Musgrave Prescribed Wells Areas

I, Ian Hunter, Minister for Sustainability, Environment and Conservation, hereby adopt this Water Allocation Plan pursuant to section 80(3)(a) of the *Natural Resources Management Act 2004*

Ian Hunter Date: 28/6/16

Minister for Sustainability, Environment and Conservation

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1 Introduction

1.1 Background to the Water Allocation Plan

This document is the *Water Allocation Plan for the Southern Basins and Musgrave Prescribed Wells Areas.* It replaces the *Water Allocation Plan for the Southern Basins Prescribed Wells Area* (Government of South Australia 2001a) and the *Water Allocation Plan for the Musgrave Prescribed Wells Area* (Government of South Australia 2001b).

The Water Allocation Plan (the Plan) for the Southern Basins and Musgrave Prescribed Wells Areas (PWAs) is made pursuant to Chapter 4, Part 2, Divisions 2 and 3 of the *Natural Resources Management Act 2004* (SA) (the Act) and is consistent with the objects and requirements of this Act. The Act requires the Eyre Peninsula Natural Resources Management Board (the Board) to prepare and review a Plan for each of the prescribed water resources in its region. The Act allows a Plan to relate to more than one prescribed water resource. Both the Southern Basins and the Musgrave PWAs are covered by this single Plan.

This Plan has been produced using the *Intergovernmental Agreement on a National Water Initiative* (NWI) (COAG 2004) as a guiding document. The NWI is an agreement signed by all state and territory governments and the Australian Government. It sets out principles on which freshwater resources should be shared for the benefit of communities, freshwater ecosystems and economic development. These principles relate to matters such as the need for science based water planning, adaptive management of the resource, open engagement with communities, secure water rights for consumptive purposes, and the provision of environmental water requirements.

This Plan is a statutory document that provides for the management of water property rights through a legally robust licensing regime, the apportioning of available water in a resource for water dependent ecosystems and for consumptive purposes, the management of the taking and use of water and the transfer of water rights between users. This Plan aims to achieve an equitable long-term balance between environmental, social and economic needs for water. This Plan also sets out those water affecting activities that are in addition to those contained in the Natural Resources Management Plan for the Eyre Peninsula NRM Region (the Regional NRM Plan, Das 2009). These extra controls on water affecting activities apply only to the prescribed resources covered by this Plan. These extra controls operate together with those contained in the Regional NRM Plan.

This Plan does not encompass the management, take and use of surface water or water in watercourses as these resources are not prescribed at this time.

The Board has commissioned significant research and investigation including groundwater modelling, to further develop the knowledge and understanding of the region's groundwater systems. This knowledge underpins the ability to adaptively manage the groundwater resources over time.

1.1.1 Objectives

By managing the take and use of water from the groundwater resources within the Southern Basins and Musgrave PWAs within the limits set by the Plan, this Plan aims to meet the following objectives:

- Allocate water for licensed consumptive purposes, including (but not limited to) public water supply, irrigation, recreation and mining, in a manner that allows for the long term viability of the water resource
- Minimise the impact of the authorised taking of water on:
    - other water resources (adjacent or overlying water resources)
    - groundwater dependent ecosystems (GDEs)
    - existing users of groundwater
- Minimise the risk of seawater intrusion due to the taking of authorised water in coastal aquifers
- Minimise the risk of increasing groundwater salinities from the authorised taking of water.

1.1.2 History of Groundwater Management

There is a scarcity of potable water resources in Eyre Peninsula. Groundwater is the principal source of water for the public water supply system, irrigation and stock and domestic use (with the exception of Whyalla which is supplied by water resources from the River Murray). Of the region's groundwater resources, those located within the Southern Basins and Musgrave PWAs are of sufficient quality and quantity to provide significant volumes for public water supply, irrigation, industrial, recreational and stock and domestic use.

Pursuant to section 41 of the *Water Resources Act 1976*, the Southern Basins and Musgrave Proclaimed Regions were declared in 1987 (DPC 2012) to better manage and protect groundwater resources used for Eyre Peninsula's public water supplies. Subsequently Water Allocation Plans were developed for the Southern Basins and Musgrave PWAs, pursuant to Part 7, Division 3 of the *Water Resources Act 1997* (SA), to regulate the use of the groundwater resources. These plans replaced the document titled *County Musgrave and Southern Basins Water Resources Management Objectives and Policies 1997* (Government of South Australia 2001a&b). The inaugural Water Allocation Plan for the Southern Basins PWA was adopted on 31

December 2000, and the inaugural Water Allocation Plan for the Musgrave PWA was adopted on 2 January 2001. The Board reviewed these Plans in accordance with the requirements of the Act and subsequently made the decision to amend both plans and to combine them into a single plan. This combined Plan supersedes any and all previous Plans.

Pursuant to the transitional provisions in the *Water Resources Act 1997* (Schedule 3), the original proclamations for the Southern Basins and Musgrave Proclaimed Regions made on 12 March 1987 remain in force, as though the Proclaimed Regions were declared as the Southern Basins and Musgrave PWAs under the *NRM Act 2004* (Schedule 4, Part 18).

1.2 Prescribed Resources

1.2.1 Southern Basins Prescribed Wells Area

The Southern Basins PWA covers an area of 870 km^2 and comprises all or parts of the Hundreds of Lincoln, Wanilla, Lake Wangary, Uley, Sleaford and Flinders (Fig. 1). The main townships near the PWA are Port Lincoln and Coffin Bay.

The PWA can be described as having an undulating topographic relief which is typical of the ancient dune systems which formed about 100 000 years ago, with dramatic coastal cliffs rising to around 140 m above the sea. Inland, there are generally large enclosed depressions with elevations that are often close to sea level, while basement rock outcrops form topographic highs up to 200 m above sea level. The dunes are capped by a very hard calcrete layer with a soil cover that is thin or absent over large areas. The groundwater resources of the Southern Basins PWA are found within the Quaternary Bridgewater Formation sedimentary aquifer, the Tertiary Sands sedimentary aquifer and the Basement fractured rock aquifer.

There are limited surface water resources because of the permeable nature of the dune landscape, which readily absorbs most of the rainfall. The few surface water features that do persist include: Sleaford Mere, a permanent saline lake which is the surface expression of the regional watertable, and Big Swamp and Little Swamp which are ephemeral lakes which generally contain brackish water derived from surface water flows originating in catchments predominantly external to the PWA. The water regime of both Big and Little Swamps are not dependent on groundwater but they contribute water to the regional groundwater system during periods of overflow. However there are some red gum communities adjacent to the swamps that are likely to be dependent on the shallow groundwater.

1.2.1.1 Southern Basins Rainfall

The Southern Basins PWA has a Mediterranean climate with a pronounced 'wet winter' period between May – August during which mean monthly rainfall exceeds mean monthly potential evaporation. Rainfall ranges between 337 and 1023 mm/yr with a long-term (1907 to 2014) average annual rainfall of 569 mm being recorded at the Bureau of Meteorology (BoM 2012) Westmere rainfall station (BoM Station 18137, Fig. 1). Figure 2 displays the annual rainfall recorded at Westmere station located 19 km south west of Port Lincoln within the Southern Basins PWA. The red line in Figure 2 displays the cumulative deviation from average annual rainfall, an upwards trend represents a period where rainfall was above the long-term average rainfall, and a downward trend indicates a drier than average period. It can be seen that rainfall was generally below average from the 1930s until 1950, with a pronounced wetter period from 1951 to 1992. Since 1992 rainfall at this station has generally been below the long-term average, and the annual variability has not been as extreme as it was historically. Whilst there have been years of above average rainfall since 1992, none have experienced rainfall in excess of 700 mm, whereas historically, annual rainfall totals were frequently greater than 700 mm. These data indicate that above or below average rainfall trends can persist for up to 40 years, highlighting the need for effective and adaptive management of these water resources.

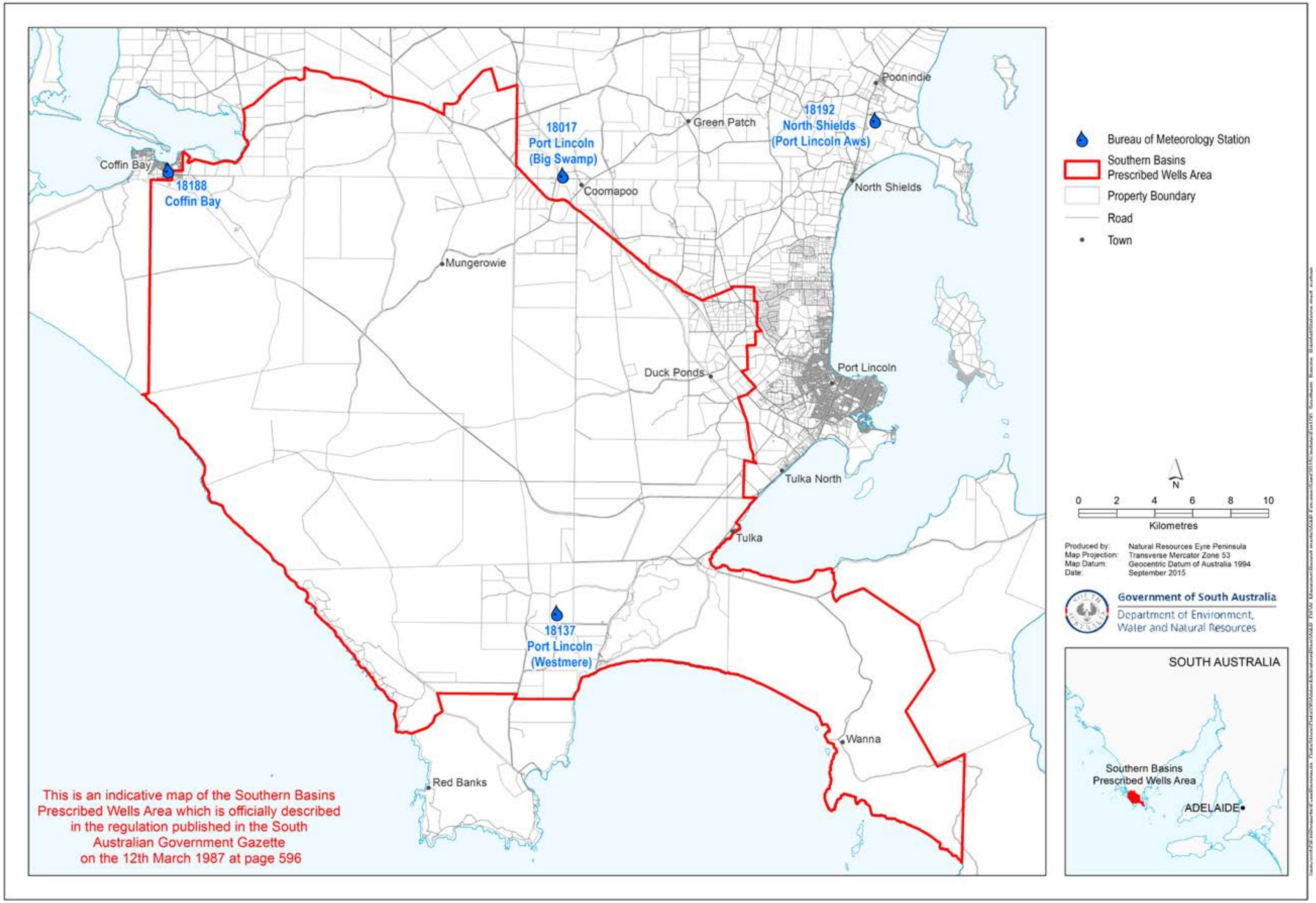


Figure 1 Indicative map of the Southern Basins Prescribed Wells Area

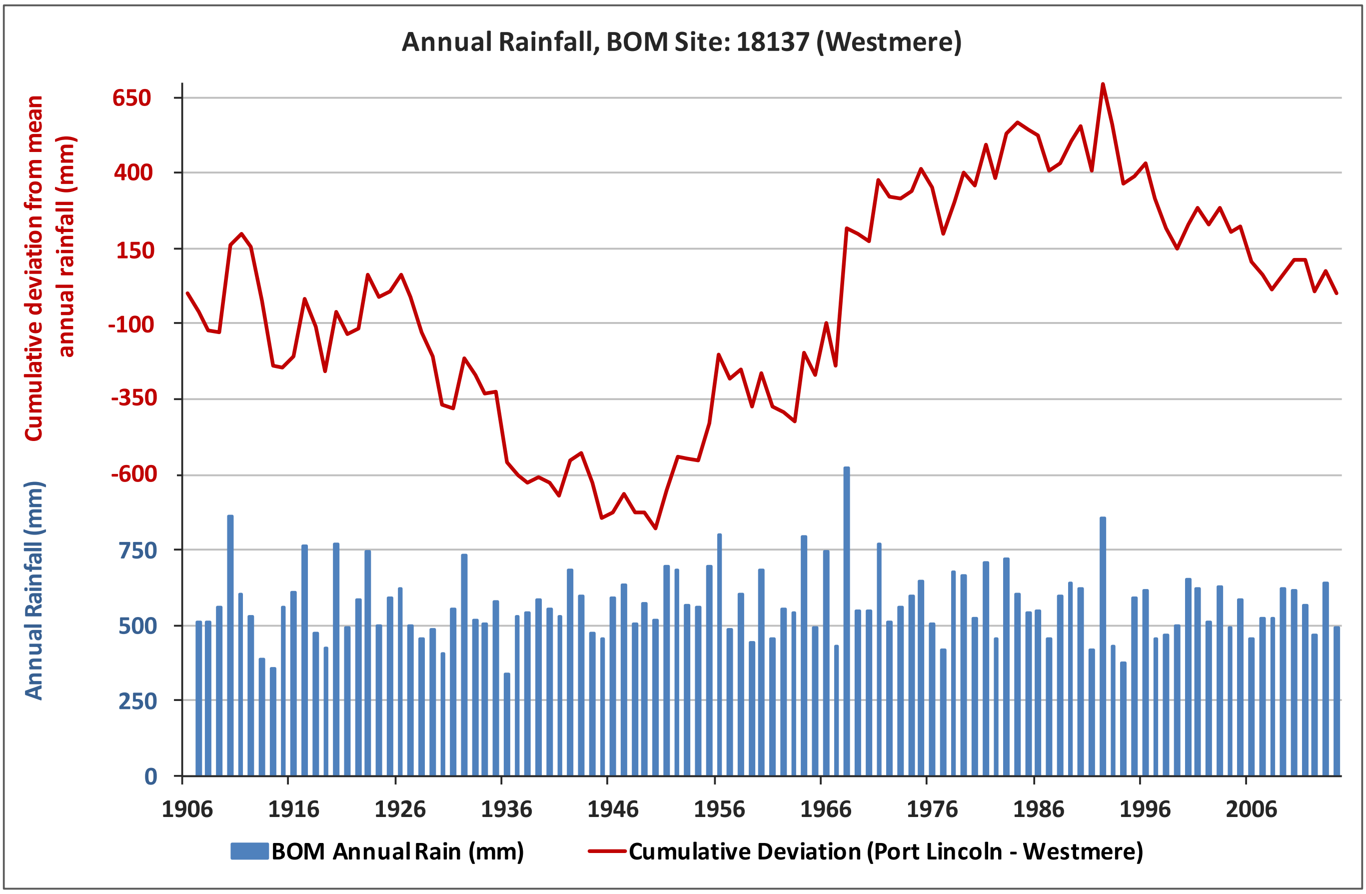


Figure 2 Annual rainfall and cumulative deviation from mean annual rainfall for BoM station 18137 (Westmere)

1.2.2 Musgrave Prescribed Wells Area

The Musgrave PWA spans an area of 3 595 km^2 and comprises the Hundreds of Colton, Talia, Tinline, Squire, Ward, Hudd, Kappawanta, Blesing, Way, Pearce, and Haig. The PWA encompasses the townships of Elliston and Bramfield (Fig. 3).

The Musgrave PWA is underlain largely by ancient coastal dune systems or similar geomorphology as those found in the Southern Basins PWA. The predominant land use is stock grazing, although some cropping occurs where soils are of suitable quality, depth and areal extent.

Rainfall varies significantly across the Musgrave PWA with rainfall decreasing towards the east and north. The groundwater resources of the Musgrave PWA are found within the Quaternary Bridgewater Formation sedimentary aquifer, the Tertiary Sands and Jurassic sedimentary aquifers and the Basement fractured rock aquifer.

Similar to the Southern Basins PWA, there are limited surface water resources in the Musgrave PWA. The Lake Hamilton and Lake Newland wetland systems are near-coastal permanent and seasonal ephemeral lakes that receive local surface drainage. These wetlands are directly connected to the local shallow groundwater systems and represent the surface expression of the watertable.

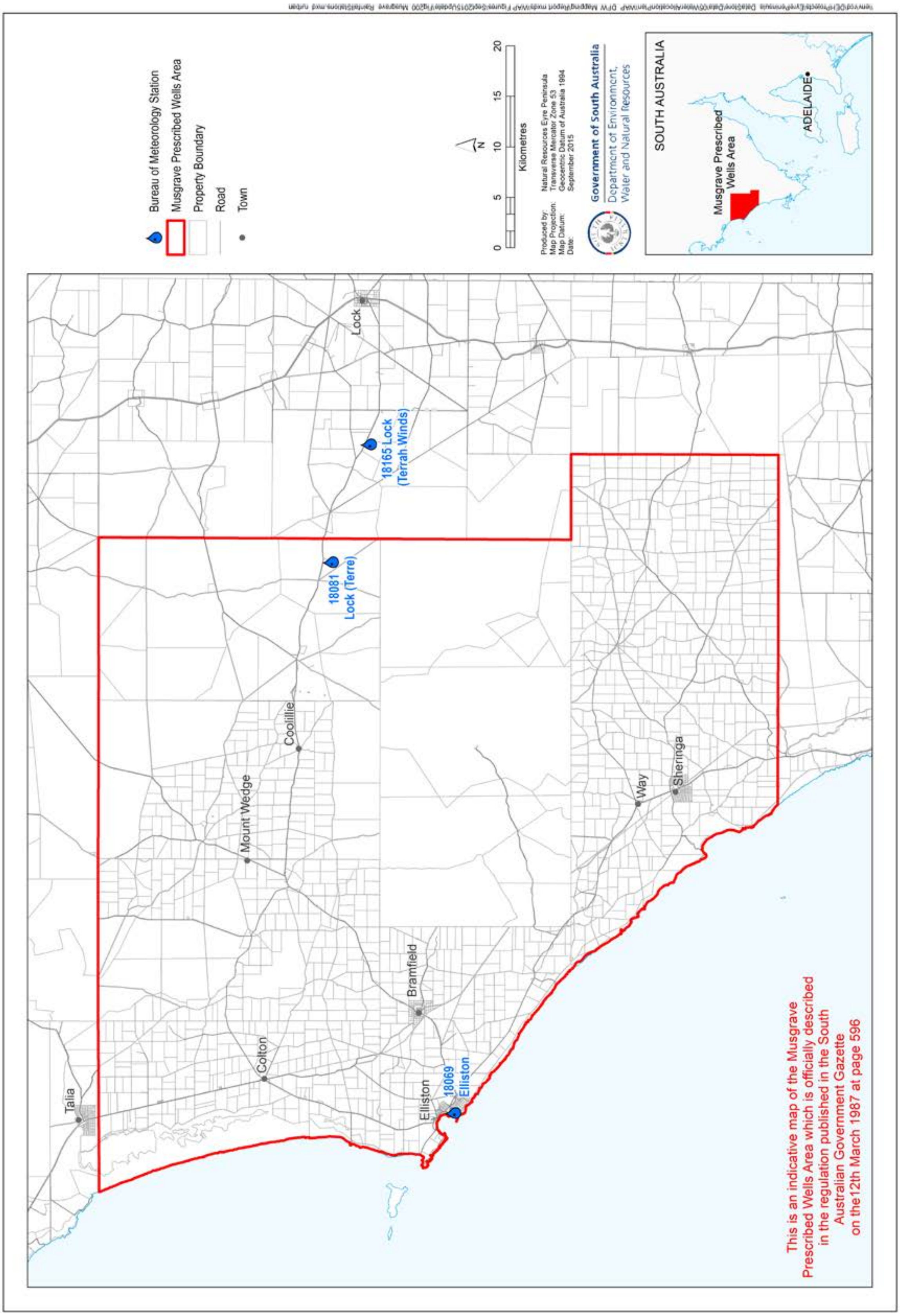


Figure 3 Indicative map of the Musgrave Prescribed Wells Area

1.2.2.1 Musgrave Rainfall

The Musgrave PWA experiences a climate with typically hot, dry summers and mild, wet winters. Rainfall is winter-dominant and ranges between 181 and 675 mm/yr with a long-term (1889 to 2014) average annual rainfall of 430 mm at Elliston (BoM Station 18069, Fig. 3). Mean monthly rainfall exceeds mean monthly potential evaporation only in June and July.

Figure 4 displays the annual rainfall recorded at Elliston (BoM Station 18069), which is located 3 km south east of the Elliston township. The red line in Figure 4 displays the cumulative deviation from average annual rainfall.

An upward trend represents a period where rainfall was above the long-term average rainfall, and a downward trend indicates a drier than average period. Prior to 1960, rainfall was variable. A significantly wetter period followed until 1981, which was then followed by a period of below average rainfall until 2009. Since 2009, rainfall has been consistently above the long-term average. These data indicate that above or below average rainfall trends can persist for up to 25 years, highlighting the need for effective and adaptive management of these water resources.

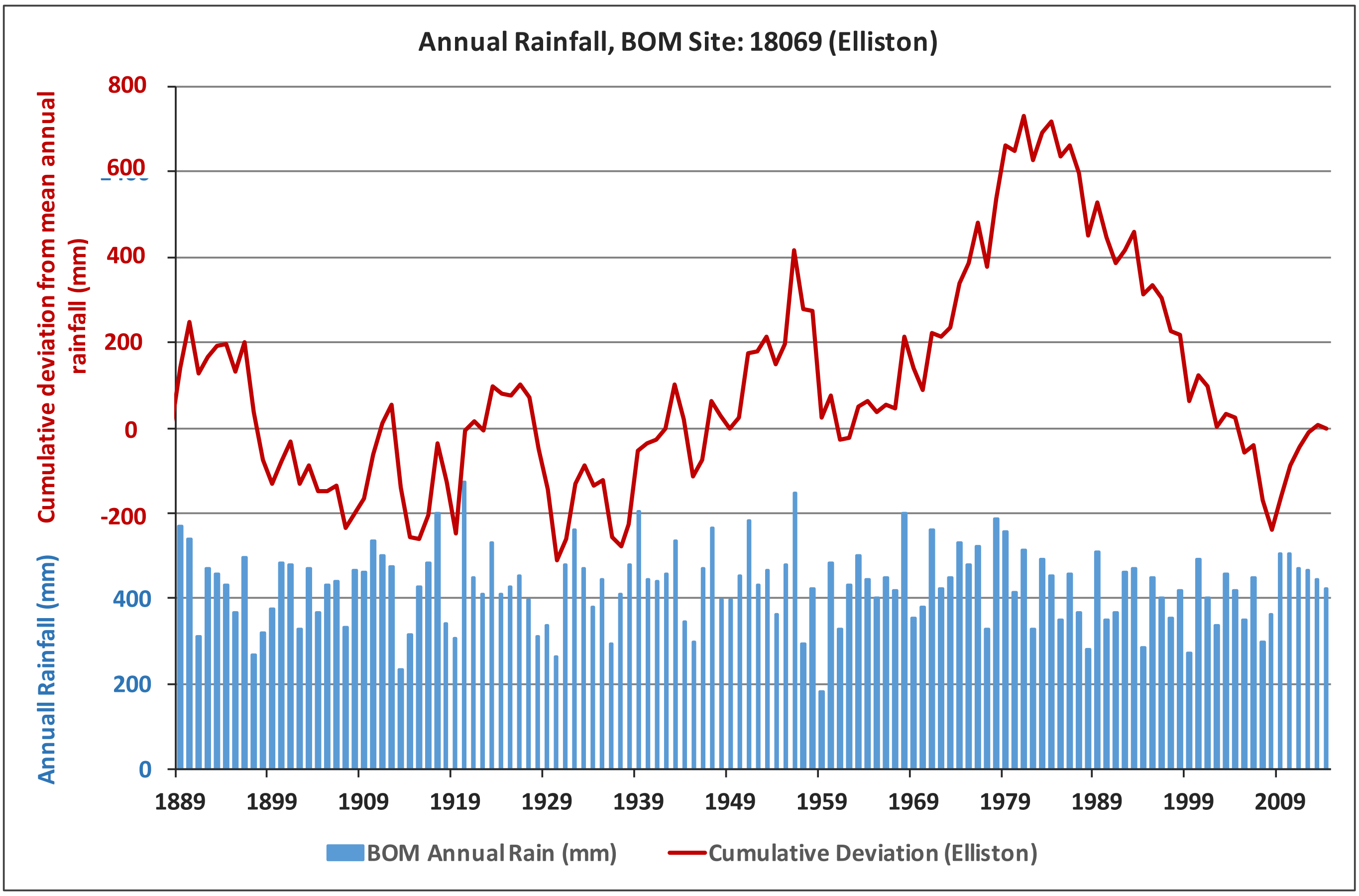


Figure 4 Annual rainfall and cumulative deviation from mean annual rainfall for BoM station 18069 (Elliston)

1.3 Hydrogeology of the Prescribed Wells Areas

A scientific understanding of the hydrogeology of the PWAs and its application in developing this Plan has been derived from three main sources:

- DFW, 2011b, *'A Literature Review of the Southern Basins and Musgrave Prescribed Wells Area Hydrogeology and Ecology'*, Report, June 2011, Department for Water, South Australia
- Stewart et al, 2012, *Science Support for the Musgrave and Southern Basins Prescribed Wells Areas Water Allocation Plan*, Technical Report 2012/15, Department for Water, South Australia
- Stewart, 2013, *Additional Science Support for the Eyre Peninsula Water Allocation Plan*, Technical Report 2013/19, Department of Environment, Water and Natural Resources, South Australia.

1.3.1 Regional Geological Setting

The Eyre Peninsula is underlain at the regional-scale by some of the oldest basement rocks found in Australia which were formed about 2 000 million years ago. These rocks form a very stable platform known as the Gawler Craton, upon which much younger sediments have been deposited in a variety of environments over the past 200 million years, as described in Table 1 (Drexel et al. 1993).

1.3.2 Aquifers

Groundwater resources of the PWAs are found primarily within the Quaternary Limestone aquifer, the Tertiary Sands aquifers, the Jurassic aquifer and Basement fractured rock aquifers.

Within the Southern Basins and Musgrave PWAs, the most important aquifer is the Quaternary Limestone aquifer. These groundwater systems contain low-salinity and brackish groundwater because they are readily recharged by incident rainfall due to the thin soil cover and permeable nature of the limestone. The freshwater resources found in the Quaternary Limestone aquifers across the PWAs are vital for the security of Eyre Peninsula's water supply.

Table 1 Sediments of the Gawler Craton, the aquifers of Eyre Peninsula

Period	Age (years)	Environment	Sediment/rock type	Geological Unit
Quaternary	Up to 1 million	Wind deposited dunes (aeolian)	Limestone	Bridgewater Formation
Tertiary	30 – 40 million	Rivers and lakes (fluvial)	Sands and clays	Wanilla Formation, Poelpena Formation
Jurassic	150 – 200 million	Rivers and lakes (fluvial)	Sands and clays (carbonaceous)	Polda Formation
Early Proterozoic	1700 – 2000 million	Basement	Quartzite, gneiss, schist, iron formation, marble, granite gneiss, amphibolite	Hutchison Group, Lincoln Complex
Archean	2300 – 2700 million	Basement	Gneiss, granite gneiss	Sleaford Complex

1.3.2.1 Quaternary Limestone Aquifer

The Quaternary Limestone aquifer (Bridgewater Formation) forms a generally thin veneer over the older Tertiary sediments and is continuous across both PWAs. The limestone consists of sand size shell fragments, calcareous algae fragments and quartz grains that were deposited as large barrier dunes on ancient shorelines during the Pleistocene era when sea levels were higher than today. These sediments are known to be over 130 m thick in parts of the Uley South Basin. Wind-blown sand sheets form extensive veneers extending well inland from the coast. The Bridgewater Formation varies from consolidated to unconsolidated across the formation where karstic features are common. Surface solution features such as sink holes are ubiquitous and enhance rainfall recharge via preferential flow.

The majority of groundwater extractions from within the PWAs are from the Quaternary Limestone aquifer (section 5). Groundwater salinities range between 400 and 1 800 milligrams per litre (mg/L), and well yields are generally high, ranging between 5 and 50 litres per second (L/sec).

Maps of the Quaternary Limestone aquifer watertable elevations indicate that groundwater movement is predominantly in a southerly flow direction in the Southern Basins PWA (Fig. 5), and a westerly to southwesterly flow direction in the Musgrave PWA (Fig. 6) where in both instances groundwater discharges to the sea. Hydrochemical evidence indicates that groundwater in the Quaternary Limestone aquifer in the Uley South Basin is less than 30 years old.

The saturated thickness (Figs. 7 and 8) and porosity of the Quaternary Limestone aquifer, and hence the amount of groundwater stored within the aquifer, varies spatially throughout the prescribed areas. Generally speaking, the saturated thickness is small in the areas of highest elevation, which are furthest inland (e.g. the Lincoln North and Polda Basins), but increases toward the coast. There are considerable areas over which the saturated thickness is less than 10 m, which suggests low robustness of these aquifers when compared to many of the groundwater systems across South Australia. The Quaternary Limestone aquifer saturated thickness can also vary rapidly over time as the watertable fluctuates in response to rainfall.

The Quaternary Limestone aquifer has been subdivided into discrete basins, which contain significant volumes of groundwater in storage. These basins are separated by areas where the Quaternary Limestone aquifer is dry or has a very small saturated thickness (which would result in poor connectivity).

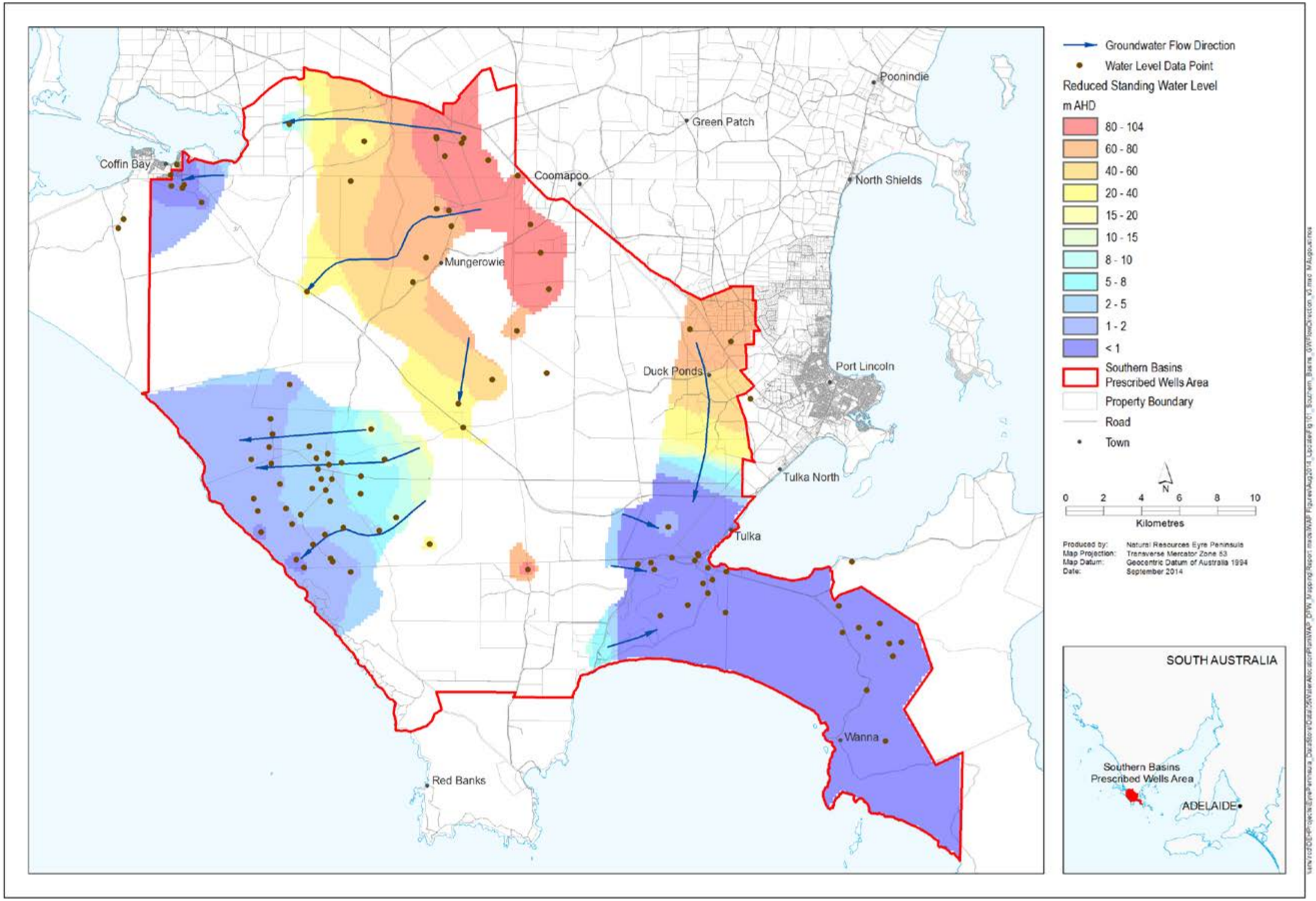


Figure 5 Indicative groundwater flow direction for the Quaternary Limestone aquifer in the Southern Basins PWA

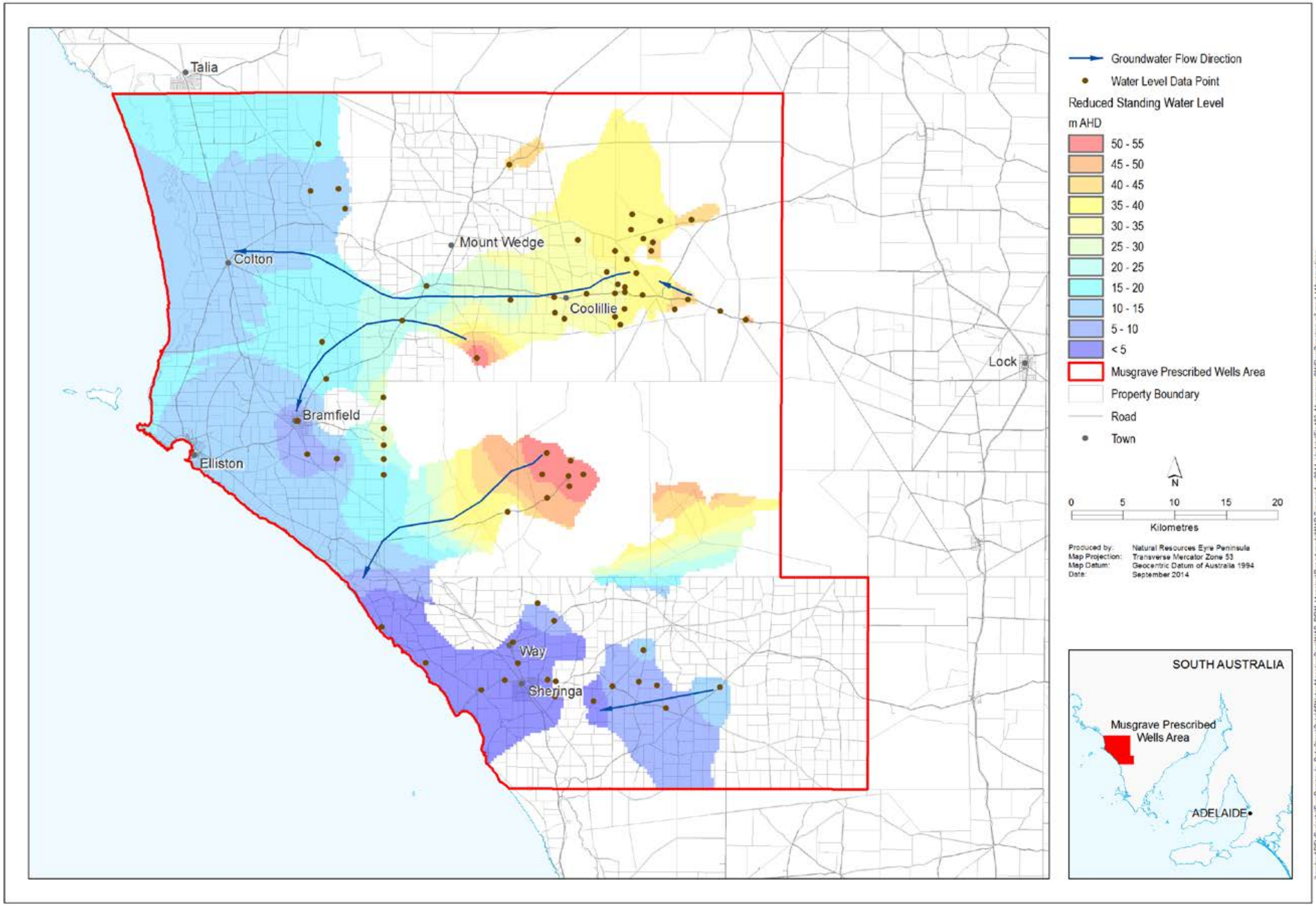


Figure 6 Indicative groundwater flow direction for the Quaternary Limestone aquifer in the Musgrave PWA

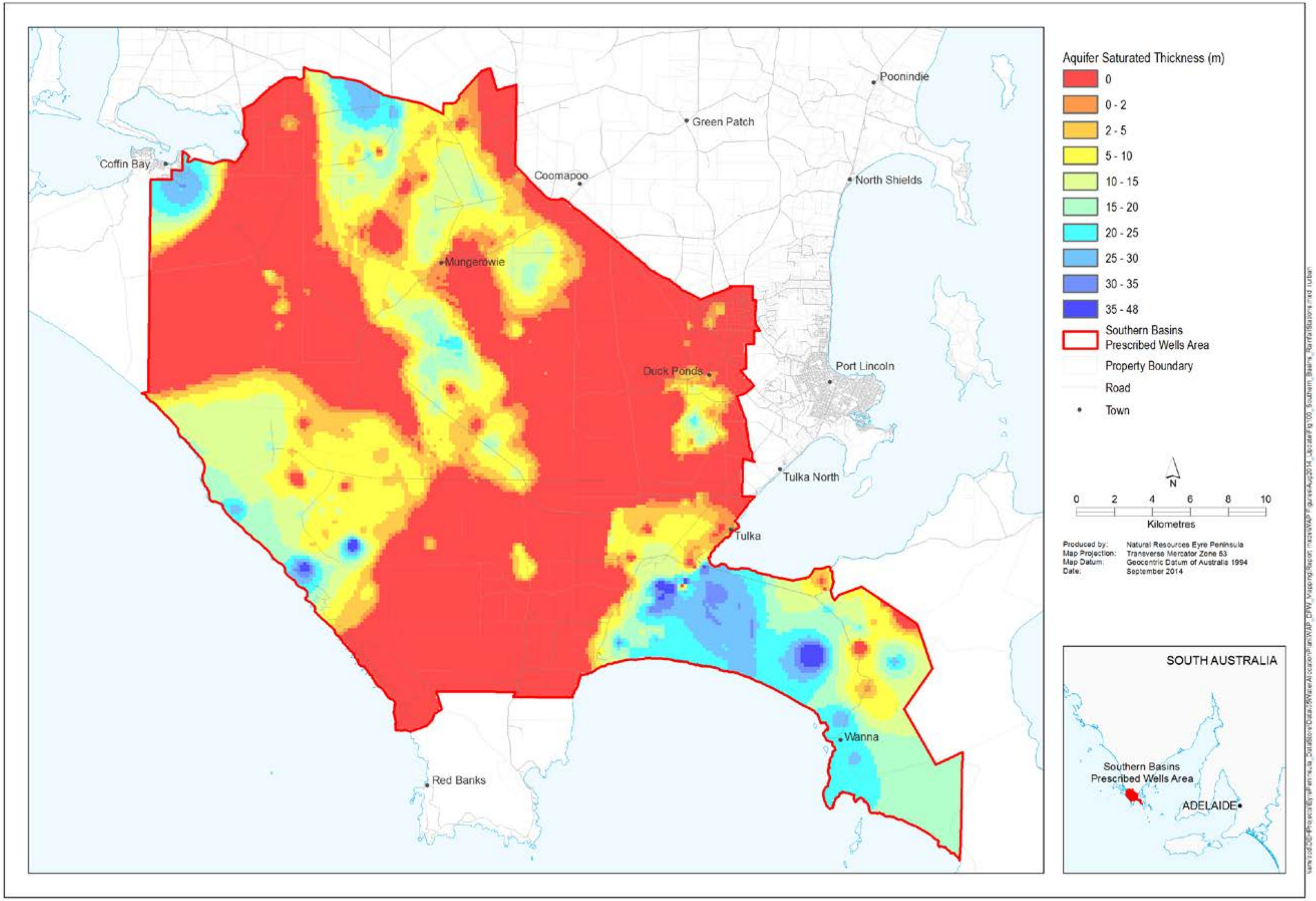


Figure 7 Saturated thickness of the Quaternary Limestone aquifer in the Southern Basins PWA

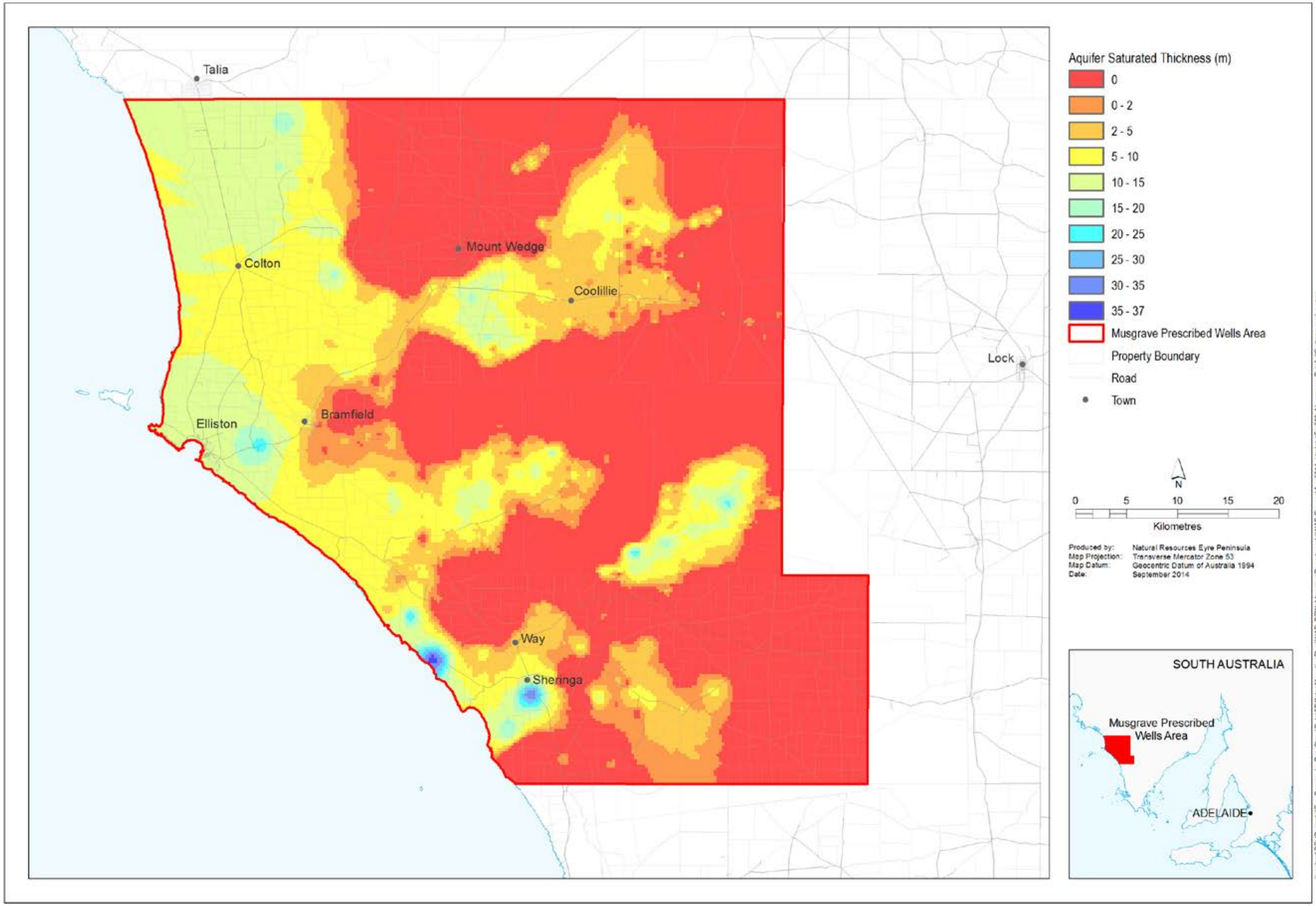


Figure 8 Saturated thickness of the Quaternary Limestone aquifer in the Musgrave PWA

1.3.2.2 Tertiary Sands Aquifer

The Tertiary Sands aquifer extends over most of the PWAs and consist of unconsolidated fine to medium grained quartz sand, silt and clay. The Tertiary Sands aquifer is generally separated from the overlying Quaternary Limestone aquifer by a low-permeability clay confining layer.

Hydrochemical evidence indicates the Tertiary groundwater is generally older than 35 years, and perhaps is of the order of 3 000 to 6 500 years old.

Within the Southern Basins PWA, the Uley Formation confining layer is a sequence of sandy clay and clayey sands that separates the underlying sand aquifer from the overlying Quaternary Limestone aquifer. This formation is observed to be absent in some areas within the Southern Basins PWA. Where the overlying Quaternary sequence is absent or dry, the Uley Formation can contain the watertable. The Wanilla Formation forms the Tertiary Sands aquifer in the Southern Basins PWA and consists of fine-grained to gravelly fluvial sands and clays interbedded with variable thicknesses of silty carbonaceous clay at its base. It generally infills troughs in the underlying basement surface. It has a maximum thickness of around 80 m. Groundwater salinities range between 500 and 7 500 mg/L and well yields are generally less than 0.5 L/sec.

The Poelpena Formation forms the Tertiary Sands aquifer in the Musgrave PWA and consists of poorly sorted, fine to coarse grained quartz sand, silt and clay. Clays at the top of the unit act as a confining layer between the sand layers and the overlying Quaternary Limestone aquifer. The formation has a highly variable thickness, but commonly exceeds 100 m in the eastern part of the Musgrave PWA. Salinities range between 240 and 35 000 mg/L with well yields averaging about 1.3 L/sec.

1.3.2.3 Jurassic Aquifer

The Jurassic aquifer occurs primarily in the east of the Musgrave PWA in a deep east-west trending trough that occurs below the Tertiary sediments. It consists of fine-grained sands, sandstone and conglomerate of the Polda Formation that is up to 86 m thick. Groundwater salinities within this sequence are high, ranging between 30 000 and 50 000 mg/L.

The Jurassic aquifer does not occur in the Southern Basins PWA.

1.3.2.4 Basement Aquifers

There are two broad groups of Basement aquifers.

The Hutchison Group comprises a basal quartzite sequence, which is overlain by carbonate, banded iron formation, amphibolite and schist (all of which are subject to mineral exploration). The Hutchison Group is comprised of crystalline rocks of mainly very low permeability. However, during the Tertiary weathering process, local solution cavities have formed near the surface in some of the carbonate rocks (marble and calcsilicate gneiss).

Rocks of the Lincoln Complex and Sleaford Complex consist mainly of very low permeability granite, granite gneiss and amphibolite. Although there is limited data, hydrochemical evidence indicates that Basement groundwater is generally older than 35 years (maybe older than 1 000 years), and salinities range between 500 and 8 000 mg/L.

The Basement fractured rock aquifers typically show irregular yields and salinities that are difficult to predict due to the highly variable nature of the joints and fractures that control groundwater mixing and movement. The Basement aquifer around Green Patch (immediately north-west of the Southern Basins PWA) has been developed for irrigation purposes, although the volumes extracted are likely to be low.

1.3.3 Aquifer Recharge and Discharge Processes

Recharge and discharge processes provide inputs and outputs to the groundwater systems. These processes occur naturally where recharge to aquifers can occur from rainfall and surface water, and discharge from aquifers can occur by evapotranspiration, lateral flow to the sea and discharge to surface water features such as swamps and wetlands. Human activities can also contribute to these processes, through managed aquifer recharge schemes or extraction by pumping from wells (including extraction for public water supply).

Natural groundwater discharge processes are ongoing and continuous (Freeze and Cherry 1979), whereas groundwater recharge is quite variable as it is primarily controlled by rainfall duration and intensity, the nature of the soil profile, and the underlying geology. Vegetation is also understood to be significant for recharge and discharge processes in terms of interception of rainfall by the leaf canopy, and transpiration of water in the soil profile or shallow watertable by the root system.

Groundwater level trends give an indication of the state of the balance between the discharge processes and the variable recharge inputs from rainfall. Water level declines indicate that discharges from the aquifer (which may also include extraction) are higher than the recharge entering the aquifer. Conversely, water level rises are observed when recharge exceeds the groundwater discharge processes.

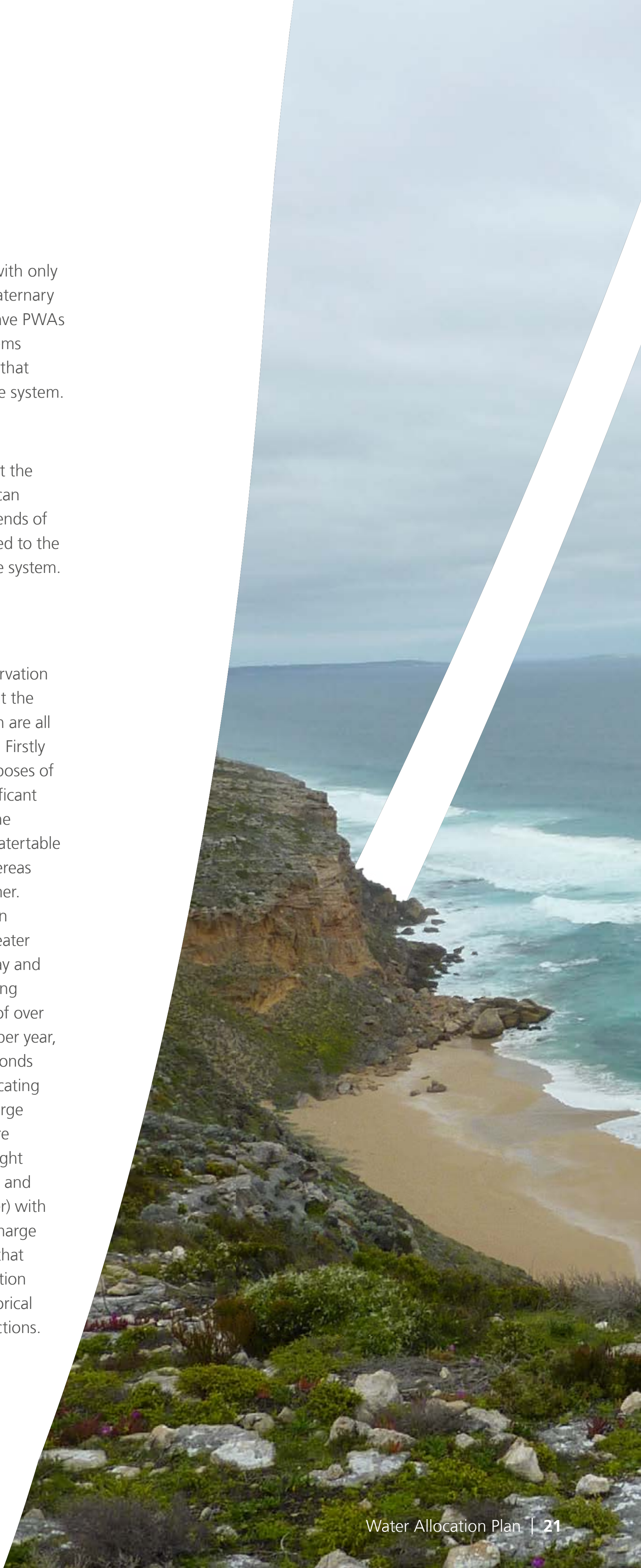
In general, systems without extraction tend to remain in steady state (i.e. long-term water levels remain static with only seasonal variations observed). However within the Quaternary Limestone aquifers of the Southern Basins and Musgrave PWAs declines in water level are commonly observed in systems where no extraction from wells is occurring indicating that natural discharges are in exceedance of recharge to the system.

1.3.3.1 Quaternary Aquifer Recharge

Because the Quaternary Limestone aquifer is exposed at the ground surface or covered only by thin skeletal soils, it can readily receive recharge from rainfall. The water level trends of the Quaternary Limestone aquifer are strongly connected to the rainfall, and more importantly the recharge entering the system.

1.3.3.1.1 Recharge of Uley South in the Southern Basins PWA

Figure 9(b) displays typical water level trends from observation wells ULE135 and ULE196 with daily measured rainfall at the Caroona pluviometer (station number A5121004) which are all located in the centre of the Uley South Basin (Fig. 9(a)). Firstly it should be noted that although extraction for the purposes of public water supply is occurring from this area, no significant impacts from pumping trends have been observed in the recording period (Sept 2009- Sept 2014). The lowest watertable levels are generally observed in late autumn/winter whereas the highest extraction volumes generally occur in summer. Previous studies indicate that recharge occurs only when the Uley South Basin receives more than ten days of greater than 10 mm of daily rainfall between the months of May and October. Figure 9(b) demonstrates that over the recording period (Sept 2009 – Sept 2014), only about eight days of over 10 mm of rainfall between May and October occurred per year, with the exception of the winter of 2013 which corresponds to the steepest rise in the watertable level, thereby indicating that the rainfall intensity is important in providing recharge to the aquifer, not just the total volume of rainfall. Figure 9(b) further demonstrates that the watertable shows slight seasonal trends with water levels falling during summer and slowly rising during the recharge season (May – October) with maximum watertable elevations occurring after the recharge season in November. This data demonstrates evidence that water levels have a strong relationship with rainfall. Section 1.5 of this Plan provides further assessment on the historical impact on water levels from rainfall recharge and extractions.



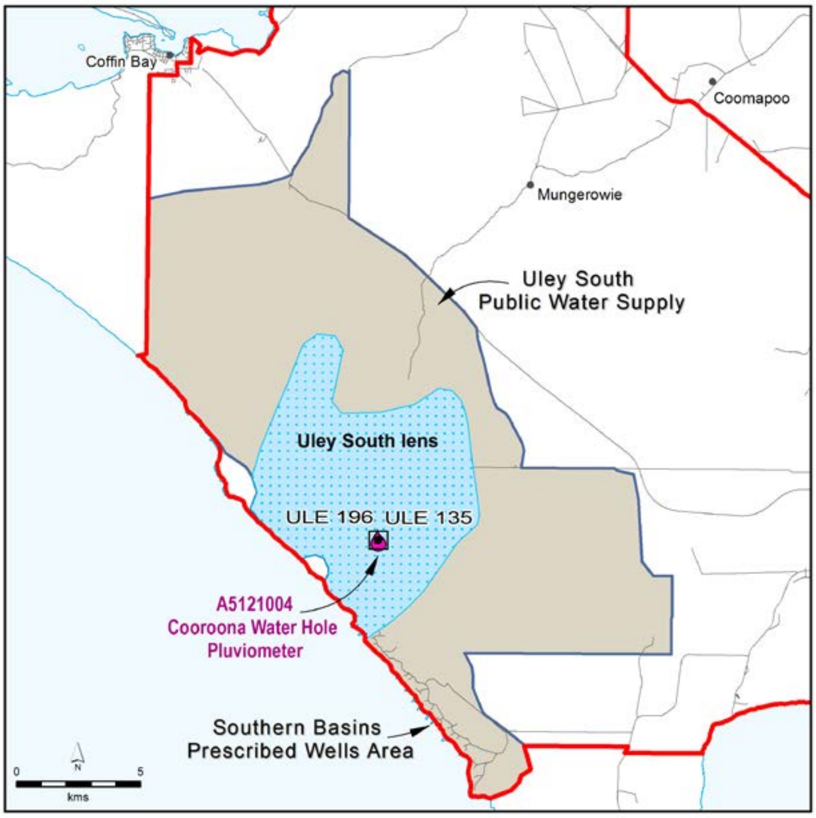


Figure 9(a) Rainfall and water level monitoring locations in Uley South

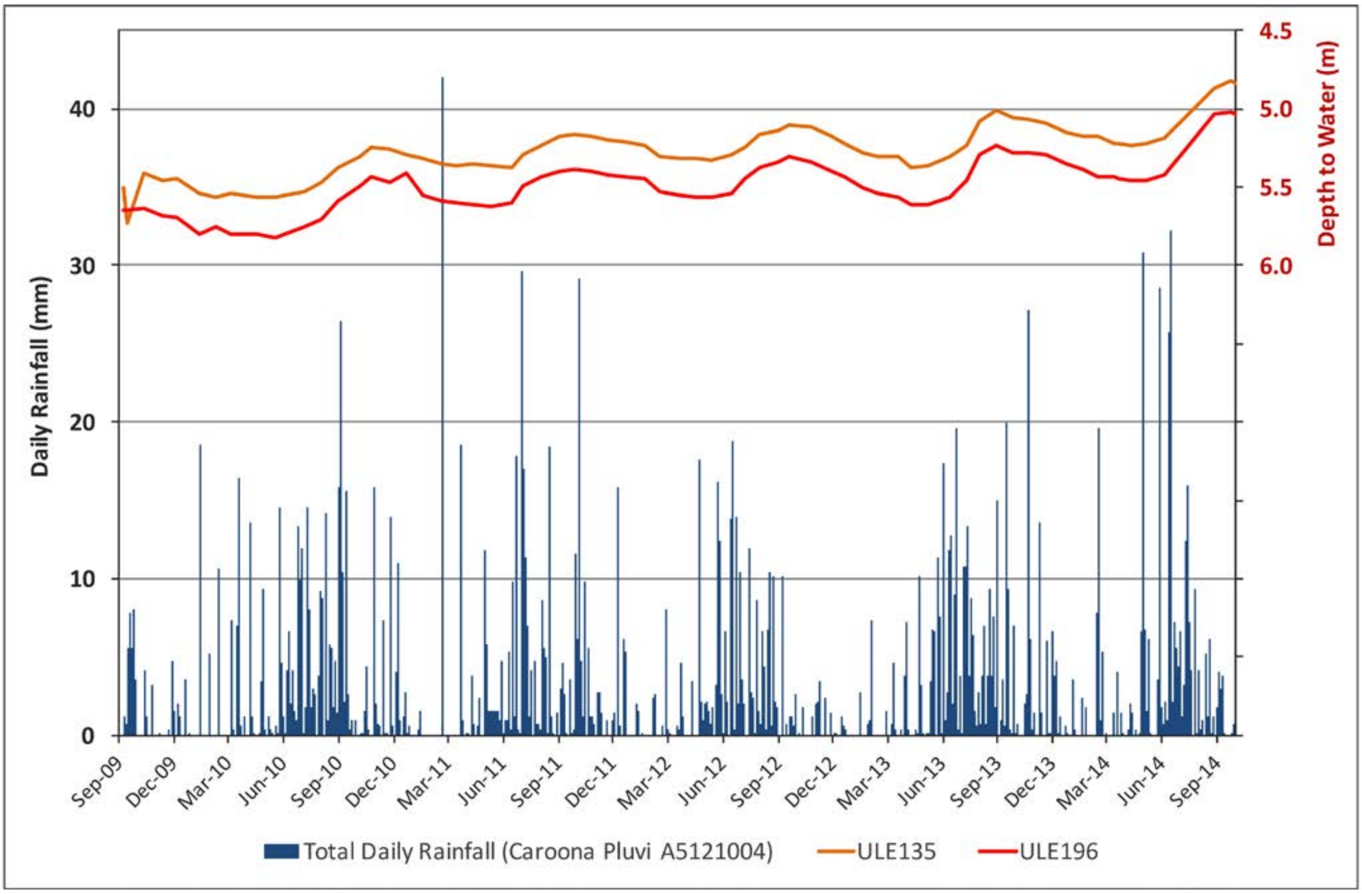


Figure 9(b) Uley South water level and rainfall correlation

1.3.3.1.2 Recharge of Polda in the Musgrave PWA

Figure 10 displays a typical water level trend from observation well SQR101 located in Polda in the Musgrave PWA, together with the monthly rainfall monitored at the Birdseye Highway pluviometer (station number A0211004) located adjacent to the well (see Fig. 16(a) for location). Figure 10 firstly indicates that the data logger and manually recorded water levels match well for the period of overlap. It also identifies that the water level responds to high rainfall events. It can be seen that when the monthly rainfall is less than 10 mm, the water level generally declines. Conversely, when rainfall is above 10 to 20 mm, a peak in water level is generally observed with a delay of approximately one month. It should be noted that the water level does not always respond to rainfall over 10 mm per month and this is most likely due to a low rainfall intensity.

Previous studies indicate that recharge only occurs in Polda when more than 60 mm of rainfall is received over a period of one month, between May and October. Figure 10 demonstrates that since August 2010 when the pluviometer was constructed, rainfall has not exceeded 50 mm in any one month between May and October, however rises in the water level trend are still observed which indicates that recharge to the aquifer occurs even when monthly rainfall is much less than 60 mm. Public water supply extractions from the Polda lens ceased in 2008 suggesting that water level responses observed in Figure 10 are primarily due to recharge and natural discharge from the system. Section 1.5 of this Plan provides further assessment of the historical impact on water levels from rainfall recharge and extractions.

As there is no evidence of regional scale lateral inflows from other nearby aquifers outside the prescribed areas, it can be concluded that the main groundwater resources within the Southern Basins and Musgrave PWAs are dependent on recharge from local rainfall as their main input, which is also the predominant control on water levels.

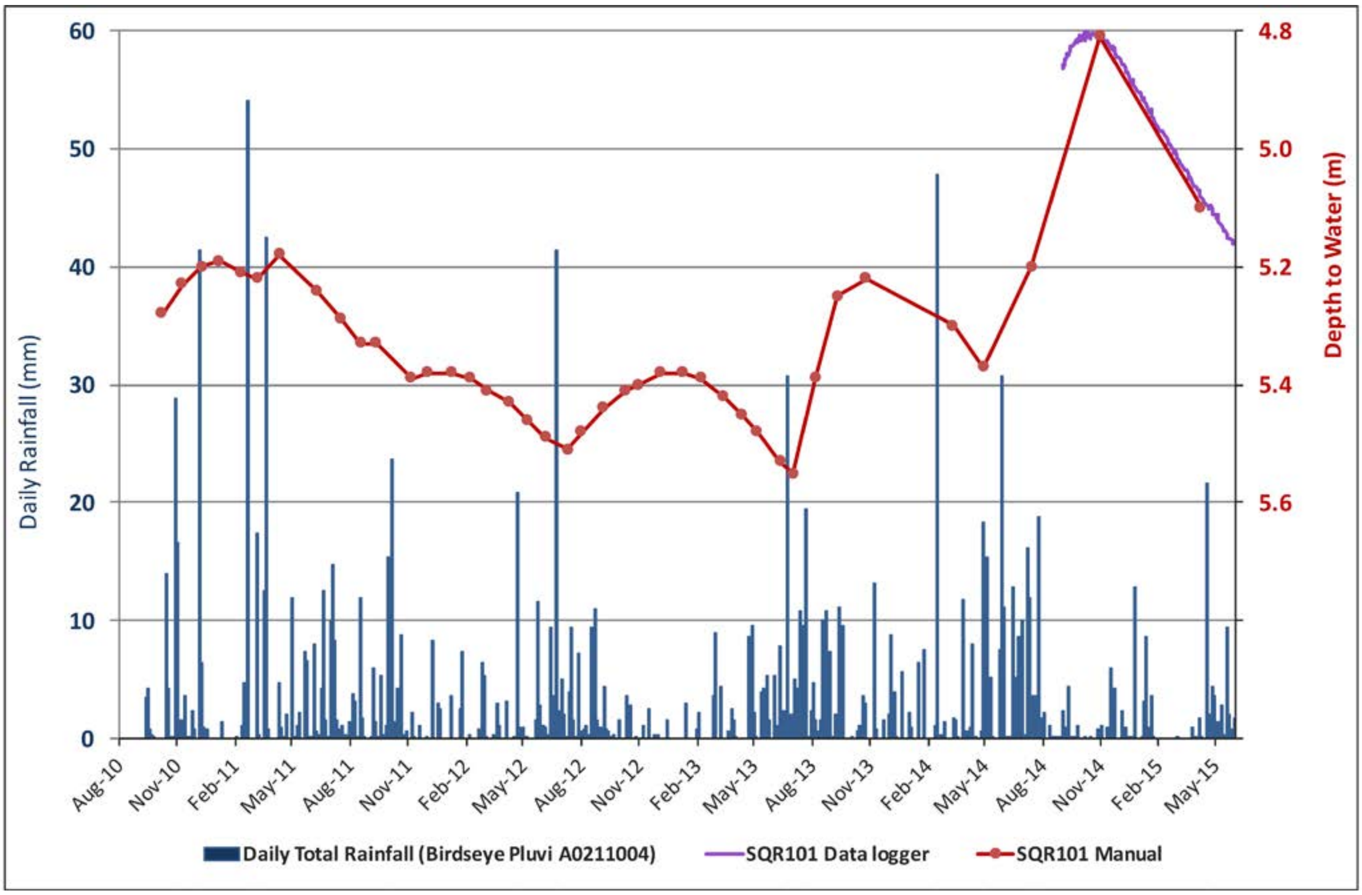


Figure 10 Polda water level and rainfall correlation

1.3.3.2 Tertiary Sands Aquifer Recharge

Where the Tertiary Sands aquifer is confined by impermeable clay, it receives no direct recharge from rainfall. High groundwater ages and a lack of water level response to rainfall suggest that this aquifer is likely to receive considerably less recharge than the overlying Quaternary Limestone aquifer. In places where the confining clay is thin or absent, the Tertiary Sands aquifer may generally receive recharge by downward leakage from the overlying Quaternary Limestone aquifer. Over the regional scale of the prescribed areas, inputs to this aquifer are not likely to vary greatly from year to year.

1.3.3.3 Jurassic Aquifer Recharge

Given the high groundwater salinity of the Jurassic aquifer, its depth below the ground surface and the fact there is no known outcrop of Jurassic sediments, it is highly unlikely that any recharge has occurred to this aquifer in modern times.

1.3.3.4 Basement Aquifer Recharge

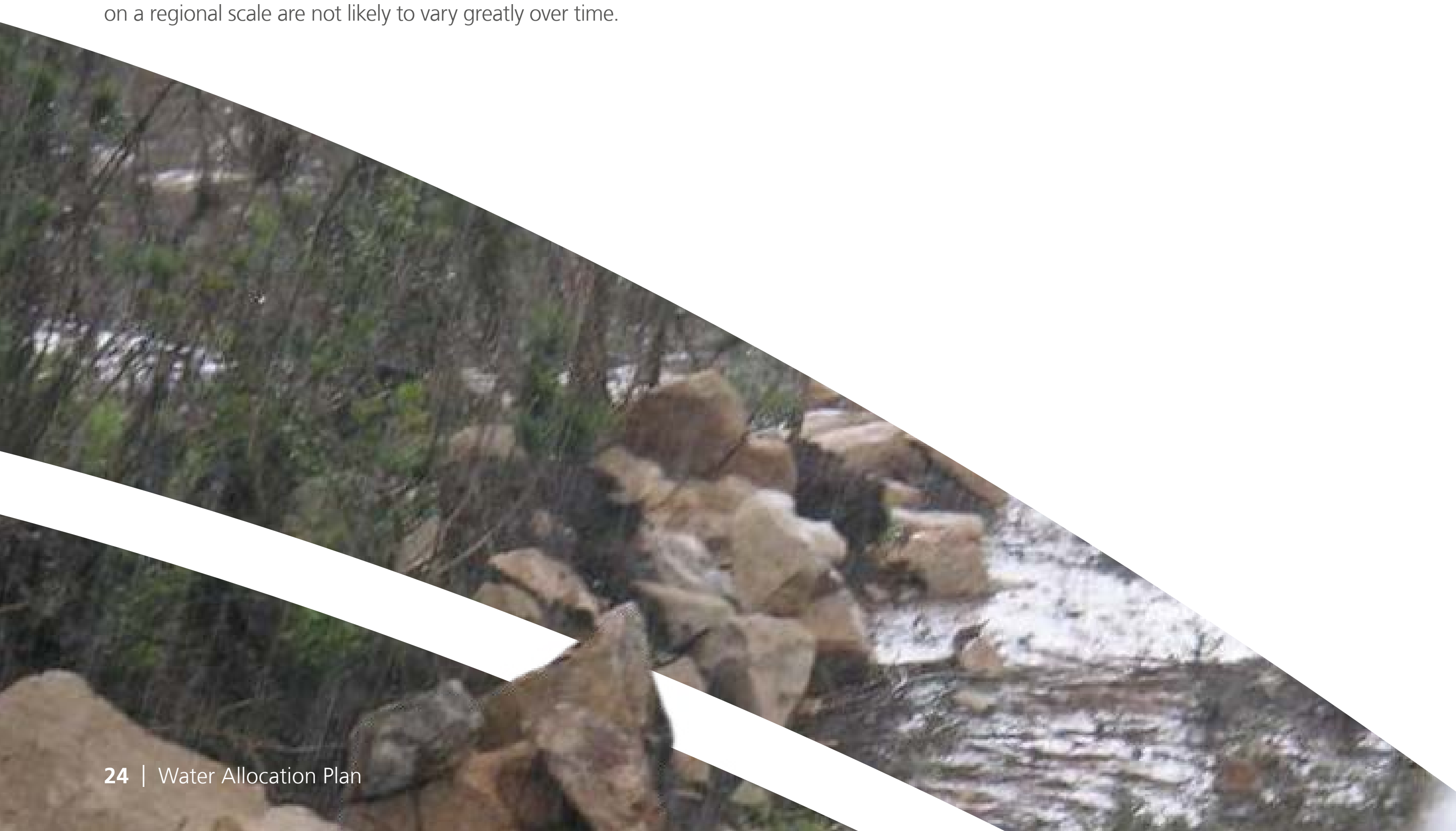
Recharge to the Basement aquifer is likely to occur in areas where basement rocks are exposed at the ground surface (e.g. in the hills around Green Patch or north of Big Swamp). The recharge rate is a function of the degree of fracturing, the composition of the rock, and the presence of any impermeable clayey weathered zone at the surface. In addition, it is possible that some vertical leakage from overlying aquifers may also occur. Because of the limited areas of outcrop, inputs to this aquifer on a regional scale are not likely to vary greatly over time.

1.3.4 Climate Change

Variable climatic patterns have been observed to have a key impact on aquifer recharge. In a recent study, Green et al. (2012) carried out detailed hydrologic modelling to evaluate the potential impact of climate change on the groundwater and surface water resources of the Eyre Peninsula. The numerical models allowed evaluation of the sensitivity of recharge to changes in rainfall and potential evaporation and to estimate the likely percentage reductions in runoff and recharge for a given reduction in rainfall.

Projected reductions in recharge have been referenced against historic climate data that were inputs to the calibrated numerical model, thereby generating baseline recharge rates (the 1990 baseline). For the Southern Basins PWA, it is projected that reductions in groundwater recharge resulting from median climate scenarios range from 11% in a 2030 climate, to 47% in a 2070 climate, relative to the 1990 baseline case. For the Musgrave PWA, the corresponding projected reductions in groundwater recharge range between 12% and 49% in a 2030 climate and a 2070 climate, respectively.

The models also project significant changes to the frequency of years that would be considered to be 'low' or 'high' recharge years. Under the least extreme climate scenarios, the frequency of years of relatively low recharge increases by 50–70% in a 2030 climate, and by 80–200% in a 2070 climate. The frequency of relatively 'high' recharge years reduces by 10–20% in a 2030 climate, and by 50–70% in a 2070 climate.



1.4 Historic Trends of Extraction

In 1922, water was first reticulated on Eyre Peninsula from the Tod Reservoir. Over the next few years, pipelines were constructed across the peninsula to supply the regional towns as far north as Ceduna. As demand grew, it was recognised that more water was needed to supplement the Tod Reservoir and consequently various groundwater supplies were added to the supply system. Uley Wanilla Basin was the first groundwater source to supplement supply, being commissioned in 1947. Over the next four decades, various basins were developed - Lincoln Basin in 1962, Polda Basin in 1963, Robinson Basin to supply Streaky Bay in 1973, Bramfield Basin to supply Elliston in 1974, Uley South Basin in 1976 and Coffin Bay Basin to supply Coffin Bay in 1986. In 2007, water from the River Murray via the Iron Knob – Kimba pipeline was added to the network. Figure 11 shows the sources and volumes of water extracted annually to meet demand and identifies when regulation, in the form of a water allocation plan, on the extraction from the groundwater resources in the PWAs was first implemented. It should be noted that the data available prior to the commencement of metering (in 2004-05) may have been estimated in some circumstances. The first point of importance to note is the rise in extraction in 1950 in response to the wool boom which occurred during 1950-51 when wool prices were almost 14 times greater than average, driven by the American demand for wool which was generated by the Korean War. This resulted in sheep numbers increasing from 96 million in 1946 to 113 million in 1950 (ABS 2015). The boom was short lived with returns in 1951-52 being half of those received in the previous year. Apart from a significant drop in demand in 1964, extraction has gradually increased; peaking in 1978 where the total water volume supplied to the peninsula was almost 15 GL. This peak in demand was due to the stock boom which saw livestock numbers escalate to record levels, only to crash after the American beef market collapsed (PIRSA 2015). After this, demand has generally been on a long-term gradual decline. Water restrictions introduced during the millennium drought in 2002 helped maintain that trend. Demand has remained relatively low since the drought, with consumers of residential water apparently continuing with water saving measures. The lowest water level use in recent years occurred in 2014 with a total demand from the public water supply system of 6.38 GL (only 43% of that consumed in 1978).

The 2008 document, *SA Water's Long Term Plan for Eyre Region*, identified that there was a fairly even split between water supplied to meet rural (52%) and township (48%) demand. Residential demand made up by far the majority of water demand in townships on the peninsula (66.5%) from the public water supply system, with recreation (7.4%) and public institution (7%) being the two following demand types (SA Water 2008). The changing patterns in extraction displayed in Figure 11 emphasise that extraction from the various resources is solely driven by the demand from the community for water. The recent data shows that as demand has decreased following the drought, the total extraction from the various resources has also decreased.

Some resources are no longer providing water for public supply. The Tod Reservoir closed in 2002 due to high salinity levels and pesticide contamination due to run off from upstream farming practices making it unsuitable for human consumption. In 2007, the Robinson Basin at Streaky Bay ceased extractions due to increasing groundwater salinity levels (DFW 2011a) and water for the town has since been supplied from the Ceduna Pipeline.

SA Water ceased extractions from the Polda Basin in 2008 due to an increasing salinity trend within the aquifer. This was followed by a Notice of Prohibition (NOP), which prohibited the take of water for public water supply from the resource for four years and following this, only allowed 3000 kL for operational maintenance of the pumps for the two years following. Extraction from this resource under the NOP was also restricted for other licensed users of the resource and was based on their maximum extraction from the resource for the period 1 July 2005 to 30 June 2008. In 2015 SA Water voluntarily relinquished its licence for extraction from the Polda Basin.

Currently, the Uley South Basin is supplying the majority of the public water supply for the Eyre Peninsula, which is supplemented by the Iron Knob-Kimba River Murray pipeline water and supplies for the local townships of Coffin Bay and Elliston being provided from local basins.

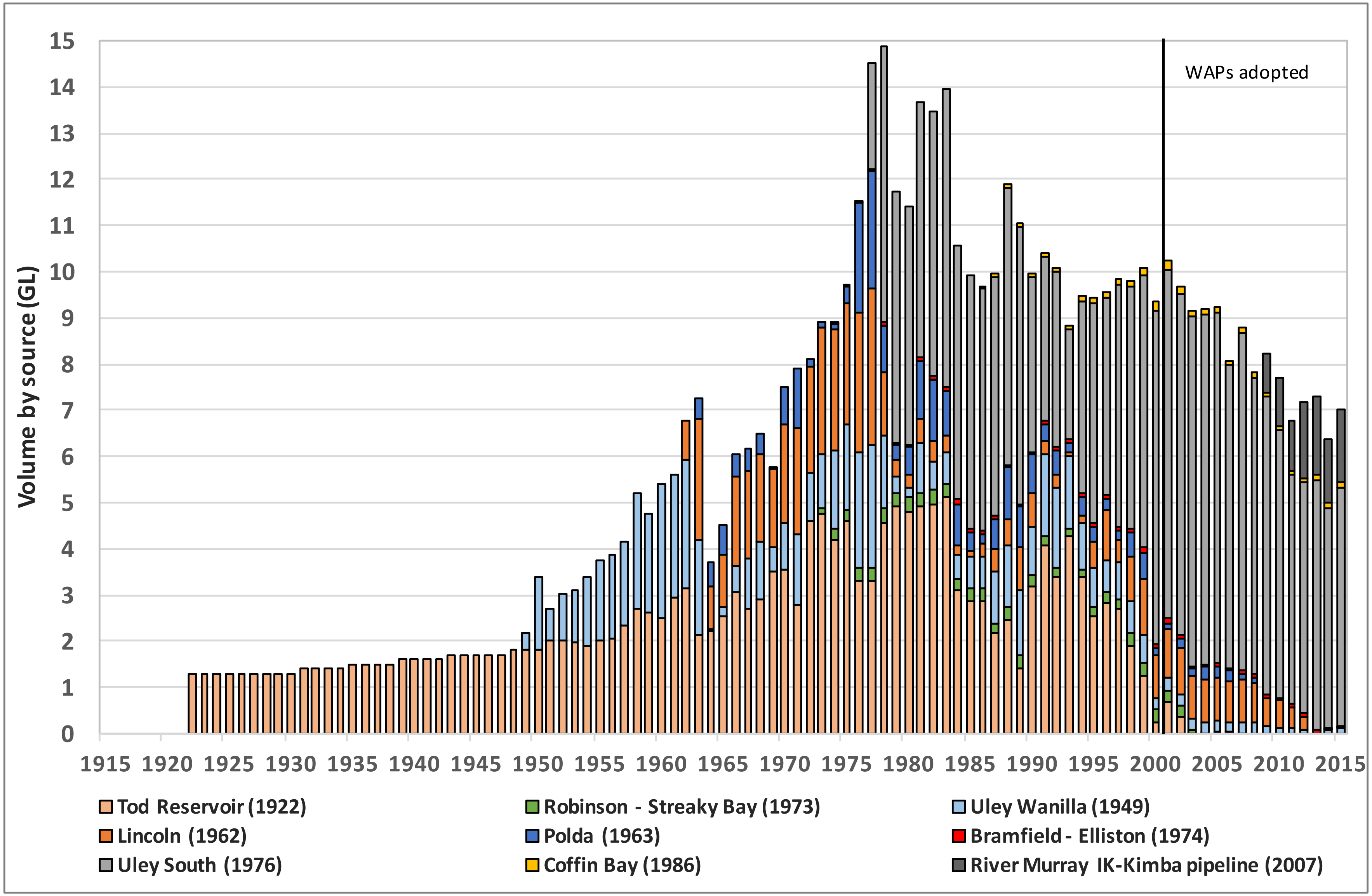


Figure 11 Historical use and source of water for public water supply for Eyre Peninsula

1.5 Trends in Water Level, Extraction and Rainfall for Groundwater Resources used for Public Water Supply

Below is a summary of trends in rainfall and water levels and the volumes of extraction from the various groundwater resources which are, or have been, used for public water supply. Locality maps are included and correspond with each graph. The cumulative deviation from average annual rainfall represents the rainfall trend. An upward slope of the cumulative deviation line indicates a period of above average rainfall whilst a downward slope indicates a period of below average rainfall. The nomenclature used (i.e. consumptive pool) is described in section 2 of this Plan but is provided here for consistency throughout the document.

1.5.1 Coffin Bay

The BoM rainfall station Big Swamp, observation wells LKW 38, LKW 15 and ULE 72 (Fig. 12(a)) and extraction by SA Water from Coffin Bay have been used to compare the water level, rainfall and extraction trends. Figure 12(b) indicates that observation well LKW 38 shows fairly static water levels, which is most likely due to its location close to the coast which is buffering any water level response to impacts (recharge or extraction).

However ULE 72 shows a very strong correlation with the rainfall trend with peaks and troughs being observed at the same times. LKW 15 displays a 3 m long-term decline in water level since 1991 and a slightly delayed and subdued relationship with rainfall.

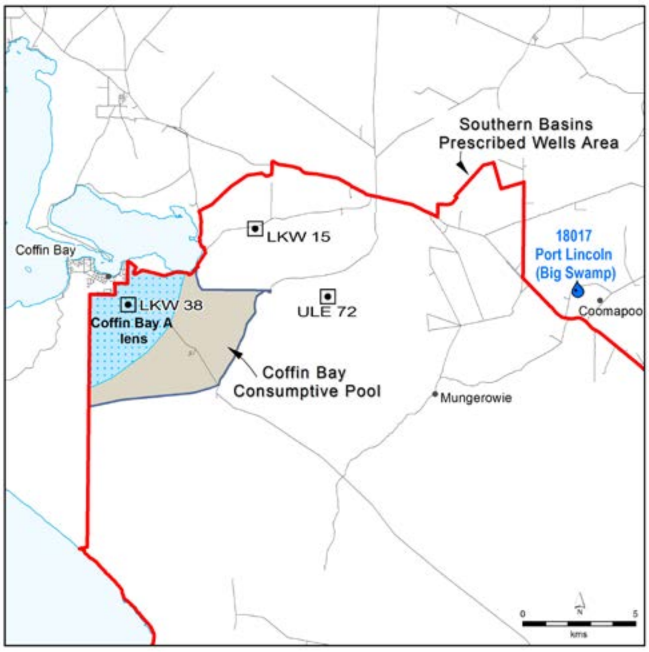


Figure 12(a) Location Map for wells and rainfall stations for Coffin Bay consumptive pool

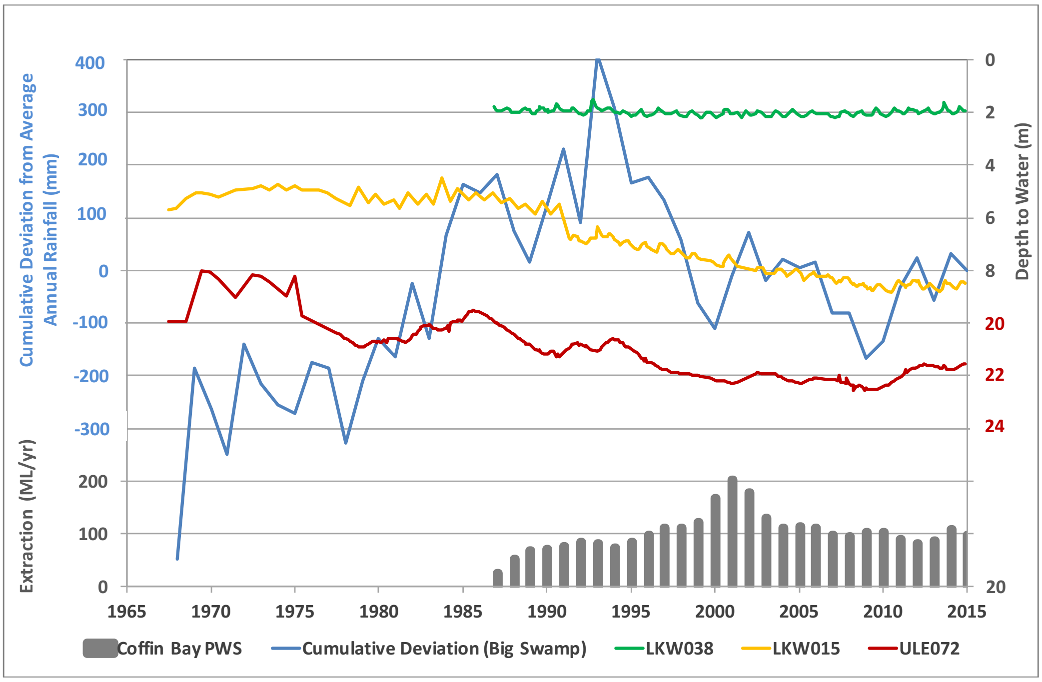


Figure 12(b) Water level, rainfall and extraction trends for the Coffin Bay consumptive pool

1.5.2 Uley Wanilla Public Water Supply

The BoM rainfall station Big Swamp, observation wells WNL 3, ULE 36 and ULE 7 (Fig. 13(a)) and extraction by SA Water from Uley Wanilla have been used to compare the water level, rainfall and extraction trends. These trends in Figure 13(b) show that either recharge or extraction can be the dominant influence on water level trends at different times, as described below and delineated on Figure 13(b):

a. Long-term water level decline from 1940 until 1962 correlates with both a gradual increase in extractions as well as below average rainfall. These declines commenced prior to any extractions occurring.

b. The period from 1963 to 1968 shows a recovery in water levels in response to a significant reduction in pumping. Rainfall appears to be average.

c. A large rise in levels from 1968 to 1972 coincides with above average rainfall, despite increasing levels of extraction.

d. A slow decline during the period 1973 to 1978 associated with significant increasing extraction.

e. A gradual rise in levels until 1985 corresponding to reduced extraction and above average rainfall.

f. Further declines during the period 1986 to 1992 associated with significant increasing extraction.

g. Following 1992, a long term declining trend until 2010 associated with below average rainfall and possibly reduced recharge due to the revegetation of basin. Both WNL 3 and ULE 7 show rises in water level in 2010 which correlates with above average rainfall.

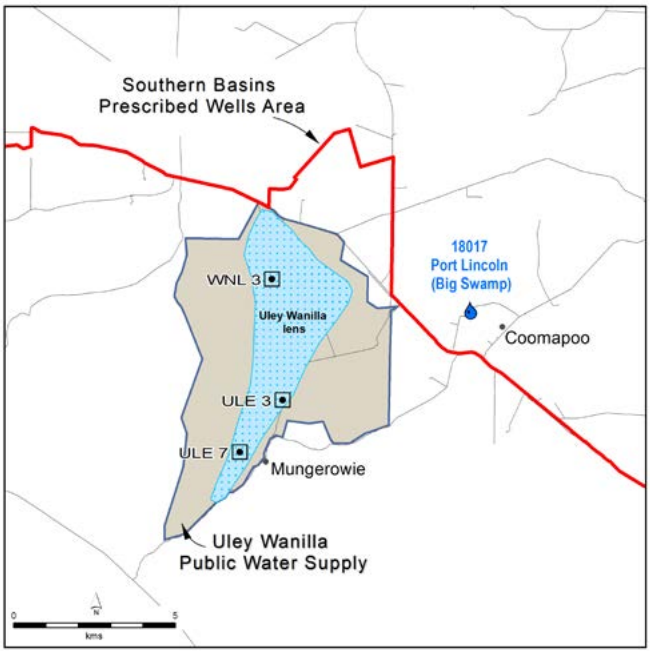


Figure 13(a) Location Map for wells and rainfall stations for Uley Wanilla Public Water Supply consumptive pool

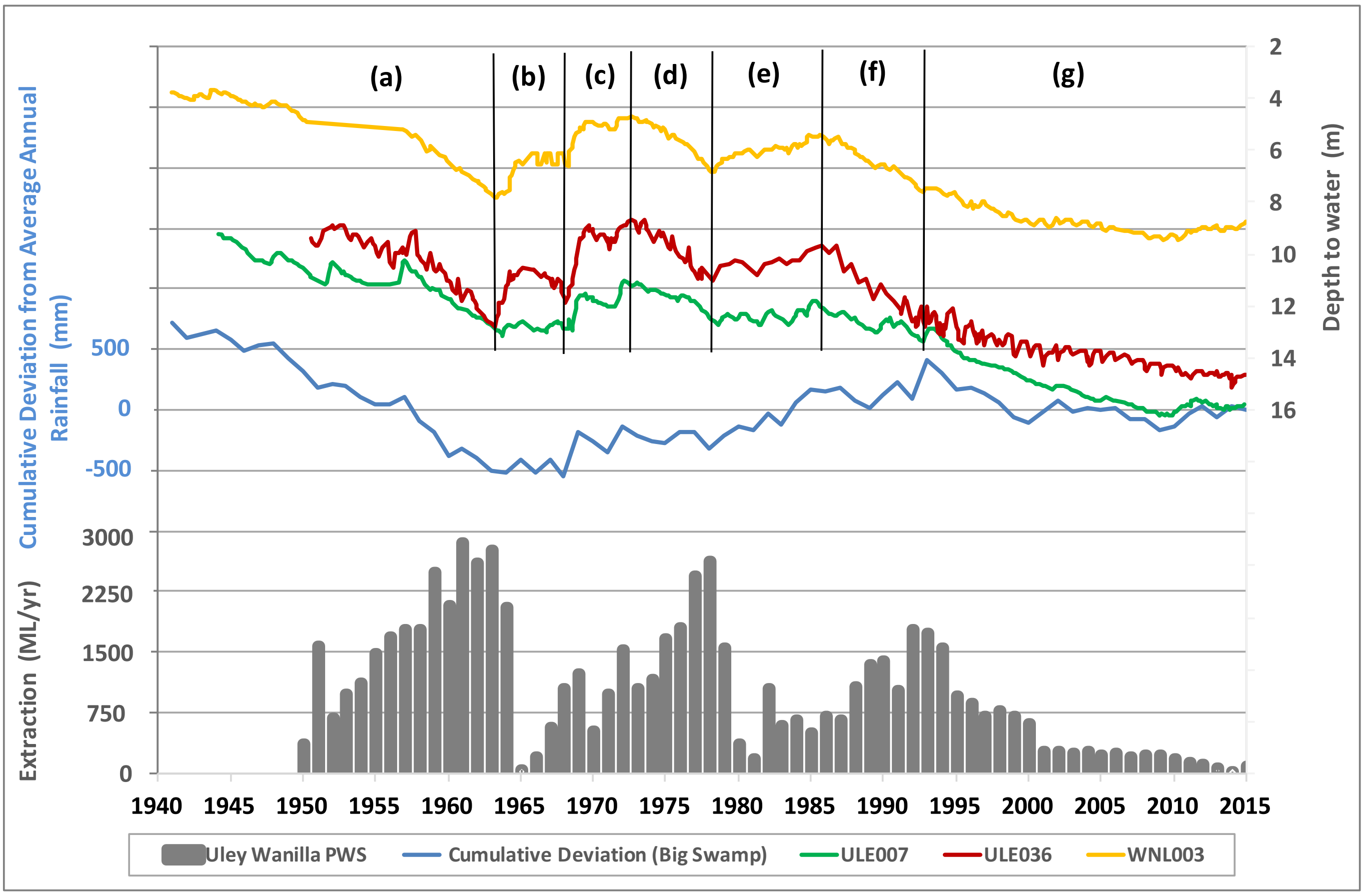


Figure 13(b) Water level, rainfall and extraction trends for the Uley Wanilla consumptive pool

1.5.3 Uley South Public Water Supply

The BoM rainfall station Westmere, observation wells ULE 101, ULE 145 and ULE 139 (Fig. 14(a)) and extraction by SA Water from Uley South have been used to compare the water level, rainfall and extraction trends. Figure 14(b) indicates that from 1969 to 1976, prior to extractions occurring, a decline in water level of up to 2 m was observed despite above average rainfall during this period. From 1977, when extractions commenced, through to 1986, water levels recovered despite extractions occurring from the area. From 1986 to 2000, declines in water level of up to 3 m were observed, which correlate with a varying level of extraction and a fluctuating rainfall trend. The hydrographs flatten out during the period 2000 to 2009 which correlates with the wellfield expansion where extraction was spread more evenly over the basin. After 2010, the reduction in extraction volumes may have contributed to the recovery in water levels together with the slightly above average rainfall over the same period.over the same period.

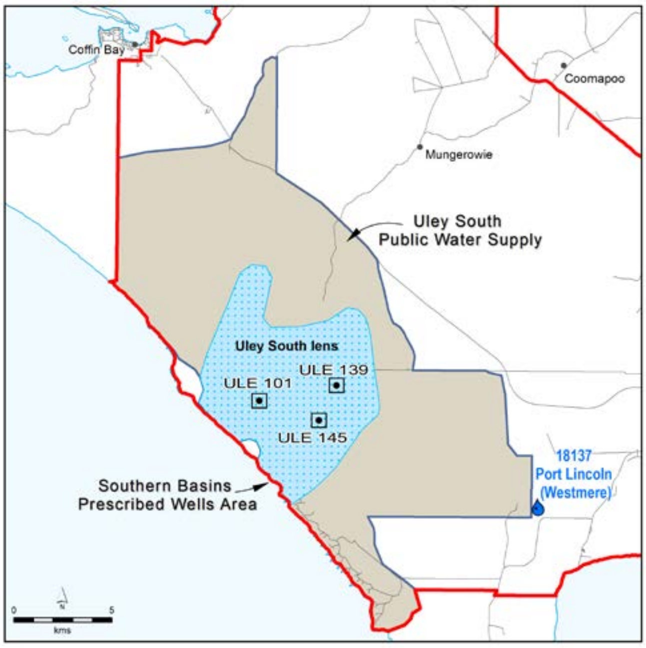


Figure 14(a) Location Map for wells and rainfall stations for Uley South Public Water Supply consumptive pool

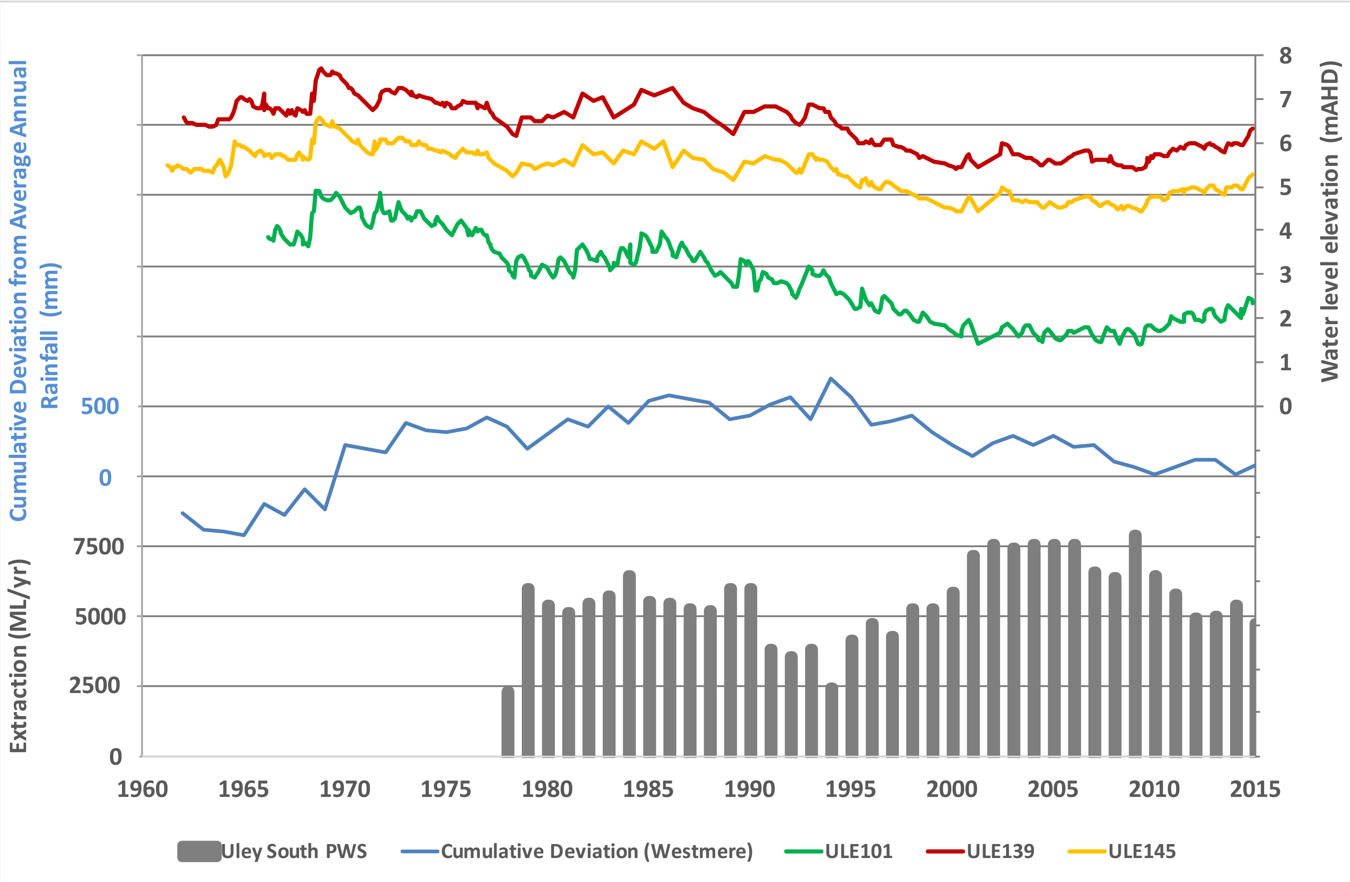


Figure 14(b) Water level, rainfall and extraction trends for the Uley South consumptive pool

1.5.4 Lincoln South Public Water Supply

The BoM rainfall station Westmere, observation wells SLE 47, SLE 30 and FLN 25 (Fig. 15(a)) and extraction by SA Water from Lincoln South have been used to compare the water level, rainfall and extraction trends. Figure 15(b) indicates that due to the basins locality close to the coast, water levels tend to show only small seasonal fluctuations throughout the monitoring period. There is a general trend of water levels following rainfall trends, however the influence of heavy pumping from 1969 to 1978 can be seen in the steady decline in water levels over this period. The rise in water levels after 2010 may be a combination of higher rainfall and recovery due to a marked reduction in extractions.

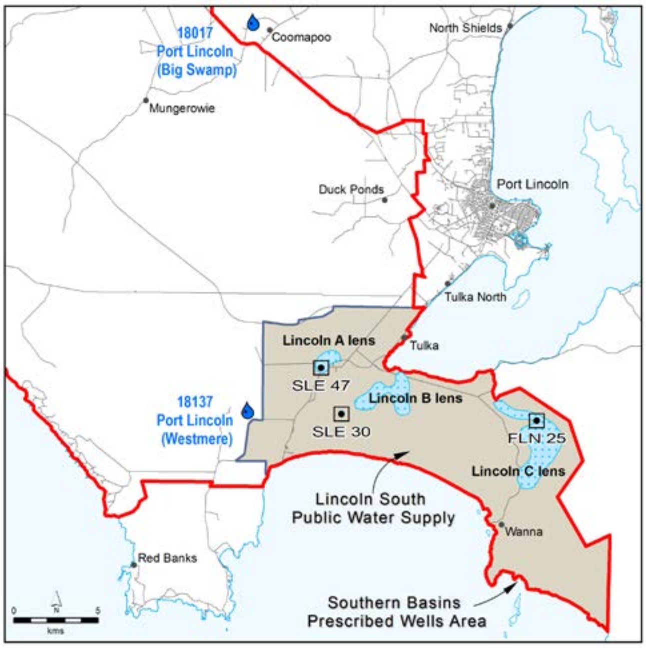


Figure 15(a) Location Map for wells and rainfall stations for Lincoln South Public Water Supply consumptive pool

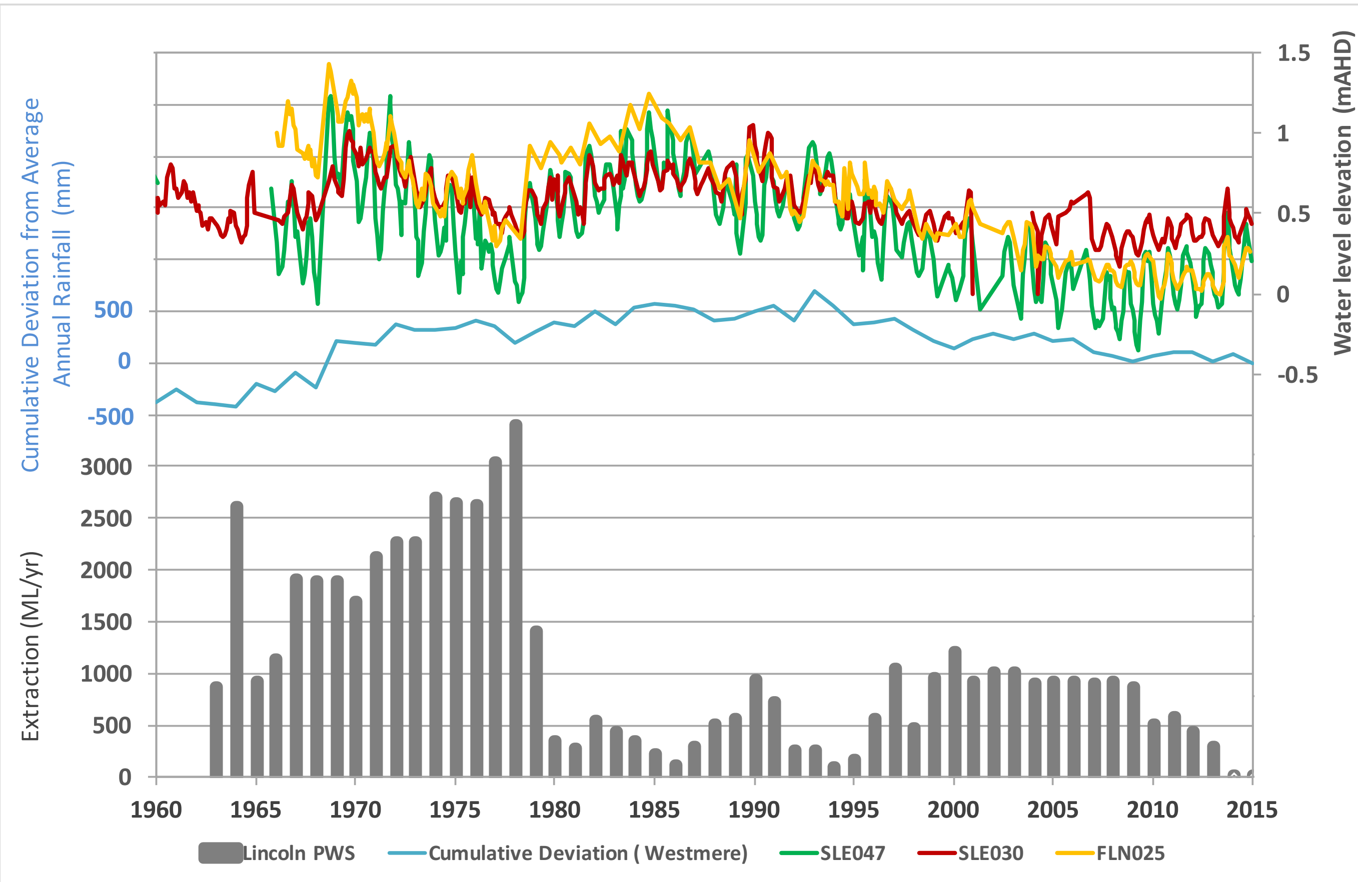


Figure 15(b) Water level, rainfall and extraction trends for the Lincoln South consumptive pool

1.5.5 Polda

The BoM rainfall stations Terre and Terrah Winds, observation wells SQR 9, SQR 88 and SQR 101 (Fig. 16(a)) and extraction by SA Water from Polda have been used to compare the water level, rainfall and extraction trends. Figure 16(b) displays the rainfall cumulative deviation from the average annual rainfall. The break in the blue line in Figure 16(b) is due to the incorporation of Terrah Winds data after the closure of Terre station in 2002.

The water level trends have a close correlation with rainfall with extractions having more defined impacts in the 1970-71 and 1976-78 periods coinciding with dramatic increases in demand.

Following a long term decline since 1982 watertable rises of up to 1.5 m are observed.

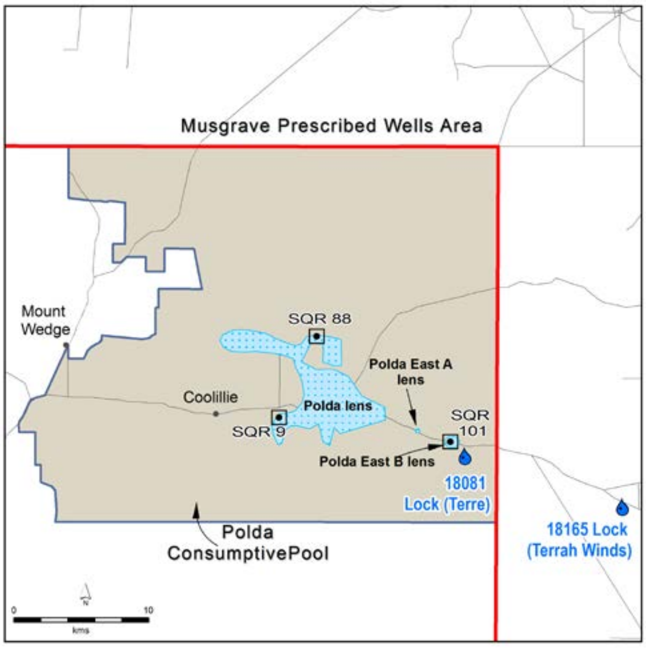


Figure 16(a) Location Map for wells and rainfall stations for Polda consumptive pool

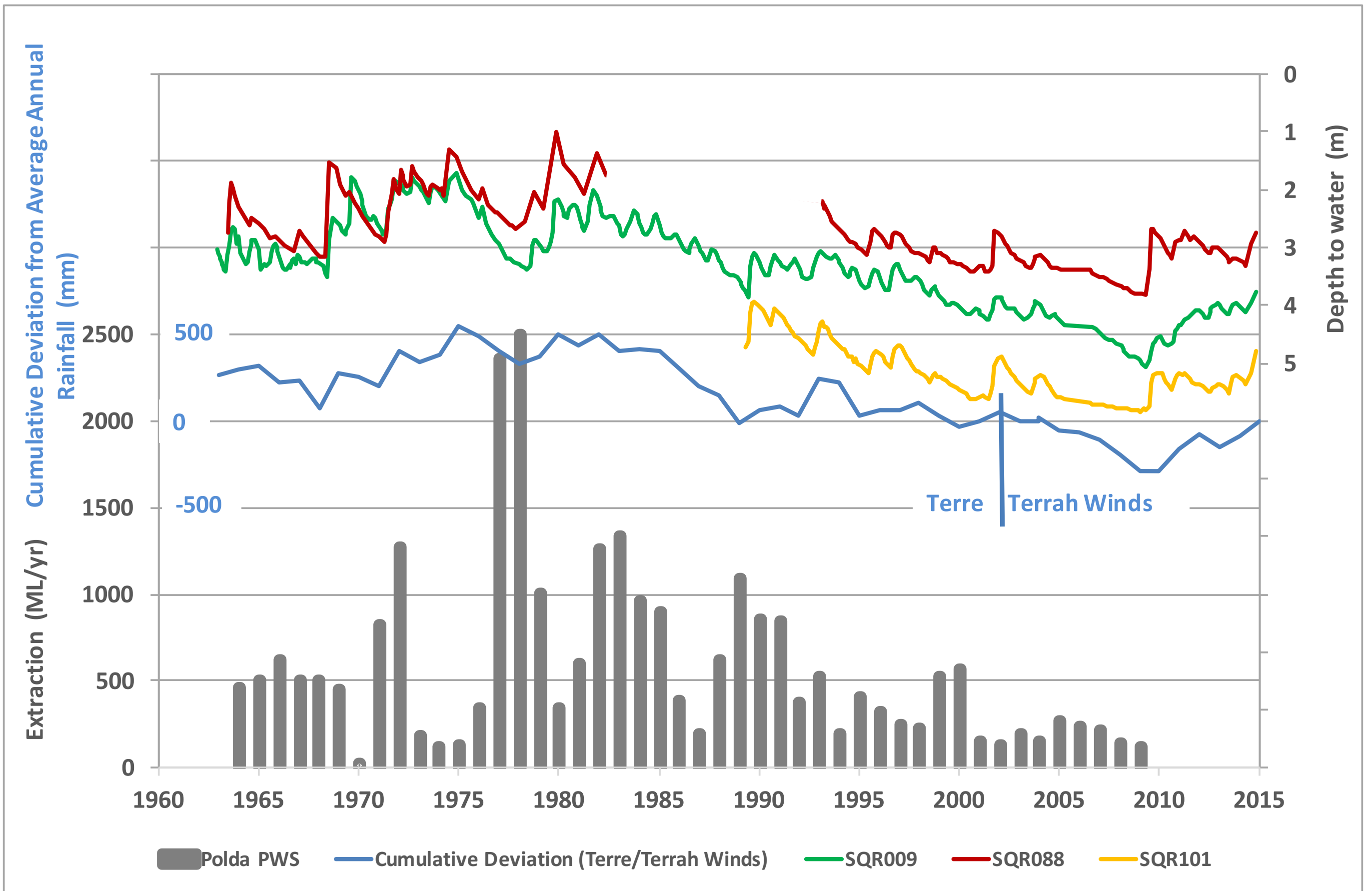


Figure 16(b) Water level, rainfall and extraction trends for the Polda consumptive pool

1.5.6 Bramfield

The BoM rainfall station Elliston, observation wells WAD 31 and WAD 17 (Fig. 17(a)) and extraction by SA Water from Bramfield have been used to compare the water level, rainfall and extraction trends. Figure 17(b) indicates that water level trends are highly correlated to rainfall patterns. The extraction from the Bramfield Basin is solely for the Elliston town water supply, which has remained stable over time. As with the trends observed at Polda, a significant period of below average annual rainfall was observed from 1981 until 2009, resulting in water level declines of up to 5.5 m. Since 2009, water levels have risen by up to 2 m due to above average rainfall.

Figure 17(a) Location Map for wells and rainfall stations for Bramfield consumptive pool

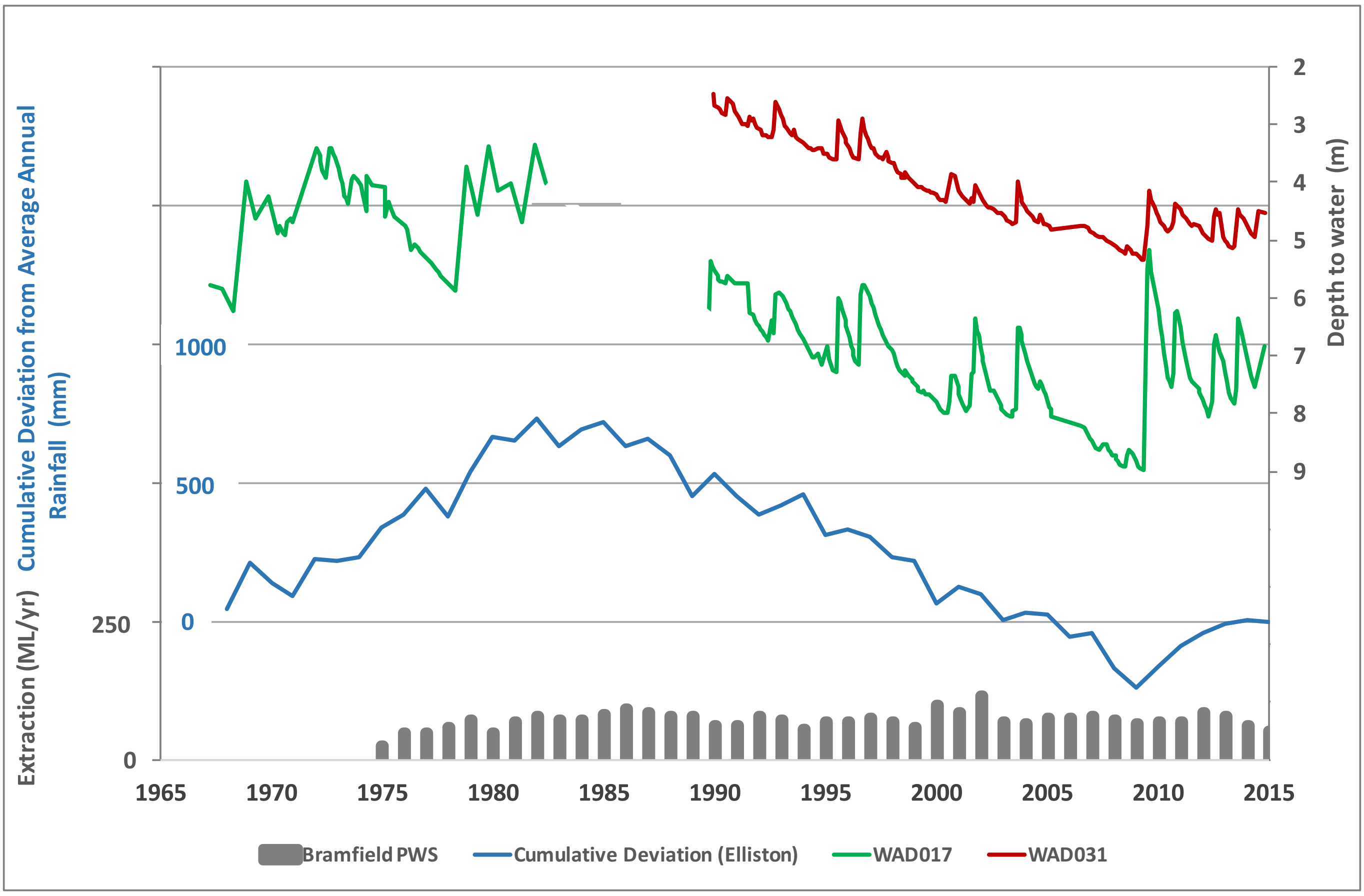


Figure 17(b) Water level, rainfall and extraction trends for the Bramfield consumptive pool

1.5.7 Alterations in Groundwater Dependent Ecosystems in Response to Historic Water Level Changes

It is thought that up until the 1950s - 1960s (over 20 years prior to formal water management in the region), the groundwater levels were significantly higher in some aquifers, most likely due to the wetter than average period from 1950 to 1958 (Fig. 2). In some areas, the groundwater was expressed as surface water in wetlands that are no longer present or have changed ecological character. For example, in Uley South there were surface water wetlands (waterholes), such as Paradise Swamp, that have been dry since the 1960s and now support tussock grasslands (Hyde pers. comm.). There is also anecdotal evidence that Lake Pillie has transitioned from a permanent surface water wetland to a basin being colonised by terrestrial plants in the last 15-20 years (Hyde pers. comm.).

These recollections are consistent with the historically higher water levels measured in the Quaternary aquifer of Uley Wanilla and Uley South Basins. This period of high rainfall and high watertables may be typical of extreme events such as droughts and does not represent 'normal' conditions. This Plan has the objective of minimising the impact of the authorised taking of water on GDEs as they occur today.

1.6 Management Approach

The management approach adopted by this Plan must take into account the unique characteristics of the groundwater resources on Eyre Peninsula, which can be summarised as highly dependent on rainfall recharge (see section 1.3.3 of this Plan) and having a low aquifer robustness in some areas where the saturated thickness of the aquifer is relatively thin. This variability and lack of robustness is best suited to an adaptive management approach whereby the volume of water available for consumptive purposes may be varied annually depending on the condition of the resource. This approach is also considered to be the most appropriate way to deal with the uncertainties in how and when climate is predicted to change in the future. This approach is consistent with principle 25(iv) of the NWI to create planning frameworks which "provide for adaptive management of … groundwater systems in order to meet productive, environmental and other public benefit outcomes".

Although this adaptive approach represents a continuation of the overarching philosophy adopted in the previous Plans, this Plan uses the change in the amount of groundwater stored in the aquifer as a basis for varying the volume of water available for consumptive purposes. This provides a more responsive and transparent methodology than the ten year moving average of recharge estimates used previously.

This new groundwater storage-based adaptive management approach applies only to the Quaternary Limestone aquifer as the other deeper aquifers show little response to rainfall variations.

2 Capacity of Groundwater Resources

Section 76(4)(d) of the Act requires a water allocation plan to "assess the capacity of the resource to meet the demands for water on a continuing basis…".

This section of the Plan defines the geographic locations (referred to as management areas) used to determine the volumetric capacity of the resource, and as a sub-set of this volumetric capacity, the water available for consumptive purposes (the "consumptive pool"). Whilst the geographic locations used to determine the volumetric capacity of the resource are fixed for the life of the Plan, the water available for consumptive purposes, in some instances, will be re-calculated annually (section 6.1).

The capacity of the resource, which is expressed as a volume, represents the upper limit of water available for all uses (i.e. consumptive and non-consumptive uses). Consumptive use includes licensed water use (irrigation, industrial, recreational, mining and public water supply) and non-licensed water use such as water for stock or domestic use or water authorised by the Minister under section 128 of the Act. Non-consumptive use includes water for maintaining natural processes such as aquifer throughflow and discharge, and water for groundwater dependent ecosystems where they are present.

Given the fragile nature of the Quaternary Limestone aquifer on the Eyre Peninsula (thin and heavily reliant on rainfall recharge), it is not possible to provide an assessment of the capacity of the resources in the same way as other groundwater resources in South Australia. In the Mallee and the South East for instance, the large and robust sedimentary aquifers enable a portion of the water stored in the aquifers to be considered as a part of the resource capacity.

As described previously in section 1, the Quaternary Limestone aquifer on the Eyre Peninsula is highly dependent on rainfall recharge and is fragile in some areas where the aquifer is quite thin. The water levels and consequently the amount of water stored in the aquifer, are strongly controlled by rainfall patterns which can be variable. These characteristics require the capacity of the groundwater resources to be determined by a methodology unique to Eyre Peninsula. For this Plan, the process for determining the capacity of the groundwater resources has therefore been combined with another requirement of the Act, namely the determination of consumptive pools.

Sections 76(4)(ab) of the Act requires a Plan to "determine or provide a mechanism for determining, from time to time, a consumptive pool or pools for the water resource". Additionally section 3 of the Act defines consumptive pool to mean:

"The water that will from time to time be taken to constitute the resource within a particular part of a prescribed water resource, as determined –

a. by or under a water allocation plan for that water resource or
b. in prescribed circumstances – by the Minister".

Section 2 of this Plan defines the consumptive pools by way of geography and section 6 defines the consumptive pools by way of volume. Principles for the determination of new consumptive pools, should they be required, are also provided in section 6.

2.1 Management Areas Used to Determine Consumptive Pools

For the purposes of this Plan, consumptive pools are determined on the basis of geographic locations. These geographic locations are referred to as management areas. For each management area, a volumetric resource capacity has been determined which represents the water available to meet both consumptive and non-consumptive demand. The portion of the resource capacity available for consumptive demand is referred to as the consumptive pool.

Within this Plan, the management areas can be broken into three different groupings:

1. Management areas relating to the saturated Quaternary Limestone aquifer
2. Management areas relating to the unsaturated Quaternary Limestone aquifer
3. Management areas relating to the Tertiary Sands and Basement aquifers, and the Quaternary Lincoln North management area.

There are nine management areas for which consumptive pools are determined in the Southern Basins PWA and six for the Musgrave PWA. These management areas are listed in Table 2. The management areas for the saturated Quaternary Limestone aquifer of the Southern Basins PWA are outlined in Figure 18, and for the Musgrave PWA in Figure 19. Figure 18 also shows the Quaternary Lincoln North management area. Despite its location within the saturated Quaternary Limestone aquifer, the limited data available on this management area (section 2.2.3) requires that it be managed in a similar manner to the deeper aquifers.

Whilst the Jurassic aquifer is present within the Musgrave PWA (see section 1.3.2.3), no consumptive pool has been determined for this aquifer, as no water is known to be extracted from this aquifer for consumptive purposes. If in the future, extraction from this aquifer is required, a new consumptive pool may be created in accordance with sections 2.3 and 6 of this Plan.

The management areas of the saturated Quaternary Limestone aquifer take into account the maximum extent of the aquifer (determined by the highest historically recorded water levels and shown in Figs. 14 and 15 in Stewart 2013) to allow for the potential lateral expansion of the saturated aquifer over time from current levels, if periods of significant recharge were to occur.

The management areas are also tied to the nearest cadastral boundary (Figs. 18 and 19) for greater clarity to determine where the boundaries actually exist on the ground as opposed to a boundary projected on a map (Stewart 2013). Tying the management areas to the nearest cadastral boundary is particularly important when there are principles regarding the location of where new wells can be drilled or where additional volumes can be taken.

The management areas for the Tertiary Sands and Basement aquifers of the Southern Basins PWA (Fig. 20) and the Musgrave PWA (Fig. 21) align with the relevant PWA boundaries.

Table 2 Management areas within the Southern Basins and Musgrave PWAs

PWA	Aquifer Type Grouping	Management Area
Southern Basins	Saturated Quaternary Limestone aquifer	Coffin Bay
		Uley Wanilla Public Water Supply
		Uley North
		Uley South Public Water Supply
		Lincoln South Public Water Supply
	Unsaturated Quaternary Limestone aquifer	Unsaturated Quaternary Limestone
	Tertiary Sands and Basement aquifers and Quaternary Lincoln North management area	Quaternary Lincoln North
		Tertiary Sands
		Basement
Musgrave	Saturated Quaternary Limestone aquifer	Polda
		Bramfield
		Sheringa
	Unsaturated Quaternary Limestone aquifer	Unsaturated Quaternary Limestone
	Tertiary Sands and Basement aquifer	Tertiary Sands
		Basement

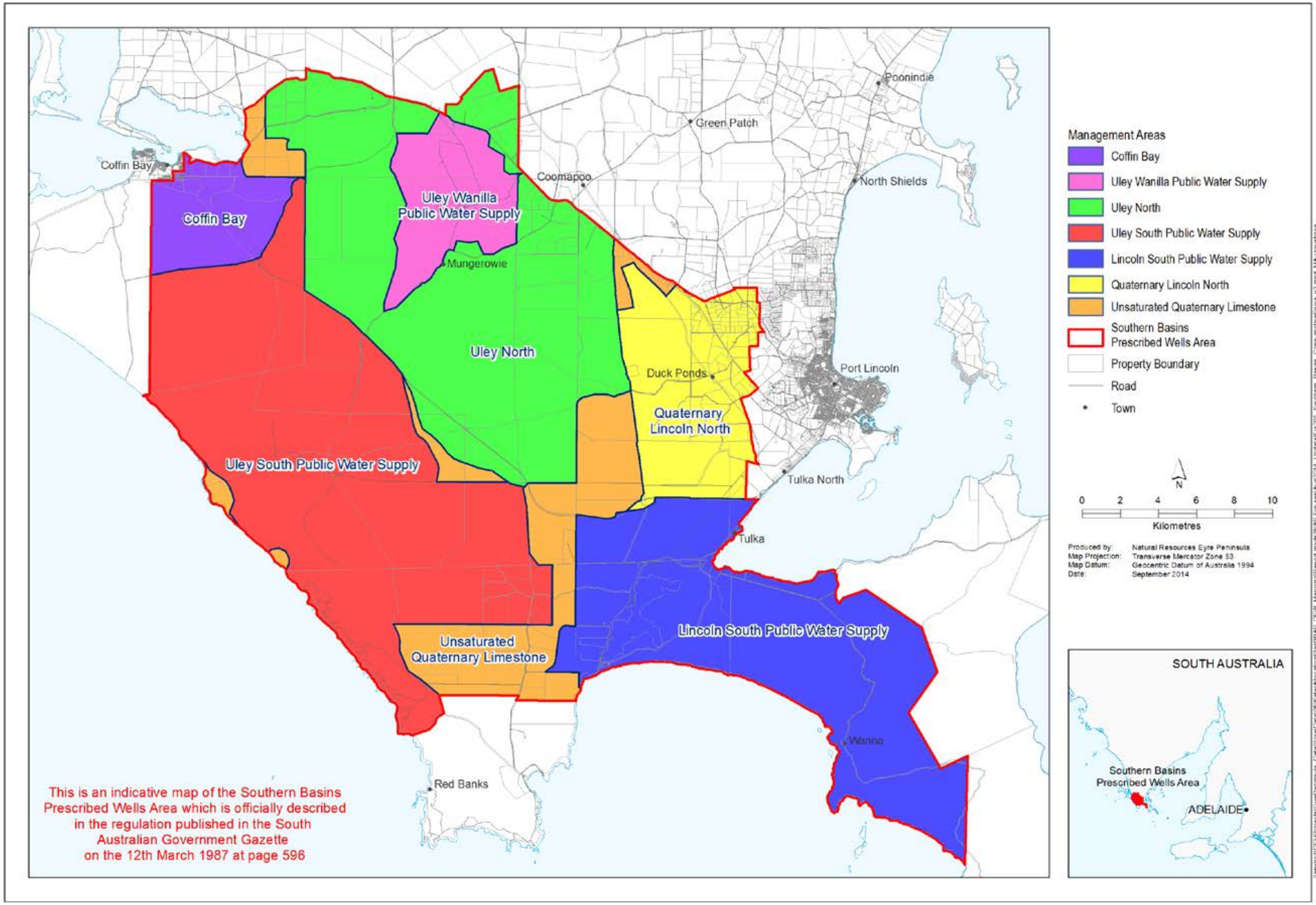


Figure 18 Management areas for the saturated and unsaturated Quaternary Limestone aquifer of the Southern Basins PWA

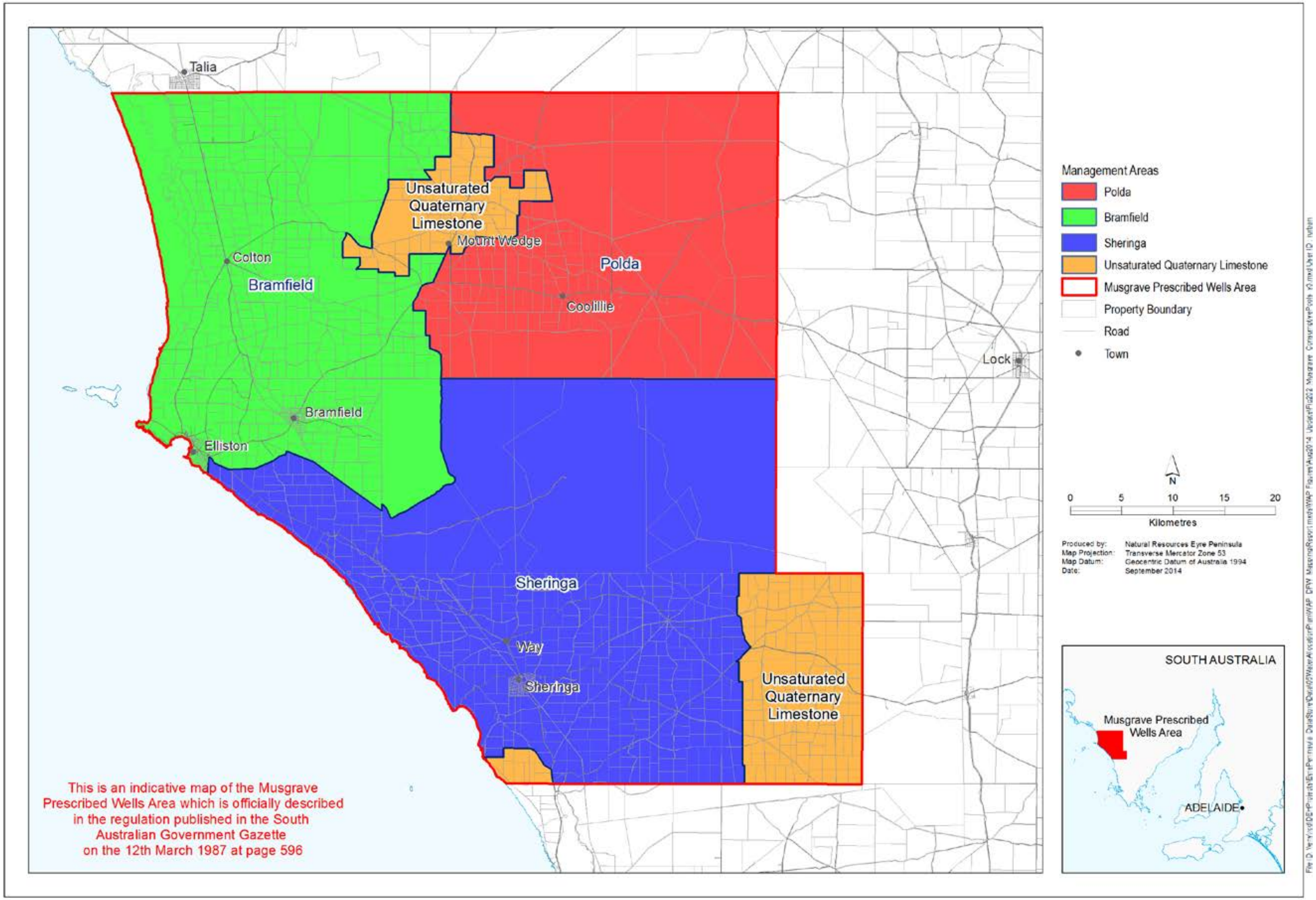


Figure 19 Management areas for the saturated and unsaturated Quaternary Limestone aquifer of the Musgrave PWA

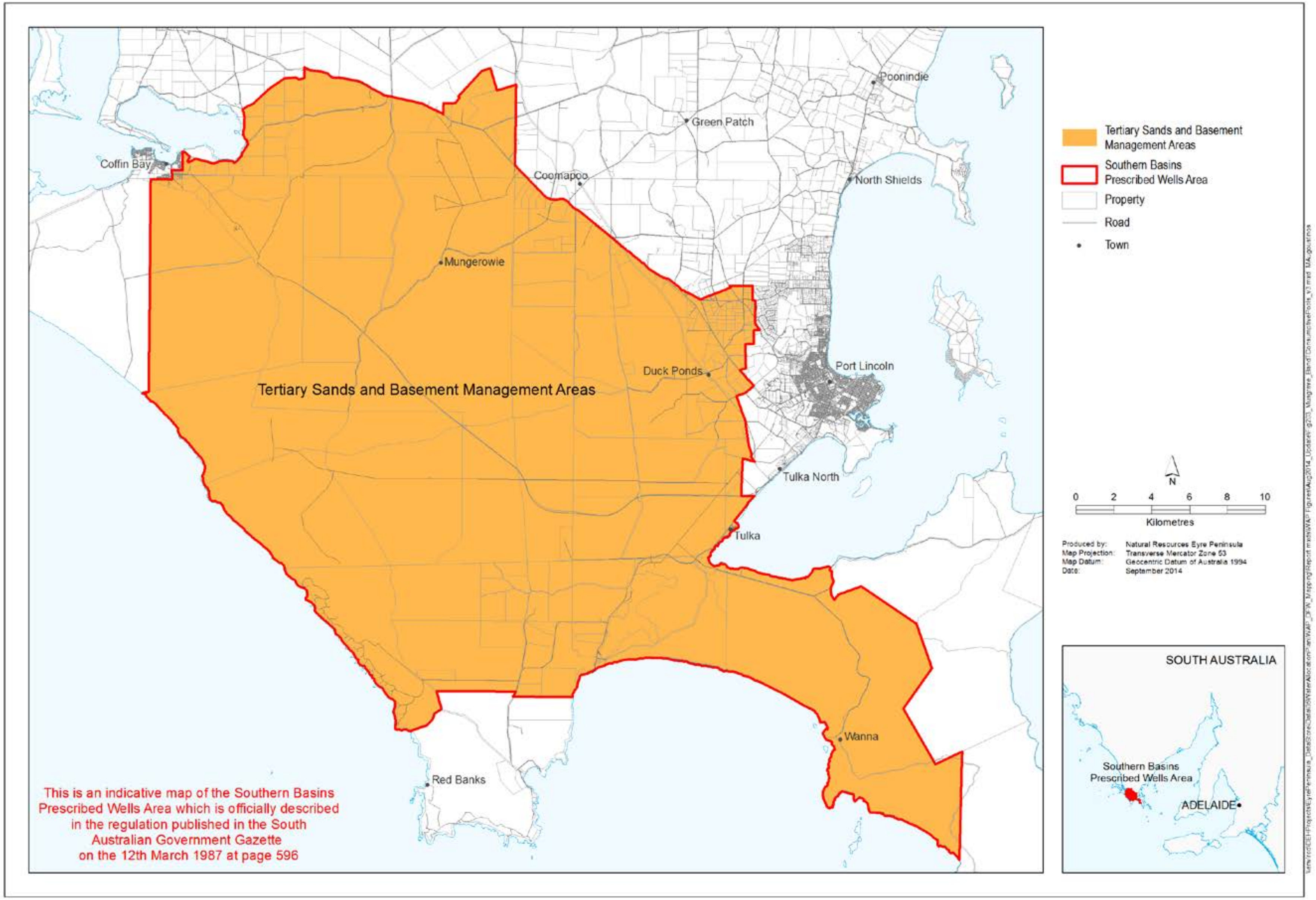


Figure 20 Management areas for the Tertiary Sands and Basement aquifers of the Southern Basins PWA

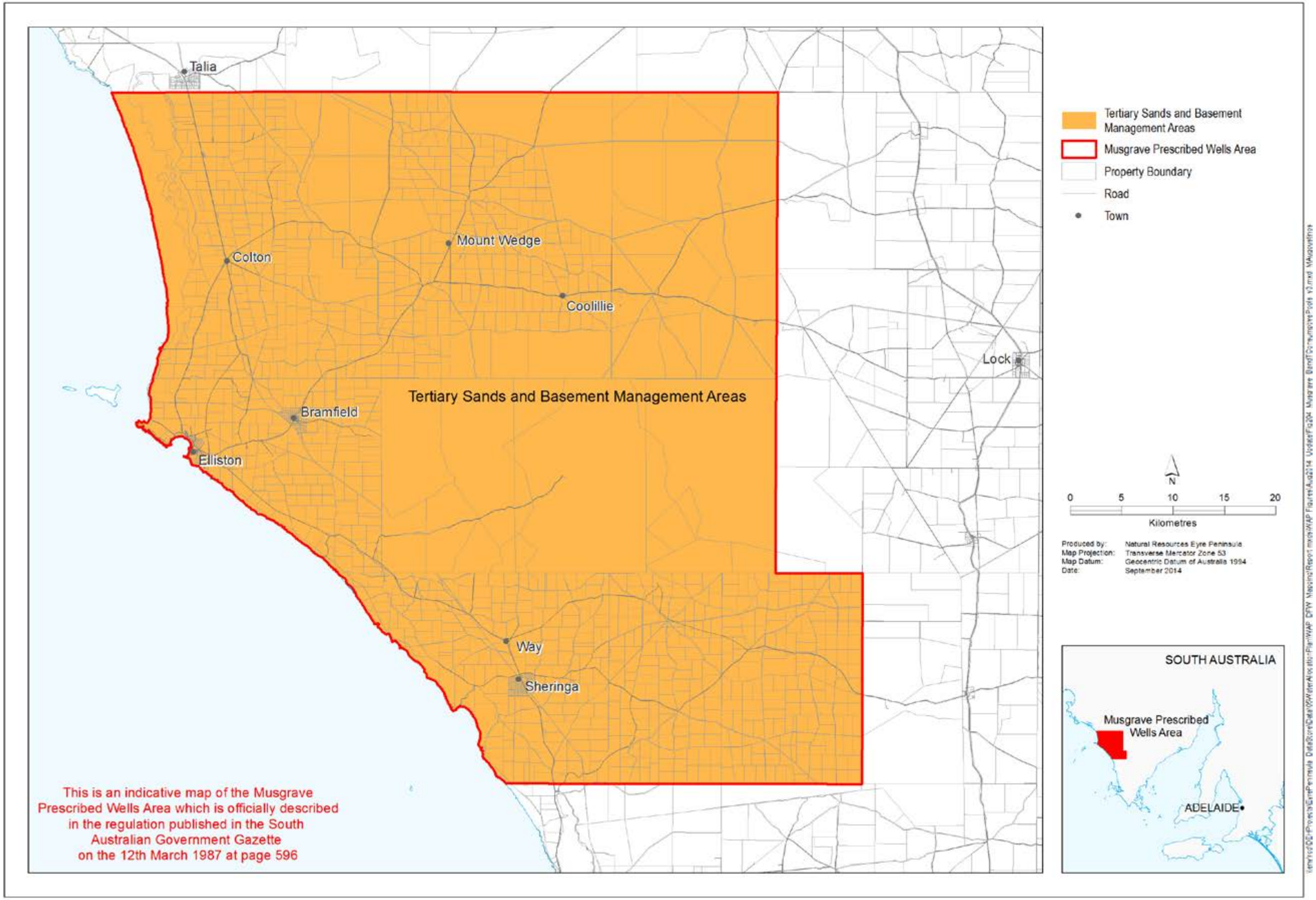


Figure 21 Management areas for the Tertiary Sands and Basement aquifers of the Musgrave PWA

2.2 Resource Capacity of the Consumptive Pools

There is significantly more information available on the Quaternary groundwater resources of the Eyre Peninsula than for the deeper Tertiary Sands or Basement aquifers, because the Quaternary aquifer is more productive and is widely developed for public water supply, irrigation, industrial and recreational purposes, and for stock and domestic supplies.

Due to the disparities in data availability, the calculation of the resource capacity (or volumetric limit) for the three consumptive pool groupings has been undertaken using different methodologies.

2.2.1 Saturated Quaternary Limestone Aquifer Management Areas

The capacity of the saturated Quaternary Limestone management areas is defined as the recharge zone area (section 2.2.1.1 and Figs. 22 and 23) multiplied by the recharge rate (section 2.2.1.2 and Tables 3 and 4), and is calculated as:

Resource Capacity (ML) = Recharge Area (km^2) x Recharge Rate (mm)

The resource capacity of the saturated Quaternary Limestone aquifer management areas represents the estimated volume of water that has recharged the aquifer over a period of one year. This volume is considered to be a starting point from which to provide water for the environment, and for consumptive non-licensed and licensed use.

2.2.1.1 Recharge Zones

Stewart et al. (2012) determined the extent of saturation of the Quaternary aquifer in autumn of 2011 using groundwater level monitoring data in addition to supplementary water level data collected by Natural Resources Eyre Peninsula staff.

For a conservative approach, the period of autumn was chosen to represent the extent of aquifer saturation as it is most likely to align with the time at which the watertable is at its lowest level during any year, i.e. after discharge occurs during the summer, but prior to any significant recharge occurring.

Salinity sampling throughout 2009 and 2010 allowed for the extent of the fresh groundwater lenses (less than 1000 mg/L) to be re-defined within the saturated extent of the aquifer, with the remaining saturated portion being described as brackish. It is considered the 2009-10 salinity data is valid to align with the 2011 water level data because the salinity content of groundwater is not as variable as water levels and has a much slower rate of change. It should be noted that whilst areas may be identified as brackish, they may not necessarily have a salinity of over 1000 mg/L.

The delineation of the lenses took the most conservative approach and minimised the area of the lens rather than overestimating the extent of the lens in the absence of sufficient salinity data. In many cases (e.g. Uley South, Uley North, Bramfield) the absence of any salinity data resulted in the area outside of the lens being defined as brackish when in fact the salinity (in 2009-10) was unknown (see Figs. 12a and 12b on page 23 of Stewart et al. 2012).

The recharge zones (Figs. 22 and 23) within the management areas are represented by a combination of (a) the extent of the relevant fresh groundwater lenses (less than 1000 mg/L) and (b) the saturated extent of the remaining brackish Quaternary Limestone aquifer as derived from information available for water level data in autumn 2011 and salinity data in 2009-2010.

2.2.1.2 Recharge Rate

In order to determine the resource capacity of the saturated Quaternary Limestone management areas as per the equation in section 2.2.1, the recharge rates for the individual recharge zones needed to be determined.

The recharge rates for the various recharge zones were calculated using the Water Table Fluctuation (WTF) method. The WTF method is applicable only to unconfined aquifers and is based on the premise that rises in groundwater levels are due to recharge water entering the aquifer (Healy and Cook 2002). A large number of observation wells across the recharge zones were used to determine the recharge rate for 2008, the driest year observed during the millennium drought.

The methodology used is outlined in detail in the DEWNR Technical Note *Supporting Documentation for the Amendment of the Water Allocation Plan for the Southern Basins and Musgrave PWAs* (Stewart 2015). The methodology used a range of specific yield values for each recharge zone to determine the recharge rate via the WTF methodology. Given that the result was a range of values based on the varying specific yield, the average was taken to be representative of the recharge rate for the recharge zone. In instances where there were no monitoring wells available within a recharge zone to determine a recharge rate, or the wells showed no rise in the watertable, a conservative recharge rate of 0 mm/yr was applied. The recharge rates and corresponding resource capacity volumes can be seen in Tables 3 and 4.

The Uley South fresh and brackish recharge zones require a different approach because of the following factors;

- Recent investigations (Ordens et al. 2011) highlighted the spatial variability of recharge in the Uley South lens by using multiple methods to refine the existing estimates of annual recharge rate. Values ranged between 47 and 129 mm/yr. The upper limit of 129 mm/yr, which was obtained by the watertable fluctuation method (Ordens et al. 2011), has been applied to the Uley South fresh and brackish recharge zones
- The water levels are currently displaying stable or rising trends, indicating that the current levels of extraction (around 5 720 ML/yr) are sustainable. These trends could not be sustained if the lower range of the Ordens et al. (2011) recharge estimates were applicable
- Within the Uley South Basin, groundwater levels suggest there is potential for upward leakage from the underlying Tertiary Sands aquifer into the Quaternary Limestone aquifer (Harrington et al. 2006). This leakage is estimated to occur at a rate of 14 mm/yr where the Tertiary Clay is thought to be absent, and translates into a volume of 130 ML/yr.

Therefore for the purposes of this Plan, a value of 129 mm/yr was assigned as the recharge rate for the Uley South fresh and brackish recharge zones with an additional recharge of 14 mm/yr for the specific area where the upward leakage is likely to be occurring (Stewart 2013, page 22). For a better understanding of Tables 3 and 4, it is reiterated that:

Resource Capacity (ML) = **Recharge Area** (km^2) x **Recharge Rate** (mm)

Table 3 Assessment of the capacity of the Southern Basins PWA saturated Quaternary water resources

Management Area	Recharge Zone	Recharge Rate (mm)	Recharge Zone Area (km^2)	Resource Capacity (ML)
Coffin Bay	Coffin Bay A lens	25	13.82	345.4
Uley Wanilla Public Water Supply	Uley Wanilla lens	20.5	14.33	293.8
	Uley Wanilla brackish	22.5	25.61	576.3
Uley North	Coffin Bay B lens	0	0.42	0
	Coffin Bay C lens	1.9	5.47	10.4
	Uley East A lens	73.5	5.48	402.5
	Uley East B lens	0	2.42	0
	Uley North brackish	7.5	92.97	697.3
Uley South Public Water Supply	Uley South lens	129	65.42	8439.5
	Uley South brackish	129	43.06	5555.3
	Uley South Tertiary Leakage	14	9.29	130.1
	Pantania lens	0	0.38	0
	Mikkira lens	0	2.13	0
Lincoln South Public Water Supply	Lincoln A lens	0	1.20	0
	Lincoln B lens	0	3.95	0
	Lincoln C lens	0	7.92	0
	Lincoln South brackish	33	138.92	4584.2

Table 4 Assessment of the capacity of the Musgrave PWA saturated Quaternary water resources

Management Area	Recharge Zone	Recharge Rate (mm)	Recharge Zone Area (km^2)	Resource Capacity (ML)
Polda	Polda lens	5.6	37.21	208.4
	Polda East A lens	0	0.07	0
	Polda East B lens	0	0.72	0
	Polda brackish	11.2	273.84	3067
	Tinline lens	0	3.13	0
	Talia East lens	0	6.15	0
Bramfield	Bramfield lens	2.2	99.46	218.8
	Bramfield brackish	5	639.93	3199.6
	Talia lens	0	44.17	0
Sheringa	Sheringa A lens	0	36.23	0
	Sheringa B lens	0.7	38.99	27.3
	Kappawanta lens	11.4	48.86	557
	Sheringa brackish	5.9	519.82	3066.9

2.2.1.3 Management Areas Reserved for Public Water Supply

Within the Southern Basins PWA, several management areas have been reserved for public water supply (PWS) purposes in an effort to secure fresh groundwater resources for now and into the future for critical human needs. Within these management areas (Uley South PWS, Uley Wanilla PWS and Lincoln South PWS), new well permit applications will only be granted if the purpose of use is for public water supply.

2.2.1.4 Management Areas Reserved for Irrigation, Industrial and Recreational Purposes

Within the Musgrave PWA the Polda consumptive pool has been reserved only for irrigation, industrial and recreational purposes, in an effort to allow the water resource to recover. Therefore, new well permit applications will only be granted if the purpose of use is for irrigation, industry or recreation. Stock and domestic water supply will still be available and will not require a water access entitlement.

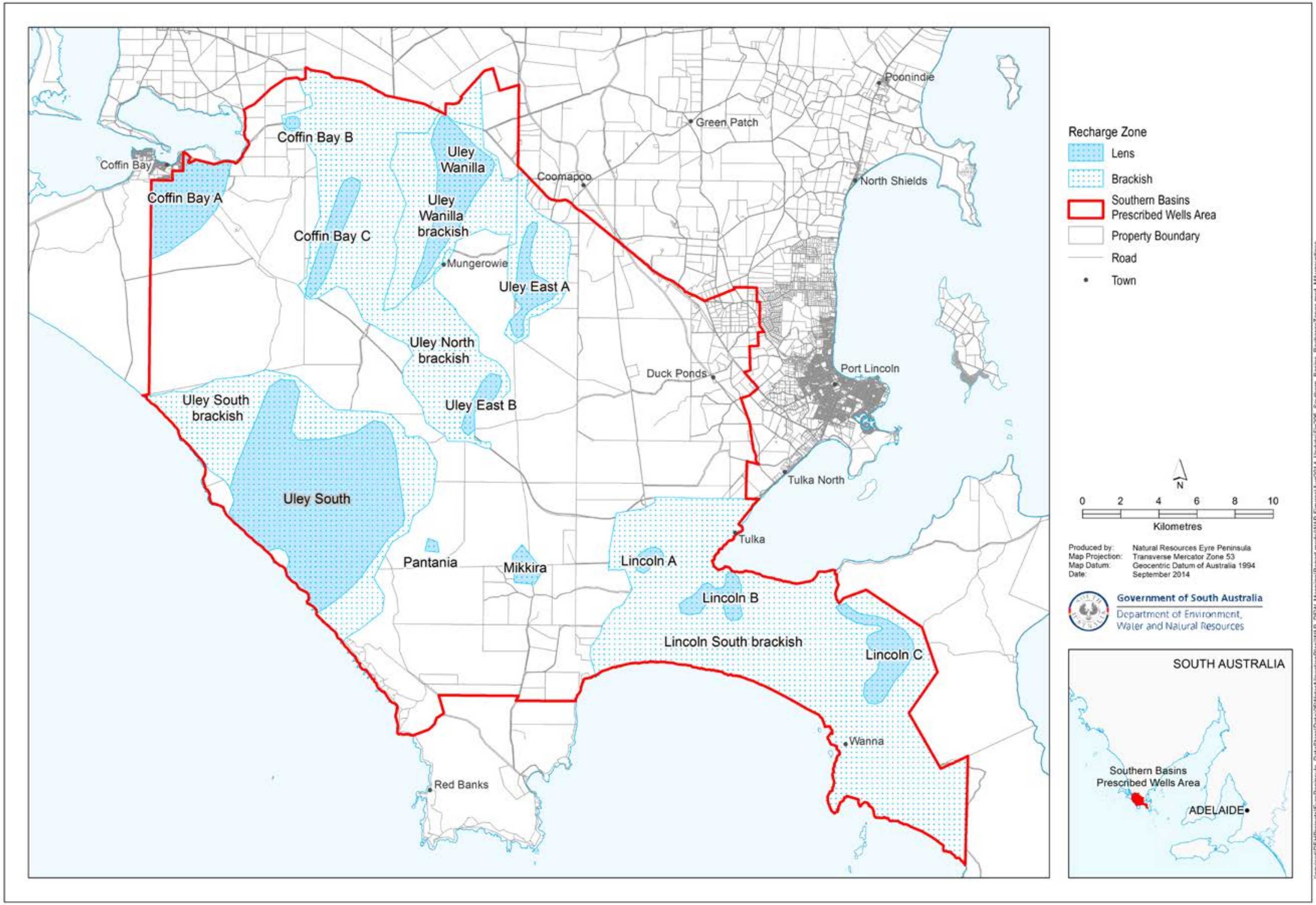


Figure 22 Recharge zones for the saturated Quaternary Limestone aquifer of the Southern Basins PWA

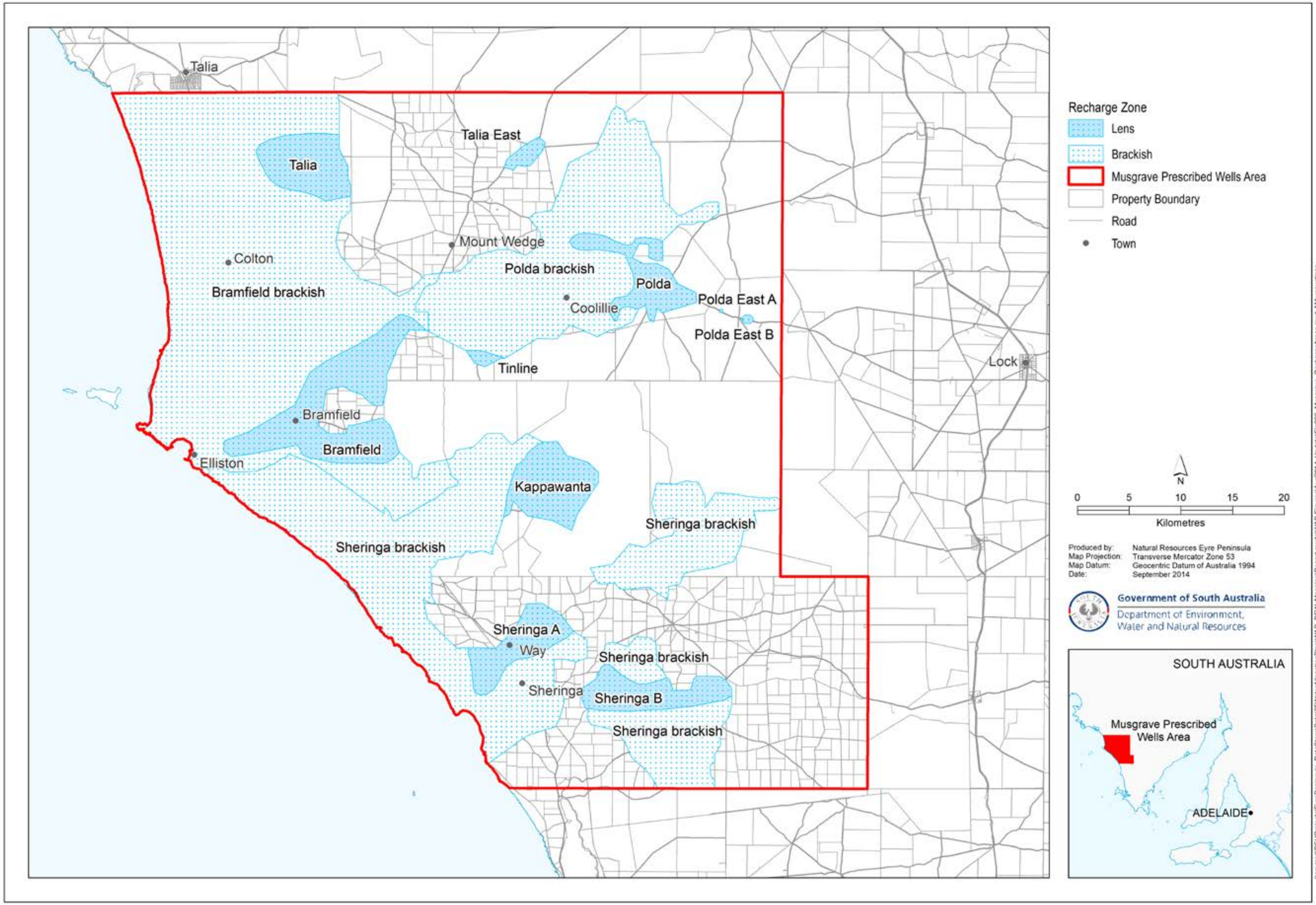


Figure 23 Recharge zones for the saturated Quaternary Limestone aquifer of the Musgrave PWA

2.2.2 Unsaturated Quaternary Limestone Management Areas

The unsaturated Quaternary Limestone management areas exist within the PWAs where the assessment of the saturated extent of the Quaternary aquifer did not identify any water within the aquifer (Stewart 2013, Figures 12 and 13). It is possible that the unsaturated Quaternary Limestone may be able to provide limited highly unreliable water supplies in small isolated areas where there may be gaps in the water level or geological data used in the spatial modelling process used to determine the extent of saturation.

As a management area, the unsaturated Quaternary Limestone resource requires a volumetric capacity due to its potential use for non-licensed stock or domestic purposes (given the unsuitability for higher demand licensed uses) and any Minister's authorisations. Because of the lack of water level and recharge data, the resource capacity is unable to be calculated in the same manner as the saturated Quaternary Limestone management areas (section 2.2.1). In this instance, the resource capacity for the unsaturated Quaternary Limestone management areas is calculated to be the likely non-licensed demand from within this area (Table 5). This volume will not vary for the life of this Plan. There is also no provision of water to meet environmental or licensed requirements in this pool. If future hydrogeological investigations determine that there is additional water available for consumptive purposes from this region, a new consumptive pool will be created in accordance with sections 2.3 and 6 of this Plan.

2.2.3 Tertiary Sands, Basement and Quaternary Lincoln North Management Areas

In the absence of detailed knowledge of water level trends and recharge to the deeper Tertiary Sands and Basement aquifers and the Quaternary Lincoln North management area due to the low licensed extraction, the methodology for determining the resource capacity of the saturated Quaternary Limestone management areas was not appropriate in these instances. Sections 2.2.3.1 – 2.2.3.3 discuss an alternative approach.

2.2.3.1 Tertiary Sands Management Areas

There is no licensed extraction from the Tertiary Sands consumptive pool in either the Southern Basins or Musgrave PWAs and due to the depth of the confined Tertiary Sands aquifer, it is unlikely to be providing water to, or be connected to, any known groundwater dependent ecosystems (GDEs) (see section 3.3.7). Consequently groundwater within these management areas is required only to meet non-licensed demands. In this instance, it is considered that the current low extraction volumes for non-licensed use are not having any observed detrimental impact on other water resources, and therefore would be an appropriate volume for the resource capacity of this management area in addition to a nominal amount available to meet future Minister's authorisations (Table 5). This volume will not vary for the life of this Plan. If future hydrogeological investigations determine that there is additional water available for consumptive purposes from this aquifer, a new consumptive pool will be created in accordance with sections 2.3 and 6 of this Plan.

2.2.3.2 Basement Management Areas

Whilst there is some licensed extraction from the Basement management area in the Southern Basins PWA, there is no licensed extraction from the Basement management area in the Musgrave PWA. Due to the depth of the confined Basement aquifer it is unlikely to be providing water to, or be connected to, any known GDEs (see section 3.3.7). As such, groundwater within these management areas is required only to meet licensed and non-licensed demands in the Southern Basins PWA and non-licensed demands in the Musgrave PWA. As with the overlying Tertiary Sand aquifer, it is considered that the current extractions are not having any observed detrimental impact on other water resources, and therefore would be an appropriate volume for the resource capacity of this management area in addition to a nominal amount available to meet future Minister's authorisations (Table 5). This volume will not vary for the life of this Plan. If future hydrogeological investigations determine that there is additional water available for consumptive purposes from this aquifer, a new consumptive pool will be created in accordance with sections 2.3 and 6 of this Plan.

2.2.3.3 Quaternary Lincoln North Management Area

Similarly to the previous management areas, there is little extraction and limited monitoring of the aquifer within the Quaternary Lincoln North management area. It is considered that the current extractions are not having any observed detrimental impact on other water resources or GDEs (see section 3.3.7). It is however noted that in several instances, licensees have had difficulties accessing the water resource due to water level declines. Given the limited extractions occurring within this management area, it is thought that these water level declines are driven by a significant period of below average rainfall and diminished recharge.

Anecdotal evidence suggests that dams upstream of Little Swamp, located to the north of the Lincoln North management area in Green Patch, have decreased flow though Little Swamp and therefore decreased recharge into the aquifer from the associated streams (Bobrige pers. comm.). There is no groundwater monitoring in this area and as such the decline due to these changes cannot be observed. However it should be noted that DWLBC Report 2009/26 *Impact of farm dams on streamflow in the Big Swamp and Little Swamp Catchments* (Alcorn 2009), which reports on surface flow modelling of the impact of dams in this area, found that in median–to–wet years, farm dams are not considered to cause significant reductions in annual stream flow, except in a few localised cases. The median reduction in stream flow at both Big Swamp and Little Swamp was estimated to be around 5%. The impact during drier years was considerably higher with approximately 12% of water estimated to be extracted from the catchments upstream of both swamps. This raises concern, particularly during a succession of dry years, however this is unlikely to have a significant effect on recharge to the Quaternary aquifers, as the streams are mostly gaining (i.e. receiving water from the aquifer) and underlain by Basement aquifers.

Therefore it is still considered that the current licensed and non-licensed extractions would be an appropriate volume for the resource capacity of this management area in addition to a nominal amount available to meet future Minister's authorisations (Table 5). This volume will not vary for the life of this Plan. If future hydrogeological investigations determine that there is additional water available for consumptive purposes from this region, a new consumptive pool will be created in accordance with sections 2.3 and 6 of this Plan.

2.3 Creation of Additional Consumptive Pools

The estimates of the resource capacity for each management area are based on the best available hydrogeological information (Stewart 2013). Where additional capacity is discovered as a result of future hydrogeological investigations this water may become available for consumptive purposes, if the prospective licensees can satisfactorily demonstrate to the Minister that the taking of the new found water will not have a detrimental impact on the existing management area resource, other water resources, existing water users, or GDEs. This condition applies to all previously defined consumptive pools in this Plan.

The complexity of hydrogeological investigations required to fulfil the above ecologically sustainable development requirements will vary depending on the purpose and volume of the proposed extraction, and will be determined by the Minister. However it is likely to include aquifer tests (pump tests) to determine the yield of the aquifer and the likely zone of impact from such extractions to ensure that the extraction of such water will only present a low level of risk to the present and future health and maintenance of ecosystems that depend on water from the aquifer and the extraction will not adversely affect the reliability of supply or the quality of water accessed by existing users of water from any other consumptive pool.

For the purposes of this Plan, any additional groundwater capacity that is determined to exist and is approved under this Plan will constitute a new consumptive pool. The water available for licensed purposes in these consumptive pools may be granted under the Act as a water allocation on account of a water access entitlement, as set out in section 6 of this Plan.

Table 5. Estimated resource capacity of the unsaturated Quaternary Limestone, Tertiary Sands, Basement and Quaternary Lincoln North management areas

PWA	Management Area	Domestic Use (ML)	Stock Use (ML)	Minister's Authorisation (ML)	Licensed Use (ML)	Resource Capacity (ML)
Southern Basins	Quaternary Lincoln North	3.36	30.95	5	53.9	93.21
	Unsaturated Quaternary	1.96	0	5	0	6.96
	Tertiary Sands	1.12	23.02	5	0	29.14
	Basement	0.28	23.02	5	535.2	563.5
Musgrave	Unsaturated Quaternary	5.6	0	5	0	10.6
	Tertiary Sands	1.12	62.27	5	0	68.39
	Basement	0	62.27	5	0	67.27

2.4 Annual Calculation of the Resource Capacity of the Saturated Quaternary Management Areas

The resource capacity for the unsaturated Quaternary Limestone, Tertiary Sands, Basement and Quaternary Lincoln North management areas is considered to be provided for at the volume outlined in Table 5, with no variation over the life of the Plan. As discussed in section 6.2 of this Plan, the consumptive pools with respect to these aquifers will be defined by way of fixed volume.

The volumetric resource capacity of the saturated Quaternary Limestone management area displayed in Tables 3 and 4 represents an upper limit on the volume of water that is available for all uses (i.e. licensed, non-licensed, the environment and aquifer maintenance). As defined previously, the resource capacity does not include any water held in storage within the aquifer, but represents the approximate volume of one year's recharge to the aquifer. The resource capacity is the commencement volume for the resource, a portion of which is provided to the environment on a continuing basis (see section 5.1.1), and the remainder of which is made available to meet consumptive needs (see section 5.1.2).

However, the volumetric capacity of the saturated Quaternary Limestone aquifer is variable because it responds quickly to climatic variations. Therefore, this Plan provides for the adaptive management of the dynamic saturated Quaternary Limestone aquifer. As discussed in section 6 of this Plan, the consumptive pools with respect to the saturated Quaternary Limestone aquifer will be defined by way of volume determined annually. The variable consumptive pool volume will reflect the condition of the groundwater resource and will greatly assist in ensuring that "the rate of the taking and use of the water is sustainable" as required by section 76(4)(b)(ii) of the Act. The methodology for determining the annual consumptive pool volume is discussed in section 6 of this Plan.

3 Needs of Groundwater Dependent Ecosystems

3.1 Environmental Water Requirements and Provisions

Section 76(4)(a)(i) of the Act requires a water allocation plan to complete "an assessment of the quantity and quality of water needed by the ecosystems that depend on the water resource and the times at which, or periods during which, those ecosystems will need that water".

Section 76(4) of the Act also requires that a water allocation plan includes:

- An assessment of the capacity of the water resource to meet environmental water requirements (section 5.1.1 and 5.3.1)
- Information about the water that is to be set aside for the environment including, insofar as is reasonably practicable, information about the quantity and quality of water, the time when that water is expected to be made available, and the type and extent of the ecosystems to which it is to be provided, a statement of the environmental outcomes expected to be delivered on account of the provision of environmental water under the plan.

Whilst the Plan defines optimal water requirements for the environment (environmental water requirements – defined in section 3.1.1) these may be different to what is provided (environmental water provisions – defined in section 3.1.2) under the Plan in order to achieve an equitable balance between environmental, social and economic needs.

3.1.1 Environmental Water Requirements

Section 76(8a) of the Act defines environmental water requirements (EWRs) to mean "those water requirements that must be met in order to sustain the ecological values of ecosystems that depend on the water resource, including their processes and biodiversity, at a low level of risk".

The EWRs of ecosystems that depend on the groundwater resources being managed in the PWAs through this Plan are discussed in section 3.4. These ecosystems rely on there being sufficient water in the aquifer to maintain natural discharge processes, including discharge to wetlands and other groundwater dependent ecosystems (GDEs).

3.1.2 Environmental Water Provisions

A water allocation plan must achieve an equitable balance between environmental, social and economic needs for water under section 76(4)(b)(i) of the Act. For the purposes of this Plan 'environmental water provisions' mean those parts of environmental water requirements that can be met at any given time, with consideration to existing users' rights and social and economic impacts.

Environmental water provisions (EWPs) for the PWAs are described in section 3.5. It should be noted that these EWPs do not aim to return the groundwater dependent ecosystems within the PWAs to a 'pristine', pre-European or historic condition, but rather they aim to maintain the current condition and distribution of these ecosystems at a low level of risk. It is not the role of this Plan to address historic adverse impacts on environmental values that depend on groundwater. The groundwater extraction limits in this Plan have been set at levels that are expected to maintain current environmental values identified within the PWAs that may be affected by higher unsustainable groundwater extraction levels.

3.2 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) contain a diverse range of complex ecological communities of plants, animals, fungi and microbes whose functions depend on water. In general, GDEs include watercourses, riparian zones, wetlands, floodplains, salt lakes and estuaries, as well as near-shore marine, hyporheric and aquifer ecosystems. Within the PWAs these ecosystems are often dominated by plants such as red gums (*Eucalyptus camaldulensis*), tea-tree (*Melaleuca* spp.) or reeds, which have relatively high water needs and are typically considered to be riparian plants that occur on the edges of wetlands, springs or watercourses. There are also terrestrial ecosystems that occur away from recognised water bodies, which depend on groundwater for some or all of their water needs and thus would be considered GDEs.

GDEs have a highly complex dependence on their water regime, that is: the extent, duration, frequency, timing and depth of inundation or soil saturation. The influence of the water regime is so fundamental that the very occurrence of these ecosystems in the landscape is dependent on the water regime they have historically experienced. This is especially true on the Eyre Peninsula where alternate water sources may be unreliable (e.g. rainfall) or largely non-existent (e.g. permanent watercourses). It is important to note that it is not just the total volume of water these ecosystems receive in a given period that is important for their ecological functionality, but also how, when and where that water is delivered and whether the quality of that water is suitable to support the full range of life stages for the full complement of water dependent biota.

In the case of this Plan, the prescribed water resource is the groundwater contained in the Quaternary Limestone and the deeper Tertiary Sands and Basement aquifers within the Southern Basins and Musgrave PWAs. It does not include transient water in overlying soil strata (recharge areas), or perched systems disconnected from the regional Quaternary Limestone aquifer. As such, the GDEs that this Plan needs to provide for, are those dependent on the groundwater in the Quaternary Limestone the deeper Tertiary Sands and Basement aquifers within the PWAs.

Ecosystems that rely on groundwater for some or all of their water requirements are classified as GDEs. Not all GDEs draw on groundwater directly and not all are solely reliant on groundwater. However, groundwater provides a vital and reliable source of water to these ecosystems because of the generally low rainfall environment and the lack of watercourses in the region. It is understood that groundwater availability is the main factor controlling the distribution of these GDE types within the PWA landscape. Changes in groundwater quantity (e.g. depth, extent, duration) and quality (e.g. salinity, pH) may affect the condition and survival of these GDEs, depending on the degree and nature of their groundwater dependency. Some systems may have an 'obligate' groundwater dependence where the system would be lost if groundwater was no longer available in a suitable regime. Other systems are likely to have 'facultative' groundwater dependence where other sources of water (e.g. rainfall, runoff or recharge) are generally used, but groundwater will be used when and where it is available particularly during low rainfall periods. Groundwater may be a significant source of water for GDE persistence between other watering events.

3.3 Groundwater Dependent Ecosystems within the PWAs

The following list of GDEs have been identified and mapped, with respect to current condition and spatial extent, within the PWAs. They have been characterised into five distinct groups based on ecosystem type and will be used as the environmental values that may be affected by groundwater extraction for the purposes of this Plan. Terrestrial fauna that drink from groundwater can also be considered a separate GDE component, but for the purposes of this Plan it is assumed that their water needs will be provided by providing water to the GDEs listed below. Therefore they have not been considered as a separate environmental value.

3.3.1 Wetlands

Wetland systems within the PWAs that receive ephemeral, seasonal or continuous groundwater contribution, including lakes, damplands and springs are considered to be GDEs and constitute environmental values to be provided for by this Plan. These wetland GDEs include saline wetlands (e.g. Lake Newland and Sleaford Mere) and freshwater-brackish wetlands (e.g. Myrtle Swamp – near Elliston, and Lake Hamilton), as well as springs such as the Weepra Spring at Lake Newland. Those wetlands that depend on catchment water and are thought to be disconnected from the Quaternary aquifer, such as Big and Little Swamp (SKM 2009), were not considered to be GDEs and thus are not considered to be current groundwater-dependent environmental values for the purposes of determining the non-consumptive portion of the resource capacity this Plan (section 5.1.1). However, environmental protection zones have been placed around Big and Little Swamps to protect these wetlands and their surrounding red gums from possible adverse impacts from adjacent groundwater extractions (section 4.2.3).

Groundwater contributions to a given wetland are determined by the bathymetry or shape of the wetland basin (i.e. deep or shallow) and how it intersects with groundwater levels over time and space. The minimum and maximum depths to groundwater relative to the depth of the wetland basin will determine the frequency, extent, timing, depth and duration of wetland inundation (i.e. its water regime). When the groundwater level is higher than the base of the wetland, the wetland will be inundated to the depth and extent that the groundwater level exceeds the wetland base. When groundwater levels drop below the base of the wetland, groundwater will not be expressed at the surface but the soil below the groundwater level will remain saturated.

Generally, the wetland GDEs within the PWAs are shallow with respect to observed changes in groundwater levels, and thus they are vulnerable to relatively small changes in groundwater level that may not significantly affect other water users. As such, they are susceptible to groundwater development and/or periods of low recharge that result in lowered groundwater levels and/or increased salinity. Semeniuk and Semeniuk (2007) grouped wetlands on the Eyre Peninsula based on their topographical, hydrological and ecological character. The wetland groups found within the PWAs that are known to have groundwater dependency are described below and displayed in Figures 24 and 25.

Sleaford Wetland Group: Located on the south-eastern tip of the Southern Basins PWA (Fig. 24) and consisting of two basins, Sleaford Mere and Little Sleaford Mere. Sleaford Mere is a shallow, saline, permanent wetland and a site of national and international importance for shorebirds (Environment Australia 2001). Little Sleaford Mere is ephemeral. Together these basins provide important habitat for a wide range of fauna including waders, shorebirds, other waterbirds, and frogs. The water regime appears to be dependent on direct rainfall and groundwater recharge from the supporting Quaternary Limestone aquifer (Lincoln South management area). Permanent freshwater soaks occur at the northern end of Sleaford Mere.

Wanilla Wetland Group: Consists of a number of short channels originating in the Lincoln Hills that flow into waterlogged flats in the northern section of the Southern Basins PWA (Fig. 24). These channels have flow periods of approximately five months (Semeniuk and Semeniuk 2007). The two main wetlands are Merintha Creek and Wanilla. They appear to be recharged by direct rainfall and runoff from Lincoln Hills and lose water to the groundwater (Uley North management area). However, changes in regional groundwater levels may affect flow and thus they are included as environmental values.

Pillie Wetland Group: Consists of a number of small elongate dampland basins on the south-eastern tip of the Southern Basins PWA (Fig. 24). The selected representative site is Lake Pillie, although there is anecdotal evidence that it has become more terrestrial in character over the last 15 years (Hyde pers. comm.). The water regime appears to be dependent on direct rainfall and groundwater recharge from the supporting Quaternary Limestone aquifer (Lincoln South management area).

Hamilton Wetland Group: Includes a single large elongate basin (Lake Hamilton) and a number of smaller associated basins along the coastal edge of the Musgrave PWA (Fig. 25). All are seasonally inundated. The selected representative sites are Lake Hamilton and Round Lake. Lake Hamilton is listed as a nationally important wetland in the *Directory of Important Wetlands in Australia* (Environment Australia 2001) and is a good example of a wetland type occurring within a biogeographic region in Australia. The water regime for Lake Hamilton is dependent on several pathways. Fresh surface water from the eastern and western limestone ridges discharge into the lake from multiple sources, predominantly two large springs at the northern end. There is saline surface water on the western side of the lake with salinities in the order of 2-3 times seawater concentration. It is thought that this may be due to saline springs discharging into the lake (Nosworthy pers. comm.) or tidal channel connections (Semenk 2007). The water regime of Round Lake appears to be dependent on direct rainfall and groundwater recharge from the supporting Quaternary Limestone aquifer (Sheringa management area).

Newland Wetland Group: Consists of a complex of large wetland basins within the Musgrave PWA (Fig. 25), with the main body of water, Lake Newland, being a relatively permanent salt lake with freshwater springs. Parts of the lake system dry over the summer period. Lake Newland is one of the most ecologically important wetlands on the Eyre Peninsula. According to Wainwright (2008) it attracts bird species considered vulnerable in South Australia and has an important role as a drought refuge for waterfowl. Wainwright (2008) considered Lake Newland to be of 'international importance for banded stilt' and of 'national importance' as a summer feeding habitat for the vulnerable hooded plover. It is also listed as a nationally important wetland in the *Directory of Important Wetlands in Australia* (Environment Australia 2001). Fresh water is delivered into the Newland Lake by rainfall and groundwater (Semeniuk and Semeniuk 2007) from the supporting Quaternary Limestone aquifer (Bramfield management area). The saline lakes become shallower and more saline in summer, but are freshened by winter rain and a number of fresh water springs and seepages, which enter the lakes at their edges.

Poelpena Wetland Group: Consists of a single large elongate basin to the east of the Musgrave PWA (Fig. 25) that is likely to be intermittently inundated. Poelpena Swamp is the representative site. Recharge to the wetland appears to be via direct rainfall and groundwater discharge from the supporting Quaternary Limestone aquifer (Polda management area).

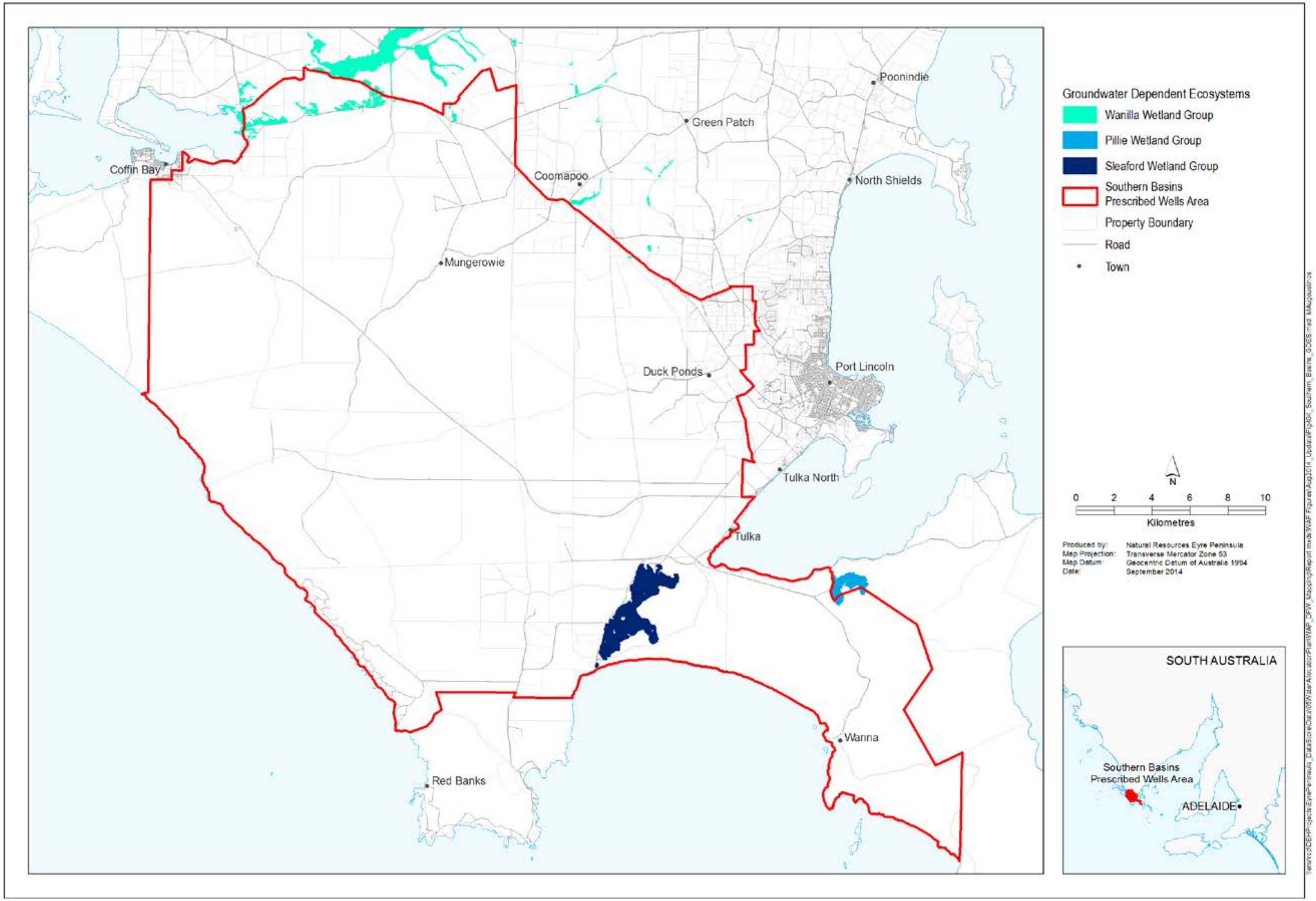


Figure 24 Wetland groundwater dependent ecosystems (GDEs) of the Southern Basins PWA

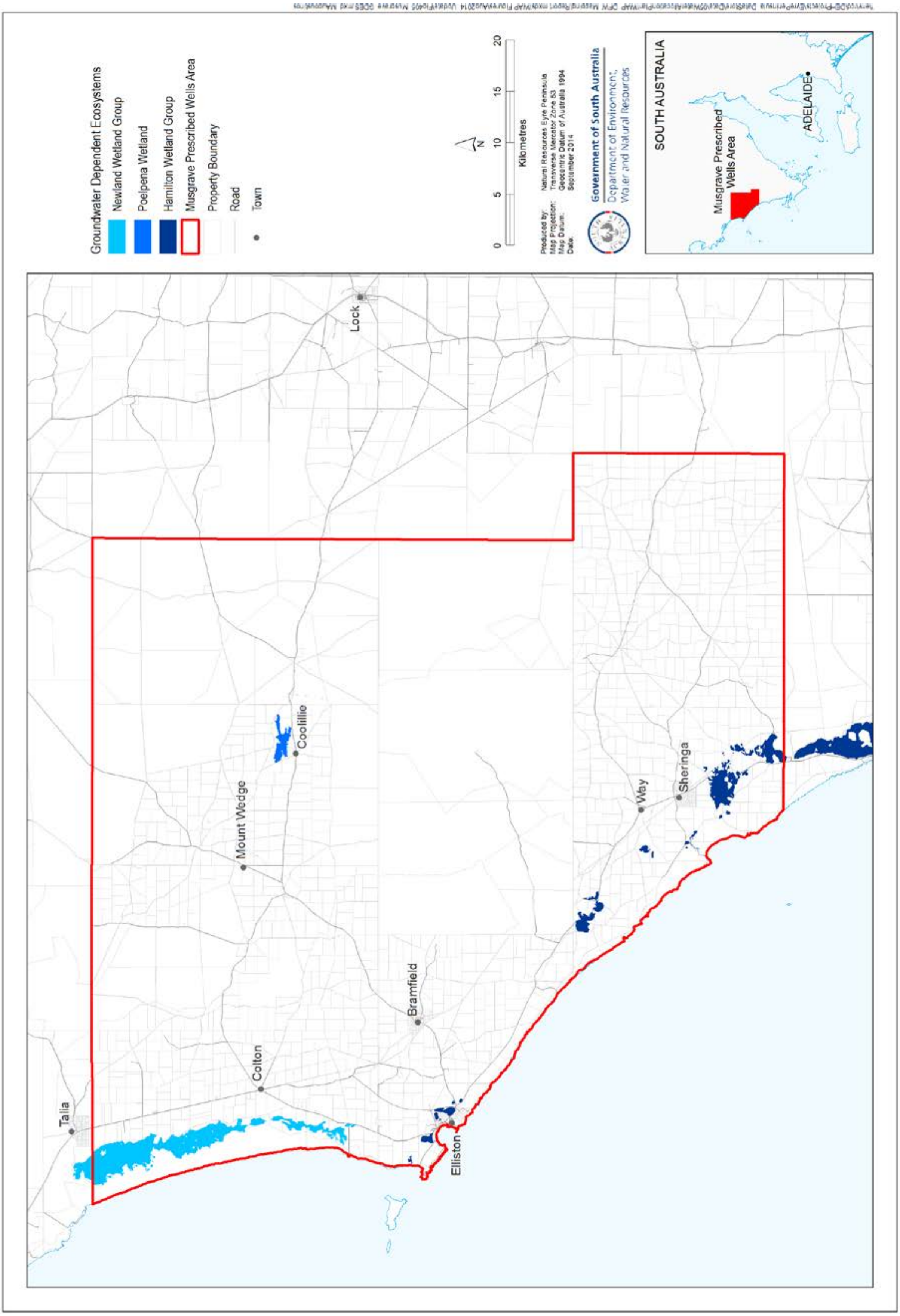


Figure 25 Wetland groundwater dependent ecosystems (GDEs) of the Musgrave PWA

3.3.2 Phreatophytes (especially Red Gum Forests and Woodlands)

Vegetation communities that use groundwater to meet some or all of their water requirements are referred to as phreatophytes. Eucalyptus forest and woodlands are considered to be the only obligate groundwater dependent vegetation community within the PWAs (SKM 2009). There may be other facultative phreatophytes but these were not readily identified by SKM (2009) and are not included as environmental values in this Plan (Doeg et al. 2012).

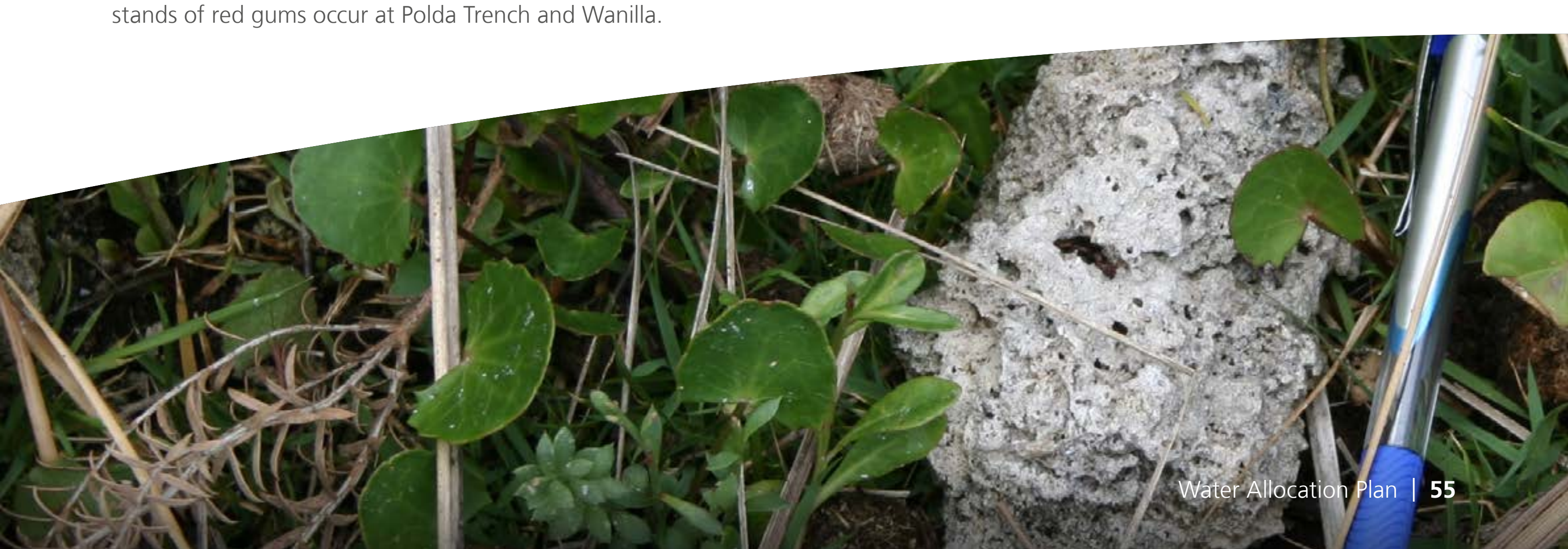
Phreatophytic eucalypts include *Eucalyptus camalduensis* (red gums) and *E. petiolaris* (Eyre Peninsula blue gum or water gum). *E. petiolaris* only occurs on the Eyre Peninsula (Nicolle 2013) and are listed as Threatened Ecological Communities under the *Environment Protection and Biodiversity Conservation Act 1999*. Very little is known about the ecophysiology of Eyre Peninsula blue gums. Given this, for the purposes of this Plan, they are assumed to have similar water requirements to the better studied *E. camaldulensis*.

Regardless of species, *phreatophytic eucalypts* use deep root systems to access groundwater that is brought into the unsaturated soil layers via capillary rise. The typical water use requirements of red gums are greater than that provided by the average annual rainfall on Eyre Peninsula, and thus their survival is dependent on additional water supplies (e.g. catchment run-off after summer storms or regional groundwater). They cannot, however, withstand long periods of inundation. Recruitment processes for red gums and blue gums within the PWAs are unclear but it appears that new trees germinate and establish when depressions are inundated for a prolonged period. This seems to be linked to pooling of water on the soil surface after large, infrequent rainfall events rather than to groundwater levels rising above ground level for extended periods. The critical components of the water regime for phreatophytes are the frequency and duration of groundwater levels that intersect with their active root system (Doeg et al. 2012). Representative stands of red gums occur at Polda Trench and Wanilla.

3.3.3 Baseflow and Groundwater Soaks

Ephemeral or permanent streams can occur where there is a continuous or seasonal groundwater discharge into watercourses. Ecosystems that rely on these streams are known as baseflow GDEs. Groundwater soaks are surface water expressions of groundwater and occur where the groundwater intersects with the surface, and the pressure of the groundwater is sufficient to move water to the surface. Therefore, they only occur where and when the groundwater rises to the surface. Soaks like those entering Sleaford Mere provide a source of water much fresher than the surrounding saline water and form a stream within the wetland that supports plants with lower salinity tolerances (e.g. *Hydrocotyle* sp.) and facilitates processes such as frog breeding (Doeg et al. 2012).

Baseflow and groundwater soaks may be permanent where the groundwater is in constant contact with the surface providing a permanent water source, or may only be temporary with flow ceasing when the groundwater level drops below the surface. Also, the distance that the expressed groundwater travels before it infiltrates below land surface, and therefore the area affected by the discharge, is a function of the flux and pressure of the groundwater (determining the discharge rate) and the porosity of the down-slope soils (determining the rate of loss back into the ground). Therefore, the critical components of the water regime for baseflow and groundwater soaks are the difference between the minimum and maximum levels of groundwater local to the discharge, determining the frequency and duration that the springs are active, and the groundwater flux and pressure determining the rate at which groundwater is expressed. There are no baseflow or groundwater soak GDEs known within the PWAs that are not associated with one of the identified wetlands, thus they have not been identified as a separate environmental value.



3.3.4 Hypogean, Hyporheic and Collapsed Sinkhole Ecosystems

Aquifer and/or cave habitat ecosystems that depend on groundwater interaction are another suite of GDEs. Little is known about the microbes, plants and animals that use these systems on the Eyre Peninsula, although some records of stygofauna have been identified from sampling of select observation wells and caves (Doeg et al. 2012). Hypogean and hyporheic ecosystems occur beneath the surface of the ground in saturated pore spaces, in cracks or fractures in consolidated material, or in caves formed below the surface. Hyporheic systems generally occur closer to the surface where there can be mixing of surface and groundwater, while hypogean systems occur deeper in the ground.

These systems provide habitat for a diverse group of micro-organisms and minute invertebrates, and even fish species can be found in caves. The biota of these systems are obligate groundwater users that are isolated by physical and hydrological barriers to migration. Therefore, the critical components of the water regime for hypogean and hyporheic systems are the difference between the minimum and maximum levels of the watertable determining the amount of available habitat, particularly in cave systems. It is still uncertain what role water quality plays in maintaining these systems (Doeg et al. 2012).

3.3.5 Marine Discharges

Marine discharges are surface expressions of groundwater that occur under the ocean or in near-shore marine environments. These can only occur where the terrestrial groundwater intersects with the marine bed, and the pressure of the groundwater is sufficient to discharge water against the head of the seawater. The introduction of fresher water (depending on the salinity of the groundwater) into the marine environment creates a localised habitat with different water chemistry to the surrounding areas, and can therefore lead to a distinct biotic community adapted to that chemical regime. The critical components of the water regime for marine discharges are the difference between the minimum and maximum levels of the groundwater and the relative hydraulic pressures of the groundwater system and the adjacent marine environment determining whether groundwater can exceed the head of the seawater above it.

Anecdotal reports suggest that the occurrence of marine discharges was once very common and has declined over time along the coastline, which may be an impact of groundwater extraction and/or low (rainfall-driven) recharge rates. In Kellidie Bay and Coffin Bay groundwater discharge is readily visible in the shallow coastal waters, particularly at low tide. These are representative sites.

Coffin and Kellidie Bays: are part of the same inverse estuary: a long and narrow marine inlet whose waters become hypersaline each summer (with saltier waters occurring nearer to land than to the open ocean). Inverse estuaries typically occur in hot arid climates without large freshwater inputs, such as the South Australian gulfs (Kampf and Ellis 2015). Modelling by Kampf and Ellis (2015) showed that despite the existence of strong tidal flows (more than 1 m/s) in passages within Coffin Bay, there was little connection between tidal stirring zones and therefore water could remain in the bay for 80-100 days. However, the increased salinity from the long residence time was less than expected compared to two local, large inverse estuaries: Spencer Gulf and Gulf St. Vincent (Kampf and Ellis 2015). This indicates that there are freshwater inputs to Coffin and Kellidie Bays in the form of rainfall on the surface of the bays and groundwater discharge from the Coffin Bay A lens. Observations of the near-shore upwellings in Kellidie Bay suggest that the groundwater inputs fluctuate but persist through summer and autumn each year, independent of rainfall (Saunders pers. comm.).

Coffin and Kellidie Bays have a range of marine habitats including: mangroves, saltmarsh, reef, sandflats, biogenic rock, algal pools, seagrass meadows (two species), mussel beds, tidal flats and rocky shorelines (Miller et al. 2009; Saunders 2012). It is a multi-species breeding and feeding ground for commercial and recreational finfish, a nursery for Western king prawn and a drought refuge for shorebirds and waterfowl. Kellidie Bay and the two creeks that connect with it, Merintha and Minniribbie Creeks, form essential environments for diadromous fish to complete their life cycles in fresh and saline waters, such as Galaxiids and Hardyheads (Saunders pers. comm.). The bays also support commercial oyster farms. The unique ecosystems of Kellidie Bay are a considered to be a High Conservation Value Aquatic Ecosystem and the eastern end is a sanctuary within the Thorny Passage Marine Park.

3.3.6 Aquifer Maintenance

Whilst aquifer maintenance is not technically a GDE, there is a need to maintain natural flows through the aquifer, including natural discharge. If too much water is made available for consumptive purposes, there may be impacts on the water balance in other areas, such as reducing natural discharges or altering flow directions. These natural discharges occur not only to marine environments, but also to groundwater dependent ecosystems. Therefore, the environmental water requirements and provisions should have some consideration toward the need for water to maintain the aquifers natural flow regime.

3.3.7 Management Areas with no known Groundwater Dependent Ecosystems

Groundwater that discharges into wetland GDEs is typically shallow, that is, the watertable is within the top 2 m of the soil profile, and as such, the deeper Tertiary and Basement aquifers are unlikely to provide water to any GDEs within the PWAs. Assessments of the extent of saturation (Stewart 2013, Figs. 12 and 13) identified that there was no such shallow groundwater within the unsaturated Quaternary Limestone, which is consistent with the lack of mapped GDEs in those areas (Figs. 24 and 25). On this basis it was assumed that the following management areas contain no wetland GDEs:

- Unsaturated Quaternary Limestone
- Tertiary Sands
- Basement
- Quaternary Lincoln North

It is acknowledged that stygofauna or other subterranean ecosystems may be present within these areas that are not yet mapped or studied. Also, phreatophytes (e.g. red gums) are scattered throughout the region and thus may occur within these management areas. Any inferred mapping such as Normalised Differential Vegetation Index (NDVI) (SKM 2009) or aerial photography has yet to be ground-truthed. For the purposes of this Plan, it is assumed that the water set aside for the environment in each management area (section 5.1.1) will be sufficient to maintain existing phreatophytes at a low level of risk. As noted above (section 3.3.2), groundwater levels are not thought to drive recruitment of phreatophytes but may affect the condition of mature trees, which will be tracked through the monitoring, evaluation, reporting and improvement program that complements this Plan.

3.4 Environmental Water Requirements

The Environmental Water Requirements (EWRs) of the GDEs within the PWAs, were determined by Doeg et al. (2012) using the following ecological approach:

- All relevant information on identified GDEs was collated and analysed in terms of identification, classification and mapping of the wetlands and describing the associated biota and ecological processes (environmental values)
- Ecological objectives for the maintenance of these environmental values were set to define the scope and guide the determination of the EWRs
- The relationship between the environmental values used in the ecological objectives and their water requirements were described using conceptual models (i.e. how the GDE system 'works') formulated through literature research and application of expert opinion, which were used to identify the critical characteristics of the water regime
- The water regimes that fulfil all of the objectives set for the different GDEs were determined.

It is recognised that wetlands on the Eyre Peninsula that have surface water for some or all of the time have been relatively well-mapped, but the dependence of some of them on groundwater sources has not been well demonstrated (see Doeg et al. 2012 for discussion). It is assumed here that all wetland groups within the PWAs, except where stated otherwise, are dependent on regional groundwater and may be susceptible to impacts from groundwater development (e.g. decreased water availability and/or increased salinity). The exception as stated above (see section 3.3.1) is the Greenly Wetland Group (including Big and Little Swamps), which have been shown not to be groundwater dependent (Doeg et al. 2012). Rather, these wetlands rely on surface water and are managed through the Regional NRM Plan (Das 2009). Groundwater dependent ecosystems other than wetlands have not been as well mapped within the PWAs. For these ecosystems it is assumed that the generic EWRs that have been applied to well-studied GDEs that support similar vegetation associations will apply.

The environmental values employed for this plan are limited to those GDEs that have been identified and mapped (with respect to current condition and spatial extent) within the PWAs. It is acknowledged that there may be other unknown GDEs that are at risk from groundwater extraction in the PWAs and that there are significant gaps in knowledge about groundwater reliance for some identified GDEs (e.g. importance of baseflows to the Wanilla Wetland Group), which should be explored for future versions of this Plan.

The determination of EWRs was guided by the following objectives (Doeg et al. 2012):

1. A watering regime that will promote self-sustaining populations of groundwater dependent flora and fauna that currently exist within the area
2. The watering regime will reduce the likelihood of future degradation of assets and increase their resilience to future low rainfall periods
3. The current spatial distribution of groundwater dependent flora and fauna will be maintained.

Note that these objectives are for the Environmental Water Requirements (EWRs). The Environmental Water Provisions (EWPs) adopted for this Plan (see section 3.5) have taken these EWR objectives, as well as social and economic factors relevant to other groundwater users, into consideration.

The EWRs presented below were based on maintaining the current environmental values at a low level of risk. It is recognised that during dry periods, the quantity and quality of groundwater available to support the identified environmental values may not always meet the recommended regime. This is seen as a natural part of climate variability, albeit one that may be exacerbated by climate change. The biota have adapted to survive some periods where water availability is lower than optimal, but the combination of future climate change impacts and groundwater extraction may exceed their tolerances if too much groundwater is extracted and/or if groundwater is extracted too close to the groundwater dependent ecosystems to maintain them at a low level of risk. Therefore environmental protection zones and consumptive use limits exist to minimise this risk.

3.4.1 Environmental Water Requirements for Groundwater Dependent Plants

Most of the biological data relevant to the Eyre Peninsula GDEs was for plant species. This is due to plants in the GDEs being readily observable over time and space, in fact most GDEs are identified because of their distinct plant assemblages, and because plants are widely recognised as robust indicators of both short and long-term changes, and thus attract scientific attention. Relatively few studies have been conducted on more mobile or cryptic biota such as aquatic macro-invertebrates, fish, birds and other vertebrates (Doeg et al. 2012). Therefore, the EWRs for all GDEs within the PWAs that contain plants were primarily determined by the EWRs of the current plant communities. It should be noted however, that many of the wetlands on the Eyre Peninsula appear to be sub-optimal for the more aquatic plant species i.e. those that demand more permanent, deeper or more frequent inundation or the less salt-tolerant plant species, and where they occur they are likely to be persisting at their limits of aquatic viability under current water availability and quality conditions. The majority of wetlands identified are dominated by more terrestrial and resilient vegetation, with aquatic species inhabiting smaller and more marginal niches. This means that the more aquatic or less salt-tolerant plant species and their associated fauna (e.g. freshwater plants and frogs at Sleaford Mere) are highly susceptible to the impacts of groundwater extraction, increasing groundwater salinity, and/or periods of low recharge.

In order to classify plants in terms of susceptibility to changes in groundwater quality and quantity, plant species were classified into a variety of 'functional groups'. Plants that occur in the GDEs can be assigned to various functional groups based upon our understanding of their water requirements and their tolerances for duration and depth of inundation and desiccation (dryness). Plant functional groups can be visualised as a theoretical zonation of sometimes overlapping plant communities along the elevation gradient. In a permanent freshwater-brackish wetland there is often a larger range of functional groups along the elevation gradient (Fig. 26) than in saline, temporary wetlands that tend to support only limited functional groups - i.e. saline and desiccation tolerant ones (Fig. 27). The functional groups can also be depicted as a relationship between the duration of inundation and the depth of inundation at a particular site (Fig. 28). The degree of overlap in functional group zonation within a given wetland GDE at different times may indicate the degree of variability in water levels and/or water quality within that GDE.

Terrestrial damp taxa (e.g. Wilsonia backhousei) are typically found higher on the banks of permanent wetlands, above the high water mark (Fig. 26). Only in exceptionally wet years will the water inundate that zone and then only for a short time. However, the plants there depend in part on the saturated soil beneath as a source of water. In temporary wetlands, terrestrial damp taxa may occupy niches on the wetland basin if the periods of inundation are not too extensive for their water-logging tolerance (Fig. 27). Most of the identified wetland GDEs did not have plant communities dominated by terrestrial dry or floodplain taxa and thus these functional groups were not used for EWR determination.

Further down gradient in permanent wetlands, amphibious species (e.g. coastal saw-sedge (Gahnia trifida), tea-tree (Melaleuca halmaturorum)) occur (Fig. 26). They are more regularly flooded by increased wetland depth, but remain out of the water for the majority of the time. Again, the plants there depend on the saturated soil beneath as a source of water between inundation periods. Fluctuation tolerant amphibious plants (e.g. samphires) may occur right across the basin of temporary wetlands (Fig. 27).

At the edge of a permanent wetland basin (or alongside a permanent creek like Merintha Creek near Coffin Bay), where soils remain permanently wet and inundation is common, emergent species (e.g. reeds and sedges) can form a narrow to wide band, depending on the slope of the shoreline, which determines the width of the band between the minimum and maximum water marks (Fig. 26). It is unlikely that emergent plants will be supported by the water regime in temporary wetlands (Fig. 27).

In the basin of a permanent wetland, standing water is always available and provides habitat for floating or submergent species (e.g. Ruppia megacarpa; Fig. 26). In temporary wetlands, different submergent species (e.g. Chara and Ruppia tuberosa) may be found during periods when surface water is present (Fig. 27).

Therefore, the critical components of the water regime for wetlands are the:

- Difference between the minimum and maximum levels of the watertable (determines the persistence of water and the functional groups present)
- Frequency and duration of water levels that intersect with the wetland surface (determines the regularity of surface water and the time for evaporation to reduce surface water levels)
- Water chemistry (particularly salinity).

Monitoring and evaluation of any changes in the location and/or condition of plants from the different functional groups can be used to indicate if significant changes in water regime have occurred.

A subset of common plants found on the Eyre Peninsula was selected as surrogate or indicator plants for monitoring conditions over time for each functional group (Table 6) in order to determine the EWRs for the identified GDEs (as discussed in sections 3.4.2 and 3.4.3). It is assumed that providing an adequate water regime for these surrogate or indicator plants (Table 7) will adequately provide for other plants in the same functional group that are less common and/or less well understood. It is further assumed that provision of water for these surrogate or indicator plants will also provide for their dependent fauna, which is especially true for species dependent on small patches of fresher water such as the amphibious plants and animals (e.g. Hydrocotyle sp. and frogs) that depend on groundwater soaks at Sleaford Mere.

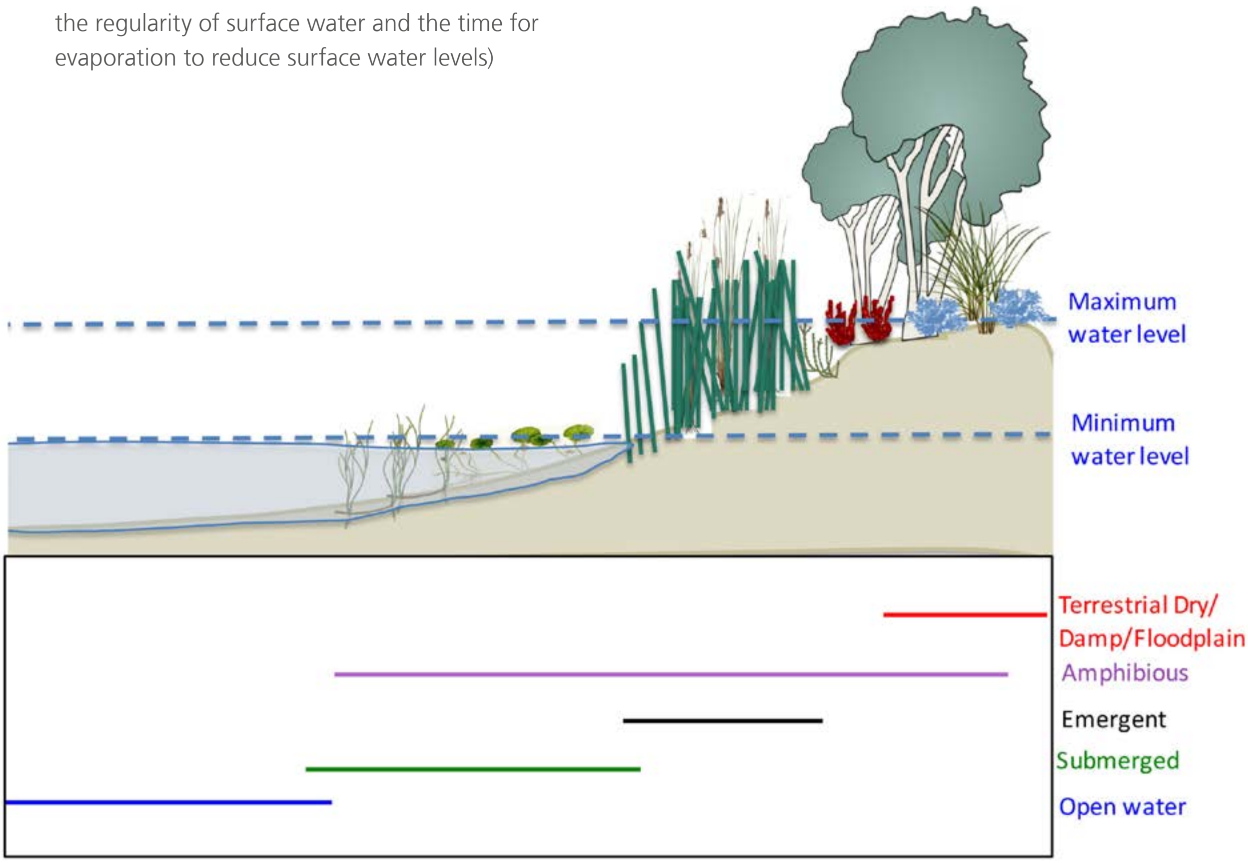


Figure 26 Plant functional groups in relation to elevation in a permanent, freshwater-brackish wetland

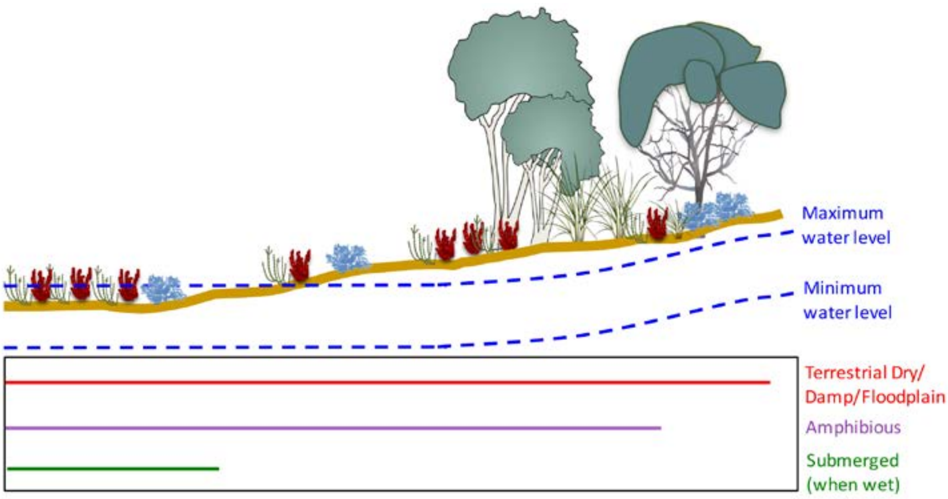


Figure 27 Plant functional groups in relation to elevation in a temporary, saline wetland

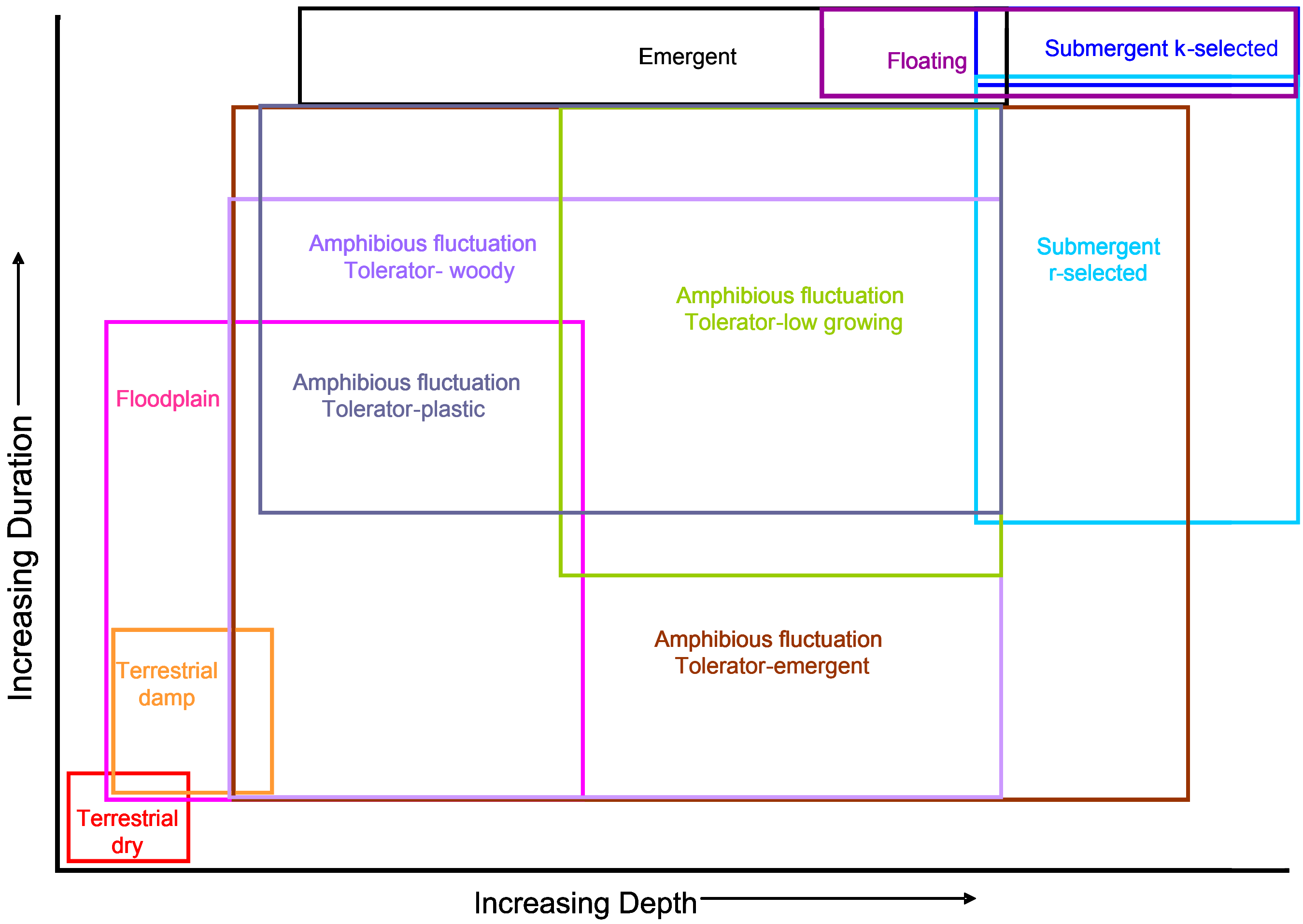


Figure 28 Plant functional groups in relation to depth and duration of inundation

Table 6 Selected plant Taxa, functional groups and water requirements used as surrogates or indicators for determining the EWRs of GDEs (Doeg et al. 2012)

Taxon	Common name	Functional group	Water requirements
Wilsonia backhousei	Narrow leaf Wilsonia	Terrestrial Damp	Indicative of the highest elevation that retains damp soil
Melaleuca halmaturorum	Tea-tree or Swamp paperbark	Amphibious fluctuation tolerator woody	Dominant tree species Decline suggests change from wetland to terrestrial
Gahnia spp.	Cutting sedge or saw sedge	Amphibious fluctuation tolerator emergent	Indicates periodic waterlogging in the root zone (surface to ~3 m).
Baumea juncea	Bare twigrush	Amphibious fluctuation tolerator emergent	Most sensitive of the emergent plants to water source variations
Sarcocornia quinqueflora and Tecticornia pruinosa	Samphires	Amphibious fluctuation tolerator emergent	Dominant shrub species Only vegetation in most saline wetlands Indicative of wet, saline areas Decline suggests change from wetland to terrestrial conditions
Triglochin striatum	Short arrow grass	Amphibious fluctuation tolerator emergent	Indicative of areas of permanently damp brackish conditions
Hydrocotyle spp.	Pennywort	Amphibious fluctuation responder plastic	Desiccation and salt intolerant Indicative of fresher and permanent habitats (e.g. freshwater soaks at Sleaford Mere)
Phragmites australis	Common reed	Emergent	Indicative of fresher and permanently wet or damp habitats (e.g. Merintha Creek)
Ruppia spp.	Seatassels	Submerged r-selected	Indicative of periodic inundation Significant food resource for birds and other fauna
Chara spp.	Stoneworts	Submerged r-selected	Indicative of periodic inundation Significant food resource for birds and other fauna

Table 7 EWRs of surrogate or indicator taxa (from Doeg et al. 2012)

Taxa and Process	Water Level requirement (Surface or Groundwater)	Minimum Duration	Timing	Frequency
Wilsonia backhousei or W. humilis	Groundwater within 25 cm of surface leading to damp soil (no surface water)	3 months	Any time	Annual
Melaleuca halmaturorum Persistence & growth	Groundwater within 2-3 m of surface based on assumed root depth	3 months	Any time	Annual
Melaleuca halmaturorum Recruitment	Groundwater within 25 cm of surface leading to damp soil (no surface water)	3 months without drying	Spring	Once every 10-25 years
Gahnia trifida Persistence & growth	Groundwater within 3-4 m of surface based on assumed root depth	2 months	Any time	Annual
Baumea juncea Persistence & growth	Groundwater within 1 m of surface based on assumed root depth	3 months	Any time	Annual No rarer than once every 3 years
Baumea juncea Recruitment	Groundwater within 25 cm of surface leading to damp soil (no surface water)	3 months	Spring – early summer (optimal)	Once every 3 years; No rarer than once every 5-10 years
Samphires Persistence & growth	Surface water depth <50 cm	6-9 months	Any time	Annual
Sarcocornia quinqueflora & Tecticornia pruinosa Recruitment	Groundwater within 25 cm of surface leading to damp soil (no surface water)	3 month	Any time	1 in 3 years
Triglochin striatum Persistence & growth	Wetland margins with damp soil to shallow water (2-10 cm)	3 months	Any time	Annual No rarer than once every 3 years
Triglochin striatum Recruitment	Freshening of saline soils by inundation	3 months	Spring to early summer (optimal)	Once every 2 years; No rarer than once every 3-5 years
Hydrocotyle spp.	Permanent shallow (2-10 cm) fresh water	12 months	Continuous	Annual
Phragmites spp. Persistence & growth	Permanent shallow water (20-45 cm) or saturated soils	12 months	Continuous	Annual
Phragmites spp. Recruitment	No surface water	<4 weeks inundation of seedlings	Any time	1 in 7 years
Ruppia tuberosa. Persistence, growth and recruitment	Surface water depth 2-3 cm	6 months	Any time	1 in 3 years
Chara spp.	Surface water depth >25 cm	>16 weeks	Any time	Annual

3.4.2 Environmental Water Requirements for Groundwater Dependent Wetlands

The wetland GDEs within the PWAs are relatively well mapped and understood compared with some of the other GDE types. Most of the wetland GDEs are shallow and are thus vulnerable to small changes in groundwater level and/or quality that may not significantly affect other users. Some of the wetlands have international or national conservation ratings (Environment Australia 2001) and all of them are considered important habitats and water sources for their dependent flora and fauna. Therefore, the wetland GDEs could be used as indicators of the success of this Plan in maintaining and/or improving the current environmental values, but would require the ability to distinguish between extractions or climate induced changes in groundwater levels or quality.

Doeg et al. (2012) developed the EWRs for the wetland GDEs presented in Table 8 based on the presence of different vegetation components and the persistence of water. It should be noted that Wanilla Group EWRs apply only if future investigations show dependence upon the groundwater in the Quaternary aquifer for these ecosystems.

Table 8 The Environmental Water Requirements (EWRs) adopted for each Wetland Group

Wetland Group	Adopted Environmental Water Requirements
Sleaford Wetland Group	For the entire year, the groundwater level needs to be in direct contact with the sources of the freshwater soaks. The watertable needs to maintain the surface water to a depth of 10 to 20 cm throughout the year. For at least three months of the year (at any time), the watertable needs to be maintained within 1 m of the *Baumea* zone. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once every three years) the watertable needs to be maintained within 25cm of the *Baumea* zone.
Wanillla Wetland Group	For the entire year, the watertable needs to maintain damp soil throughout the creekline for *Phragmites*. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least three months of the year over spring (at least once in ten years) the watertable needs to be maintained within 25cm of the *Melaleuca* zone.
Pillie Wetland Group	For at least six to nine months of the year, a water depth of up to 50 cm needs to be maintained in the basin for *Sarcocornia*. Where present, a surface water depth >25cm needs to be present for at least 16 weeks for *Chara* each year. For at least three months of the year (at least once in every three years), no surface water should be present, but the watertable needs to maintain damp soil within the parts of the basin where *Sarcocornia* is located. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once in ten years) the watertable needs to be maintained within 25cm of the *Melaleuca* zone.
Hamilton Wetland Group	For the entire year, the groundwater level needs to be in direct contact with the spring source. For at least six to nine months of the year, a water depth of up to 50 cm needs to be maintained in the basin for *Tecticornia* and *Sarcocornia*. For six months of the year, a water depth of 2 to 3 cm needs to be maintained in the basin for *Ruppia*. For at least three months of the year (one in three years), no surface water should be present, but the watertable needs to maintain damp soil within the parts of the basin where *Tecticornia* and *Sarcocornia* are located (for recruitment). Where present, a surface water depth >25 cm needs to be present for at least 16 weeks for *Chara* each year. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once in ten years) the watertable needs to be maintained within 25 cm of the *Melaleuca* zone.

Wetland Group	Adopted Environmental Water Requirements
Round Lake - Hamilton Wetland Group	For at least six to nine months of the year, a water depth of up to 50 cm needs to be maintained in the basin for *Tecticornia* and *Sarcocornia*. For at least three months of the year (at least once in every three years), no surface water should be present, but the watertable needs to maintain damp soil within the parts of the basin where *Tecticornia* and *Sarcocornia* are located (for recruitment). For at least three months of the year (at any time), the watertable needs to be maintained within 1 m of the *Baumea* zone. For three months of the year over spring (at least once in every three years) the watertable needs to be maintained within 25 cm of the *Baumea* zone. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once in ten years) the watertable needs to be maintained within 25 cm of the *Melaleuca* zone.
Newland Wetland Group	For the entire year, the groundwater level needs to be in direct contact with the spring source. For at least six to nine months of the year, a water depth of up to 50 cm needs to be maintained in the basin for *Tecticornia* and *Sarcocornia*. For six months of the year, a water depth of 2 to 3 cm needs to be maintained in the basin for *Ruppia*. Where present, a surface water depth >25 cm needs to be present for at least 16 weeks for *Chara* each year. For at least three months of the year (at least once in every three years), no surface water should be present, but the watertable needs to maintain damp soil within the parts of the basin where *Tecticornia* and *Sarcocornia* are located. For at least three months of the year (at any time), the watertable needs to be maintained within 1 m of the *Baumea* zone. For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once in everyt three years) the watertable needs to be maintained within 25 cm of the *Baumea* zone. For at least three months of the year over spring (at least once in ten years) the watertable needs to be maintained within 25 cm of the *Melaleuca* zone.
Poelpena Wetland Group	For three to six months of the year, saturated soil or surface water depth <200 mm needs to be maintained in the basin for *Tecticornia*. For at least three months of the year (at least once in every three years), no surface water should be present, but the watertable needs to maintain damp soil within the parts of the basin where *Tecticornia* is located (for recruitment). For at least three months of the year (at any time), the watertable needs to be maintained within 2 to 3 m of the *Melaleuca* zone. For at least two months of the year (at any time), the watertable needs to be maintained within 3 to 4 m of the *Gahnia* zone. For at least three months of the year over spring (at least once in 10 years) the watertable needs to be maintained within 250 mm of the *Melaleuca* zone. To maintain the water regime within the limits of red gum adaptability (as indicated by the historic groundwater regime).

3.4.3 Environmental Water Requirements for other Groundwater Dependent Ecosystems

Sections 3.4.3.1 – 3.4.3.5 discuss the environmental water requirements for phreatophytes, baseflow and groundwater soaks, hypogean, hyporheic and collapsed sinkhole ecosystems and marine discharges.

3.4.3.1 Phreatophytes (especially red gum forests and woodlands)

The EWR for red gum and the Eyre Peninsula blue gum or water gums is to maintain the water regime within the limits of their capacity to adapt to changes in water regime (i.e. ability to change morphological and physiological characteristics). Further research into the water sources used by phreatophytic eucalypts within the PWAs and their ability to switch water sources is needed to further refine this EWR for particular stands of gums (e.g. those occurring near to or over the Polda lens).

3.4.3.2 Baseflow and Groundwater Soaks

EWRs for these systems are guided by the need to maintain groundwater discharge to support associated vegetation communities, which in turn are assumed to support a wider diversity of other aquatic biota.

3.4.3.3 Hypogean, Hyporheic and Collapsed Sinkhole Ecosystems

There is inadequate data to determine the location and groundwater dependency of environmental values of hypogean and hyporheic ecosystems, and therefore generic EWRs for these systems could not be developed.

3.4.3.4 Marine Discharges

EWRs for these systems predicate that the associated aquifer system needs to maintain a pressure at least sufficient to prevent seawater intrusion. Improved mapping of near-shore discharges is required to identify the discharge points and their dependent environmental values and hydraulic processes.

3.4.3.5 Aquifer Maintenance

EWRs for these systems are guided by the need to maintain groundwater discharge to support associated vegetation communities, and maintain a pressure at least sufficient to prevent sea water intrusion. Additionally, there is also a need to provide a buffer of suitable aquifer storage for extended periods of below average rainfall and recharge.

3.5 Assessment of Environmental Water Provisions

Environmental Water Provisions (EWPs) are those portions of the environmental water requirements (EWRs) presented above that can be met at any given time within this Plan. In this case, the EWPs are equal to the EWRs because the relatively shallow groundwater levels that dictate current GDE water availability are highly responsive to, and primarily driven by, rainfall. The levels of consumptive use in this Plan, even at full usage of water on licence, are unlikely to significantly impact on water availability or water quality for identified GDEs. Therefore, this Plan seeks to provide adequate water to meet the EWRs of identified GDEs stated in section 3.4 with due consideration of existing users' rights, as well as social and economic impacts under current levels of resource development.

As stated above, water made available for consumptive use within this Plan is not expected to impact groundwater levels or behaviour sufficiently enough to prevent EWPs from being met. However, there is some uncertainty inherent in the technical investigations that inform this expectation. This uncertainty will be considered via the monitoring, evaluation, reporting and improvement processes that support this Plan, with regard to trends in GDE condition.

By its nature, a water allocation plan requires an equitable balance between consumptive uses and environmental water requirements. This Plan is intended to maintain GDEs at a low level of risk and allow for the utilisation of the water resources for human needs.

The Plan seeks to provide an adequate water regime to maintain the identified GDEs. It achieves this by utilising a combination of the following tools:

- Ensuring a proportion of recharge is set aside for the environment when determining the water available for consumptive use (section 5.1.1)
- Providing for the adaptive management of the variable saturated Quaternary Limestone aquifer (section 6.1)
- Utilising buffers and exclusion zones to protect environmental assets/values and promote natural groundwater flow processes by preventing the construction of new wells and setting conditions on replacement wells (section 4.2.3 - 4.2.5).
- Consideration was given to the presence or absence of GDEs within management areas when determining the methodology for varying consumptive pool volumes (section 6.1).

Using this approach, EWPs will be available to GDEs in the same patterns as would naturally occur. The principles included in this Plan are not expected to alter the timing of EWPs because the timing of environmental water availability is largely driven by rainfall, recharge and discharge processes that are unlikely to be modified significantly by the permissible extraction levels.

This Plan is limited in its ability to prevent the degradation of the GDEs that may be caused by drought (or extended periods of below average rainfall) and the subsequent lowering of groundwater levels below tolerance levels.

4 Assessment of the Effect on Other Water Resources

Section 76(4)(a)(ii) of the Act requires that a water allocation plan include "an assessment as to whether the taking or use of water from the resource will have a detrimental effect on the quantity or quality of water that is available from any other water resource". This includes water resources in neighbouring prescribed and non-prescribed areas.

An aquifer may have a hydraulic connection to other nearby aquifers, but the rate of flow and the volumes that flow between them are controlled by the permeability of the geological materials and the differences in their groundwater levels (i.e. does a hydraulic gradient exist between them?).

It must be recognised that climatic factors will affect water resources throughout the Eyre Peninsula and care should be taken such that influences are not confused with any effects on the water resources attributed to the taking of water.

4.1 Impacts from Aquifer Utilisation

The extraction of groundwater is likely to have an impact on the groundwater resource and it is the role of this Plan to ensure that these potential impacts, as well as impacts on, other groundwater users, and GDEs are within acceptable limits.

Around each point of extraction, there will be a zone of influence where drawdown (or a decline in water level, often referred to as a 'cone of depression') will be observed. Outside of this zone, the impact on water levels and groundwater flow will be insignificant, not only within the same aquifer from which the extraction is occurring but also in nearby aquifers that may or may not have a hydraulic connection.

4.1.1 Seawater/Fresh Groundwater Interface

Under natural conditions, coastal aquifers with hydraulic connectivity to the sea typically form a seawater/fresh groundwater interface. The shape and location of this interface is governed by natural processes including tidal action and climate-driven seasonal or annual changes in aquifer discharge to the sea.

Changes to this natural balance may cause a landward migration of the seawater/fresh groundwater interface (seawater intrusion). The estimation of the distance and rate at which landward migration may occur is complex and difficult to predict. This landward migration can occur as a result of:

- Groundwater extraction that induces a lowering of the fresh groundwater level close to the sea level
- Lower recharge as a result of lower rainfall (as projected by some future climate change scenarios), which lowers the fresh groundwater level and reduces ocean discharge.

It is important to ensure adequate aquifer discharge to the sea occurs as protection against the threat of seawater intrusion.

4.1.2 Saltwater Upconing

Aquifer systems that exhibit vertical salinity stratification (where higher-density saline groundwater underlies lower-density fresh groundwater), can be unbalanced when extraction from the upper fresh zones causes a local reduction in hydrostatic pressure. This can result in the upward movement of the underlying saline groundwater at the point of extraction. This process may be reversed if the pumping ceases or the pumping rate decreases.

4.2 Impact of Taking from One Resource on Another

There are no perennial watercourses within the Southern Basins or Musgrave PWAs. Consequently, all watercourses flow predominantly under losing stream conditions, meaning that the streams generally lose water to the aquifer, and so are not reliant on groundwater discharge as their source of water.

Sleaford Mere, Sheringa Lagoon (Lake Hamilton Wetland complex) and Lake Newland are the only perennial surface water bodies within the PWAs. These water bodies are essentially back-dunal saline lakes and are recipients of groundwater discharge. The taking of water from connected aquifers is not likely to impact on water quantity or general water quality of these surface water bodies. However local fresh-to-brackish groundwater discharges are known to be of ecological significance, and therefore warrant protection from groundwater extraction.

Little Swamp, Big Swamp and numerous minor surface water bodies are generally ephemeral and rely on rainfall and local surface water inflows as water sources. Surface water from Little Swamp and Big Swamp has been observed to either overflow or infiltrate down to the Quaternary Limestone aquifers of the Lincoln and Uley Basins respectively (Harrington et al. 2006, Evans 2009). The taking of water from adjacent management areas will not impact these surface water bodies as they are disconnected and lie at a higher elevation than the watertable.

Even if there is hydraulic connectivity between two adjacent management areas within the saturated Quaternary Limestone aquifer, the taking of water from one area is likely to only have an impact if the zone of influence from extraction extends to the other area. Such impacts will be restricted to the area near the management area boundary. The majority of inflow to each of these management areas is predominately from infiltration of local rainfall (both rapid and diffuse) and not lateral inflow.

4.2.1 Protection for Public Water Supply Resources

Groundwater Protection Zones (GWPZs) are applied in this Plan to constrain the taking of water in order to maintain the integrity of the Quaternary Limestone aquifer PWS management areas. GWPZs have been assigned to the Tertiary Sands and Basement management areas of the Southern Basins PWA (Fig. 29) where the aquifers are overlain by publicly owned land that falls within a PWS management area. Within these GWPZs, the construction of new wells and the taking of water will be subject to Principles 30d and 34c in section 7 to ensure that pumping from the deeper aquifers does not cause downward leakage and losses from the Quaternary Limestone aquifer into the Tertiary Sands or Basement aquifers. Where the management area extends to privately owned land the GWPZs do not exist, thereby allowing landholders to access water from the deeper aquifers.

4.2.2 Protecting the Saturated Quaternary Aquifer where the Tertiary Clay Aquitard is Absent

In locations where the Tertiary clay aquitard is absent, there is the potential for the Quaternary Limestone aquifer to be connected to the underlying Tertiary Sands or Basement aquifers. In these cases, the construction of new wells and the taking of water for licensed purposes from the Tertiary Sands or Basement aquifers should be limited to protect the overlying Quaternary Limestone aquifer (see section 7, Principles 30c, 33 and 34d). This is to minimise the potential for downward leakage in these areas if the hydraulic head gradients are varied.

As a way of protecting the saturated Quaternary Limestone aquifer from this downward leakage, buffer zones have been established around areas where the Tertiary clay aquitard is absent (based on the best science currently available (Stewart 2013). Figures 30 and 31 outline the areas of clay absence, as well as the buffer distances required to protect the Quaternary resource in the Southern Basins and Musgrave PWAs respectively. Details on how the buffer distances have been determined are outlined in Stewart 2013 (pages 48-51).

The setting of buffer zones limiting the location of new licensed wells will protect the Quaternary Limestone aquifer from 'indirect' stress associated with taking water from a connected aquifer system.

Table 9 outlines the distance from the clay absent area within which new wells for the purposes of extraction from the Tertiary Sands or Basement aquifer will be prohibited.

Table 9 Adopted buffer distances around areas where the Tertiary clay is absent

Location	Buffer Distance (m)
Talia area	5059
Remaining areas in Musgrave PWA	1417
Uley South area	163
Remaining areas in Southern Basins PWA	1417

Data presented in Figures 30 and 31 are based on the best science available at the time of producing this Plan (Stewart 2013) and it is acknowledged that there may be additional areas of Tertiary clay absence where there is no drillhole data currently available.

Additionally there may be areas where, although the Tertiary clay aquitard is absent, there is a similar low-permeability confining layer present which separates the Quaternary Limestone aquifer from the underlying aquifers. In these situations, it may be possible for new or additional extractions to be taken from the Tertiary Sands or Basement aquifers provided it can be proven (to the satisfaction of the Minister) that either:

- The Quaternary Limestone is unsaturated and a management regime exists which can adequately manage all aquifers should it become saturated; or
- A similar confining layer to the Tertiary clay aquitard is present and will protect the Quaternary Limestone aquifer from downward leakage should water be taken from the underlying aquifers.

Section 7 of this Plan provides the rules for the siting of wells and the taking of groundwater where the Tertiary clay aquitard is absent.

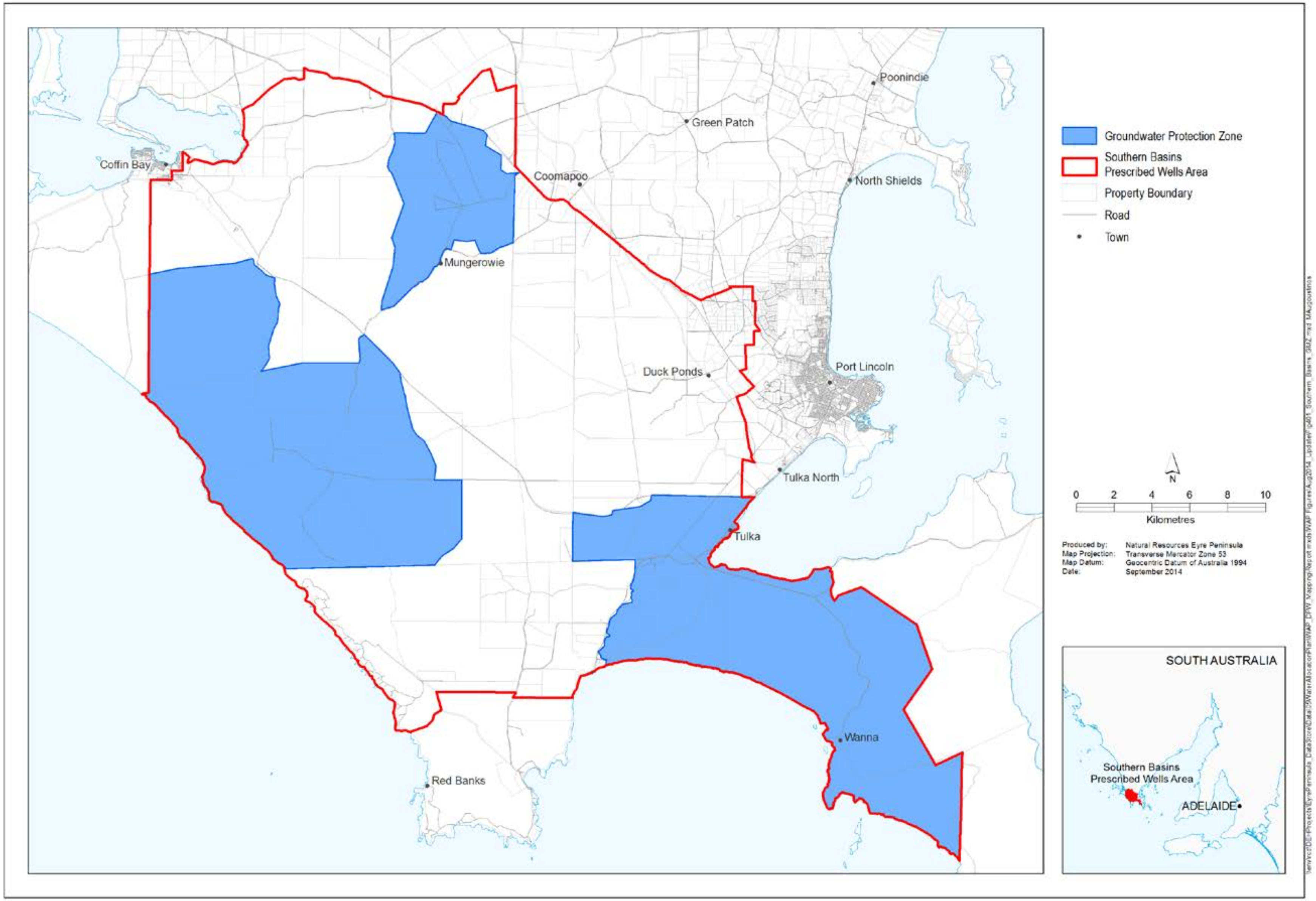


Figure 29 Groundwater Protection Zones for the Tertiary Sands and Basement aquifers of the Southern Basins PWA

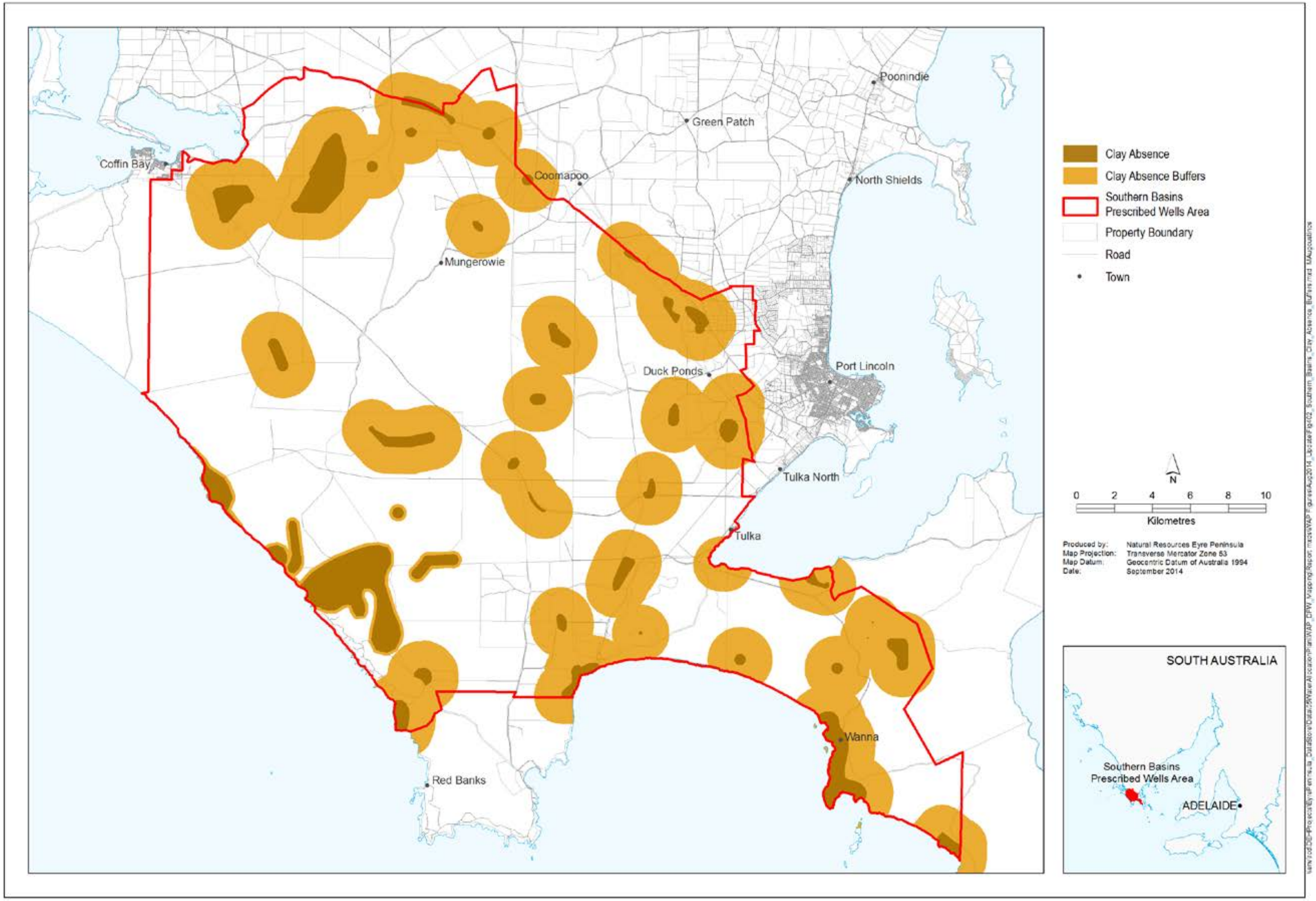


Figure 30 Spatial extent and adopted buffer areas where the Tertiary clay aquitard is absent within the Southern Basins PWA

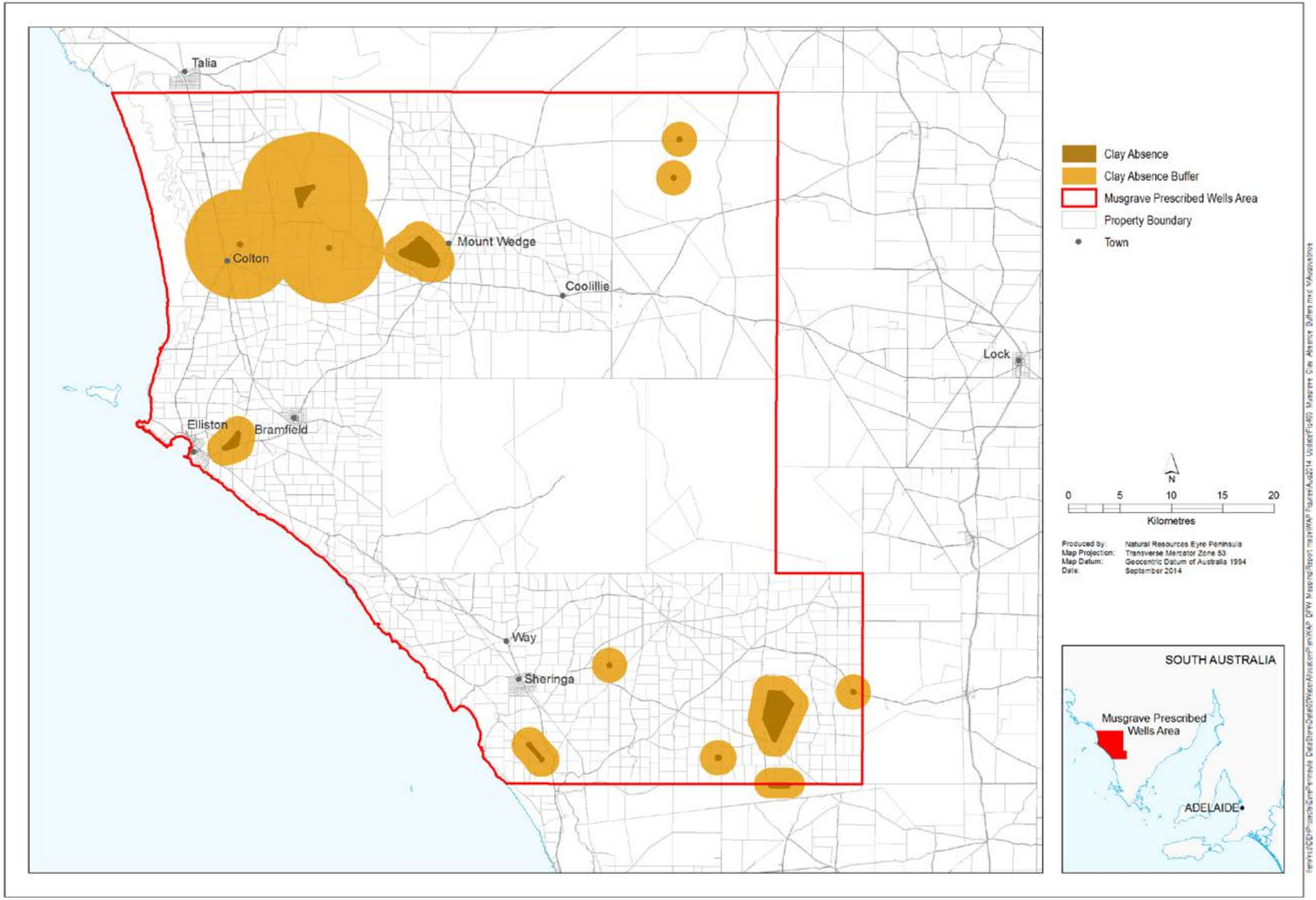


Figure 31 Spatial extent and adopted buffer areas where Tertiary clay aquitard is absent within the Musgrave PWA

4.2.3 Protection around Wetland Groundwater Dependent Ecosystems

Wetland GDEs are at risk from groundwater extraction if that extraction leads to a reduction in the surface expression of groundwater (levels) or periodicity of inundation that, in turn, adversely affects wetland biota or changes the ecological character of the wetland GDE. This is illustrated in Figure 32 where a natural, undeveloped landscape containing a wetland GDE is shown (a). The seasonal maximum and minimum water levels are displayed and indicate that this would be a permanent wetland (e.g. Sleaford Mere). If unmanaged groundwater pumping occurred close to this wetland GDE, it may generate a localised cone of depression that could reverse the groundwater flow direction and deprive the wetland GDE of water (b). In this case, unmanaged pumping would convert the permanent wetland into a temporary one with a lower maximum water level. This would lead to the sedges and tea-trees fringing the wetland no longer being inundated which would then lead to degradation of these environmental values.

Implementation of Environmental Protection Zones (EPZs) that require wells to be placed at a set back distance from the GDE wetland will mitigate the impacts of pumping. This, coupled with implementation of consumptive limits that manage the level of take, effectively protects the wetland GDE by generating a much smaller cone of depression further away from the wetland GDE (c). This will also protect the water resource by preventing excessive take.

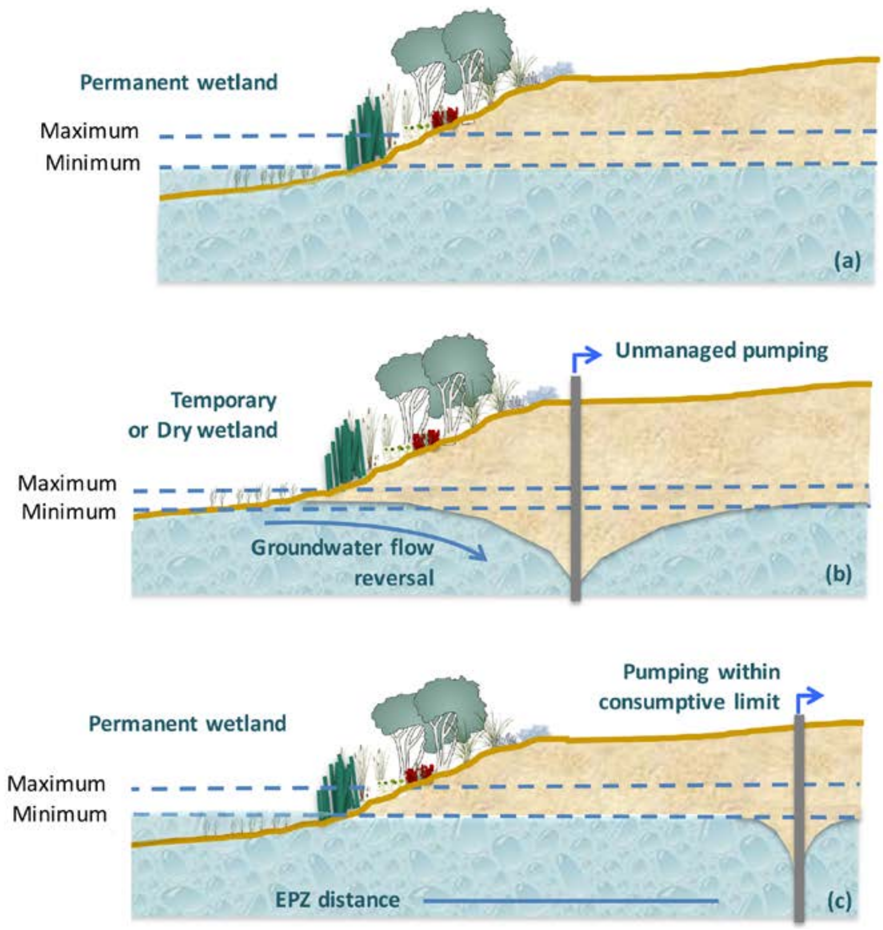


Figure 32 Conceptual diagram of how the use of Environmental Protection Zones (EPZ) and consumptive limits protects wetland GDEs

a = permanent wetland GDE with no development showing groundwater maximum and minimum levels,

b = unmanaged pumping leading to cone of depression and drying of the wetland and surrounding vegetation and

c = managed pumping outside of EPZ and within consumptive limits showing mitigation of the effects of pumping on the wetland GDE.

EPZs (shown in Figs. 34 and 35 and in Table 10) are set around the known wetland GDEs within the Southern Basins and Musgrave PWAs (see section 3 and Stewart 2013 pages 42-47). Within these GDEs and EPZs, the construction of new wells for the taking of water from the Quaternary Limestone aquifer for licensed purposes will not be permitted (see section 7 Principles 30b and 34e) unless it can be proven (to the satisfaction of the Minister) that take from within these GDEs and EPZs will not detrimentally affect the GDE.

This restriction will protect the known wetland GDEs from the impacts of extraction which could lower groundwater levels and reduce the availability of water for these GDEs. This prohibition will not however protect the wetland GDEs against the impacts of drought-induced declines in groundwater level.

Whilst analysis of regional geology, lithological logs and depth to groundwater (SKM 2009) suggests that both Big and Little Swamp are disconnected from the Quaternary Limestone aquifer, consensus from the community is that these wetlands should also have EPZs given that Big Swamp is listed on the register of nationally important wetlands. It is considered that the EPZs may act to protect the vegetation reliant on groundwater in the vicinity of the swamps from any extraction from the Quaternary Limestone aquifer.

EPZs for the Quaternary Limestone aquifer have been calculated from the range of transmissivity and specific yield values stated in Table 12 in Stewart 2013 (page 43), assuming a pumping rate of 133 kL/d (i.e. an annual allocation of 10 ML, used in its entirety and extracted continuously over an irrigation season of 75 days). This is likely to be a conservative estimate, as the majority of users on the Eyre Peninsula will extract their allocations over a longer period of time resulting in smaller zones of impact. The maximum allowable drawdown of water within the wetland is 1 cm. Due to the exponential nature of the equation used to calculate the EPZ distances in cases where the aquifer properties (specific yield or transmissivity) were very low the resultant EPZ was unrealistically large. Therefore in these cases the EPZ has been limited to a maximum extent of 5 km (Stewart 2015).

Table 10. Adopted Environmental Protection Zone (EPZ) distances around identified GDEs

PWA	Groundwater Dependent Ecosystem	EPZ Distance (m)
Southern Basins	Pillie Wetland Group	2187
	Sleaford Wetland Group	2187
	Wanilla Wetland Group	1294
	Big Swamp	1294
	Little Swamp	1294
	Duck Ponds Creek	1294
	Black Swan Lane	1294
Musgrave	Hamilton Wetland Group	3530
	Newland Wetland Group	5000
	Poelpena Wetland	5000

4.2.4 Protection of Red Gum Communities

Phreatophytic red gums on the Eyre Peninsula are dependent on groundwater when mature for survival and require access to significant soil moisture when growing from a seedling into a mature tree (Fig. 33). They do not seem to be dependent on groundwater for germination. Instead they seem to germinate following infrequent heavy rain fall when rainwater ponds around mature red gums for a period of weeks. This ponding then simulates flood conditions suitable for the germination of fallen seeds (Doeg et al. 2012). There is limited scope for management to protect these red gums and ensure recruitment of new trees into the population. Groundwater management through the implementation of EPZs around red gums as well as storage triggers in relevant consumptive pools are the main options for protecting the red gums. The other key management strategy would be to exclude stock from areas where red gums are germinating and growing but this type of land management is outside the scope of this Plan.

Given that the distribution of phreatophytes such as red gums is regionally widespread and any inferred mapping such as Normalised Differential Vegetation Index (NDVI) or aerial photography has yet to be ground-truthed, there is currently insufficient information to apply EPZs to individual red gums. However, based on community input, significant red gum communities will be protected from the authorised taking of water through EPZs around these communities. Significant red gum communities were identified through community consultation and are presented in Figures 34 and 35. EPZs have been calculated from the maximum transmissivity and specific yield values stated in Table 12 in Stewart 2013 (page 43), assuming a pumping rate of 133 kL/d (i.e. an annual allocation of 10 ML, used in its entirety and extracted continuously over an irrigation season of 75 days). The maximum allowable watertable drawdown at the full extent of the zone is 10 cm as this is considered to be within the red gums tolerance to changes in water level. The resultant EPZ for all red gum communities is 1894 m (Stewart 2015).

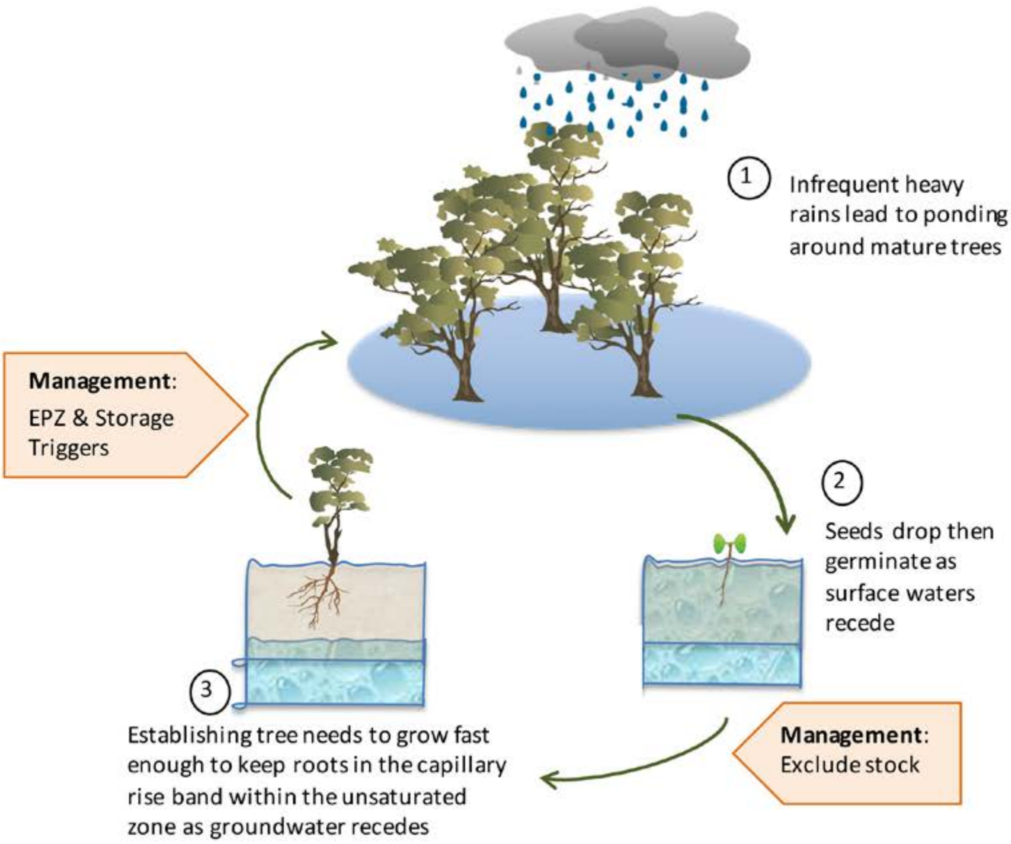


Figure 33 Conceptual model showing the phreatophytic red gum life cycle, roles of different water sources and management influences (Environmental Protection Zones and storage triggers).

Note stock exclusion is outside of the scope of this Plan.

4.2.5 Protection of Marine Discharges

The maintenance of groundwater discharge to the sea to prevent sea water intrusion (as discussed in section 4.1.1) will have the added benefit of providing on-going fresh groundwater discharge to estuarine systems (e.g. Kellidie Bay). This is important for some ecosystems that have at least some dependence on such groundwater discharge.

To protect such groundwater discharges, a setback distance from the coast (in the form of an EPZ) has been calculated to restrict the taking of water near the shore.

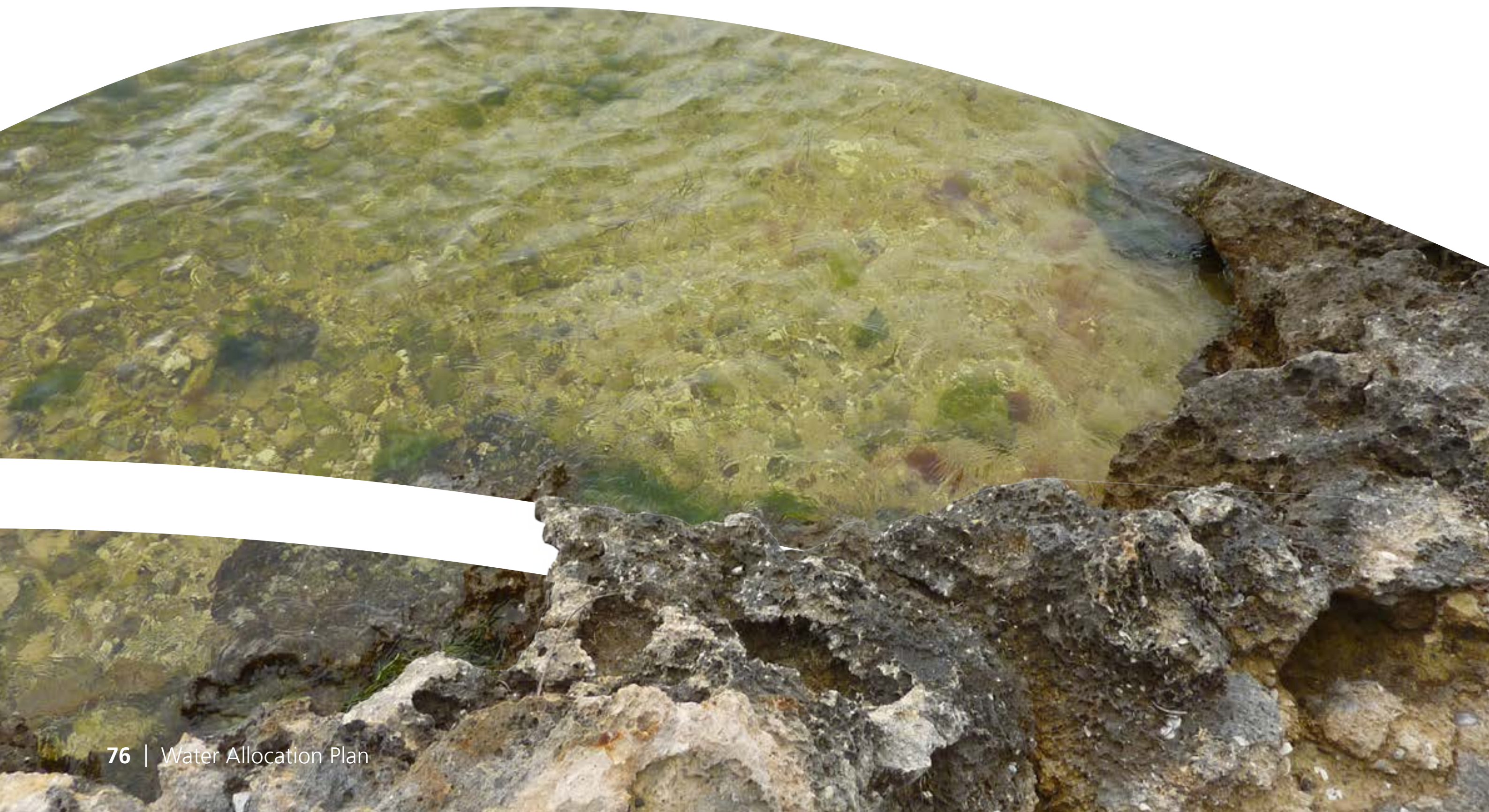
EPZs have been calculated from the range of transmissivity and specific yield values stated in Table 12 in Stewart 2013 (page 43), assuming a pumping rate of 133 kL/d (i.e. an annual allocation of 10 ML, used in its entirety and extracted continuously over an irrigation season of 75 days). The maximum allowable watertable drawdown at the full extent of the zone is 10 cm (Stewart 2015). The resultant EPZs for marine discharges can be seen in Table 11 and Figures 34 and 35.

4.3 Water Resources in Adjacent Non-Prescribed Wells Areas

The groundwater resources in the adjacent non-prescribed areas are generally of poor quality and are low-yielding. The taking and use of water from the Quaternary, Tertiary Sands and Basement aquifers in the Southern Basins PWA or Musgrave PWA is not expected to detrimentally affect these resources. Minor impacts could occur in areas near the PWA boundary if the resultant zone of influence of water extraction (i.e. cone of depression) extends into the PWA.

Table 11 Adopted buffer distances around identified marine discharges

PWA	Marine Discharge Location	EPZ Distance (m)
Southern Basins	Kellidie Bay	444
	Tulka	751
Musgrave	Elliston	147



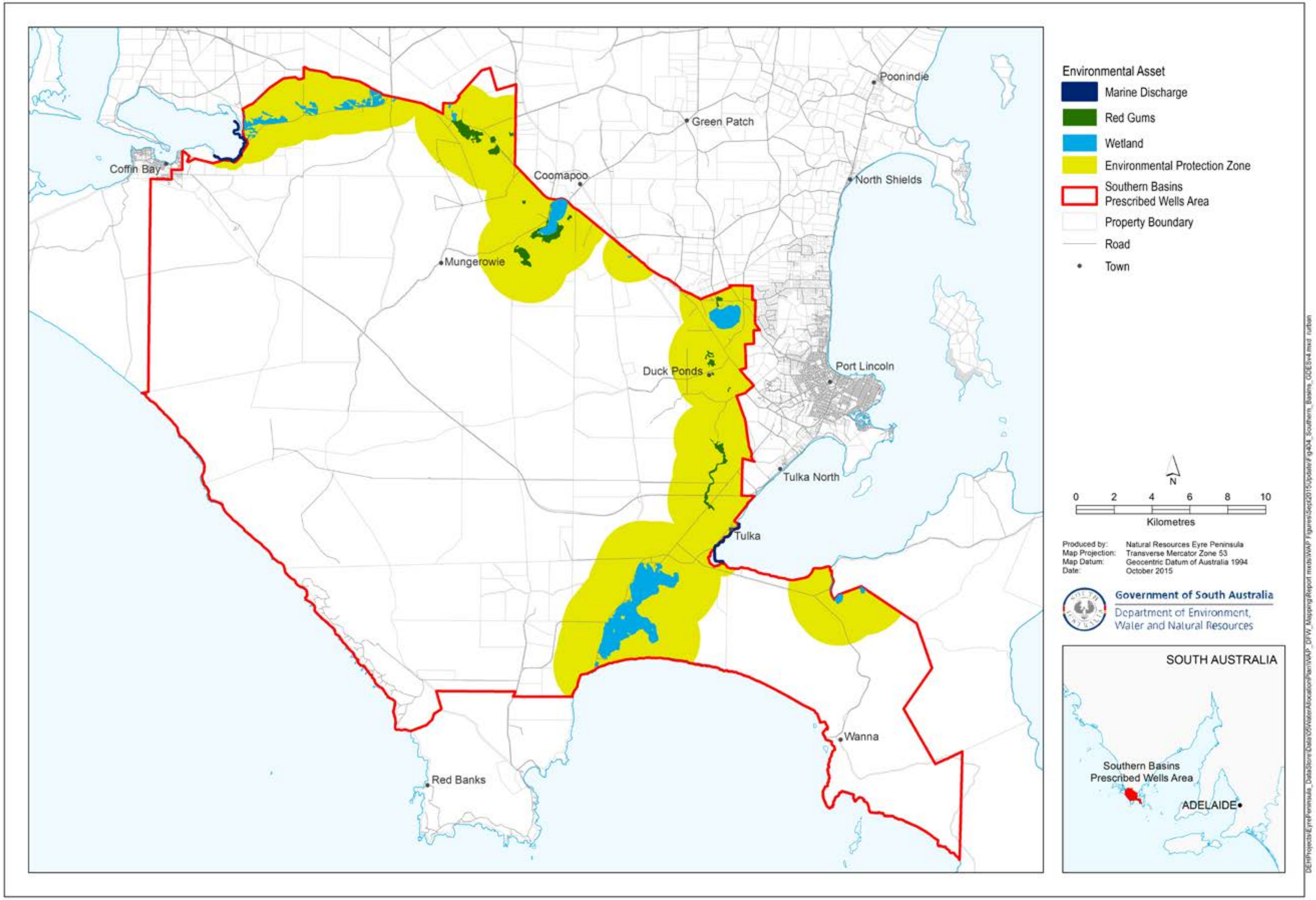


Figure 34 Spatial distribution of Environmental Assets and Environmental Protection Zones within the Southern Basins PWA

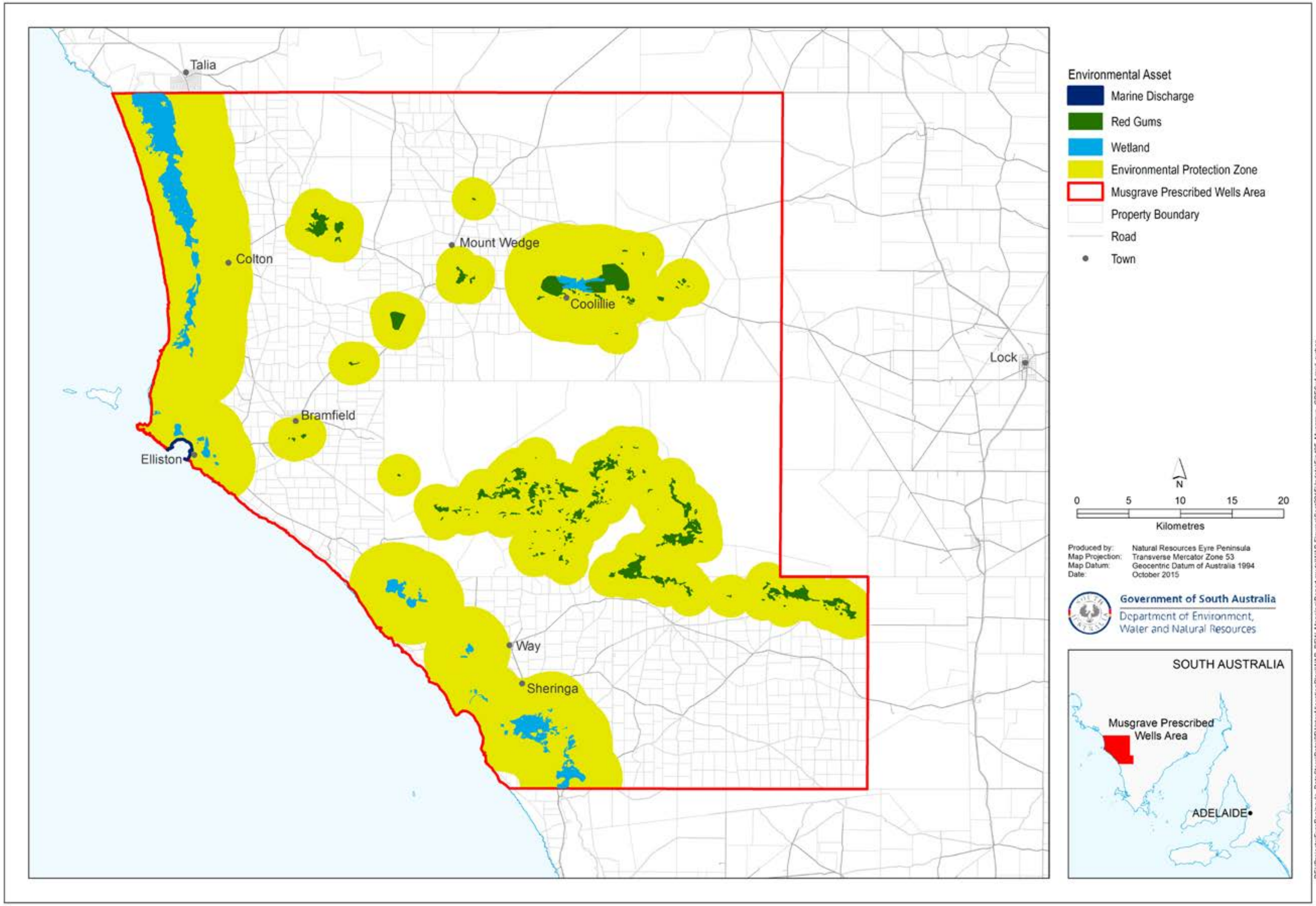


Figure 35 Spatial distribution of Environmental Assets and Environmental Protection Zones within the Musgrave PWA

5 Assessment of the Demands on the Resource

Section 76(4)(d) of the Act requires a water allocation plan to "assess the capacity of the resource to meet the demands for water on a continuing basis…". The demands on the resource include water for both consumptive and non-consumptive purposes. Consumptive demands refer to licensed water use, for example water for commercial irrigation and public water supply, and non-licensed water use including water for stock or domestic use, and water authorised by the Minister under section 128 of the Act such as water for emergency fire fighting and water used in the making of public roads. Non-consumptive demands include water required to maintain natural groundwater processes such as aquifer throughflow and groundwater discharge (that assist in the provision of water for the environment).

5.1 Saturated Quaternary Limestone Management Areas

The resource capacity for the saturated Quaternary Limestone management areas was calculated as the recharge rate multiplied by the recharge area as outlined in section 2.2.1 of this Plan. This resource capacity is required to meet non-consumptive demands (GDEs and aquifer maintenance) and consumptive demands (water for licensed, stock and non-licensed purposes).

5.1.1 Non-Consumptive Demands

The non-consumptive demand is important for several reasons. If too much water is made available for licensed and consumptive purposes, there may be impacts on the water balance in other areas, such as reducing natural discharges and altering flow directions. For example, maintaining groundwater flow gradients toward the sea is particularly important in coastal areas to minimise the risk of sea water intrusion. There is also a need to provide a buffer of sufficient aquifer storage for extended periods of below average rainfall and recharge, as well as maintaining natural discharge to provide sufficient water for GDEs. In order to maintain the processes which constitute the non-consumptive demand, not all of the recharge to the aquifer can be made available for extraction for consumptive purposes.

Ultimately, the percentage of water set aside for aquifer maintenance and GDEs depends on a balance between the various management objectives from a resource perspective and the social and economic considerations. The percentage of the recharge that is set aside for non-consumptive purposes for the various saturated Quaternary Limestone management areas has been determined through a risk assessment undertaken by Sinclair Knight Merz (SKM 2013). The risk assessment approach was consistent with the *Risk Management Policy and Guidelines for Water Allocation Plans* (DEWNR 2012). This risk assessment took into consideration:

- Accessibility Risk - The risks to users (licensed and non-licensed) of restricting water for consumptive use, that is - risks to the social, cultural and economic values of not being able to access groundwater
- Environmental Risk -The risks to the aquifer and environment of extracting water for consumptive use.

5.1.1.1 Defining Accessibility Risk

Groundwater is used widely across the PWAs of Eyre Peninsula and provides a critical source of water for drinking, stock, recreation, irrigation, industrial and mining. There are potentially severe social and economic impacts if there is not sufficient access to groundwater to meet these demands.

Two types of risk factors were used to assess the 'Accessibility Risk':

1. Users are not allocated sufficient groundwater to meet their consumptive needs
2. There is no alternate water supply available to meet user needs.

The likelihood and consequence of these factors occurring is based on several criteria. For example, the likelihood of there being insufficient groundwater available for consumptive demand depends partly on the amount of extraction (number of users and the volumes taken) compared with the resource capacity. The likelihood is low for under-developed systems and higher for more developed systems.

The potential availability of a cost effective alternative water supply is also taken into account. The lowest risk ranking is given in areas where there are existing lower cost alternatives to groundwater, such as access to an SA Water pipeline, and the highest ranking was applied where accessing an alternative water supply would be expensive, such as where desalinisation is the only alternative.

This risk ranking was influenced depending on the ease of access to alternative water supplies for all users including water utilities, irrigators, recreational and stock and domestic users.

5.1.1.2 Defining Environmental Risk

The groundwater resource supports many types of ecosystems across Eyre Peninsula including wetlands, estuaries and vegetation. If there is too much extraction of groundwater, then less will be available to sustain these ecosystems, possibly leading to degradation.

Three types of risk factors were used to assess the 'Environmental Risk':

3. The presence of GDEs in an area where there is extraction
4. Aquifer integrity (based on salinity) could be impacted by extraction
5. Aquifer integrity (based on groundwater levels) could be impacted by extraction.

The likelihood and consequence of these factors occurring is based on several criteria. For example, GDEs are assessed based on whether they are present, how sensitive they are to changes in groundwater salinity or levels and whether there is licensed extraction nearby.

Aquifer integrity is assessed using groundwater monitoring records, beneficial use criteria (i.e. what is the groundwater used/needed for) and how 'robust' the aquifer is considered to be. The 'robustness' of the groundwater resource (each consumptive pool) is assessed by comparing the storage capacity within the aquifer with the estimated amount of recharge (i.e. how much water enters the aquifer).

The overall Environmental Risk ranking is decided by taking into account all these factors.

5.1.1.3 The Risk Matrix

By considering the likelihood and consequence of the different risk factors, scores for individual management areas were able to be determined by ranking the 'Accessibility' and 'Environmental' risks as either 'High', 'Moderate' or 'Low' (Table 12).

The split between water that is made available to the environment (non-consumptive portion) and users (consumptive portion) is determined based upon where each management area fits in the risk matrix. Management areas with high accessibility risk and low environmental risk requires a high proportion allocated to users (consumptive demand) to mitigate risk. Management areas with higher environmental risk and lower accessibility risk required a high proportion allocated to aquifer maintenance (Table 13). The amount provided to each management area is dependent on which is more at risk from lack of groundwater. It was acknowledged that a management area with a high environmental risk requires a higher proportion for aquifer maintenance even if there was a high accessibility risk. This recognises that even if there is a high risk to users if consumptive use is restricted, if the aquifer storage or salinity is affected (environmental risk) the aquifer may not be able to provide suitable water (volume or quality) to meet consumptive demands.

Table 12 Risk assessment matrix with management areas

Composite rankings		**Accessibility Risk**		
		Low	**Moderate**	**High**
Environmental Risk	**Low**	Uley North		Uley South PWS
	Moderate	Sheringa		
	High			Coffin Bay Polda Bramfield Uley Wanilla PWS Lincoln South PWS

Table 13 Risk assessment matrix with environmental and accessibility split

Composite rankings		Accessibility Risk		
		Low	**Moderate**	**High**
Environmental Risk	**Low**	More even split		Larger consumptive demand portion and smaller aquifer maintenance portion
	Moderate		More even split	
	High	Smaller consumptive demand portion and larger aquifer maintenance portion		More even split

5.1.1.4 Consumptive/Non-Consumptive Ratios

Each management area in the PWAs is different. Each area may have different aquifer properties and support different levels of extraction. Some contain and maintain more GDEs than others and there is some variation in the availability of feasible or cost effective water sources other than groundwater. This variety means that users within each management area may be at lower or higher risk from insufficient water supply and that an aquifer or the environment is at greater risk from extraction in some management areas compared to others. The results of the risk assessment for all management areas of the saturated Quaternary Limestone aquifer across the Southern Basins and Musgrave PWAs are given in Tables 14 and 15.

5.1.1.5 Variations to the Risk Assessment

In some management areas there was a need to vary from the results of the risk assessment, the reasons for these are outlined in sections 5.1.1.5.1 to 5.1.1.5.3.

Table 14 Risk assessment matrix ratios

Composite rankings		Accessibility Risk		
		Low	**Moderate**	**High**
Environmental Risk	**Low**	50% consumptive 50% non-consumptive	60% consumptive 40% non-consumptive	70% consumptive 30% non-consumptive
	Moderate	40% consumptive	50% consumptive	60% consumptive
		60% non-consumptive	50% non-consumptive	40% non-consumptive
	High	20% consumptive 80% non-consumptive	30% consumptive 70% non-consumptive	40% consumptive 60% non-consumptive

Table 15 Preliminary resource capacity for non-consumptive and consumptive demand

PWA	Management Area	Non-Consumptive Demands (%)	Consumptive Demands (%)
Southern Basins	Coffin Bay	60	40
	Uley Wanilla PWS	60	40
	Uley North	50	50
	Uley South PWS	30	70
	Lincoln South PWS	60	40
Musgrave	Polda	60	40
	Bramfield	60	40
	Sheringa	60	40

5.1.1.5.1 Uley South Public Water Supply Management Area

Historically under the inaugural Southern Basins Water Allocation Plan, the distribution of the resource capacity between non-consumptive and consumptive portions was the same for all Quaternary resources, with 60% of the resource capacity provided to meet non-consumptive requirements, and 40% for consumptive purposes (60/40 ratio).

The risk assessment undertaken for this Plan varies significantly from the 60/40 ratio previously applied to the Uley South Basin. Consequently, a groundwater modelling exercise of the Uley South lens was commissioned to determine what impacts would result from the proposed 30/70 ratio. The groundwater flow model (Knowling and Werner 2015) is based on the existing Knowling et al. (2015) model and therefore the model extent varies somewhat from the spatial distribution of the Uley South PWS management area as outlined in this Plan. However as the model area is designed to include the Uley South well field, it is thought to be representative of the impacts that are likely to be seen for the whole management area. The model ran five scenarios (Table 16) and compared them to the Base Case being the 2013-14 extraction rate of 4.74 GL/y.

The results (Knowling and Werner 2015) predict that under scenarios S2 and S3, water levels would decline below the historical lowest level by up to 50 cm, whilst scenarios S1 and S4 resulted in water levels similar to that previously observed (generally within 20 cm of the historical low).

Scenario S5 resulted in water levels likely to be higher than the historical low. The risk of sea water intrusion was considered and is unlikely to occur in all five scenarios.

Scenario S1 has been adopted for this Plan, as the modelling indicates that water levels in the majority of wells would show slight declines of only up to 18 cm below the historically low water level, with a maximum fall in one well of 29 cm, but some rises in water level of up to 38 cm. This volume would allow licensees to access sufficient water to meet current demand whilst protecting the resource from any significant impacts. Current extractions from Uley South PWS consumptive pool are well below the proposed volume of 7.25 GL/yr, with 2006-07 being the last time extractions were in this range. Therefore the portion of the resource capacity to be set aside for the environment, based on the Uley South modelling, has been varied from 30% to 48.5%.

Table 16 Uley South PWS modelling scenarios

PWA	Pumping Rate (GL/y)	Non-Consumptive Demand (%)
Base Case	4.74	66.37
S1	7.25	48.5
S2	9.90	30
S3	8.49	40
S4	7.07	50
S5	5.65	60

5.1.1.5.2 Uley Wanilla Public Water Supply Management Area

The results of the risk assessment assigned 60% of the Uley Wanilla PWS management area resource to meet non-consumptive requirements. This is the same ratio as was provided under the previous Plan.

Prior to the inaugural Southern Basins Water Allocation Plan, there were no formal restrictions on the take of water from the Uley Wanilla PWS management area and due to the high historical demand discussed previously (section 1.5.2), and the limited availability of other resources, the Uley Wanilla PWS management area was heavily relied upon until 1977. Observation wells within the Uley Wanilla PWS management area show long-term declines in water level since 1986, which have only slightly recovered since 2010. This could be due to high extractions in the late 1980s, but more likely is a result of reduced recharge due to below average rainfall and increased vegetation cover as extractions have declined significantly since 1993.

In line with the National Water Initiative clause 23(iv) "complete the return of all currently over allocated or overused systems to *environmentally-sustainable levels of extraction*" (COAG 2004), it would be considered a conservative approach to amend the portion of the resource capacity set aside to meet non-consumptive requirements to limit any excess water within the management area. As such the portion of the resource capacity set aside for non-consumptive requirements has been varied from 60% outlined in the risk assessment to 72.7289% (this number of decimal points is required to ensure there is 0 ML of excess water within the consumptive pool).

5.1.1.5.3 Polda Management Area

The results of the risk assessment assigned 60% of the Polda management area resource to meet non-consumptive requirements. This is the same ratio as was provided under the inaugural Musgrave Water Allocation Plan.

It is recognised that since November 2008, the Polda resource has been under a Notice of Prohibition (NOP) restricting the take of licensed water from the Polda area as it was considered that "the rate at which water is being taken from wells that take underground water from the Quaternary Limestone aquifer in the Polda Basin … is such that the quantity of water available can no longer meet the demand" (DPC 2015, Government Gazette 15 January 2015). Consequently it is considered a conservative approach to amend the portion of the resource capacity provided to non-consumptive requirements in order to limit the excess water within the Polda management area to 10 ML. This variation will prohibit any significant future extraction from within this area, which will allow existing users the right to take water whilst allowing the resource to recover.

The portion of the resource capacity set aside for non-consumptive requirements has therefore been varied from 60% outlined in the risk assessment to 97.6384% (this number of decimal points is required to ensure there is only 10 ML of excess water available within the consumptive pool). Additionally, SA Water voluntarily surrendered two allocations held within the Polda consumptive pool. This water has been allocated to the environment rather than allowing for future use of this water.

A summary of the adopted percentages of the resource capacity set aside to meet consumptive and non-consumptive demands is displayed in Table 17.

Table 17 Resource capacity reserved for non-consumptive and consumptive demand

PWA	Management Area	Non-Consumptive Demands (%)	Consumptive Demands (%)
Southern Basins	Coffin Bay	60	40
	Uley Wanilla PWS	72.7289*	27.2711*
	Uley North	50	50
	Uley South PWS	48.5	51.5
	Lincoln South PWS	60	40
Musgrave	Polda	97.6384*	2.3616*
	Bramfield	60	40
	Sheringa	60	40

**Multiple decimal points are required in order to result in the excess water volume specified above*

5.1.2 Consumptive Demands

The resource capacity for the saturated Quaternary Limestone management areas was defined by the equation in section 2.2.1 as:

Resource Capacity (ML) = **Recharge Area** (km^2) x **Recharge Rate** (mm)

The resource capacity is the total amount of water available for consumptive demand and non-consumptive demand, that is, total demand. Thus:

Resource Capacity = Total Demand

Where:

Total Demand = **Consumptive Demand** + **Non-Consumptive Demand**.

Therefore consumptive demand can be calculated as:

Consumptive Demand = Total Demand – **Non-Consumptive Demand**

Consumptive demand includes water available for **Non-Licensed Demand**, water available for **Licensed Demand** and **Excess Water** where (Fig. 36):

Non-Licensed Demand includes stock and domestic requirements and Minister's authorisations

Licensed Demand is water for any purpose that requires a licence

Excess Water is water that may be granted on account of a new water access entitlement under a water licence, or additional water that may be granted on account of an existing water access entitlement, but which is yet to be granted.

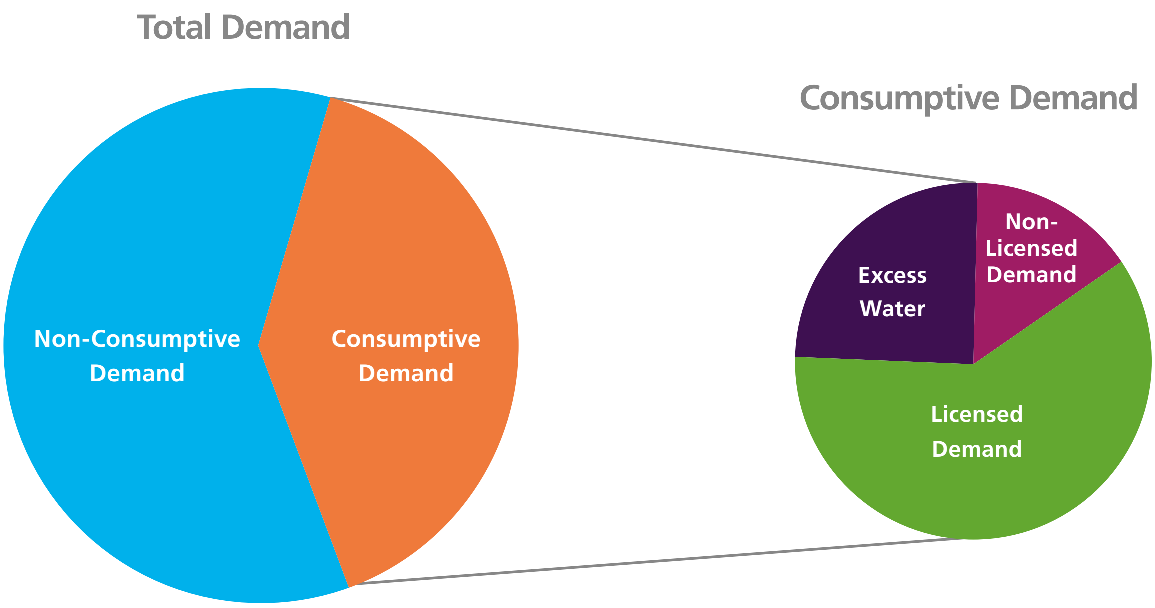


Figure 36 Diagrammatic representation of total demand and consumptive demands of the saturated Quaternary Limestone management areas

5.1.2.1 Non-Licensed Demand

Non-licensed water use includes water for stock and domestic use and water authorised by the Minister under section 128 of the Act, for example water for fire fighting and public road making. Note that these estimates may vary from those outlined in the Regional NRM Plan (Das 2009), as the processes outlined in sections 5.1.2.1.1 and 5.1.2.1.2 use the most up to date available information to determine domestic requirements and a more robust process for estimating stock water use. It is unlikely that the estimates of stock and domestic water use outlined in the sections below will vary significantly throughout the life of this Plan as there is unlikely to be significant changes to land use, increases in stock numbers or new developments that would require groundwater. However the estimates are based on current data and are subject to change with variations in market conditions. A standard 5 ML per management area has been assumed to be sufficient to meet Minister's authorisations in the future.

5.1.2.1.1 Method for Estimating Stock Water Use

The number of stock held on any given parcel of land can be normalised to a standard unit - the Dry Sheep Equivalent (DSE). The DSE is a standard unit used to estimate feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given area of land. Normalising absolute stock numbers to DSEs enables water demand estimates to be calculated based on estimated water consumption per unit DSE.

The *Eyre Peninsula Demand and Supply Statement* (DFW 2011a) estimates the rate of water use of sheep located on the Eyre Peninsula to be 10 L/sheep/d (or 7.14 L/DSE/d). This estimate of water use is based on advice from Primary Industries and Regions South Australia (PIRSA 2010) and includes an allowance for on-farm losses.

PIRSA collect information from properties with current registrations under the *Livestock Act 1997* (SA). The Primary Industries Information Management System (PIIMS) provides a spatially referenced data set of stock numbers for the PWAs. The spatial nature of the dataset allows water to be assigned to management areas or aquifers.

Stock water use was estimated by overlying the spatially referenced PIIMS parcel data on the recharge zones and assigning stock numbers to each zone. These stock numbers were multiplied by the DSE for the relevant stock, and the DSE was then converted into a water use consumption by multiplying by 7.14 L/d (Stewart 2013, pages 28-30).

The distribution of estimated stock water use across saturated Quaternary Limestone management areas is indicated in Tables 20 and 21.

5.1.2.1.2 Method for Estimating Domestic Water Use

The method used to estimate domestic water use was to multiply the number of domestic wells by the average water consumption per household. The SA Geodata database records the intended purpose of wells when they are permitted; those wells that have been ascribed the purpose 'domestic use' have been used in this assessment.

The State's water security plan, *Water for Good* (DWLBC 2009), reports that average household mains water consumption in the greater Adelaide region, prior to water restrictions, was 280 kL/yr. For the purposes of this plan domestic groundwater consumption is conservatively estimated to be 280 kL/yr per well (Stewart 2013) as it is likely that additional water supplies such as mains and rainwater would be available to compliment the groundwater supply.

The distribution of estimated domestic water use across the saturated Quaternary Limestone management areas is indicated in Tables 20 and 21.

5.1.2.2 Licensed Demand

The Department keeps a record of the licensed groundwater extractions for the Southern Basins and Musgrave PWAs in the Water Information and Licensing Management Application (WILMA). This data record details historic licensed groundwater extraction and allocation limits on an annual basis since the 2004–05 water use year. The portion of water access entitlements used for differing purposes, for all Quaternary Limestone consumptive pools, is shown in Figure 37.

Extractions from the saturated Quaternary Limestone management areas for 2013–14 are shown in Table 18. The majority of extractions are from the Uley South Basin, which accounts for around 95% of the total extractions from the Southern Basins PWA. Annual groundwater extractions solely for the purpose of public water supply for the period 2001-02 to 2013-14 is shown in Table 19 and Figure 38. The demand on SA Water to extract water for public water supply has decreased over recent years. SA Water (2008) attribute falling demand to; Eyre Peninsula water restrictions, increased use of rainwater tanks, community projects involving stormwater re-use, and wastewater re-use schemes by local councils.

The distribution of licensed water use across the saturated Quaternary Limestone management areas is indicated in Tables 20 and 21.

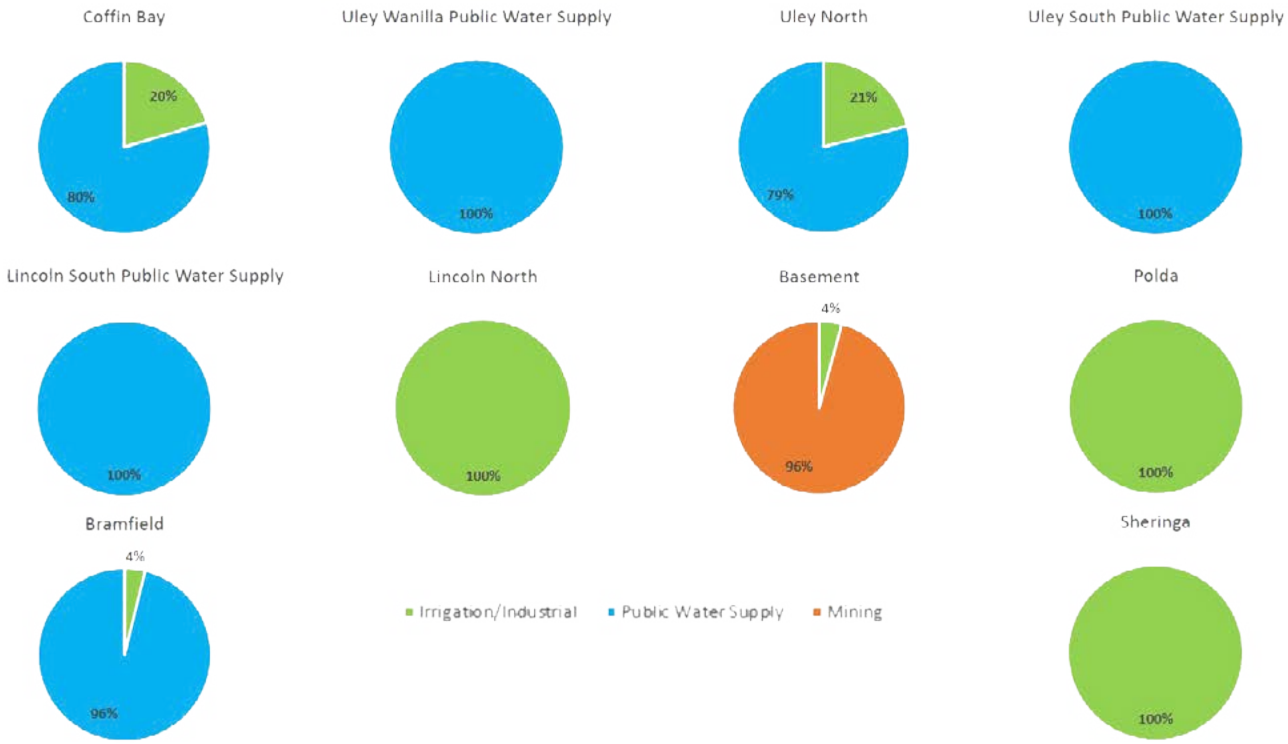


Figure 37 Portion of water access entitlements used for differing purposes for all Quaternary Limestone consumptive pools in the Southern Basins and Musgrave PWAs

Table 18 Metered usage for the Quaternary aquifer for the 2013-2014 water use year in the Southern Basins and Musgrave PWAs

PWA	2013-14 Usage Irrigation/Industrial (ML)	2013-14 Usage Public Supply (ML)	2013-14 Total Use (ML)
Southern Basins	26.65	4928.33	4954.98
Musgrave	18.80	52.70	71.50
TOTAL	45.45	4981.03	5026.48

Table 19 Metered usage (ML) for public water supply 2001-02 to 2013-14

PWA	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Southern Basins (ML)	8805	8857	8847	8866	7772	8545	7616	7228	6591	5583	5462	5522	4928
Musgrave (ML)	316	220	340	314	290	209	183	70	70	86	78	62	53
TOTAL (ML)	9121	9077	9187	9180	8062	8754	7799	7298	6661	5669	5540	5584	4981

Note: SA Water has been restricted from taking groundwater from the Polda resource since 2008 (DPC 2012).

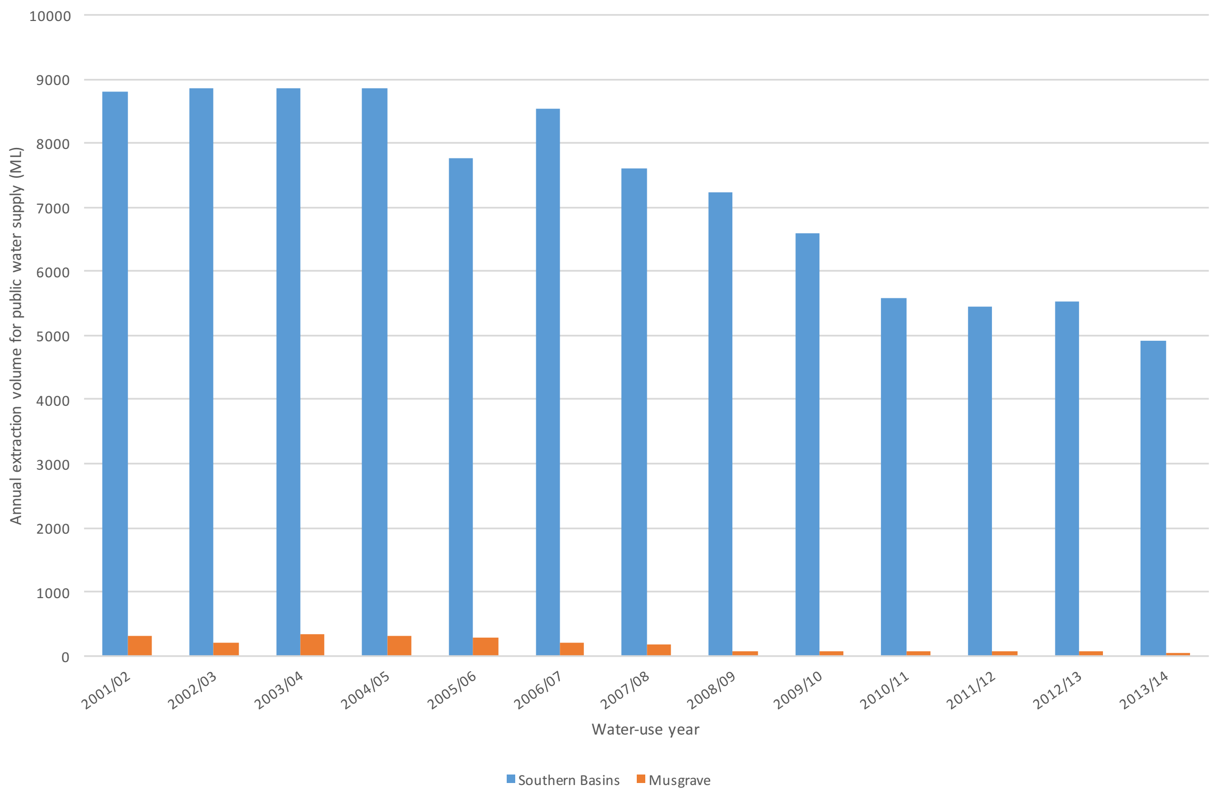


Figure 38 Metered usage for public water supply from 2001–2002 to 2013–2014 from the Southern Basins and Musgrave PWAs

5.1.2.2.1 Southern Basins PWA – Existing Licensed Demand

Public Water Supply

Of the water allocated in 2014-15 from the Quaternary Limestone groundwater resource of the Southern Basins PWA, SA Water held 98% of the total water available on licence for the purpose of public water supply.

Irrigation/Industrial

At the date of adoption of this Plan, within the Quaternary Limestone groundwater resource of the Southern Basins PWA there are six existing water licences issued for the purposes of accessing groundwater for irrigation (and other minor industry/recreational) uses. Of these uses, golf course irrigation is the dominant activity.

Mining Industry

There is currently no licensed demand for mining industry activities from the Quaternary Limestone management areas of the Southern Basins PWA.

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5.1.2.2.2 Musgrave PWA - Existing Licensed Demand

Public Water Supply

Of the water allocated in 2014-15 from the Quaternary Limestone groundwater resource of the Musgrave PWA, SA Water held 93% of the total water available on licence for the purpose of public water supply. However it should be noted that in May 2015 SA Water voluntarily surrendered their licences for the Kappawanta, Polda and Polda North lenses. Therefore the portion of water allocated for the purposes of public water supply will be different in future years.

Irrigation/Industrial

At the date of adoption of this Plan, within the Quaternary Limestone groundwater resource of the Musgrave PWA, there are six existing water licences issued for the purposes of accessing groundwater for irrigation (and other minor industry/recreational) uses. Of these uses, fruit and nut tree irrigation is the dominant activity.

Mining Industry

There is currently no licensed demand for mining industry activities from the Quaternary Limestone management areas of the Musgrave PWA.

5.1.2.3 Excess Water

If the total volume of water available for licensed demand in any management area exceeds current demand, a resultant excess water volume may exist. The excess water may be made available for use, subject to the Minister's discretion. Section 6 outlines the principles of how to manage the release of excess water.

5.2 Unsaturated Quaternary Limestone Management Areas

Based on current knowledge, there is unlikely to be any significant volumes of water available for consumptive purposes on an ongoing basis from the unsaturated Quaternary Limestone management areas in either the Southern Basins or Musgrave PWAs. Any such supplies are likely to be highly unreliable. Currently, there is no water on licence from the unsaturated Quaternary Limestone aquifer, and consequently, the only demands for water are potentially for the purposes of domestic supply and Minister's authorisations (see section 2.2.2 and Tables 5, 20 and 21).

5.3 Tertiary Sands, Basement and Quaternary Lincoln North Management Areas

The demands on the Tertiary Sands, Basement and Quaternary Lincoln North management areas are outlined below in sections 5.3.1 and 5.3.2.

5.3.1 Non-Consumptive Demands

The non-consumptive demands for each of the management areas associated with the Tertiary Sands and Basement aquifers and the Quaternary Lincoln North region were unable to be determined due to limited knowledge of these aquifers (see section 2.2.3).

5.3.2 Consumptive Demands

The water available for consumptive demand in the Tertiary Sands, Basement and Quaternary Lincoln North management areas is calculated as the sum of the licensed and non-licensed demands (sections 5.3.2.1 and 5.3.2.2).

5.3.2.1 Non-Licensed Demand

Non-licensed water use includes water for stock and domestic use, and water use authorised by the Minister under section 128 of the Act, such as water for fire fighting and for the making of public roads. A standard 5 ML per consumptive pool has been assumed to be sufficient to meet Minister's authorisations in the future.

5.3.2.1.1 Method for Estimating Stock Water Use

The methodology for determining the stock demands for the Quaternary Lincoln North management area follows that outlined in section 5.1.2.1.1. For the deeper management areas, the methodology for determining the stock demands assumes that if the Quaternary Limestone aquifer is dry, then any stock water use must come from either the underlying Tertiary Sands or Basement management areas. As there is no information available to determine the proportion of water being accessed for stock purposes from each management area, the volume of water apportioned to parcels overlying the unsaturated Quaternary Limestone have been split evenly between the Tertiary Sands and Basement management areas.

The distribution of estimated stock water use across the Tertiary Sands, Basement and Quaternary Lincoln North management areas is indicated in Tables 20 and 21.

5.3.2.1.2 Method for Estimating Domestic Water Use

The method for estimating domestic water allowance in the Tertiary Sands, Basement and Quaternary Lincoln North management areas follows that outlined in section 5.1.2.1.2.

The distribution of estimated domestic water use across the Tertiary Sands, Basement and Quaternary Lincoln North management areas is indicated in Tables 20 and 21.

5.3.2.2 Licensed Demand

Extraction for the Southern Basins and Musgrave PWAs has been recorded by the Department in WILMA since the 2004-05 water-use year. It details historic licensed groundwater extraction and allocation limits on an annual basis for the past ten years.

The distribution of licensed water use across the Tertiary Sands, Basement and Quaternary Lincoln North management areas is indicated in Tables 20 and 21.

5.3.2.2.1 Southern Basins PWA – Existing Licensed Demand

Public Water Supply

There is currently no licensed demand for public water supply from the Tertiary Sands, Basement and Quaternary Lincoln North management areas of the Southern Basins PWA.

Irrigation/Industrial

At the date of adoption of this Plan, within the Tertiary Sands, Basement and Quaternary Lincoln North management areas of the Southern Basins PWA there are 10 existing water licences issued for the purposes of accessing groundwater for irrigation (and other minor industry/recreational) uses. Of these uses, golf course irrigation is the dominant activity.

Mining Industry

At the date of adoption of this Plan, within the Tertiary Sands, Basement and Quaternary Lincoln North management areas of the Southern Basins PWA, there are two water licences issued with a total volume of 436 ML/yr for the purposes of mineral exploration or mining operations.

5.3.2.2.2 Musgrave PWA - Existing Licensed Demand

Public Water Supply

There is currently no licensed demand for public water supply from the Tertiary Sands or Basement management areas of the Musgrave PWA.

Irrigation/Industrial

There is currently no licensed demand for irrigation or industrial supply from the Tertiary Sands or Basement management areas of the Musgrave PWA.

Mining Industry

There is currently no licensed demand for mining industry activities from the Tertiary Sands or Basement management areas of the Musgrave PWA.

Resource Capacity = **Recharge Area** x **Recharge Rate**

Resource Capacity = **Non-Consumptive Demand** + **Consumptive Demand** which is (**Non-Licensed Demand** + **Licensed Demand** + **Excess Water**)

Table 20 Assessment of the capacity and demands for Southern Basins PWA water resources

Management Area	Recharge Zone	Recharge Rate (mm)	Area of Recharge (km^2)	Resource Capacity (ML) (Total Demand)	Non-Consumptive Demand (ML [%])	Consumptive Demand (ML)	Non-Licensed Demand			Maximum Volume of Water Available for Licensed Use (ML)	Licensed Demand (ML)*	Excess Water (ML)*
							Domestic Demands (ML)	Stock Demands (ML)	Minister's Authorisations (ML)			
Coffin Bay	Coffin Bay A lens	25	13.82	345.4	207 (60)	138	0.28	0	5	133	133	0
Uley Wanilla Public Water Supply	Uley Wanilla lens	20.5	14.33	293.8	214 (72.7)	80	1.4	0	5	231	231	0
	Uley Wanilla brackish	22.5	25.61	576.3	419 (72.7)	157	0	0				
Uley North	Coffin Bay B lens	0	0.42	0	0 (50)	0	0	0	5	527	239	288
	Coffin Bay C lens	1.9	5.47	10.4	5 (50)	5	0	0.43				
	Uley East A lens	73.5	5.48	402.5	201 (50)	201	0	3.31				
	Uley East B lens	0	2.42	0	0 (50)	0	0	0.07				
	Uley North brackish	7.5	92.97	697.3	349 (50)	349	0.56	18.49				
Uley South Public Water Supply	Uley South lens	129	65.42	8439.5	4093 (48.5)	4346	0	1.02	5	7266	7250	16
	Uley South brackish	129	43.06	5555.3	2694 (48.5)	2861	0	1.41				
	Uley South Tertiary Leakage	14	9.29	130.1	63 (48.5)	67	0	0				
	Pantania lens	0	0.38	0	0 (48.5)	0	0	0				
	Mikkira lens	0	2.13	0	0 (48.5)	0	0	0.71				
Lincoln South Public Water Supply	Lincoln A lens	0	1.20	0	0 (60)	0	0	0.01	5	1826	929	897
	Lincoln B lens	0	3.95	0	0 (60)	0	0	0				
	Lincoln C lens	0	7.92	0	0 (60)	0	0	0				
	Lincoln South brackish	33	138.92	4584.2	2751 (60)	1834	1.4	1.41				
Quaternary Lincoln North				173	0	173	3.36	30.95	5	134	134	0
Unsaturated Quat. Limestone				7	0	7	1.96	0	5	0	0	0
Tertiary Sands				29	0	29	1.12	23.02	5	0	0	0
Basement				484	0	484	0.28	23.02	5	455	455	0

*at the date of adoption of this plan

Table 21 Assessment of the capacity and demands for the Musgrave PWA water resources

Management Area	Recharge Zone	Recharge Rate (mm)	Area of Recharge (km^2)	Resource Capacity (ML) (Total Demand)	Non-Consumptive Demand (ML [%])	Consumptive Demand (ML)	Non-Licensed Demand			Maximum Volume of Water Available for Licensed Use (ML)	Licensed Demand (ML)*	Excess Water (ML)*
							Domestic Demands (ML)	Stock Demands (ML)	Minister's Authorisations (ML)			
Polda	Polda lens	5.6	37.21	208	203 (97.6)	5	0.84	3.6	5	43	33	10
	Polda East A lens	0	0.07	0	0 (97.6)	0	0	0				
	Polda East B lens	0	0.72	0	0 (97.6)	0	0	0				
	Polda brackish	11.2	273.84	3067	2995 (97.6)	72	1.68	23.34				
	Tinline lens	0	3.13	0	0 (97.6)	0	0	0.03				
	Talia East lens	0	6.15	0	0 (97.6)	0	0	0.24				
Bramfield	Bramfield lens	2.2	99.46	218.8	131 (60)	88	7.56	9.57	5	1188	1188	0
	Bramfield brackish	5	639.93	3200	1920 (60)	1280	13.44	134.41				
	Talia lens	0	44.17	0	0 (60)	0	0.56	9.24				
Sheringa	Sheringa A lens	0	36.23	0	0 (60)	0	0.28	0.88	5	1406	33	1373
	Sheringa B lens	0.7	38.99	27	16 (60)	11	0.28	0.58				
	Kappawanta lens	11.4	48.86	557	334 (60)	223	0	0				
	Sheringa brackish	5.9	519.82	3067	1840 (60)	1227	2.8	44.45				
Unsaturated Quat Limestone				11	0	11	5.6	0	5	0	0	0
Tertiary Sands				68	0	68	1.12	62.27	5	0	0	0
Basement				67	0	67	0	62.27	5	0	0	0

*at the date of adoption of this plan

5.4 Future Demand for Water

The content of this section has been informed by the *Eyre Peninsula Demand and Supply Statement* (DFW 2011a), which aims to provide a long-term (40 years) overview of water supply and demand in the Eyre Peninsula region. *The Eyre Peninsula Demand and Supply Statement* applies an adaptive management process to outline the state and condition of all water resources in the region for drinking water and non-drinking water, lists major demands on these water resources, and identifies likely time frames for any possible future demand/supply imbalance.

If demand and supply projections indicate a gap is likely to exist within five years or less, the Minister will establish an independent planning process to consider management or supply options.

The *Eyre Peninsula Demand and Supply Statement* is currently reviewed annually. The Statement is also proposed to be comprehensively reviewed and updated every five years.

The *Eyre Peninsula Demand and Supply Statement* and the annual reviews are available on the DEWNR website.

5.4.1 Public Water Supply

Recent public water supply trends indicate that consumption has decreased (see Table 19 and Fig. 38), but the future trend is uncertain given the possibility that stock numbers may marginally increase. However, expansions in tourism activity and townships that utilise public water supply are not expected to place additional demand on supply in the near future.

The development of mining operations could lead to an increase in regional employment opportunities resulting in a possible increase in the public water supply demand as more people are drawn to the region. Mining operations may also source some of their water needs for production purposes from the public water supply.

5.4.2 Water for Stock and Domestic Use

Future demand for stock water and domestic water use will be driven by a range of factors that include, but are not limited to, land carrying capacity, commodity prices and local climatic conditions.

There is evidence of expanding or increasing urban development within some areas of the PWAs. Where public water supply is not provided to these newly developed areas, it is likely that there will be increased demand for groundwater for domestic purposes with potential local influences on the groundwater resource.

Future water requirements for increasing stock numbers are extremely difficult to predict. Primary production forecasts estimate an increase in demand for water in rural areas of 1.5% per annum for the period 2008–18 (SA Water 2008). It should be noted that this predicted increase in demand for water is not limited to stock water use but all sectors that comprise rural demand.

Analysis of land carrying capacity found that most of the Southern Basins and Musgrave PWAs have low grazing potential. The results of this analysis suggest that it is unlikely that stock numbers will increase markedly in the near future (Stewart et al. 2012). Long-term landholders have observed that stock numbers in both the Southern Basins and Musgrave PWAs have been largely static and they believe a significant increase in stock numbers in the future is highly unlikely.

All estimates of stock and domestic use is based on the best available information and is calculated based on current conditions. However, there is the potential for stock numbers to increase if grain prices decrease. The take of water to support additional stock will be limited to the access of reasonable groundwater quality water or access to the mains water system.

5.4.3 Recreational/Industrial

Tourism and aquaculture industry activities are identified as areas of potential development in the PWAs. It is anticipated that in the most part, these activities will utilise the public water supply for water requirements. Where public water supply is not available, aquaculture developments will need to acquire a water access entitlement to take water from the groundwater resources within the PWAs. It is difficult to estimate the demand for these uses.

The *Eyre Peninsula Demand and Supply Statement* (DFW 2011a) projected that water demand for visitors in 2009-10 for the whole peninsula (not just the prescribed regions) was 400 ML and that this would grow at a simple annual rate of 4% from this base. As a result, visitor water demand was expected to be 416 ML in 2010-11, and so on until 2050.

The Demand and Supply Statement also estimated the non-residential water use of drinking water quality across the whole peninsula in 2009-10 to be 8 000 ML, growing at a simple annual rate of 0.3% from this base. Therefore non-residential water use was estimated to be 8 024 ML in 2010-11 continuing at this rate until 2050.

5.4.4 Mining Industry

Demand for water from the mining sector in Eyre Peninsula is expected to increase in the future, and mining operations can require significant volumes of water. Typically, activities such as mineral processing and dust suppression can be undertaken using water of lower quality than is required for stock or irrigation. It is important that associated water resource demands are considered, planned for and managed, while balancing this against environmental and social requirements. Potential impacts from mining can include issues associated with aquifer dewatering and aquifer interference.

In accordance with current State Government policy (DWLBC 2009), mining ventures must source their own water supplies within the sustainable framework of natural resources management planning. Within PWAs, the taking of water for mine development and operational activities is subject to the same licensing requirements as any other water use. As a general principle, mining companies would be required to hold a water access entitlement to take water in any circumstance where other water users would also be required to hold a water access entitlement. Mine water supplies reliant on the public water supply system would operate within the licensing limits held by the public water supply water access entitlement and associated water allocations specified under the Act.

5.4.5 Land Values

There is no evidence at present to suggest that the demand for water will increase substantially in the near future. The demand on the public water supply has reduced in recent years and the use of water for stock or irrigation is not expected to greatly change. Mining ventures may seek to use groundwater but forecasting mining start-ups in the future is a difficult exercise. Given the likely stability in future demand, it is not expected that land values will be influenced by the availability of water.

However, some landholders have indicated that land values may have been affected as a result of reduced accessibility to groundwater.

5.4.6 Indigenous and Cultural Requirements for Water

The Traditional Owners of the land within the Southern Basins and Musgrave PWAs are the Wirangu, Nauo and Barngarla people. At the time of preparing this Plan, no native title claims have been determined. The Board continues to engage with the Traditional Owners who have an interest in water management within the prescribed areas through the claimant groups, as well as through the recently formed Aboriginal Advisory Committee.

6 Consumptive Pools, Water Access Entitlements and Water Allocations

6.1 Consumptive Pools for the Saturated Quaternary Limestone Aquifer

Once a water resource is prescribed under the Act, the Act requires that a water allocation plan be developed to manage the water resource. A key aspect of a water allocation plan is that it establishes a water licensing regime to regulate the taking of water from the resource. The first step in establishing this licensing regime is the determination of a consumptive pool or pools.

The Act requires that a water allocation plan must "determine, or provide a mechanism for determining, from time to time, a consumptive pool, or consumptive pools for the water resource" that the plan seeks to manage (s.76(4)(ab)).

For the saturated Quaternary Limestone aquifer, this Plan defines consumptive pools in two ways;

- By geography, using the management areas which are fixed for the life of the Plan (shown in section 2, Figs. 18 and 19)
- As a volume of water determined annually for each consumptive pool, which is referred to as 'the consumptive pool volume'.

The Act defines a consumptive pool as the water "taken to constitute the resource within a particular part of a prescribed water resource for the purposes of Chapter 7" of the Act (s.3(1)). A consumptive pool, therefore, is the resource for the purposes of:

a. Water for stock and domestic use;
b. Water authorised for use by the Minister under section 128 of the Act; and
c. Water available for licensed purposes.

As there is unlikely to be any change in the volume of water for stock and domestic use and water authorised by the Minister under section 128 of the Act (non-licensed demand) for each management area (for reasons that have been described in section 5.1.2.1) the volume required for non-licensed demand has been fixed for the life of this Plan. The fixed volumes of water for non-licensed demand are included in the consumptive pool volume which is calculated annually. These volumes are shown in Tables 20 and 21 of this Plan (section 5) in the columns marked 'non-licensed demand'.

The volume of water stored within the saturated Quaternary Limestone aquifer within both PWAs is known to vary annually in response to changes in recharge to the aquifer. The condition of the groundwater resource should therefore be used as a trigger to determine the consumptive pool volume on an annual basis. This process allows for the adaptive management of the resource in response to the changes in recharge due to impacts of climate variability in the short term and climate change in the long term. This ability to respond with a variable consumptive pool is consistent with the adaptive management clauses in the NWI (COAG 2004) and the unbundled licence provisions in the Act. Therefore, a variable component of the consumptive pool volume will be determined in accordance with the method set out in this section ('the variable component').

Accordingly, the consumptive pool volume shall be the sum of: fixed volume (stock and domestic use) + fixed volume (s.128 authorisations) + variable component ([a portion of the] maximum volume of water available for licensed use).

The variable component is determined by reference to the 'maximum volume of water available for licensed used' for each management area as defined in Tables 20 and 21 of this Plan. The variable component cannot exceed that maximum volume. However, the variable component may be less than the defined maximum volume with a reduction in the volume determined on the basis of storage levels within each management area.

The method for determining the variable component of the consumptive pool volume is based on the scientific technical reports produced to support this Plan, namely the DFW Technical Report 2012/15, *Science Support for the Musgrave and Southern Basins Prescribed Wells Areas Water Allocation Plan by Stewart et al.* (2012) and the DEWNR Technical Report 2013/19 *Additional Science Support for the Eyre Peninsula Water Allocation Plan by Stewart* (2013).

The process for determining the annual level of storage is discussed in section 8 of this Plan. The assessment of the level of storage for each saturated Quaternary Limestone management area will be undertaken after the groundwater level monitoring is carried out in autumn of each year, which will then determine the maximum volume for licensed use for the next water use year commencing on 1st July.

It is important to note that under section 146(4) of the Act, the Minister has a discretion to determine the volume of water that is to be made available for licensed use (allocation) from a consumptive pool. The Minister's discretion is to operate within the capacity of the resource, that is, the consumptive pool volume.

6.1.1 Trigger Levels

The variable component of the consumptive pool volume is determined by reference to trigger levels, which represent key levels of storage and their relationship to aquifer sustainability. The trigger levels allow the consumptive pool volume to reflect changes in storage level from year to year. If the trigger levels are not taken into account, storage levels could reach critically low levels and aquifers could almost dry out with no change in the entitlements to take water.

Three trigger levels have been chosen to represent various levels of stress within the resource. They are presented schematically in Figure 39 and are defined as follows:

- **The Upper Storage Trigger:** When the level of storage for the aquifer is greater than the Upper Storage Trigger, the resource is considered to be in a good condition and the volume of water available for the variable component will be 100% of the total available (i.e. 100% of the 'maximum volume of water available for licensed use' as defined for the management area in Tables 20 and 21 of this Plan).
- **The Mid Storage Trigger:** When the level of storage falls below the Upper Storage Trigger but remains higher than the Mid Storage Trigger, the resource is considered to be at low risk and the volume of water available for the variable component will vary at a rate similar to the change in the level of storage. When the storage level falls below the Mid Storage Trigger but remains higher than the Lower Storage Trigger, the resource is considered to be at moderate risk and the volume of water available for the variable component will vary at a greater rate than the change in the level of storage.
- **The Lower Storage Trigger:** When the storage level is assessed to be equal to or less than the Lower Storage Trigger, the resource is considered to be at high risk and no water will be available for the variable component.

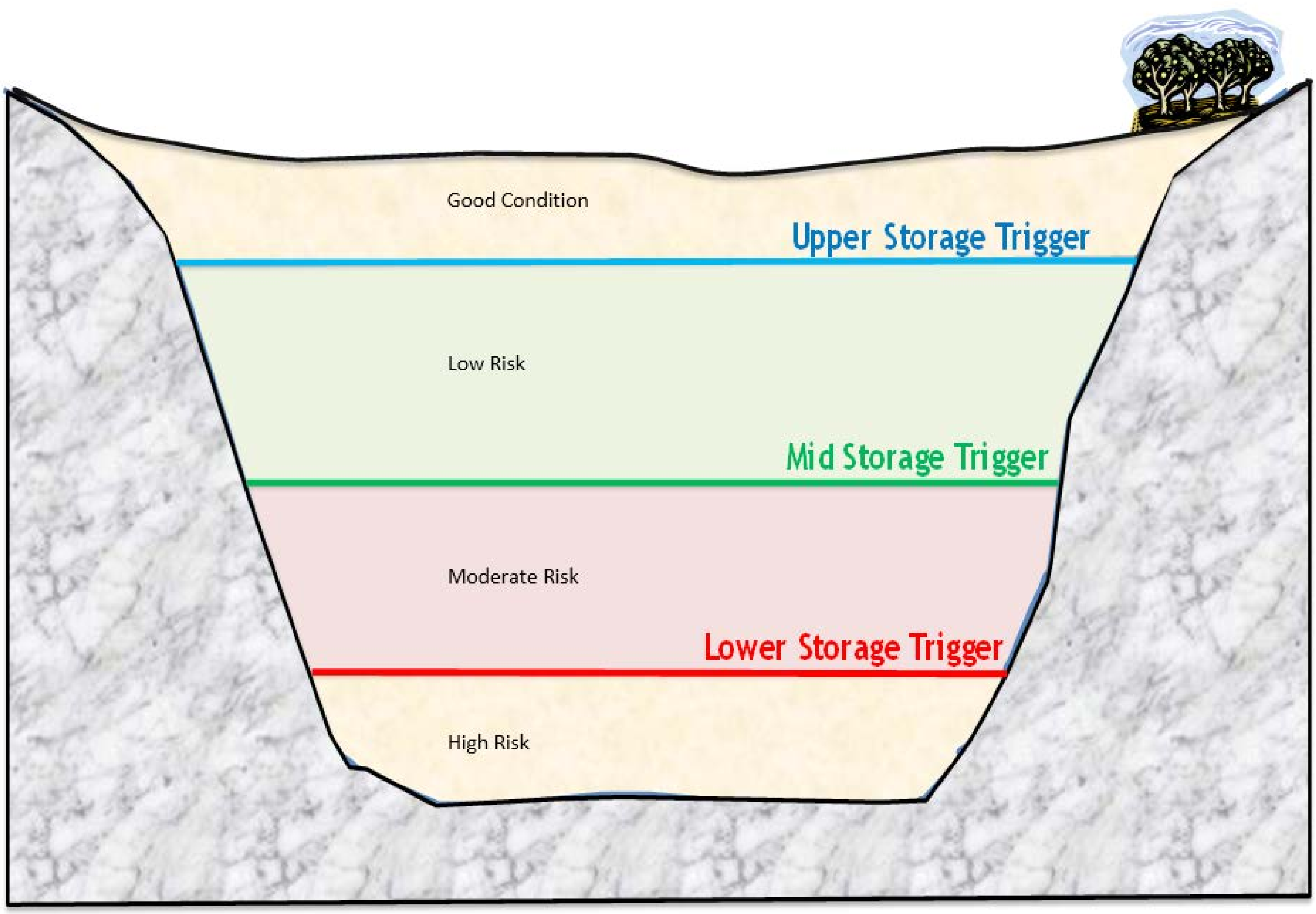


Figure 39 Schematic representation of trigger level in a typical aquifer

6.1.2 Aquifer Storage Reference Level

The next step in annually determining the variable component of the consumptive pool volume for each saturated Quaternary Limestone management area requires assessing the level of storage within each management area. This volume of storage is expressed as a percentage of the reference storage level (at which storage is set to 100%). The reference storage level does not represent the maximum level of storage that has been recorded in the past, nor does it represent the optimum level required for sustainable extraction. It is simply a reference point from which the annual changes in storage level can be measured and compared.

It is considered that the climatic conditions experienced since 1992 provide a realistic scenario of the likely climatic conditions that will be experienced during the life of this Plan. Consequently the reference level is set as the year in which water levels were highest since 1992, and monitoring data has indicated that this occurred for most wells in 1993. The season of autumn has been chosen as the time of year from which to measure the level of storage, as it represents the period when water levels are likely to be at their lowest elevation after summer and prior to any significant winter recharge occurring. This is a precautionary approach to ensure that the seasonal declines that are observed due to the natural discharge from aquifers and higher seasonal use levels across the warmer months are taken into account in the determination of the consumptive pool volume. Therefore the aquifer storage level of autumn 1993 has been chosen as the reference level.

An important consideration for selection of the reference level is the availability of consistent monitoring locations that can be used for a calculation of the storage level both historically and for the life of this Plan. Changes in the areal distribution of the locations used to calculate storage levels will lead to significant errors. It is not possible to make these consistent calculations using data obtained prior to 1993.

It should be noted that in reality, the storage levels in any given year could have been chosen as the reference level from which annual changes in storage could have been measured. The important consideration is how the level of storage relates to the trigger level, as this leads to the determination of the variable component. Figure 40 is an example of how the reference level, whether it be 1993 or 1963 (a higher recorded storage level), does not alter the current level of storage in comparison to the trigger levels.

It should be noted that Figure 40 represents only an example of how the triggers are assigned, while section 6.1.5 provides the detail on the triggers for each management area of the saturated Quaternary Limestone aquifer.

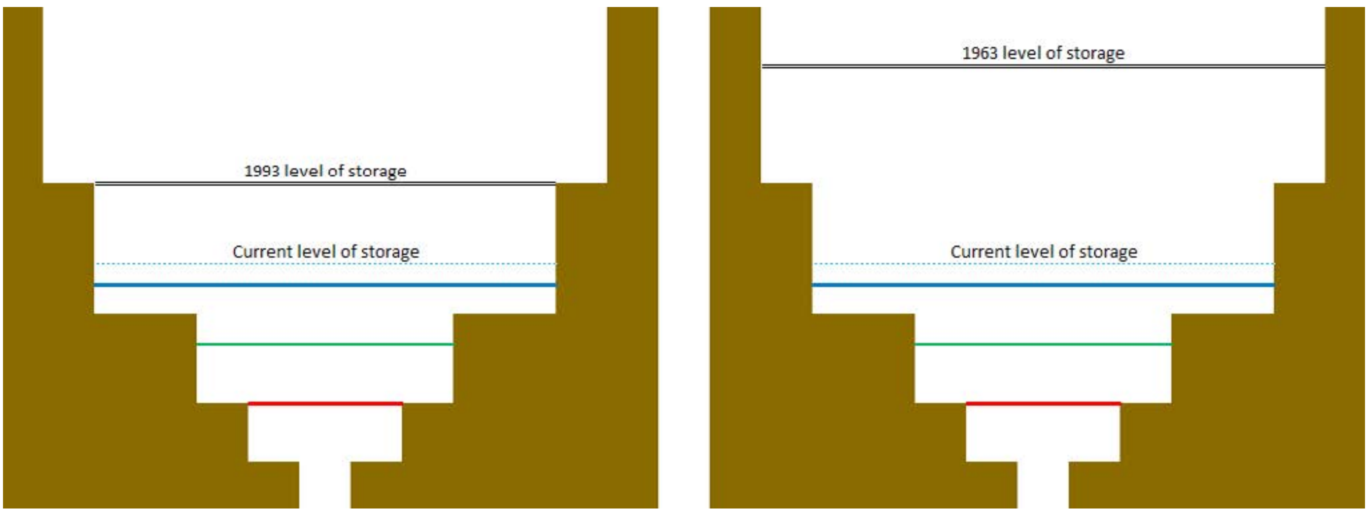


Figure 40 Schematic indicating the reference level in relation to the current level of storage for two examples

6.1.3 Annual Variation of the Consumptive Pool Volume

The variable component of the consumptive pool volume for a saturated Quaternary Limestone aquifer management area is determined by the relationship between the calculated storage levels and the fixed trigger levels. This relationship is proportional and is unique to each management area. The proportional relationship enables the consumptive pool volume to be sensitive to the level of stress being experienced by the groundwater resource. The level of storage, and thus the variable component of the consumptive pool volume, may vary with each water-use year.

Figure 41 shows how the variable component of the consumptive pool volume for a particular year varies depending on how the calculated level of storage relates to the various trigger levels for a hypothetical management area.

The DEWNR Technical Report 2013/19 by Stewart (2013) and Stewart (2015) describes the methodology for determining the triggers and rates of change for the various saturated Quaternary Limestone management areas. The values chosen take into consideration the accessibility and environmental risks derived from the risk assessment (SKM 2013), the response of the different management areas to scenario testing (specifically the variation in the level of storage observed), and the robustness of the lenses which fall within the management areas.

The defined triggers reflect the specific characteristics of the aquifer in individual management areas and are expressed as a percentage of the 1993 reference storage level. The rate of change is defined as the percentage change in the 'maximum volume of water available for licensed use' (as defined in Tables 20 and 21 of this Plan) for each percentage change in the level of storage, e.g. if the rate of change is 0.5, the variable component will be the 'maximum volume of water available for licensed use' (Tables 20 and 21, section 5) varied by 0.5 % for every 1 % change in storage level.

6.1.4 Example

Using the hypothetical example presented in Figure 42, three different scenarios have been used to demonstrate how the proportional relationship works. The level of storage that has been calculated by the process outlined in section 8.3 is located on the x-axis of the graph (on the bottom). That value is then traced vertically upwards until the purple line is met, and then horizontally traced to the y-axis (left hand side) to determine the variable component of the consumptive pool volume.

Example 1:

Level of Storage:	**90%**
Proportion of the 'maximum volume of water available for licensed use':	**100%**

Example 2:

Level of Storage:	**70%**
Proportion of the 'maximum volume of water available for licensed use':	**85%**

Example 3:

Level of Storage:	**50%**
Proportion of the 'maximum volume of water available for licensed use':	**42%**

6.1.5 Saturated Quaternary Limestone Management Areas Storage Triggers

The various trigger levels and rates of change for each management area of the saturated Quaternary Limestone aquifer of the Southern Basins and Musgrave PWAs have been summarised in Table 22 and are displayed in Figures 43 - 50, using the colour coding applied in Figure 41. Figures 43 - 50 also display the 2015 storage level, the reference level (100%) and the 1973 storage level to allow visualisation of historical high storage levels with current levels in comparison to the trigger levels.

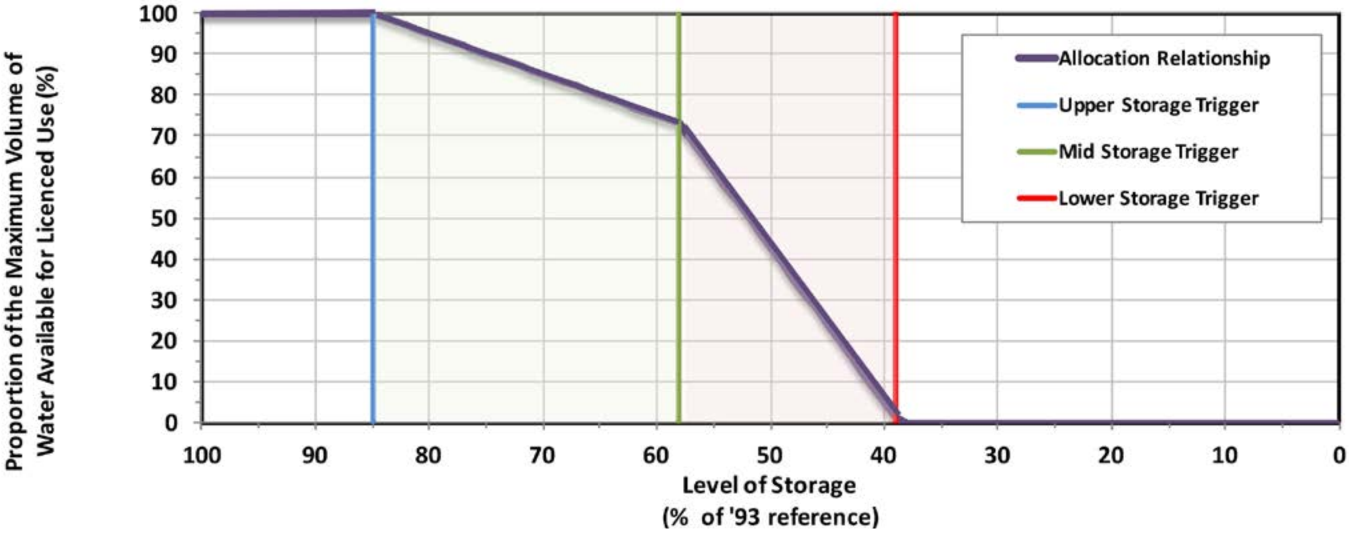


Figure 41 Schematic representation of trigger levels in a hypothetical consumptive pool

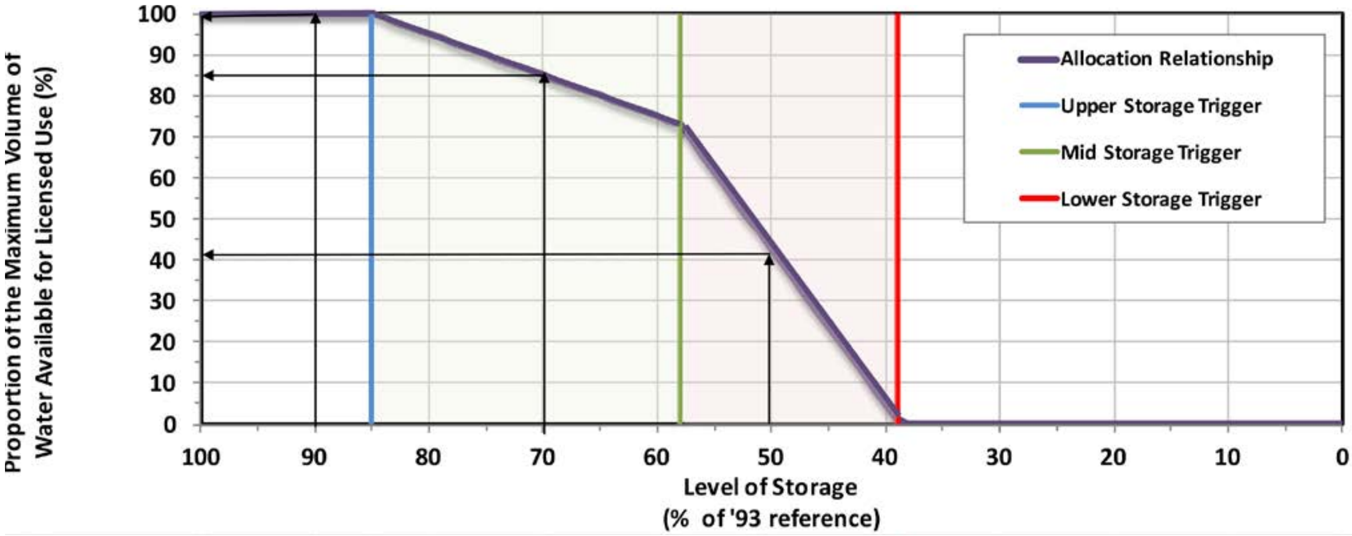


Figure 42 Example allocations for the hypothetical management area

Table 22 Proportional relationship trigger levels and rates of change for the saturated Quaternary Limestone management areas

PWA	Management Area	Upper Storage Trigger (% of reference)	Upper Rate of Change	Mid Storage Trigger (% of reference)	Lower Rate of Change	Lower Storage Trigger (% of reference
Southern Basins	Coffin Bay	95	1.0	94	49.5	92
	Uley Wanilla PWS	88	1.0	79	10.11	70
	Uley North	90	0.5	86	24.5	82
	Uley South PWS	90	1.0	81	9.1	71
	Lincoln South PWS	95	1.0	94	99	93
Musgrave	Polda	100	1.0	84	5.25	68
	Bramfield	90	1.0	81	9.10	71
	Sheringa	100	0.5	87	6.68	73

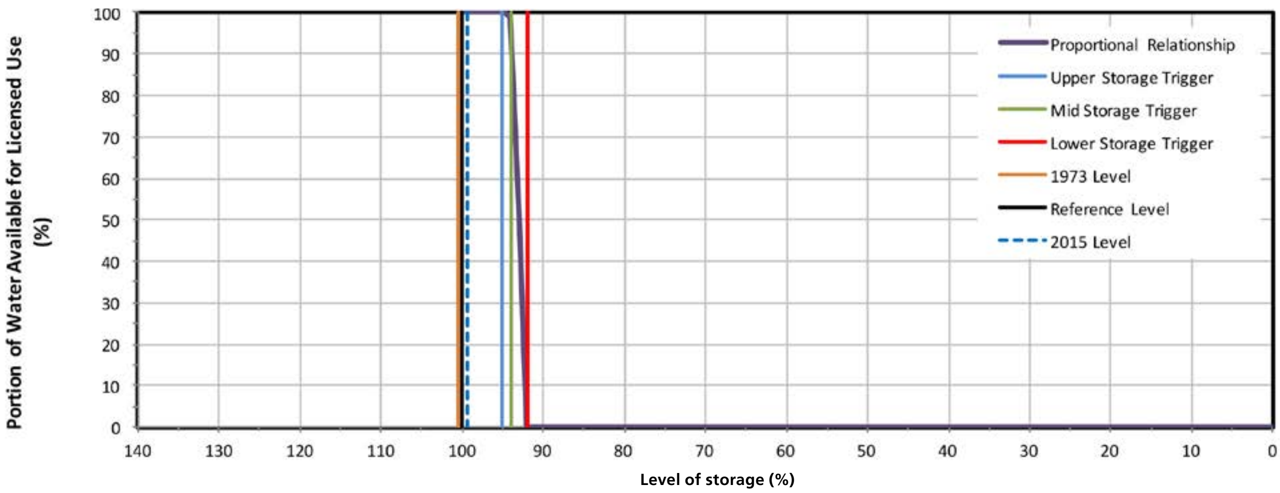


Figure 43 Proportional relationship for the Coffin Bay management area

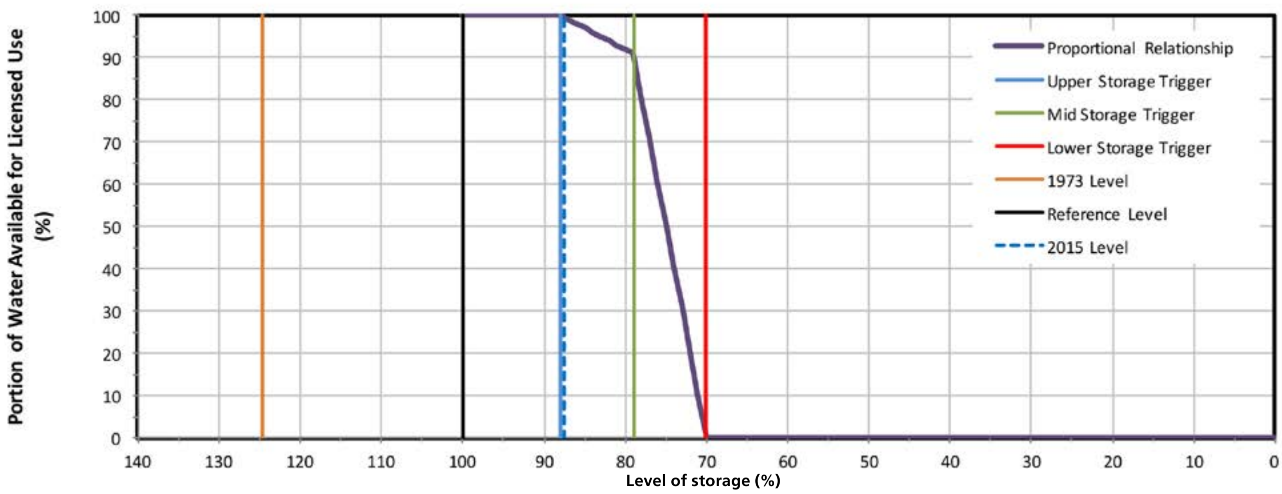


Figure 44 Proportional relationship for the Uley Wanilla Public Water Supply management area

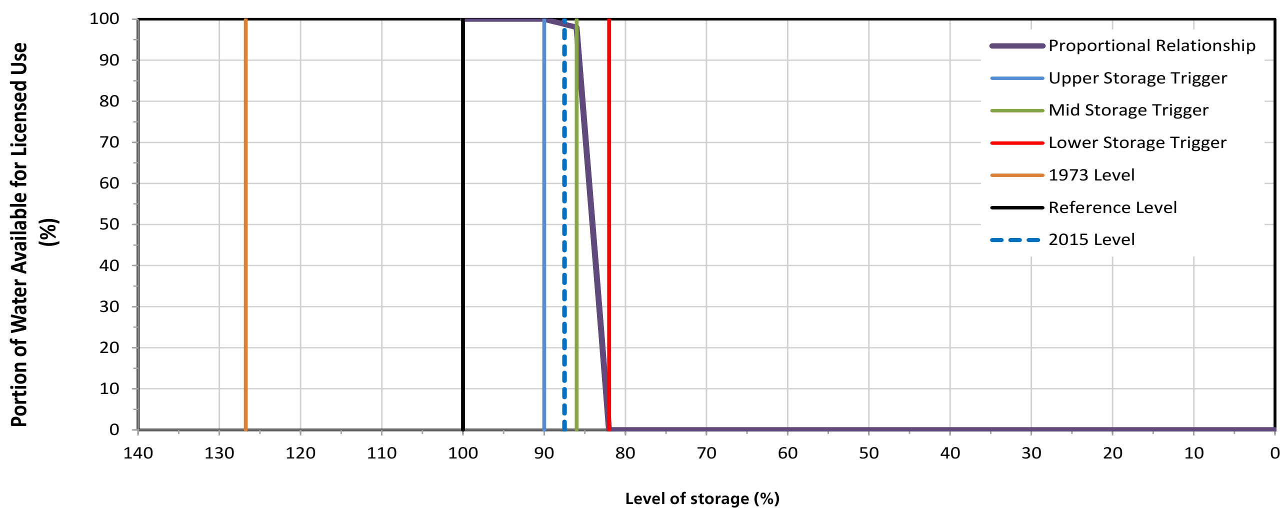


Figure 45 Proportional relationship for the Uley North management area

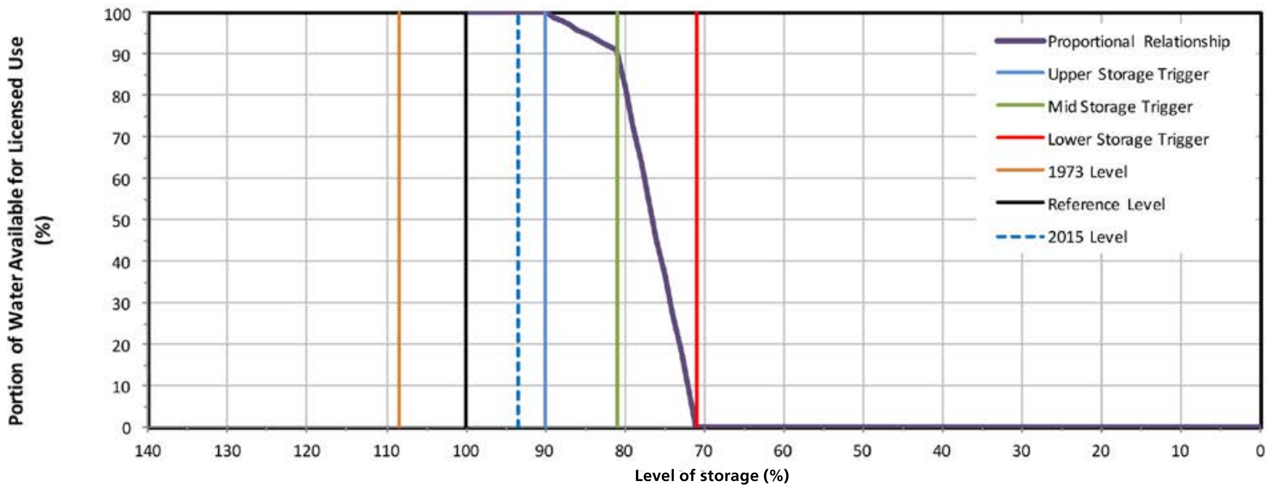


Figure 46 Proportional relationship for the Uley South Public Water Supply management area

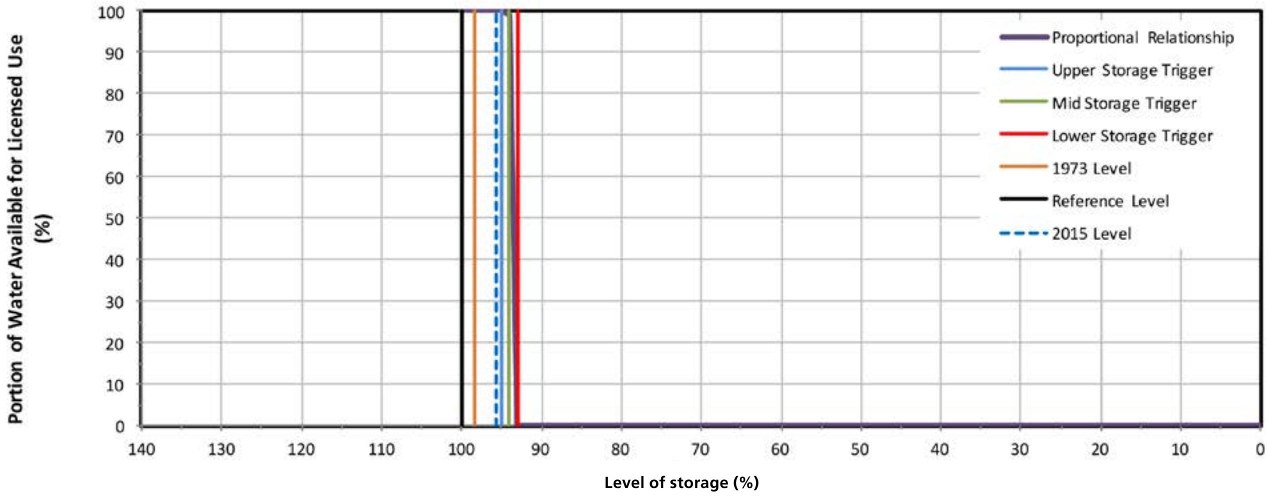


Figure 47 Proportional relationship for the Lincoln South Public Water Supply management area

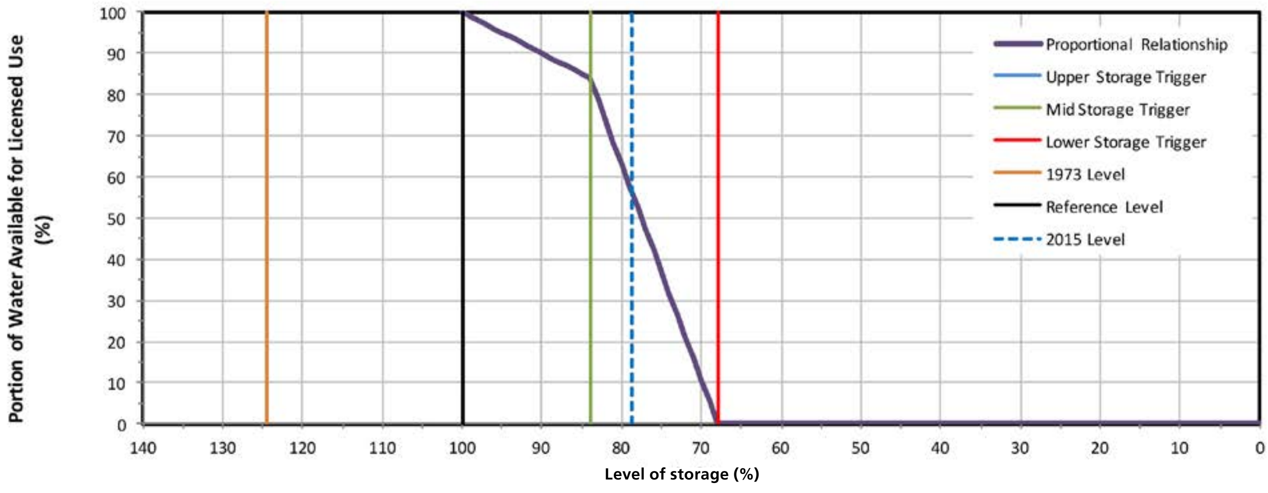


Figure 48 Proportional relationship for the Polda management area

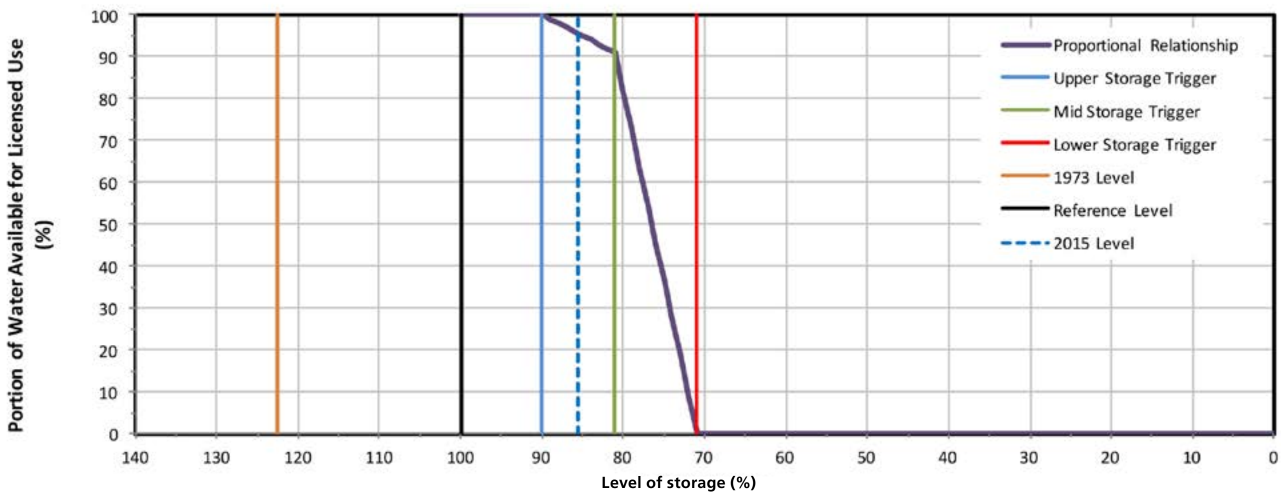


Figure 49 Proportional relationship for the Bramfield management area

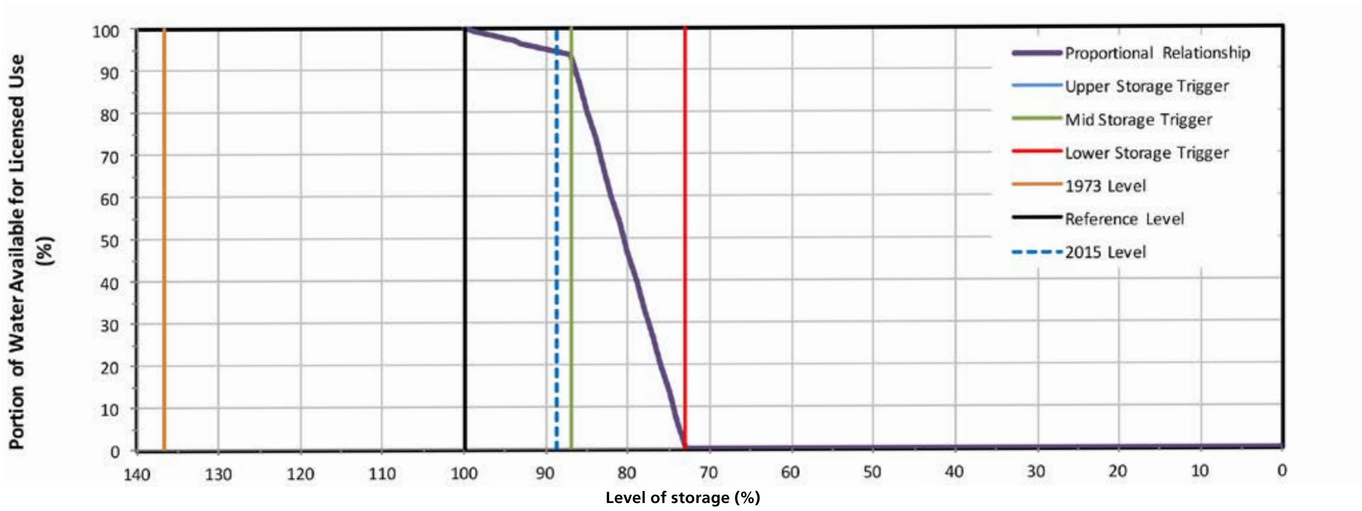


Figure 50 Proportional relationship for the Sheringa management area

6.1.6 Saturated Quaternary Limestone Management Areas 2015 Level of Storage

The 2015 levels of storage for the saturated Quaternary Limestone management areas have been calculated as an indication of the current condition of the management areas, this data is summarised in Table 23. This data indicates the following:

Coffin Bay: The 2015 level of storage is above the upper storage trigger, indicating that the variable component would be equivalent to that outlined in Table 20 in the field titled 'maximum volume of water available for licensed use'.

Uley Wanilla PWS: The 2015 level of storage is between the upper and mid storage triggers, indicating that the variable component would be a portion of that outlined in Table 20 in the field titled 'maximum volume of water available for licensed use', determined using the proportional relationship on Figure 44.

Uley North: The 2015 level of storage is between the upper and mid storage triggers, indicating that the variable component would be a portion of that outlined in Table 20 in the field titled 'maximum volume of water available for licensed use', determined using the proportional relationship on Figure 45.

Uley South PWS: The 2015 level of storage is above the upper storage trigger, indicating that the variable component would be equivalent to that outlined in Table 20 in the field titled 'maximum volume of water available for licensed use'.

Lincoln South PWS: The 2015 level of storage is above the upper storage trigger, indicating that the variable component would be equivalent to that outlined in Table 20 in the field titled 'maximum volume of water available for licensed use'.

Polda: The 2015 level of storage is between the mid and lower storage triggers, indicating that the variable component would be a portion of that outlined in Table 21 in the field titled 'maximum volume of water available for licensed use', determined using the proportional relationship on Figure 48.

Bramfield: The 2015 level of storage is between the upper and mid storage triggers, indicating that the variable component would be a portion of that outlined in Table 21 in the field titled 'maximum volume of water available for licensed use', determined using the proportional relationship on Figure 49.

Sheringa: The 2015 level of storage is between the upper and mid storage triggers, indicating that the variable component would be a portion of that outlined in Table 21 in the field titled 'maximum volume of water available for licensed use', determined using the proportional relationship on Figure 50.

Table 23 Level of storage for each saturated Quaternary Limestone management area for 2015

PWA	Management Area	2015 Level of Storage (% of reference)
Southern Basins	Coffin Bay	99.31
	Uley Wanilla PWS	87.46
	Uley North	87.48
	Uley South PWS	93.34
	Lincoln South PWS	95.57
Musgrave	Polda	78.84
	Bramfield	85.66
	Sheringa	88.77

6.2 Consumptive Pools for the unsaturated Quaternary Limestone, Tertiary Sands, Basement and Quaternary Lincoln North Management Areas

For the unsaturated Quaternary Limestone, Tertiary Sands, Basement and Quaternary Lincoln North management areas, this Plan defines the consumptive pools in two ways:

- By geography, using the management areas which are fixed for the life of the Plan (shown in Figures 20 and 21).
- As a volume of water fixed for the life of this Plan, which is referred to as the consumptive pool volume.

The fixed consumptive pool volumes are the sum of: 'non-licensed demand' + 'maximum volume of water available for licensed use' as defined in Tables 20 and 21 of this Plan for each management area. The fixed consumptive pool volumes are set out below at section 6.3(4).

The principles in this section apply to all licensed water users.

6.3 Consumptive Pools

1. Consumptive pools shall be determined by way of a fixed geographic boundary and volume.
2. The consumptive pools for the saturated Quaternary Limestone aquifer shall be defined by way of volume varied annually, in accordance with the method prescribed in this Plan.
3. The consumptive pools for the unsaturated Quaternary Limestone, Tertiary Sands, Basement and Quaternary Lincoln North consumptive pools are defined by way of volume, fixed for the life of this Plan.
4. For the purposes of this Plan, there shall be 15 consumptive pools. These consumptive pools are defined as:
    a. the Southern Basins Coffin Bay consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured purple in Figure 18 in section 2;
    b. the Southern Basins Uley Wanilla Public Water Supply consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured pink in Figure 18 in section 2;
    c. the Southern Basins Uley North consumptive pool being the consumptive pool volume determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured green in Figure 18 in section 2;
    d. the Southern Basins Uley South Public Water Supply consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured red in Figure 18 in section 2;
    e. the Southern Basins Lincoln South Public Water Supply consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured blue in Figure 18 in section 2;
    f. the Southern Basins Quaternary Lincoln North consumptive pool, being the fixed consumptive pool volume of 173.19 ML available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the area coloured yellow in Figure 18 in section 2;
    g. the Southern Basins Unsaturated Quaternary consumptive pool being the fixed consumptive pool volume of 6.96 ML available to be taken from the Quaternary Bridgewater Formation aquifer in the Southern Basins PWA within the areas coloured orange in Figure 18 in section 2;
    h. the Southern Basins Tertiary Sands aquifer consumptive pool being the fixed consumptive pool volume of 29.14 ML available to be taken from the Tertiary Wanilla Formation aquifer in the Southern Basins PWA within the area coloured orange in Figure 20 in section 2;
    i. the Southern Basins Basement aquifer consumptive pool being the fixed consumptive pool volume of 483.52 ML available to be taken from the Basement aquifer in the Southern Basins PWA, within the area coloured orange in Figure 20 in section 2;
    j. the Musgrave Polda consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Musgrave PWA within the area coloured red in Figure 19 in section 2;
    k. the Musgrave Bramfield consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary Bridgewater Formation aquifer in the Musgrave PWA within the area coloured green in Figure 19 in section 2;
    l. the Musgrave Sheringa consumptive pool, being the consumptive pool volume, determined annually and available to be taken from the Quaternary

Bridgewater Formation aquifer in the Musgrave PWA within the area coloured blue in Figure 19 in section 2;

m. the Musgrave Unsaturated Quaternary consumptive pool, being the fixed consumptive pool volume of 10.6 ML available to be taken from the Quaternary Bridgewater Formation aquifer in the Musgrave PWA within the areas coloured orange in Figure 19 in section 2;

n. the Musgrave Tertiary Sands aquifer consumptive pool, being the fixed consumptive pool volume of 68.39 ML available to be taken from the Tertiary Poelpena Formation aquifer in the Musgrave PWA within the area coloured orange in Figure 21 in section 2;

o. the Musgrave Basement aquifer consumptive pool, being the fixed consumptive pool volume of 67.27 ML available to be taken from the Basement aquifer in the Musgrave PWA within the area coloured orange in Figure 21 in section 2.

5. Additional groundwater consumptive pools may be determined from time to time, to provide for the taking of water from aquifers where water is found to exist, which is additional to that water already determined for each consumptive pool in the Southern Basins and Musgrave PWAs (Tables 20 and 21).

6. For the purposes of Principle 5, the Minister shall determine a consumptive pool by confirming through appropriate scientific means that water is available for taking by wells in the relevant aquifers, and that the taking of this water:

   a. will only present a low level of risk to the present and future health and maintenance of ecosystems that depend on water from these aquifers; and

   b. will not adversely affect the reliability of supply or the quality of water accessed by existing users of water from any other consumptive pool.

7. For the purposes of Principle 6, low level of risk is defined as the combination of the likelihood and consequences of an event such that the probability of not meeting the environmental objectives are deemed acceptably low, according to a set risk criteria.

8. The Minister will publish a notice in *The South Australian Government Gazette* advising of the determination of additional consumptive pools.

9. The Minister may issue a water access entitlement expressed as a number of units of a total number of units in relation to an additional consumptive pool, under procedures determined by the Minister which may include applications to be submitted subject to a market based mechanism such as a tender or auction process.

10. For the purpose of this Plan, water that is drained or discharged via a prescribed well into an underground water resource for the purpose of storage and later recovery of that water, shall constitute a separate consumptive pool or pools in accordance with Principle 5 above.

11. Further to Principle 10, the total number of units of water access entitlements for the consumptive pool shall be determined on the basis of 100% of the volume of water that is drained or discharged into the well and at a rate of 1 kilolitre = 1 unit.

6.4 Water Access Entitlements

12. The Minister may grant a water licence in respect of a prescribed water resource in the Southern Basins and Musgrave PWAs. A water licence provides a water access entitlement to the holder of the licence to gain access to a share of the water available in the consumptive pool that is available for licensed purposes.

13. A water access entitlement shall be a specified share of the water available for licensed use, as determined from time to time by the Minister under section 146(4) of the Act, expressed as a number of units of a total number of units (discussed below in section 6.5).

14. A water access entitlement cannot be transferred or varied (on application of the holder) so as to become an entitlement to take water from any other consumptive pool.

15. Where water from a prescribed water resource is used in the conduct of activities subject to a mining or petroleum lease or licence pursuant to the *Mining Act 1971* or the *Petroleum and Geothermal Energy Act 2000*, the Minister may grant a water licence for the purposes of those activities, subject to the provisions of this Plan.

16. Further to Principle 15, a separate water licence is required for each lease or licence issued pursuant to the Mining Act 1971 or the Petroleum and Geothermal Energy Act 2000, including but not limited to exploration licences, retention licences and production licences.

17. Where a water licence has been issued subject to Principle 15 that licence shall expire on 30 June following the relinquishment of the associated mining or petroleum lease or licence.

6.5 Transition Arrangements from Previous Plan

18. The water access entitlements are to be expressed as a number of units of a total number of units.

19. The total number of units for water access entitlements available for each consumptive pool at the date of adoption of the Plan shall be the 'maximum volume of water available for licensed use' as defined in Tables 20 and 21 of this Plan (determined at the rate of 1 kilolitre = 1 unit) (refer to Table 24).

20. At the date of adoption of this Plan, the holder of a current water licence (granted under the previous Plan) is entitled to be granted a water access entitlement under this Plan. The number of units issued to the water access entitlement holder shall be determined by converting the maximum volume of water on allocation from 2000/01 to 2013/14 to that licensee into units, at a rate of one kilolitre per unit share, limited to the maximum volume of the consumptive pool limit. For example: if the maximum volume of water on allocation during the period 2000/01 to 2013/14 to that licensee was 10 000 kilolitres (10 ML) then the number of units issued to the entitlement holder will be 10 000 units. The rate of one kilolitre per unit is relied upon solely for the purposes of conversion of a water licence under the previous Plan to a water licence and water access entitlement under this Plan. The actual kilolitre value per unit share will depend upon the Minister's determination of the amount of water available from the consumptive pool for allocation (discussed below at section 6.7).

    Note that the granting of water access entitlements will occur following a day designated by the Minister, subject to the *Natural Resources Management (General) Regulations 2005* - Regulation 47.

21. For the purpose of this Plan, any additional water that is available for licensed use but has not yet been granted on a licence will be known as excess water.

22. The Minister may issue a water access entitlement in relation to excess water, subject to a new or an existing water licence, under procedures determined by the Minister which may include applications to be submitted subject to a market based mechanism such as a tender or auction process.

Table 24 Water access entitlement units at the date of adoption of this Plan

Consumptive Pools	Non-Licensed Demand (kilolitres)	Licensed Demand (kilolitres)	Excess Water (kilolitres)	Maximum Volume of Water Available for Licensed Use (kilolitres)	Water access entitlements (in units)		
					Licensed Demand	Excess Water	Total WAE
Southern Basins Coffin Bay	5280	132890	0	132890	132890	0	132890
Southern Basins Uley Wanilla Public Water Supply	6400	230880	0	230880	230880	0	230880
Southern Basins Uley North	27860	238736	288490	527226	238736	288490	527226
Southern Basins Uley South Public Water Supply	8140	7249893	16230	7266123	7249893	16230	7266123
Southern Basins Lincoln South Public Water Supply	7820	928571	897288	1825859	928571	897288	1825859
Southern Basins Quaternary Lincoln North	39310	133880	0	133880	133880	0	133880
Southern Basins Quaternary Unsaturated	6960	0	0	0	0	0	0
Southern Basins Tertiary Sands aquifer	29140	0	0	0	0	0	0
Southern Basins Basement aquifer	28300	455218	0	455218	455218	0	455218
Musgrave Polda	34730	32621	10000	42621	32621	10000	42621
Musgrave Bramfield	179780	1187596	0	1187596	1187596	0	1187596
Musgrave Sheringa	54270	32882	1373320	1406202	32882	1373320	1406202
Musgrave Quaternary Unsaturated	10600	0	0	0	0	0	0
Musgrave Tertiary Sands aquifer	68390	0	0	0	0	0	0
Musgrave Basement aquifer	67270	0	0	0	0	0	0

6.6 Water Allocations

A water allocation may be obtained on account of a water access entitlement under a water licence. A water access entitlement represents the licensee's ongoing right to a share of the resource. A water allocation will be issued for a period of no more than 12 months and represents the volume of water available to be accessed during the water use year on account of the water access entitlement. The volume of water issued on a water allocation may vary annually, in part depending on changes to the consumptive pool volume.

Under section 146(4) of the Act, the Minister has a discretion to determine the volume of water that is to be made available for licensed use (allocation) from a consumptive pool. Therefore, the Minister's discretion is to operate within the ambit of the consumptive pool.

A water licence or water allocation is not required for the taking of water for:

a. watering stock (other than stock subject to intensive farming);
b. domestic purposes as defined by the Act;
c. the purpose of using it in the course of any operation or activity reasonably necessary for, or incidental to the drilling or construction of wells; or
d. aquifer testing where the proponent can prove to the satisfaction of the Minister that the water required to be taken will not adversely affect the reliability of supply or the quality of water accessed by existing users of water from the same or any other consumptive pool, and will only present a low level of risk to the present and future health and maintenance of ecosystems that depend on water from these aquifers.

6.7 Notices to be Published in *The South Australian Government Gazette*

For the purposes of this Plan, the Minster shall publish the following notices in *The South Australian Government Gazette*:

23. With respect to the saturated Quaternary Limestone aquifer, the Minister shall publish in *The South Australian Government Gazette*, the following:
    a. the level of storage of each consumptive pool calculated as a percentage of the reference level storage as determined by the means set out in this Plan; and
    b. the consumptive pool volume of each consumptive pool.

    The notice is intended to be published on or about 1 June of the preceding water-use year.
24. The Minister will from time to time, by publication in *The South Australian Government Gazette*, give notice of any additional consumptive pool and the total number of water access entitlement units available in relation to that consumptive pool.
25. The Minister will from time to time, by publication in The South Australian Government Gazette, give notice of the volume of water that is to be made available for allocation from each consumptive pool under section 146(4) of the Act and the calculated value of an individual unit share of a water access entitlement from each consumptive pool.

6.8 Transfers

6.8.1 Water Licence and Water Access Entitlement Transfers

26. Subject to section 150 of the Act and this Plan, the holder of a water licence:
    a. may transfer the licence to another person; or
    b. may transfer a water access entitlement, or part of a water access entitlement, under the licence to another person.
27. Water access entitlements may be transferred to another person only where it remains an entitlement for the consumptive pool from which it was initially granted.

6.8.2 Water Allocation Transfers

28. Subject to section 152 of the Act and this Plan, the holder of a water allocation may transfer the water allocation, in part or full, to another person for the period of time that the water allocation is current or for any shorter period of time.
29. A Water allocation obtained on account of a water access entitlement specific to a consumptive pool may be transferred to another person only where the water allocation remains specific to the consumptive pool from which it was initially granted.

7 Management of the Take and Use of Water

Water affecting activities are managed by the objectives and principles set out in the Regional NRM Plan. Under section 75(3)(k) of the Act, the Regional NRM Plan must set out the matters that the Minister will consider when exercising the powers to grant or refuse permits for water affecting activities. In addition to the matters set out in the Regional NRM Plan, section 76(4)(h)(i) allows for this Plan to set out further principles that apply to the Southern Basins and Musgrave PWAs regarding the granting of permits by the Minister.

7.1 General Principles

Wells may only be constructed, maintained and operated, and water may only be taken, in circumstances where the Minister is satisfied that the taking of water and the proposed manner of taking will have no significant detrimental impact on:

a. the water resource

b. groundwater dependent ecosystems

c. existing water users, and/or

d. the availability or quality of water accessed by a public water supply well.

For the purposes of (d) above, a public water supply well is defined as a well used or available to be used by a water industry entity as defined by the *Water Industry Act 2012*, or a water utility engaged in the extraction of underground water for distribution, reticulation or supply for consumptive purposes such as, but not limited to, domestic or industrial/commercial use.

The principles in this section apply to all water users.

7.1.1 The Management of Wells

An authorisation is required for the drilling, plugging, backfilling or sealing of a well and the repairing, replacing or altering of the casing, lining or screen of a well pursuant to section 127(3)(a) and (b) of the Act. Section 127(5a)(a) further requires an authorisation in some instances for the construction, operation and maintenance of wells as works for the purpose of taking water from a prescribed water resource. A regulation under section 127(5b)(a) exempts wells constructed and operated and maintained for the purpose of taking water that does not require a water allocation from requiring an authorisation under section 127(5a). However, a permit under section 127(3) is still required. For the purpose of this Plan, 'well' has the same meaning as stated in the Act and means:

- an opening in the ground excavated for the purpose of obtaining access to groundwater;
- an opening in the ground excavated for some other purpose but that gives access to groundwater; or
- a natural opening in the ground that gives access to groundwater.

The construction or modifications of wells must be in accordance with the *General Specifications for Well Construction, Modification and Abandonment in South Australia* pursuant to the well construction permit issued under the Act. This document is available from the Department.

7.1.2 Location of a Well

30. A new well for the taking of groundwater must not be located:

    a. within 300 m from an existing operational production well that accesses the same aquifer, except where:

        i. The well is to be drilled on land owned by the proponent, including land that is contiguous, and the proponent's property or contiguous properties are too small to enable a minimum distance of 300 m, or

        ii. the proponent has undertaken a hydrogeological investigation that demonstrates to the satisfaction of the Minister, that there will be no detrimental impact on the existing operational production well;

    b. within the Quaternary aquifer in the areas identified as environmental assets or the Environmental Protection Zones as shown in Figure 34, Figure 35 and Tables 10 and 11, unless the proponent has undertaken a hydrogeological investigation that demonstrates to the satisfaction of the Minister, that there will be no detrimental impact on the environmental asset;

    c. within the Tertiary Sands and/or Basement aquifers in the zones identified as areas of clay absence or the buffer zones surrounding the areas of clay absence as shown in Figure 30, Figure 31 and Table 9; or

    d. within the Tertiary Sands or Basement aquifers in the Southern Basins PWA in the areas identified as Groundwater Protection Zones, as shown in Figure 29.

31. For the purposes of Principle 30a., an existing operational production well is defined as a well that is used, or is able to be used, to supply water for irrigation, stock, domestic or commercial use; is known to the Department; and is owned by the existing owner or another party.

32. Principle 30 does not apply where the well is:
    a. to be drilled for the taking of water that does not require an allocation and the rate of groundwater extraction is less than 1.0 L/sec; or
    b. to be used for scientific purposes including but not limited to the monitoring of the groundwater resource; or
    c. a replacement well that will:
        i. replace an existing production well owned by the existing owner or another party, that is authorised for the purpose of taking a water allocation
        ii. be located no farther than 50 metres from the well being replaced
        iii. be constructed in the same management area as the well being replaced
        iv. be used for the same purpose as the existing well
        v. if located within an environmental protection zone or a buffer zone surrounding an area of clay absence, not be located closer to the environmental asset or area of clay absence protected by those zones; and
        vi. the volume proposed to be extracted from the well is equal to, or less than, that from the existing production well.
33. In addition to the exemptions listed in Principle 32, Principle 30c may not apply where it can be proven to the satisfaction of the Minister that:
    a. although the Tertiary clay layer is absent in a specific location, a similar confining layer is present that limits the connection between the Quaternary Limestone aquifer and the underlying Tertiary Sands or Basement aquifers such that downward leakage is restricted should water be taken from the Tertiary Sands or Basement aquifers; or
    b. the Quaternary Limestone is unsaturated and a management regime exists that can adequately manage all aquifers should the Quaternary Limestone become saturated; or
    c. the siting of the well within an area of clay absence or within the buffer zone surrounding an area of clay absence, and the subsequent taking of water from that well, will not cause or lead to the downward movement of water from the Quaternary aquifer to the underlying aquifers.

The onus of proof in all situations relating to this principle lies with the proponent and not the Minister or the South Australian Government.

7.1.3 Taking Water from a Well

34. A water resource works approval is required before water can be taken from a well. Subject to the transitional provisions in Principle 43, a water resource works approval will only be granted where:
    a. water taken subject to a water allocation is taken through an approved water meter;
    b. the headworks of a well from which water is taken subject to a water allocation, is constructed so that the extraction of water from the well can be metered without interference;
    c. water to be taken from the Southern Basins Tertiary Sands aquifer or the Southern Basins Basement aquifer does not underlie the Uley Wanilla PWS, the Uley South PWS, or the Lincoln South PWS management areas, as delineated by the groundwater protection zones identified in section 4.2.1 and shown in Figure 29;
    d. it can be proven to the satisfaction of the Minister that, with respect to water to be taken from a well or wells within an area of clay absence or within a buffer surrounding an area of clay absence as shown in Figures 30 and 31 and Table 9:
        i. an alternate confining layer to the Tertiary clay aquitard is present that limits the connection between the Quaternary Limestone aquifer and the underlying Tertiary Sands or Basement aquifers such that downward leakage is restricted should water be taken from the Tertiary Sands or Basement aquifers,
        ii. the Quaternary Limestone is unsaturated and a management regime exists that can adequately manage all aquifers should the Quaternary Limestone become saturated
        iii. the water taken will not cause or lead to the downward movement of water from the Quaternary aquifer to the underlying aquifers

    The onus of proof in all situations relating to Principle 34d lies with the proponent and not the Minister or the South Australian Government;
    e. water to be taken from the Quaternary Limestone management areas of the Southern Basins and Musgrave PWAs, is not within areas identified as environmental assets or zones identified as environmental protection zones surrounding the environmental assets shown in Figures 34 and 35, unless the proponent has undertaken a hydrogeological investigation that demonstrates to

the satisfaction of the Minister, that there will be no detrimental impact on the environmental asset;

f. water to be taken from the Uley South Public Water Supply consumptive pool, the Uley Wanilla Public Water Supply consumptive pool or the Lincoln South Public Water Supply consumptive pool is solely for the purpose of supplying public water;

g. water to be taken from the Polda consumptive pool is solely for the purposes of irrigation, industrial use or recreational use only; and

h. the taking of water drained or discharged into a consumptive pool, will only be recovered from the consumptive pool into which it was drained.

35. An annual water use report may be required (as a condition on a water resource works approval), and may include:

a. the volume of water actually taken through a water meter and recorded on each meter during the water-use year (i.e. opening and closing meter readings);

b. where the water allocation represents a volume that exceeds 100 ML, the volume of water taken by the holder of the water allocation at each point of extraction for each month of the water-use year;

c. where the water allocation represents a volume that exceeds 100 ML, the salinity and water level of the groundwater for the relevant aquifer from which the water allocation is taken, measured each month of a water-use year at a monitoring site(s) nominated on the water resources works approval; and/or

d. the total amount of water drained or discharged to groundwater, as measured by each meter, in the water-use year (where applicable).

36. Principle 35 is additional to those conditions on a water resources works approval issued pursuant to Principle 43 (transitional provisions at the end of section 7).

7.1.4 Draining or Discharging Water into a Well

A permit is required for the draining or discharging of water directly or indirectly into a well pursuant to section 127(3)(c) of the Act.

37. Water that is drained or discharged into a well must comply with the *Environment Protection Act 1993* and any associated policy.

38. The granting of a permit to drain or discharge water into a well will only be considered following the undertaking of a risk assessment by the proponent to the satisfaction of the Minister. This risk assessment must be consistent with the *National Water Quality Management Strategy* – Australian Guidelines for Water Recycling: Managing Health & Environmental Risks, Phase 2 (DOE 2008) or any subsequent document and other related documents current at the time.

39. Principle 38 does not apply to roof runoff (surface water) which is proposed to be drained or discharged into a well via a closed system of capture and transport, provided that the system is equipped with a mechanism to divert first flush water and is drained under gravity.

40. Draining or discharging water sourced from a different aquifer to the receiving aquifer can only occur where the proponent can prove to the satisfaction of the Minister that such draining or discharging will have no negative consequence on:

    a. the quality of the water in the receiving aquifer;

    b. the integrity of the receiving aquifer;

    c. groundwater dependent ecosystems;

    d. existing water users;

    e. surface and near-surface drainage including, but not limited to, waterlogging of soils, creating perched watertables or excessive increase in the height of watertables; or

    f. direct or indirect damage to buildings, roads and infrastructure.

    Additional authorisations may be required under the *Environment Protection Act 1993*

7.1.5 Conversion of a Mineral Well to a Water Well

41. A mineral well may be converted to a water well in accordance with approved water well construction standards. For the purpose of this Plan, the conversion of a mineral well to a water well is regarded as a new well and is subject to the principles contained in section 7 of this Plan.

7.2 The Management of the Use of Water

Prior to the use of water taken pursuant to a water allocation, the Act requires that a site use approval is required to authorise the use of that water. A site use approval is subject to conditions specified by regulations. At the date of adoption of this Plan, a regulation exists which allows a water allocation plan to determine the circumstances where a site use approval is not required.

42. For the purposes of this Plan, a site use approval is not required in all circumstances, except those circumstances determined by the Minister and under conditions set out by the Minister and published in *The South Australian Government Gazette*.

7.3 Transitional Provisions

43. At the date of adoption of this Plan, the holder of a current water licence (granted under the previous Plan) is entitled to be granted a site use approval and/or a water resource works approval if relevant to their circumstances, as determined by the Minister. Note that the granting of water access entitlements will occur following a day designated by the Minister, subject to the *Natural Resources Management (General) Regulations 2005* – Regulation 47.

8 Monitoring and Evaluation

Section 76(4)(d) of the Act requires a water allocation plan to "assess the capacity of the resource to meet the demands for water on a continuing basis and provide for regular monitoring of the capacity of the resource to meet those demands".

This includes ensuring that the demands on the resource are able to be met, without impacting on the ecological sustainability of the resource. Additionally, monitoring assists in the review of the Plan to consider if the Plan is achieving the set objectives.

This Plan is accompanied by a Monitoring, Evaluation, Reporting and Improvement (MERI) Plan (NREP 2015) that outlines a comprehensive program aimed at measuring and assessing hydrogeological, ecological and water use parameters.

8.1 Monitoring Strategy

The monitoring strategy set out in this Plan aims to ensure sufficient data are available to:

- Assess changes in the condition of priority groundwater resources and environmental assets
- Determine the level of storage of the saturated Quaternary Limestone management areas on an annual basis
- Monitor demands placed on the groundwater resource (licensed extractions)
- Ensure compliance with conditions on water licences, water resources works approvals and permits
- Inform the evaluation of the effectiveness of the Plan in meeting its objectives.

8.2 Assess Changes in Condition of Priority Groundwater Resources and Environmental Assets

8.2.1 Groundwater Monitoring Network

A network of monitoring wells will be maintained and monitored on a temporal and spatial scale sufficient to enable the assessment of the change in condition of water levels and salinities in priority groundwater aquifers within the PWAs. This current network is outlined in the MERI Plan.

A selection of wells will be monitored for water level annually in autumn in order to determine the level of storage in each saturated Quaternary Limestone management area. These wells are listed in the MERI Plan.

Additionally, when indicated as a condition on a Water Resources Works Approval, an Annual Water Use Report must be prepared, as indicated in Principle 35(c) of section 7, which may require the licensee to monitor water level and salinity at selected wells on a monthly basis.

8.2.2 Environmental Asset Monitoring

The water needs of GDEs are described in section 3 and the principles for the maintenance and protection of environmental assets are included in sections 6 and 7. In order to evaluate the success of these provisions, a program targeting priority environmental assets in management areas where extraction is occurring and at representative control sites will ensure baselines are established. The monitoring required to observe changes in critical hydrogeological and ecosystem parameters is detailed in the MERI.

8.3 Annual Assessment of the Level of Storage of the Saturated Quaternary Limestone Management Areas

The level of storage for each water-use year will be derived from monitoring data obtained from the nominated groundwater observation wells listed in the MERI Plan and will be calculated using the 3D AquaveoTM Arc Hydro Groundwater software package or an equivalent package.

The calculations of the level of storage are carried out at a smaller scale than the management areas (Figs. 51 and 52).

As the management areas are made up of multiple lenses and brackish areas, a process for scaling the level of storage for each individual zone to the management area is required. As water level data for the brackish area is generally sparse or infrequent, it is considered that the lenses should be the source of the storage level for the management area. If only one lens is present for a particular management area, the level of storage for that lens will be applied to the whole management area. If multiple lenses are present in a particular management area, the average of the storage level for the various lenses will be used to determine the level of storage for the management area (Table 25).

The water level data for autumn of the relevant year will be imported into the Geographic Information System (GIS) program and the interpolation tool will be used to create a layer that represents the elevation of the watertable relative to mean sea level. The watertable elevation layer will be overlain on the Tertiary clay layer (which is based on lithological logs that define the depth at which the Tertiary clay is intercepted) as shown in Figure 53. This clay layer outlines the base of the Quaternary Limestone aquifer which will not change over time. Using the areas delineated in Figures 51 and 52, the Arc Hydro Groundwater (or equivalent) software package will be utilised to calculate the volume of groundwater stored in the saturated Quaternary Limestone aquifer within each area above the Tertiary clay layer.

As per the equations on page 115, the volume of storage for each lens area for the relevant year will be compared to the reference storage level of 1993. As the reference storage level is taken to equate to 100%, the difference from the reference storage level can be calculated as a percentage for the relevant year. By then subtracting this difference from 100, the level of storage as a percentage of the reference storage level for the relevant year can be calculated for each area. Table 26 outlines the 2015 level of storage calculations based on autumn 2015 water level data.

Table 25 Process of up scaling the level of storage for each modelled area to the management area

PWA	Management Area	Lens(es) used to determine management area storage level
Southern Basins	Coffin Bay	Coffin Bay A lens
	Uley Wanilla Public Water Supply	Uley Wanilla lens
	Uley North	Average of Coffin Bay B and C and Uley East A and B lenses
	Uley South Public Water Supply	Uley South lens
	Lincoln South Public Water Supply	Average of Lincoln A, B and C lenses
Musgrave	Polda	Polda lens
	Bramfield	Average of Bramfield and Talia lenses
	Sheringa	Average of Sheringa A and B and Kappawanta lenses

Annual Storage Difference from Reference =
[(Reference Level Storage Volume – Annual Storage Volume)/ Reference Level Storage Volume] x 100
Annual Storage Level (%) = 100 – Annual Storage Difference from Reference

Table 26 Example of 2015 level of storage calculations for each ‘modelled lens’ area

PWA	Management Area	Lens	Reference Volume (GL)	Reference Level of Storage (%)	2015 Volume (GL)	2015 Difference from Reference (%)	2015 Level of Storage (%)
Southern Basins	Coffin Bay	Coffin Bay	254.09	100	252.34	0.69	99.31
	Uley Wanilla PWS	Uley Wanilla	170.73	100	149.32	12.54	87.46
	Uley North	Coffin Bay B	13.47	100	13.24	1.73	98.27
		Coffin Bay C	81.21	100	76.71	5.55	94.45
		Uley East A	11.01	100	7.73	29.78	70.22
		Uley East B	11.77	100	10.24	13.03	86.97
	Uley South PWS	Uley South	746.16	100	696.45	6.66	93.34
	Lincoln South PWS	Lincoln A	13.33	100	12.46	6.58	93.42
		Lincoln B	112.34	100	111.02	1.17	98.83
		Lincoln C	90.62	100	85.59	5.55	94.45
Musgrave	Polda	Polda	113.75	100	89.68	21.16	78.84
	Bramfield	Bramfield	356.98	100	303.57	14.96	85.04
		Talia	311.64	100	268.89	13.72	86.28
	Sheringa	Sheringa A	198.64	100	168.78	15.04	84.96
		Sheringa B	184.98	100	174.00	5.94	94.06
		Kappawanta	236.56	100	206.49	12.71	87.29

The storage level for each lens as outlined in Table 26 will then be then scaled to the management area following the details outlined in Table 25. A summary of the level of storage for each saturated Quaternary Limestone management area for 2015 can be seen in Table 27.

Table 27 Example 2015 level of storage for each management area

PWA	Management Area	2015 Level of Storage (% of reference storage)
Southern Basins	Coffin Bay	99.3
	Uley Wanilla PWS	87.5
	Uley North	87.5
	Uley South PWS	93.3
	Lincoln South PWS	95.6
Musgrave	Polda	78.8
	Bramfield	85.7
	Sheringa	88.8

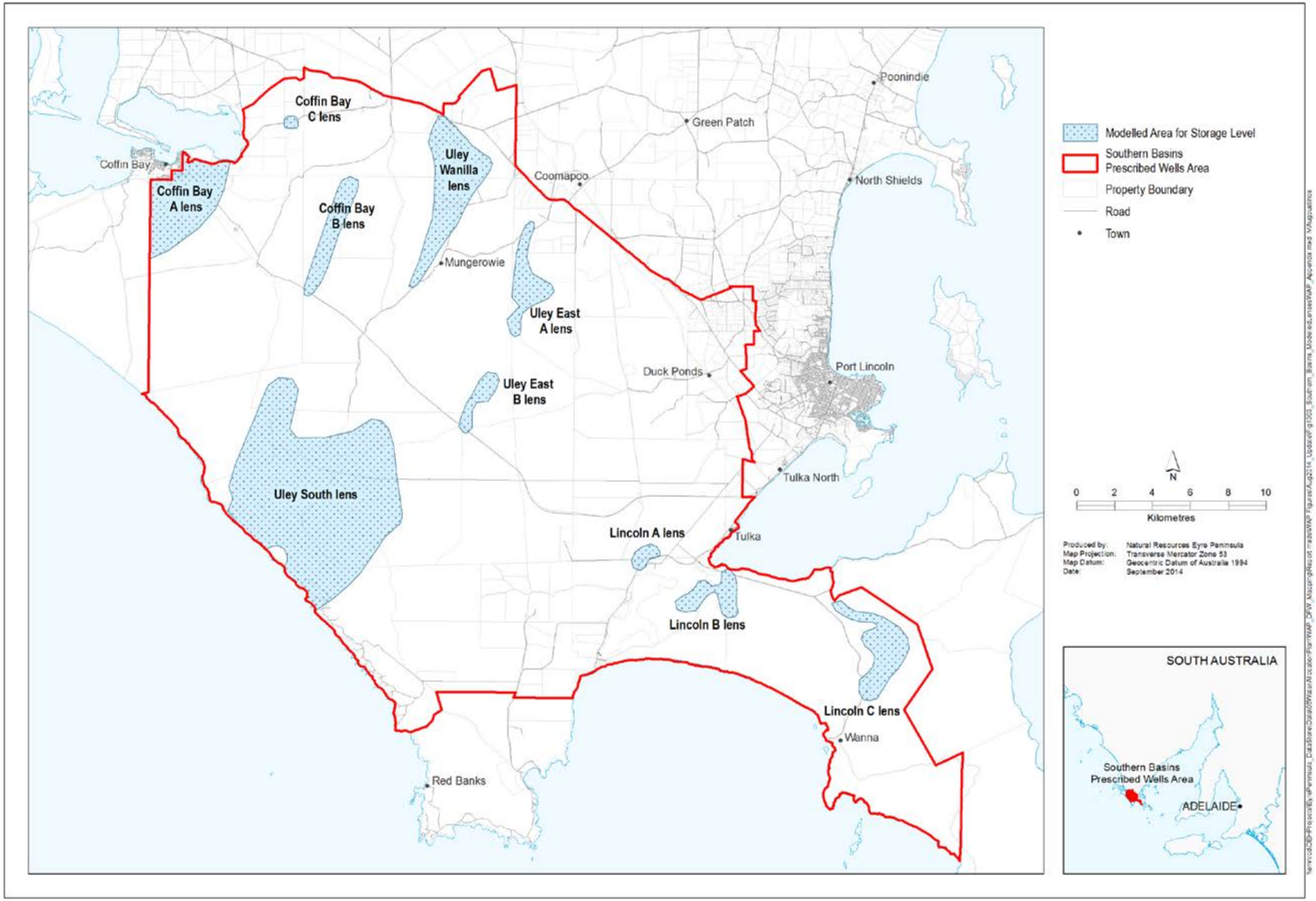


Figure 51 Areas used to assess the level of storage for the saturated Quaternary Limestone aquifer for each management area of the Southern Basins PWA

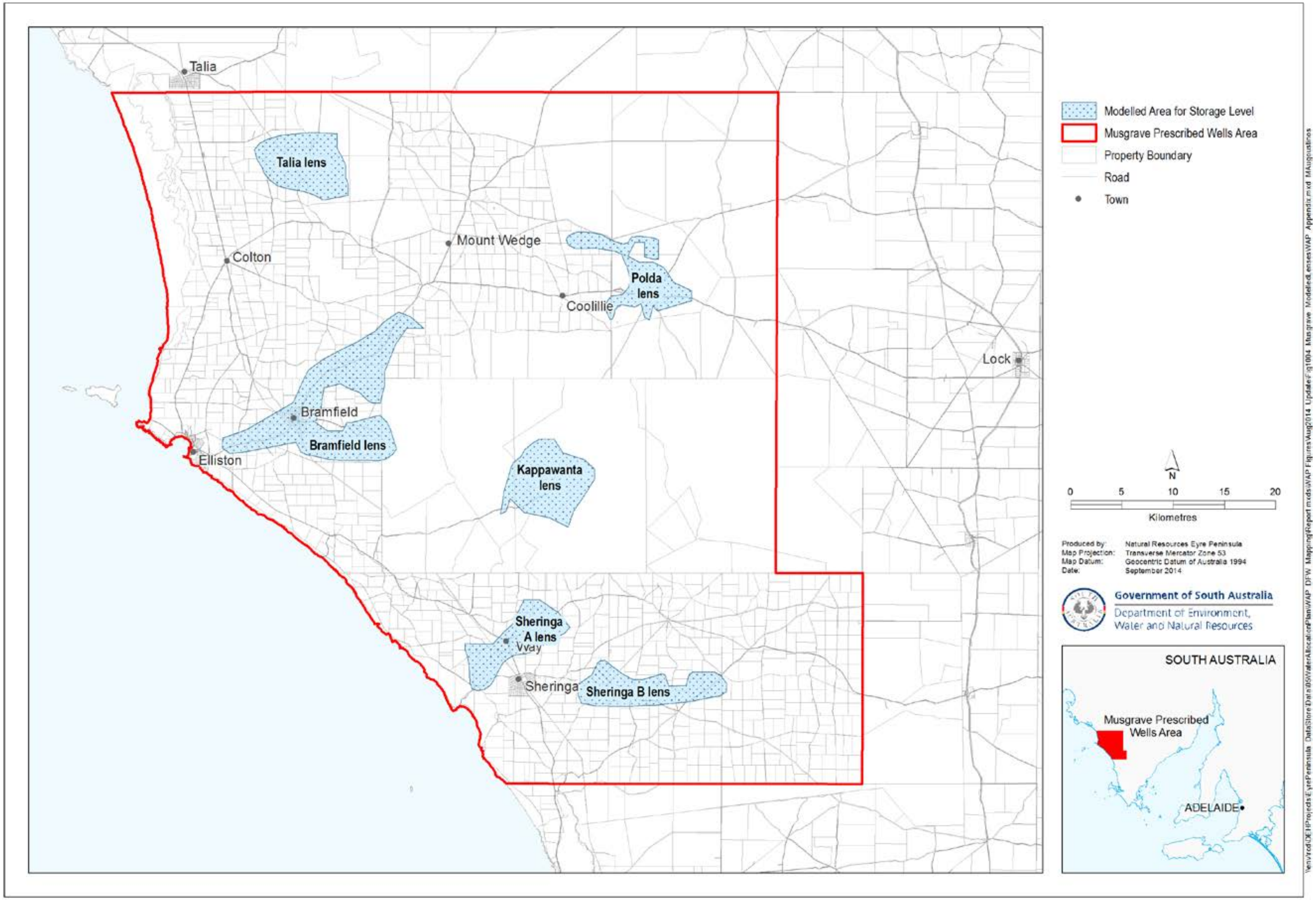


Figure 52 Areas used to assess the level of storage for the saturated Quaternary Limestone aquifer for each management area of the Musgrave PWA

8.4 Monitoring of Demands Placed on the Groundwater Resource

The Department keeps a record of the licensed groundwater extractions for the Southern Basins and Musgrave PWAs in the Water Information and Licensing Management Application (WILMA). Metering of licensed groundwater extractions will continue for both PWAs.

Additionally, when indicated as a condition on a Water Resources Works Approval, an Annual Water Use Report must be prepared, as indicated in Principle 35 of section 7, which may require the licensee to monitor extraction from production wells on an annual or monthly basis.

8.5 Compliance with Conditions on Authorisations

The monitoring data obtained in sections 8.2 to 8.4 will assist in determining compliance with any conditions placed on a water licence, a water resource works approval, any relevant permits or site use approvals (where required).

8.6 Evaluation

Evaluation is required at different stages to assess changes in the condition of groundwater resources and dependent ecosystems, determine annual storage volumes, periodically assess the effectiveness of the Plan in meeting objectives, and to inform future reviews.

Evaluation of monitoring data will be undertaken in a manner that considers the groundwater and environmental asset condition trends, primarily in relation to the proximity of water affecting activities in the vicinity of environmental assets, but also recognising that other factors such as climate variability and land management may be contributing to observed environmental asset condition. Further detail regarding the content, timing and responsibility for evaluation activities is defined in the MERI Plan.

The MERI Plan aims to identify knowledge gaps and research required to improve the science that underpins the Plan and provide for continual improvement.

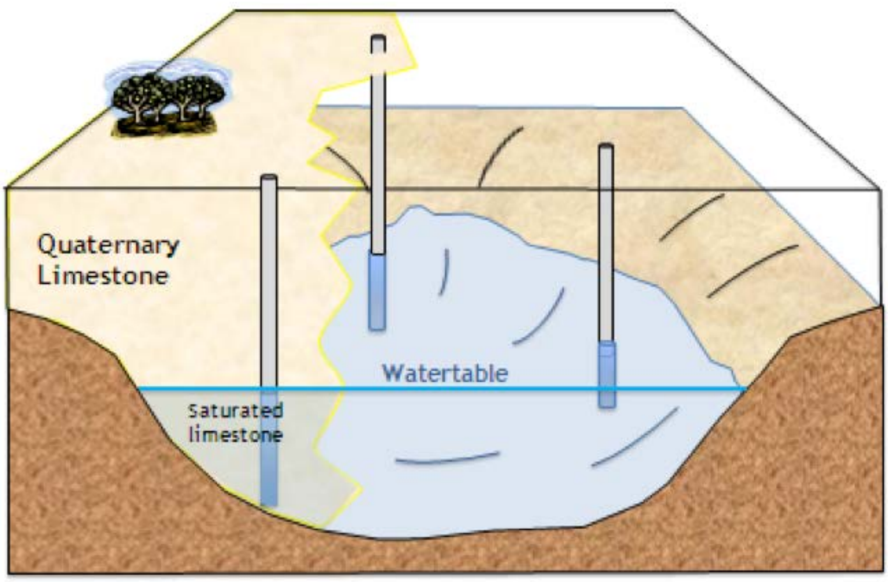
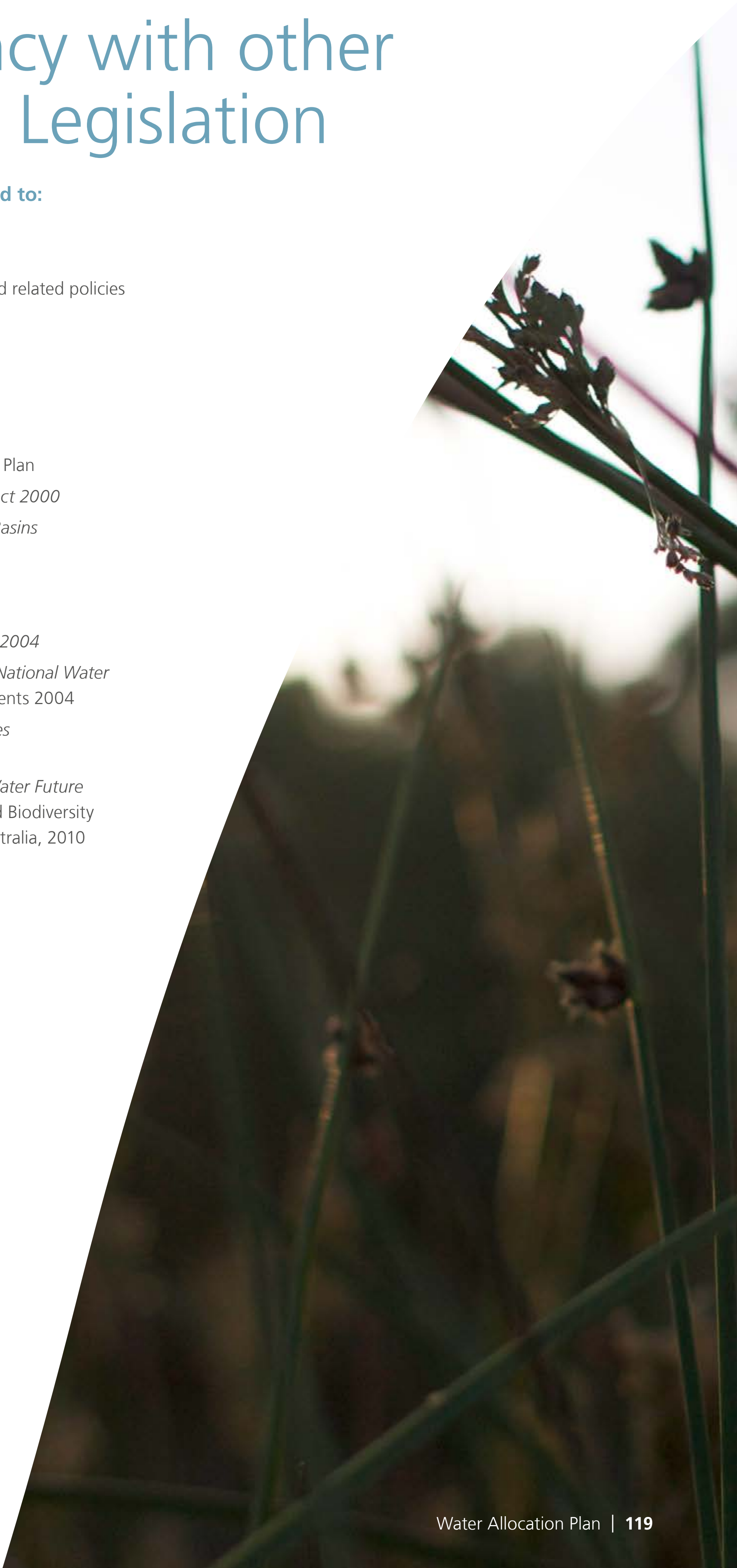


Figure 53 Schematic cross-section of saturated Quaternary Limestone

9 Consistency with other Plans and Legislation

This Plan was developed having regard to:

- the *Mining Act 1971*
- the *Native Vegetation Act 1991*
- the *Environment Protection Act 1993* and related policies
- the *Development Act 1993*
- Relevant development plans under the *Development Act 1993*, including the;
  - Lower Eyre Peninsula District Council Development Plan
  - Elliston District Council Development Plan
- the *Petroleum and Geothermal Energy Act 2000*
- the *Water Allocation Plan for Southern Basins Prescribed Wells Area*, December 2000
- the *Water Allocation Plan for Musgrave Prescribed Wells Area*, January 2001
- the *Natural Resources Management Act 2004*
- the *Intergovernmental Agreement on a National Water Initiative*, Council of Australian Governments 2004
- Eyre Peninsula Regional Na*tural Resources Management Plan*, 2009
- *Water for Good: A Plan to Ensure Our Water Future to 2050*, Department of Water, Land and Biodiversity Conservation, Government of South Australia, 2010
- *South Australia's Strategic Plan*, 2011
- the State NRM Plan 2012-2017, *Our Place Our Future*, 2012



Units of Measurement

kL = Kilolitre (1,000 litres)

kL/yr = Kilolitres per year

km² = Square kilometre

L/s = Litres per second

mg/L = Milligrams per litre

ML = Megalitre (1,000,000 litres)

Shortened Forms

Board – Eyre Peninsula Natural Resources Management Board

BoM – Bureau of Meteorology

DEWNR – Department of Environment, Water and Natural Resources

DFW – Department for Water

DSE – Dry Sheep Equivalent

EWP – Environmental Water Provision

EWR – Environmental Water Requirement

Regional NRM Plan – Natural Resources Management Plan for the Eyre Peninsula Natural Resources Management Region

EPZ – Environmental Protection Zone

GDE – Groundwater Dependent Ecosystem

GWPZ – Groundwater Protection Zone

MERI – Monitoring, Evaluation, Reporting and Improvement

NDVI – Normalised Differential Vegetation Index

NRM – Natural Resource Management

PIIMS – Primary Industries Information Management System

PIRSA – Department of Primary Industries and Regions South Australia

PWA – Prescribed Wells Area

PWS – Public Water Supply

Plan – Water Allocation Plan

WAE – Water access entitlement

WILMA – Water Information and Licensing Management Application

Glossary

Act (the)
The Natural Resources Management Act 2004.

Allocation
See Water Allocation.

Annual Water Use Report
A report produced by a licensee outlining water use during the water use year (1 July – 30 June), in accordance with the conditions on a water resource works approval.

ArcGIS
A geographic information system (GIS) for working with maps and geographic information.

Aquifer
An underground layer of rock or sediment that holds water and allows water to percolate through.

Aquitard
A layer in the geological profile that separates two aquifers and restricts the flow between them.

Australian Height Datum (AHD)
the datum adopted for vertical control, measured in metres. Zero metres AHD is approximately mean sea level.

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

Bathimetry
The underwater depth of lake or ocean floors (i.e. the underwater equivalent to topography)

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

Biota
All of the organisms at a particular locality.

Brackish water
Water of intermediate salt content between fresh and saline.

Buffer zone
An area within which certain management objective exist in order to protect a specific water resource or groundwater dependent ecosystem.

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

Confining layer
The aquitard (that is, a rock unit impervious to water) which forms the upper bound of a confined aquifer.

Consumptive pool
The water that will from time to time be taken to constitute the resource within a particular part of a prescribed water resource for the purposes of Chapter 7 of the Natural Resources Management Act 2004, as determined by this Plan.

Consumptive use
Licensed and non-licensed water use for the purposes of Chapter 7 of the Natural Resources Management Act 2004.

Critical human needs
The estimated minimum amount of water to meet core human consumption requirements in urban and rural areas.

Dampland
A seasonally waterlogged basin. Date of adoption or Adoption date: means the date that the Minister adopts this Plan.

Department
The administrative unit designated from time to time, by the Minister, by notice in the Gazette as being the Department primarily responsible for assisting the Minister in the administration of the Natural Resources Management Act 2004.

Discharge
Discharge is the process whereby groundwater leaves the aquifer, either through groundwater leakage to surface water bodies (e.g. baseflow), or spring seepage.

Domestic purpose
In relation to the taking of water, domestic purpose does not include: (a) taking water for the purpose of watering or irrigating land, other than land used solely in connection with a dwelling; or (b) without limiting paragraph (a), taking water for the purpose of watering or irrigating more than 0.4 of a hectare of land; or (c) taking water to be used in carrying on a business (except for the personal use of persons employed in the business).

Drawdown
The reduction in piezometric head due to pumping or gravitational drainage. Especially relating to reservoirs and groundwater. A large drawdown can be caused by low transmissivity or low well efficiency, or both.

Drillhole
A drilled hole in the ground. Most hydrogeological data is obtained from drillholes.

DSE
Dry Sheep Equivalent (DSE) is a unit to compare the feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given farm or area of grazing land, taking into account district practices and climatic conditions.

Ecology
The study of the relationships between living organisms and their environment.

Ecosystem
A dynamic complex of plant, animal, fungal and microorganism communities and the associated non-living environment interacting as an ecological unit.

Ecosystem services
Those processes and attributes of an ecosystem (or part of an ecosystem) that benefit humans.

Environmental Asset
Ecosystems that are protected by Environmental Protection Zones (EPZs) because they require access to groundwater (groundwater dependent ecosystems), opportunistically use groundwater or are not groundwater dependent but may be adversely affected by new wells (Big and Little Swamp).

Environmental Protection Zones
An environmental buffer defined as the desirable set-back distance that any water affecting activity must be from an environmental asset so as to mitigate the effect of groundwater use on the environmental asset.

Environmental Water Provisions (EWP)
Those parts of environmental water requirements that can be met at any given time with consideration to existing users' rights and social and economic impacts.

Environmental Water Requirements (EWR)
Those water requirements that must be met in order to sustain the environmental values of ecosystems that depend on the water resource, including their processes and biodiversity, at a low level of risk.

Estuaries
Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences and experience periodic fluctuations and gradients in salinity.

Excess water
Excess water is water that may be granted on account of a new water access entitlement under a water licence, or additional water that may be granted on account of an existing water access entitlement, but which is yet to be granted.

Existing user
A person who held a water licence under the previous Southern Basins or Musgrave Water Allocation Plans.

Groundwater
Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground.

Groundwater Dependent Ecosystem (GDE)
an ecosystem that require access to groundwater, on a permanent or intermittent basis, to meet all or some of its water requirements to maintain the community of plants and animals, and the ecological processes and ecosystem services they provide.

Groundwater extraction
The process of taking water from an underground source, either temporarily or permanently.

Groundwater soaks
Surface water expressions of groundwater that occurs where the groundwater intersects with the surface, and the pressure of the groundwater is sufficient to move water to the surface. Groundwater soaks may be permanent where the groundwater is in constant contact with the surface providing a permanent water source, or may only be temporary with flow ceasing when the groundwater level drops below the surface.

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

Hydraulic gradient
In unconfined groundwater, the mean watertable gradient in the direction of groundwater flow. In confined aquifers, the pressure gradient in the direction of flow.

Hydrogeology
The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers.

Hydrostatic pressure
The pressure exerted by gravity at a given point within a fluid that is at equilibrium.

Hypogean
Hypogean and hyporheic ecosystems occur beneath the surface of the ground in saturated pore spaces, in cracks or fractures in consolidated material, or in caves formed below the surface. Hyporheic systems generally occur closer to the surface where there can be mixing of surface and groundwater, while hypogean systems occur deeper in the ground.

Hyporheic zone
The wetted zone among sediments below and alongside rivers; a refuge for some aquatic fauna.

Land
According to the context, (a) land as a physical entity, including land under water; or (b) any legal estate or interest in, or right in respect of, land; and includes any building or structure fixed to the land.

Lens
A discrete occurrence of relatively fresh groundwater, where groundwater salinity is less than 1 000 mg/L.

Licence
see 'water licence'.

Licensee
A person or entity who holds a water licence pursuant to section 146 of the Act.

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

Landward
In a direction moving toward the land.

Macro-invertebrates
Aquatic invertebrates visible to the naked eye including insects, crustaceans, molluscs and worms that inhabit a river channel, pond, lake, wetland or ocean.

m AHD
Defines elevation in metres (m) according to the Australian Height Datum (AHD).

Managed aquifer recharge
The intentional draining and discharging of water to aquifers for subsequent recovery or environmental benefit.

Megalitre (ML)
one million litres.

Metered water use
Water volume measured through a water flow meter.

Minister
The Minister responsible for the administration of the Natural Resources Management Act 2004.

Model
A conceptual or mathematical means of understanding elements of the real world that allows for the assessment of certain conditions.

Monitoring
The systematic measurement of variables and processes over time to address a clearly defined set of objectives.

Non-consumptive use
water for maintaining natural processes, including but not limited to aquifer throughflow and discharge, and water for groundwater dependent ecosystems.

Obligate groundwater dependence
Refers to GDEs where the system would be lost if groundwater was no longer available in a suitable regime.

Permeability
A measure of the ease with which water flows through an aquifer or aquitard, measured in metres/day.

Phreatophyte
A type of plant that exhibits a high rate of transpiration by virtue of a taproot that extends down to the water table.

Potable water
Water suitable for human consumption such as drinking or cooking water.

Prescribed well
A well declared to be a prescribed well under section 125 of the Natural Resources Management Act 2004.

Prescribed Wells Area (PWA)
An area of land within which wells are prescribed.

Proponent
An applicant for a licence, a permit or approval, or a person who puts forward a proposition or proposal.

Public Water Supply (PWS)
Potable water that is distributed to residential and commercial customers by a water utility via a reticulated system.

Public Water Supply well
A groundwater well used for the purpose of providing Public Water Supply.

Recharge

Recharge is the process whereby groundwater is replenished by water draining into the groundwater system. Recharge does not include water held in the soil in the unsaturated zone that may be evaporated, taken up by plants, or discharge at topographic lows. Groundwater can be recharged from rainfall, irrigation infiltration or leakage from surface water bodies (e.g. stream, channel, lake). Recharge to unconfined aquifers occurs over a wide area directly above the aquifer.

Resource capacity

The capacity of a groundwater resource, calculated by multiplying the recharge area (km2) by the recharge rate (mm). Also known as the total amount of water available for consumptive demand and non-consumptive demand, that is, total demand.

Riparian zone

That part of the landscape that is adjacent to, that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses.

SA Geodata database

A collection of linked databases storing geological and hydrogeological data, which the public can access through the offices of the Department of Primary Industries and Regions SA. Custodianship of data related to minerals and petroleum and groundwater, is vested in PIRSA and DEWNR, respectively. DEWNR should be contacted for database extracts related to groundwater.

Site use approval

An approval which permits the use of water at a specific site for a particular purpose.

Stock water use

The taking of water to provide drinking water for stock other than stock subject to intensive farming.

Stygofauna

Aquifer fauna or the term encompassing all organisms inhabiting underground water.

Surface water

(a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner or, (ii) after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Sustainability

The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.

Taxa

General term given to a group identified by taxonomy. Taxonomy being the science of describing, naming and classifying organisms.

Throughflow

Shallow groundwater flow through a soil sub-parallel to a hillside. If the underlying rock is reasonably permeable, then the infiltrated water percolates vertically, and there is no throughflow.

Tertiary Sands aquifer

A term used to describe a water-bearing-sand formation deposited in the Tertiary geological period (1–70 million years ago).

Unconfined aquifer

An aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Upconing

In a stratified aquifer, especially a coastal aquifer with fresh overlying sea water, upconing is the upward migration of the saline interface in hydrostatic compensation for a falling watertable in and around a pumped well.

Water access entitlement (WAE)

An entitlement to the holder of a water licence to gain access to a share of water available in the consumptive pool or pools to which the licence relates, as specified by the licence and after taking into account any factors specified by the relevant water allocation plan or prescribed by the regulations.

Water allocation

An allocation of water under the terms of a water licence in accordance with Chapter 7 Part 3 Division 2 of the Natural Resources Management Act 2004, and includes the water available in connection with a water access entitlement.

Water allocation plan

A plan prepared by a natural resources management board and adopted by the Minister in accordance with the Act.

Water resource works approval

An approval which permits the construction, operation and maintenance of works for the purpose of taking water from a prescribed water resource at a specific location and in a particular manner.

Watercourse

A river, stream, creek or other natural watercourse (whether modified or not) in which water is contained or flows whether permanently or from time to time and includes a dam or reservoir that collects water flowing in a watercourse, a lake through which water flows, a channel (but not a channel declared by regulation to be excluded from the ambit of this definition) into which the water of a watercourse has been diverted, part of a watercourse, an estuary through which water flows, or any other natural resources, or class of natural resources, designated as a watercourse for the purpose of this Act by an NRM plan.

Water licence

A licence granted by the Minister under section 146 of the NRM Act.

Water quality

The physical, chemical and biological characteristics of water.

Water regime

The extent, duration, frequency, timing and depth of inundation or soil saturation.

Water-use year

A water use year runs from 1 July to 30 June in the following calendar year.

Well

As defined by the Natural Resources Management Act 2004, means (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; and/or (c) a natural opening in the ground that gives access to underground water.

Wetland

An area that comprises land that is permanently or periodically inundated with water (whether through a natural or artificial process) where the water may be static or flowing and may range from fresh water to saline water and where the inundation with water influences the biota or ecological processes (whether permanently or from time to time).

Zone of influence

The area around a pumped well, tile drain, quarry, foundation, etc., in which there is detectable drawdown.

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