# Supporting documentation for the amendment of the Water Allocation Plan for the Southern Basins and Musgrave PWAs

DEWNR Technical report 2015/18

Government of South Australia
Department of Environment, Water and Natural Resources

# Supporting documentation for the amendment of the Water Allocation Plan for the Southern Basins and Musgrave PWAs

Simone Stewart
Department of Environment, Water and Natural Resources

October, 2015

DEWNR Technical note 2015/18

Government of South Australia
Department of Environment,
Water and Natural Resources

Department of Environment, Water and Natural Resources

GPO Box 1047, Adelaide SA 5001

Telephone National (08) 8463 6946

International +61 8 8463 6946

Fax National (08) 8463 6999

International +61 8 8463 6999

Website www.environment.sa.gov.au

**Disclaimer**



**ISBN** 978-1-925369-29-8

**Preferred way to cite this publication**

Stewart S, 2015, *Supporting documentation for the amendment of the Water Allocation Plan for the Southern Basins and Musgrave PWAs,* DEWNR Technical note 2015/18, Government of South Australia, through the Department of Environment, Water and Natural Resources, Adelaide

# Acknowledgements

The author would like to acknowledge Megan Hancock for recalculating the recharge rates for the Water Allocation Plan and providing thorough documentation on the methodology for inclusion in this report.

# Contents

## List of figures



## List of tables

# 1 Background

In April 2015, statutory consultation on the Southern Basins and Musgrave Prescribed Wells Areas (PWA) draft Water Allocation Plan (WAP) commenced and lasted nine weeks. The consultation involved over 70 community members attending an independently facilitated stakeholder meeting and open house forum which were both held in Port Lincoln and Elliston, as well as multiple meetings with stakeholder groups and individuals.

The meetings were an opportunity for the Eyre Peninsula Natural Resources Management Board to outline the draft WAP to the community, hear their feedback and assist them in providing formal submissions on the WAP.

A total of 22 formal submissions were received from 19 entities as part of the statutory consultation process. The consultation process resulted in a total of 269 individual comments on issues which have required careful consideration.

A number of submissions contained suggestions on how the draft WAP could be improved, such as recalculating recharge rates, providing buffers to protect additional wetlands and Red gums, and consideration of varying the triggers for the different consumptive pools. Where practicable the amendments and scientific reasoning for such amendments has been included directly into the draft WAP. However there were instances where a more detailed analysis was required and this detail was out of place in the WAP. As such this report is a supporting document for the draft WAP which includes the more detailed analyses that were not considered appropriate to be included in the draft WAP. Furthermore, this report contains a reference guide to the changes to figures, tables and the text that were included in the final version of the draft WAP.

On 20 November 2015 the draft WAP was submitted by the Eyre Peninsula Natural Resources Management Board to the Minister for Sustainability, Environment and Conservation for consideration and adoption. As such the adopted WAP may vary slightly from that presented in this document.

# 2 Significant Changes

## 2.1 Environmental protection zones

### 2.1.1 Groundwater dependent ecosystems

Comments from the community consultation indicated that the environmental protection zone (EPZ) buffer should be recalculated using a maximum 1 cm drawdown at the groundwater dependent ecosystem (GDE) as it was considered that the current calculations based on a 10 cm drawdown may result in undesirable impacts to the GDE. Many of the wetlands are very shallow and a 10 cm drawdown could equate to a loss of 50% of the water body depth in the wetland in some cases.

Additionally, supplementary EPZs were requested for other sites where freshwater discharge is thought to occur to shallow marine environments such as Tulka, Kellidie Bay and Elliston. Other EPZs were suggested to protect Red gum communities at Big and Little Swamps, Black Swan Lane (connected to Big Swamp), Duck Ponds Creek (connecting Little Swamp to Tulka), and other sites drawn on maps at the meetings.

For all wetland communities, the EPZ has been re-calculated using a 1 cm drawdown and the smaller of either the EPZ distance or a 5 km distance has been applied. The results of these recalculations are shown in Table 1 below. In cases where aquifer properties are at the extreme end of the range (i.e. very low specific yield (Sy) or transmissivity (T)), the resultant EPZ distances can be up to 56 km wide. This is unrealistic and is a result of the exponential equation used to determine the zone of influence. It is considered that a 5 km EPZ would be more than sufficient in these cases as it is highly unlikely that effects will be observable beyond this distance. It should be noted that for the GDEs with a calculated EPZ of 45,572 m and 56,323 m the drawdown at the GDEs with a 5 km EPZ would be 7.2 and 4.75 cm respectively.

**Table 1: Environmental protection zones for groundwater dependent ecosystems**

| Wetland group | Minimum transmissivity ($m^2/d$) | Minimum specific yield | Calculated EPZ distance (m) | Adopted EPZ distance (m) |
|---|---|---|---|---|
| Newland | 750 | 0.00003 | 45572 | 5000 |
| Poelpena | 1370 | 0.00002 | 56323 | 5000 |
| Hamilton | 750 | 0.005 | 3530 | 3530 |
| Pillie | 252 | 0.007 | 2187 | 2187 |
| Sleaford | 252 | 0.007 | 2187 | 2187 |
| Wanilla | 252 | 0.02 | 1294 | 1294 |
| Big Swamp | 252 | 0.02 | 1294 | 1294 |
| Little Swamp | 252 | 0.02 | 1294 | 1294 |
| Duck Ponds Creek | 252 | 0.02 | 1294 | 1294 |
| Black Swan Lane | 252 | 0.02 | 1294 | 1294 |

### 2.1.2 Red Gums

EPZs for all Red gum communities have been added to the Draft WAP and have been calculated using a 10 cm drawdown as this is expected to be within the Red gum tolerance for water level variation. Given these communities extend across both PWAs, it was considered a single EPZ distance would suffice. In this case, the maximum EPZ distance (as determined from the smallest Sy and T values) identified from Tables 16–20 from Stewart (2013) would be the most conservative. As such, all identified Red gum communities have an EPZ of 1894 m.

**Table 2: Environmental protection zones for Red Gums**

| Red Gums | Minimum transmissivity (m²/d) | Minimum specific yield | Calculated EPZ distance (m) | Adopted EPZ distance (m) |
|---|---|---|---|---|
| All communities | 750 | 0.00003 | 1894 | 1894 |

### 2.1.3 Marine discharges

Supplementary EPZs have been established for marine discharges (specifically Kellidie Bay, Elliston and Tulka). EPZs have been determined from the range of T and Sy values applicable to the area (see Tables 16–20 in Stewart, 2013), with an allowable watertable drawdown at the extent of the protection zone of 10 cm.

**Table 3: Environmental protection zones for marine discharges**

| Marine discharge | Minimum transmissivity (m²/d) | Minimum specific yield | Calculated EPZ distance (m) | Adopted EPZ distance (m) |
|---|---|---|---|---|
| Elliston | 750 | 0.005 | 147 | 147 |
| Tulka | 252 | 0.007 | 751 | 751 |
| Kellidie Bay | 252 | 0.02 | 444 | 444 |

## 2.2 Triggers

Many of the community submissions requested that the storage triggers for specific consumptive pools should be reconsidered. This was investigated and the findings are presented below.

### 2.2.1 Polda consumptive pool triggers

The Draft WAP considered the condition of Polda to be poor and therefore the triggers for allocation prevented any extraction from the consumptive pool until it recovered to 99% of the storage observed in 1993. After discussions with the licensees within the consumptive pool, SA Water advised that they would voluntarily relinquish their allocations for Polda, Polda North and Kappawanta, and therefore would no longer take water from these consumptive pools. With this in mind, the remaining licensees in the Polda consumptive pool suggested an approach to allow some licenced extraction to occur.

It was requested that the triggers be lowered to allow one licensee to access half of his allocation of 6720 kL. The 2015 storage levels for Polda are 78.84%, therefore the lower storage trigger was required to be lowered from 99% to 68%, with the mid storage trigger reducing from 99.5% to 84%. Based on the 2015 storage level, the licensee will be entitled to an allocation of 7056 kL. There was further discussion around the remaining licensees transferring allocations to the aforementioned licensee. Such transfers will need to be consistent with the new WAP requirements, with any monetary component associated with the transfer to be determined between the licensees.

It should be noted that if the storage level falls below 68% of that observed in 1993, allocations from this consumptive pool will cease until the water level recovers. Additionally, the Polda consumptive pool will be reserved for irrigation, industrial and recreational purposes only. Therefore in the future, even if the resource recovers significantly, the taking of water for public water supply or mining purposes will not be possible. Further discussion considered varying the portion of water available within the consumptive pool that is reserved for the environment to allow only 10 ML of excess water to be available. This has been reflected in the WAP.

As a result of these discussions, a new principle has been included in the WAP concerning the allocation of excess water within a consumptive pool. If an application for a water access entitlement is greater than 10 ML, then a hydrological assessment will be required to determine if the taking of that volume of water at any particular location is likely to impact on existing users, GDEs or adjacent aquifers. For water access entitlements of less than 10 ML, no such assessment will be required.

### 2.2.2 Coffin Bay consumptive pool triggers

Submissions on the WAP from the community indicated that the storage triggers for Coffin Bay should refer not to water level changes but rather to changes in the thickness of fresh water within the aquifer. In the Draft WAP the lower storage trigger (the point at which allocations will be reduced to zero) for Coffin Bay is equivalent to mean sea level (i.e. the storage in the aquifer which would result in the average water level within the aquifer being 0 m AHD). Sonding data undertaken by SA Water over several years (Somaratne and Ashman, 2015, Draft report 'Salinity in Uley South and Coffin Bay Lens A Groundwater Basins) has indicated that:

- At observation well LKW038, which has its production zone in the middle portion of the Quaternary Limestone aquifer, fresh groundwater (below 650 mg/L) is still observed at approximately 20 m below ground level which is equivalent to -17.26 m AHD indicating that the freshwater lens in this location is quite thick. Sonding of the production zone of this well in 2002, 2004, 2008 and 2015 (Figure 1) indicates that salinity is uncharacteristically freshening slightly with depth i.e. at about 17 m below ground level there appears to be a much fresher source of groundwater identified by the sonde. Additionally, the general salinity within the basin at this point has freshened over time i.e. from a salinity range in 2002 of 325 to 650 mg/L, compared to 2015 when the salinity ranged from 325 to 455 mg/L. SA Water indicate this reduction is due to the new operational practice for extractions which reduces up-coning of underlying more saline groundwater.
- At observation well LKW039, which has its production zone at the base of the Quaternary Limestone aquifer, the salinity varied between 975 and 1300 mg/L. When sonded in 2004, 2008 and 2015 (Figure 2) the salinity increased slightly with depth from 26–32 m below ground (-23.33 to -29.33 m AHD), the report postulates this is due to water from the Tertiary Clay aquitard (which is known to have a salinity of 1000 – 3000 mg/L) leaking water upwards into the Quaternary Limestone. The salinity profile does not appear to have significantly varied over time.
- The above wells LKW038 and LKW039 are approximately 10 m apart and therefore it appears that within the depth range of -17.26 m AHD to -23.33 m AHD, the salinity at this point in the aquifer increases from approximately 455 to 1300 mg/L.
- Observation well LKW040, which has its production zone in the Tertiary Sand aquifer, intersected brackish water. Salinity in this well ranges from 2600 to 33 800 mg/L). When sonded in 2002, 2004 and 2008 there was no significant variation in the salinity profile within the well (Figure 3). The data indicates that at about 50 m below ground level (-45.67 m AHD), the salinity sharply increases over a 6 m interval from brackish to saline water.

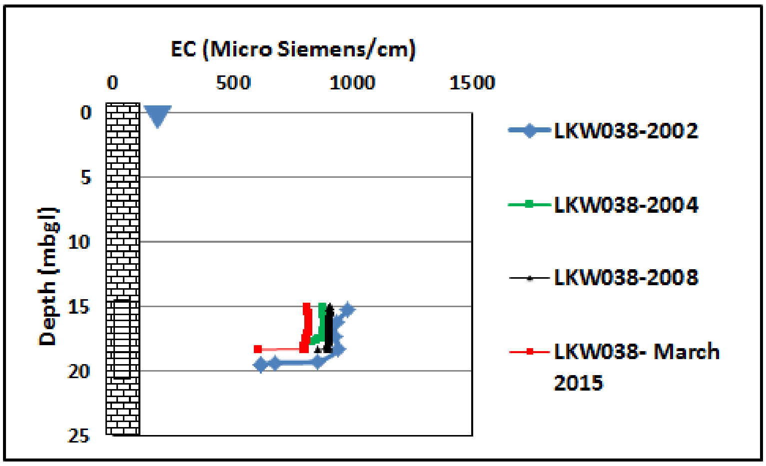


**Figure 1. Sonding results for observation well LKW038**

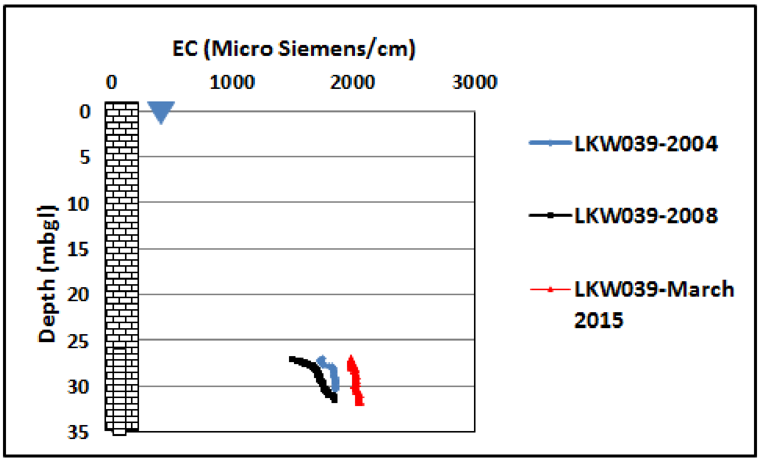


**Figure 2. Sonding results for LKW039**

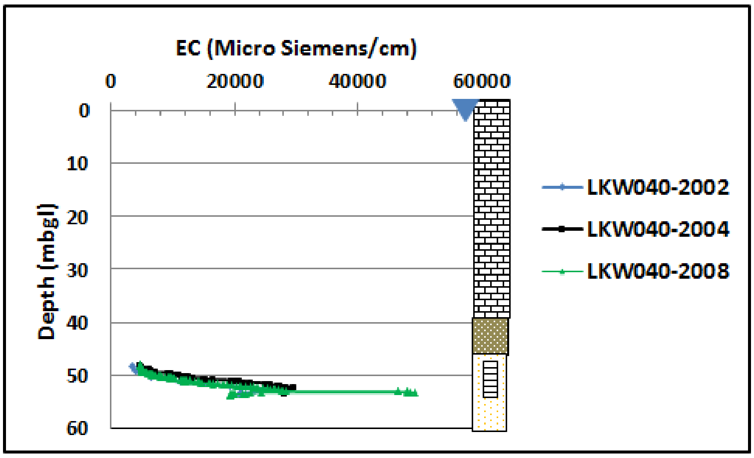


**Figure 3. Sonding results for LKW040**

The report identifies that the column of fresh water within the Quaternary Limestone aquifer at the point of sonding (LKW038 and LWK039) is about 18 to 24 m thick, as water levels are approximately 1.6 m below ground. It further identifies that this thickness has not changed significantly in the past 13 years. The report also identifies that the interface in the Tertiary Sand aquifer at LKW040 has remained stable over the past 13 years.

Given the significant depth of fresh water below the 0 m AHD lower storage trigger (up to 17 to 23 m), it is thought that maintaining the storage triggers as defined in the Draft WAP would be the more conservative (lower risk) way to manage allocations from the resource, with regular monitoring of the interface to be undertaken in the form of sonding the above mentioned wells to ensure the take of licenced water does not result in the rise of the interface within the aquifer. As such no change has been made to the triggers for the Coffin Bay consumptive pool.

### 2.2.3 Uley Wanilla consumptive pool triggers

During the consultation process, the community expressed concern about the Uley Wanilla Public Water Supply consumptive pool. In response, the upper storage trigger has been raised to equate to the 2015 storage level, indicating that if storage was to decrease from the current level, allocations would be varied immediately. Currently, the upper storage level sits at 85% of that observed in 1993, whilst the current level is 87.5% of the storage observed in 1993. Consequently, the upper storage trigger has been raised to 88% of the 1993 level.

### 2.2.4 Bramfield consumptive pool triggers

Concern was raised by licensees that the lower storage trigger for the Bramfield consumptive pool was unnecessarily high, i.e. allocations would cease faster than they needed to based on the resource condition. The lower storage trigger for Bramfield was set at the storage level which was observed when water levels were at their lowest historically during 2008. However, the storage levels are set for the consumptive pool rather than for individual lenses, as such the lower storage trigger for the Bramfield consumptive pool takes into account both the storage level for the Bramfield and Talia lenses.

Currently, the lower storage trigger for the Bramfield consumptive pool is set at 72%, however the storage level observed in the Bramfield lens in 2008 was 69%. It is reasonable to adjust the lower storage trigger for the Bramfield consumptive pool to match the lower storage level observed the Bramfield lens alone given that all licensees are located within this Bramfield area rather than near the Talia lens, since this is where the extractions are occurring. As such the lower storage trigger for the Bramfield consumptive pool has been varied in the Draft WAP to 71% of the 1993 storage. A conservative approach was taken to maintain it as high a level as possible (i.e. not dropping the lower storage trigger right down to 69%) but at a level which allows licensees to take 10% of their water access entitlement if water levels declined to reach those observed during the height of the drought. This seems appropriate given water levels are currently rising or stable.

## 2.3 Changes of the portion of the resource capacity reserved for the environment

### 2.3.1 Coffin Bay consumptive pool

Community consultation suggested a variation to the percentage of the resource capacity to be set aside for the environment within the Coffin Bay consumptive pool, which would result in no excess water being available from the pool in order to maintain current groundwater discharges to Kellidie Bay. If additional water was to be taken from the resource, there were concerns that there would be a reduction in the groundwater discharge to the Bay. Concerns were also expressed about the recharge rates used to determine the resource capacity. As such the recharge rates have been re-calculated as outlined in Section 2.4, with this process resulting in a lower recharge rate being adopted for Coffin Bay which in turn, resulted in no excess water being available within the consumptive pool and a 10.7% allocation reduction for all current licensees.

### 2.3.2 Uley South Public Water Supply consumptive pool

Historically under the previous WAP, the distribution of the resource capacity between non-consumptive and consumptive was the same for all Quaternary Limestone resources, with 60% of the resource capacity provided to meet non-consumptive requirements (a 60/40 ratio).

The risk assessment undertaken for the draft WAP proposed that only 30% be provided to the environment (a ratio of 30/70) which is half the amount adopted by the previous WAP for the Uley South Public Water Supply (PWS) consumptive pool. Given this significant change, a groundwater flow modelling exercise was carried out to determine the impacts of the proposed 30/70 ratio on the Uley South Basin. The groundwater flow model (Knowling and Werner, 2015) is based on the existing Knowling et al. (2015) model and therefore the model extent varies somewhat from the boundary of the Uley South PWS consumptive pool as outlined in the WAP. However as the model area includes the Uley South well field, it will include the greatest impacts that are likely to be predicted by the model. The model ran five scenarios (outlined below) and compared them to the base case being the 2013–14 extraction rate of 4740 ML/y. For scenarios S2 and S3, SA Water advised that additional wells would likely be drilled to assist in extracting the additional water and consequently, eight additional extraction wells were added to the model..

**Table 4: Model scenarios for non-consumptive demands in the Uley South PWS consumptive pool.**

| PWA | Pumping rate (ML/y) | Non-consumptive demand (%) |
|---|---|---|
| Base case | 4740 | 66.37 |
| S1 | 7250 | 48.5 |
| S2 | 9900 | 30 |
| S3 | 8490 | 40 |
| S4 | 7070 | 50 |
| S5 | 5650 | 60 |

The scenarios were compared to the baseline condition. All scenarios result in a decline in water level from the baseline condition (which is expected given that all extraction rates are higher than the baseline condition).

Scenario 2 (the largest extraction volume proposed) results in drawdowns from the baseline condition of up to 1.1 m, with drawdowns of 0.6 m observed over 17 km$^2$. In contrast, scenario 5 resulted in less than 0.2 m drawdown from the baseline condition across virtually all of the basin area (with the exception of production well locations).

Because extractions historically have been as high as 7575 ML/y, it is therefore important to compare the scenario results with the historical water levels. It was considered that if the scenario resulted in water levels being similar to those previously observed within the aquifer, the take of that volume of water would be sustainable and within the bounds of the demands exerted on the aquifer historically. However it is important to note that baseline water levels are averaged over the period 2004-09 and they will vary up or down in the future depending on rainfall patterns. Actual extractions will also vary in the future depending on demand.

Results at the nine observation well locations indicate that Scenario 5 predicted water levels generally well above the averaged historical minimum, ranging from 0.19 m below the averaged historical low to 1.02 m above. Scenarios 1 and 4 predicted water levels similar to those previously observed (ranging from 0.29 m below to 0.42 m above), whilst Scenario 2 predicted water levels which were generally below those historically observed (0.51 m below to 0.08 m above). The Scenario 3 predictions were similar to Scenario 2 but to a lesser extent (0.31 m below to 0.38 m above).

The risk of seawater intrusion was considered by examining if water levels were predicted to fall below sea level, but in all cases, this did not occur.

Based on the predicted results, it was considered that whilst Scenario 5 would result in the best outcomes for the aquifer (water levels much higher than the historical low), it would require a reduction in allocation for SA Water, the only licence holder within the consumptive pool. SA Water has historically extracted up to 7575 ML/y with no substantial negative impact to the aquifer having been observed. Whilst Scenario 5 represents a conservative approach, it does not provide sufficient water to meet the critical human needs of the population of Eyre Peninsula.

Scenario 2 would result in high security for the reticulated water supply from Uley South into the future, making an additional 2652 ML/y available as excess water within the consumptive pool, which SA Water could apply for to augment to their current allocation. However the modelling indicates that it is likely to result in declines in water level below the historical low of up to 0.5 m. Given this type of stress has not been experienced by the resource before, the risk to the resource is much higher (based on the assumption that water levels will not rise significantly in the future and that extractions are constantly at a level of 9900 ML/y).

Scenario 1 appears to be the most suitable option for the WAP, as the modelling indicates that water levels in the majority of wells show declines of only 0.18 m but rises of up to 0.38 m. This volume would allow access to sufficient water to meet demand whilst protecting the resource from any significant impacts. Current extractions from Uley South PWS consumptive pool are well below the scenario volume of 7250 ML/y, with 2006–07 being the last time extractions were in this range. Therefore the portion of the resource capacity to be set aside for the environment, based on the Uley South modelling, has been varied from 30% to 48.5%.

#### 2.3.3 Polda consumptive pool

The results of the risk assessment assigned 60% of the Polda consumptive pool resource to meet non-consumptive requirements. This is the same 60/40 ratio as was provided under the previous Plan.

It is recognised that since November 2008, the Polda resource has been under a Notice of Prohibition (NOP) restricting the take of licensed water from the Polda area as it was considered that "*the rate at which water is being taken from wells that take underground water from the Quaternary Limestone aquifer in the Polda Basin….. is such that the quantity of water available can no longer meet the demand*" (DPC 2015). Consequently, a conservative approach is proposed to amend the portion of the resource capacity provided to non-consumptive requirements in order to limit the excess water within the Polda consumptive pool to be only 10 ML. This variation will prohibit any significant allocations being issued within this area, which will allow existing users the right to take water whilst allowing the resource to recover from the historical water level declines. As such, the portion of the resource capacity set aside for non-consumptive requirements has been varied from 60% outlined in the risk assessment to 97.6384% (the multiple decimal points are required in order to achieve 10 ML of excess water). In addition, the volumes relinquished by SA Water has been allocated to the environment and will not be available for future extraction.

#### 2.3.4 Uley Wanilla Public Water Supply consumptive pool

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

Since extractions began in about 1950, long term monitoring has shown that either recharge or extraction can be the dominant influence on water level trends at different times. Long-term declines in water level have occurred since 1986 which are only stabilising or slightly recovering since 2010.

A conservative approach is proposed to amend the portion of the resource capacity set aside to meet non-consumptive requirements to limit any excess water within the consumptive pool. As such, the portion of the resource capacity set aside for non-consumptive requirements has been varied from 60% outlined in the risk assessment to 72.7289% (the multiple decimal points are required to eliminate any excess water).

## 2.4 Recharge rates

There was significant feedback about the recharge rates, specifically questioning how the 10 year rolling average used to calculate recharge from the previous WAP operates. The millennium drought highlighted how the 10 year rolling average recharge rates were not effective in managing the resource when the recharge to the aquifers significantly and dramatically decreased. Consequently, changes in groundwater storage will be used to vary annual allocations for licensed purposes under the new WAP. However, in order to determine the starting resource capacity, a recharge rate is required. The recharge rates were recalculated based on suggestions from the community feedback.

The recharge rates for the various recharge zones were recalculated using a larger number of observation wells for both 2008 and 2013 (2008 being the driest year during the drought, and 2013 being the most recent year with monthly data available to calculate recharge). The methodology is outlined in detail in Appendix 1 with more detailed tables of data contained in Appendix 2. This methodology used a range of specific yield values for each recharge zone to determine the recharge rate via the water table fluctuation methodology. Given that the result was a range of values based on the varying specific yield, the average was taken to be representative of the recharge rate for the recharge zone.

In instances where there were no monitoring wells available within a recharge zone to determine a recharge rate, or the wells showed no rise in the watertable a conservative approach was taken with a recharge rate of 0 mm/y being applied. The re-calculated recharge rates resulted in two options: a) the average recharge rate for 2008 and b) the average recharge rate for 2013. A conservative approach was taken to adopt the lower 2008 average recharge rate. These new recharge rates can be seen in Table 5. An exception to this methodology is the recharge rate for Uley South PWS resource which is determined by the Ordens et al. (2011) paper for reasons outlined in Stewart (2013).

**Table 5: Recalculated recharge rates**

| Management area | Recharge zone | Recharge rate (mm) | Draft WAP Recharge Rate (mm) |
|---|---|---|---|
| Coffin Bay | Coffin Bay A lens | 25 | 29 |
| Uley Wanilla Public Water Supply | Uley Wanilla lens | 20.5 | 13 |
| | Uley Wanilla brackish | 22.5 | 13 |
| Uley North | Coffin Bay B lens | 0 | 6 |
| | Coffin Bay C lens | 1.9 | 9 |
| | Uley East A lens | 73.5 | 22 |
| | Uley East B lens | 0 | 22 |
| | Uley North brackish | 7.5 | 13 |
| Uley South Public Water Supply | Uley South lens | 129 | 129 |
| | Uley South brackish | 129 | 129 |
| | Uley South Tertiary Leakage | 14 | 14 |
| | Pantania lens | 0 | 13 |
| | Mikkira lens | 0 | 13 |
| Lincoln South Public Water Supply | Lincoln A lens | 0 | 35 |
| | Lincoln B lens | 0 | 35 |
| | Lincoln C lens | 0 | 35 |
| | Lincoln South brackish | 33 | 35 |
| Polda | Polda lens | 5.6 | 15.8 |
| | Polda East A lens | 0 | 6.8 |
| | Polda East B lens | 0 | 6.8 |
| | Polda brackish | 11.2 | 14.1 |
| | Tinline lens | 0 | 17.5 |
| | Talia East lens | 0 | 15.8 |
| Bramfield | Bramfield lens | 2.2 | 25 |
| | Bramfield brackish | 5 | 14.1 |
| | Talia lens | 0 | 15.8 |
| Sheringa | Sheringa A lens | 0 | 16.3 |
| | Sheringa B lens | 0.7 | 15.8 |
| | Kappawanta lens | 11.4 | 22 |
| | Sheringa brackish | 5.9 | 14.1 |

# 3 Summary of changes to the document

## 3.1 Changes to figures

- Figures 1 & 2: - inserted new rainfall and cumulative deviation figures
- Figures 3 and 4 (previously 1 & 2): updated to include additional rainfall stations which are referred to later in the Plan.
- Figure 11: new figure displaying the historical take of water from the various resources across Eyre Peninsula
- Figures 12–17: new figures displaying rainfall and water level trends and extraction from the lenses used for public water supply
- Figure 37: new figure displaying the purpose of use for the water access entitlements
- Figure 39 (previously 26): updated to include risk category
- Figures 42–49 (previously 29–36): updated to reflect new triggers and include the historical high and current storage assessments

## 3.2 Changes to tables

- Table 1: updated with Archean time period and more detail on the rock types present
- Table 3 & 4: updated with new Recharge Rates
- Table 10: varied to include additional swamps/surface water systems
- Table 11: new – displays buffers for the marine discharges
- Table 16: new – displays the scenarios tested for the Uley South modelling
- Table 17: new – Adopted consumptive/non-consumptive demand ratios after amendments
- Table 20 & 21 (previously 17 and 18): updated due to new recharge rates and changes to the non-consumptive demand
- Table 22 (previously 19): updated to reflect new triggers
- Table 23 (previously 20): updated with 2015 data
- Table 24 (previously 21): updated with new numbers due to new recharge rates and changes to the non-consumptive demand
- Table 26 (previously 23): updated with 2015 levels
- Table 27 (previously 24): updated with 2015 levels

## 3.3 Changes to text

- Minor language and sentence structure changes throughout document
- 1.1 – intro to include reference to NWI and state that it is a statutory document
- 1.1.1 – objectives made more specific
- 1.2.1 and 1.2.2 – insert sections on long-term rainfall trends
- 1.3.3.1 – amend section on recharge processes, including new figures

- 1.3.2.1 – Quaternary Limestone Aquifer: provide further description on Bridgewater Formation deposition.
- 1.3.3.4 – Basement Aquifer Recharge: include example of Green Patch where recharge could occur
- 1.4 – add new section describing historic extraction and water level trends, includes additional graphs and the possibility of extinct GDEs
- 1.5 – previously 1.4: updated with reference to NWI
- 2.2.1 – add description of conservative approach taken to delineate the fresh water lenses (i.e. brackish area may not be brackish)
- 2.2.1.2 – recharge rates updated with new methodology and results
- 2.2.1.4 – new addition of section outlining that Polda is reserved for irrigation, industrial and recreational purposes only
- 2.2.3.3 – include anecdotal evidence of dams impacting on recharge to Lincoln North and findings of farm dams study
- 2.3 – add that aquifer tests may be required when determining new consumptive pools
- 3.3.1 – addition of Big and Little Swamp to have environmental protection zones
- 3.3.1 – Pillie wetland group – addition of anecdotal evidence of Lake Pillie becoming terrestrialised
- 3.3.1 – Hamilton wetland group – anecdotal evidence of salinity variations
- 3.3.5 – addition of section on Coffin and Kellidie bay
- 4.2.3 – include description of possible impacts on wetlands from the take of water, includes figure, addition of text about big and little swamp
- 4.2.4 – new section on red gum environmental protection zones, includes figure
- 4.2.5 – new section on marine discharges EPZs, additional table
- 5.1.1.5 – new section describing variations to the risk assessment to determine the portion of the resource that is set aside for the environment, includes two new tables
- 5.1.2.2 – new figure of purpose of water access entitlement for each consumptive pool
- 5.1.2.2.2 – acknowledgement that SA Water voluntarily surrendered their licences for Polda, Polda North and Kappawanta
- 5.4.2 – Water for Stock and Domestic Use: identify that a change in land use may require further water for stock.
- 5.4.4 – Mining Industry: include possibility that an operating mine within the PWA will require licenced groundwater in the near future.
- 5.4.5 – Land Values: amend text to reflect Musgrave landholders views on how access to groundwater can affect land values
- 6.1 – acknowledgement of adaptive management approach link to NWI and the Act
- 6.1.5 – updated with 2015 data
- 6.4 – Principles 15 and 16: re-written with the addition of Principle 17 to convey principles in relation to mining clearly
- 6.5 (Principle 19 – now 20): updated to reflect period over which WAE are determined and that these are limited to the max volume of the consumptive pool
- 6.6 – content added to describe what a water allocation isn't required for

- 7.1.2 (Principle 29 – now 30) b: updated due to significantly larger area of EPZs (many of which are anecdotal and not based on scientific evidence) to allow for development if it will cause no harm
- 7.1.3 (Principle 33 – now 34) e: updated due to significantly larger area of EPZs (many of which are anecdotal and not based on scientific evidence) to allow for development if it will cause no harm. Addition of f and g describing the consumptive pool reserved for specific purposes and h describing that drained or discharged water can only be recovered from the consumptive pool into which it was drained
- 7.1.3 (Principle 33 – now 34) f-h: included outlining that reserved consumptive pools can't be used for another purpose and that water drained or discharged into one consumptive pool can only be recovered from that pool
- 7.1.3 (principle 34 – now 35) c, addition of water level measurements
- 7.1.5 – new section with new principle on conversion of a mineral well to a water well
- 7.2 – updated with regulation determination
- 8.2.1 – additional text talking about requirements from annual water use reports
- 8.3 – addition of text that demands on the resource are recorded by DEWNR and that extraction may be required to be monitored monthly is outlined on an annual water use report
- 9 – addition of NWI
- References – addition of new references.

# 4 Appendix 1: Watertable fluctuation method – Musgrave PWA and Southern Basins PWA

## 4.1 Recharge estimates

The watertable fluctuation method was used to calculate recharge rates for Quaternary Limestone resources in the Southern Basins and Musgrave PWAs. Recharge rates were calculated for a low recharge year (2008) and the most recent period where sufficient monitoring data was available (2013[1]).

Recharge rates for the Uley South Basin do not require review as they are based on findings by Ordens et al. (2011), who used a combination of the watertable fluctuation method and the chloride mass balance method to derive a maximum recharge rate for the basin of 129 mm/y.

## 4.2 Watertable fluctuation method

The watertable fluctuation (WTF) method is applicable only to unconfined aquifers and is based on the premise that rises in groundwater levels are due to recharge water arriving at the watertable (Healy and Cook, 2002). The WTF method is summarised here for ease of reference, for a detailed discussion of the method along with its assumptions and limitations see Healy and Cook (2002).

Recharge ($R$) is calculated as:

$$R = Sy * \Delta h/\Delta t \qquad \text{(Equation 1)}$$

Where $Sy$ is specific yield, $\Delta t$ is the change in time and $\Delta h$ is equal to the height difference between the peak of the water level rise, and the low point of an extrapolated antecedent recession curve, which is the trace that the hydrograph would have followed if recharge did not occur. Drawing this curve is quite subjective and should only be applied where long-term data is available and many recession curves can be drawn.

For the assumptions of the WTF method to be valid, application of the method is most appropriate for high-temporal logger data, where groundwater level is measured at least hourly and Equation 1 is applied to each individual water-level rise (i.e. discreet recharge events). Each rise is then summed for a "gross" annual estimate of recharge. An example is given in Figure 4. The "gross" recharge is calculated using Equation 1 where $\boldsymbol{\Delta h}$ is equal to the height difference between the peak of the rise and the low point of the extrapolated antecedent recession curve (dashed line), and $\boldsymbol{\Delta t}$ is equal to the time over which $\boldsymbol{\Delta h}$ is estimated.

[1] Data from 2014 was not used as monitoring was reduced from monthly to quarterly.

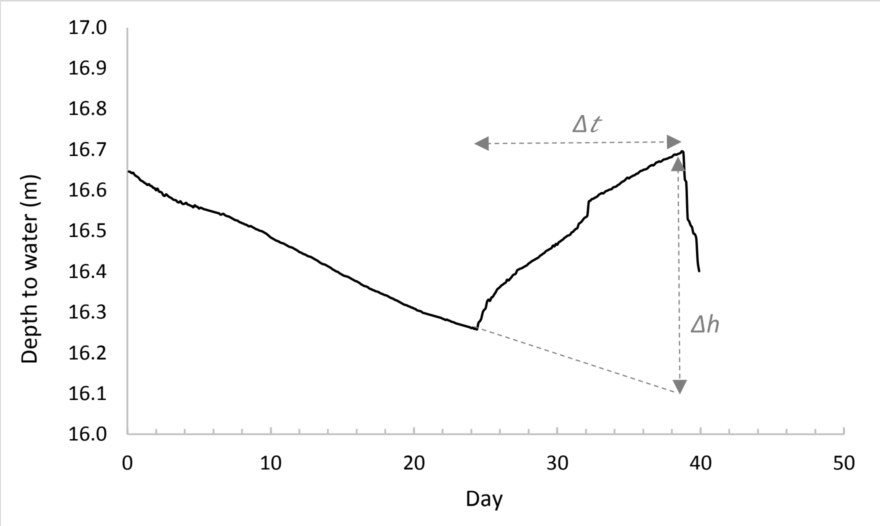


**Figure 4. Hypothetical example of the watertable rise in a well in response to rainfall**

The method can also be applied to seasonal or annual data to estimate "net" recharge. However there are two ways to choose the low point of the watertable (which are illustrated in Figure 5). The first is to use the low point of the extrapolated antecedent recession curve, and the second is to use the lowest measured water level value. In Figure 5 the 'net' recharge is calculated using Equation 1 where $\Delta h$ can be, i) equal to the height difference between the peak of the rise and the low point of the extrapolated antecedent recession curve (dashed line) or, ii) equal to the height difference between the peak of the rise and the measured low point.

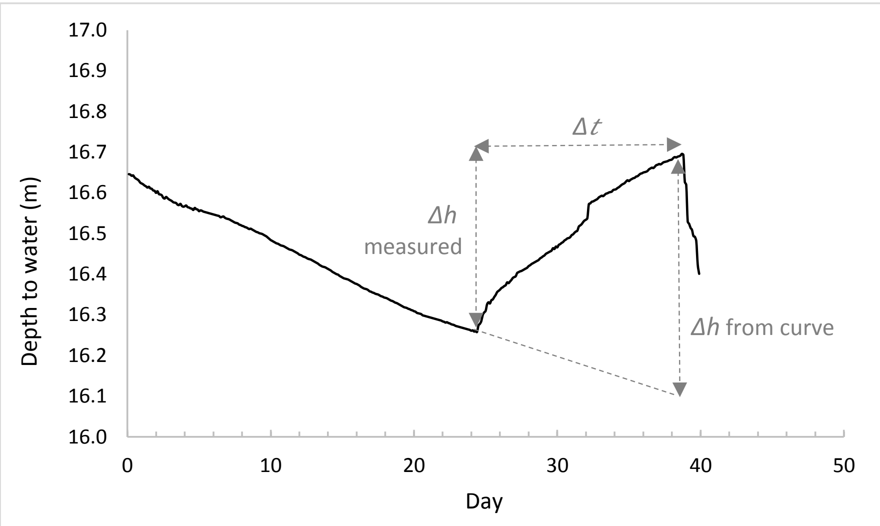


**Figure 5. Hypothetical example of the watertable rise in a well in response to rainfall**

Considering that high-temporal logger data is not available for each Quaternary Limestone resource, the WTF method has been applied to monthly monitoring data. The low point of the watertable was selected using the lowest measured point from the monitoring data set, rather than using the low point of an extrapolated antecedent recession curve. This approach is more conservative as it results in a lower $\Delta h$ value, and therefore a lower recharge value.

Published values for specific yield ($Sy$) across each PWA have previously been summarised in Stewart *et al*. (2012, Appendix A). The full range of published $Sy$ values for each Quaternary Limestone resource were used to calculate recharge rates (Appendix 2).

## 4.3 Selected wells

116 observation wells are used to calculate storage each year in the Southern Basins and Musgrave PWAs (Stewart 2013). These observation wells were initially selected for application of the WTF method as they have robust monitoring datasets. However as recharge is calculated using the difference between the lowest and highest water level measurement ($\Delta h$), recharge would be overestimated if pumping near the observation well reduced the watertable further than would naturally occur.

To account for the effects of pumping on recharge estimates, observation wells that are located close to production wells were excluded from analysis. Here a production well was interpreted as a well in which groundwater extraction is greater than 10 ML/y. The method used to calculate buffer distances around these production wells is described in detail in Stewart *et al.* (2012, pp74-75). In summary, the buffers were calculated using a variation on the Theis Solution (Fetter 1994), which uses aquifer parameters, well functions and groundwater allocation volumes to estimate drawdown at a specified distance from a well. The buffer distance around production wells in each Quaternary Limestone resource is shown in Table 6. The wells selected for recharge rate estimation using the WTF method are shown in Figures 6 and 7. In the Southern Basins PWA, 19 wells were selected for analysis and 40 wells were excluded. In the Musgrave PWA, 53 wells were selected for analysis and four wells were excluded (WAD031 was also excluded in 2013. The wells was used in the 2008 analysis as the adjacent production well did not extract more than 10 ML, however in 2013 the adjacent production well extracted 12 M).

**Table 6: Adopted buffer distances around production wells for each Quaternary Limestone resource (after Stewart 2013, Table 21)**

| PWA | Quaternary Limestone resource | Adopted buffer (m) |
|---|---|---|
| Southern Basins | Coffin Bay | 450 |
| | Coffin Bay C | 450 |
| | Lincoln Basins | 750 |
| | Lincoln C | 750 |
| | Lincoln South brackish | 750 |
| | Uley East A | 450 |
| | Uley East B | 450 |
| | Uley North brackish | 450 |
| | Uley Wanilla | 450 |
| | Outside lens area | 750 |
| Musgrave | Bramfield | 1900 |
| | Kappawanta | 150 |
| | Musgrave (regional) | 150 |
| | Sheringa A | 150 |
| | Sheringa B | 150 |
| | Polda | 170 |

Notes:

Uley South is not included in the analysis as per the discussion in Section 2.2.1.2 of the WAP

Where there is insufficient aquifer parameter data to calculate a buffer, the buffer distance for the nearest water resource was adopted.

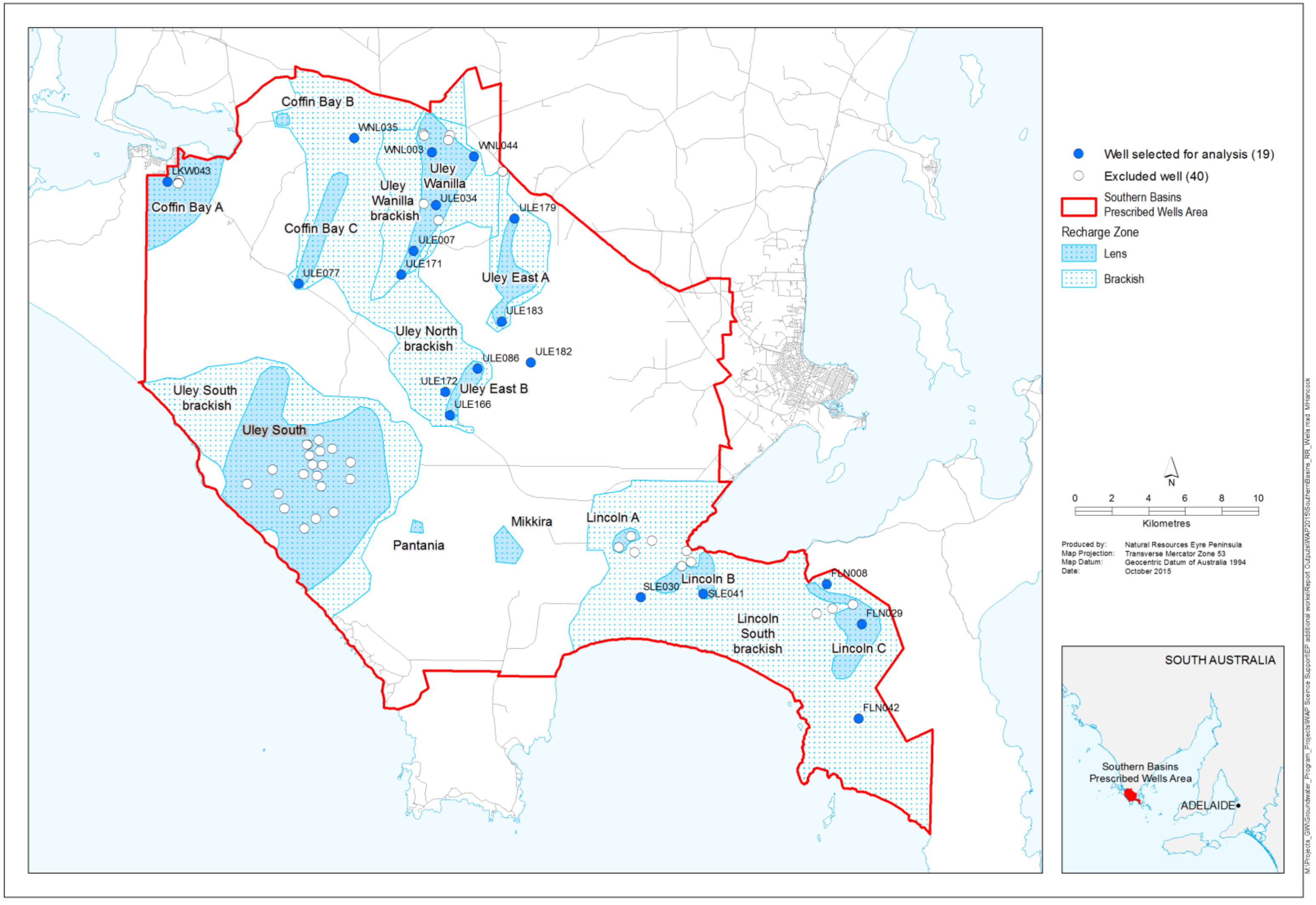


**Figure 6. Observation wells in the Southern Basins PWA selected for recharge rate estimation using the WTF method**

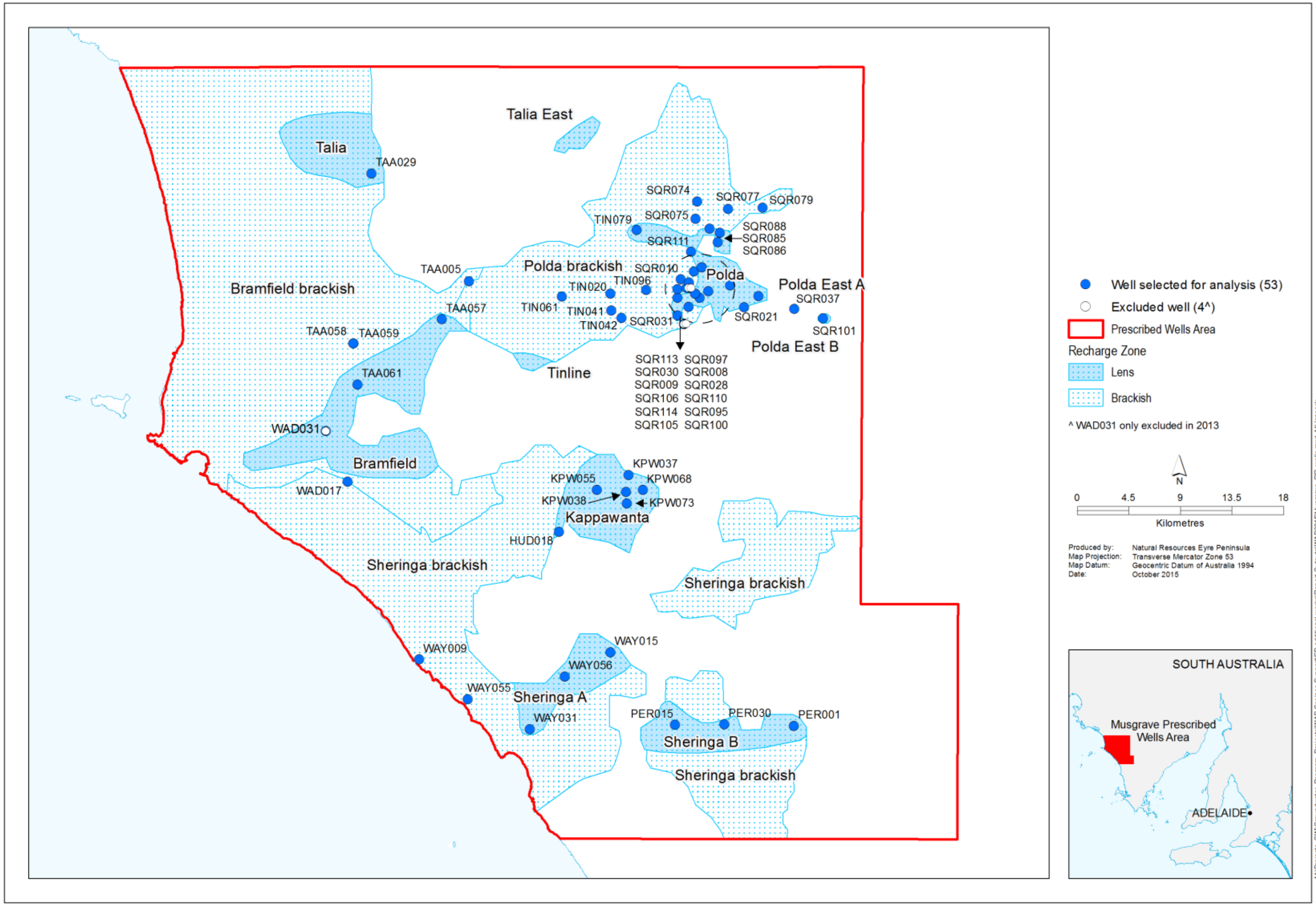


**Figure 7. Observation wells in the Musgrave PWA selected for recharge rate estimation using the WTF method**

## 4.4 Results

The range in recharge estimates for the Southern Basins and Musgrave PWAs for 2008 and 2013 are displayed in Figures 5 to 8. The full results are presented in Appendix 2.

The recharge rates for each Quaternary Limestone resource are of lower importance now that each resource is managed adaptively using storage volumes and trigger levels to determine allocations. Nevertheless, a precautionary approach has been adopted and the average of the estimated recharge rate for a low rainfall year (2008) will be adopted as the revised recharge rate for each resource (Table 7). Results for the 2014 data can be observed in Appendix 2.

Observation wells ULE171 and WNL044 are located on the perimeter of the Uley Wanilla lens and were used to estimate recharge for the surrounding Uley Wanilla brackish resource. In the absence of any monitoring wells in the vicinity of a resource, recharge was unable to be estimated using the water table fluctuation method and in order to take a conservative approach a recharge rate of 0 mm/y has been adopted. However it should be noted that this will not affect the majority of existing users, as the allocation will vary based on the storage level assessment. The recharge rate variations only have influence over the starting resource capacity, and may reduce the portion of water available in some consumptive pools for licenced purposes.

On the north-eastern edge of the Uley Wanilla brackish resource, the measured $\Delta h$ in well WNL045 (0.65 m in 2008; 1.35 m in 2013) is more than three times greater than any other well in the entire Southern Basins PWA. Whilst these measurements could be real and suggest recharge from nearby Big Swamp overflow, a precautionary approach has been adopted and WNL045 has been excluded from analysis using the WTF method.

Where the $\Delta h$ is less than 0.05 m, there is low confidence in the calculated recharge rate as the errors associated with water level measurements may actually be larger than the recorded water level rise (Post & von Asmuth, 2013) and as such any results in this range have been assumed to be a recharge of 0 mm/y.

**Table 7: Adopted recharge rates for each Quaternary Limestone resource**

| PWA | Quaternary water resource | Average recharge rate 2008 (mm/y) |
|---|---|---|
| Southern Basins | Coffin Bay A | 25 |
| | Coffin Bay C | 1.9 |
| | Lincoln B | 0.0 ^ |
| | Lincoln C | 0.0 * |
| | Lincoln South brackish | 33.0 |
| | Uley East A | 73.5 |
| | Uley East B | 0.0 * |
| | Uley North brackish | 7.5 |
| | Uley Wanilla | 20.5 |
| | Uley Wanilla brackish | 20.5 |
| | Outside lens area | 0.0 ^ |
| Musgrave | Bramfield | 2.2 |
| | Bramfield brackish | 5 |

| | | |
|---|---|---|
| | Kappawanta | 11.4 |
| | Sheringa A | 0.0 * |
| | Sheringa B | 0.7 |
| | Sheringa brackish | 5.9 |
| | Polda | 5.6 |
| | Polda brackish | 11.2 |
| | Polda East A | 0.0 ^ |
| | Polda East B | 0.0 * |
| | Talia | 0.0 * |

^ No data available

* No observed rise in watertable

Uley South is not included in the analysis as per the discussion in Section 2.2.1.2 of the WAP

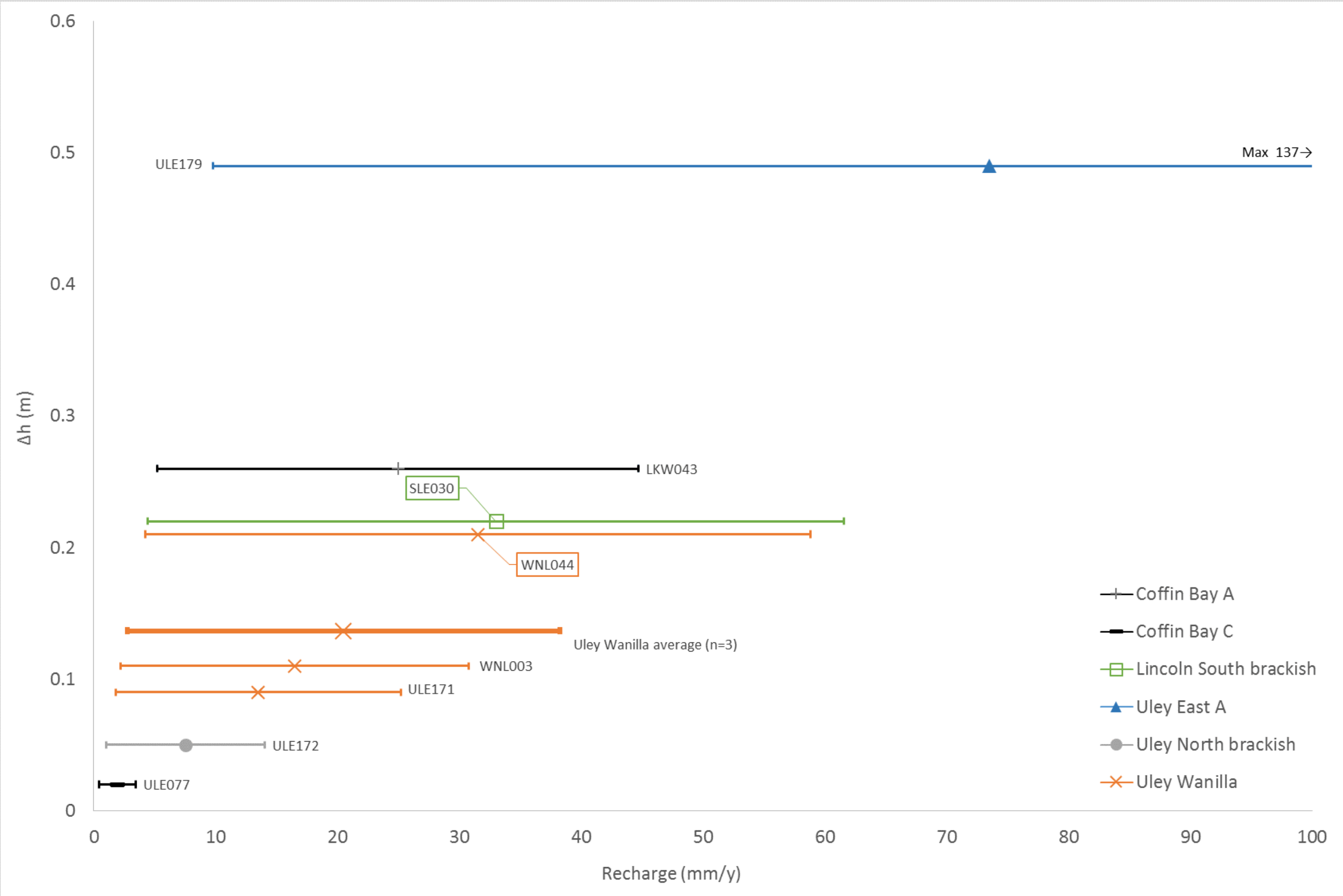


**Figure 8. Range in recharge estimates for the Southern Basins PWA Quaternary Limestone resources in 2008, using the WTF method. The marker represents the average and the error bars represent the range, as determined by the range in specific yield. The basin average is also shown for the Uley Wanilla resource, using a larger marker and thicker error bars.**

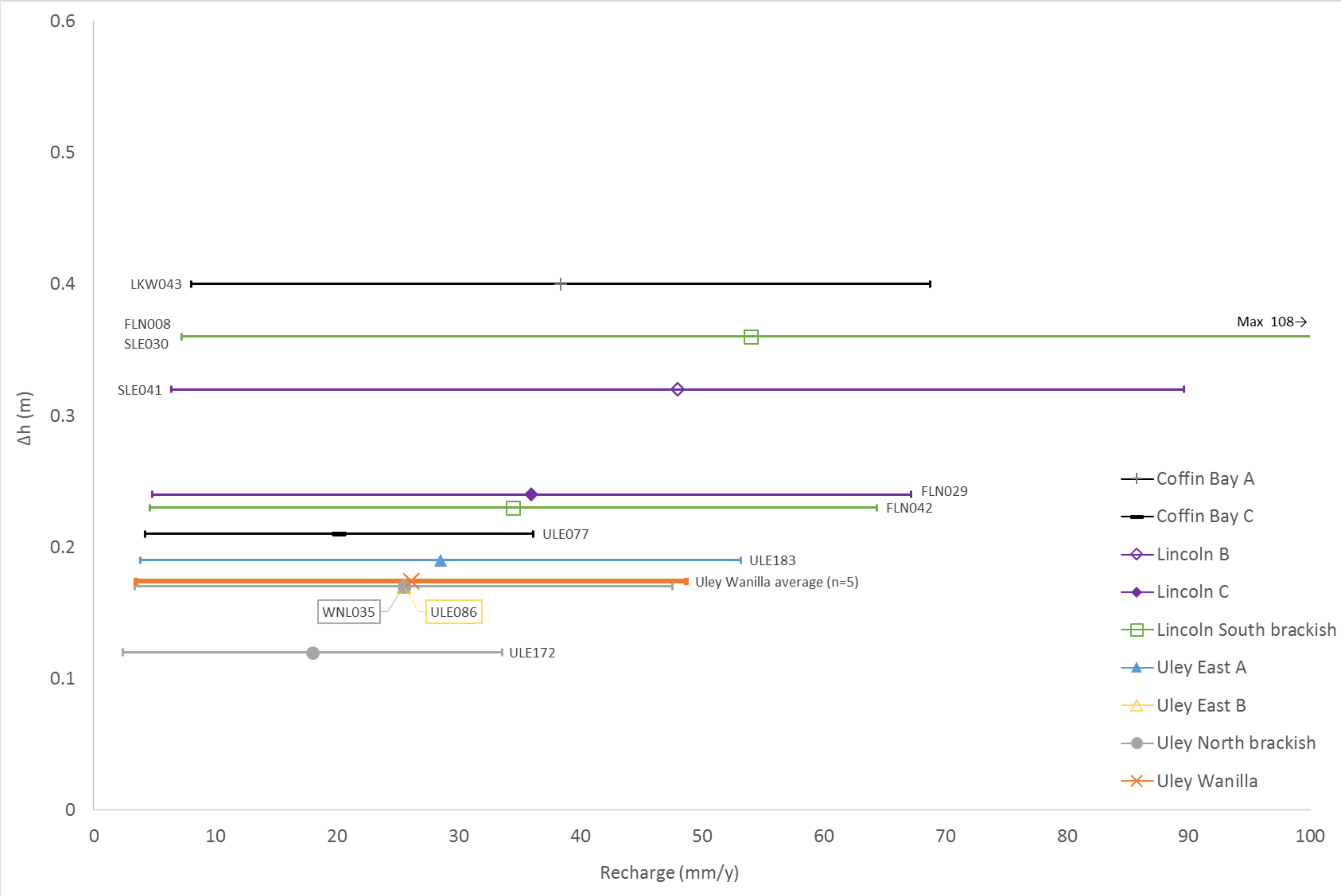


**Figure 9. Range in recharge estimates for the Southern Basins PWA Quaternary Limestone resources in 2013, using the WTF method.**
**The marker represents the average and the error bars represent the range, as determined by the range in specific yield. Due to the number of wells monitored in 2013, only the average is shown for the Uley Wanilla resource.**

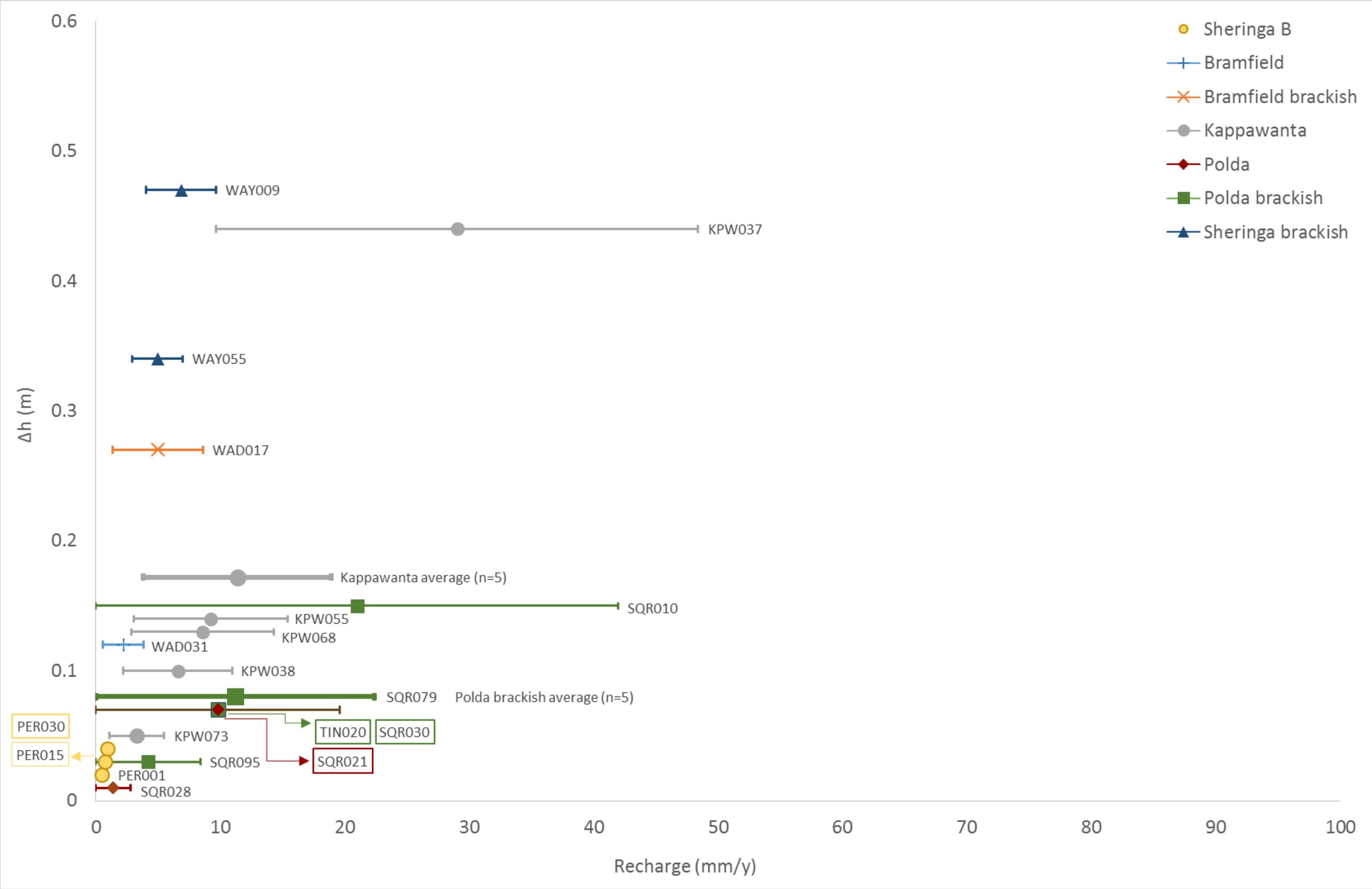


**Figure 10. Range in recharge estimates for the Musgrave PWA Quaternary Limestone resources in 2008, using the WTF method.**
**The marker represents the average rate and the error bars represent the range, which is determined by the range in specific yield. The basin average is also shown for the Polda brackish and Kappawanta resources, using a larger marker and thicker error bars.**

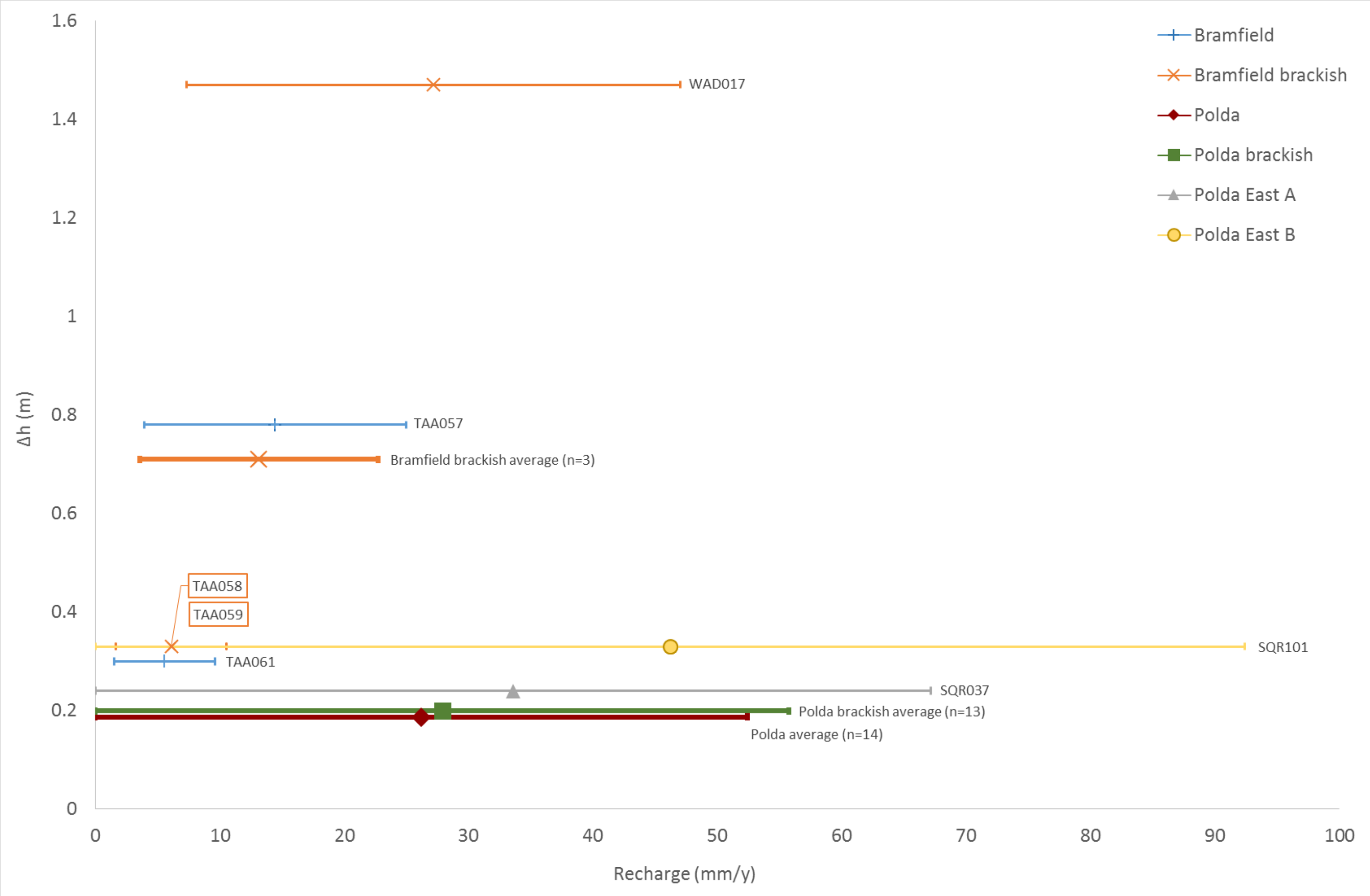


**Figure 11. Range in recharge estimates for the Musgrave PWA Quaternary Limestone resources in 2013, using the WTF method.**
**Note the different y-axis scale. The marker represents the average rate and the error bars represent the range, which is determined by the range in specific yield. The basin average is also shown for the Bramfield brackish resource, using a larger marker and thicker error bars. Considering the large number of wells monitored in 2013, only the average rate is displayed for the Polda and Polda brackish resources.**

# 5 Appendix 2: Watertable fluctuation data

**Table 8: 2008 recharge rates for Southern Basins PWA Quaternary Limestone resources using the watertable fluctuation method. Wells with sufficient data available for recharge estimates are displayed graphically in Figure 8.**

| Obs number | Unit number | Basin | Sy min | Sy max | Δh (m) | Δt (days) | R min (mm/y) | R max (mm/y) | R avg (mm/y) | Basin average | R min (mm/y) | R max (mm/y) | R avg (mm/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LKW043 | 592800308 | Coffin Bay A | 0.02 | 0.17 | 0.26 | 124 | 5.2 | 44.72 | 24.96 | Coffin Bay A | 5.2 | 44.7 | 25.0 |
| ULE077 | 602800910 | Coffin Bay C | 0.02 | 0.17 | 0.02 | 35 | 0.4 | 3.44 | 1.92 | Coffin Bay C | 0.4 | 3.4 | 1.9 |
| SLE041 | 602800397 | Lincoln B | 0.02 | 0.28 | No data | | | | | Lincoln B | | | N/A |
| FLN029 | 602800536 | Lincoln C | 0.02 | 0.28 | No rise | | | | | Lincoln C | | | N/A |
| FLN008 | 602800532 | Lincoln South brackish | 0.02 | 0.28 | No data | | | | | | | | |
| FLN042 | 602800514 | Lincoln South brackish | 0.02 | 0.28 | No clear rise | | | | | | | | |
| SLE030 | 602800457 | Lincoln South brackish | 0.02 | 0.28 | 0.22 | 125 | 4.4 | 61.6 | 33 | Lincoln South brackish | 4.4 | 61.6 | 33.0 |
| ULE182 | 602801612 | Outside lens area | 0.02 | 0.28 | No rise | | | | | Outside lens area | | | N/A |
| ULE179 | 602801607 | Uley East A | 0.02 | 0.28 | 0.49 | 125 | 9.8 | 137.2 | 73.5 | | | | |
| ULE183 | 602801610 | Uley East A | 0.02 | 0.28 | No rise | | | | | Uley East A | 9.8 | 137.2 | 73.5 |
| ULE086 | 602800854 | Uley East B | 0.02 | 0.28 | No rise | | | | | | | | |
| ULE166 | 602800906 | Uley East B | 0.02 | 0.28 | No rise | | | | | Uley East B | | | N/A |
| ULE172 | 602800872 | Uley North brackish | 0.02 | 0.28 | 0.05 | 55 | 1 | 14 | 7.5 | | | | |
| WNL035 | 602801159 | Uley North brackish | 0.02 | 0.28 | No rise | | | | | Uley North brackish | 1.0 | 14.0 | 7.5 |
| ULE007 | 602800981 | Uley Wanilla | 0.02 | 0.28 | No rise | | | | | | | | |
| ULE034 | 602800968 | Uley Wanilla | 0.02 | 0.28 | No rise | | | | | | | | |
| ULE171 | 602800999 | Uley Wanilla | 0.02 | 0.28 | 0.09 | 27 | 1.8 | 25.2 | 13.5 | | | | |
| WNL003 | 602801517 | Uley Wanilla | 0.02 | 0.28 | 0.11 | 253 | 2.2 | 30.8 | 16.5 | | | | |
| WNL044 | 602801603 | Uley Wanilla | 0.02 | 0.28 | 0.21 | 70 | 4.2 | 58.8 | 31.5 | Uley Wanilla | 2.7 | 38.3 | 20.5 |

Where R = recharge; Sy = specific yield; Δt is the change in time and Δh is equal to the height difference between the peak of the water level rise and the lowest measured water level value.

N/A = insufficient data to determine a recharge rate.

**Table 9: 2013 recharge rates for Southern Basins PWA Quaternary Limestone resources using the watertable fluctuation method. Wells with sufficient data available for recharge estimates are displayed graphically in Figure 9.**

| Obs number | Unit number | Basin | Sy min | Sy max | Δh (m) | Δt (days) | R min (mm/y) | R max (mm/y) | R avrg (mm/y) | Basin average | R min (mm/y) | R max (mm/y) | R avrg (mm/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LKW043 | 592800308 | Coffin Bay A | 0.02 | 0.17 | 0.4 | 225 | 8 | 68.8 | 38.4 | Coffin Bay A | 8.0 | 68.8 | 38.4 |
| ULE077 | 602800910 | Coffin Bay C | 0.02 | 0.17 | 0.21 | 47 | 4.2 | 36.12 | 20.16 | Coffin Bay C | 4.2 | 36.1 | 20.2 |
| SLE041 | 602800397 | Lincoln B | 0.02 | 0.28 | 0.32 | 78 | 6.4 | 89.6 | 48 | Lincoln B | 6.4 | 89.6 | 48.0 |
| FLN029 | 602800536 | Lincoln C | 0.02 | 0.28 | 0.24 | 113 | 4.8 | 67.2 | 36 | Lincoln C | 4.8 | 67.2 | 36.0 |
| FLN008 | 602800532 | Lincoln South brackish | 0.02 | 0.28 | 0.36 | 112 | 7.2 | 100.8 | 54 | | | | |
| FLN042 | 602800514 | Lincoln South brackish | 0.02 | 0.28 | 0.23 | 84 | 4.6 | 64.4 | 34.5 | | | | |
| SLE030 | 602800457 | Lincoln South brackish | 0.02 | 0.28 | 0.36 | 168 | 7.2 | 100.8 | 54 | Lincoln South brackish | 6.3 | 88.7 | 47.5 |
| ULE182 | 602801612 | Outside lens area | 0.02 | 0.28 | No clear rise | | | | | Outside lens area | | | N/A |
| ULE179 | 602801607 | Uley East A | 0.02 | 0.28 | No data | | | | | | | | |
| ULE183 | 602801610 | Uley East A | 0.02 | 0.28 | 0.19 | 83 | 3.8 | 53.2 | 28.5 | Uley East A | 3.8 | 53.2 | 28.5 |
| ULE086 | 602800854 | Uley East B | 0.02 | 0.28 | 0.17 | 22 | 3.4 | 47.6 | 25.5 | | | | |
| ULE166 | 602800906 | Uley East B | 0.02 | 0.28 | No clear rise | | | | | Uley East B | 3.4 | 47.6 | 25.5 |
| ULE172 | 602800872 | Uley North brackish | 0.02 | 0.28 | 0.12 | 22 | 2.4 | 33.6 | 18 | | | | |
| WNL035 | 602801159 | Uley North brackish | 0.02 | 0.28 | 0.17 | 86 | 3.4 | 47.6 | 25.5 | Uley North brackish | 2.9 | 40.6 | 21.7 |
| ULE007 | 602800981 | Uley Wanilla | 0.02 | 0.28 | 0.1 | 22 | 2 | 28 | 15 | | | | |
| ULE034 | 602800968 | Uley Wanilla | 0.02 | 0.28 | 0.09 | 22 | 1.8 | 25.2 | 13.5 | | | | |
| ULE171 | 602800999 | Uley Wanilla | 0.02 | 0.28 | 0.14 | 80 | 2.8 | 39.2 | 21 | | | | |
| WNL003 | 602801517 | Uley Wanilla | 0.02 | 0.28 | 0.18 | 83 | 3.6 | 50.4 | 27 | | | | |
| WNL044 | 602801603 | Uley Wanilla | 0.02 | 0.28 | 0.36 | 83 | 7.2 | 100.8 | 54 | Uley Wanilla | 3.5 | 48.7 | 26.1 |

Where R = recharge; Sy = specific yield; Δt is the change in time and Δh is equal to the height difference between the peak of the water level rise and the lowest measured water level value.

N/A = insufficient data to determine a recharge rate.

**Table 10: 2008 recharge rates for Musgrave PWA Quaternary Limestone resources using the watertable fluctuation method. Wells with sufficient data available for recharge estimates are displayed graphically in Figure 10.**

| Obs number | Unit number | Basin | Sy min | Sy max | Δh (m) | Δt (days) | R min (mm/y) | R max (mm/y) | R avrg (mm/y) | Basin average | R min (mm/y) | R max (mm/y) | R avrg (mm/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TAA057 | 593001063 | Bramfield | 0.005 | 0.032 | No rise | | | | | | | | |
| TAA061 | 593000005 | Bramfield | 0.005 | 0.032 | No rise | | | | | | | | |
| WAD031 | 583000235 | Bramfield | 0.005 | 0.032 | 0.12 | 66 | 0.6 | 3.8 | 2.2 | Bramfield | 0.6 | 3.8 | 2.2 |
| TAA005 | 593000057 | Bramfield brackish | 0.005 | 0.032 | No rise | | | | | | | | |
| TAA058 | 593000027 | Bramfield brackish | 0.005 | 0.032 | No rise | | | | | | | | |
| TAA059 | 593000028 | Bramfield brackish | 0.005 | 0.032 | No rise | | | | | | | | |
| WAD017 | 593000138 | Bramfield brackish | 0.005 | 0.032 | 0.27 | 66 | 1.4 | 8.6 | 5.0 | Bramfield brackish | 1.4 | 8.6 | 5.0 |
| HUD018 | 593000253 | Kappawanta | 0.022 | 0.11 | No rise | | | | | | | | |
| KPW037 | 593000754 | Kappawanta | 0.022 | 0.11 | 0.44 | 60 | 9.7 | 48.4 | 29.0 | | | | |
| KPW038 | 593000753 | Kappawanta | 0.022 | 0.11 | 0.1 | 36 | 2.2 | 11.0 | 6.6 | | | | |
| KPW055 | 593000755 | Kappawanta | 0.022 | 0.11 | 0.14 | 66 | 3.1 | 15.4 | 9.2 | | | | |
| KPW068 | 593000757 | Kappawanta | 0.022 | 0.11 | 0.13 | 36 | 2.9 | 14.3 | 8.6 | | | | |
| KPW073 | 593001060 | Kappawanta | 0.022 | 0.11 | 0.05 | 66 | 1.1 | 5.5 | 3.3 | Kappawanta | 3.8 | 18.9 | 11.4 |
| SQR009 | 593001001 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR021 | 593000912 | Polda | 0.00002 | 0.28 | 0.07 | 36 | 0.0 | 19.6 | 9.8 | | | | |
| SQR028 | 593001004 | Polda | 0.00002 | 0.28 | 0.01 | 66 | 0.0 | 2.8 | 1.4 | | | | |
| SQR031 | 593001005 | Polda | 0.00002 | 0.28 | No clear rise | | | | | | | | |
| SQR085 | 593100128 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR086 | 593100123 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR088 | 593100129 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR097 | 593001050 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR100 | 593100397 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR105 | 593001046 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR106 | 593001059 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR111 | 593100402 | Polda | 0.00002 | 0.28 | No data | | | | | | | | |
| SQR114 | 593001073 | Polda | 0.00002 | 0.28 | No rise | | | | | | | | |
| TIN079 | 593100200 | Polda | 0.00002 | 0.28 | No rise | | | | | Polda | 0.0 | 11.2 | 5.6 |
| SQR008 | 593001000 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR010 | 593000958 | Polda brackish | 0.00002 | 0.28 | 0.15 | 66 | 0.0 | 42.0 | 21.0 | | | | |
| SQR030 | 593000962 | Polda brackish | 0.00002 | 0.28 | 0.07 | 66 | 0.0 | 19.6 | 9.8 | | | | |
| SQR074 | 593100131 | Polda brackish | 0.00002 | 0.28 | No data | | | | | | | | |
| SQR075 | 593100130 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR077 | 593100133 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR079 | 593100051 | Polda brackish | 0.00002 | 0.28 | 0.08 | 66 | 0.0 | 22.4 | 11.2 | | | | |
| SQR095 | 593100396 | Polda brackish | 0.00002 | 0.28 | 0.03 | 66 | 0.0 | 8.4 | 4.2 | | | | |
| SQR110 | 593001062 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| SQR113 | 593001072 | Polda brackish | 0.00002 | 0.28 | No clear rise | | | | | | | | |
| TIN020 | 593000660 | Polda brackish | 0.00002 | 0.28 | 0.07 | 66 | 0.0 | 19.6 | 9.8 | | | | |
| TIN041 | 593000653 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| TIN042 | 593000625 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| TIN061 | 593000086 | Polda brackish | 0.00002 | 0.28 | No rise | | | | | | | | |
| TIN096 | 593000639 | Polda brackish | 0.00002 | 0.28 | No clear rise | | | | | Polda brackish | 0.0 | 22.4 | 11.2 |
| SQR037 | 593000885 | Polda East A | 0.00002 | 0.28 | No data | | | | | Polda East A | | | N/A |
| SQR101 | 593001045 | Polda East B | 0.00002 | 0.28 | No rise | | | | | Polda East B | | | N/A |
| WAY015 | 593000453 | Sheringa A | 0.0051 | 0.0052 | No rise | | | | | | | | |
| WAY031 | 593000361 | Sheringa A | 0.0051 | 0.0052 | No clear rise | | | | | | | | |
| WAY056 | 593000315 | Sheringa A | 0.0051 | 0.0052 | No rise | | | | | Sheringa A | | | N/A |
| PER001 | 593000546 | Sheringa B | 0.012 | 0.036 | 0.02 | 63 | 0.2 | 0.7 | 0.5 | | | | |
| PER015 | 593000535 | Sheringa B | 0.012 | 0.036 | 0.04 | 37 | 0.5 | 1.4 | 1.0 | | | | |
| PER030 | 593000550 | Sheringa B | 0.012 | 0.036 | 0.03 | 66 | 0.4 | 1.1 | 0.7 | Sheringa B | 0.4 | 1.1 | 0.7 |
| WAY009 | 593000320 | Sheringa brackish | 0.00855 | 0.0206 | 0.47 | 122 | 4.0 | 9.7 | 6.9 | | | | |
| WAY055 | 593001067 | Sheringa brackish | 0.00855 | 0.0206 | 0.34 | 30 | 2.9 | 7.0 | 5.0 | Sheringa brackish | 3.5 | 8.3 | 5.9 |
| TAA029 | 593100297 | Talia | 0.005 | 0.032 | No rise | | | | | Talia | | | N/A |

Where R = recharge; Sy = specific yield; Δt is the change in time and Δh is equal to the height difference between the peak of the water level rise and the lowest measured water level value.

N/A = insufficient data to determine a recharge rate.

**Table 11: 2013 recharge rates for Musgrave PWA Quaternary Limestone resources using the watertable fluctuation method. Wells with sufficient data available for recharge estimates are displayed graphically in Figure 11.**

| Obs number | Unit number | Basin | Sy min | Sy max | Δh (m) | Δt (days) | R min (mm/y) | R max (mm/y) | R avrg (mm/y) | Basin average | R min (mm/y) | R max (mm/y) | R avrg (mm/y) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TAA057 | 593001063 | Bramfield | 0.005 | 0.032 | 0.78 | 141 | 3.9 | 25.0 | 14.4 | | | | |
| TAA061 | 593000005 | Bramfield | 0.005 | 0.032 | 0.3 | 35 | 1.5 | 9.6 | 5.6 | | | | |
| WAD031 | 583000235 | Bramfield | 0.005 | 0.032 | Excluded^ | | | | | Bramfield | 2.7 | 17.3 | 10.0 |
| TAA005 | 593000057 | Bramfield brackish | 0.005 | 0.032 | No data | | | | | | | | |
| TAA058 | 593000027 | Bramfield brackish | 0.005 | 0.032 | 0.33 | 35 | 1.7 | 10.6 | 6.1 | | | | |
| TAA059 | 593000028 | Bramfield brackish | 0.005 | 0.032 | 0.33 | 35 | 1.7 | 10.6 | 6.1 | | | | |
| WAD017 | 593000138 | Bramfield brackish | 0.005 | 0.032 | 1.47 | 56 | 7.4 | 47.0 | 27.2 | Bramfield brackish | 3.6 | 22.7 | 13.1 |
| HUD018 | 593000253 | Kappawanta | 0.022 | 0.11 | No data | | | | | | | | |
| KPW037 | 593000754 | Kappawanta | 0.022 | 0.11 | No data | | | | | | | | |
| KPW038 | 593000753 | Kappawanta | 0.022 | 0.11 | No data | | | | | | | | |
| KPW055 | 593000755 | Kappawanta | 0.022 | 0.11 | No data | | | | | | | | |
| KPW068 | 593000757 | Kappawanta | 0.022 | 0.11 | No data | | | | | | | | |
| KPW073 | 593001060 | Kappawanta | 0.022 | 0.11 | No data | | | | | Kappawanta | | | N/A |
| SQR009 | 593001001 | Polda | 0.00002 | 0.28 | 0.2 | 140 | 0.0 | 56.0 | 28.0 | | | | |
| SQR021 | 593000912 | Polda | 0.00002 | 0.28 | 0.3 | 70 | 0.0 | 84.0 | 42.0 | | | | |
| SQR028 | 593001004 | Polda | 0.00002 | 0.28 | 0.17 | 70 | 0.0 | 47.6 | 23.8 | | | | |
| SQR031 | 593001005 | Polda | 0.00002 | 0.28 | 0.07 | 140 | 0.0 | 19.6 | 9.8 | | | | |
| SQR085 | 593100128 | Polda | 0.00002 | 0.28 | 0.11 | 70 | 0.0 | 30.8 | 15.4 | | | | |
| SQR086 | 593100123 | Polda | 0.00002 | 0.28 | 0.22 | 70 | 0.0 | 61.6 | 30.8 | | | | |
| SQR088 | 593100129 | Polda | 0.00002 | 0.28 | 0.07 | 70 | 0.0 | 19.6 | 9.8 | | | | |
| SQR097 | 593001050 | Polda | 0.00002 | 0.28 | 0.21 | 91 | 0.0 | 58.8 | 29.4 | | | | |
| SQR100 | 593100397 | Polda | 0.00002 | 0.28 | 0.2 | 122 | 0.0 | 56.0 | 28.0 | | | | |
| SQR105 | 593001046 | Polda | 0.00002 | 0.28 | 0.25 | 115 | 0.0 | 70.0 | 35.0 | | | | |
| SQR106 | 593001059 | Polda | 0.00002 | 0.28 | 0.21 | 70 | 0.0 | 58.8 | 29.4 | | | | |
| SQR111 | 593100402 | Polda | 0.00002 | 0.28 | 0.28 | 70 | 0.0 | 78.4 | 39.2 | | | | |
| SQR114 | 593001073 | Polda | 0.00002 | 0.28 | 0.26 | 70 | 0.0 | 72.8 | 36.4 | | | | |
| TIN079 | 593100200 | Polda | 0.00002 | 0.28 | 0.07 | 35 | 0.0 | 19.6 | 9.8 | Polda | 0.0 | 52.4 | 26.2 |
| SQR008 | 593001000 | Polda brackish | 0.00002 | 0.28 | 0.12 | 120 | 0.0 | 33.6 | 16.8 | | | | |
| SQR010 | 593000958 | Polda brackish | 0.00002 | 0.28 | 0.4 | 153 | 0.0 | 112.0 | 56.0 | | | | |
| SQR030 | 593000962 | Polda brackish | 0.00002 | 0.28 | 0.32 | 166 | 0.0 | 89.6 | 44.8 | | | | |
| SQR074 | 593100131 | Polda brackish | 0.00002 | 0.28 | 0.13 | 91 | 0.0 | 36.4 | 18.2 | | | | |
| SQR075 | 593100130 | Polda brackish | 0.00002 | 0.28 | 0.05 | 116 | 0.0 | 14.0 | 7.0 | | | | |
| SQR077 | 593100133 | Polda brackish | 0.00002 | 0.28 | 0.02 | 70 | 0.0 | 5.6 | 2.8 | | | | |
| SQR079 | 593100051 | Polda brackish | 0.00002 | 0.28 | 0.16 | 91 | 0.0 | 44.8 | 22.4 | | | | |
| SQR095 | 593100396 | Polda brackish | 0.00002 | 0.28 | 0.28 | 91 | 0.0 | 78.4 | 39.2 | | | | |
| SQR110 | 593001062 | Polda brackish | 0.00002 | 0.28 | 0.22 | 128 | 0.0 | 61.6 | 30.8 | | | | |
| SQR113 | 593001072 | Polda brackish | 0.00002 | 0.28 | 0.32 | 180 | 0.0 | 89.6 | 44.8 | | | | |
| TIN020 | 593000660 | Polda brackish | 0.00002 | 0.28 | 0.25 | 165 | 0.0 | 70.0 | 35.0 | | | | |
| TIN041 | 593000653 | Polda brackish | 0.00002 | 0.28 | No data | | | | | | | | |
| TIN042 | 593000625 | Polda brackish | 0.00002 | 0.28 | No data | | | | | | | | |
| TIN061 | 593000086 | Polda brackish | 0.00002 | 0.28 | 0.04 | 35 | 0.0 | 11.2 | 5.6 | | | | |
| TIN096 | 593000639 | Polda brackish | 0.00002 | 0.28 | 0.28 | 166 | 0.0 | 78.4 | 39.2 | Polda brackish | 0.0 | 55.8 | 27.9 |
| SQR037 | 593000885 | Polda East A | 0.00002 | 0.28 | 0.24 | 70 | 0.0 | 67.2 | 33.6 | Polda East A | 0.0 | 67.2 | 33.6 |
| SQR101 | 593001045 | Polda East B | 0.00002 | 0.28 | 0.33 | 115 | 0.0 | 92.4 | 46.2 | Polda East B | 0.0 | 92.4 | 46.2 |
| WAY015 | 593000453 | Sheringa A | 0.0051 | 0.0052 | No data | | | | | | | | |
| WAY031 | 593000361 | Sheringa A | 0.0051 | 0.0052 | No data | | | | | | | | |
| WAY056 | 593000315 | Sheringa A | 0.0051 | 0.0052 | No data | | | | | Sheringa A | | | N/A |
| PER001 | 593000546 | Sheringa B | 0.012 | 0.036 | No data | | | | | | | | |
| PER015 | 593000535 | Sheringa B | 0.012 | 0.036 | No data | | | | | | | | |
| PER030 | 593000550 | Sheringa B | 0.012 | 0.036 | No data | | | | | Sheringa B | | | N/A |
| WAY009 | 593000320 | Sheringa brackish | 0.00855 | 0.0206 | No data | | | | | | | | |
| WAY055 | 593001067 | Sheringa brackish | 0.00855 | 0.0206 | No data | | | | | Sheringa brackish | | | N/A |
| TAA029 | 593100297 | Talia | 0.005 | 0.032 | No data | | | | | Talia | | | N/A |

Where R = recharge; Sy = specific yield; Δt is the change in time and Δh is equal to the height difference between the peak of the water level rise and the lowest measured water level value.

N/A = insufficient data to determine a recharge rate.

^ WAD031 was excluded from analysis in 2013 as the observation well was located within a buffer to a production well

# 6 References

DPC – see Department of the Premier and Cabinet

Department of the Premier and Cabinet, 2015, *The South Australian Government Gazette*, viewed September 2015, http://www.governmentgazette.sa.gov.au/

Healy RW and Cook PG, 2002, *Using groundwater levels to estimate recharge*. Journal of Hydrology, Vol. 20(1): pp. 61–72.

Knowling MJ and Werner AD, 2015, *Provision of Uley South modelling to support the development of the Eyre Peninsula Water Allocation Plan*, unpublished, Flinders University, South Australia

Knowling MJ, Werner AD and Herckenrath D, 2015, *Quantifying climate and pumping contributions to aquifer depletion using a highly parameterised groundwater model: Uley South Basin (South Australia)*. Journal of Hydrology, Vol. 523, pp. 515–530

Ordens CM, Werner AD, Post VE, Hutson JL, Simmons CT and Irvine BM, 2011, *Groundwater recharge to a sedimentary aquifer in the topographically closed Uley South basin, South Australia*. Journal of Hydrology, Vol. 10, pp. 91–109.

Post VE and von Asmuth JR, 2013, *Review: hydraulic head measurements – new technologies, classic pitfalls*. Journal of Hydrology, Vol. 6, pp. 664–67

Stewart S, Alcoe D and Risby L, 2012, *Science support for the Musgrave and Southern Basins Prescribed Wells Areas Water Allocation Plan*. DFW Technical Report 2012/15, Government of South Australia, through Department for Water, Adelaide.

Stewart S, 2013, *Additional Science Support for the Eyre Peninsula Water Allocation Plan*. DEWNR Technical Report 2013/19, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.

Government of South Australia
Department of Environment, Water and Natural Resources