MUSGRAVE PRESCRIBED WELLS AREA GROUNDWATER MONITORING STATUS REPORT 2002

DWLBC
Report

2002/23

The Department of Water, Land and Biodiversity Conservation

Government of South Australia

Musgrave Prescribed Wells Area groundwater monitoring status report 2002

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Groundwater Assessment
Department of Water, Land and Biodiversity Conservation

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of South Australia

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Foreword

South Australia's natural resources are fundamental to the economic and social wellbeing of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies. Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

Bryan Harris
Director, Resource Assessment Division
Department of Water, Land and Biodiversity Conservation

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INTRODUCTION

The Musgrave Prescribed Wells Area (PWA) is located around the township of Elliston on Eyre Peninsula. It covers an area of ~3595 km^2 and comprises all the Hundreds of Colton, Talia, Tinline, Squire, Ward, Hudd, Kappawanta, Blesing, Way, Pearce and Haig (Fig. 1). It also incorporates the towns of Elliston and Bramfield.

In general, water resources are limited in occurrence throughout Eyre Peninsula. In the Musgrave PWA there is very little available surface water, however there are moderately good supplies of groundwater.

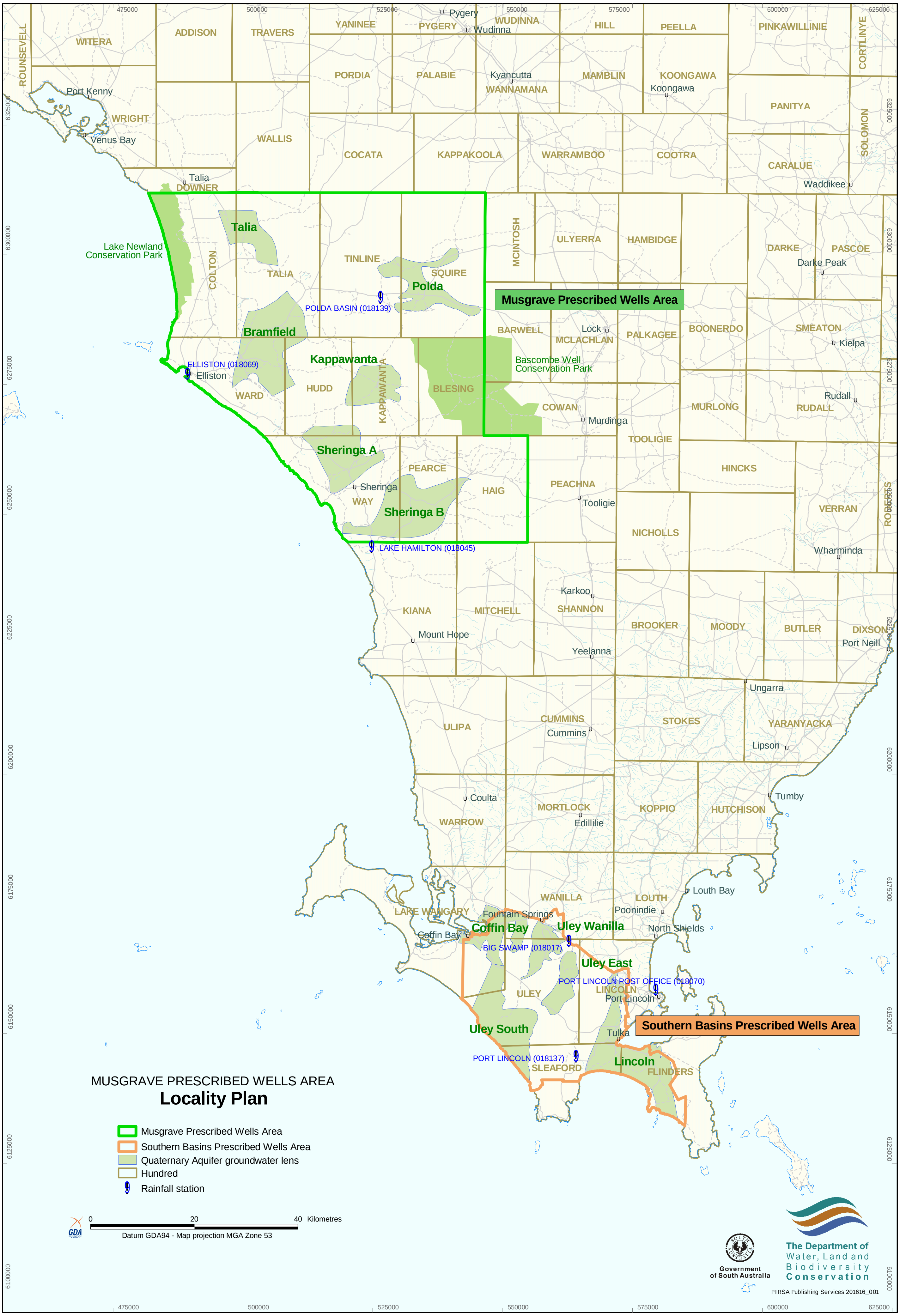
The area is generally characterised by undulating topographic relief typical of an ancient dunal system with dramatic coastal cliffs and large internal drainage catchments. Ground level elevations range from 100 m coastal cliffs to inland depressions reaching near sea level to bedrock highs exceeding 240 m.

The area incorporates the Lake Newland and part of the Bascombe Well Conservation Parks which are managed under the *National Parks and Wildlife Act 1972*. Pursuant to this Act, the management plan for the Lake Newland Conservation Park is in preparation.

The groundwater resources of the Musgrave PWA are contained primarily within the Quaternary Bridgewater Formation Limestone (Quaternary Limestone) and the Tertiary Sand Aquifers. Minor groundwater resources are found within the Jurassic Polda Basin and fractured basement rocks. The major resources within the Quaternary Limestone Aquifer are in separate geologically controlled structures and include the Bramfield, Kappawanta, Polda, Polda North, Talia and Sheringa A and B Lenses. The Polda lens contributes to the reticulated water supply for upper Eyre Peninsula via the major Tod to Ceduna pipeline and the Bramfield lens is the source of water for the township of Elliston. A schematic cross-section identifying the key hydrogeological units of the Musgrave PWA is provided in Figure 2.

The majority of the Musgrave PWA is an undulating calcrete plain with shallow soils and areas of sand dunes overlying the calcrete. Soil cover is generally discontinuous and calcareous in nature. The predominant land use is stock grazing. Some cropping occurs in pockets of better soils, where these are large enough. The thin soils over the limestone promote rapid infiltration of rainfall that favours relatively high recharge rates in selective areas. Increased understanding of the natural processes operating within these groundwater resources suggests that the primary source of recharge water to these aquifers is from infiltration of rainfall falling directly onto the land overlying them. The shallow occurrence of these groundwater resources increases the vulnerability of the resource to contamination, such that the water quality of these resources is easily threatened. This could be by inappropriate land use such as intensive stock production or by conscious or accidental waste disposal or chemical spill.

Groundwater from the Musgrave PWA currently provides a minor proportion of Eyre Peninsula's reticulated public water supply needs (Fig. 3). South Australian Water Corporation (SA Water) is the major groundwater user within the Musgrave PWA, withdrawing between 230 and 1200 ML per annum of groundwater from the Bramfield and Polda Lenses over the last decade. Fluctuations in groundwater use can generally be attributed to annual rainfall variations and also to the development of the Eyre Peninsula. Bramfield Lens is used to supply the township of Elliston, and over the last decade



MUSGRAVE PRESCRIBED WELLS AREA
Locality Plan
Musgrave Prescribed Wells Area
Southern Basins Prescribed Wells Area
Quaternary Aquifer groundwater lens
Hundred
Rainfall station
0
20
40
Kilometres
Datum GDA94 - Map projection MGA Zone 53
Musgrave Prescribed Wells Area
Southern Basins Prescribed Wells Area
Talia
Polda
Bramfield
Kappawanta
Sheringa A
Sheringa B
Coffin Bay
Uley Wanilla
Uley East
Uley South
Lincoln
Lake Newland Conservation Park
Bascombe Well Conservation Park
POLDA BASIN (018139)
ELLISTON (018069)
LAKE HAMILTON (018045)
BIG SWAMP (018017)
PORT LINCOLN POST OFFICE (018070)
PORT LINCOLN (018137)
ROUNSEVELL
WITERA
ADDISON
TRAVERS
YANINEE
PYGERY
WUDINNA
HILL
PEELLA
PINKAWILLINIE
CORTLINYE
PORDIA
PALABIE
WANNAMANA
MAMBLIN
KOONGAWA
PANITYA
SOLOMON
WRIGHT
WALLIS
COCATA
KAPPAKOOLA
WARRAMBOO
COOTRA
CARALUE
DOWNER
COLTON
TALIA
TINLINE
SQUIRE
MCINTOSH
ULYERRA
HAMBIDGE
DARKE
PASCOE
BARWELL
MCLACHLAN
PALKAGEE
BOONERDO
SMEATON
WARD
HUDD
KAPPAWANTA
BLESING
COWAN
MURLONG
RUDALL
TOOLIGIE
PEARCE
WAY
HAIG
PEACHNA
HINCKS
VERRAN
ROBERTS
NICHOLLS
KIANA
MITCHELL
SHANNON
BROOKER
MOODY
BUTLER
DIXSON
ULIPA
CUMMINS
STOKES
YARANYACKA
WARROW
MORTLOCK
KOPPIO
HUTCHISON
WANILLA
LOUTH
LAKE WANGARY
ULEY
LINCOLN
SLEAFORD
FLINDERS
Pygery
Wudinna
Kyancutta
Koongawa
Port Kenny
Venus Bay
Talia
Waddikee
Darke Peak
Lock
Kielpa
Elliston
Rudall
Murdinga
Sheringa
Tooligie
Wharminda
Karkoo
Mount Hope
Yeelanna
Port Neill
Ungarra
Cummins
Lipson
Coulta
Tumby
Edillilie
Louth Bay
Poonindie
Fountain Springs
North Shields
Coffin Bay
Port Lincoln
Tulka
475000
500000
525000
550000
575000
600000
625000
6325000
6300000
6275000
6250000
6225000
6200000
6175000
6150000
6125000
6100000
GDA
Government of South Australia
The Department of Water, Land and Biodiversity Conservation
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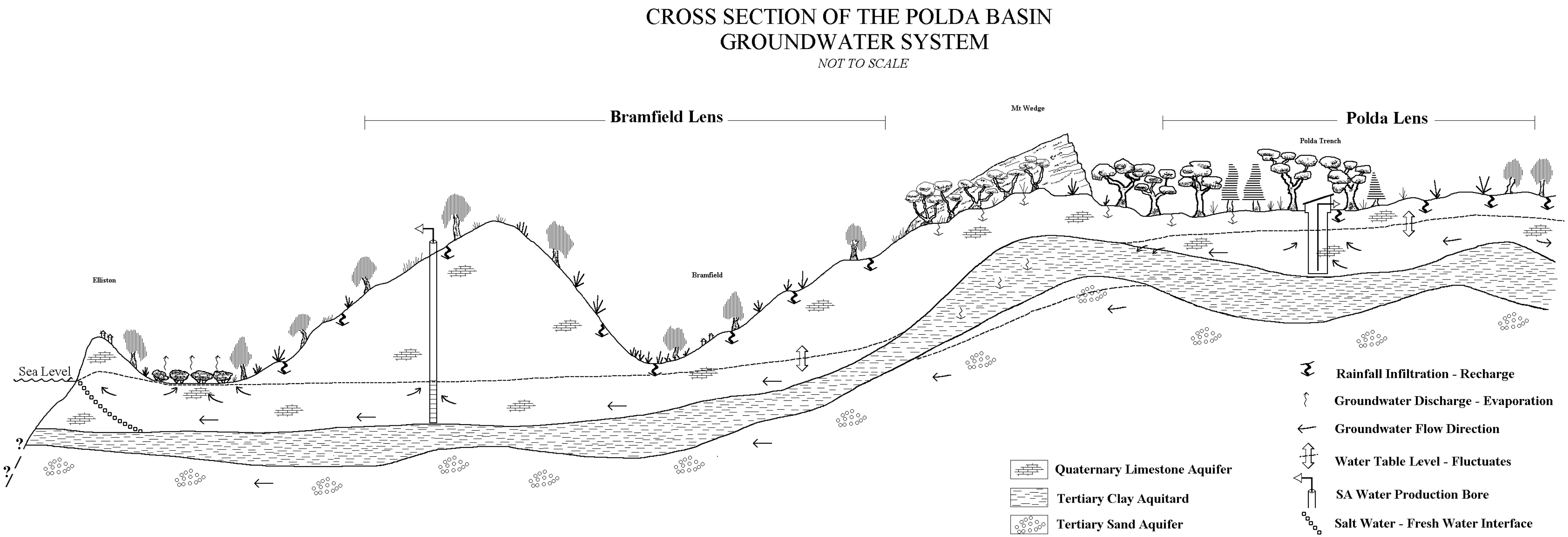
Figure 1



CROSS SECTION OF THE POLDA BASIN
GROUNDWATER SYSTEM
NOT TO SCALE
Bramfield Lens
Mt Wedge
Polda Lens
Polda Trench
Elliston
Bramfield
Sea Level
?
?
Rainfall Infiltration - Recharge
Groundwater Discharge - Evaporation
Groundwater Flow Direction
Water Table Level - Fluctuates
SA Water Production Bore
Salt Water - Fresh Water Interface
Quaternary Limestone Aquifer
Tertiary Clay Aquitard
Tertiary Sand Aquifer

Figure 2

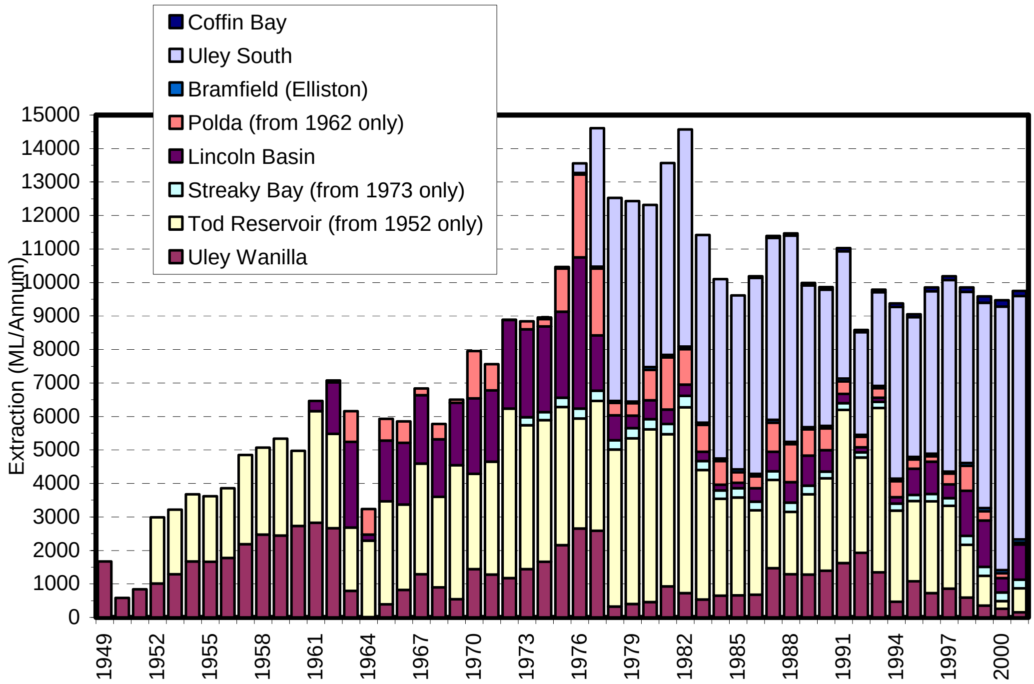


Figure 3 Annual Extraction for the Eyre Peninsula Public Water Supply

produced between 40 and 90 ML per annum for that supply. Polda Lens is used to augment the Tod Trunk Main, and between 160 and 1135 ML per annum has been withdrawn from Polda for that purpose over the last decade, at an average of ~480 ML per annum.

There are currently eight water licences issued for the purpose of irrigation; excluding SA Water, approximately only half of licence holders use groundwater on a regular basis. Those licensed groundwater users were allocated 148.6 ML of water for irrigation purposes during the 2001–02 irrigation season, all of which was used to irrigate nut (mainly pistachios and almonds) and fruit trees. SA Water extracted a total of 269 ML from the Musgrave PWA during 2001–02. Numerous stock and domestic supplies are scattered throughout the area.

CLIMATE

Three rainfall stations located in the vicinity of the Musgrave PWA were selected as representative of the rainfall pattern throughout the area:

Elliston Post Office	Station 18069
Polda Basin (Gum View)	Station 18139
Lake Hamilton	Station 18045.

The rainfall records are available for a period of up to 125 years; however, the Polda Basin Station record begins in 1967, so for consistent comparison cumulative deviation from month averages is taken from 1967 until the present for all stations. Rainfall is winter dominant, with the average monthly and annual rainfall for these stations shown in Table 1.

Table 1. Average monthly rainfall (mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Elliston	9.8	13.1	14.4	27.5	53.2	72.6	70.9	59.6	40.1	30.5	19.4	16.3	428.3
Polda Basin	14.3	13.6	15.7	23.1	44.2	53.5	61.9	57.4	46.9	31.4	19.7	20.3	401.1
Lake Hamilton	8.8	13.4	15.3	27.9	52.8	73.4	75.9	60.3	40.8	30.2	18.3	16.3	434.1

Figure 4 shows the annual rainfall and cumulative deviation from monthly mean obtained from these stations for the period length of continuous recording.

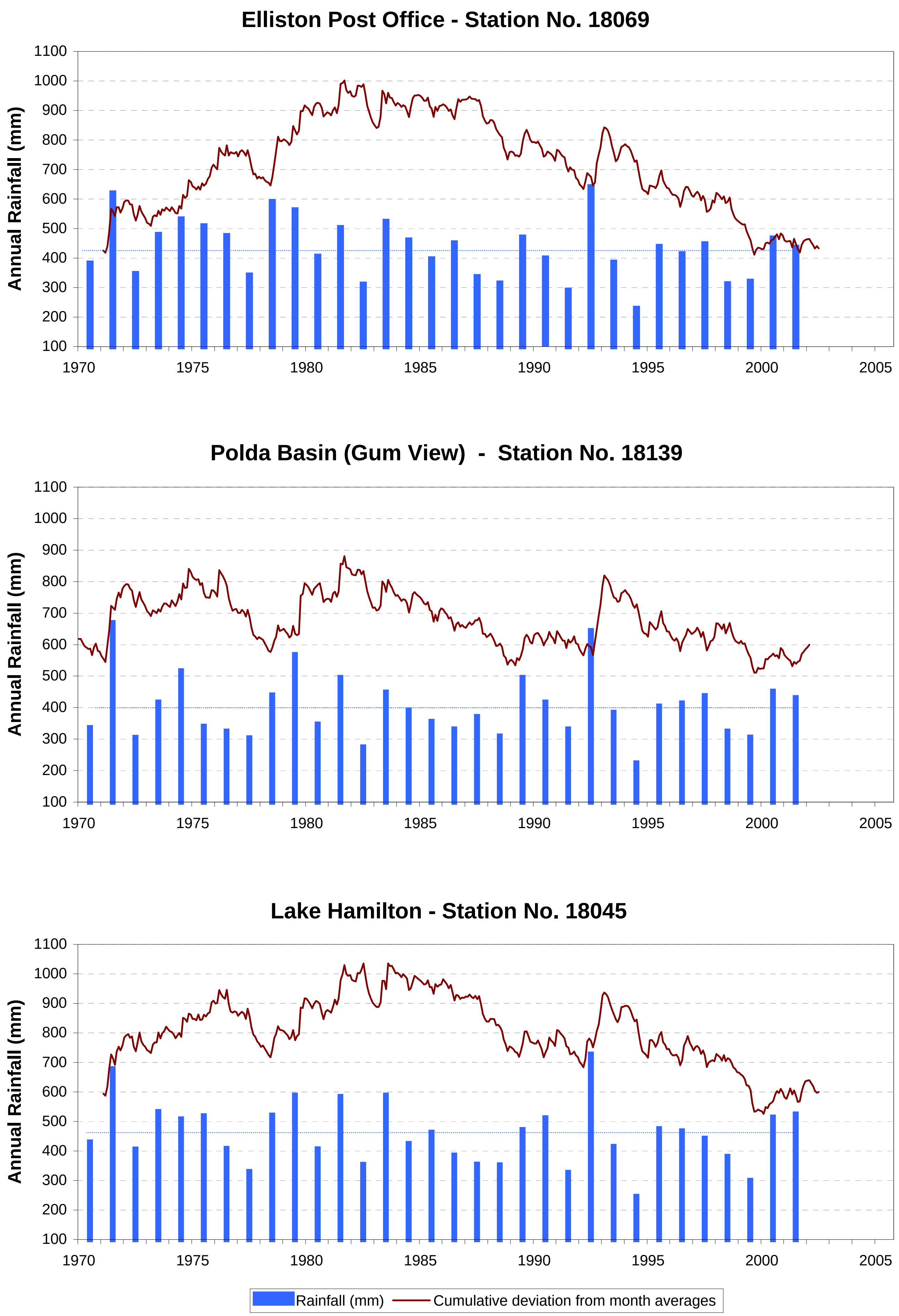


Figure 4 Annual rainfall and Cumulative Deviation from Month Averages

HYDROGEOLOGY

Fresh groundwater resources occur along the western coastal margin of the Eyre Peninsula, due to slightly elevated rainfall and the exposure of a suitable host rock (Quaternary limestone) to receive recharge. This has resulted in relatively higher recharge rates and significantly lower salinity groundwater than would normally be associated with similar semi-arid environments. Groundwater is contained mainly within two formations, an upper Quaternary Limestone Aquifer and the underlying Tertiary Sand Aquifer. The Jurassic sequence (Jurassic Aquifer) and the Basement Aquifer are not well explored and are little utilised.

The groundwater systems of the Musgrave PWA are recharge controlled. The origin of the groundwater is predominantly via infiltration of 'recent' rainfall. Diffuse infiltration of rainfall is limited due to the calcrete layers and recharge to the watertable occurs predominantly through discrete solution features when the rainfall event is moderately intense. There is a strong positive correlation between groundwater levels and rainfall. Monitoring data indicates that a recharge event only occurs when monthly rainfall exceeds 60 mm. Moreover, the rainfall intensity is a more significant controlling factor than overall rainfall volume when considering the effectiveness for recharge events. For example, intense rainfall events will result in recharge to the groundwater system, whereas events of similar volumes that fall over extended periods are often lost as recharge through the processes of evapotranspiration.

The spatial variation in recharge rate dictates the location of the fresh groundwater resources. Where large proportions of the total rainfall are allowed to infiltrate to the water table the resource is usually fresh. In regions where environmental conditions reduce the proportion of rainfall that infiltrates the salinity of the groundwater resource is typically higher. Thus the Quaternary limestone lenses are confined partly by geologically controlled structures and partly by salinity variation (the 1000 mg/L isohaline contour).

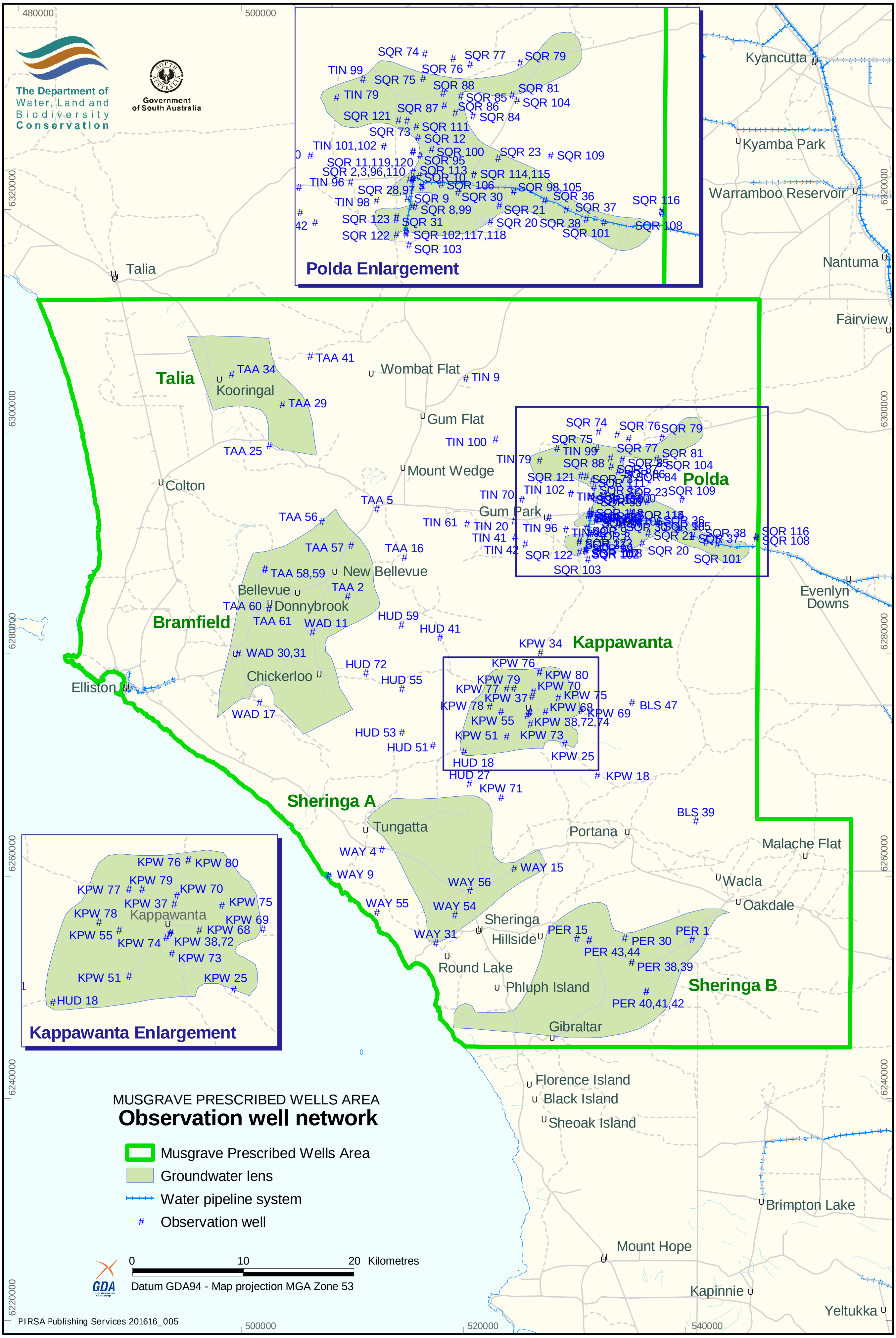
Fig. 5 shows the location of the observation wells in the Musgrave PWA.

Quaternary Limestone Aquifer

The Quaternary Limestone Aquifer consists of fine shell fragments, which in some areas has developed solution features as well as secondary cementation. The latter is evident as calcretised horizons where evaporation from the aquifer occurs. This formation is the predominant host for reliable fresh groundwater resources. The Quaternary Limestone Aquifer is unconfined and occurs where the underlying formations are either confining in nature or are saturated and connected by continuous moisture. Depth to watertable and salinity of the groundwater vary widely across the region.

Groundwater flow within the Quaternary Limestone Aquifer is predominantly in a westerly to southwesterly direction towards the southern ocean. Groundwater flow direction of these basins is depicted in Figure 6. The resources of most significance are the major lenses, which generally have high yields (from 5 up to 50 L/s) and low salinity (<1000 mg/L TDS; Fig. 7).

The major lenses of the Quaternary Limestone Aquifer are Bramfield, Kappawanta, Polda, Sheringa A and B and Talia. Of these major lenses, the Polda and Bramfield Lenses have been developed for reticulated public water supply. The Polda, Bramfield and Sheringa



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Polda Enlargement
Kappawanta Enlargement
Talia
Bramfield
Polda
Kappawanta
Sheringa A
Sheringa B
Kyancutta
Kyamba Park
Warramboo Reservoir
Nantuma
Fairview
Evenlyn Downs
Malache Flat
Wacla
Oakdale
Portana
Talia
Kooringal
Wombat Flat
Gum Flat
Mount Wedge
Colton
Gum Park
New Bellevue
Bellevue
Donnybrook
Chickerloo
Elliston
Tungatta
Sheringa
Hillside
Round Lake
Phluph Island
Gibraltar
Florence Island
Black Island
Sheoak Island
Brimpton Lake
Mount Hope
Kapinnie
Yeltukka
TAA 41
TAA 34
TAA 29
TAA 25
TAA 5
TAA 56
TAA 57
TAA 16
TAA 58,59
TAA 2
TAA 60
TAA 61
WAD 11
WAD 30,31
WAD 17
TIN 9
TIN 100
TIN 79
TIN 70
TIN 61
TIN 20
TIN 41
TIN 42
TIN 96
TIN 102
HUD 59
HUD 41
HUD 72
HUD 55
HUD 53
HUD 51
HUD 18
HUD 27
KPW 34
KPW 18
KPW 71
BLS 47
BLS 39
WAY 4
WAY 9
WAY 15
WAY 56
WAY 55
WAY 54
WAY 31
PER 15
PER 30
PER 1
PER 43,44
PER 38,39
PER 40,41,42
SQR 74
SQR 77
SQR 79
TIN 99
SQR 76
SQR 75
SQR 88
SQR 81
TIN 79
SQR 85
SQR 104
SQR 87
SQR 86
SQR 121
SQR 84
SQR 73
SQR 111
SQR 12
TIN 101,102
SQR 100
SQR 23
SQR 109
SQR 11,119,120
SQR 95
SQR 2,3,96,110
SQR 113
SQR 114,115
TIN 96
SQR 10
SQR 106
SQR 98,105
SQR 28,97
SQR 36
TIN 98
SQR 9
SQR 30
SQR 116
SQR 8,99
SQR 21
SQR 37
SQR 123
SQR 31
SQR 20
SQR 38
SQR 108
SQR 122
SQR 102,117,118
SQR 101
SQR 103
KPW 76
KPW 80
KPW 79
KPW 77
KPW 70
KPW 37
KPW 75
KPW 78
KPW 69
KPW 55
KPW 68
KPW 74
KPW 38,72
KPW 73
KPW 51
KPW 25
HUD 18
MUSGRAVE PRESCRIBED WELLS AREA
Observation well network
Musgrave Prescribed Wells Area
Groundwater lens
Water pipeline system
Observation well
0
10
20 Kilometres
Datum GDA94 - Map projection MGA Zone 53
GDA
480000
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Figure 5

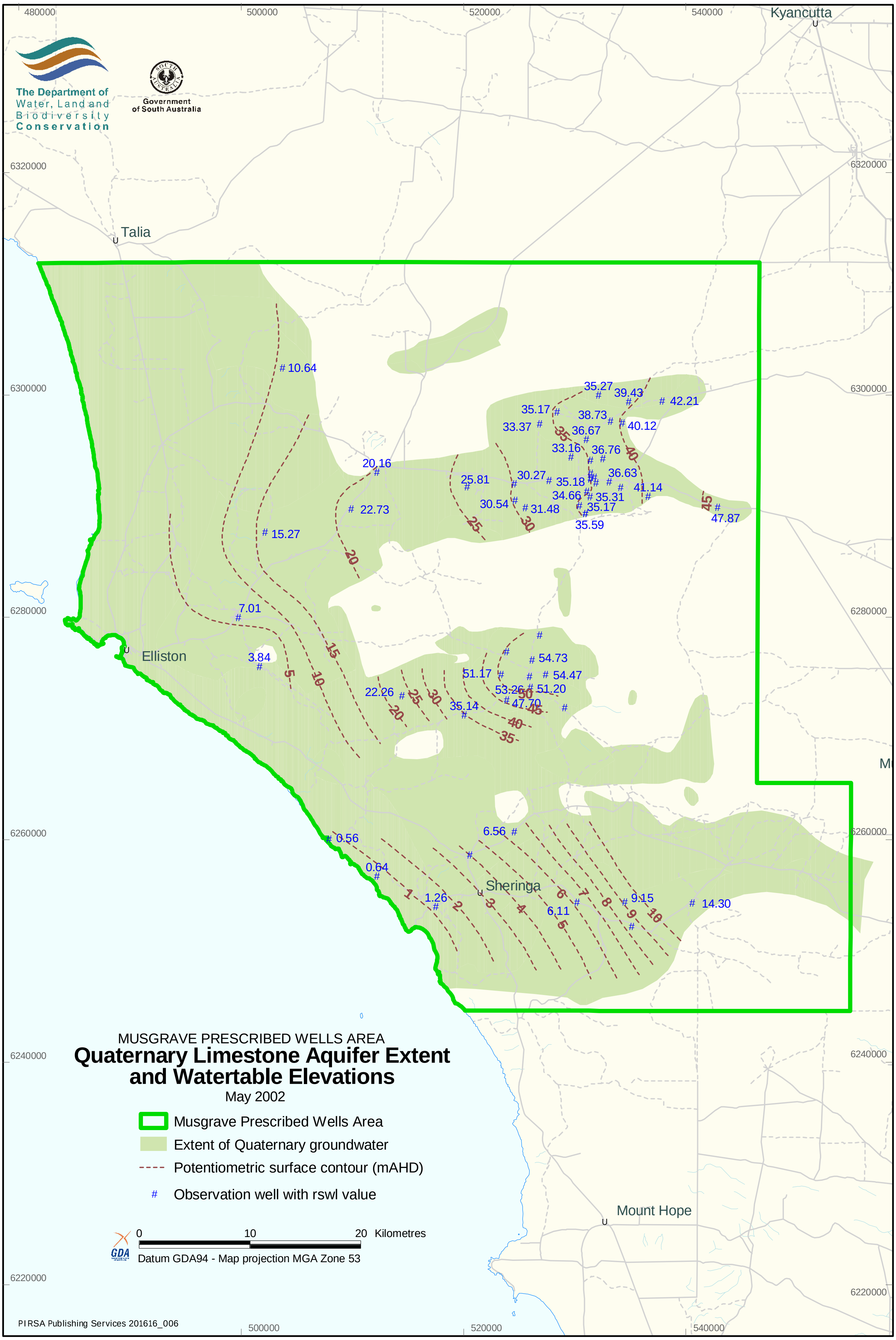
The Department of Water, Land and Biodiversity Conservation
Government of South Australia
Kyancutta
Talia
Elliston
Sheringa
Mount Hope
MUSGRAVE PRESCRIBED WELLS AREA
Quaternary Limestone Aquifer Extent and Watertable Elevations
May 2002
Musgrave Prescribed Wells Area
Extent of Quaternary groundwater
Potentiometric surface contour (mAHD)
Observation well with rswl value
0 10 20 Kilometres
Datum GDA94 - Map projection MGA Zone 53
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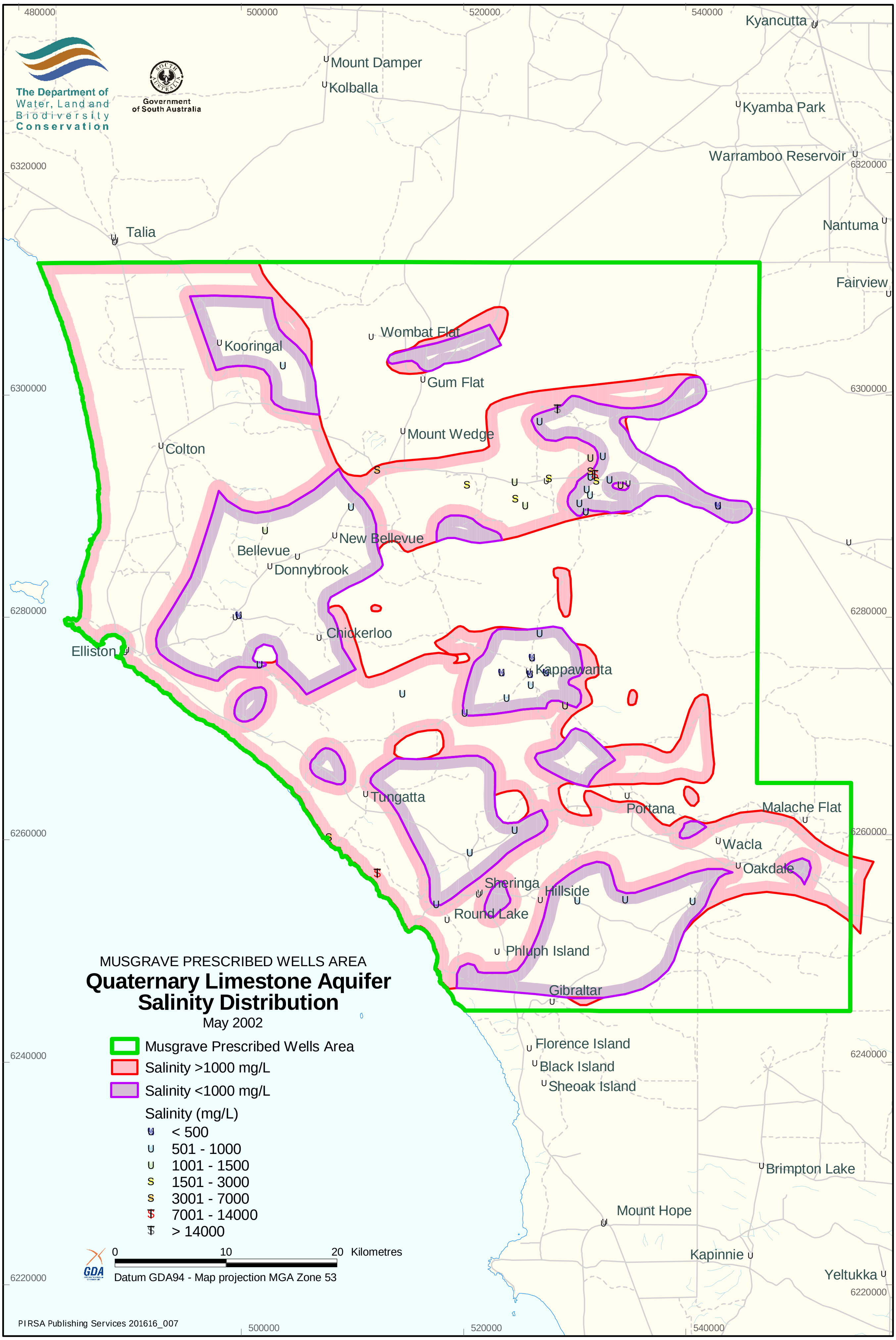
Figure 6


MUSGRAVE PRESCRIBED WELLS AREA
Quaternary Limestone Aquifer
Salinity Distribution
May 2002
Musgrave Prescribed Wells Area
Salinity >1000 mg/L
Salinity <1000 mg/L
Salinity (mg/L)
< 500
501 - 1000
1001 - 1500
1501 - 3000
3001 - 7000
7001 - 14000
> 14000
0
10
20
Kilometres
Datum GDA94 - Map projection MGA Zone 53
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Government of South Australia
Kyancutta
Mount Damper
Kolballa
Kyamba Park
Warramboo Reservoir
Talia
Nantuma
Fairview
Wombat Flat
Kooringal
Gum Flat
Mount Wedge
Colton
New Bellevue
Bellevue
Donnybrook
Chickerloo
Elliston
Kappawanta
Tungatta
Portana
Malache Flat
Wacla
Oakdale
Sheringa
Hillside
Round Lake
Phluph Island
Gibraltar
Florence Island
Black Island
Sheoak Island
Brimpton Lake
Mount Hope
Kapinnie
Yeltukka
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Figure 7

Lenses have been utilised for irrigation. Otherwise the unconfined Quaternary Limestone Aquifer is predominantly used for local stock and domestic watering requirements.

Tertiary Sands Aquifer

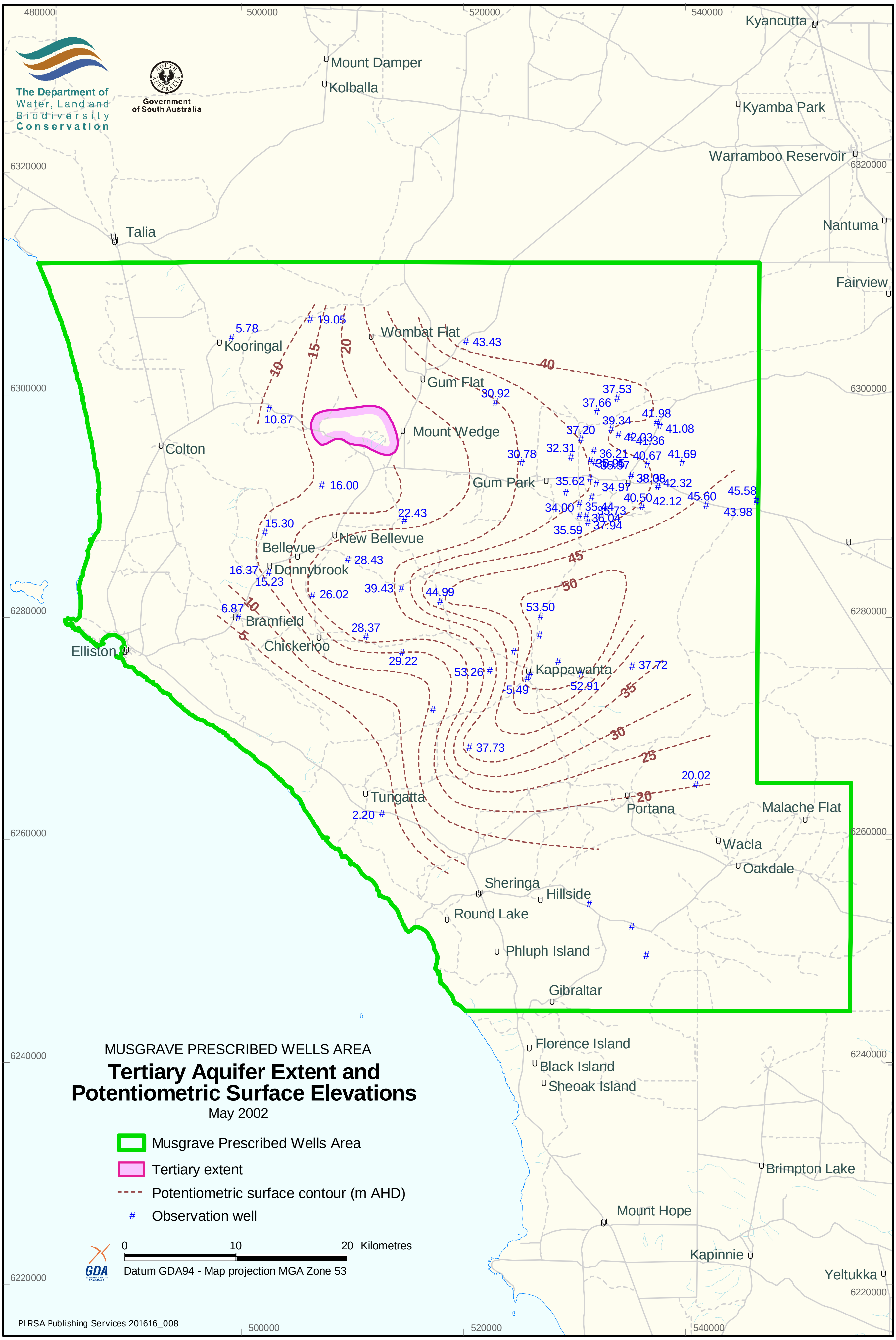
The Tertiary Sands Aquifer generally occurs throughout the area and consists of unconsolidated fine quartz-sands and has significant storage. The Tertiary Sands Aquifer receives both lateral flow and downward leakage as recharge from the Quaternary Limestone Aquifer. Groundwater flow within the Tertiary system is predominantly in a southwesterly direction towards the Southern Ocean (Fig. 8). The aquifer salinity ranges from 500–5500 mg/L TDS (Fig. 9), but has poor to moderate yields (1–10 L/s). It is considered to be a confined aquifer in those areas where it underlies the saturated Quaternary Limestone Aquifer; elsewhere it is unconfined. Well production difficulties exist due to the fine quartz-sands of the Quaternary Limestone Aquifer, which have limited development of the Tertiary Sands Aquifer to local stock and domestic supplies.

Jurassic Aquifer

The Jurassic Aquifer has fine-grained sands and occurs predominantly in the east of the Musgrave PWA. Due to high salinity (30 000–50 000 mg/L TDS) and low yields, it is of little significance within the PWA.

Basement Aquifer

There is limited information and understanding of the Basement Aquifer. The groundwater resource is found within a fractured rock environment, which is poorly defined and appears to be irregular in occurrence, salinity and yield within the Musgrave PWA. The small level of development of the Basement Aquifer within the Musgrave PWA is primarily for stock and domestic purposes.


MUSGRAVE PRESCRIBED WELLS AREA
Tertiary Aquifer Extent and Potentiometric Surface Elevations
May 2002
Musgrave Prescribed Wells Area
Tertiary extent
Potentiometric surface contour (m AHD)
Observation well
0 10 20 Kilometres
Datum GDA94 - Map projection MGA Zone 53
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PIRSA Publishing Services 201616_008
Kyancutta
Mount Damper
Kolballa
Kyamba Park
Warramboo Reservoir
Talia
Nantuma
Fairview
Wombat Flat
Kooringal
Gum Flat
Mount Wedge
Colton
Gum Park
New Bellevue
Bellevue
Donnybrook
Bramfield
Chickerloo
Elliston
Kappawanta
Tungatta
Portana
Malache Flat
Wacla
Oakdale
Sheringa
Hillside
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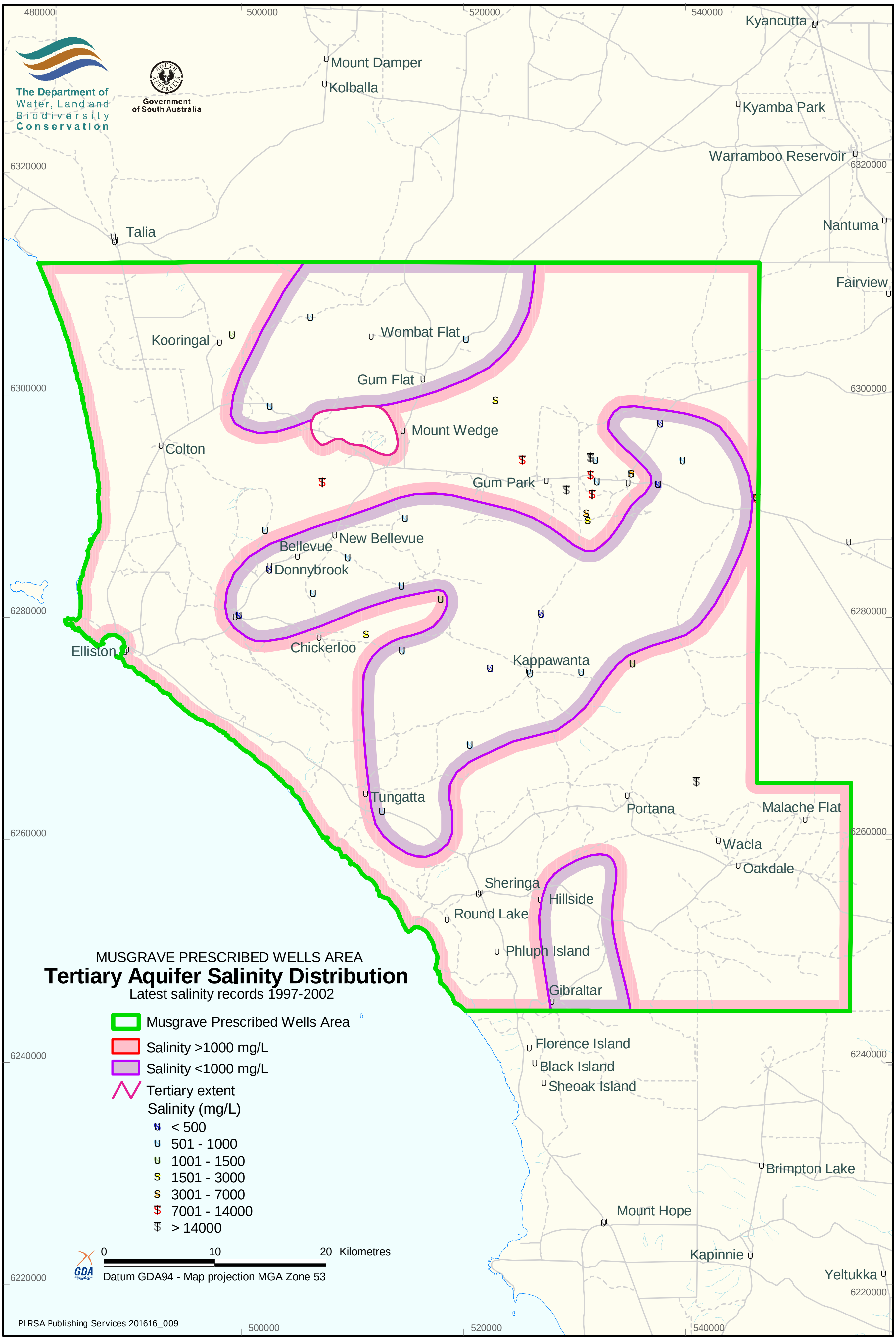
Phluph Island
Gibraltar
Florence Island
Black Island
Sheoak Island
Brimpton Lake
Mount Hope
Kapinnie
Yeltukka

Figure 8



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Kyancutta
Mount Damper
Kolballa
Kyamba Park
Warramboo Reservoir
Talia
Nantuma
Fairview
Kooringal
Wombat Flat
Gum Flat
Mount Wedge
Colton
Gum Park
New Bellevue
Bellevue
Donnybrook
Elliston
Chickerloo
Kappawanta
Tungatta
Portana
Malache Flat
Wacla
Oakdale
Sheringa
Hillside
Round Lake
Phluph Island
Gibraltar
Florence Island
Black Island
Sheoak Island
Brimpton Lake
Mount Hope
Kapinnie
Yeltukka
MUSGRAVE PRESCRIBED WELLS AREA
Tertiary Aquifer Salinity Distribution
Latest salinity records 1997-2002
Musgrave Prescribed Wells Area
Salinity >1000 mg/L
Salinity <1000 mg/L
Tertiary extent
Salinity (mg/L)
< 500
501 - 1000
1001 - 1500
1501 - 3000
3001 - 7000
7001 - 14000
> 14000
0
10
20
Kilometres
GDA
Datum GDA94 - Map projection MGA Zone 53
PIRSA Publishing Services 201616_009

Figure 9

RECHARGE TO THE GROUNDWATER RESOURCES WITHIN THE PRESCRIBED WELLS AREA

The water resources on Eyre Peninsula are dependent on local rainfall as the source of water. There is no regional inflow of water, either surface or underground to the Eyre Peninsula.

Quaternary Limestone Aquifer

The major lenses of the unconfined Quaternary Limestone Aquifer are primarily dependent upon local rainfall falling directly on the overlying land for recharge. Surface water runoff from catchments adjacent to aquifers only contributes a minor portion of (usually poor quality) water to some of the Quaternary lenses. Water level behaviour within the Quaternary lenses reveals that recharge occurs after intense rainfall events, where short-lived overland flow allows the water to enter the solution features (sink-holes) and reach the watertable rapidly. Research of the Polda Basin system indicates that these resources show an annual water level rise when they receive more than 60 mm of rainfall in a month between the months of May and October. Of the annual rainfall, it is estimated that ~10% will infiltrate as recharge to these Quaternary lenses.

As recharge to these systems is dependent on seasonal rainfall patterns, water levels show a strong relationship to periods of above and below average winter rainfall. Historic rainfall data has indicated that above or below average trends can last up to 25 years. For effective management of these resources, consideration must be given to the recent climatic conditions prior to any utilisation.

Tertiary Sand Aquifer

Recharge to the Tertiary Sand Aquifer is irregular. Where the Tertiary Clay under the Quaternary Limestone Aquifer lenses confines the Tertiary Sand Aquifer, the aquifer receives negligible recharge. Where this clay is non-confining, the aquifer receives vertical leakage from the Quaternary aquifers and direct infiltration of rainfall. The water level response of the unconfined Tertiary Sand Aquifer to seasonal recharge is muted relative to the Quaternary aquifers, indicating that these systems receive significantly less annual recharge than the Quaternary aquifers and that the recharge is not as instantaneous.

Table 2 shows the hydrogeology of the Eyre Peninsula.

Jurassic and Basement Aquifers

Recharge to these systems is localised and irregular. Apart from vertical leakage from the overlying aquifers, recharge into the sedimentary or fractured rock aquifer is limited to surface exposures, usually where basement highs occur throughout the PWA. The rate of recharge is variable and is a function of the geomorphology of the exposure, the degree of fracturing present and the composition of the rock type (i.e. of metamorphic or igneous nature in the case of the Basement Aquifer).

Table 2. Hydrogeology of Eyre Peninsula

Groundwater predominantly occurs in rocks and sediments of five different geological environments.

Age			Stratigraphy	Hydrostratigraphy	Southern Basins	Musgrave	Streaky Bay
Cainozoic	Recent	Holocene	*Coastal dunes:* Fine-grained aeolianites, unconsolidated, actively mobile. Grains comprise calcite and shell fragments.	*Unconfined aquifer:* seasonal, small yielding, thin, low salinity supplies located at the base of the mobile sand dune systems	**Semaphore Sand and Gantheaume Sand Members (St Kilda Formation) (Qhcks, Qhckg)**		
	Quaternary	Pleistocene	*Bridgewater Formation:* Aeolianites, fine to medium-grained, cross-bedded, weakly to moderately cemented, Grains are calcite and shell fragments, mainly 0.1–1.5 mm. Generally calcrete at surface.	*Unconfined aquifer:* generally low salinity. Permeability ranges from low to very high. Transmissivity ranges from 2.0 x 10^3 to 8.0 x 10^3 m^3/d/m. The usual target aquifer for large water supplies on Eyre Peninsula.	**Bridgewater Formation (Qpcb)**		
	Tertiary	Eocene	*Uley Formation:* Sandstone, clayey to orange–brown quartz, well sorted and rounded, minor lateritic and non-lateritic gravel.	*Aquitard:* generally a confining layer beneath the Quaternary Aquifer. Where it is permeable can hold the watertable or allow infiltration to the underlying sediments	**Uley Formation (TpQau)**	**Undifferentiated (TpQ)**	
			Wanilla, Poelpena and Pidinga Formations: Clays, sands (quartz) and gravels with thin lignite layers. Sand is generally fine-grained, less than 0.5 mm, uncemented or weakly cemented.	*Semi-confined to confined aquifer:* low to moderate permeability but with marked variations vertically and laterally. Salinity variable and generally higher than the overlying unconfined aquifer.	**Wanilla Formation (Tbw)**	**Poelpena Formation (Tbe)**	**Pidinga Formation (Tbp)**
Mesozoic	Jurassic		*Polda Formation:* Sands (quartz), silts and clays. Sand grains usually less than 0.5 mm; occasionally up to 3 mm. Sediments generally carbonaceous and contain lignite beds.	*Confined aquifer:* very low permeability, high groundwater salinity generally exceeding 14 000 mg/L. Jurassic sediments are not present in the Southern Basins and Streaky Bay regions.		**Polda Formation (J-o)**	
Proterozoic	Neo-Proterozoic		*Pre-Cambrian Basement:* Schists, gneisses and quartzites intruded by granites and basic rocks. Deeply weathered in places.	*Semi-confined to confined aquifers:* groundwater occurs in the weathered profile or within the fracture spaces of these rocks. Salinity generally exceeds 7000 mg/L, occasionally lower.	**(Als, Lh)**	**(Als, Mcb, Lh)**	**(Mh, Lp)**

Note: Shaded cells represent the presence of an aquitard.
The Jurassic is not present in two regions.

MONITORING NETWORK

Groundwater monitoring in the Musgrave PWA began in the 1960s. Historically 601 observation wells were constructed, however 132 observation wells (Fig. 5) are currently monitored on a regular monthly basis for water level. Of these wells:

- 56 monitor the shallow Quaternary Bridgewater Formation limestone aquifer (Qpcb; Quaternary Limestone Aquifer)
- 67 monitor the Tertiary Poelpena Formation sand aquifer (Tbe; Tertiary Sand Aquifer)
- one monitors the Jurassic Polda Formation sand aquifer (J-o; Jurassic Aquifer)
- two monitor the Basement aquifer system (Als; Basement Aquifer)
- six wells have undetermined completions.

Water quality monitoring occurs less frequently (as TDS tends to vary at a slower rate). Currently 134 observation wells are monitored randomly (approximately six monthly from 1992 to 1997 with the area soon to be revisited) for TDS. Of these wells:

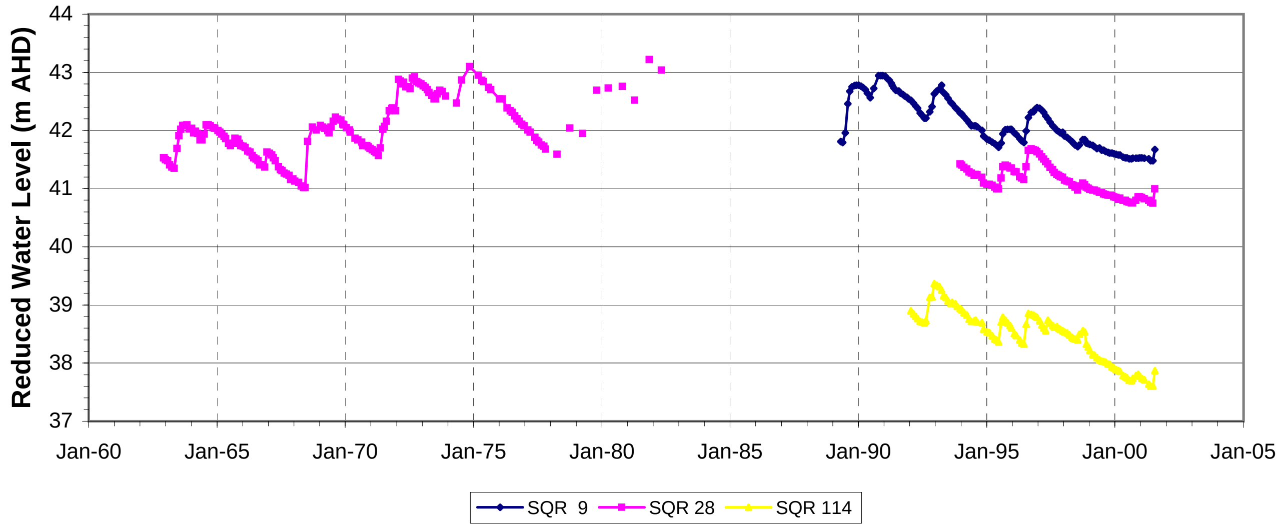
- 57 monitor the shallow Quaternary Bridgewater Formation limestone aquifer (Qpcb; Quaternary Limestone Aquifer)
- 67 monitor the Tertiary Poelpena Formation sand aquifer (Tbe; Tertiary Sand Aquifer)
- one monitors the Jurassic Polda Formation sand aquifer (J-o; Jurassic Aquifer)
- two monitor the Basement Aquifer system (Als; Basement Aquifer)
- seven wells have undetermined completions.

Groundwater level trends

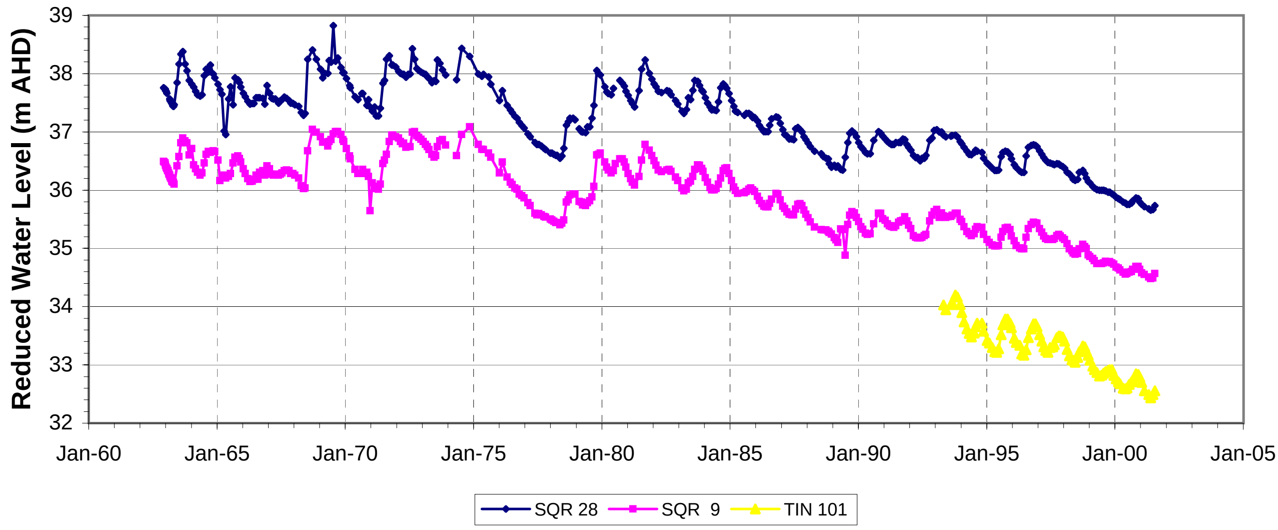
As the groundwater system is strongly linked to rainfall, inferences can be drawn about past groundwater levels by knowing the rainfall distribution history. The rainfall statistics (Fig. 4) strongly mirror observed groundwater level data (Figs 10–13). Years of below-average rainfall (a downward sloping cumulative monthly deviation from the mean) correspond to lower groundwater levels in the lenses, while years of above-average rainfall (upward sloping cumulative monthly deviation from the mean) correspond to high groundwater levels in the lenses. By examining the rainfall statistics prior to groundwater monitoring, an inference about past groundwater levels in the lenses can be drawn. Groundwater levels may have been at a peak around the early 1920s in the north and east of the region. Groundwater levels may have been at regional lows in the early 1900s and around the 1930s through to the early 1950s. The length of rainfall record influences the correlation of these rainfall statistics to groundwater levels and changes in climatic trends such as those predicted by the greenhouse effect.

The Department of Water, Land and Biodiversity Conservation (Groundwater Assessment Branch) monitors an observation well network primarily focussing on the Quaternary Limestone Aquifer (Fig. 5). A comparison of public water supply groundwater extraction from the Polda Lens and groundwater levels indicates a notable decline in groundwater levels associated with the large extractions in 1975 and 1976. Since then, annual reticulated public water supply groundwater extractions have reduced and the impact of public water supply extractions on groundwater levels has lessened.

Up-gradient from Extraction Zone



Adjacent Extraction Zone



Down-gradient from Extraction Zone

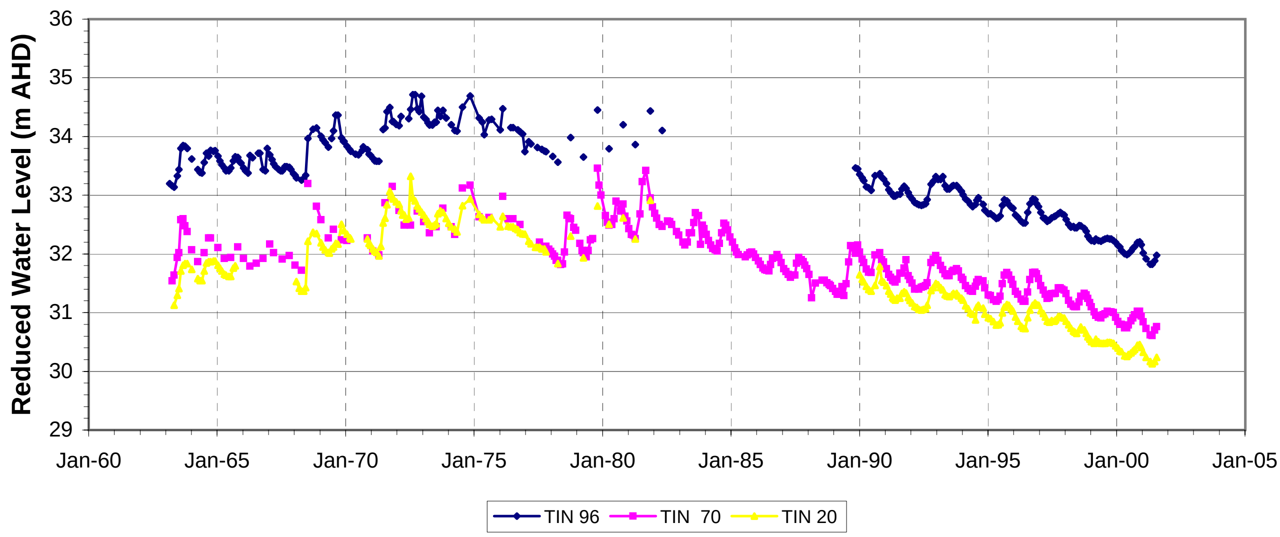
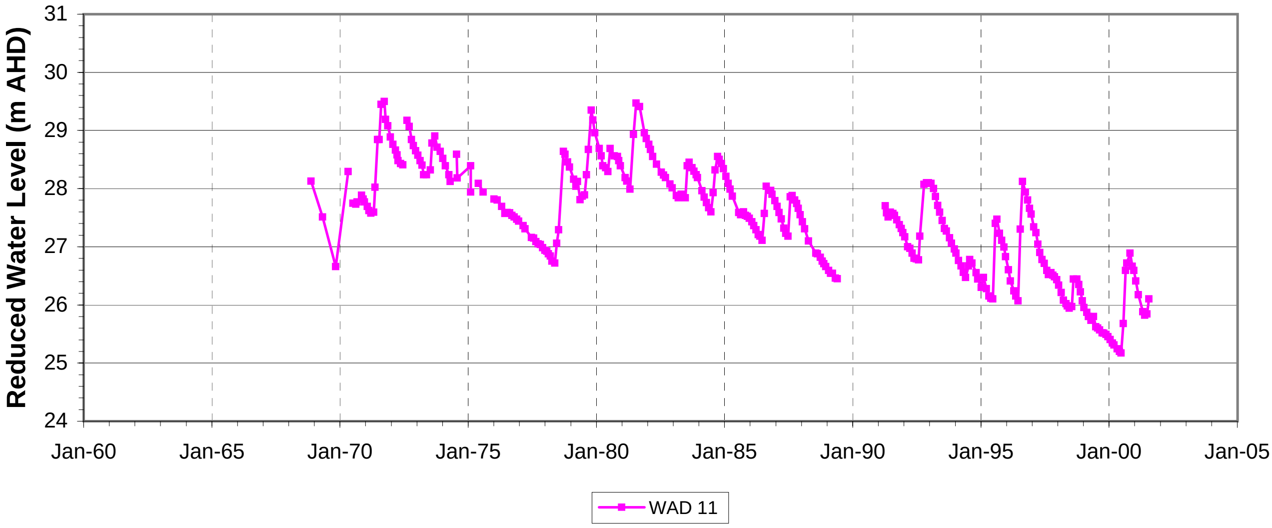
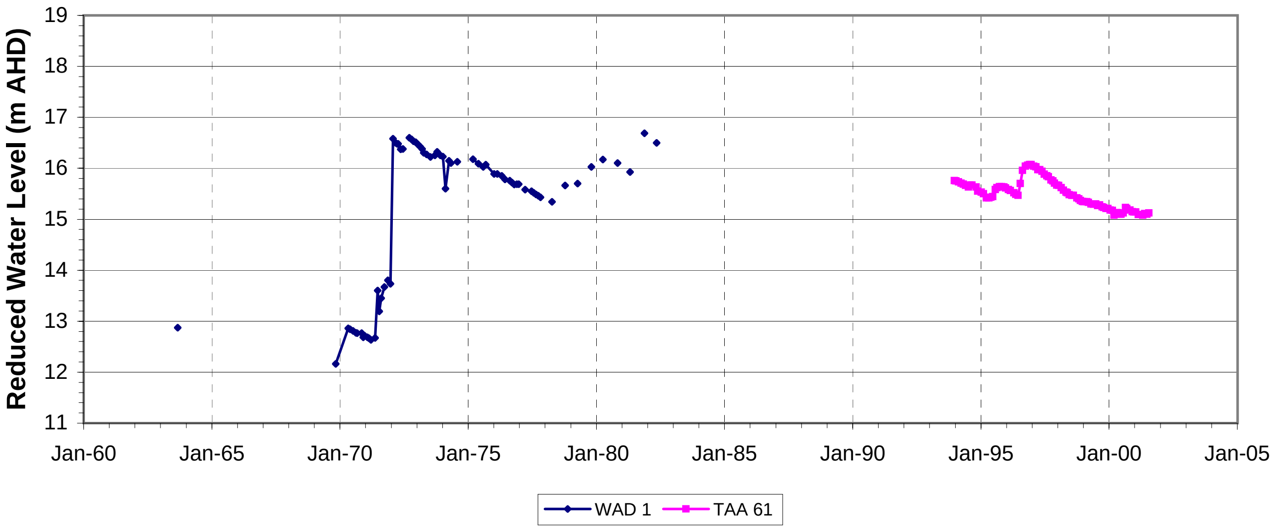


Figure 10 Polda Quaternary Limestone Lens Hydrographs

Up-gradient Region



Central Region



Down-gradient Region

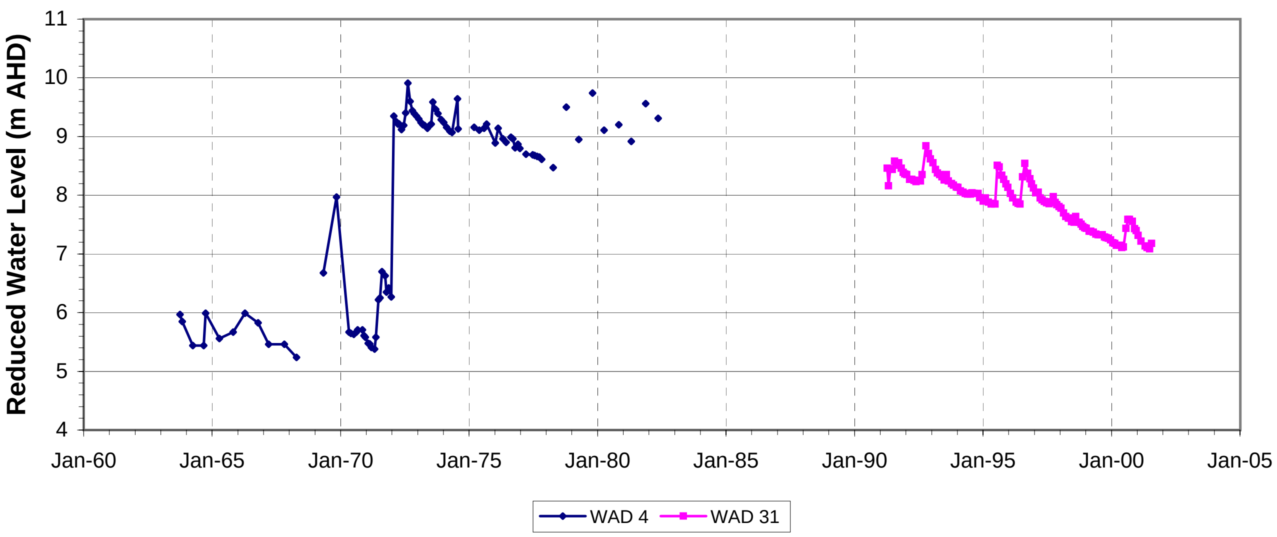
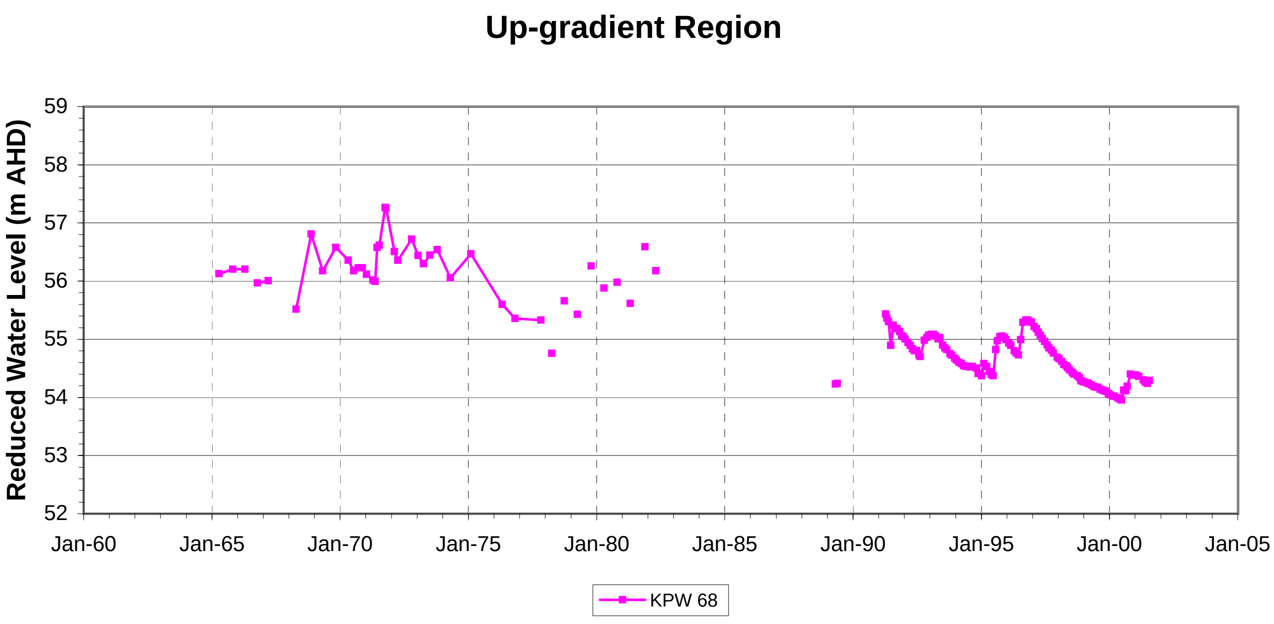
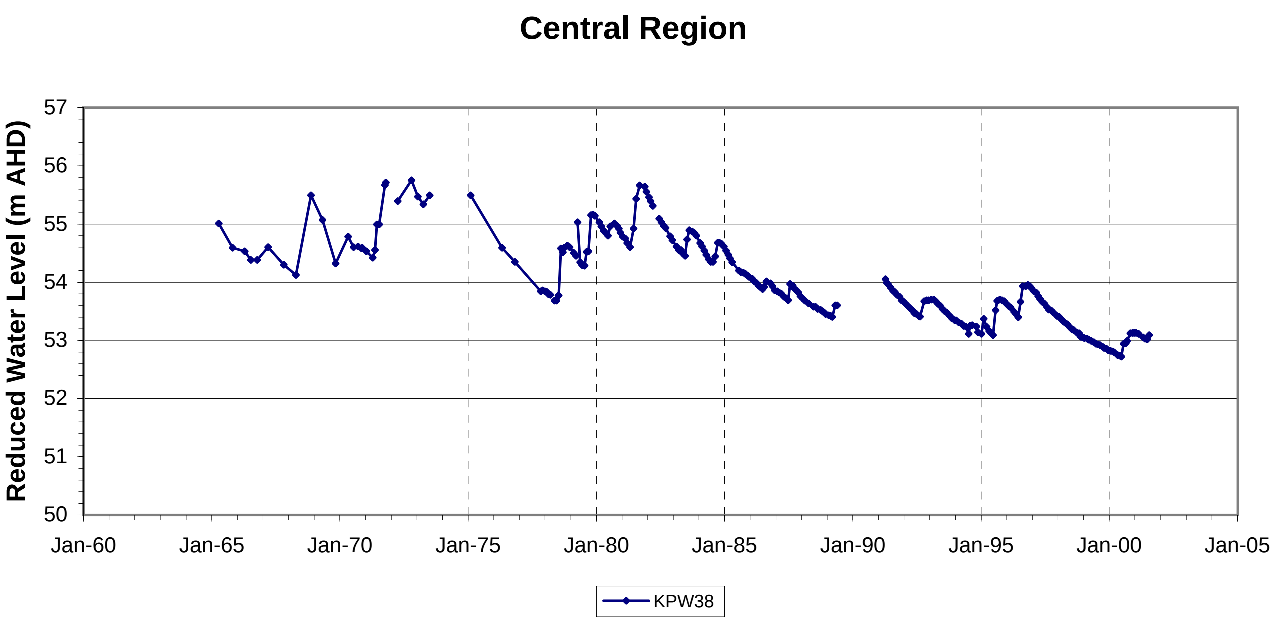


Figure 11 Bramfield Quaternary Limestone Lens Hydrographs





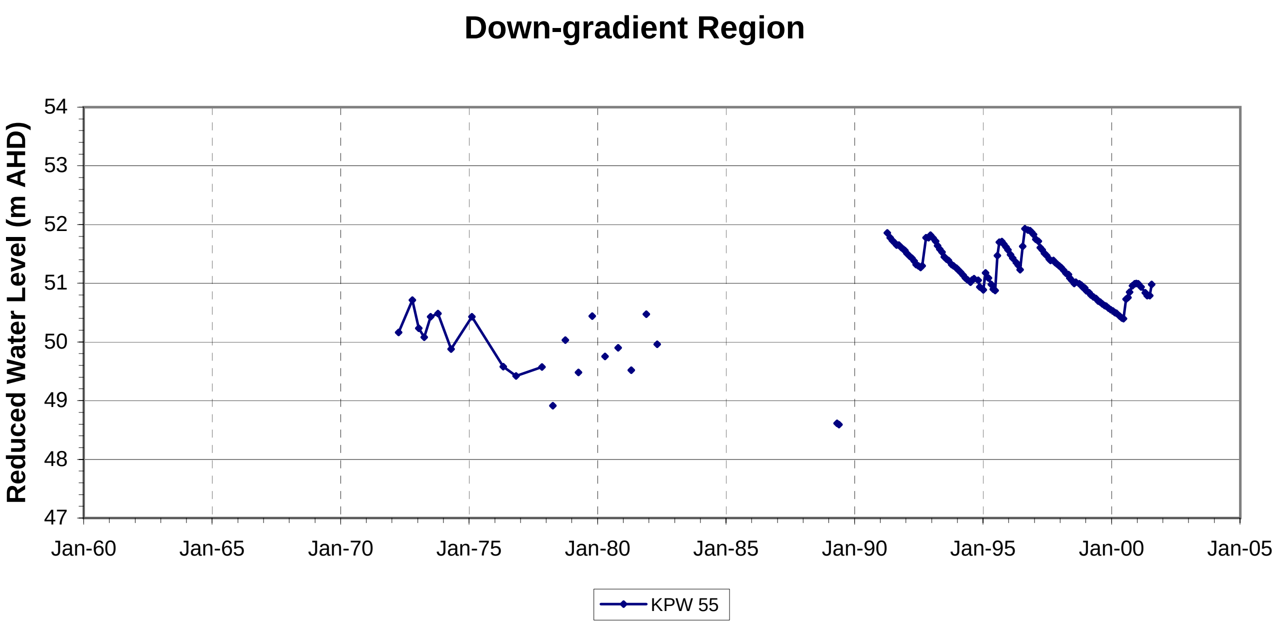
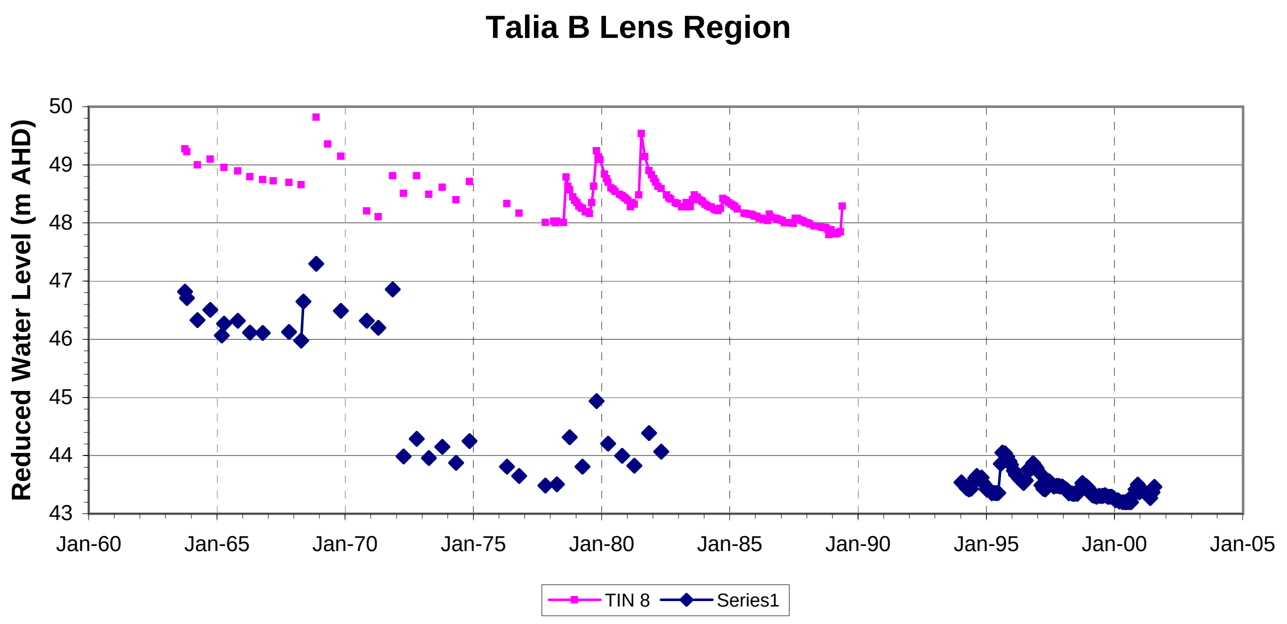
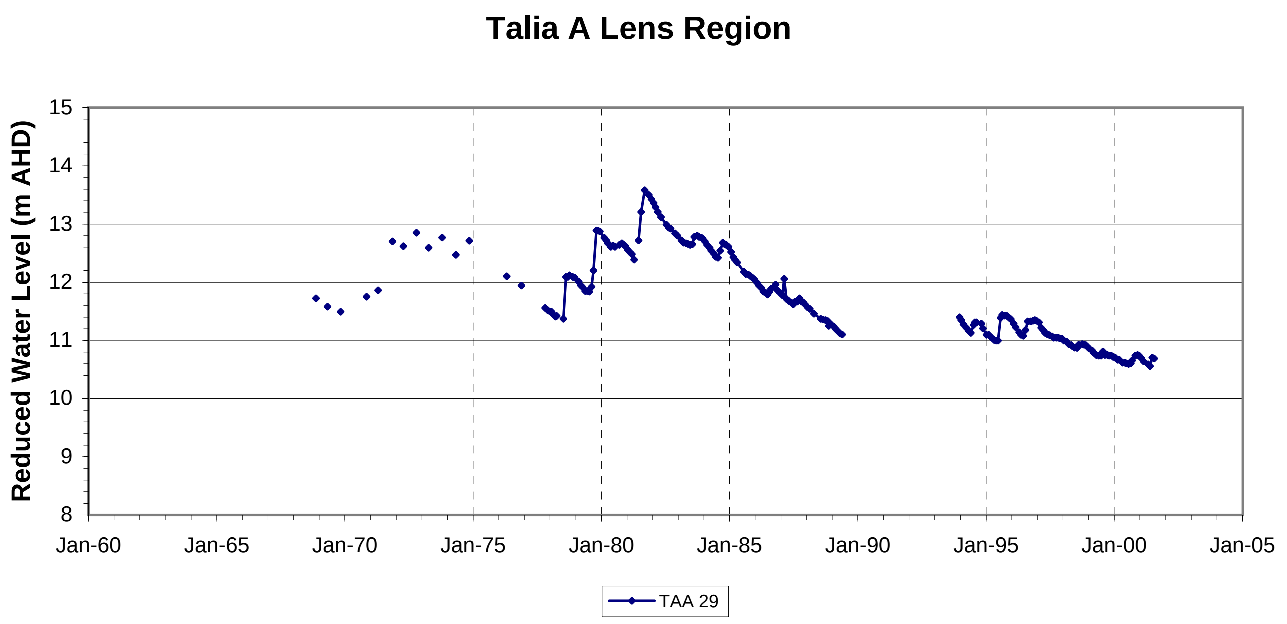


Figure 12 Kappawanta Quaternary Limestone Lens Hydrographs





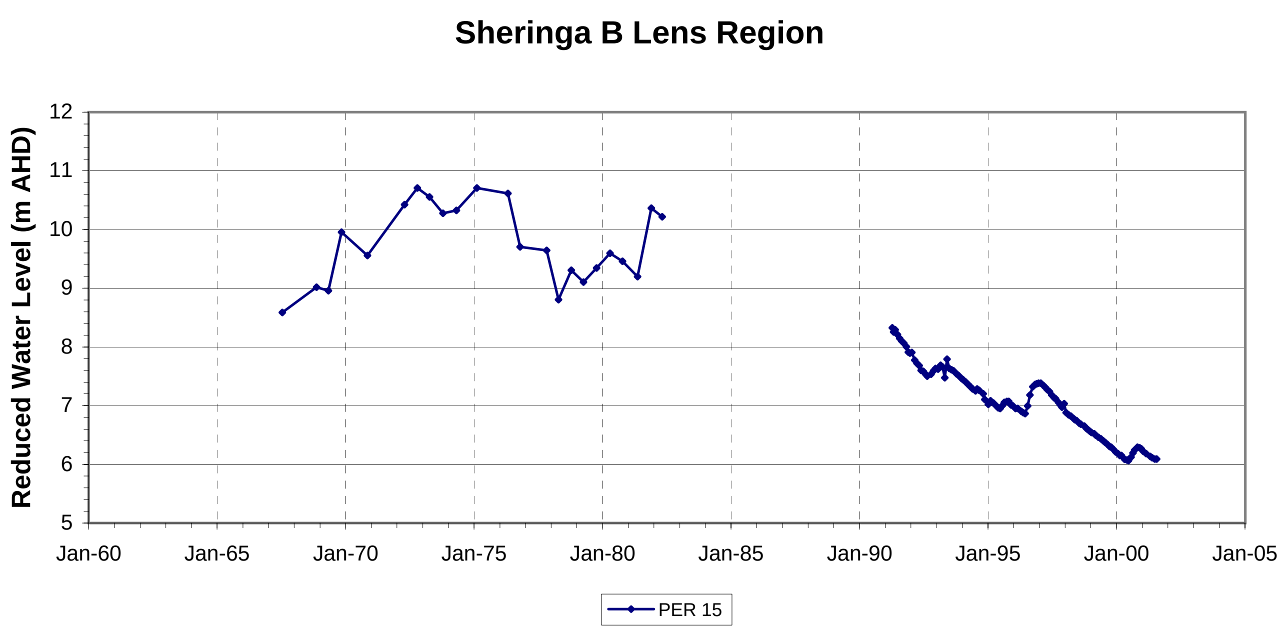


Figure 13 Talia and Sheringa Quaternary Limestone Lenses Hydrographs

Currently, the groundwater systems of the Musgrave PWA have been undergoing regional decline in water levels of between 1 and 5 m (Figs 10–13). This is reflected by a reduction of ~10% in the areal extent of the saturated Quaternary Limestone Aquifer. This reduction in size of the groundwater lenses is not due to over pumping (for example from the Polda trench by SA Water). Declines in groundwater levels occur in all groundwater lenses, regardless of the presence of large pumping centres. The primary cause is consecutive low-rainfall seasons, resulting in reduced recharge rates and consequent declining groundwater levels. The groundwater systems continue their natural discharge process (from one aquifer to another or to the surface), causing water levels to drop.

Groundwater flow (discharge) and extractions are the primary factors affecting aquifer storage. The Polda and Bramfield (in a limited way) Lenses have been developed for reticulated public water supply. The Polda Lens has experienced water level decline due to previous over extraction practices. Recent research has refined the understanding of the hydrological processes that operate within these aquifers and has determined the amount of water that is available for extraction with acceptable impacts to the resources. Kappawanta, Talia and Sheringa Lenses have generally only been developed for stock and domestic purposes, and yet the groundwater level trends of these have also notably declined since 1993 (Figs 12, 13). This highlights how dominating effective rainfall is for recharge for both developed and undeveloped lenses.

Groundwater trends over the 2001–02 monitoring period have generally risen in response to the second consecutive average to slightly above average rainfall. Despite this slight rise, groundwater levels regionally are low relative to the 1970s. These low water levels indicate that overall aquifer storage is low and a strongly conservative approach to utilisation of these resources is still warranted

Groundwater quality trends

Since monitoring began, groundwater quality has fluctuated within a small range, despite relatively large groundwater extractions from some lenses. Primarily these lenses are isolated from adjoining saline waters that could mix under the stress of pumping.

Salinisation of aquifers can be commonly associated with crop irrigation over unconfined aquifers, whereby the majority of water-borne salts remain in the soil profile to be subsequently recycled back to the aquifer with recharge. Within the Musgrave PWA, water-borne salts are removed from the recharge area by extractions for public water supply purposes. Therefore irrigation should be encouraged to only occur outside the recharge areas of the Quaternary lenses.

Salinity trends from the most recent pumped sampling program (1992–97) indicated that there have been virtually no changes in aquifer salinity (Fig. 14). The only notable change in salinity over the sampling period is from SQR 9 (unit number 5930-1001) and to a lesser extent SQR 11 (5930-1045), with an initial decreasing salinity trend that becomes steady from about 1995. This decreasing trend may be associated with the lower extraction taken from the Polda Lens during this time, as SQR 9 is in the vicinity of the Polda Trench extraction point. The decreasing trend may also be associated with the high rainfall of 1992–93; however other observation wells appear not to have responded to this, and is therefore likely to be discounted as a cause.

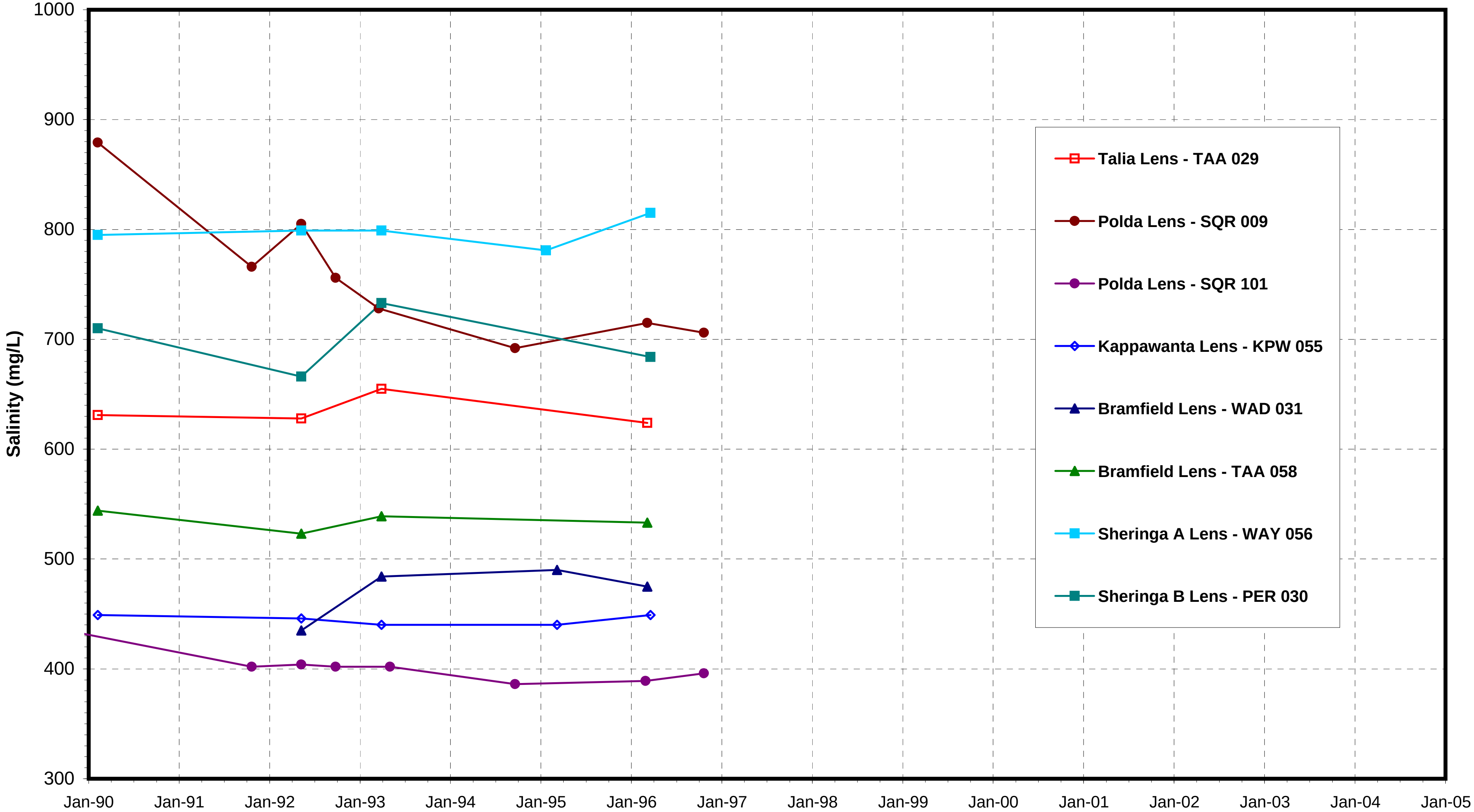


Figure 14 Salinity graphs of observation wells representative of the Quaternary Limestone Lenses

FUTURE INVESTIGATIONS

Due to the high dependence the region has on its groundwater resources, DWLBC will undertake an evaluation of the condition of the monitoring networks within the Musgrave Prescribed Wells area.

The scope of the investigation may include;

- Review spatial extent and adequacy of existing monitoring wells and frequency of monitoring,
- Purge, clean and redevelop/deepen wells to obtain true downhole salinity profiles using SONDE and collect pumped samples for electrical conductivity (EC) determinations,
- Undertake preliminary geophysical TEM surveys to enhance the understanding of basin geometry and to establish the existence of salt water intrusion into the fresh groundwater resources,
- Identification of sites to establish additional monitoring wells to enable an assessment of the potential threat from saline intrusion to be made, and
- Identify sites for equipping with remote monitoring devices.

The anticipated outcomes include;

- Enhanced definition of basin geometry,
- Definition of current spatial variability of salinity within Musgrave PWA, including the existence of the fresh/salt water interface,
- Establishment of a more rigorous monitoring framework to facilitate the management of the resource, and
- Identification of the scope of works to be undertaken to understand the hydrodynamic behaviour of these systems in response to recharge and pumping demands.

SHORTENED FORMS

Measurement

Name of unit	Symbol	Definition in terms of other metric units	
Day	d		time interval
Gram	g		Mass
Kilometre	km	10^3 m	Length
Litre	L	10^{-3} m^3	Volume
Litres per second	L/s		
Metre	m		Length
Metres per day	m/d		
Milligram	mg	10^{-3} g	Mass
Milligrams per litre	mg/L		
Megalitre	ML	10^{-6} m^3	Volume
Millimetre	mm	10^{-3} m	Length
Second	s		time interval

General

Shortened form	Description
AHD	Australian height datum
DWLBC	Department of Water, Land and Biodiversity Conservation
PWA	prescribed wells area
TDS	total dissolved solids