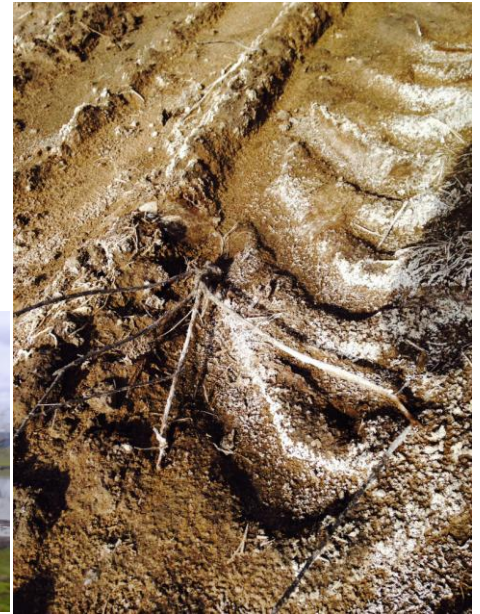


Coorong Dryland Salinity Review

Improving Salinity Understanding - June 2019



*This project is supported by the South Australian Murray-Darling Basin
Natural Resources Management Board through funding from the
Australian Government's National Landcare Program and the NRM levies*



**National
Landcare
Program**



Government of South Australia
South Australian Murray-Darling Basin
Natural Resources Management Board



Natural Resources
SA Murray-Darling Basin

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Figure 1 Salinity affected cropping paddock Cooke Plains

1. Dryland Salinity Review Background

***Tony Randall – Team Leader, Sustainable Agriculture
Natural Resources SA Murray Darling Basin***

Dryland salinity has been a significant issue in many Southern Australian farming regions from the later part of the last century. Australian Government investment in the understanding and management of dryland salinity peaked from 2003 to 2009 through the establishment of a major national program, The National Action Plan for Salinity and Water Quality (NAP), which aimed to prevent, stabilise, and reverse trends in salinity.

The NAP allocated \$1.4 billion of public funds to 1700 projects over the 7 years of the programs existence and was largely successful in determining the cause and effect of dryland salinity, and in identifying, testing and promoting a range of management options. In the Coorong Tatiara Local Action Plan, SA Murray-Darling Basin and South East NRM Regions, this largely involved the lowering of water tables through the strategic planting of perennial vegetation including productive perennial pastures, fodder shrubs, farm forestry, and native vegetation. Delivery and implementation was supported with landholder incentive schemes funded through NAP and the Australian Government's National Heritage Trust (NHT), and this support saw increased adoption and implementation of management actions and perennial vegetation establishment.

The Coomandook, Cooke Plains, Meningie East and Tintinara West /Colebatch areas have been identified as having high potential for dryland salinity formation due to the low lying nature of some parts of this landscape and it's proximity to the regional groundwater system drainage point to the Lower Murray Lakes and Coorong, see **Figure 2**. Significant management actions were adopted by land owners throughout this area during the NAP and NHT programs, in particular the establishment of dryland lucerne, revegetation and saltland agronomy to address rising groundwater tables and associated salinisation of soils. The Coorong Tatiara Local Action Plan (CTLAP) has played a pivotal role in encouraging and supporting land managers in the adoption of these management actions through awareness raising and the delivery of incentive payment schemes to encourage perennial vegetation establishment. As a result, the spread of dryland salinity was thought to have been halted in the area.

Since the completion of the NAP, public investment in salinity management has been modest, with some practitioners declaring that the issue had been sufficiently investigated and addressed. Whilst this was somewhat true at the time of NAP completion, farming systems and associated landscapes have undergone significant transformation since that time with greater adoption of continuous cropping under no till farming systems, potentially some reduction in perennial vegetation cover in the landscape, and changes to climate and intensity of rainfall events.

In recent years there has again been an increase in area affected with a recent land owner survey from the area revealing that 1835 hectares of good arable land has been lost to dryland salinity in the past 5 years. Land owners estimating that a further 2289 hectares will be lost in the next 5 years if current trends continue.

In 2016, the CTLAP organised public meetings at the Coomandook Hall and Meningie Golf Club to discuss the issue and seek local land owner ideas about the cause of salinity resurgence and potential remedies. Over 100 people attended including 80 land owners.

Key issues of concern were loss of arable land, wind erosion on bare saline soils, and impacts on adjacent paddocks. A range of options to address the issue were discussed and collated, and through further community consultation, the Saltland Pasture Redemption Project was developed. The project largely focused on the establishment of saltland pastures to provide vegetative cover and regain some productive capacity on bare salt affected soils. The introduction of a new waterlogging and salt tolerant legume, 'Neptune Messina', as a complimentary plant to the tried and true saltland pastures; Tall Wheat Grass and Puccinellia is a key part of the project. This was funded by the SAMDB NRM Board with significant contributions from the CTLAP and a wide range of agricultural retailers including Landmark Cooke Plains,

Elders Murray Bridge, Coorong Platinum Ag, Heritage Seeds and Seednet. Over the 2018/2019 year funding support is also provided through a Commonwealth National Landcare Project - Small Smart Farms project.

Trial work establishing Neptune Messina in saltland pastures commenced in 2017 and continued through 2018 with mixed success due to salinity levels being variable and above the Messina tolerance of up to 30 ds/m (sea water is 50 ds/m) in some places. Land owners also trialled the use of manure and straw mulches to reduce evaporation and in turn, salinity levels. Success has been mixed and the dry year in 2018 has proved a challenge on some sites.

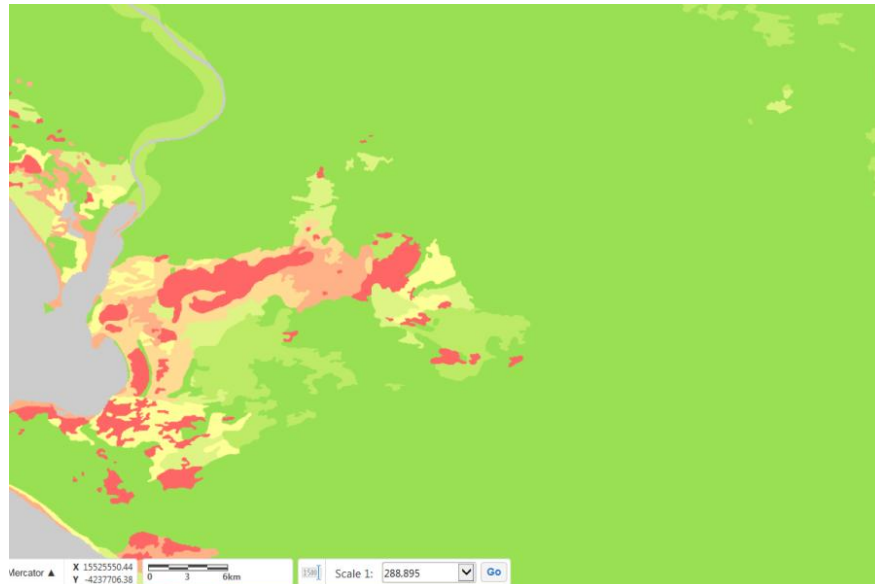


Figure 2: State mapping of Dryland Salinity Potential. Impacts now extend beyond the areas shown on this map as having potential for dryland salinity

The dry season experienced in 2018 has caused a significant increase in the affected area throughout the district. Rainfall levels were too low to ‘flush’ salts below the root zone, and increased evaporation causing greater concentration of salts at the soil surface. A number of large areas that had not previously been affected by dryland salinity are now unable to support cereal crop growth due to salinisation over the last 2 years. Some of these areas consistently produced yields well above district average in previous years, thus is the speed and ferocity at which dryland salinity has spread.

Another area of dryland salinity is also present in the area to the East of Meningie. This is unusual as the landscape is dominated with perennial pastures and perennial vegetation with no annual cropping practiced. It is thought that improvement in pasture and grazing management to improve plant vigour and plant water use could address this issue to some degree. The affected area is predominantly in the South East NRM Region at present but is on and around the regional boundary. This has the potential to spread to the SAMDB Region in time if the issue worsens and management options are not employed to address the rising water table. The Coorong Tatiara Local Action Plan are working on this with limited resources

A key concern is that Dryland Salinity is not specifically mentioned in current National Landcare Funding Programs including the Regional Land Partnerships funding recently received by the Board. This makes accessing funding to investigate and address the issue more difficult.

This Coorong Dryland Salinity Review will;

- **Bring together resources to provide an overview of the current level of dryland salinity in the Coorong District**
- **Provide discussion of the potential causes of the dryland salinity**
- **Recommend the best responses, and where further resourcing is required**

2. Salinity Risk Mapping

**Steve Barnett– Principal Hydrogeologist
Department for Environment and Water**

These Dryland Salinity Risk Maps were provided by Steve Barnett – Principal Hydrogeologist, Department for Environment and Water in October 2018.

They show areas that have already been salinised together with those areas at risk of salinisation in the future. These areas constitute the lowest topography in the region and were defined using a digital elevation model, depth to watertable information and satellite imagery. Local landholders were consulted to ensure any new areas of salinity were picked up on this new version of the salinity risk mapping.

Figure 3: Coomandook / Cooke Plains Salinity

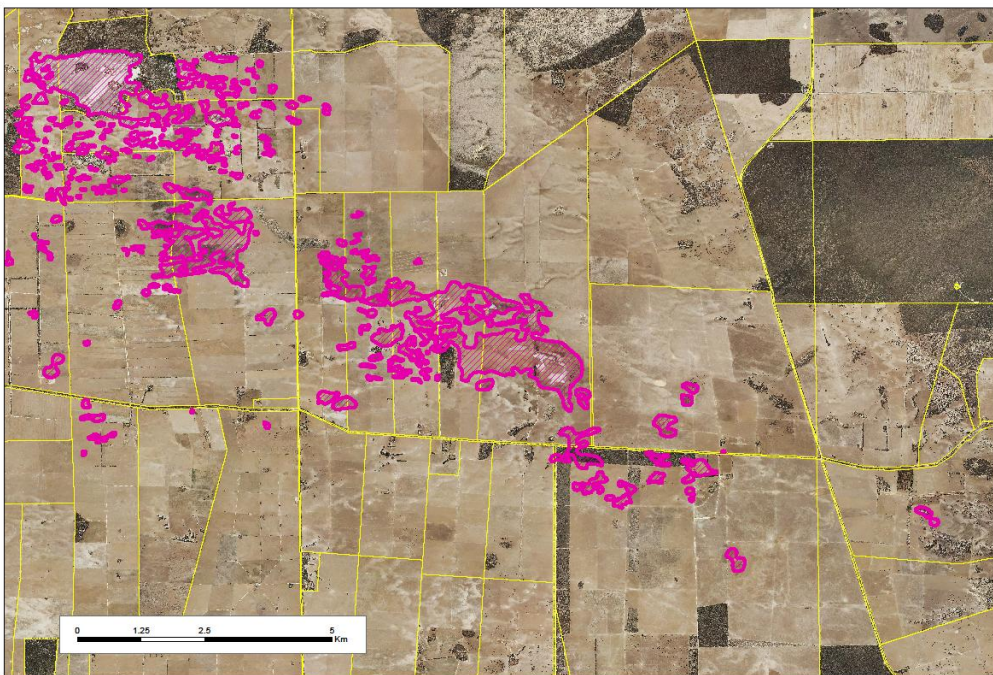
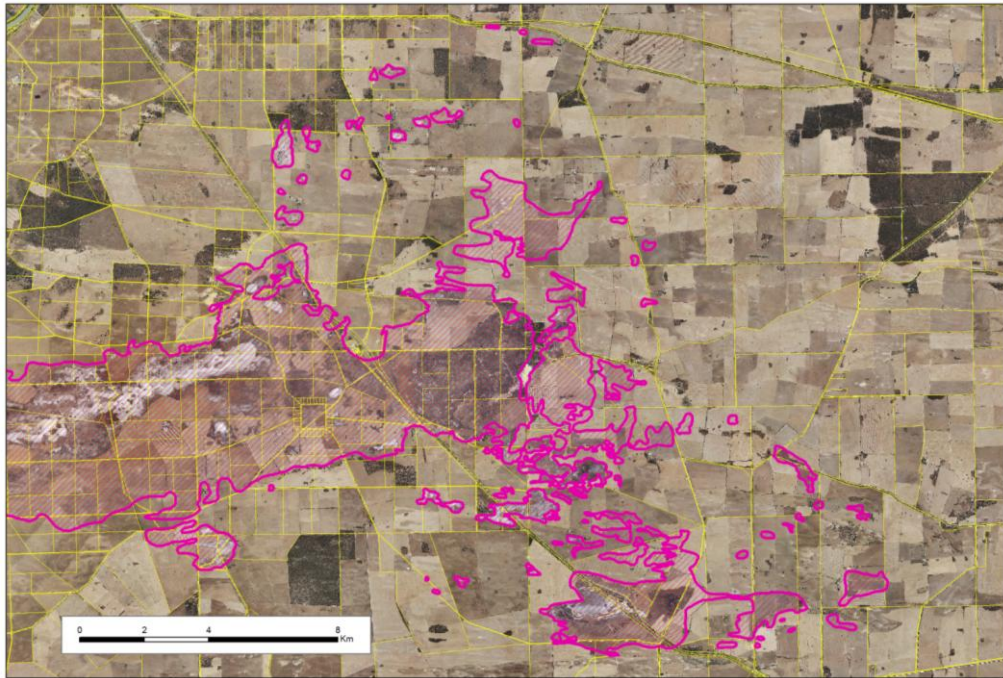


Figure 4: Meningie East Salinity

3. Coorong Dryland Salinity Survey

Tracey Strugnell & Graham Gates

Coorong Tatiara Local Action Plan - Coorong & Tatiara District Councils

A Coorong Dryland Salinity Survey was conducted in late 2018 via direct land owner contact. Here are the results.

Coorong Dryland Salinity Survey Results

	Coomandook - Cooke Plains	Meningie East
What new areas have been affected by dryland salinity in the last 5 years?	1610ha	225ha
How much land do you think is at risk over the next 5 years?	2159ha	130ha
How much perennial pasture do you plan to establish in the next 5 years?	5857ha	10,550ha

These results confirmed that dryland salinity is increasing in the Coorong District. Since this survey was conducted reports of increases in area have also come through from West of Tintinara / Colebatch area.

The survey questions can be found in **Appendix 3**.

This data confirmed concerns that had been expressed since 2015/2016 by land managers and agronomists.

Of particular note is; - the larger area of increase, - the belief by land managers that this areas is likely to increase, - the considerable areas likely to be sown to perennial pasture in coming years.

The impact of this increase dryland salinity is causing extreme concern for affected landholders.

They want to understand why it is occurring, and how this increase can be most effectively repounded to.

4. Coorong Dryland Salinity Description and Impacts

This section is adapted from;

Natural Resources of the Tatiara – A plan for action. 2013-2018

Recharge Reduction – Reaping the Rewards. March 1997

Coorong District Local Action Plan – Sustainability, Agriculture, Environment. 2012

Tracey Strugnell

Coorong Tatiara Local Action Plan - Coorong & Tatiara District Councils

4.1 Dryland Salinity and the Coorong Landscape

A huge amount of salt is stored in the subsurface soils underlying parts of the Coorong. Historically this salt was accumulated when the area was originally covered with seawater. In the Mallee highland zone the salt is held at depth while on the Coastal plains it is much closer to the surface.

A dryland salinity problem emerges when a rising watertable mobilises salts and carries them upwards close to the ground surface where they are further concentrated by evaporation.

The topography of the region formed by the ancient coastlines has resulted in a landscape of salty flats and range country. Where the summer – autumn watertable is within two metres of the soil surface the effects of dryland salinity are likely to be most severe. Groundwater is drawn up through the soil profile by capillary action, eventually evaporating as it reaches the surface, leaving the salts at or near the topsoil root zone.

Natural expressions of this can be seen at Waltowa Wetlands, Elephant Lake, and the extension of Blink Creek extending inland from Lake Alexandrina though to Cooke Plains.

Historically, the higher elevation areas of the Coorong District have been somewhat immune to the water balance and salinity issues affecting the lower lying areas of the district.

The section above is adapted from ‘Natural Resources of the Tatiara – A plan for action. 2013-2018’.

4.2 Recharge and Discharge Defined

Recharge – is the unused rainfall that percolates down past the root zone of plants and eventually reaches the water table.

Originally the deep rooted native vegetation cover kept the watertables at depth by providing a balance between rainfall recharge and evapotranspiration. However with clearance of scrublands and their replacement with shallow rooted annual crops and pastures, this balance was disrupted and more rainfall reached the watertable causing a general rise bringing the dissolved salts closer to the surface. The widespread sowing of lucerne when the land was first cleared assisted in keeping watertables in check, however the pasture aphid invasions of the late 1970's and the dramatic loss of susceptible lucerne stands at that time led to a general watertable rise and a rapid spread of dryland salinity in adjacent low lying areas.

Over the 2000's the spread of dryland salinity appeared to stabilise. However from around 2015 onward increases in the area of affected as covered in Sections 2 and 3 have occurred.

Low lying areas where the groundwater is removed by evaporation are known as **discharge** areas. These can be associated with very high levels of soil salinity.

As the water table rises, dissolved salts from the soil are carried with it. When the water table rises to within one or two metres of the soil surface, evaporation and use of the water by plants removes the groundwater but leaves the salt behind, which raises the salinity of the remaining groundwater.

In low lying areas where the water table is close to the soil surface, the salt is concentrated at the surface, resulting in dryland salinity which causes; the death of plants that are not salt tolerant, adversely affect soil structure, and reduce the quality of water supplies.

4.3 Agriculture & Enterprise Mix Impact

The impact of dryland salinity and agriculture and farm business can include;

- The range of production possible on saline areas is significantly reduced. See Figure 5 below,
- Potential reduction in property values,
- More rapid deterioration of farm improvements such as sheds, fences, roads, vehicles and equipment due to operating in a wet and salty environment,
- Potential drop in farm equity, affecting the ability of farm businesses to access finance,
- The need to restrict livestock access to wet saline areas seasonally,
- Salinisation of farm water supplies sourced from the unconfined aquifer, leading to increased reliance on SA Water mains and an increased cost to the farm business,
- Increased pressure on non saline land. In an attempt to offset the losses from salt affected area, non salinised land may be put under increased pressure,
- Aesthetic impact.

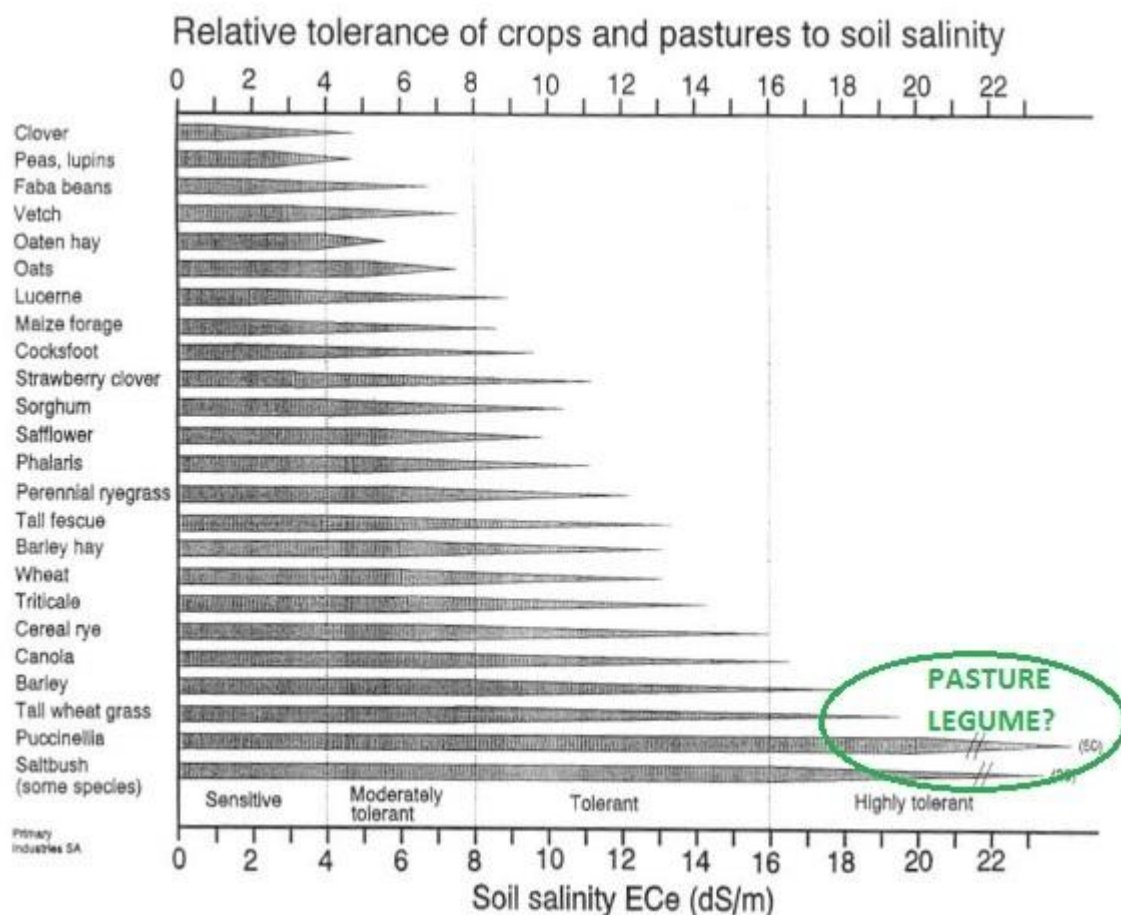


Figure 5 Relative tolerance of crops and pastures to soil salinity. Source: PIRSA Fact Sheet – Tim Herrmann.

Where discharge are not hyper saline these areas can be appropriate for a range of salt tolerant pastures. Where successful and well managed this can provide good quality feed for sheep and cattle. These options are discussed further in Section 12 – Dryland Salinity Management Recommendations.

Bare salinised land can be at risk of wind erosion. Establishment of ground cover is a high priority to both prevent erosion, but also to reduce the evapo-concentration of salts at the soil surface.

The reduction in ground cover, and health of crops and pastures growing in these low lying areas can further compound the cycle of reduced plant water use, and increased recharge to groundwater.



Figure 6 Salinity affected paddock Cooke Plains

4.4 Environmental Impact

Increases in the level of the saline unconfined aquifer also has environmental impacts, on low lying native vegetation, mature trees, and wetlands. Groundwater dependant wetlands can also be adversely affected by higher salinity levels.

Impacts include;

- Decline in native vegetation and mature trees,
- Loss of nesting sites and decline in bird populations,
- Loss of food sources for wildlife populations,
- Increased soil and wind erosion,
- Loss of wetland habitat,
- Loss of aesthetic value,
- Reduced species diversity.
-

The reduction in the health of native vegetation in these low lying areas can further compound the cycle of reduced plant water use, and increased recharge to groundwater.



Figure 7 & 8 Dryland Salinity affected native vegetation

4.5 Impact on the Built Environment

Some township areas in the Coorong District are located in low lying areas.

Where groundwater levels beneath the soil surface the built environment dryland salinity can impact on;

- Structural damage to houses, sheds, and other buildings,
- Reduced life of water pipes and electrical equipment,
- Decline of quality in unconfined groundwater bores for use on sporting grounds, gardens and domestic uses,
- Damage to pumping and water reticulation equipment,
- Roads, footpaths, pipelines, culverts, septic systems, underground communication cables, and the footings of powerlines and electrical transmission towers



Figure 8 Salinity affected road and building foundation. Photo credit: NSW Government

Figure 9 Repairs as a result of rising salt damp at Tintinara CWA Building

4.6 Social Impact

The main social impacts occur at the farm and local community level. Reduced farm incomes, potentially decreased land values, have a direct flow on impact to the local economy.

Property sizes are likely to increase, leading to flow population decreases impacting local business, schools, volunteer dependant services like CFS and Ambulance, and sporting clubs.

Dryland salinity has a real social impact;

- The stress caused by the expansion and production impact of dryland salinity to land owners and farm businesses,
- Social impact on rural communities due to reduced economic activity,
- Reduction in tourism and recreational activities due to the unattractive damage caused by salt as well as a reduced capacity of resources to support aesthetic, tourism, and recreational based activities.

4.7 Dryland Salinity and Climate Variability

Both dryland salinity and climate change have the potential to reduce the agricultural production options available where they have an impact. The reduction in the production options increases business vulnerability in response to commodity market fluctuations and seasonal variability.

The relationship between dryland salinity and climate variability also needs to be considered as an additional risk factor looking forward in the Coorong District.

Climate Variability in the Coorong

There is empirical evidence that the climate within the Coorong District is not the same as it was fifty or more years ago. Analysis of local rainfall data suggests that annual rainfall has been steadily decreasing since the 1950s, resulting in annual rainfall of up to 60mm less than they were in the earlier part of the 20th century. These trends are supported by long-term, high quality data from the Bureau of Meteorology.

Looking at local daily data, the autumnal break appears to be arriving later and with less regularity. The spring months appear drier and the total number of months without rain appears to be increasing.

There is limited long-term temperature data for the Coorong District, however long term (50-120 year) temperature data from Robe, Nhill, Lameroo and Murray Bridge suggest that there has been an increase in extremely hot days ($>40^{\circ}\text{C}$), a decrease in frost events and an increase in average night-time temperatures. This is supported by shorter term (20-50 yr) temperature data from the Coorong District.

A range of government agencies (CSIRO, Australian Bureau of Meteorology, South Australian Research & Development Institute) have looked at these long term trends in climate. The tables below show the results

of their more sophisticated extrapolation of climate data, done for four other towns within or near the Coorong District.

Projected changes from current (<2000) conditions by 2030 (CSIRO, 2009)

Town	Temperature increase (°C)	Rainfall reduction (%)	Rainfall reduction (mm)	Evaporation increase (mm)
Lameroo	0.74 – 0.98	2.1 – 12.6	8 - 49	33.2 – 48.6
Tailem Bend	0.72 – 0.91	2.5 – 12.0	12 - 56	32.9 – 47.6
Meningie	0.69 – 0.86	2.7 – 11.5	10 - 43	39.4 – 50.8

Number of days likely to experience high or low temperatures (CSIRO, 2009)

Site	Minimum below 0°C			Maximum above 35°C			Maximum above 40°C		
	Present	2030	2070	Present	2030	2070	Present	2030	2070
Tailem Bend	3	1-2	0-1	25	25-31	28-55	5	5-9	7-22
Keith	4	1-3	0-2	23	24-30	26-53	4	5-7	6-19

Reference: Coorong District Local Action Plan – Sustainability, Agriculture, Environment. 2012

The relationship between dryland salinity and climate

As discussed further in Sections 5 – 9 groundwater and dryland salinity trends are influenced by climatic and seasonal factors in the following ways;

- Intense rainfall events can cause a spike in levels of recharge,
- Intense rainfall events can cause a spike in groundwater levels,
- Evapotranspiration causes ‘wicking up’ from the shallow saline groundwater leaving the salt behind,
- Long hot and dry conditions further concentrate salt at the soils surface,
- Rainfall is essential at the start of the growing season to ensure salts are flushed from the top soil to allow seedlings to successfully establish.

Long dry periods such as the millennium drought, 2015-16 drought, and 2018-19 drought would have significantly impaired the health, vigour, density and water use potential of perennial pastures on both saline and non saline land. In particular the summer active perennial pasture base that prevails in this region of dryland lucerne, perennial veldt grass and primrose. When rainfall did return after these dry periods, these pastures would have not been in optimum condition to ‘use the rain where it fell’, and hence reduce recharge to groundwater.

In Section 9. Watertable Trends and Graphs, it is shown that the watertable rose by up to 1 m following high rainfall episodic events in 2010/11, 2013 and 2016.

Saltland areas could still expand into the future, due to increased evapotranspiration causing ‘wicking up’ from the shallow saline groundwater leaving the salt behind, and lower rainfall leading to less leaching of salts down through the soil profile.

Improved awareness of the interactions between climatic variations and groundwater trends could inform farm management decisions that respond to episodic rainfall events.

5. Local Watertables Explained

*Chris Henschke— Senior Consultant Hydrogeology
PIRSA Rural Solutions*

5.1 Hydrogeological Overview

There are two groundwater flow systems occurring in the Upper SE; a local unconfined aquifer and a deeper regional confined aquifer. The shallow unconfined system lies on top of the confining clay layer which separates it from the underlying confined aquifer. The whole area can be likened to a big ‘bucket’ that has now filled up to capacity beneath the low-lying Coastal Plain See Figure 10 below. Refer to Aquifer Maps in **Appendix 7**.

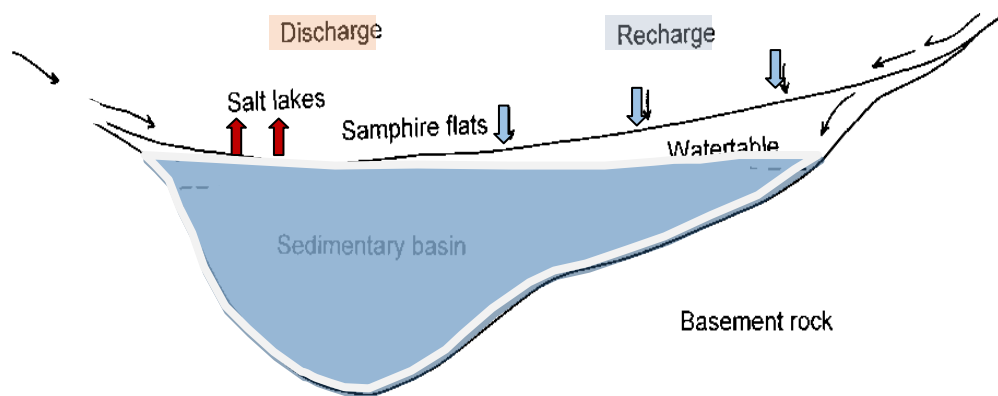


Figure 10: Unconfined aquifer flow system

Local groundwater recharge from rainfall is the cause of the rising watertable in the shallow unconfined aquifer. The deeper confined regional system which is recharged in Western Victoria, does not contribute to dryland salinity as it is confined by a clay layer which only allows very small amounts of flow between the two aquifers.

The impacts of clearing native vegetation are no longer a major driver of rising watertables and the expansion of dryland salinity. Long term monitoring data indicates that groundwater levels respond strongly to changing rainfall patterns.

The influence of climate change is difficult to predict because any beneficial impacts are counterbalanced by negative influences. For example, decreases in rainfall and recharge are conflicting with increasing evapotranspiration (ET) and more intense rainfall events.

The patterns of groundwater trends can be related to landscape, topography, and elevation. Continuously rising watertables are often associated with higher elevation land because the large depth to the watertable results in a delayed cumulative response to rainfall with any seasonal variations smoothed out. On flat lower lying land, the shallow watertable responds rapidly to rainfall in winter and evaporative discharge in summer, resulting in fluctuating watertables (seasonal highs and lows).

Saltland areas could still expand into the future, due to increased evapotranspiration causing ‘wicking up’ from the shallow saline groundwater leaving the salt behind, and lower rainfall leading to less leaching of salts down through the soil profile.

5.2 Previous Research

The local effect is stronger than any regional input, so the adoption of high water use crops and pastures at a large scale can have an impact, especially in dune-swale topography where local water flow cells overlie the regional flow system.

Groundwater flow modelling suggested that a 50% recharge reduction in the Coorong District would be required to limit the spread of land salinisation. This would not prevent salt from spreading entirely, as it would not cause watertables to fall significantly, but it could slow down the rate at which salinity would expand.

There was some scepticism by CSIRO scientists in the early 1990s that recharge reduction could be achieved to control dryland salinity in landscapes underlain by regional groundwater flow systems. This is because a large proportion of the landscape needs to be planted to perennial vegetation and realistically, 100% adoption is unlikely to be achieved. For example, lucerne needs to be well managed to be effective in recharge reduction. An analysis by CSIRO in 2004 suggested that possibly 10-20% recharge reduction had been achieved, far short of the 50% recharge reduction goal.

Because the local groundwater flow system dominates the regional flow system, land management at the local scale can have an impact. However watertable monitoring of a Coomandook Landcare Network trial site (see **Appendix 4**) suggests that even if the watertable is lowered under the sandhill, it does not have an immediate impact on the salinised area down slope. Because the limestone aquifer has a large through-flow and is highly transmissive (i.e. very porous to groundwater flow), small scale treatments at the farm scale (i.e. hundreds of hectares) will not have a significant impact.

Recharge reduction needs to be carried out on a very large scale (i.e. thousands rather than hundreds of hectares). Individually, farmers undertaking recharge reduction management on a single paddock will not make a difference, but collectively, many farmers doing the same thing can make a difference.

Saltland agronomy was considered to be the most cost effective solution. Living with salt is being revisited as the best option in dealing with the long term impacts of climate change. A surface drainage network is not considered to be a viable option in the undulating dune topography occurring in this area because of the excavation difficulties associated with sandy terrain, the very low hydraulic gradients which would result in very small flows in any drain that was constructed.

5.3 Watertable Trends Analysis

Watertable monitoring wells (also called boreholes, observation wells or piezometers) completed in the unconfined limestone aquifer in the Coomandook and Meningie East areas, were selected for trend analysis.

Analysis of watertable data combined with rainfall trend data helps to determine the major driver of groundwater responses and hence the causes of expanding dryland salinity.

Of some concern is the number of sites that have been removed from the monitoring network in recent years. This has contributed to wells becoming lost or destroyed due to the vulnerability of PVC riser tubes not being adequately protected, or new landholders being aware of their significance. Also of concern is the reduction of funding and resources to monitor dryland salinity and the unconfined aquifer.

For each region, key strategic sites should be identified for consistent long term monitoring. Key watertable monitoring wells need to be adequately identified, labelled and protected from damage by stock, farming operations etc.

6. Coorong Hydrogeological Systems

Chris Henschke– Senior Consultant Hydrogeology
PIRSA Rural Solutions

Steve Barnett– Principal Hydrogeologist
Department for Environment and Water

There are two distinct groundwater flow systems: a shallower unconfined sandy limestone aquifer and a deeper confined limestone aquifer. They are separated by a layer of confining clay which does not transmit water between the two systems. Refer to aquifer maps in **Appendix 7**.

6.1 Shallow Local Unconfined Watertable Aquifer

The Quaternary Limestone (QL) aquifer is an unconfined groundwater system comprising two main geological units which sits on top of the deeper regional system. In the Coomandook area, the unconfined aquifer occurs in the Bridgewater Formation (**Qbp**) which is made up of sandy and shelly limestones being derived from beach and coastal dune deposits. This formation is usually capped with calcrete.

Further south around Tintinara, the unconfined aquifer occurs in the Padthaway Formation, a shallow highly permeable Quaternary limestone that can be seen outcropping in inter-dunal flats.

In some places the Bridgewater Formation directly overlies the Murray Group Limestone (MGL) (**Tml**) which consists of a fossiliferous sandy limestone. This aquifer is recharged in south west Victoria and forms the unconfined aquifer in the highland areas to the east where the watertable occurs at much greater depths (>20m). The low permeability grey clays of the Ettrick Formation (**Toe**) then forms the base of this unconfined system and separates it from the deeper confined aquifer.

6.2 Deep Regional Confined Aquifer

The confined aquifer consists of the Renmark Group (**Ter**) comprising interbedded sands, clays and limestone units. This aquifer is very well confined with minimal upward leakage into the watertable aquifer. This suggests that the deeper system does not contribute to the recent expansion of dryland salinity.

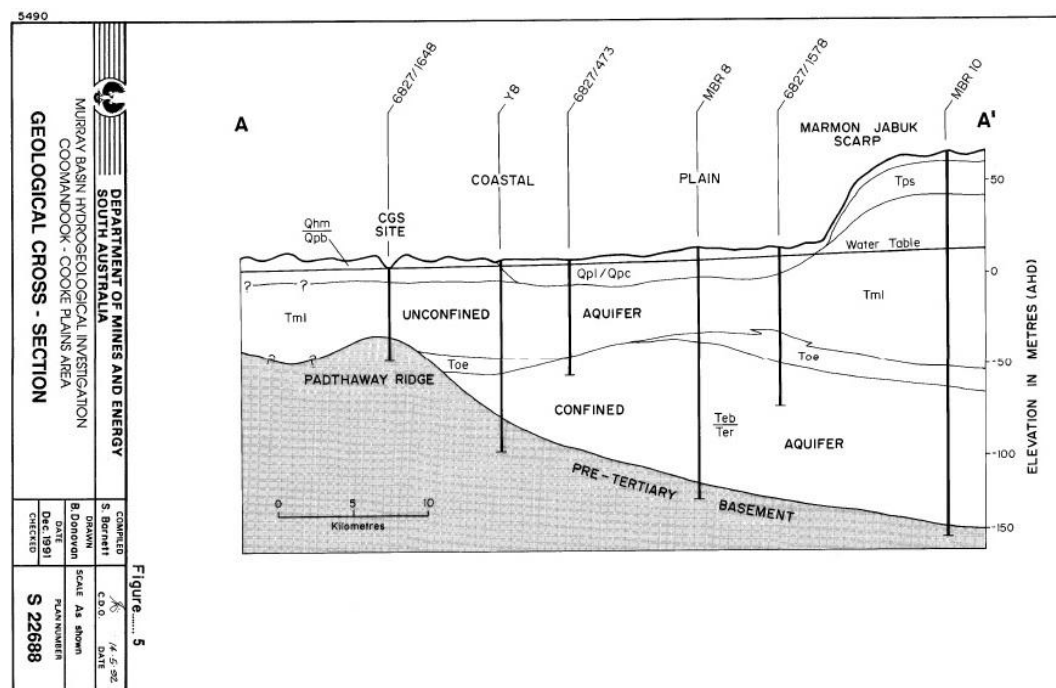


Figure 11 Cooke Plains Transects

6.3 Basement rocks of the Padthaway Ridge

The Padthaway Ridge is a north-south trending basement formation comprising of metamorphic rocks and granite intrusions. It runs through the middle of the salinity focus area, outcropping at sites such as Binnie Lookout west of Coonalpyn. The ridge forms an impermeable localised barrier to the lateral flow of groundwater which needs to flow around the barrier. To some extent, this isolates the groundwater between the eastern and western parts of the region and differences in processes have been observed between east and west.

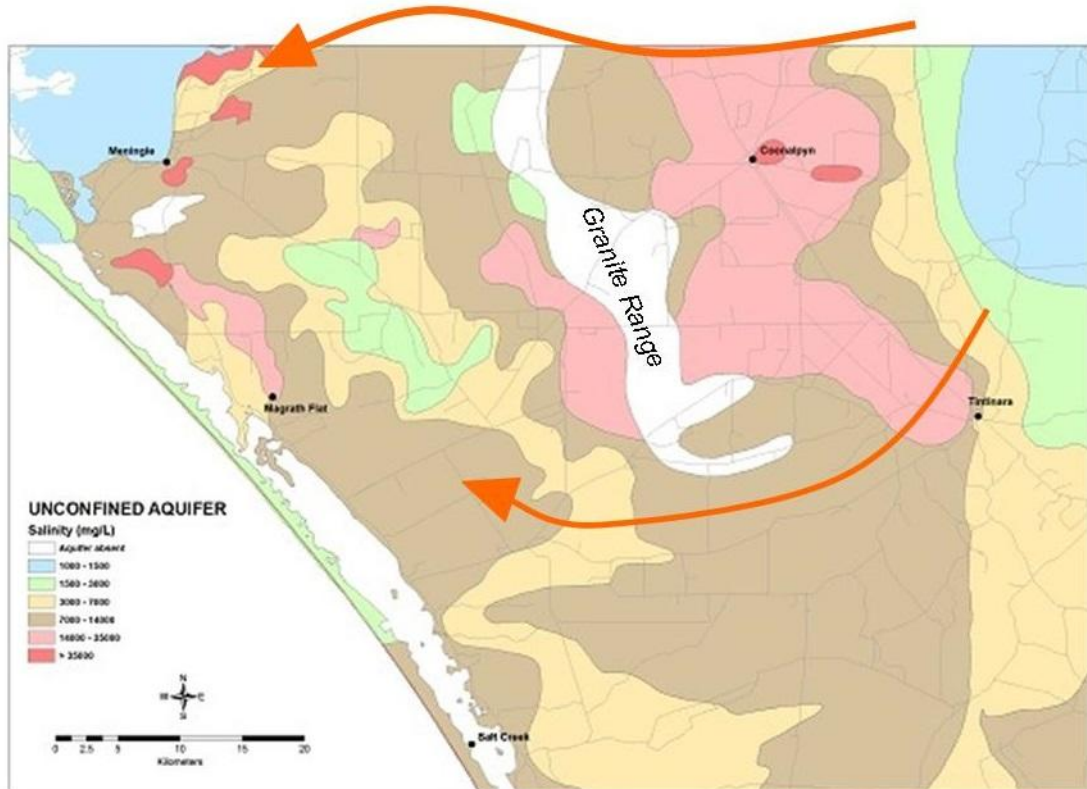


Figure 12: Unconfined aquifer movement around the Padthaway Ridge

Some areas directly to the western down-gradient side of the Padthaway Ridge have been affected by dryland salinity between the Range and Meringue. This area is likely to be influenced by a more localised groundwater system as opposed to the more regional nature of groundwater in the Coomandook area.

7. Rainfall Trend Graphs

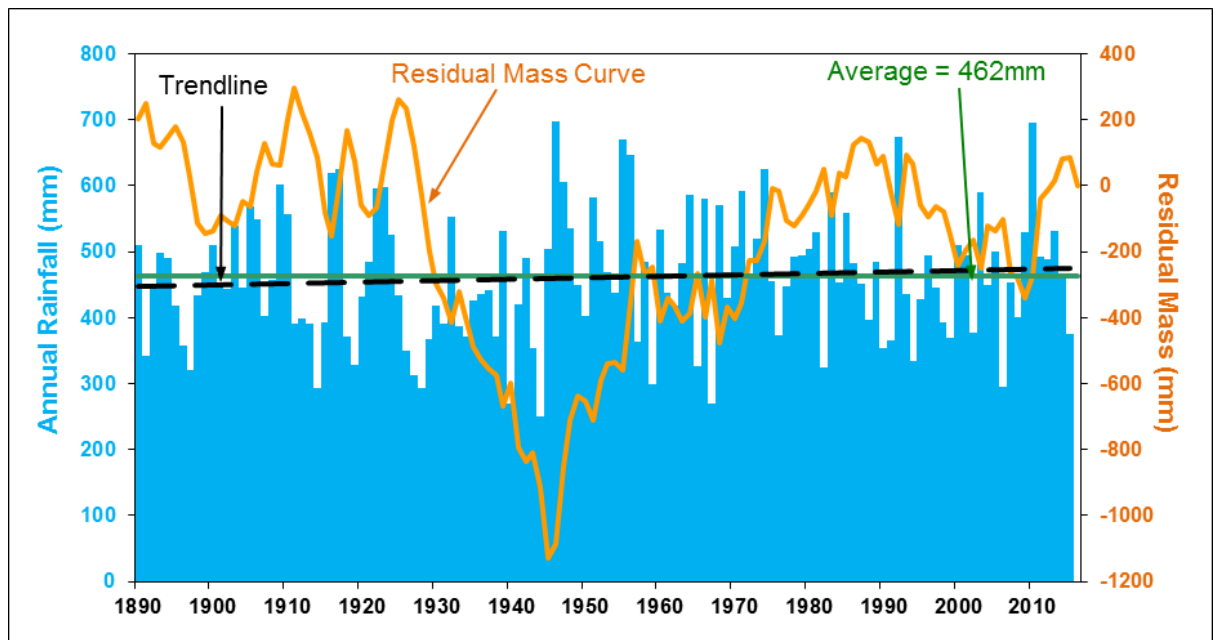
Chris Henschke– Senior Consultant Hydrogeology
PIRSA Rural Solutions

Monthly rainfall data is available on the Bureau of Meteorology website. Records for Coomandook only have a minor number of data gaps in the period from the late 1980s up until the present.

Rainfall trend analysis is calculated using the cumulative variation / deviation from the mean rainfall (also called a residual rainfall or residual mass curve). In periods where mostly above average rainfall occurs, graphs show a positive or increasing variation from the mean. A falling curve represents periods receiving below average rainfall.

Figure 13 below shows annual rainfall since 1890 for Meningie and the calculated 'Residual Mass Curve' (i.e. residual accumulative rainfall trends). In broad terms, more recent trends indicate a rising trend (wetter cycle) during the 1950s and again in the 1970s up until the early 1990s. This was followed by a drying trend until the 2000s which included the 'Millennium Drought' extending from 2006-09. A rising trend then resulted from the wet summer of 2010/11 and the wet spring of 2016.

Figure 13: Rainfall Trend Graph



8. Rainfall Deciles

Chris Henschke– Senior Consultant Hydrogeology
PIRSA Rural Solutions

8.1 Dry Periods 1990 to 2018

The table below highlights some of the very dry periods that have occurred since 1990 at Coomandook. This is for the time period since regular watertable monitoring commenced in this region. It shows the months that have experienced Decile 1 and 2 monthly rainfall (i.e. the lowest 20% of rainfall totals on record). These dry periods if sustained over time, can produce a falling trend in the watertable record.

8.2 Wet Periods 1990 to 2018

The table highlights some of the wetter periods that have occurred since regular watertable monitoring commenced in the region. Months with decile 9 and 10 rainfall after 1990 are shown for Coomandook (i.e. the highest 20% of rainfall totals on record). These wet periods are likely to have an impact on local groundwater flow systems producing a rising trend over time.

Year	DRY Month	Rainfall (mm)
1993	April	0.8
	May	19.8
1994	March	0.0
	April	7.6
	May	12.6
2002	February	0.4
	April	5.8
	August	21.4
2006	June	15.2
	August	3.4
	October	1.4
	November	10.2
2008	February	1.8
	March	2.8
2009	January	0.8
	February	0.0
2014	August	10.8
	September	17.8
	October	10.0
2018	February	1.0
	September	10.0
	October	14.2

Year	WET Month	Rainfall (mm)
1991	June	72.6
1992	August	90.6
	September	78.4
	November	71.4
	December	63.0
1993	January	55.4
	December	58.4
1995	July	86.8
1996	January	49.0
	June	86.0
1997	September	71.0
1998	April	78.8
2000	February	58.8
2003	May	74.2
	June	77.2
2004	November	48.4
2005	June	107.6
	October	74.5
2008	December	65.4
2009	September	75.4
	November	70.4
2010	March	64.0
	August	86.6
	December	51.2
2011	February	49.0
	March	71.2
2013	June	103.8
2016	September	123.8
	December	76.4
2017	January	49.2

9. Watertable Trends and Graphs

*Chris Henschke– Senior Consultant Hydrogeology
PIRSA Rural Solutions*

9.1 Background

The groundwater monitoring localities focussed on in this report are:

Location	Watertable Trend Graphs Appendices	PAGE
1. Coomandook-Cooke Plains	4.1 Coomandook – Cooke Plains Site Location Information & Hydrographs	45
2. Coomandook Landcare Network	4.4 Coomandook Landcare Network	63
3. Meningie East	4.2 Meningie East Site Location Information and Hydrographs	54
4. Tintinara West / Colebatch	4.3 Tintinara West Hydrographs	62

Water level data is available on the Department of Environment and Water (DEW) website. The address is www.waterconnect.sa.gov.au. The Obswell tab on the Groundwater Data page can be used to find records for each water well.

Each site has an Obswell Number based on the Hundred in which the bore is located (e.g. SHK003) and may have a field number that was used to identify the site when the bore was being drilled.

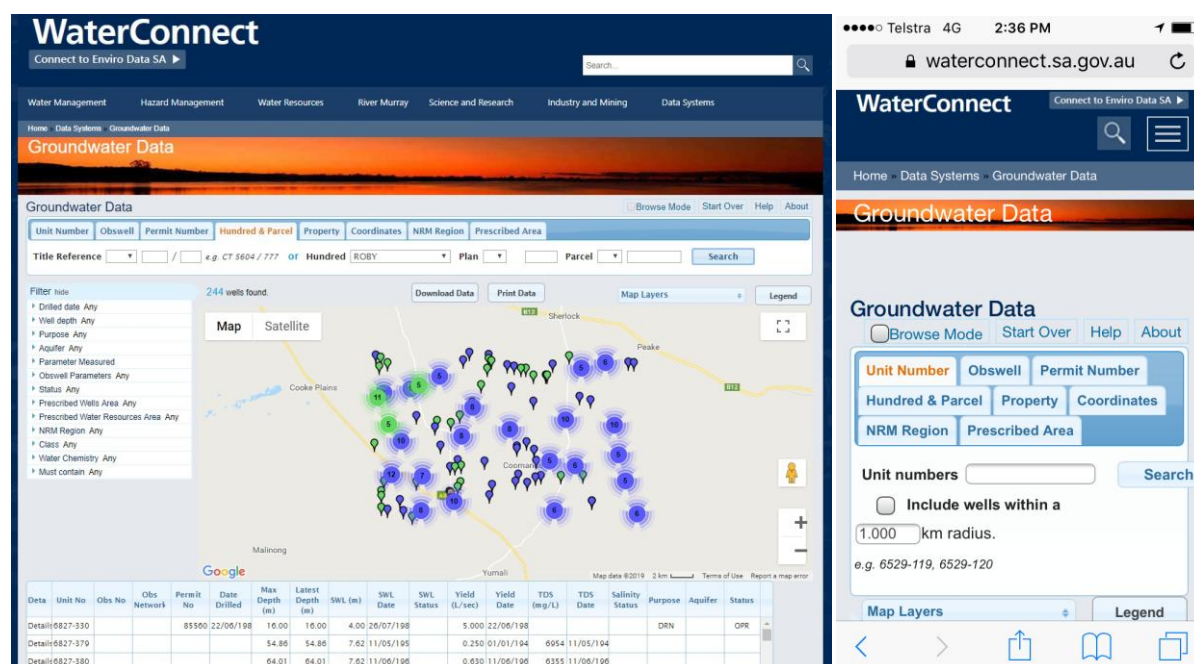


Figure 14: Screen shots of the Water Connect Groundwater Data pages – computer and smart phone

Obswell sites were selected in each focus area based on the reliability of the record. Unfortunately there is very limited data available in the Tintinara West / Colebatch area.

In the northern areas, the shallow wells are completed in the Bridgewater Formation (**Qpcb** unconfined aquifer). The formation is described as an aeolian calcarenite with palaeosol horizons often capped with calcrete. In southern areas, shallow wells are completed in the Padthaway Formation.

Watertable trends fall into the following categories:

- Continuously rising trend
- Episodic rise (rises and falls, but each rise is higher than the previous one)
- Seasonal trend (strong seasonal peaks and troughs which correlates with winter rainfall and summer evaporative discharge)
- Static / stable (has rises and falls but no overall change in the longer term)
- Falling trend

The data is summarised in **Appendix 4** which displays graphs of water level with time (groundwater hydrographs) for observation wells installed in the unconfined aquifer for each of the three focus areas, against rainfall.

Figure 15 Location of Watertable Monitoring Wells, Coomandook / Meningie below shows the location of 21 obswell sites that were selected based on the continuity of water level records over a reasonable period of time.



9.2 Results

The patterns of groundwater trends can be related to landscape, topography, and elevation. Rising watertables are often associated with higher elevation land while fluctuating watertables (seasonal highs and lows) can be correlated with rainfall on flat lower lying land.

Reading the Hydrographs:

The top blue line in each graph is the rainfall trend.

The bottom red line in each graph is the depth to watertable trend line.

Figure 16 below is an example of a rising watertable under elevated land. The sudden 'blip' in the watertable trend line is due to a change in datum/reference elevation point.

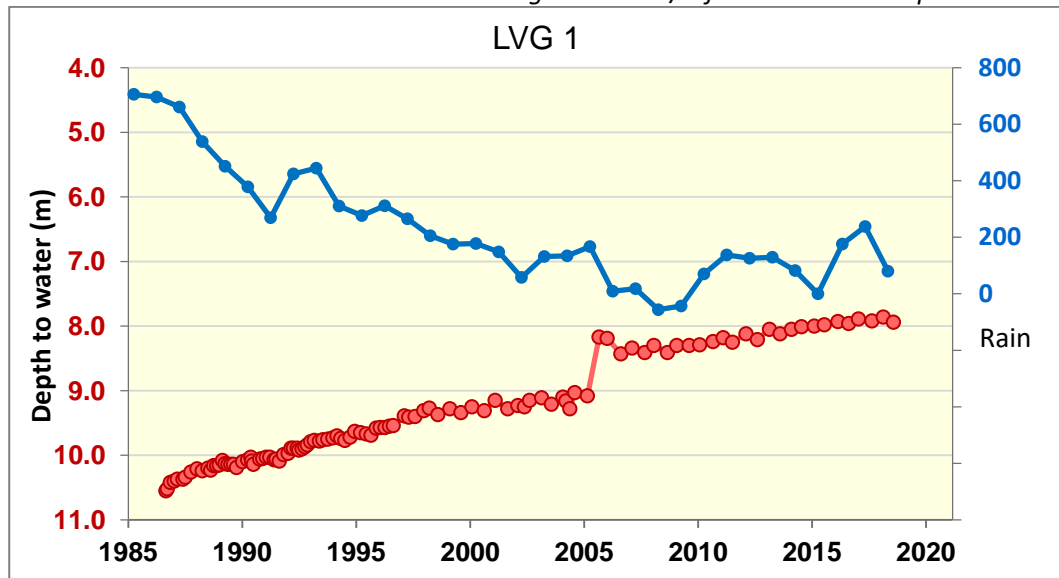
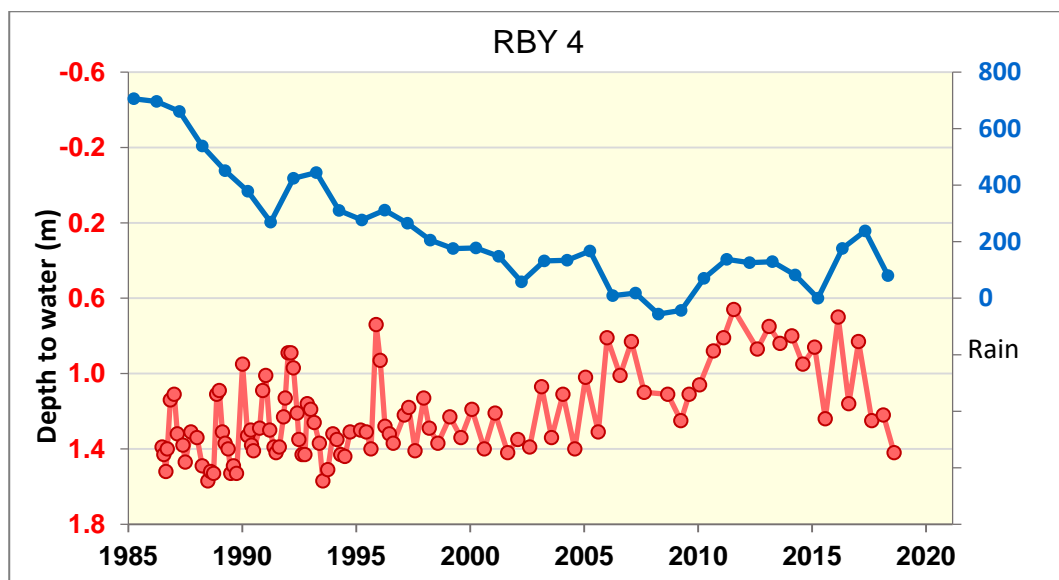


Figure 17 below is an example of a seasonally fluctuating water table on low lying land

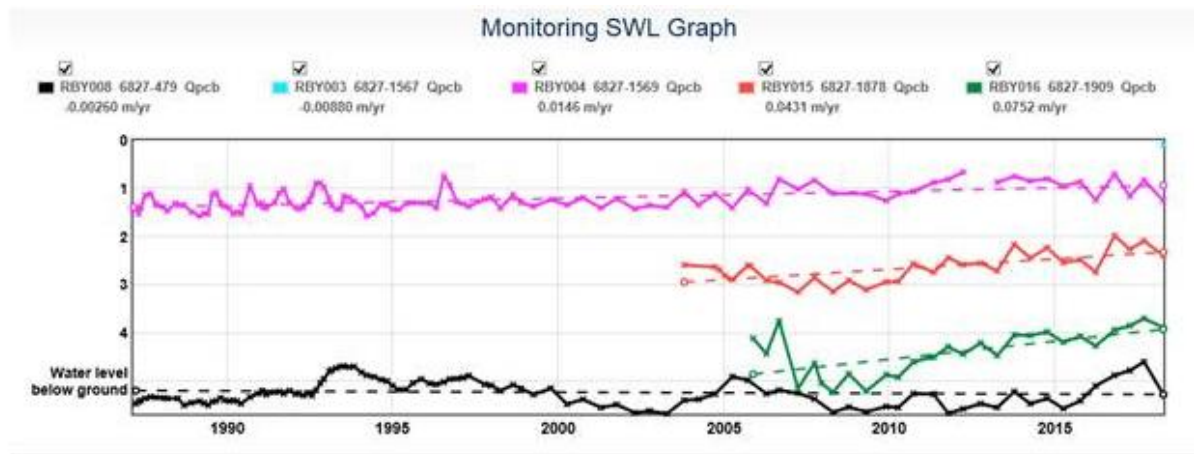


9.3 Discussion

The hydrographs of rainfall vs depth across the project area are shown in **Appendix 4**. These graphs show that over a large area the water level in shallow unconfined system is highly responsive to winter recharge, particularly in wetter years and where the groundwater is relatively shallow. This indicates that the recharge process is very local in nature (i.e. in the immediate vicinity area surrounding salinity hotspots).

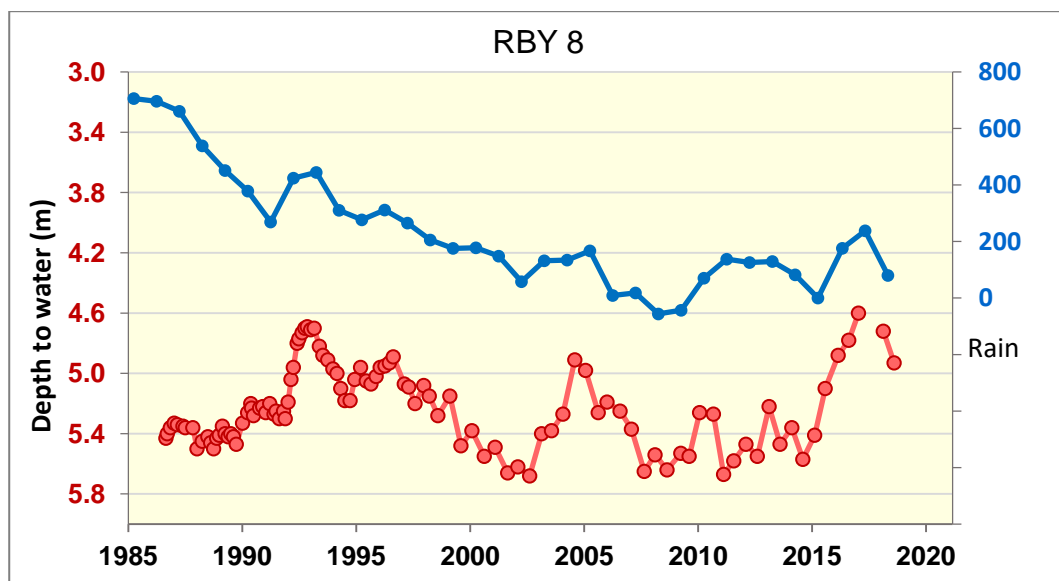
Short term water level trends are superimposed on longer term trends. For example the watertable rose by up to 1 m following high rainfall episodic events in 2010/11, 2013 and 2016. In the longer term (since 1987), there has a general rising trend of +0.002 to +0.015m/year in the unconfined aquifer in this region.

Figure 18. Graph illustrating long term rising trends



Of greatest relevance to the sudden appearance of dryland salinity in 2018 is the rapidly rising watertable trend from 2015/16 until late spring of 2017. This brought the watertable at many sites to its highest recorded level. The large episodic rainfall events as noted appears to coincide with the sudden increase in salinised area in 2018.

Figure 19 shows an example of the highest ever water level in 2017 following record rainfall in 2016



10. Coorong Dryland Salinity Mythbusting

Steve Barnett– Principal Hydrogeologist
Department for Environment and Water

These questions have often been raised at meetings and field days and require a scientific explanation.

- Is the unconfined aquifer pressurised?
- Why isn't there an immediate response to high rainfall events?
- Why do the best crops occur in the year before ground goes saline?
- What is the effect of raised Lower Lake levels on the watertable and dryland salinity
- Impact of gypsum mining in the Cooke Plains area?
- Why does dryland salinity get worse in a dry year?
- Are there 'underground rivers' pushing down from the Mallee groundwater system?

10.1 Is the unconfined aquifer pressurised?

The shallow aquifer is not pressurised as it is an unconfined groundwater system. Water moves through the aquifer under gravity at slow speeds (i.e. 5 - 10 metres per year). The water level at any point is responding to processes occurring locally (i.e. recharge that occurs on a nearby sandhill in the order of less than 1km in distance). Therefore processes occurring 10km away from a saline patch is not relevant.

Direct rainfall is the issue, for example, a 20 mm recharge event will produce a 100 mm rise in the watertable due to the porosity of the aquifer.

An unconfined aquifer is not a pressure system.

10.2 Why isn't there an immediate response to high rainfall events?

This question arose from the observation by some farmers that they are seeing higher watertable levels in their dams and pits in what has been a very dry year. For example, with less than 10mm of rain being received, water level rises of up to 1m were being observed.

There is a time lag for rainfall to infiltrate down through the soil to the watertable and then for the watertable to rise. The deeper the watertable, the longer it takes to respond. This is shown in hydrographs comparing rainfall with depth to watertable response. Watertables that are near the surface (e.g. 0 to 2m) show almost instantaneous response to rainfall events (an example includes site RBY 4 with very spiky responses to significant rainfall events). Hydrographs of deeper watertables (e.g. 5 to 10m) show lag times of months or even years to respond to large rainfall events (an example is site FID 2 where the 2010/11 rainfall event produced a large response in 2015/16). It is useful to obtain the landuse history at each site to further help interpret depth to water trends. Furthermore, it takes time for evaporation to remove the water and concentrate the salt. The salt is often concentrated in dryer years (see below).

10.3 Why do the best crops occur in the year before the ground goes saline?

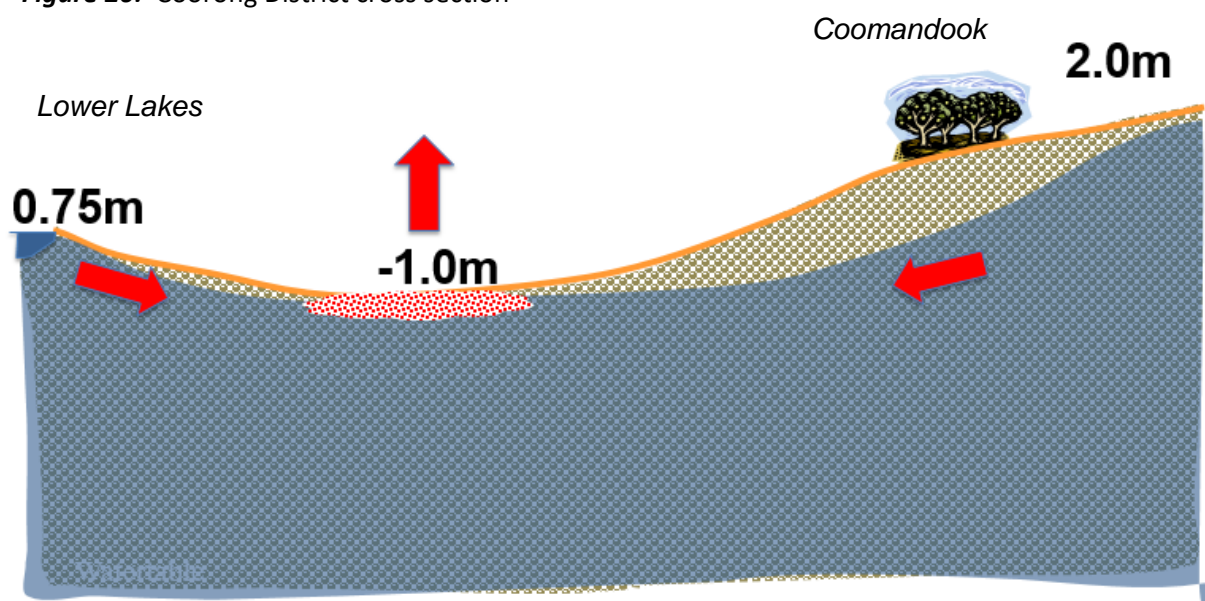
A better crop is usually the result of a wet year. A wet year means higher recharge and consequently greater watertable rise. As the watertable rises, the crop may benefit from a freshwater lens on top of the rising groundwater creating 'sub-surface irrigation' in the root zone, in the first year or two after the water table has risen. Once this freshwater lens has depleted, salinisation can then occur in the following year.

10.4 Impact of lake levels on watertables and dryland salinity

The schematic diagram **Figure 20** below is a cross-section through Lake Albert and Alexandrina to the left, samphire swamps (such as Pink Lake) in the centre and the Coomandook area to the right of the cross-section (which is across a distance of approximately 40km). The water in the Lakes is held at 0.75m AHD since the barrages were constructed in the 1940s. The Lakes are surrounded by low-lying samphire swamps. The watertable in the swamps is at minus 1.0m AHD (i.e. below sea and lake level).

The watertable in the Coomandook area is at a higher elevation (2.0m AHD) than the lake level and samphire swamps. The groundwater moves slowly westwards under gravity (downhill) to discharge in low-lying areas such as Pink Lake. The low-lying saline swampy areas around the Lakes also intercept any groundwater leaving the Lake and behave as 'natural salt interception schemes'. As the shallow groundwater is not pressurised (see previous question), it cannot move uphill against gravity to the higher areas around Coomandook. It is therefore concluded that the Lake levels do not affect groundwater levels inland.

Figure 20: Coorong District cross section



10.5 Impact of Gypsum mining around Cooke Plains

The Cooke Plains embayment contains estuarine, lagoonal and lacustrine clays, sands and carbonates. In areas of groundwater discharge, evaporite gypsum beds occur and these have been mined for gypsum. The mining excavations in the Cooke Plains area have exposed the watertable in some of the deeper excavated pits. The effect of gypsum mining is considered to have minimal effect on surrounding saline areas.



10.6 Why does dryland salinity get worse in a dry year?

Salinity may get worse in a dry year as there is less rainfall to flush salts down the profile. With less rain to flush salt out of the profile and higher evaporation rates, there is more time for evaporation to concentrate the salts, even if the watertable does not rise. This has been observed in the drier years of 2017 / 2018. Although the watertable is dropping in 2019, the recent saline areas will not disappear quickly as a good salt flushing event (wetter winter) will be required.

Figure 21: Salt concentrated on the soil surface at Cooke Plains

10.7 Are there 'Underground Rivers' pushing down from the Mallee groundwater system?

There is no influence from the Mallee since groundwater movement is from east to west as shown in the watertable contour map. The map indicates contours of the height of the watertable with the arrow showing the direction of groundwater flow. The Murray Group Limestone (MGL) forms an unconfined aquifer and originates from the Dundas Tablelands in SW Victoria. The MGL aquifer discharges into the River Murray or in low-lying swamps around the Lakes. The aquifer is 140m thick in the central Mallee, but gets thinner (40m) toward Taillem Bend due to shallow granite basement in this area.

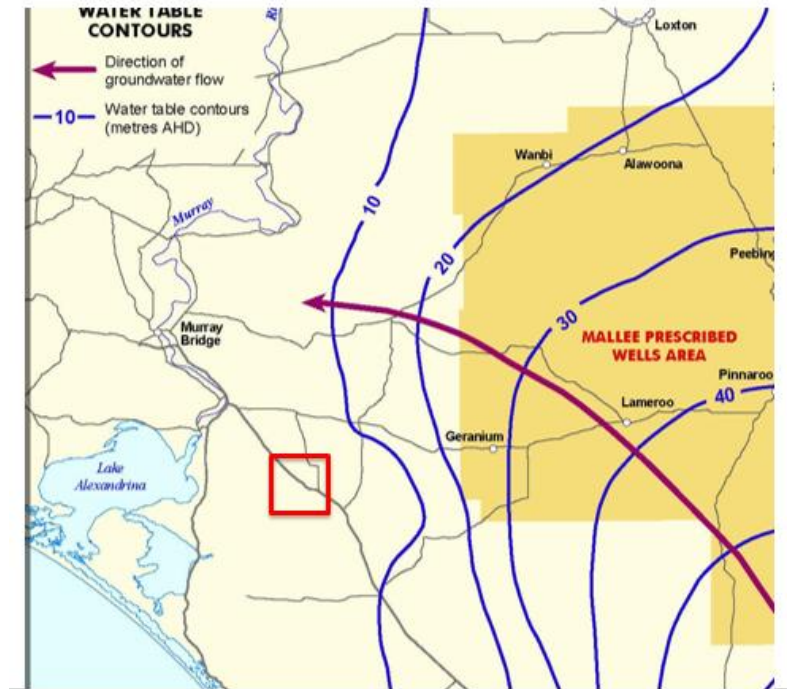


Figure 22: Map showing the direction of groundwater flow in the unconfined MGL aquifer. The flow originates in SW Victoria and flows toward the Murray River. The Cooke Plains / Coomandook area is highlighted as the red square.

11. Land Use Change and Vegetation Cover

Data provided by Natural Resources SA Murray-Darling Basin

Tracey Strugnell

Coorong Tatiara Local Action Plan - Coorong & Tatiara District Councils

A gradual change in land use can be observed in the following series of maps, showing an increase in the area of dryland cropping over time, particularly around the greater Coomandook area.

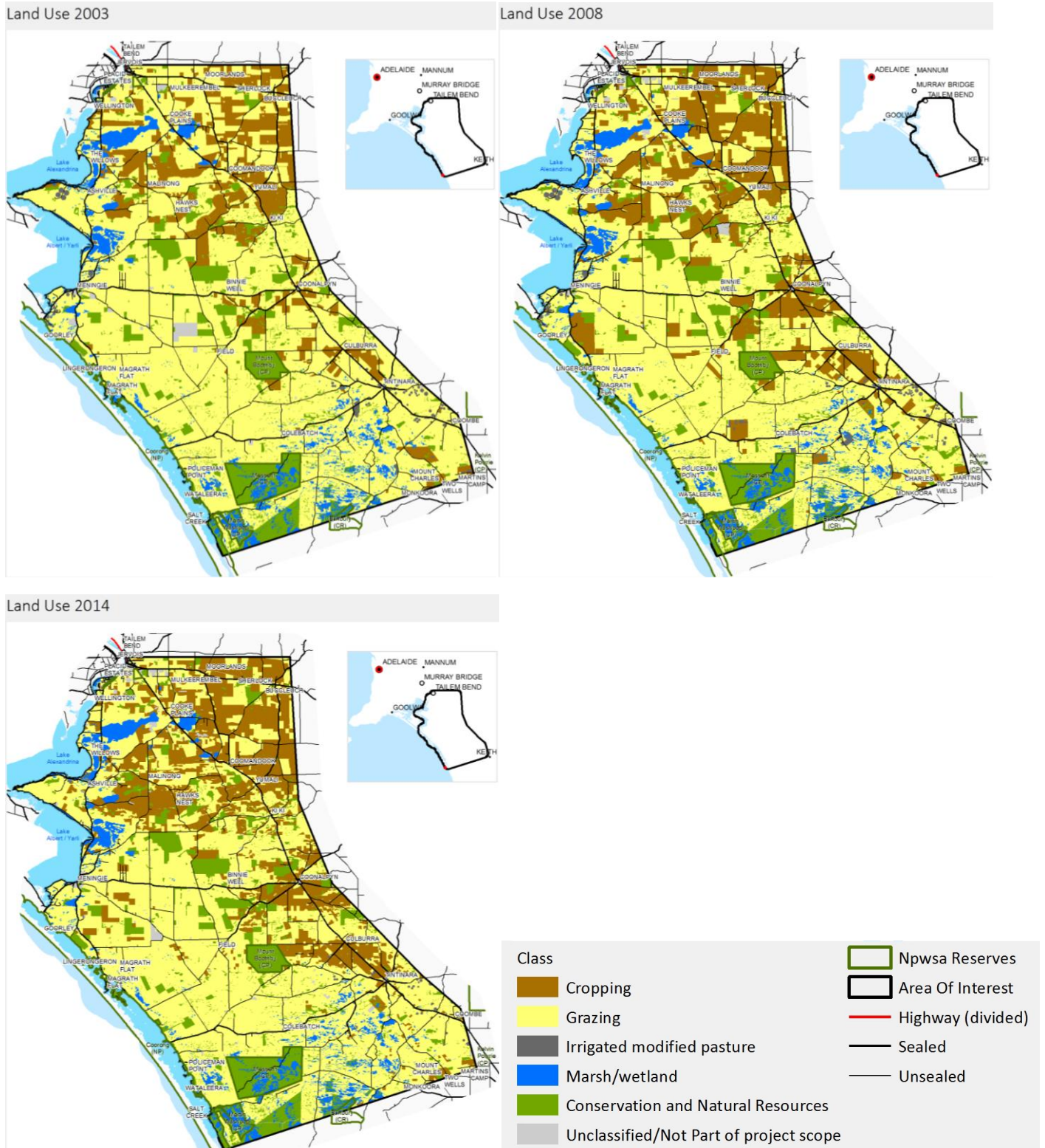


Figure 23: Land Use Change Maps 2003 2008 2014

This gradual change is further extrapolated in the following tables.

This gradual change is further extrapolated in the following tables.

Land Use 2003

	Hectares	% of Area
Cropping	70,631	13.2
Grazing	357,829	66.9
Irrigated modified pasture	3,109	0.6
Marsh/wetland	31,186	5.8
Conservation and Natural Resources	59,291	11.1
Unclassified/Not Part of project scope	12,922	2.4

Land Use 2008

	Hectares	% of Area
Cropping	101,966	19.1
Grazing	322,968	60.4
Irrigated modified pasture	3,626	0.7
Marsh/wetland	30,512	5.7
Conservation and Natural Resources	63,619	11.9
Unclassified/Not Part of project scope	12,279	2.3

Land Use 2014

	Hectares	% of Area
Cropping	107,171	20.0
Grazing	318,526	59.5
Irrigated modified pasture	744	0.1
Marsh/wetland	29,441	5.5
Conservation and Natural Resources	63,669	11.9
Unclassified/Not Part of project scope	15,418	2.9

This data does illustrate an increase in area under continuous and mixed cropping farming systems, particularly around the northern area shown on the map. This land use does have a lower plant water use than perennial pastures. When coupled with summer weed control techniques, the level of water use on these areas would be low relative to well management dryland lucerne pastures <http://www.abc.net.au/science/articles/2001/08/14/345557.htm>

It is difficult to quantify what the actual change in plant water use across the landscape could be as a result of shifts in the coverage, health, and density of perennial pastures, and increases in areas land under annual cropping. Additionally this land use change data does not quantify annual vs perennial pastures, or the quality of these pastures across the areas defined as having grazing land use.

It is widely accepted and proven through past studies that healthy perennial pastures or other perennial vegetation, when paired with ground cover, provides the greatest plant water use option and hence greatest potential in recharge reduction to saline groundwater. This remains the best option we have for reducing recharge to groundwater at both the local and regional level.

Long dry periods such as the millennium drought, 2015-16 drought, and 2018-19 drought would have significantly impaired the health, vigour, density and water use potential of perennial pastures on both saline and non saline land. In particular the summer active perennial pasture base that prevails in this region of dryland lucerne, perennial veldt grass and primrose. When rainfall did return after these dry periods, these pastures would have not been in optimum condition to 'use the rain where it fell', and hence reduce recharge to groundwater.

Larger versions of Land Use Maps can be found in **Appendix 5**.

Change in vegetation cover over time can be observed in the following series of maps, showing change in Fractional Vegetation Cover.

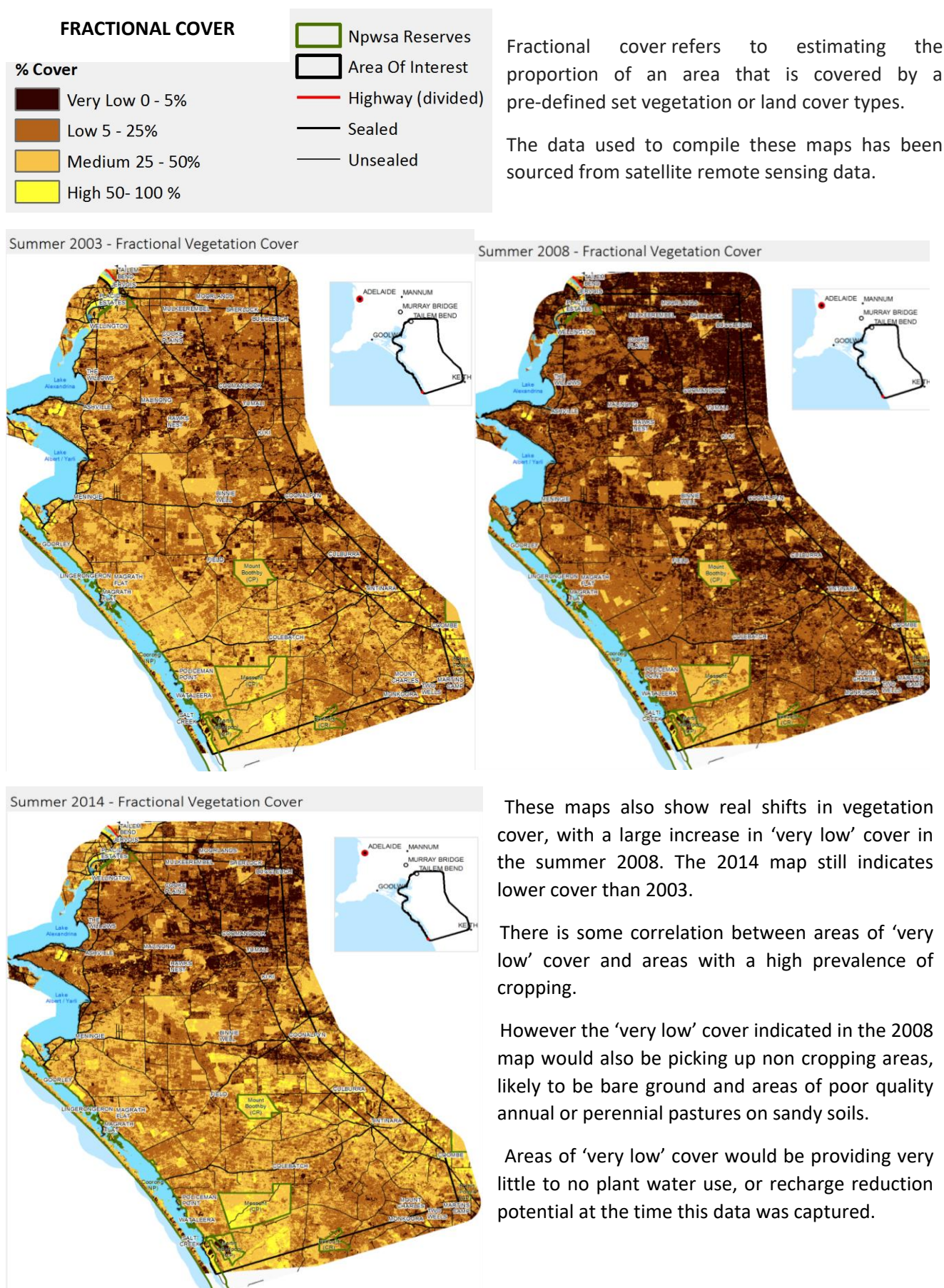


Figure 24: Fractional Vegetation Cover Maps 2003 2008 2014

12. Dryland Salinity Management Recommendations

*Information adapted from Coorong & Districts Soil Conservation Board,
Coorong & District Local Action Plan
Tracey Strugnell & Graham Gates
Coorong Tatiara Local Action Plan - Coorong & Tatiara District Councils*

This section discusses the accepted best land management practices over the last several decades to reduce recharge, address dryland salinity, and establish salt tolerant plants. All of these practices are still very relevant.

The management of dryland salinity can be divided into two sections

- 1) Attacking the cause**
- 2) Treating the effects**

12.1 Attacking the cause of dryland salinity

The main management strategy is attacking the causes of salinity is to make better use of water where it falls, in order to prevent this water from entering the groundwater system (as recharge).

This was confirmed in research undertaken by CSIRO Land and Water over the 1990's and early 2000's. The relationship was modeled between different crops and pastures and the "water balance" on a farm, presenting a breakthrough in the management of dryland salinity. The research confirmed that growing lucerne for a minimum of two years in rotation with other crops had a measurable effect in combating salinity. The researchers used huge underground "flower pots", called lysimeters, to accurately measure plant water use.

Lysimeters are steel containers 2 metres deep and 1.6 metres square, sitting on scales and were buried in the middle of the test farms. The researchers measured the weight of the container at various times to calculate the amount of water falling on and being used by the crops.

They found that planting lucerne in rotation with canola, wheat and triticale crops used more water, as did native vegetation. The study also found that other options for minimising salinity includes developing crop varieties that use more water during the growing season, and introducing companion crops into the farming system. <http://www.abc.net.au/science/articles/2001/08/14/345557.htm>

The recommended strategies to achieve this are:

1. Establish Perennial Pastures

- Perennial pastures have the advantage of being able to respond quickly to rain whenever it falls. They are also often able to make use of spring and summer rains, where annuals cannot. The deep rooted systems of perennials are able to then use more water from deep in the profile for longer periods during the year. Deep rooted perennial pastures can use up to double the water used by annual plants.
- Lucerne is a deep rooted, summer active, high water using perennial species which has productive and economic value when grown on recharge areas.

2. Consider higher water use or longer season cropping alternatives

A key recommendation of this report will be to improve our local understanding of cropping alternatives to improve plant water use under cropping rotations. Options that could be more carefully analysed include;

- Pasture Cropping, use of cover crops over Lucerne, use of Lucerne in cropping rotations,
- Increased use of summer crops such as Sorghum and Millett,

- Long season cereal varieties,
 - Cereal varieties that use more water.
- 3. Increase crop and pasture water use**
- Increase the health and productivity of crops and pastures so they are growing at their optimum production levels ensures that they are using the maximum amount of water.
- 4. Improve soil health by identifying soil constraints and ameliorating them. This improves the capacity of healthy plants to use rainfall where it falls.**
- Treating non wetting sands with clay spreading and spading
 - Treating soil acidity through spreading lime
 - Improving soil fertility through targeted application of nutrients, trace elements, or biological treatments
 - Treatment of hard pans, or nutrient poor layers in the soil through ripping, Yeomans Plough or other mechanical techniques
- 5. Establish trees and shrubs**
- Trees (particularly eucalypts) and shrubs have an annual evaporation rate of up to seven times that of surrounding annual pastures. This is due to the evergreen canopy, large leaf area and the fact that they may have their roots directly into the groundwater. Annual crops and pastures lack these features.
 - The density of trees and/or shrubs required to minimise groundwater recharge will depend on species, age and health of trees, climate, soil and position in the landscape.
 - There are a number of ways that trees and shrubs can be incorporated viably into farming systems.
 - Farm Forestry is a productive option to reduce recharge, provide stock shelter, valuable windbreak and have the potential for an economic return when harvested.
- 6. Fodder Shrubs**
- Fodder shrubs such as saltbush or tagasaste are also productive options that reduce recharge, provide shelter as well as being valuable stock feed, particularly in times of drought.
 - Perennial forage plantings that include native shrubs can extend ground cover to consolidate fragile, easily eroded soils. The use of forage shrubs for many livestock producers coupled with unfamiliarity of their advantages and short comings can limit the productivity of these plants, their effective use by grazing livestock and their contribution to soil protection. Skilled management of these plants and grazing livestock can buffer feed shortages and protect the environment
 - Experimental work carried out by the CSIRO in the Cooke Plains region demonstrated that these strategies need to be carried out over a large scale to be effective. A reduction in recharge of at least 50% and preferably 90% is needed over thousands of hectares
- <http://www.coorong.sa.gov.au/foddershrubs>

12.2 Treating the effects of dryland salinity

The second approach to the dryland salinity problem is to tackle directly the salt affected soils that result from rising water tables. Following are some strategies for rehabilitating, or at least preventing the spread of these salt affected areas.

1. Understand your Soil

- How saline is your soil? Ensure that your soil is tested. This is the first step to understanding what your options are.

2. Management of Cropping Land (land with low to moderate salinity)

- Use salt tolerant crops such as barley or canola.
- Sow salt tolerant pasture cultivars, e.g. Balansa Clover or Puccinellia.

- Grow high yielding crops and pastures to maximise plant water use.
- Aim to overcome other limiting factors ie. low fertility, disease control, weed control and seed bed preparation.
- Maintain crop and pasture residues to ensure the soil surface is covered at all times.
- Stay abreast of developments in salt tolerant cereal alternatives.

3. Management Strategies for Saline Land (land which is too saline for broad acre crops)

Salt Tolerant Pastures

- Fence off to enable the control of grazing pressure. Where possible keep this separate from annual crop and pasture land.
- Establish salt tolerant perennial pastures e.g. Puccinellia, Tall Wheat Grass, Saltbush, salt tolerant legumes.
- Encourage and maintain surface cover at all times to reduce evaporation and prevent salt from concentrating at the soil surface.
- Graze perennial pastures in Spring and Autumn and allow them to set seed on a regular basis to maintain stand density.



Left: Figure 25

Second year Puccinellia & Messina pasture on moderately saline ground at Meningie East



Right: Figure 26

Direct Seeded Native Revegetation

Revegetation

Establish salt tolerant native trees and shrubs around the edge of salt affected sites to increase water use and halt or slow down the rate of spread.

Bare Patches

- Rip area with single tyne ripper to roughen up the soil to promote the leaching of salt.
- Where possible, cover any bare patches with hay, straw, or similar material to;
 - Reduce salt concentration at the surface due to evaporation,
 - Encourage natural regeneration,
 - Reduce risk of topsoil loss.

On Farm Desalination

High SA Water mains prices are a challenge in the project area for livestock producers wholly dependent on mains water for stock. On Farm Desalination Plants are becoming more common in the project area. If technology becomes available to desalinate high salinity water economically on a small scale. It would be interesting to test if this could provide a localised draw down effect on the unconfined aquifer.

12.3 Factoring in rainfall and climatic variability

Consideration must be given to variability in rainfall and climate. Success of the plant based options discussed above is based on the assumption that there will be sufficient growing season rainfall, and in the case of summer based perennial pastures, at least some rainfall over the spring and summer.

Long dry periods such as the millennium drought, 2015-16 drought, and 2018-19 drought would have significantly impaired the health, vigour, density and water use potential of perennial pastures on both saline and non saline land. In particular the summer active perennial pasture base that prevails in this region of dryland lucerne, perennial veldt grass and primrose. When rainfall did return after these dry periods, these pastures would have not been in optimum condition to 'use the rain where it fell', and hence reduce recharge to groundwater.

12.4 Dryland Salinity Management Resources

Over the 1980's through to the early 2000's there was a wealth of salinity management resources produced on; soil and water testing, perennial pastures, saltbush, and more.

Links to many of these resources that are relevant to this region have been compiled at;

www.coorong.sa.gov.au/salinity

www.coorong.sa.gov.au/saltlandpastures

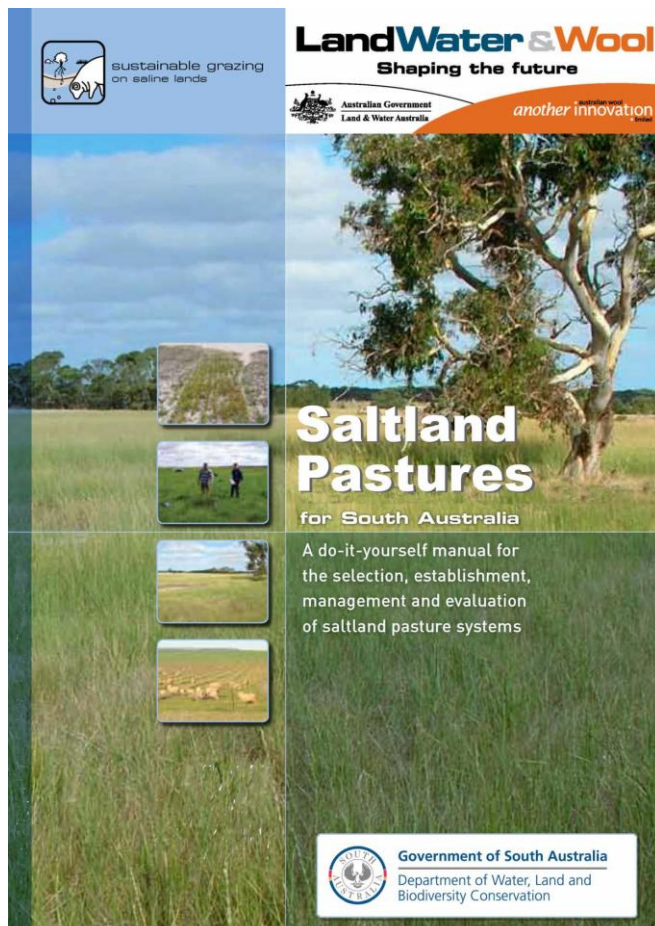
Recent findings from the Saltland Pasture Redemption Project can be accessed at

www.coorong.sa.gov.au/saltlandredemption A focus of this project has included exploring how the salt tolerant legume Neptune Messina grows in local conditions.

An excellent resource that is still extremely relevant is the 'Saltland Pastures for South Australia Manual'.

A summary of the contents of this document can be found at **Appendix 6**, or at

[http://www.coorong.sa.gov.au/webdata/resources/files/salt-land-pastures-SA-manual_20\(2\).pdf](http://www.coorong.sa.gov.au/webdata/resources/files/salt-land-pastures-SA-manual_20(2).pdf)



12.5 Current Projects

Information on the **Saltland Pasture Redemption Projects** can be accessed at

www.coorong.sa.gov.au/saltlandredemption A focus of this project has included exploring how the salt tolerant legume Neptune Messina grows in local Coorong District conditions, and use of mulching to reduce evapo-concentration of salts at the soil surface.

A series of **Mallee Seeps Projects** have and are being delivered in the Mallee to better understand this landscape phenomena. More information and access to Mallee Seeps resources can be found at

<https://www.naturalresources.sa.gov.au/samurra/ydarlingbasin/land-and-farming/soils/mallee-seeps>

Coorong Tatiara Local Action Plan will be delivering a National Landcare Program 2 project developing new dryland salinity resources for land managers over 2019-2021.

13. Report Summary

This is what is occurring

Dryland salinity began to reappear on a number of farms in the latter part of the 2010 decade in the Coomandook / Meningie West area.

An examination of groundwater trends for the shallow unconfined aquifer indicates that significant rises in watertable levels have occurred since 2010. Subtle depressions in the landscape are high risk areas for salinity to appear following watertable rises.

Even though watertables are starting to fall again under dry conditions, salinity is getting worse due to higher evaporation rates and less rainfall to flush salt out of the soil profile once the salt has accumulated.

This is why it is occurring

Dryland salinity is the result of groundwater discharge occurring from the unconfined watertable aquifer and not from the deeper regional system.

Long term groundwater records from numerous monitoring bores/wells/piezometers indicate that a close relationship exists between calculated rainfall trends and depth to watertable trends.

Recharge to groundwater occurs across the whole landscape when the soil profile cannot hold all of the stored moisture which then drains down to the watertable. This occurs to a much greater extent following large episodic (especially out of season) rainfall events. These events are becoming more common under a 'climate change' scenario.

Some sites do not follow the rainfall trend (e.g. rising watertables with decreasing rainfall). Broader issues are influencing the watertable trend. The longer term increase in the level of the unconfined aquifer levels, overlaid with spikes after rainfall events, may partly reflect this trend. Increases may also be linked to the changes in land use and vegetation cover. This reflects the increase in; -area cropped, -very effective summer weed control, -and potentially areas of poor quality annual or perennial pastures with a low capacity for plant water use. These changes may partially explain the trend of rising groundwater.

This is what we can do about it

Because of the characteristics of this unconfined aquifer (i.e. highly transmissive sand/limestone), high water use strategies to prevent excess recharge need to be carried out over a broad area of the region to be successful. In practice, this is required over large areas, not just one farm.

Under current technology, smart soil moisture monitoring can be an early warning alert for potential high recharge events.

Flexible farming practices may be required to deal with extreme climatic patterns.

Saltland agronomy will always have a role to play and needs good demonstration sites of successful productive alternatives to broad scale cropping.

Recommendations going forward

- Further targeted monitoring after large and intense rainfall events, & to understand the relationship between dry conditions, evaporation and groundwater rise.
- The need for a technical and land manager panel to review outcomes arising from this report
- Government commitment to fund consistent groundwater, land use, and climatic monitoring in non-prescribed high risk salinity regions of the state,
- More research is required to determine the impact of changed farming practices, climate and rainfall variability on groundwater recharge and the expression of dryland salinity in the landscape.

14. Key Recommendations

No	Section	Government / Funding Body Recommendations	Land Manager Recommendations
2	Salinity Risk Mapping Coomandook – Cooke Plains Meningie East	Consult with landholders in affected localities to ensure the accuracy of the maps Establish options to undertake salinity risk mapping in the Tintinara West area Do not put the Salinity Risk Maps on line or release publically	If you have dryland salinity occurring on your land, and it is not shown on the maps In Section 2 please contact the Coorong Tatiara Local Action Plan.
3	Coorong Dryland Salinity Survey	Consider expanding the survey catchment to encompass the Tintinara West area Ensure that these results are actively promoted to relevant agencies and funding bodies, to ensure they understand the current impact of dryland salinity	If you have dryland salinity occurring on your land, and you do not believe that you have been included the the Dryland Salinity Survey please contact the Coorong Tatiara Local Action Plan for your data to be captured.
4 4.7	Coorong Dryland Salinity Description and Impacts Dryland Salinity and Climate Variability	Improve awareness of the interactions between climatic variations and groundwater trends could inform farm management decisions that respond to episodic rainfall events. Consider putting together projects that measure soil moisture after episodic rainfall events, and agronomic options to use up soil moisture after episodic rainfall events.	Improve awareness of the interactions between climatic variations and groundwater trends could inform farm management decisions that respond to episodic rainfall events. Consider trying out agronomic options to use up soil moisture after episodic rainfall events.
5 5.1	Watertable trends Coomandook – Meningie Hydrogeological Summary Overview	Provide clear explanations of this relationship in updated dryland salinity information updates Continue recommendation and pursuit of landscape scale projects that promote; high water use perennial vegetation, soil and farming management techniques that promote the concept of using maximum rainfall where it falls in the landscape Promote management of existing perennial pasture stands to maximise plant water use and production Advise current and and new landholders of the existence of	Consider how to incorporate or try out higher water use options in your farming landscape as discussed in Section 12 Dryland Salinity Management Recommendations Recharge reduction needs to be carried out on a very large scale (i.e. thousands rather than hundreds of hectares. Individually, farmers undertaking recharge reduction management on a single paddock will not make a difference, but collectively, many farmers doing the same thing can make a difference. Continue implementing saltland agronomy and mulching options post flushing events to decrease concentrated salinisation through evapo-concentration / ‘wicking up’

5.2	Previous Research	<p>piezometers on their land and their significance</p> <p>Consider ways to protect the piezometers</p> <p>Consider finding ways to support land owners to collect groundwater level data themselves and provide data input</p>	<p>Advise current and and new landholders of the existence of piezometers on their land and their significance</p> <p>Consider ways to protect the piezometers</p>
5.3	Watertable Trends Analysis	<p>Consider restarting the 'Salt Watch' flag system to improve awareness</p> <p>Ensure that the concerns in regard to reduced funding and monitoring of groundwater network is communicated clearly to relevant agencies and funding bodies, to ensure they understand the current impact of dryland salinity</p> <p>For each region, key strategic sites should be identified for consistent long term monitoring. Key watertable monitoring wells need to be adequately identified, labelled and protected from damage by stock, farming operations etc.</p>	<p>Ensure that the concerns in regard to reduced funding and monitoring of groundwater network is communicated clearly to relevant agencies and funding bodies, to ensure they understand the current impact of dryland salinity</p> <p>For each region, key strategic sites should be identified for consistent long term monitoring. Key watertable monitoring wells need to be adequately identified, labelled and protected from damage by stock, farming operations etc.</p>
No	Section	Government / Funding Body Recommendations	Land Manager Recommendations
6	Coorong Hydrogeological Systems Basement rocks of the Padthaway Ridge	<p>Increase land management interventions;</p> <ul style="list-style-type: none"> -Perennial vegetation, -Healthier perennial pastures, and -Using rainfall where it falls, <p>Localised treatments may have a higher likelihood of effectiveness on the western side of the Range in the Meningie East area</p>	<p>Increase land management interventions;</p> <ul style="list-style-type: none"> -Perennial vegetation, -Healthier perennial pastures, and -Using rainfall where it falls, <p>Localised treatments may have a higher likelihood of effectiveness on the western side of the Range in the Meningie East area</p>
9	Watertable Trends & Graphs Results & Discussion	<p>Provide clear explanations of this information in updated dryland salinity information updates</p> <p>Look for opportunities to establish new piezometers to improve monitoring opportunities in the Tintinara West area</p> <p>Ensure that the trend of rising groundwater over time is communicated clearly to relevant agencies and funding bodies, to ensure they understand the current impact of dryland salinity</p>	<p>Check watertable trends around you by checking the well map In Figure 17 page 15, and the Graphs in Appendix 4</p> <p>Ensure that the trend of rising groundwater over time is communicated clearly to relevant agencies and funding bodies, to ensure they understand the current impact of dryland salinity</p>
10	Coorong Dryland Salinity Mythbusting	<p>Develop a fact sheet series to lay out the key information in this Section 10. Coorong Dryland Salinity Mythbusting.</p> <p>In particular;</p> <ul style="list-style-type: none"> - Impact of lake levels on watertables and dryland salinity 	<p>Consider the information in this section carefully, to inform future land management decisions.</p>

		<ul style="list-style-type: none"> - 'Underground Rivers' pressure pushing down from the Mallee - Why isn't there an immediate response to high rainfall events? - Why does dryland salinity get worse in a dry year? - Why do the best crops occur before the ground goes saline? - Is the unconfined aquifer pressurised? 	
No	Section	Government / Funding Body Recommendations	Land Manager Recommendations
11	Land Use Change and Vegetation Cover	<p>Explore whether any data exists to show improved vs unimproved pasture over time across the study area</p> <p>Work with landholder groups to discuss options for improving water use in cropping systems, and improved water use in mixed farming systems</p>	<p>Consider whether plant water use could be improved across your farm enterprise through;</p> <ul style="list-style-type: none"> - Use of more perennial plants in your farming system - Improving soil health and reducing limitation to enhance capture of rain where it falls - Work with grower groups to explore how to improve water use in cropping systems. Options are discussed further in Section 12.
12	Dryland Salinity Management Recommendations	<p>Review extension material, update and make accessible to land managers</p> <p>Work with grower groups to explore how to improve water use in cropping systems. Options are discussed further in Section 12.</p> <p>Work with grower groups to explore how to improve soil health by identifying soil constraints and ameliorating them. Improving the capacity of healthy plants to use rainfall where it falls. Options are discussed further in Section 12.</p> <p>Careful consideration must be given to the following paragraph. How will agencies and advisers reconsider the perennial plant based solutions in light of recent climate and rainfall variability? <i>Long dry periods such as the millennium drought, 2015-16 drought, and 2018-19 drought would have significantly impaired the health, vigour, density and water use potential of perennial pastures on both saline and non saline land. In particular the summer active</i></p>	<p>Consider whether plant water use could be improved across your farm enterprise through;</p> <ul style="list-style-type: none"> - Use of more perennial plants in your farming system - Improving soil health and reducing limitation to enhance capture of rain where it falls <p>Work with grower groups to explore how to improve water use in cropping systems. Options are discussed further in Section 12.</p> <p>Work with grower groups to explore how to improve soil health by identifying soil constraints and ameliorating them. Improving the capacity of healthy plants to use rainfall where it falls. Options are discussed further in Section 12.</p> <p>Careful consideration must be given to the following paragraph. How do farmers, land managers, and advisers reconsider the perennial plant based solutions in light of recent climate and rainfall variability. <i>Long dry periods such as the millennium drought, 2015-16 drought, and 2018-19 drought would have significantly impaired the health, vigour, density and water use potential of perennial pastures on both saline and non saline land.</i></p>

		<i>perennial pasture base that prevails in this region of dryland lucerne, perennial veldt grass and primrose. When rainfall did return after these dry periods, these pastures would have not been in optimum condition to 'use the rain where it fell', and hence reduce recharge to groundwater.</i>	<i>In particular the summer active perennial pasture base that prevails in this region of dryland lucerne, perennial veldt grass and primrose. When rainfall did return after these dry periods, these pastures would have not been in optimum condition to 'use the rain where it fell', and hence reduce recharge to groundwater.</i>
13	Report Summary	<p>Because of the characteristics of this unconfined aquifer (i.e. highly transmissive sand/limestone), high water use strategies to prevent excess recharge need to be carried out over a broad area of the region to be successful. In practice, this is required over large areas, not just one farm.</p> <p>Consider the place of smart soil moisture monitoring as an early warning alert for potential high recharge events.</p> <p>Saltland agronomy will always have a role to play and needs good demonstration sites of successful productive alternatives to broad scale cropping.</p> <p>Further targeted monitoring after large and intense rainfall events, & to understand the relationship between dry conditions, evaporation and groundwater rise.</p> <p>A technical and land manager panel to review outcomes arising from this report</p> <p>Government commitment to fund consistent groundwater monitoring in non-prescribed high risk salinity regions of the state More research is required to determine the impact of changing farming practices on groundwater recharge and dryland salinity.</p>	<p>See recommendations above in 12. Flexible farming practices may be required to deal with extreme climatic patterns.</p> <p>Saltland agronomy will always have a role to play and needs good demonstration sites of successful productive alternatives to broad scale cropping.</p> <p>Further targeted monitoring after large and intense rainfall events, & to understand the relationship between dry conditions, evaporation and groundwater rise.</p> <p>A technical and land manager panel to review outcomes arising from this report</p> <p>Seek Government support for a consistent groundwater monitoring in non-prescribed high risk salinity regions of the state</p>



Appendix 1: Background

SAMDB NRM BOARD BRIEFING PAPER

SA Murray-Darling Basin NRM Board Briefing Paper

Briefing Paper Agenda Item: **xx**

Meeting No. **xxx**

Meeting Date: **xxx**

Author: Tony Randall, Team Leader, Sustainable Agriculture

Subject: Dryland Salinity in the SAMDB NRM Region

1. Purpose

To provide the SAMDB NRM Board with an update on dryland salinity issues in the Coomandook, Cooke Plains, and Sherlock areas.

2. Background / Discussion

Dryland salinity has been a significant issue in many Southern Australian farming regions from the later part of the last century. Australian Government investment in the understanding and management of dryland salinity peaked from 2003 to 2009 through the establishment of a major national program, The National Action Plan for Salinity and Water Quality (NAP), which aimed to prevent, stabilise, and reverse trends in salinity. The NAP allocated \$1.4 billion of public funds to 1700 projects over the 7 years of the programs existence and was largely successful in determining the cause and effect of dryland salinity, and in identifying, testing and promoting a range of management options. In the SAMDB NRM Region, these largely involved the lowering of water tables through the strategic planting of perennial vegetation including productive perennial pastures, fodder shrubs, farm forestry, and native vegetation. Delivery and implementation was supported with landholder incentive schemes funded through NAP and the Australian Government's National Heritage Trust (NHT), and this support saw increased adoption and implementation of management actions and perennial vegetation establishment.

The Coomandook and Cooke Plains area (see figure 1) have been identified as having high potential for dryland salinity formation (see figure 2) due to the low lying nature of some parts of this landscape and it's proximity to the regional groundwater system drainage point to the Lower Murray Lakes and Coorong. Significant management actions were adopted by land owners throughout this area during the NAP and NHT programs, in particular the establishment of Lucerne and farm forestry to address rising groundwater tables and associated salinisation of soils. The Coorong Tatiara Local Action Plan (CTLAP) played a pivotal role in encouraging and supporting land owner adoption of these management actions through awareness raising and education programs and the delivery of incentive payment schemes to encourage perennial vegetation establishment. As a result, the spread of dryland salinity was thought to have been halted in the area.

Since the completion of the NAP, public investment in salinity management has been modest, with some practitioners declaring that the issue had been sufficiently investigated and addressed. Whilst this was somewhat true at the time of NAP completion, farming systems and associated landscapes have undergone significant transformation since that time with greater adoption of continuous cropping under no till farming systems, reductions in perennial vegetation cover in the landscape and changes to climate.

In recent years there has again been an increase in area affected with a recent land owner survey from the area revealing that 1610 Ha of good arable land has been lost to dryland salinity in the past 5 years, and land owners estimating that a further 2159Ha will be lost in the next 5 years if current trends continue.

In 2016, the CTLAP organised a public meeting at the Coomandook Hall to discuss the issue and seek local land owner ideas about the cause of salinity resurgence and potential remedies. Over 100 people attended including 80 land owners. Key issues of concern were loss of arable land, wind erosion on bare saline soils, and impacts on adjacent paddocks. A range of options to address the issue were discussed and collated, and through further community consultation, the Coomandook Saltland Redemption Project was developed. The project largely focused on the establishment of saltland pastures to provide vegetative cover and regain some productive capacity on bare salt affected soils. The introduction of a new waterlogging and salt tolerant legume, 'Neptune Messina', as a complimentary plant to the tried and true saltland pastures; Tall Wheat Grass and Puccinellia was a key part of the project. This was funded by the SAMDB NRM Board with significant contributions from the CTLAP and a wide range of agricultural retailers including Landmark Cooke Plains, Elders Murray Bridge, and Seednet.

Trial work establishing Neptune Messina in saltland pastures commenced in 2017 and continued through 2018 with mixed success due to salinity levels being variable and above the Messina tolerance of up to 30 ds/m (sea water is 50 dS/m) in some places. Land owners also trialled the use of manure and straw mulches to reduce evaporation and in turn, salinity levels. Success has been mixed and the dry year experienced in 2018 has not been favourable to the trials.

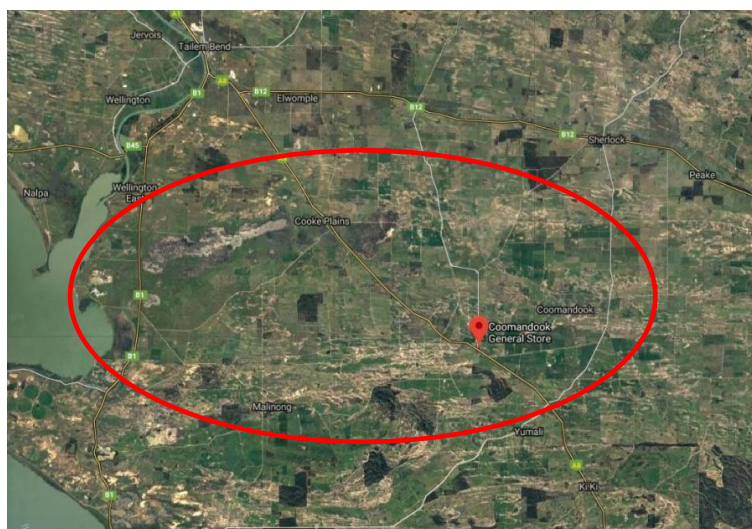


Image 1: area impacted by dryland salinity

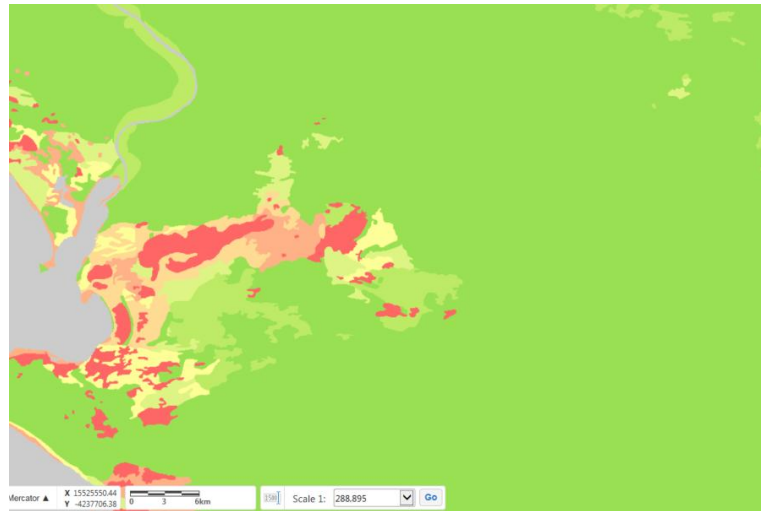


Image 2: State mapping of Dryland Salinity Potential. The impacted area now extends beyond the areas shown as having potential for salinity formation.

The dry season experienced in 2018 has caused a significant increase in affected area throughout the district due to low rainfall levels to dilute soil salts and ‘flush’ them below the root zone, and increased evaporation causing greater concentration of salts at the soil surface. A number of large areas that have not previously been affected by dryland salinity are now unable to support cereal crop growth due to salinisation in the past 12 months. Some of these areas consistently produced yields well above district average prior to the current year, thus is the speed and ferocity at which dryland salinity has spread this year.

Another area of dryland salinity is also present in the area to the East of Meningie. This is unusual as the landscape is dominated with perennial pastures and perennial vegetation with no annual cropping practiced. It is thought that improvement in pasture and grazing management to improve plant vigour and water requirement could address this issue to some degree. The affected area is predominantly in the South East NRM Region at present but is on and around the regional boundary. This has the potential to spread to the SAMDB Region in time if the issue worsens and management options are not employed to address the rising water table. The CTLAP are working on this with limited resources

A key concern is that Dryland Salinity is not specifically mentioned in current National Landcare Funding Programs including the Regional Land Partnerships funding recently received by the Board. This makes accessing funding to investigate and address the issue more difficult.

3. Budget/ Financial

A total of \$15,000 (GST Exc.) of Regional land Partnerships Sustainable Agriculture Program funds have been granted to the Coorong District Council this financial year. This follows on from similar levels of investment (\$15,000 (GST Exc.) per annum) over the past two financial years to investigate saltland agronomy options on affected saline areas. Additionally, the Board has funded field days and workshops totaling \$10,000 over the past three years.

The CTLAP has attracted over \$100,000 in funding from the Australian Government through The Mallee Sustainable Farming Smart farms Partnerships funded Mallee Seeps Project (\$20,000 per annum for four years), and a Small Smart Farms Grant \$28,000. These are both for the development and implementation of trials and management actions.

Additional work is required to develop case studies on identification of on farm risk areas, management options and the optimal areas to employ those options. Funding is not available for this work at this time through the Region, DEW or PIRSA. Opportunities exist to apply for funding through the Australian Government’s Smart Farming Small Grants program released on November 14th 2018.

4. Risks

Is the risk captured on the Board's risk register? No.

5. Recommendation (s)

The Board endorsed the recommendation:

To Note the resurgence of dryland salinity in the Coomandook, Cooke Plains, Sherlock, and Meningie East areas with a view to stay updated on the issue and support project initiatives as appropriate and as resources permit.

Appendix 2: Background



SE NRM BOARD BRIEFING PAPER

SE NRM Board - Summary

Subject: Dryland Salinity in the SE NRM Region

Purpose

To provide the SE NRM Board with an update on Dryland Salinity issues in the Meningie East, and Coomandook/Cooke Plains areas. (These areas straddle our NRM boundary with SAMBD and the SAMDB Board has received a similar update. In general the Meningie East area has more affected land in the SE region and the Coomandook/Cooke Plains area has more affected land in the SAMBD region).

Background / Discussion

Dryland Salinity has been a significant issue in many Southern Australian farming regions from the later part of the last century. Australian Government investment in the understanding and management of dryland salinity peaked from 2003 to 2009 through the establishment of a major national program, The National Action Plan for Salinity and Water Quality (NAP), which aimed to prevent, stabilise, and reverse trends in salinity. The NAP allocated \$1.4 billion of public funds to 1700 projects over the 7 years of the programs existence and was largely successful in determining the cause and effect of dryland salinity, and in identifying, testing and promoting a range of management options.

Since the completion of the NAP, public investment in salinity management has been modest, with some practitioners declaring that the issue had been sufficiently investigated and addressed. Whilst this was somewhat true at the time of NAP completion, farming systems and associated landscapes have undergone significant transformation since that time with greater adoption of continuous cropping under no-til farming systems, reductions in perennial vegetation cover in the landscape and changes to climate.

In recent years there has again been an increase in area affected with a recent land owner survey from the area revealing that 225 ha of arable land in Meningie East and 1610 ha in Coomandook/Cooke Plains has been lost to dryland salinity in the past 5 years, and land owners estimating that a further 130 ha in Meningie East and 2159 ha in Coomandook/Cooke Plains will be lost in the next 5 years if current trends continue.

A meeting to discuss the issue was held in DEW's Waymouth St office on 14 November with Garry Hansen & Paul Simmons (Coomandook Ag Bureau), Roger Wickes (Mallee Coorong NRM Group), Steve Barnett & Tim Hermann (DEW), Chris Hentschke & Brian Hughes (Rural Solutions), Tony Randall (NR SAMDB), Matt Honner (NRSE), Tracey Strugnell and Graham Gates (CTLAP) in attendance. Gary Hansen expressed his belief that in the Coomandook/Cooke Plains area, recent changes to continuous cropping under no-til systems are contributing to the rising groundwater levels which is driving the dryland salinity process (the Meningie East area is dominated by perennial pastures and perennial vegetation so not as likely to be influenced by changes in cropping systems). There is little research in this field owing to the very recent adoption of no-til systems (last five years).

Budget/ Financial

CTLAP has secured project support for the collation and synthesis of historical hydrogeological, test well, rainfall, evaporation and land use information and reports. The project will see the application of this information to the modern farming systems employed in the area to determine the causes of dryland salinity resurgence in the district and the potential impact areas. CTLAP are hoping to use the project to leverage more funding or support. A key concern is that Dryland Salinity is not specifically mentioned in current National Landcare Funding Programs. This makes accessing funding to investigate and address the issue more difficult.

Additional work is required to develop case studies on identification of on farm risk areas, management options and the optimal areas to employ those options. Funding is not available for this work at this time through the Region, DEW or PIRSA. Opportunities exist to apply for funding through the Australian Government's Smart Farming Small Grants program released on November 14th 2018.

Appendix 3: Stakeholder Survey

SALT LAND REDEMPTION PROJECT STAKEHOLDER SURVEY

We are doing this survey because;

We want to quantify the extent of the salinity issue to assist in attracting support & funding.

To provide collated data for reporting to our current funding bodies.

PLEASE FAX BACK ASAP TO 8757 2222 or EMAIL ggates@coorong.sa.gov.au

Name:

Hundred:**Section(s)**

What new areas have been affected by dryland salinity in the last 5 years?Hectares

How much land do you think is at risk over the next 5 years?Hectares

What do you think is contributing to this increase in dryland salinity?

.....
.....
.....

Have you undertaken any activities to address this?

.....
.....
.....
.....

Is there anything different you would like to try to address this?

.....
.....
.....
.....

How much perennial pasture do you plan to establish in the next 5 years?,
.....hectares of *(eg lucerne)*

Can we remain in contact with you in regard to dryland salinity projects and monitoring?

Yes ☐ No ☐

What is the best phone number and email address to contact you on?

Phone:

Email:

Appendix 4: Groundwater and Rainfall Trends

Chris Henschke— Senior Consultant Hydrogeology
PIRSA Rural Solutions

4.1 Coomandook – Cooke Plains Site Location Information & Hydrographs

The table shows a list of 12 wells (from the DEW WaterConnect groundwater network) that are currently being monitored in the Coomandook – Cooke Plains focus area. These are displayed in the WaterConnect website in the following Obswell networks: Peake, Roby & Sherlock PWA (PEAKE), SAMDB Non-prescribed area (SAMDB_NP) and Tintinara Coonalpyn PWA (TINT_COON). All of the wells listed are in the unconfined Qpcb aquifer.

Water level data is available on the Department of Environment and Water (DEW) website. The address is www.waterconnect.sa.gov.au. The Obswell tab on the Groundwater Data page can be used to find records for each water well.

Obswell No.	Obswell Network	Field Name	Location / Property / Landholder	Date Drilled / dug	Total Depth (m)
SHK003	PEAKE	CM1	Sherlock	08/04/1987	10.50
SHK005	PEAKE		Moorlands	14/02/1991	11.00
SHK006	PEAKE		Buccleuch	07/08/1992	5.50
RBY003	PEAKE		Coomandook	14/03/1987	20.00
RBY004	PEAKE		Cooke Plains	unknown	2.14
RBY008	PEAKE		Hannah Well Rd	06/05/1949	13.72
RBY015	PEAKE		Coomandook town	12/04/2003	6.59
RBY016	PEAKE		Gas Pipeline Lane	19/10/2005	9.0
PEK003	PEAKE		Peake	08/08/1992	11.00
MAL002	SAMDB_NP		Ashville	26/09/1989	30.00
CLN001	SAMDB_NP		Malinong	04/12/1951	37.49
LVG001	TINT-COON		Netherton Road	09/04/1987	16.5

Photographs have been taken by DEW at each monitoring site in the network and are presented to display the site in context of the surrounding land use.



SHK003. Photo taken Monday, 15 December 2014. Download

SHK003 is on a reserve in Sherlock town



SHK005. Photo taken Thursday, 19 April 2018. Download

SHK005 located on a roadside



SHK006. Photo taken Monday, 15 December 2014. Download

SHK006 near an existing windmill & tank



RBV003. Photo taken Monday, 16 April 2018. Download

RBV003 is in a highly saline scald



RBV004. Photo taken Friday, 1 April 2016. Download

RBV004 is an old open well



Observation Well. Photo taken Monday, 8 October 2012. Download

RBV008 is an old abandoned well



Observation Well. Photo taken Monday, 8 October 2012. Download

RBY015 in the town of Coomandook



RBY016. Photo taken Monday, 16 April 2018. Download

RBY016 on Gas Pipeline Lane



PEK003. Photo taken Monday, 15 December 2014. Download

PEK003 is on a farm property



MAL002. Photo taken Wednesday, 18 April 2018. Download

MAL002 occurs in dune swale topography



Observation Well. Photo taken Monday, 8 October 2012. Download

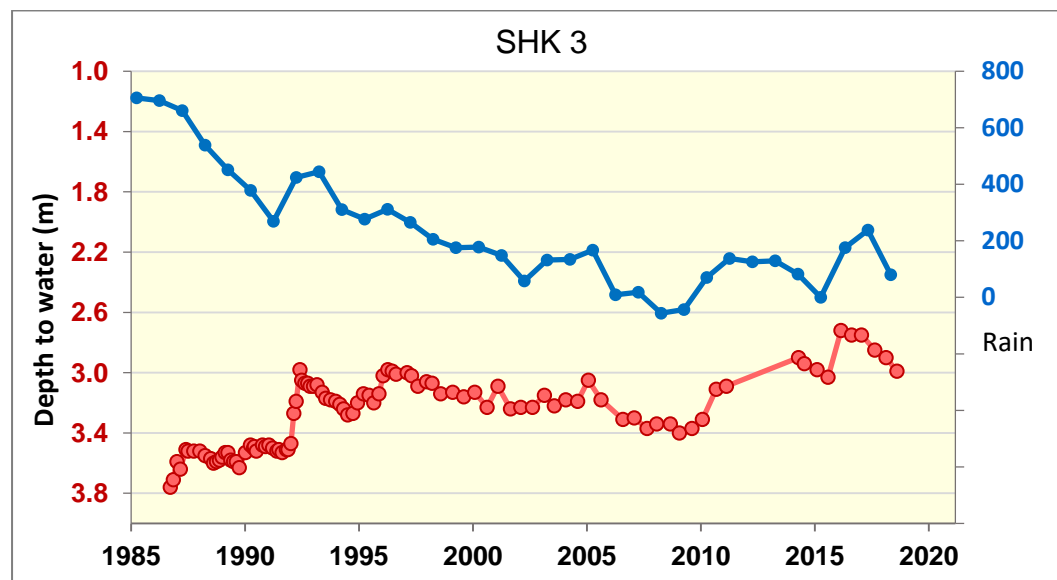
CLN001 is an abandoned bore / windmill



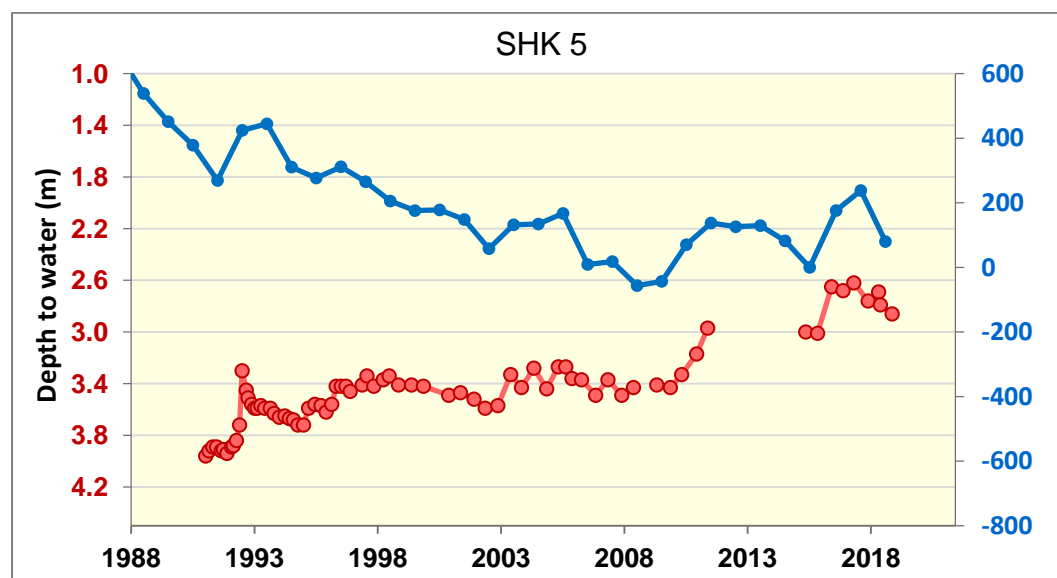
Observation Well. Photo taken Tuesday, 9 October 2012. Download

LVG001 on a roadside

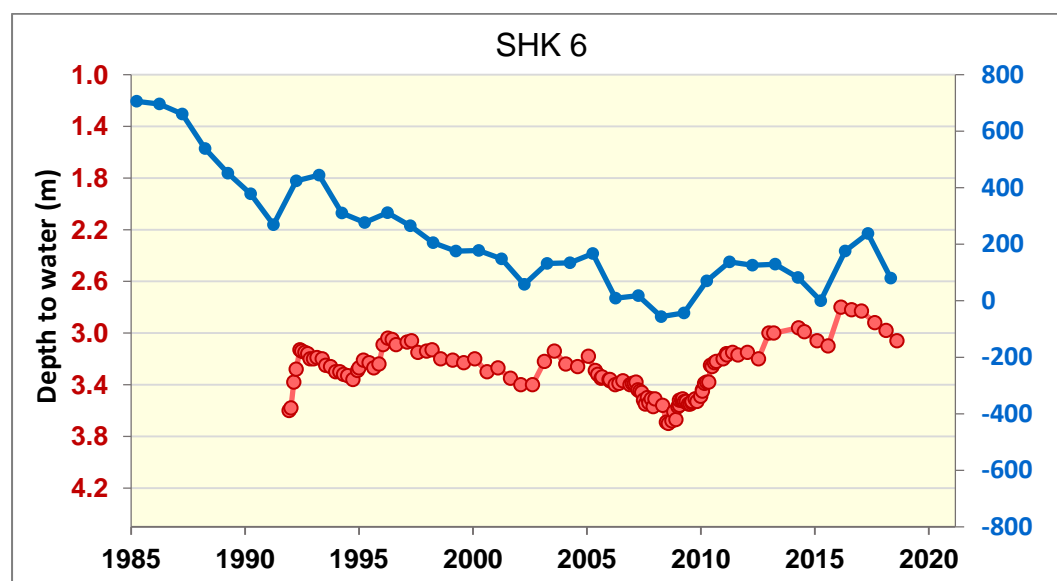
SHK003: This bore occurs on a road reserve in Sherlock town site and was drilled in April 1987 to a depth of 10.5m. The depth to water shows an overall rise in the period 1990 – 1997 followed by a static to falling trend up until 2010. There was another rising trend up until 2017 where the highest water level on record occurred. The trend can be summarised as an episodic rising trend. It shows large rises in depth to water for particular rainfall events which may be due to cemented layers causing a change in the aquifer porosity. The depth to water tends to mirror the residual accumulative rainfall trend except prior to 1990 where the rainfall curve was falling but groundwater levels were rising.



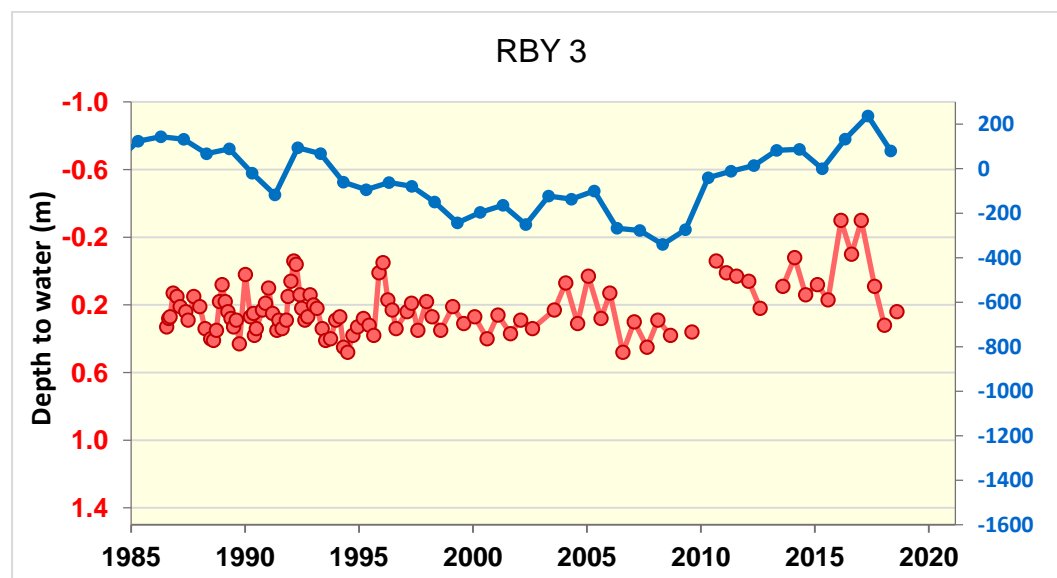
SHK005: This borehole was drilled in the Sherlock area in 1991 to 11m depth. The depth to water similarly displays an episodic rising trend with large responses observed in 1992 and 2009 to 2011. The very wet spring of 2016 resulted in the highest water level on record (NB: a gap in the record occurs between 20011 and 2015). The depth to water tends to mirror the residual accumulative rainfall trend except in the period from the mid-90s to 2010 where the rainfall curve was falling but groundwater levels were rising in this overall period.



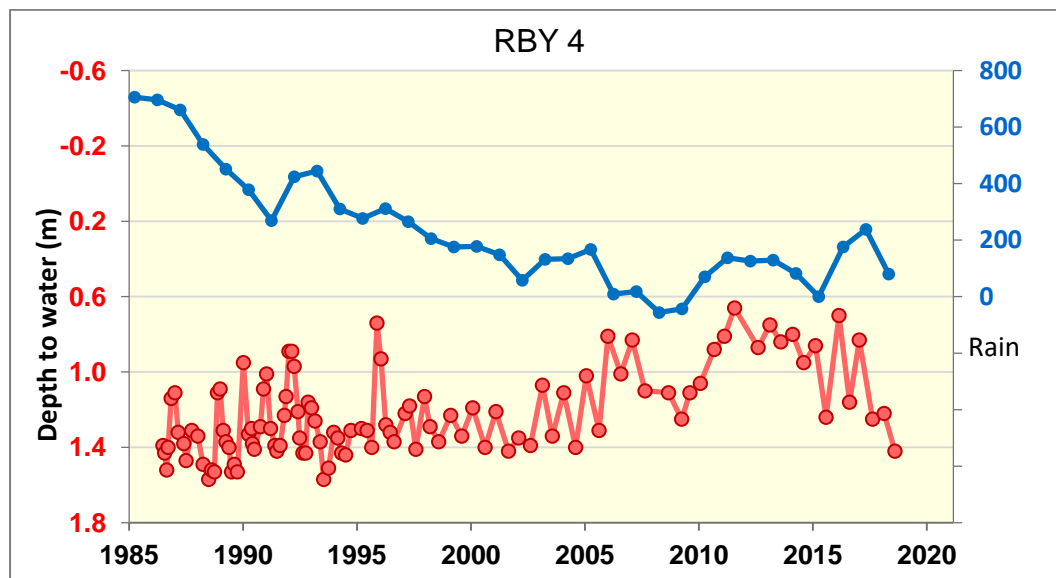
SHK006: This borehole was drilled in 1992 to 5.5m depth in the Sherlock area. Watertable rises are apparent in the wet seasons of 1992, 1996/97, 2004/05, 2010/11 and 2016. Watertable declines occurred in the dry years of 1993-95, 2002, 2006-09 and 2018/18. These rises and falls closely mirror the residual accumulative rainfall trend. The watertable has shown a continuous rise, rather than a spike in the period 2010 to 2015 and then reached its highest level on record in 2016. This significant episodic rise of the watertable provides a clue as to why dryland salinity re-emerged in the Coomandook area during 2017.



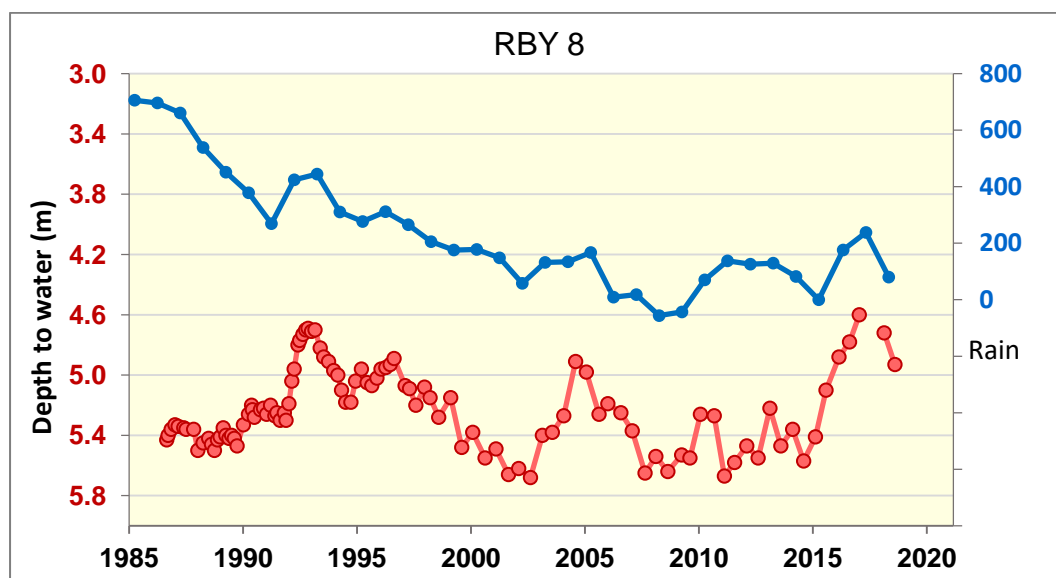
RBV003: This bore was drilled to 20m in 1987. It is located between Cooke Plains and Coomandook. The depth to water responses are very 'spiky' as the watertable is very close to the ground surface. The negative depth to water values indicate that the watertable rises above the surface following heavy rainfall. The hydrograph displays a typical winter / seasonal trend with annual highs and lows. There is an overall rising trend apparent from 2000 to 2018.



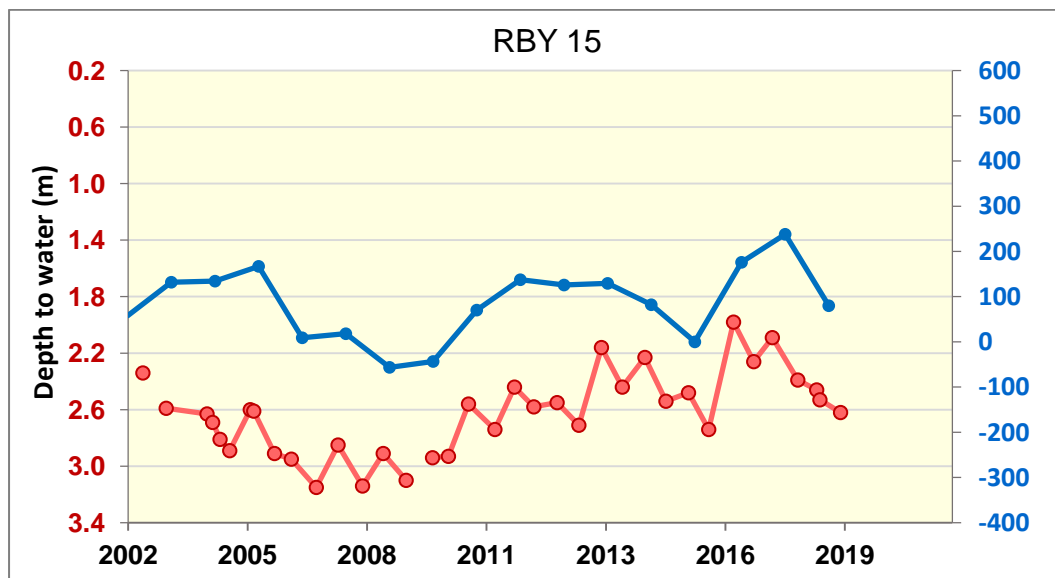
RBV004: This is a narrow diameter (0.5m) hand dug well to a depth of 2.14m in calcrete rock. It is located southeast of Cooke Plains and has a monitoring record going back to 1987. As the watertable is very shallow it is expected to show strong seasonal fluctuations (winter spikes). As the watertable is within 1.5m of the soil surface, the surrounding area could be expected to be impacted by soil salinity. It goes against the long term rainfall trend which has been falling but the shallow watertable shows an overall rising trend with time.



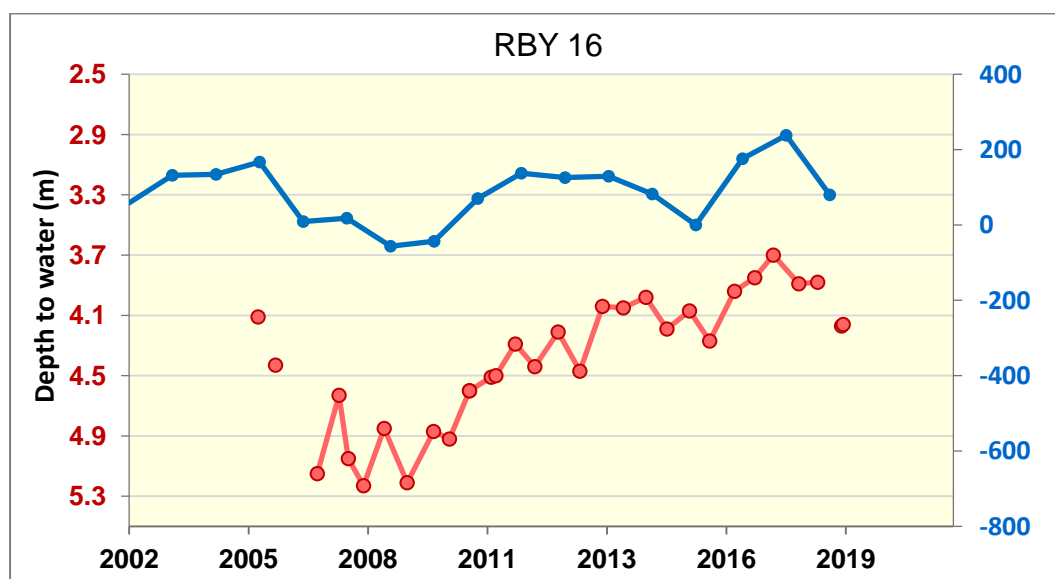
RBV008: Is located on Hannah Well Road just west of Coomandook. The old disused windmill still stands over a hand dug well which is 1.5m in diameter. The well has a continuous record going back to 1987. Again, there is a reasonably good match between rainfall and watertable level trends. There was a significant watertable rise of +1.0m between 2015 and 2017 reflecting the high amount of rainfall experienced during this period.



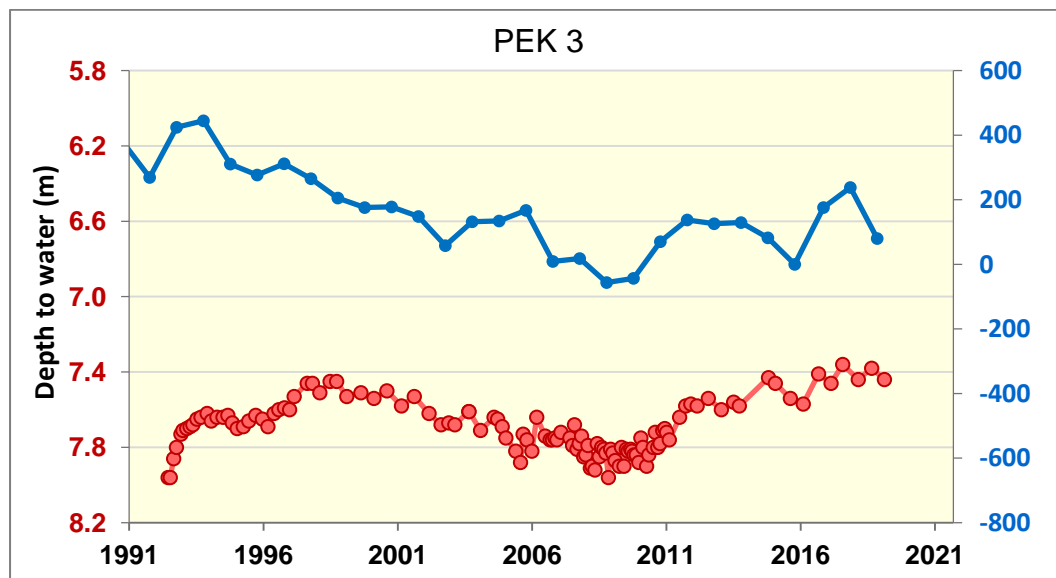
RB015: This site is located in the town of Coomandook opposite the general store. The bore was drilled by the then Dept. of Mines and Energy to a total depth of 6.6m. The purpose was to investigate damage to grain silos from shallow saline groundwater. The bore could be considered as a 'control site' that reflects the surrounding agricultural land. Depth to water level shows a falling trend (-0.8m) from 2004 to 2008 but with a 'spike' in 2005 reflecting a wet winter. There is a rising trend (+1.2m) from 2010 to 2017. Seasonal peaks and troughs are to be expected as the watertable gets closer to the ground surface.



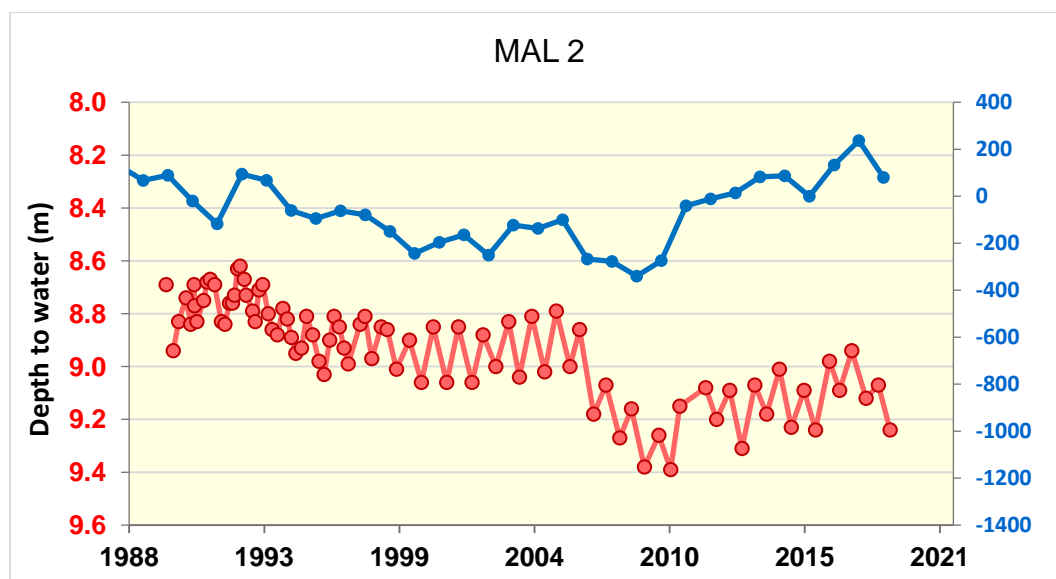
RB016 (CM1): This monitoring obswell was drilled in October 2005 to 9m depth. It is located on private property adjacent, Gas Pipeline Road and was intended to monitoring a stand of newly established Lucerne. Topographically it occurs in a swale at base of large sand dune. The borehole was rehabilitated in June 2007 as the PVC riser tube had snapped off at ground level. A new reference point was made in April 2017 with the riser tube at 0.80m above ground. A falling trend (minus 1.3m) occurs from 2006 to 2009 but with seasonal 'spikes' reflecting larger rainfall events during this period. A continually rising trend (+1.6m) then occurs from 2009 to 2017.



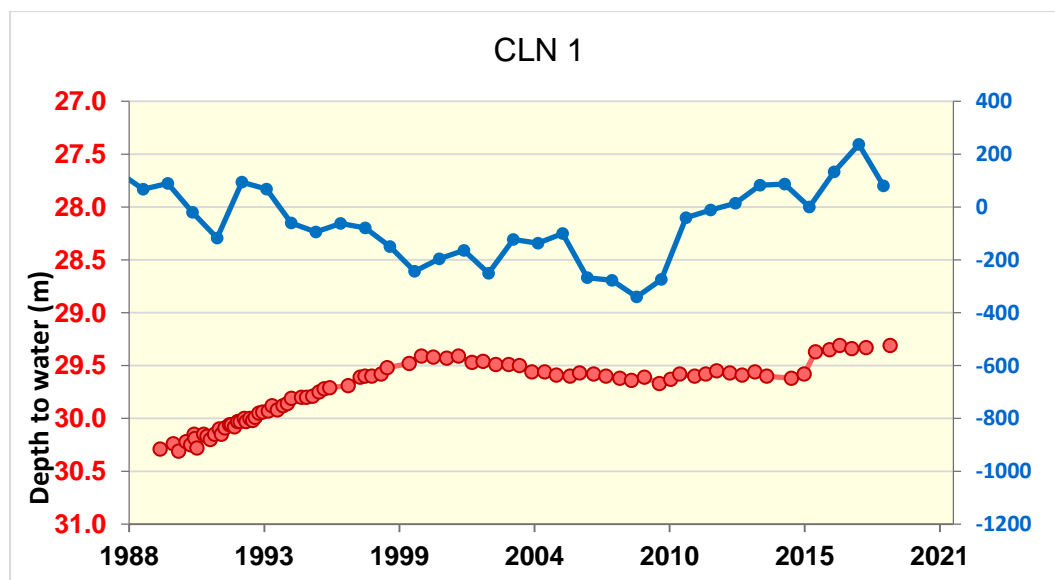
PEK003: This bore was drilled to 11m depth in 1992 and is located east of Coomandook. The borehole shows a general rise from 1994 to 1998 followed by a continuous fall from 1998 to 2010 (which reflects the falling rainfall trend). The 2010/11 summer rainfall event kicked off a continuous / episodic rise from 2010 until the present, reinforced by the 2016 high rainfall event. Seasonal responses (spring rise, autumn fall) are superimposed upon the longer term trends. This site was intensively monitored between 2007 and 2011 as indicated by the 'cramped' data points.



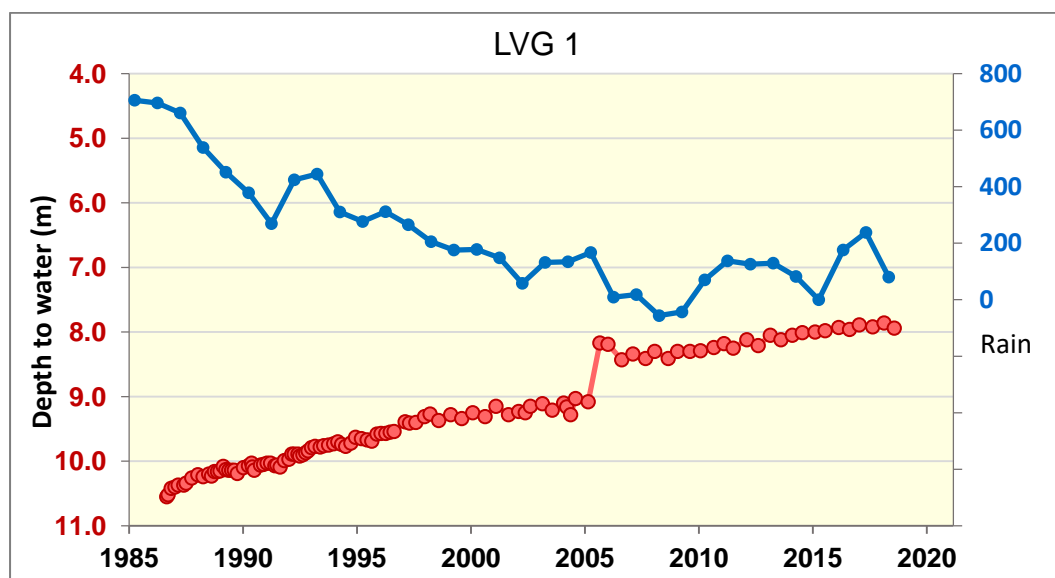
MAL002: This site is located relatively close to Lake Alexandrina and near the swamps surrounding the lake. The borehole was drilled to 30m depth in 1989. Depth to water levels show marked annual seasonal fluctuations of around 1 – 2m superimposed upon longer term trends resulting from wet and dry seasons. A low point reflects the 2006 – 2009 drought with high points reflecting wet seasons in 1992, 2005, 2010-11 and 2016. Overall, there was a general fall from 1993 until 2010, followed by a general rise from 2010 to 2018. This closely reflects the residual rainfall trends during those periods. For further details of surface water / groundwater interactions, see Appendix C.



CLN001: Located at Malinong, this borehole was drilled to a depth of 37m in 1951. Regular monitoring commenced in 1989. The watertable rose by 2.6m between 1951 and 1989 (not shown on graph due to a large data gap). It continued to rise by another 0.9m up until 2000. Since then the trend has been relatively stable with seasonal rises and falls. However there was a significant rise following the large 2016 rainfall event in spring.



LVG001: Located on Netherton Road, east of Coomandook, this borehole was drilled to 16.5m in 1987. It indicates a continuously rising trend with minor seasonal peaks and troughs. The jump-up spike in 2005/06 indicates a change in the reference point as a protective standpipe was installed above ground level (see photo). The depth to water level is almost a reverse image of the rainfall cumulative deviation suggesting that in this case groundwater is still responding to the clearing of native vegetation with the time lag being quite substantial. The total rise between 1987 and 2018 is 2.7m indicating a rise of 0.09m/year.



Appendix 4: Groundwater and Rainfall Trends *continued*

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4.2 Meningie East Site Location Information and Hydrographs

The table shows a list of eight wells (from the DEW WaterConnect groundwater network) that are currently being monitored in the Meningie east focus area. These are displayed in the WaterConnect website in the following Obswell networks: SAMDB Non-prescribed area (SAMDB_NP), South East Non-prescribed area (SE_NP) and Tintinara Coonalpyn PWA (TINT_COON).

Obswell No.	Obswell Network	Field Name	Property /Landholder Location	Date Drilled	Total Depth (m)
BNN004	SAMDB_NP	HA3	Yarindale Road	17/10/2005	6.71
JEF002	SE_NP		Settlers Road	03/10/1951	5.63
JEF004	SE_NP	MN1	McIntosh Way	18/10/2005	6.18
JEF005	SE_NP	MN2	McIntosh Way	18/10/2005	8.14
JEF007	SE_NP	MN4	McIntosh Way	18/10/2005	12.00
JEF008	SE_NP	MN5	Scrub land	18/10/2005	9.76
STB001	SE_NP		Coonalpyn	22/11/1955	15.85
STB003	SE_NP		McIntosh Way	16/02/1945	17.37
FID002	SE_NP		Naranga Road	11/08/1954	7.01
CNB002	TINT_COON		Mt Boothby Cons Park	09/04/1987	16.5

The following sites were not able to be used for reasons as outlined below:

Obswell No.	Field Name	Property / Landholder	Last date recorded	Comment
BNN001		Meningie	02/10/2007	This bore had become dry
BNN002	HA1	Yarindale Road	18/10/2011	Borehole was redrilled in Nov. 2007 but has since collapsed back to 5.75m and is dry
BNN003	HA2	Yarindale Road	07/04/2014	Destroyed by stock and removed from the network

Photographs have been taken by DEW at each monitoring site in the network and are presented to display the site in context of the surrounding land use.



Observation Well. Photo taken Sunday, 7 October 2012. [Download](#)

BNN004 in laneway between lucerne paddocks



JEF002. Photo taken Tuesday, 17 April 2018. [Download](#)

JEF002 is an old well and windmill



JEF004. Photo taken Friday, 20 April 2018. [Download](#)

JEF004 in laneway next to lucerne paddock



Observation Well. Photo taken Monday, 8 October 2012. [Download](#)

JEF005 near abandoned well and tank



Observation Well. Photo taken Monday, 8 October 2012. [Download](#)

JEF007 near old abandoned well



Observation Well. Photo taken Monday, 8 October 2012. [Download](#)

JEF008 in native scrub land



Observation Well. Photo taken Monday, 8 October 2012. Download

STB001 is an old rusted bore casing



STB003. Photo taken Wednesday, 30 March 2016. Download

STB003 is an occasionally pumped bore on a Dairy farm



Observation Well. Photo taken Monday, 8 October 2012. Download

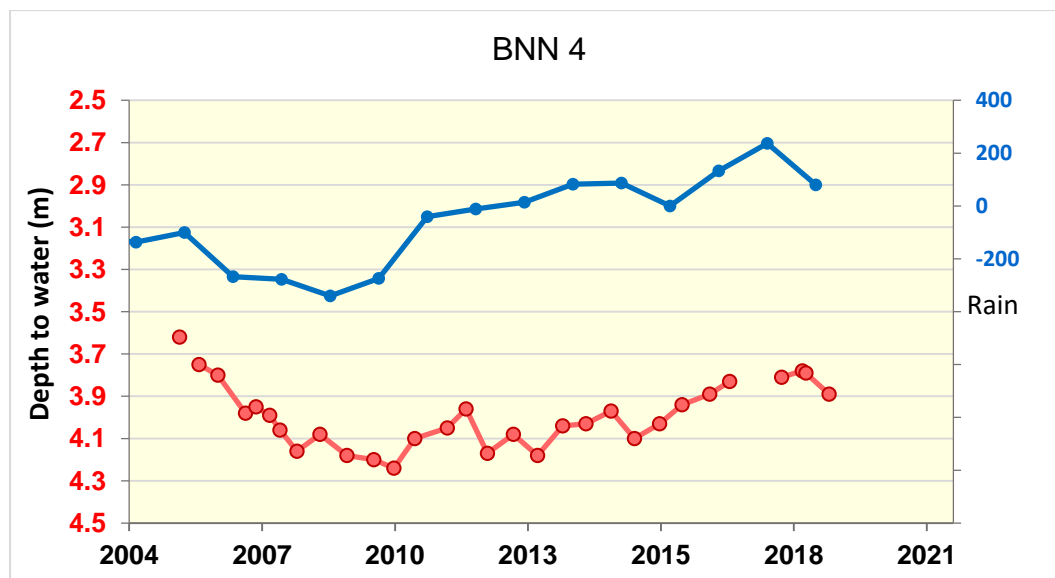
FID002 is an abandoned bore & windmill



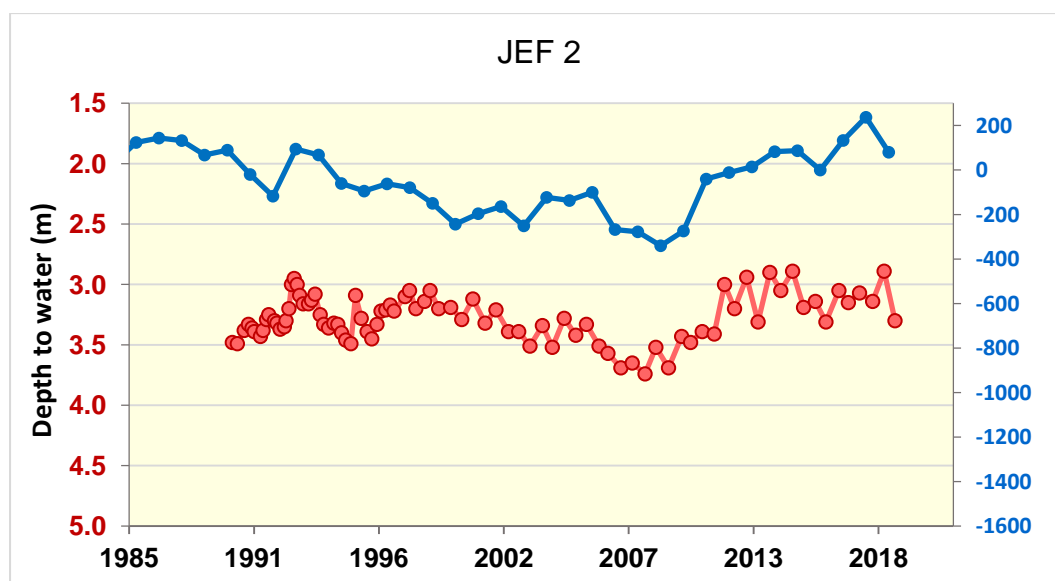
CNB002. Photo taken Friday, 20 April 2018. Download

CNB002 near cropped land & conservation park

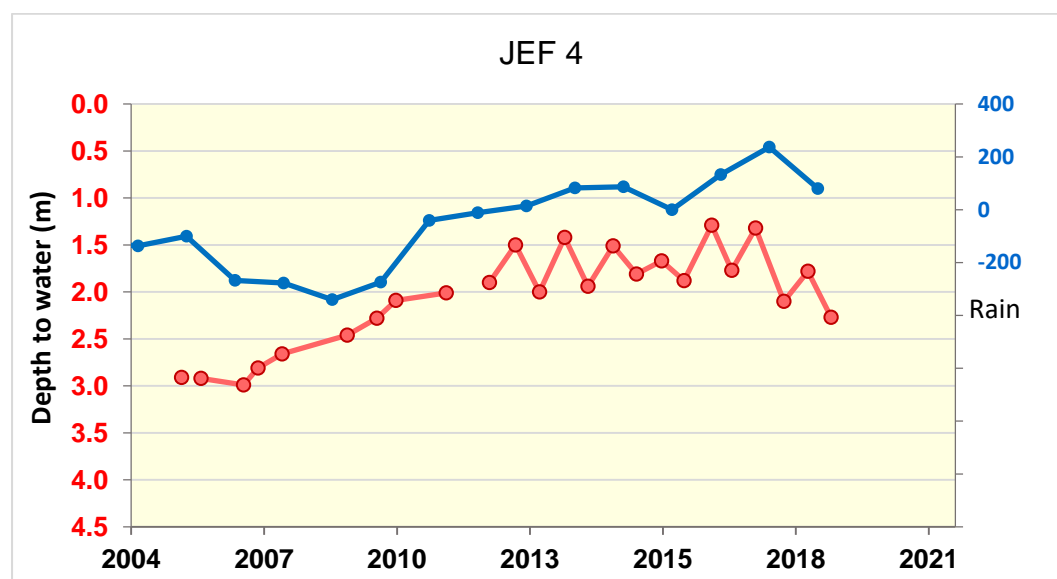
BNN004 (HA3): This obs well was drilled to 9.8m depth in October 2005, but collapsed back to 6.7m due to a very sandy profile. It is on a property off Yarindale Road, Meningie and was located on a raceway adjacent to broadscale lucerne paddocks. There was a notable falling trend (-0.6m) from 2006 to 2010 which is reflected in the decreasing residual rainfall. A rising trend (+0.4m) 2015 to 2018 is similarly reflected in the increasing residual rainfall trend for that period.



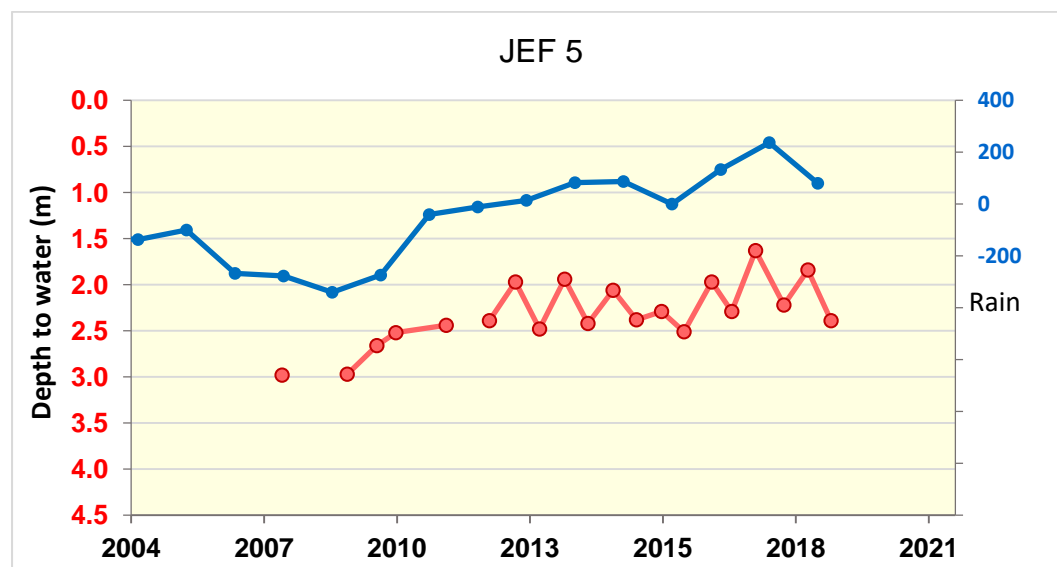
JEF002: This monitoring site is located almost mid-way between Meningie and Coonalpyn. The borehole was drilled to 5.6m depth in 1951 and the original depth to water was 5.2m from the ground surface. Regular monitoring commenced in March 1990 with a water level depth of 3.48m below ground level. The watertable had therefore risen by 2.1m over the 40 year period. Since then it has shown seasonal fluctuations ranging from 2.8m to 3.7m below ground level. The depth to water trend closely mirrors the residual accumulative rainfall trend. The highest water levels for this site occurred in December 1992, October 2013 and October 2018. This is in response to the extreme rainfall events of the spring/summer of 2010/11 and the spring of 2016. The re-emergence of dryland salinity is not surprising.



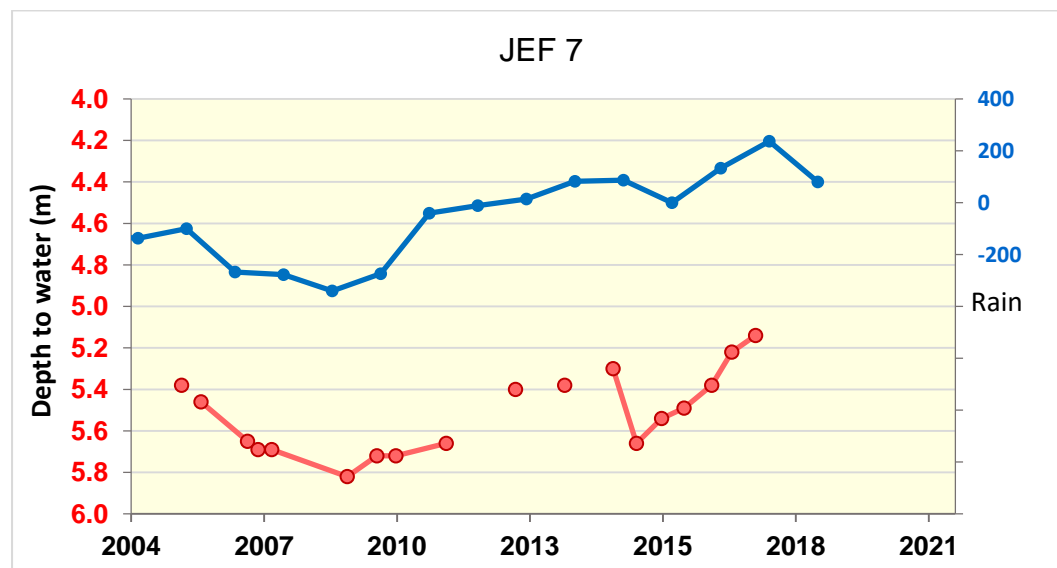
JEF004 (MN1): This purpose obs well was drilled to 6.2m on private property adjacent to McIntosh Way in October 2005. It was sited near to an existing old well (number '16'). It is located at the base of a sand dune and was surrounded by Lucerne at the time of installation. The depth to water level shows a continuously rising trend from 2005 until 2012 (+1.3m) and is a reflection of the rainfall trend for most of that period. Since then it follows a seasonal (sinusoidal) trend with spring highs and autumn lows. The rise of the watertable may reflect the loss of lucerne during the drought.



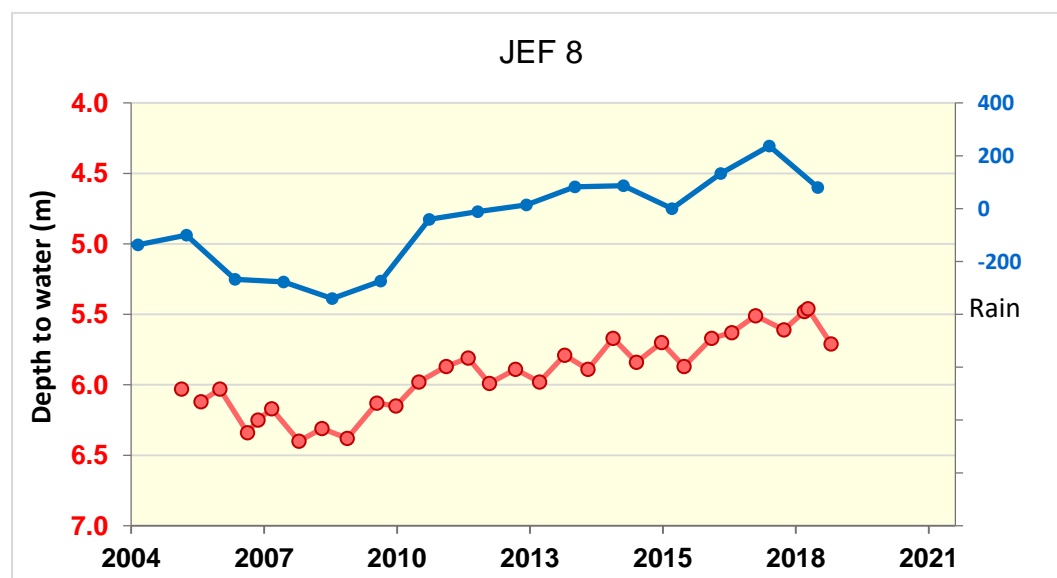
JEF005 (MN2): This purpose observation well was drilled to 8m adjacent to an old existing well (called 'Rankine') on private property adjacent to McIntosh Way in October 2005. It is located on sandplain country. It had to be re-drilled in November 2007 due to stock damage (hence the missing records from 2005 to 2007). It displays very similar responses to JEF004 with strong seasonal responses (spring peaks and autumns troughs).



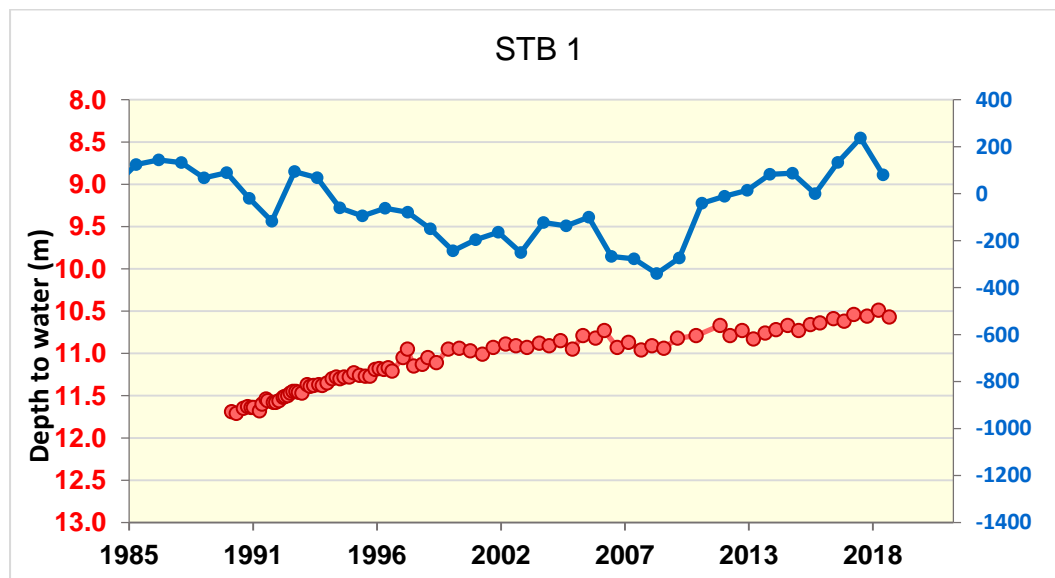
JEF007 (MN4): This purpose obs well was drilled to 12m on private property adjacent to McIntosh Way in October 2005. It is sited adjacent to an old well (called 'new vivian') in an area of jumbled sand dunes. It had to be re-drilled due to stock damage in April 2006. It was removed from the DEW monitoring network in September 2017 (under the DEW Monitoring Optimisation Project). The water level trend mirrors the falling rainfall trend from 2005 to 2009 and the rising trend from 2010 till 2014. Similarly the steep rise from 2015 to 2017 reflects the rising trend in rainfall. The depth to water reached its highest ever level in September 2017.



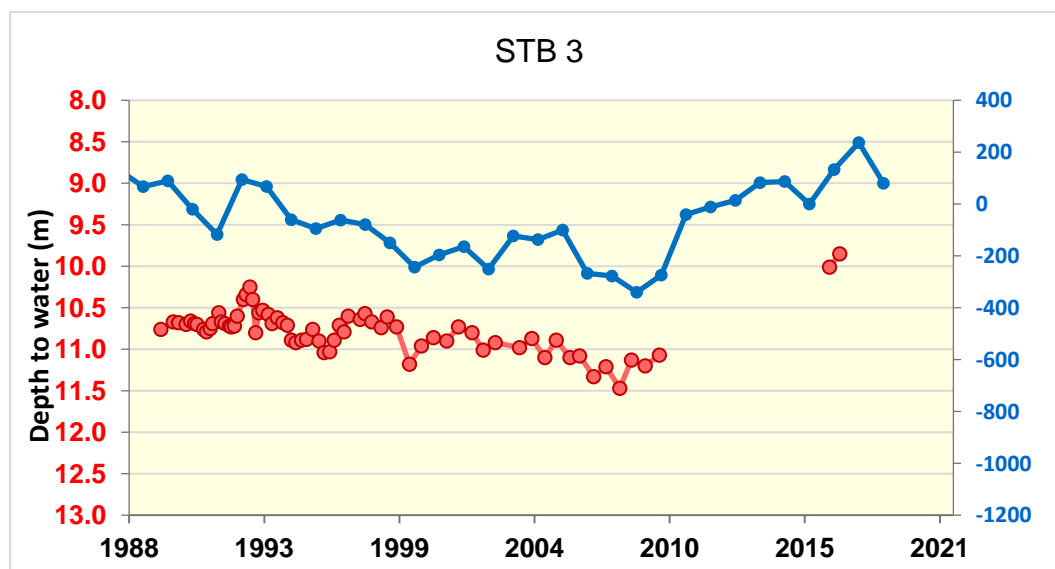
JEF008 (MN5): The site was drilled to almost 10m in October 2005 in the middle of large remnant scrub patch adjacent to the McIntosh Way. A falling trend (-0.4m) occurred from 2006 to 2008. A rising trend (+0.8m) occurred from 2009 to 2018. There is a close correlation between rainfall and water level trends. The depth to water reached its highest recorded elevation in October 2018.



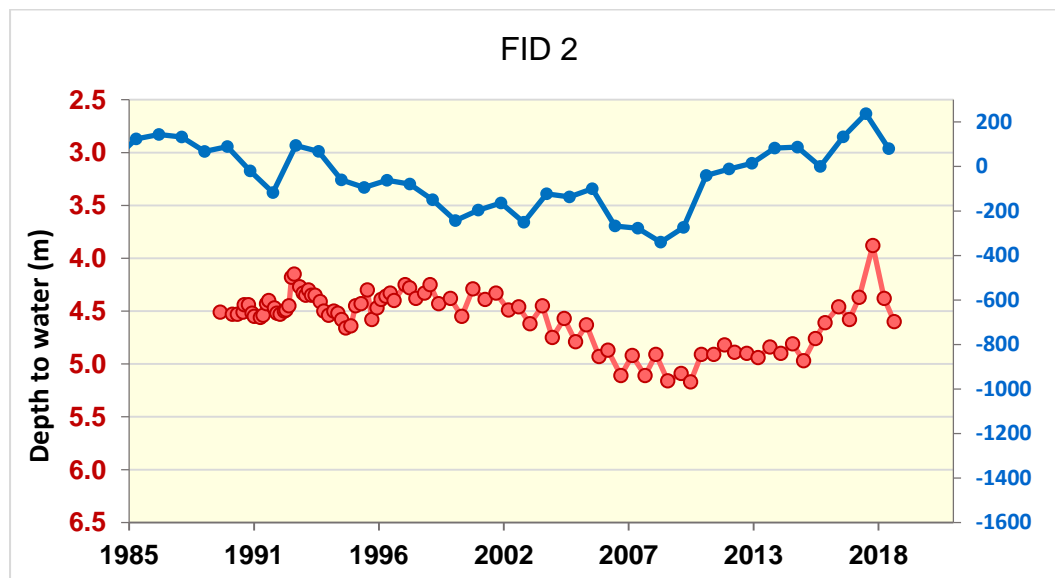
STB001: This site is located north west of Coonalpyn and was drilled to 15m in 1955. In 1955 the depth to water was recorded at 14.0m from the surface. Regular monitoring commenced in March 1990 with a water level of 11.7m. This gives a rise of 2.3m between 1955 and 1990. The bore has continued to exhibit a continuously rising trend with a further 1.2m rise between 1990 and 2018.



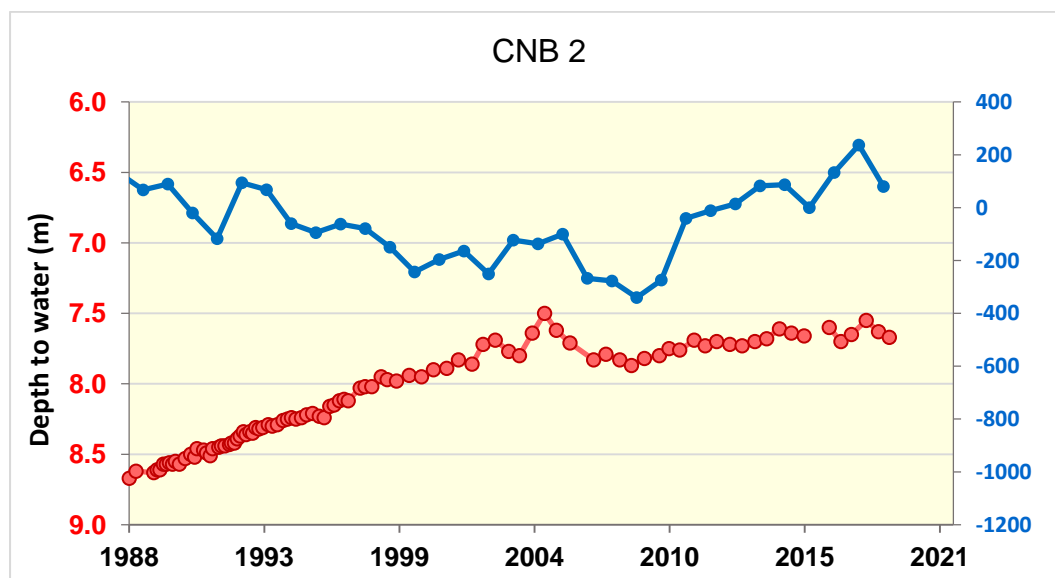
STB003: This site is located on a dairy farm south of Binnie Lookout and was drilled to 17m in 1945. The bore has a TDS of 1000mg/L and is pumped intermittently. The farm was apparently being renovated to lucerne. There is a large data gap between 2010 and 2016 due to access difficulties. It was removed from the monitoring network by DEW in September 2017 (under the DEW Monitoring Optimisation Project). Although possibly affected by pumping, the water level trend closely mirrors the falling rainfall trend from 1993 up to 2008. Of interest is that the depth to water reached its highest ever recorded level of 9.85m below the surface in March 2017.



FID002: This bore was drilled to 7m depth in 1954. Regular monitoring commenced in 1989. The watertable rose by 1.9m between 1954 and 1989. Since then it has mirrored the trends in rainfall, but with a steady decline in the decade from 2000 to 2010. Water levels began to rise again in 2015 and reached their highest level in April 2018, but falling again during the 2018/19 dry spell.



CNB002: Located on the margin of Boothby Conservation Park, south of Coonalpyn, this borehole was drilled to 16.5m in 1987. It indicates a continuously rising trend up until 2005 followed by a fall until 2007. The depth to water level is almost a reverse image of the rainfall cumulative deviation up until 2005, suggesting that in this case groundwater is still responding to the clearing of native vegetation. The peak in 2005 indicates a response to the 108mm recorded in June 2005. The falling trend from 2006 to 2008 mirrors the falling rainfall cumulative deviation. Similarly the rising trend from 2009 to 2018 mirrors the rising rainfall cumulative deviation.



Appendix 4: Groundwater and Rainfall Trends *continued*

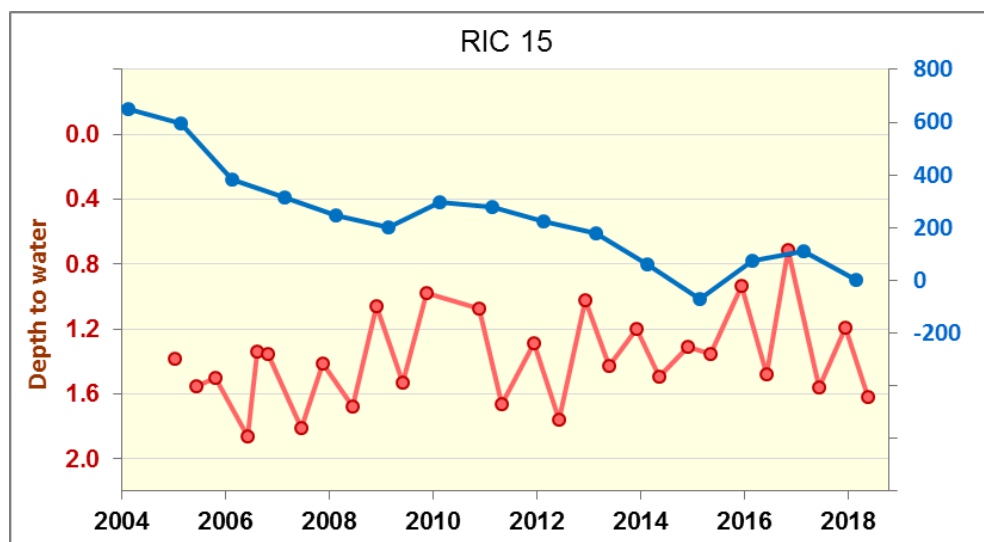
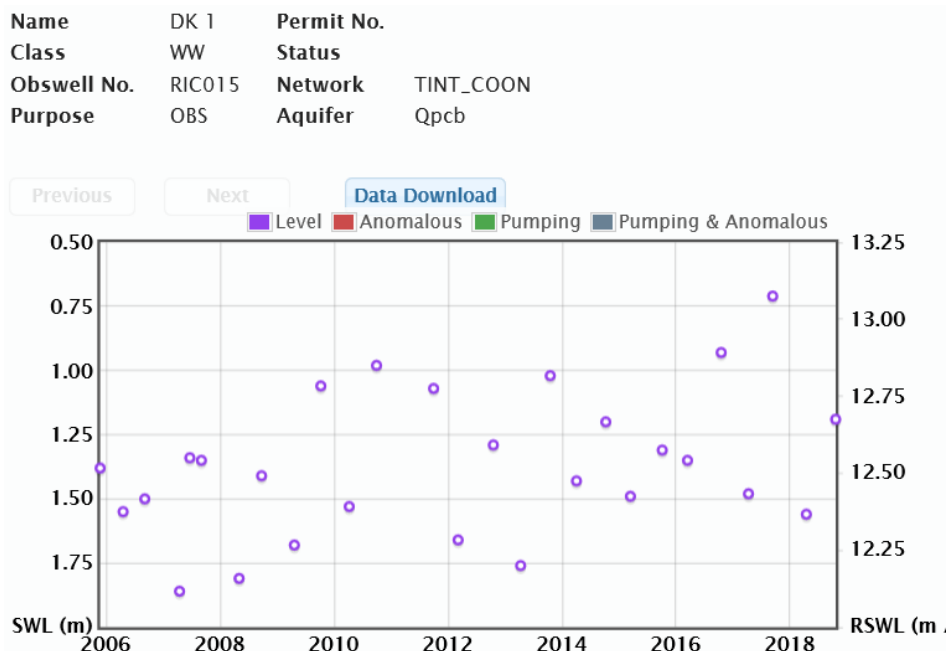
Chris Henschke— Senior Consultant Hydrogeology
PIRSA Rural Solutions

4.3 Tintinara West Hydrographs

The table shows a single well that is being monitored in the Tintinara focus area. There are no other suitable shallow wells for trend analysis in this area.

Obswell No.	Obswell Network	Field Name	Property / Landholder	Date Constructed	Total Depth (m)
RIC015	TINT_COON	DK1	R Doecke	19/10/2005	6.82

RIC015: The monitoring well was drilled in October 2005. It occurs in a raceway of a flat plain with a nearby sandhill. The area was extensively planted with lucerne. The water level fluctuations are strongly seasonal with a stable (or slightly rising?) trend.

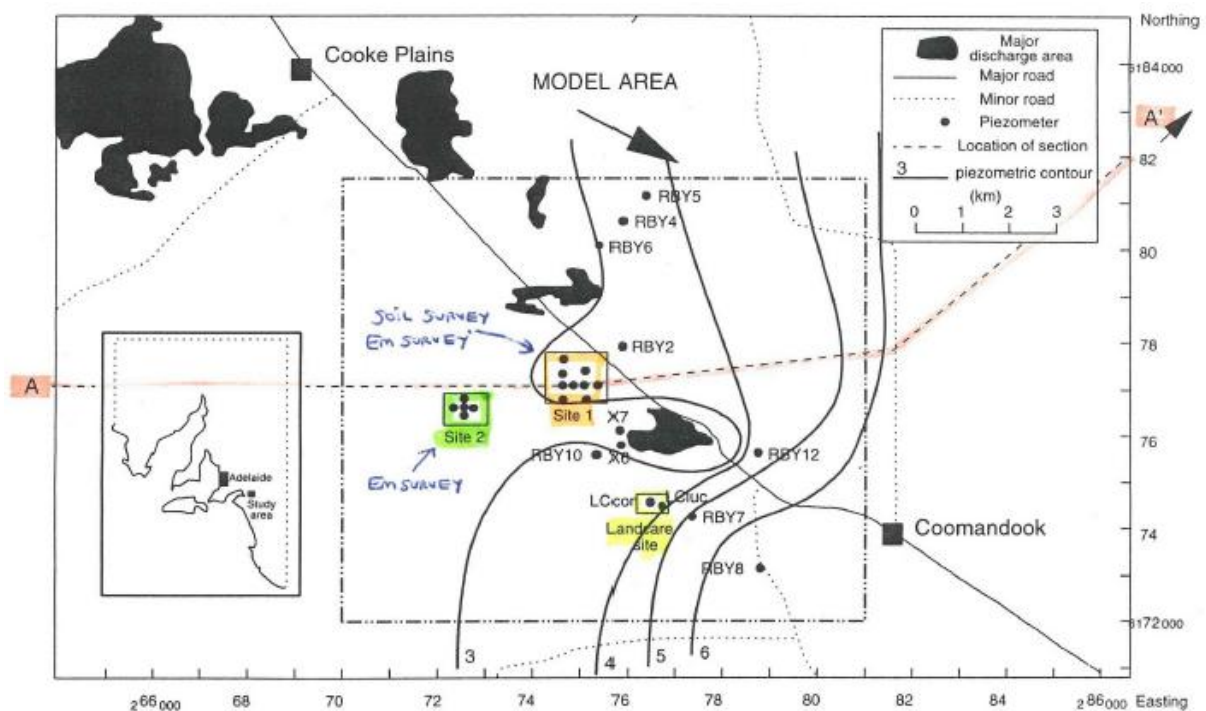


Appendix 4: Groundwater and Rainfall Trends *continued*

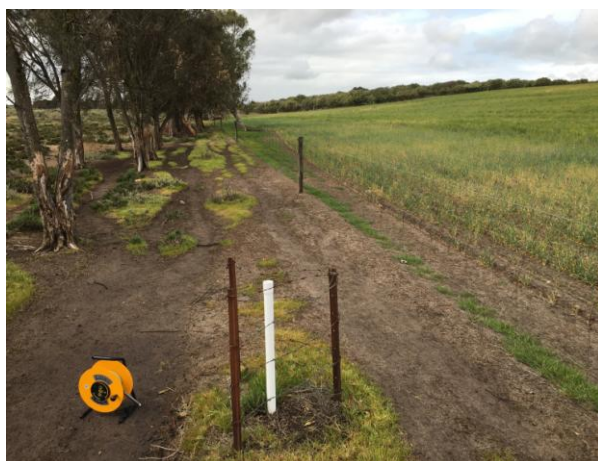
Chris Henschke— Senior Consultant Hydrogeology
PIRSA Rural Solutions

4.4 Coomandook Landcare Network

The Coomandook Landcare Network comprises 25 shallow wells up to 5.5m deep that were drilled in April 1994. The Landcare network is not part of the official DEW WaterConnect network. The location of the sites is shown on a map over the page. The map below shows the location of a revegetation Landcare site and the location of two CSIRO experimental sites which were the subject of instrumentation and groundwater flow modelling during the early 1990s.

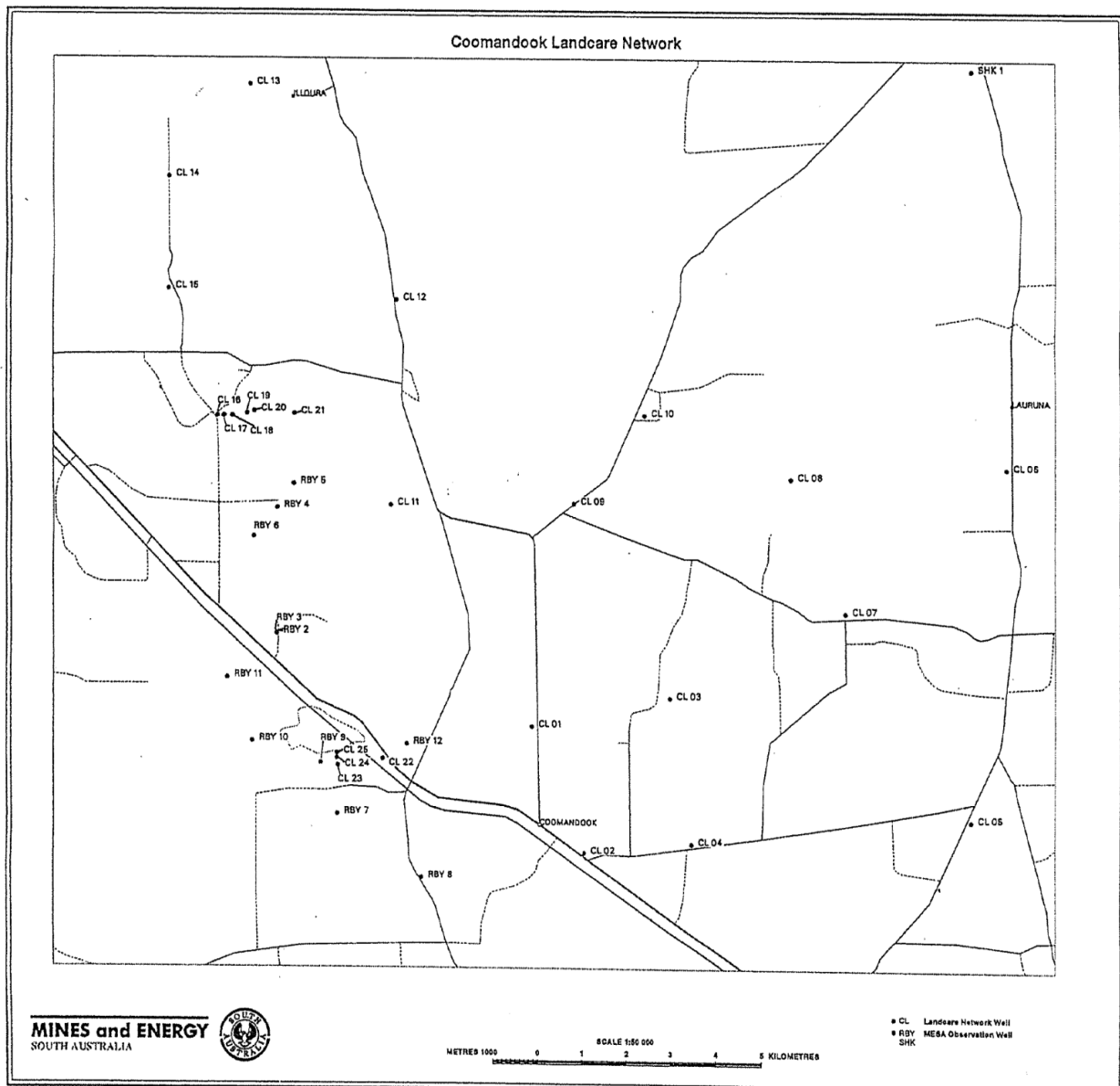


The wells / 'piezometers' were routinely monitored during the 1990s but are now monitored on an ad-hoc basis. The following table provides some data and current status of the wells.



A Coomandook Landcare Piezometer

Unit No.	Field Name	Location	Salinity TDS (mg/L)	Depth to water (m)	Comments
6827-1703	CL01	Simmons	18200	1.30	Missing since 2016
6827-1704	CL02	Teusner	2960	2.94	
6827-1705	CL03	Ballard	24100	2.02	
6827-1706	CL04	Hansen	21300	2.98	
6827-1707	CL05	Murray	18200	Dry at 3.4	
6827-1708	CL06	Poole	10700	3.20	
6827-1709	CL07	Freak	23200	3.16	
6827-1710	CL08	Freak	24000	2.85	
6827-1711	CL09	Freak	26900	2.18	
6827-1712	CL10	Freak	32900	3.94	
6827-1713	CL11	Patterson	23900	1.78	
6827-1714	CL12	Crouch	28200	2.51	
6827-1717	CL13	Piggott	29500	2.41	
6827-1716	CL14	Williams	26400	1.72	
6827-1715	CL15	Kleinig	49500	2.05	
6827-1693	CL16	Smyth	14600	2.25	Missing since 2008
6827-1694	CL17	Smyth	29300	1.89	Missing since 2009
6827-1695	CL18	Smyth	12800	1.90	Missing since 2008
6827-1696	CL19	Smyth	14600	1.67	Missing since 2008
6827-1697	CL20	Smyth	12000	1.77	Missing since 2009
6827-1698	CL21	Smyth	12500	1.83	Missing since 2009
6827-1699	CL22	Hansen	26800	1.82	Only 2 readings in 2018/19
6827-1700	CL23	Hansen	n/a	1.25	
6827-1701	CL24	Hansen	n/a	1.76	
6827-1702	CL25	Hansen	n/a	Dry at 0.90	Only 3 readings since 2001



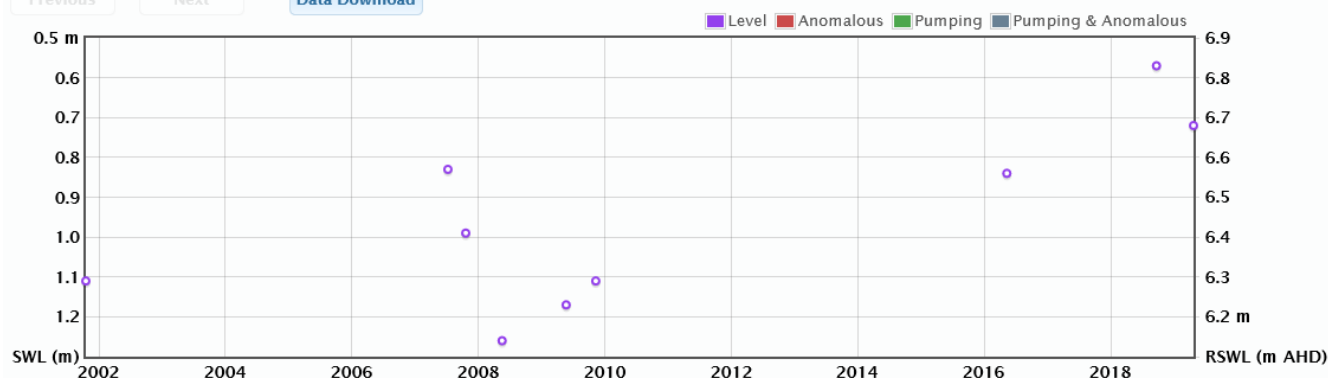
The depth to water column in the table is the water level recorded from the top of the PVC riser tube. As most of the wells have a shallow watertable (1 to 3m), records of rainfall vs. waterlevel taken during the 1990s indicate a rapid seasonal response to winter rainfall with subsequent falls of the watertable due to summer evaporation. As indicated in the table, some wells have gone dry and others are missing, presumably destroyed. In these cases, the water level is the last available reading.

The Landcare revegetation site comprised of a tagasaste plantation on a sandhill which had been in lucerne for 8 years and was renovated in 2004. Another revegetation site was located at the base of the sandhill, below the tagasaste block. A saltbush and tree shelter belt had been established around the perimeter of a large area of saline land. Despite the high water use strategy on the sandhill immediately upslope of the saline area, the watertable was still very shallow (0.6m from the surface in 2005). This confirms the difficulty of controlling dryland salinity in a regional discharge zone. Hydrographs are presented for three sites (CL 1, 6 and 11), but with large gaps in the record it is difficult to draw any further conclusions from the Landcare trial sites.

Water Level: 6827-1703

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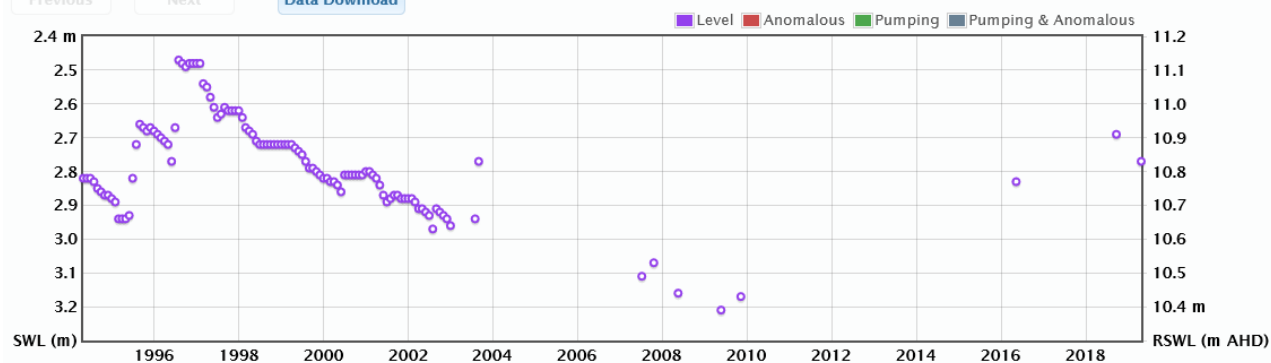
Drillhole No. [142246](#)
 Name CL 01 Permit No. 31428
 Class WW Status
 Obswell No. Network
 Purpose INV Aquifer

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Water Level: 6827-1708

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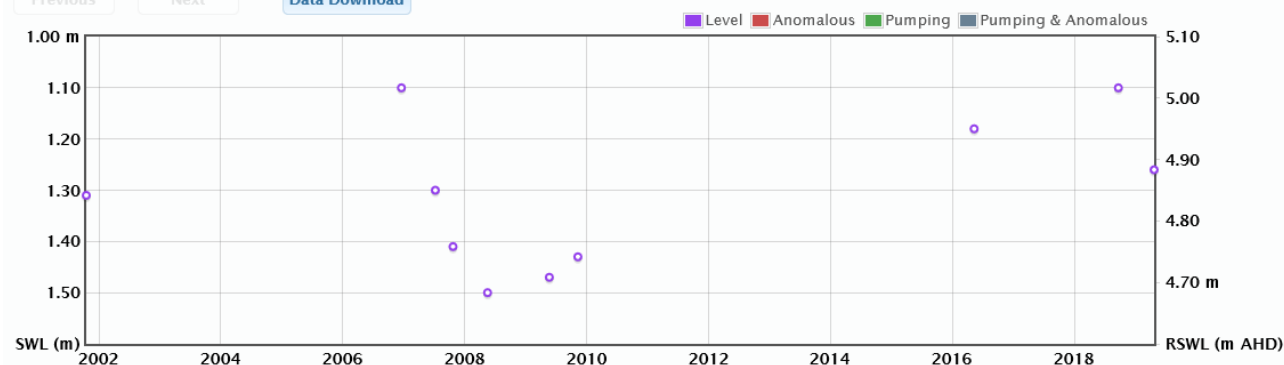
Drillhole No. [142251](#)
 Name CL 06 Permit No. 31433
 Class WW Status
 Obswell No. Network
 Purpose INV Aquifer

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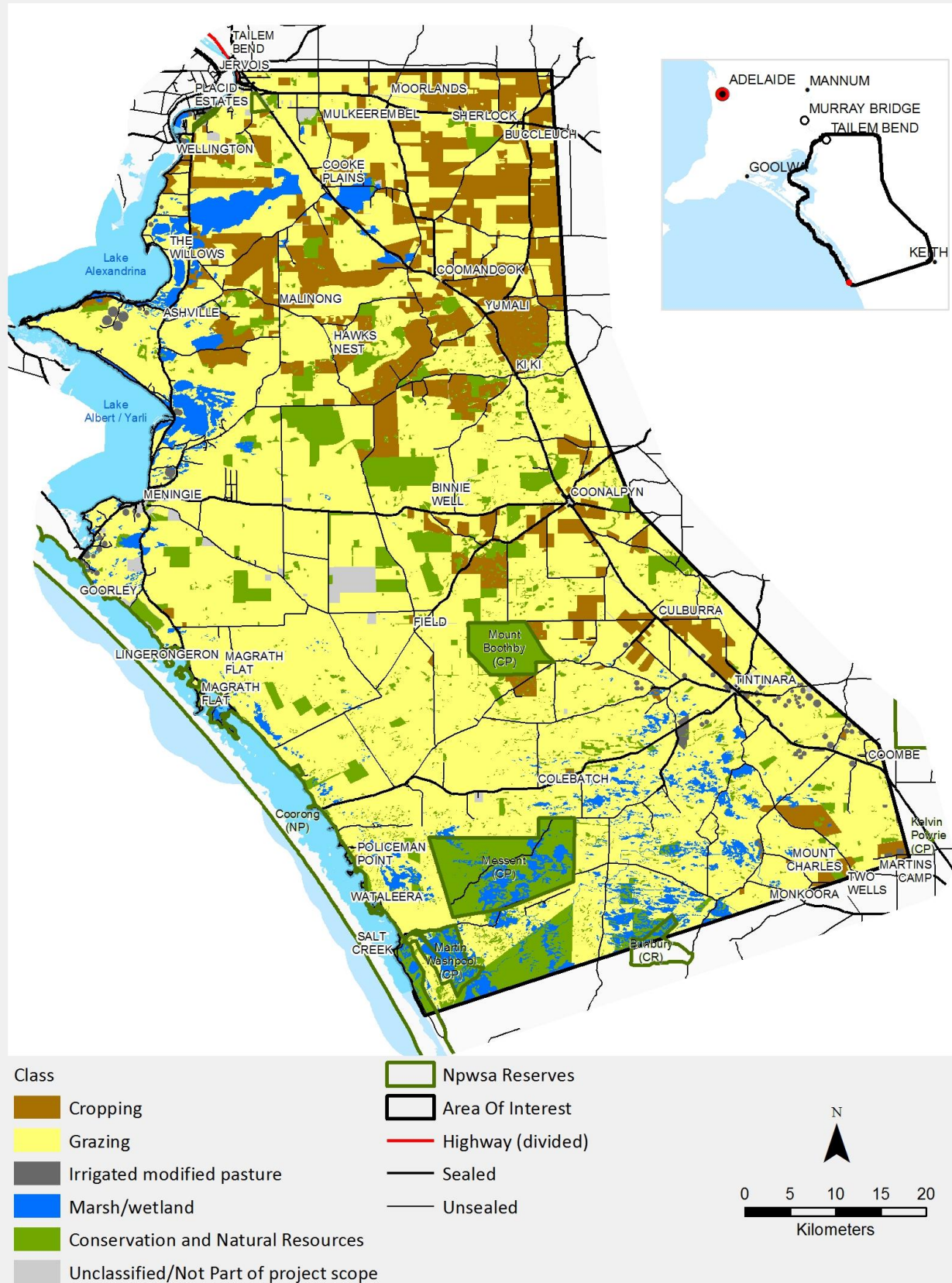
Drillhole No. [142256](#)
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 Class WW Status
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 Purpose INV Aquifer

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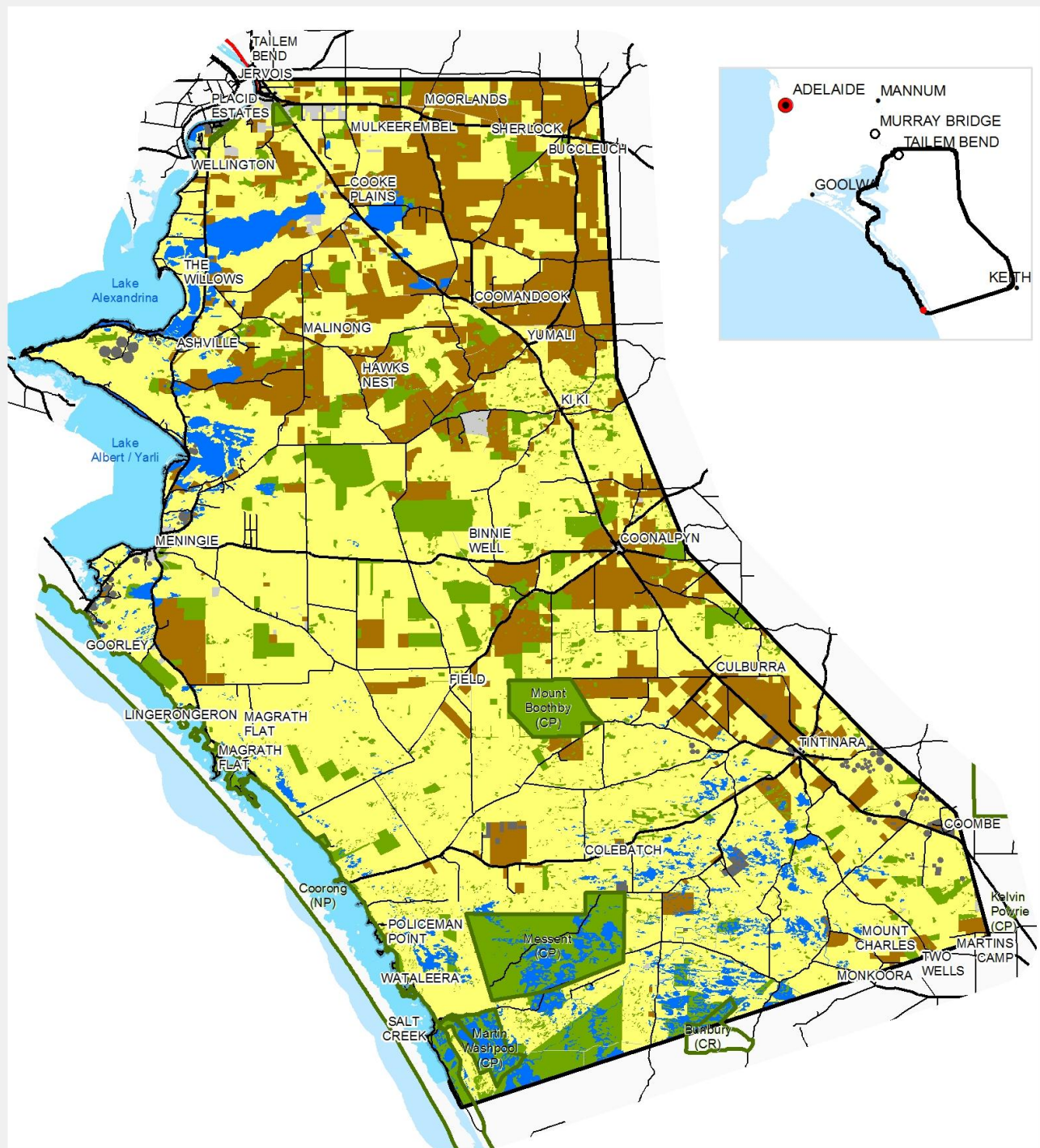
Appendix 5: Land Use Change

Data provided by Natural Resources SA Murray-Darling Basin

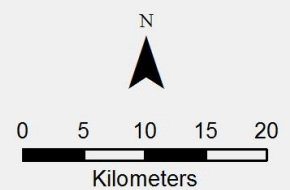
Land Use 2003



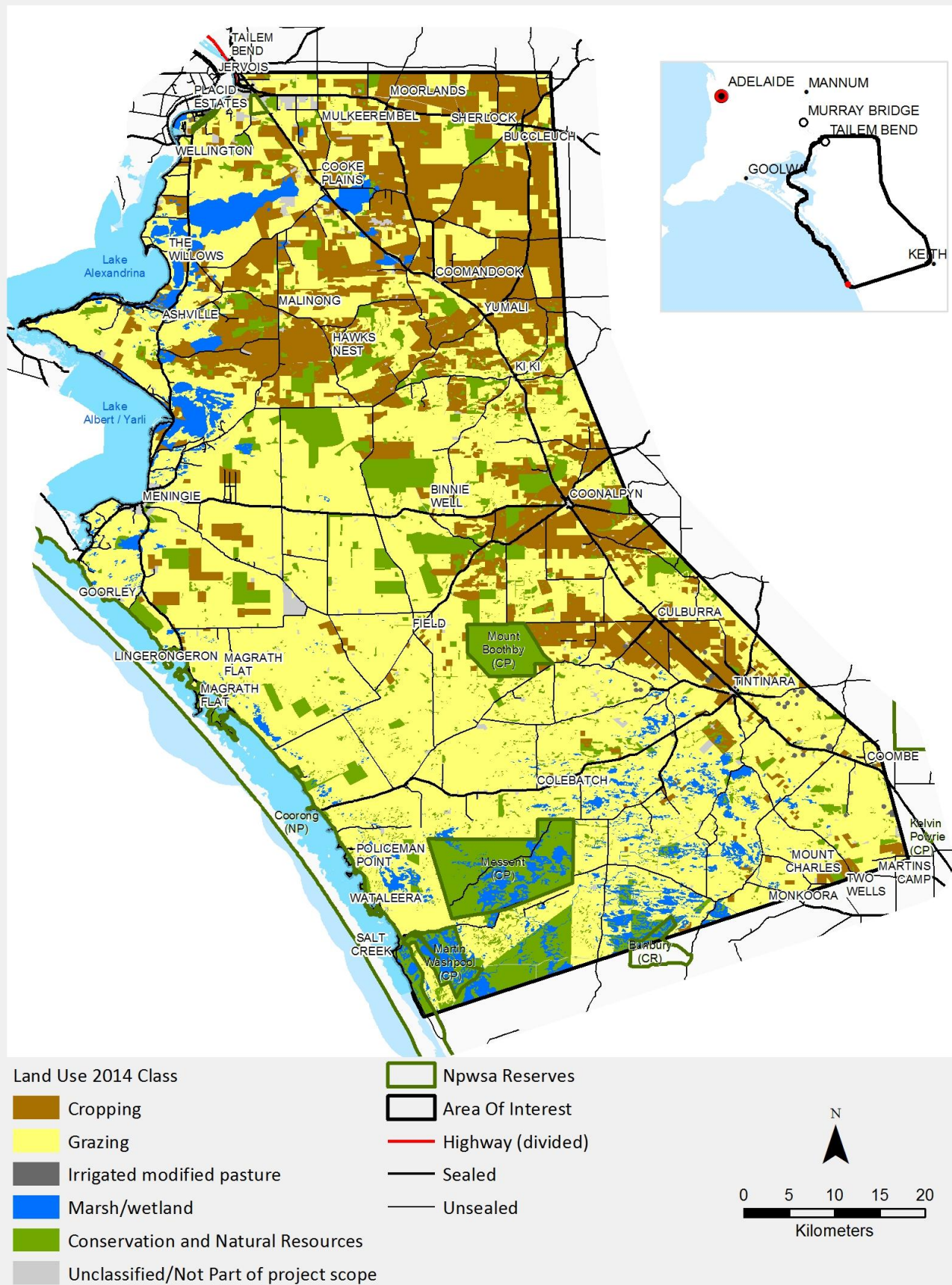
Land Use 2008



- | | |
|--|-------------------|
| Class | Npwsa Reserves |
| Cropping | Area Of Interest |
| Grazing | Highway (divided) |
| Irrigated modified pasture | Sealed |
| Marsh/wetland | Unsealed |
| Conservation and Natural Resources | |
| Unclassified/Not Part of project scope | |



Land Use 2014



Land Use 2003

	Hectares	% of Area
Cropping	70,631	13.2
Grazing	357,829	66.9
Irrigated modified pasture	3,109	0.6
Marsh/wetland	31,186	5.8
Conservation and Natural Resources	59,291	11.1
Unclassified/Not Part of project scope	12,922	2.4

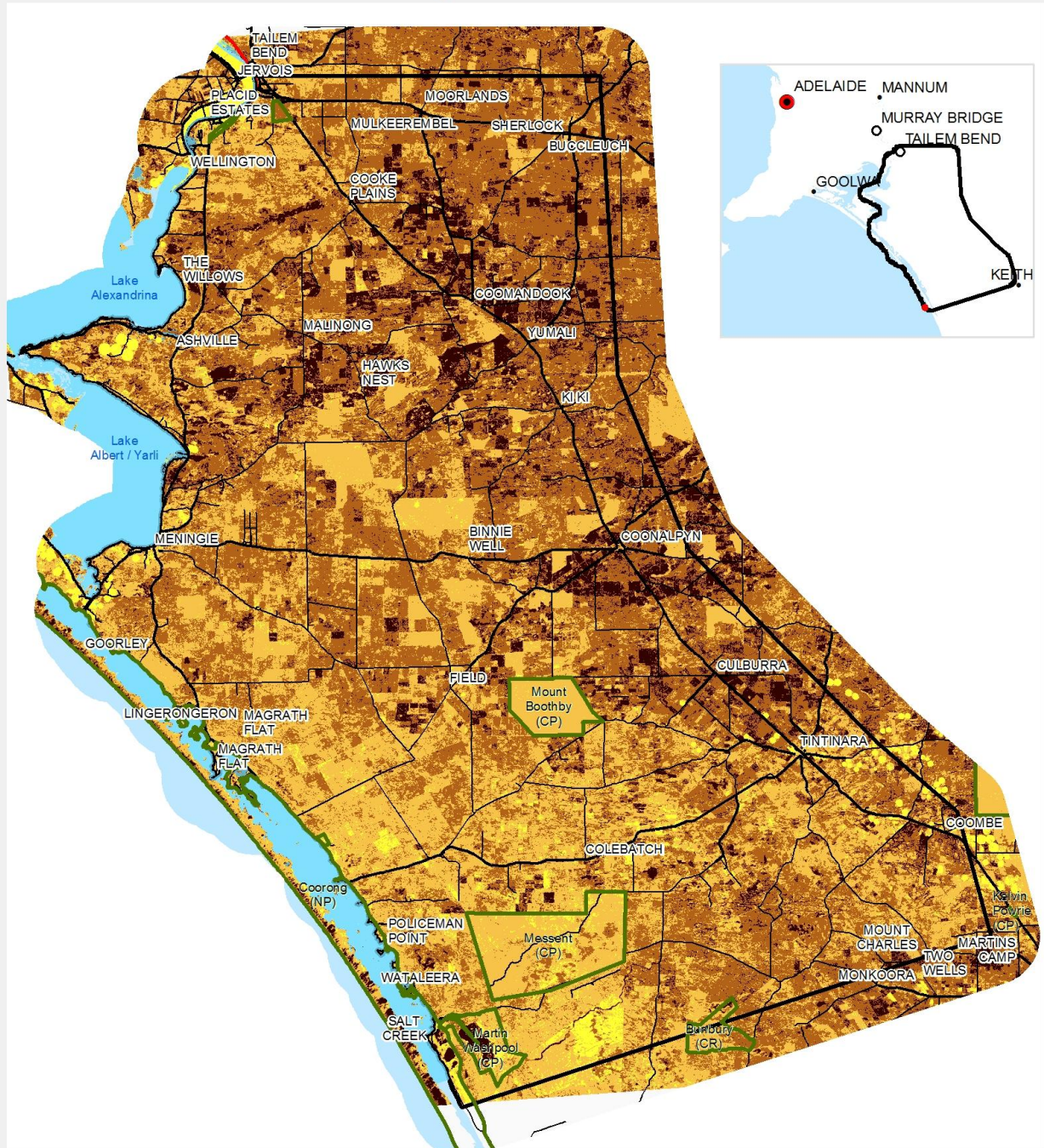
Land Use 2008

	Hectares	% of Area
Cropping	101,966	19.1
Grazing	322,968	60.4
Irrigated modified pasture	3,626	0.7
Marsh/wetland	30,512	5.7
Conservation and Natural Resources	63,619	11.9
Unclassified/Not Part of project scope	12,279	2.3

Land Use 2014

	Hectares	% of Area
Cropping	107,171	20.0
Grazing	318,526	59.5
Irrigated modified pasture	744	0.1
Marsh/wetland	29,441	5.5
Conservation and Natural Resources	63,669	11.9
Unclassified/Not Part of project scope	15,418	2.9

Summer 2003 - Fractional Vegetation Cover



Summer 2003 - Fractional Cover

% Cover

- Very Low 0 - 5%
- Low 5 - 25%
- Medium 25 - 50%
- High 50- 100 %

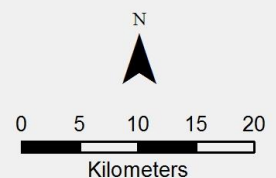
Npwsa Reserves

Area Of Interest

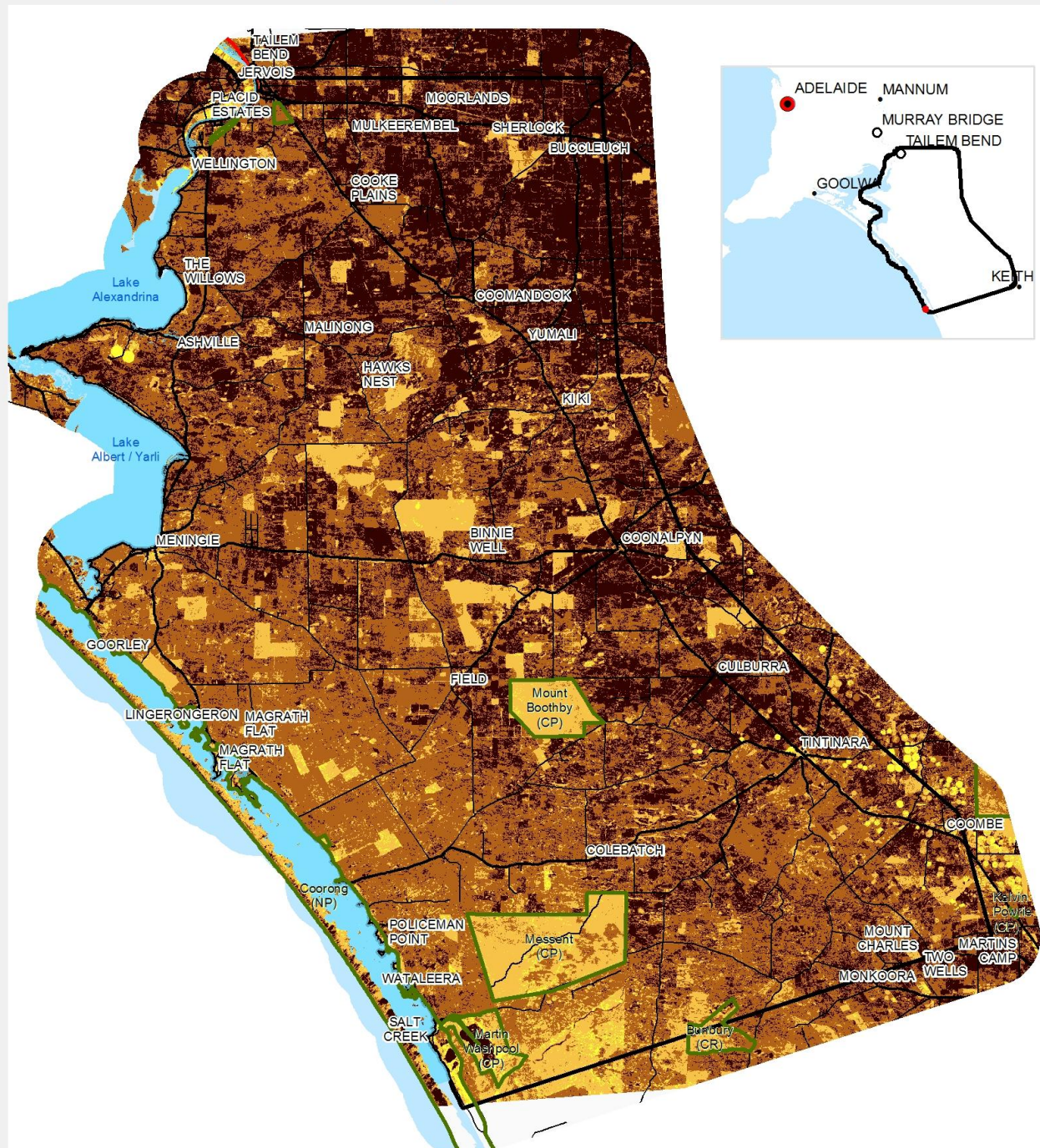
Highway (divided)

Sealed

Unsealed



Summer 2008 - Fractional Vegetation Cover

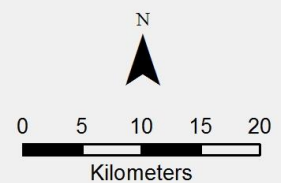


Summer 2008 - Fractional Cover

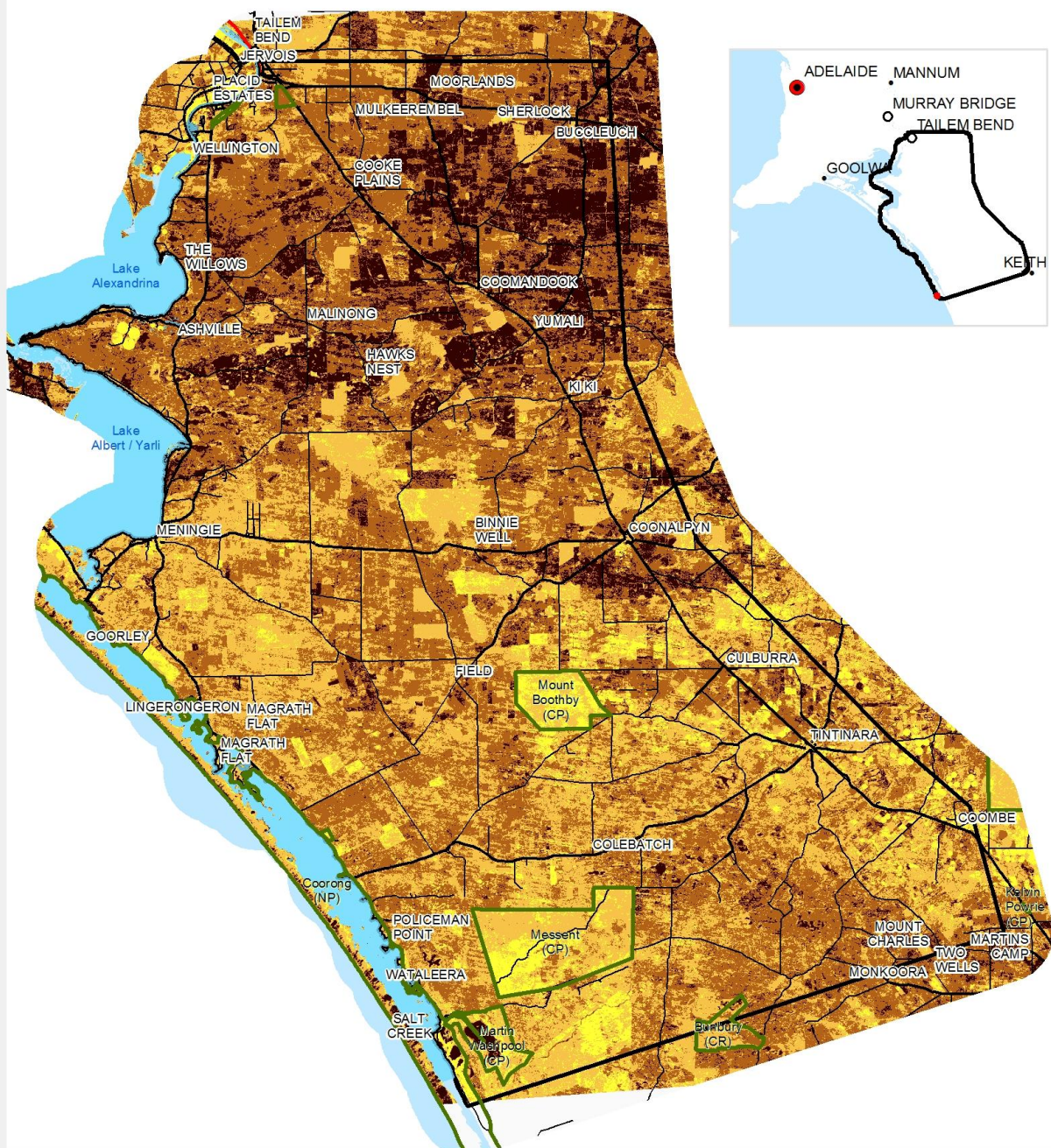
% Cover

- Very Low 0 - 5%
- Low 5 - 25%
- Medium 25 - 50%
- High 50- 100 %

- Npwsa Reserves
- Area Of Interest
- Highway (divided)
- Sealed
- Unsealed

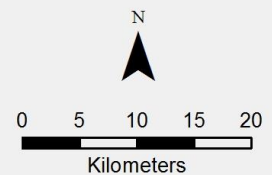
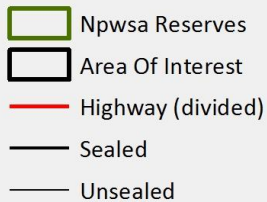
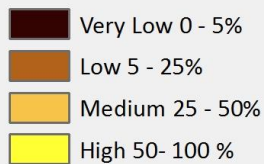


Summer 2014 - Fractional Vegetation Cover



Summer 2014 - Fractional Cover

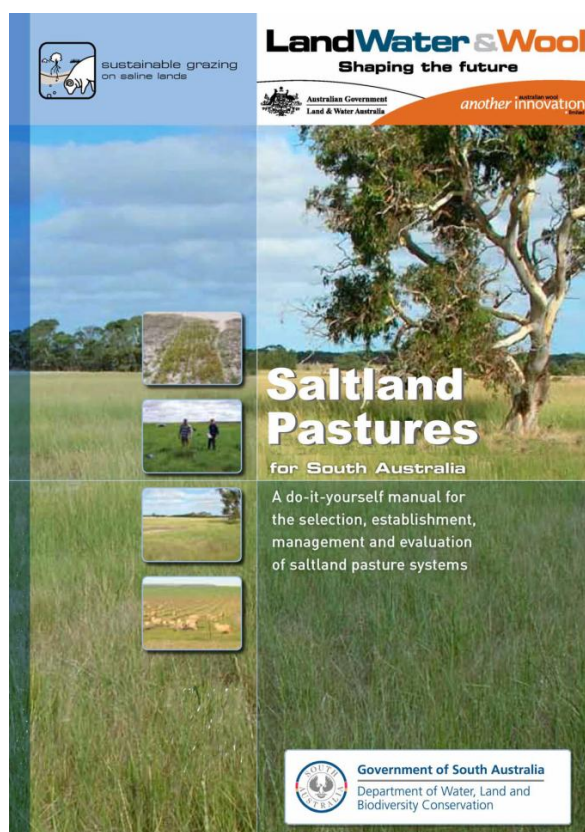
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Appendix 6: Saltland Pastures for South Australia Manual

The Saltland Pastures for South Australia Manual is a terrific summary of the Saltland Pastures and Saltbush information produced of relevance up until its publication in 2007.

This manual can be accessed on line at [http://www.coorong.sa.gov.au/webdata/resources/files/salt-land-pastures-SA-manual %20\(2\).pdf](http://www.coorong.sa.gov.au/webdata/resources/files/salt-land-pastures-SA-manual %20(2).pdf)



About the Manual

This manual has been developed through the 'Sustainable Grazing on Saline Lands' (SGSL) research and development program. SGSL was a five-year nationwide research and development program designed to provide wool growers and meat producers who are living with salt-affected land the most up-to-date, best bet information to enable sustainable, profitable production from saltland pastures. The SGSL program comprised a combination of activities based upon:

- Research conducted at five major national research sites,
- Locally relevant research trials initiated and conducted by wool and meat producer groups, and
- Knowledge sharing through regional and national networks.

Bringing together existing knowledge and new findings arising through the SGSL program, this manual aims to provide a synthesis of the current state of knowledge in the field of saltland pastures, with a focus on South Australian conditions. While it is a compilation of the best available information we don't profess to have all the answers. Knowledge of saltland pastures is continually developing and producers are encouraged to seek further information, and particularly, local expertise. We are confident however that this manual will inform producers of the range of opportunities for gaining improved production from saltland.

Who is it for?

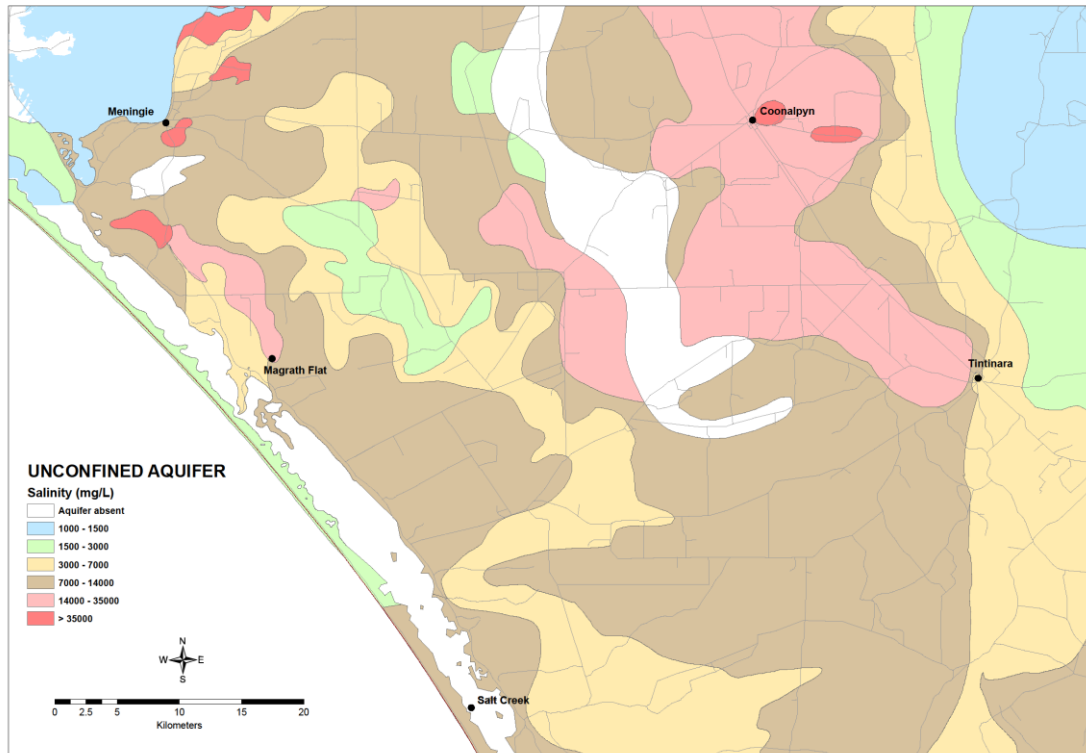
This manual provides information and resources to producers and extension workers who need to know more about saltland pastures.

It is both for farmers starting 'fresh' and those who want to get more out of their existing saltland systems. The discussion focuses on areas of saltland influenced by shallow groundwater. However some of the plant species covered may also be suited to other types of salinity

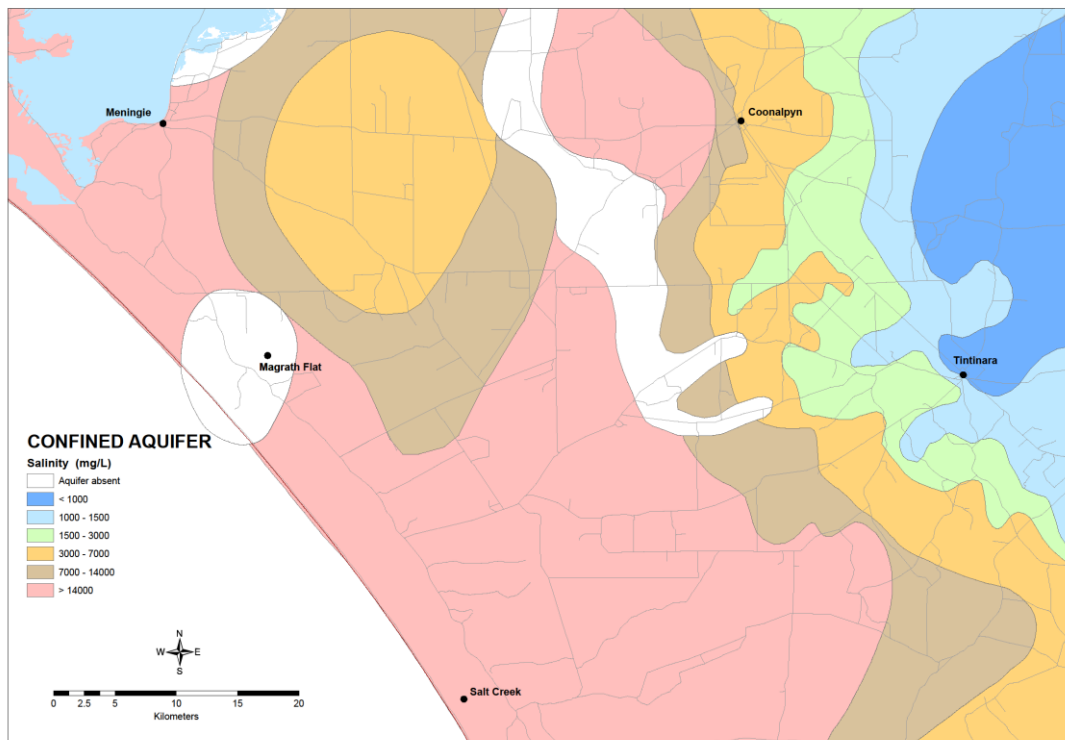
General Principles

- After looking through this manual, landholders should be able to:
- Better understand the potential of saltland pastures.
- Characterise their saltland.
- Recognise suitable pasture plants for different classes of saltland.
- Appreciate other site factors that influence production and profitability.
- Access tried and tested establishment and management techniques.
- Use tools for evaluating economic performance.
- Appreciate the payoffs and pitfalls experienced by other farmers working with saltland.
- Better understand whether or not saltland pastures are likely to be a success for them.

Appendix 7: Unconfined and Confined Aquifer Maps

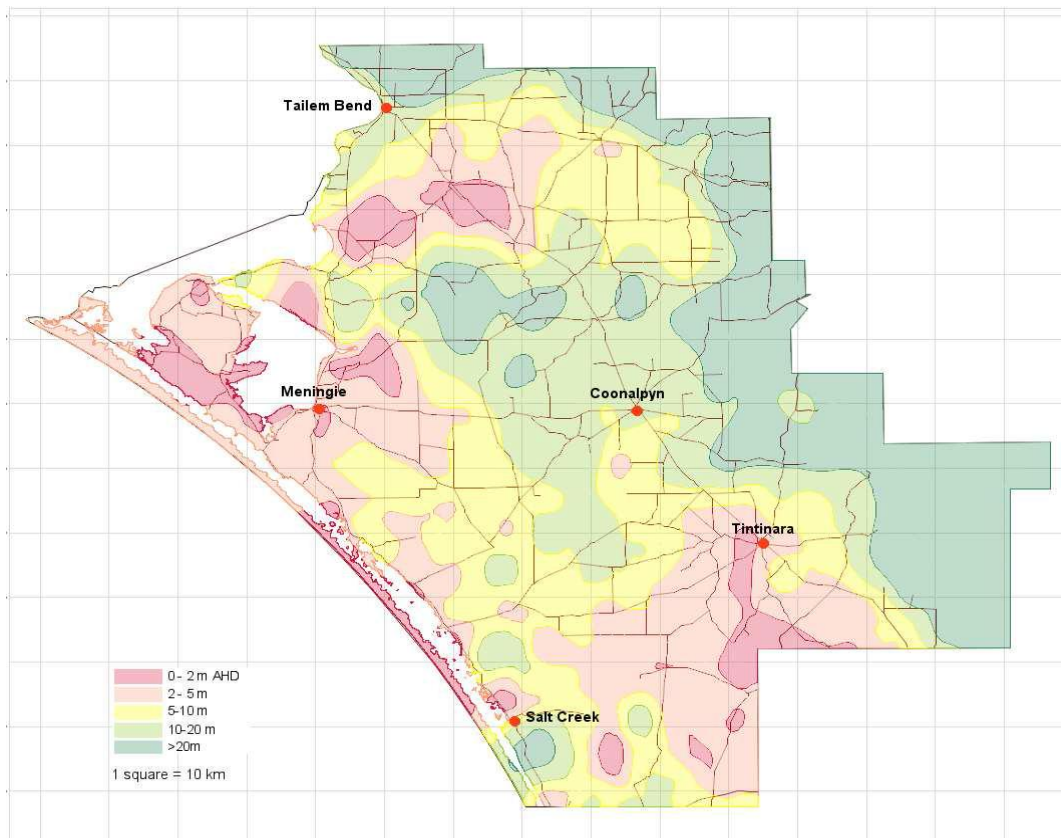


Unconfined Aquifer Map

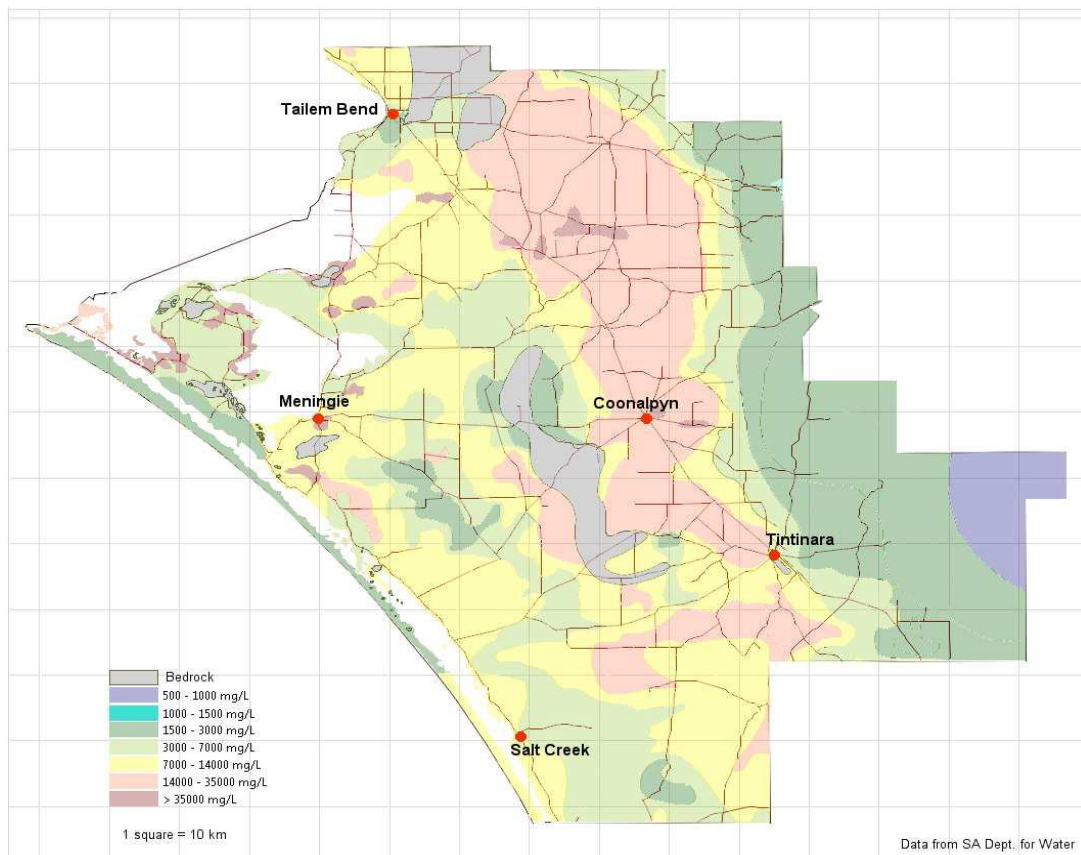


Confined Aquifer Map

Appendix 7 *continued*: Unconfined Aquifer Water Tables & Salinity Levers



Unconfined Aquifer Water Table



Unconfined Aquifer Salinity Levers

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