Additional science support for the Eyre Peninsula Water Allocation Plan

DEWNR Technical report 2013/19

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

ADDITIONAL SCIENCE SUPPORT FOR THE EYRE PENINSULA WATER ALLOCATION PLAN

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PURPOSE

The Department of Environment, Water and Natural Resources has been engaged by the Regional Eyre Peninsula Natural Resources Management office to provide additional support to the development of the revised Eyre Peninsula Water Allocation Plan (WAP).

In July 2010, the then Eyre Peninsula Natural Resources Management Board (EPNRMB) commissioned the Science, Monitoring and Information (SMI) Division of the former Department for Water (DFW) to undertake the Science Support for the Water Allocation Plan (SSWAP) project.

The broad scope of the SSWAP project was to review relevant existing literature and summarise key recommendations and findings, identify key knowledge gaps, undertake technical investigations to fill key knowledge gaps and provide written technical reports to assist the Board with the development of the revised Water Allocation Plan (WAP) for the Musgrave and Southern Basins Prescribed Wells Areas (PWAs). This report included a description of the prescribed groundwater resources, an assessment of the capacity of the prescribed water resources and demands, estimates of the effects of taking and using prescribed water resources on other water resources (i.e. both within and outside of the PWA), recommendations on how to manage these effects, and monitoring recommendations.

Upon completion of the project it was identified that in order to finalise the revised WAP, further scientific input was required to;

- further refine the consumptive pool boundaries and volumes
- further conceptualise and determine the process of managing annual allocations
- scenario test the methodology adopted
- propose relevant management options to protect groundwater dependent ecosystems, adjacent aquifers and existing users from possible impacts due to new extractions
- provide all the required figures and maps to be included in the revised WAP
- provide 3D visualisations of the Quaternary Limestone lenses

This report summarises the above. It should be noted that the work in this document supersedes that discussed in the previous SSWAP report.

1. AVAILABLE GROUNDWATER RESOURCES

Given the unique nature of the Eyre Peninsula water resources, it is proposed that the revised Water Allocation Plan outlines not only consumptive pool boundaries (administrative boundaries within which there is a specified extraction limit and particular rules on how water is allocated and distributed), but also recharge areas from which the consumptive pool volumes are calculated, in addition to the historical saturated extent boundary (the extent to which modelling is undertaken to vary annual allocations).

1.1. CONSUMPTIVE POOL BOUNDARIES

The consumptive pools for the Prescribed Wells Areas are as follows:

Southern Basins PWA: Coffin Bay Consumptive Pool, Uley Wanilla Public Water Supply Consumptive Pool, Uley North Consumptive Pool, Uley South Public Water Supply Consumptive Pool, Lincoln South Public Water Supply Consumptive Pool, Lincoln North Consumptive Pool, Unsaturated Quaternary Limestone Consumptive Pool, Tertiary Consumptive Pool and Basement Consumptive Pool.

Musgrave PWA: Polda Consumptive Pool, Bramfield Consumptive Pool, Sheringa Consumptive Pool, Unsaturated Quaternary Limestone Consumptive Pool, Tertiary Consumptive Pool, Jurassic Consumptive Pool and Basement Consumptive Pool.

The consumptive pool boundaries of the Quaternary Limestone aquifer are comprised of various recharge zones (discussed in Section 1.2) in addition to the spatial extent of maximum historical recorded water levels. The boundaries are tied to the nearest cadastral boundary (Figures 1 and 2) for greater clarity to determine where the boundaries actually exist on the ground as opposed to a boundary projected on a map.

The maximum historical saturated extent of the Quaternary Limestone aquifer is the spatial extent to which aquifer saturation has the potential to expand to, based on historical groundwater level records (see Section 1.3). Whilst all the estimates of the capacity of the resources have been made based on the recharge zones described in Section 1.2, future variations of allocations will employ the maximum historical saturated extent boundary as a reference point to calculate the aquifer thickness variability from one year to the next.

Tying the consumptive pool boundaries to the nearest cadastral boundary is particularly important when there are principles regarding the location of where new wells can be drilled or where allocation transfers can occur. In the Musgrave PWA the consumptive pool boundaries do follow the cadastral boundaries, however in the Southern Basins PWA there were some occasions where this was not possible due to the lack of cadastre boundaries near the edge of the maximum historical saturated extent boundaries. This occurs where the Uley South extent separates from the Uley North extent and in this instance, the edge of the saturated extent boundary and roads have been used to determine the edge of the consumptive pool. The area around Coffin Bay was also deficient in cadastral boundaries and consequently a road was used as the boundary to link the two Coffin Bay areas into one consumptive pool.

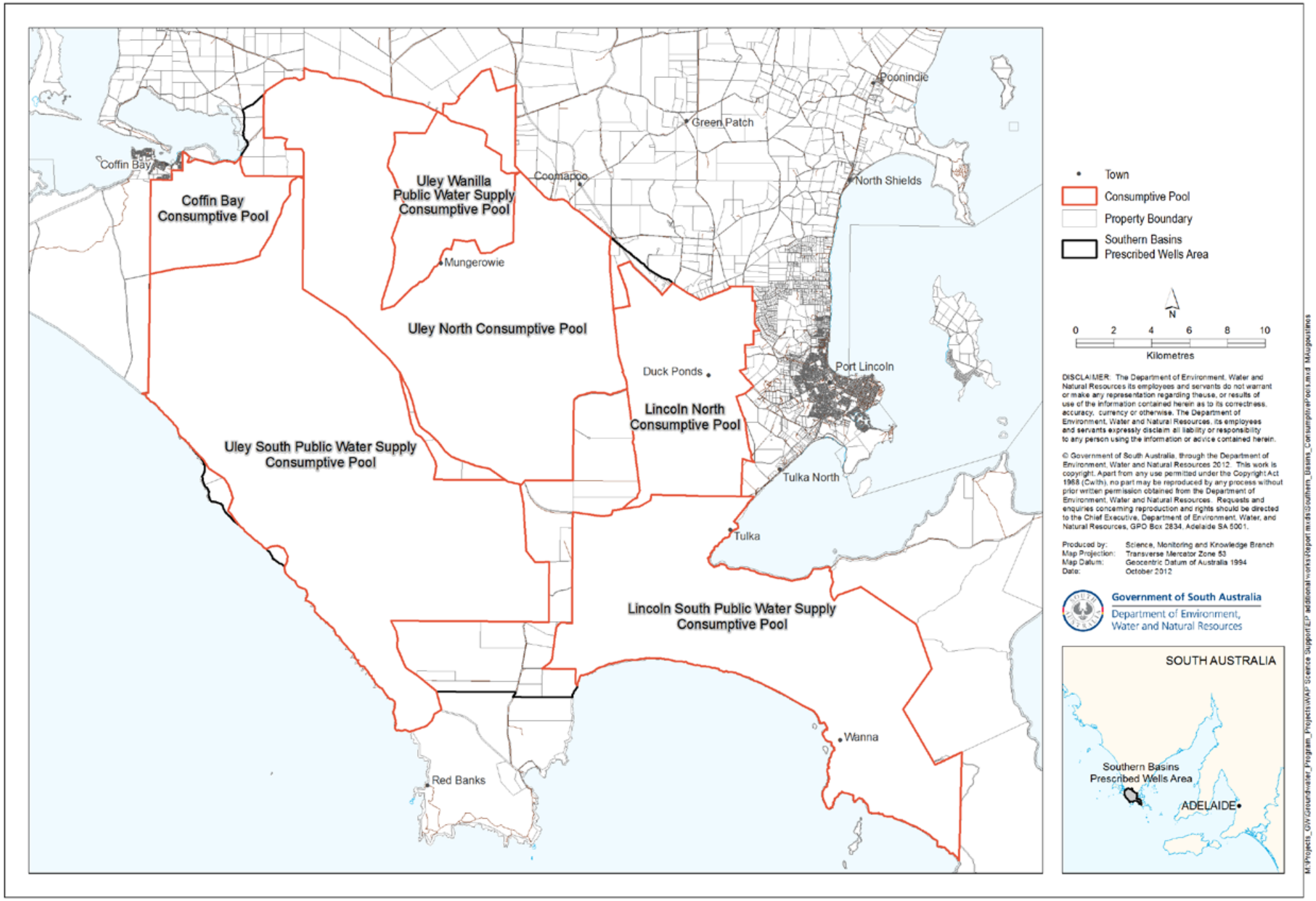

Figure 1. Consumptive Pool boundaries for the Quaternary Limestone aquifer of the Southern Basins PWA

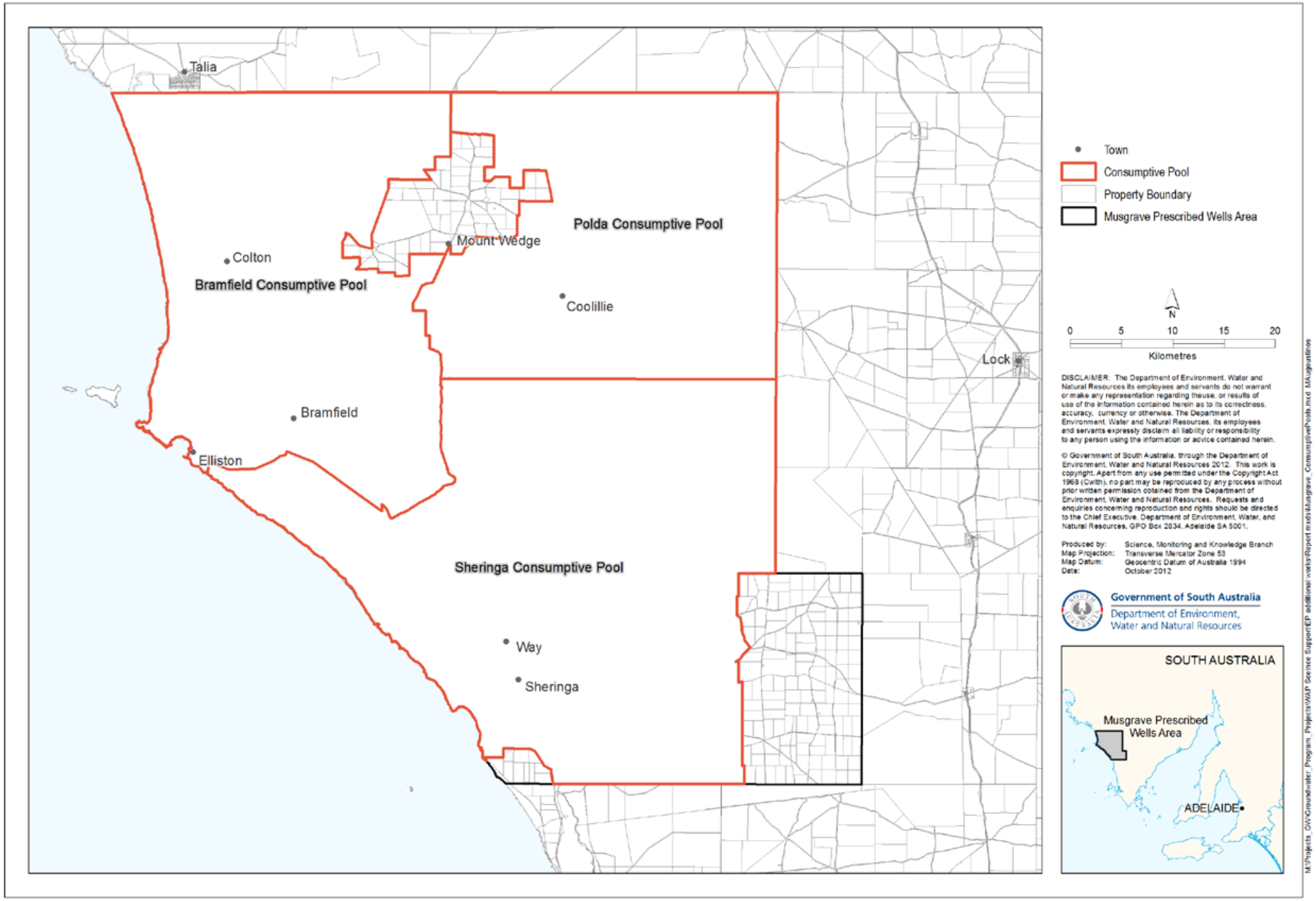

Figure 2. Consumptive Pool boundaries for the Quaternary Limestone aquifer of the Musgrave PWA

The consumptive pool boundary of the unsaturated Quaternary Limestone aquifer is represented as the inverse of the saturated Quaternary Limestone consumptive pools (Figures 3 and 4).

Consideration has been given to assigning a nominal volume of water available from the consumptive pool in the unsaturated Quaternary Limestone. It should be noted there are limited data available from the area to inform the Aquaveo™ Arc Hydro Groundwater model, used to delineate the extent of saturation, and there may be small, localised areas that are temporarily saturated where supply is likely to be unreliable. It is proposed that in these areas water would only be available for stock and domestic use and the consumptive pool would have a zero allocation limit.

The consumptive pool boundaries of the Tertiary and Basement aquifers of the Southern Basins align with the Prescribed Wells Area boundary (Figures 5 and 6). In the Musgrave PWA the Tertiary, Jurassic and Basement aquifer consumptive pool boundaries align with the PWA boundary (Figures 7 - 9).

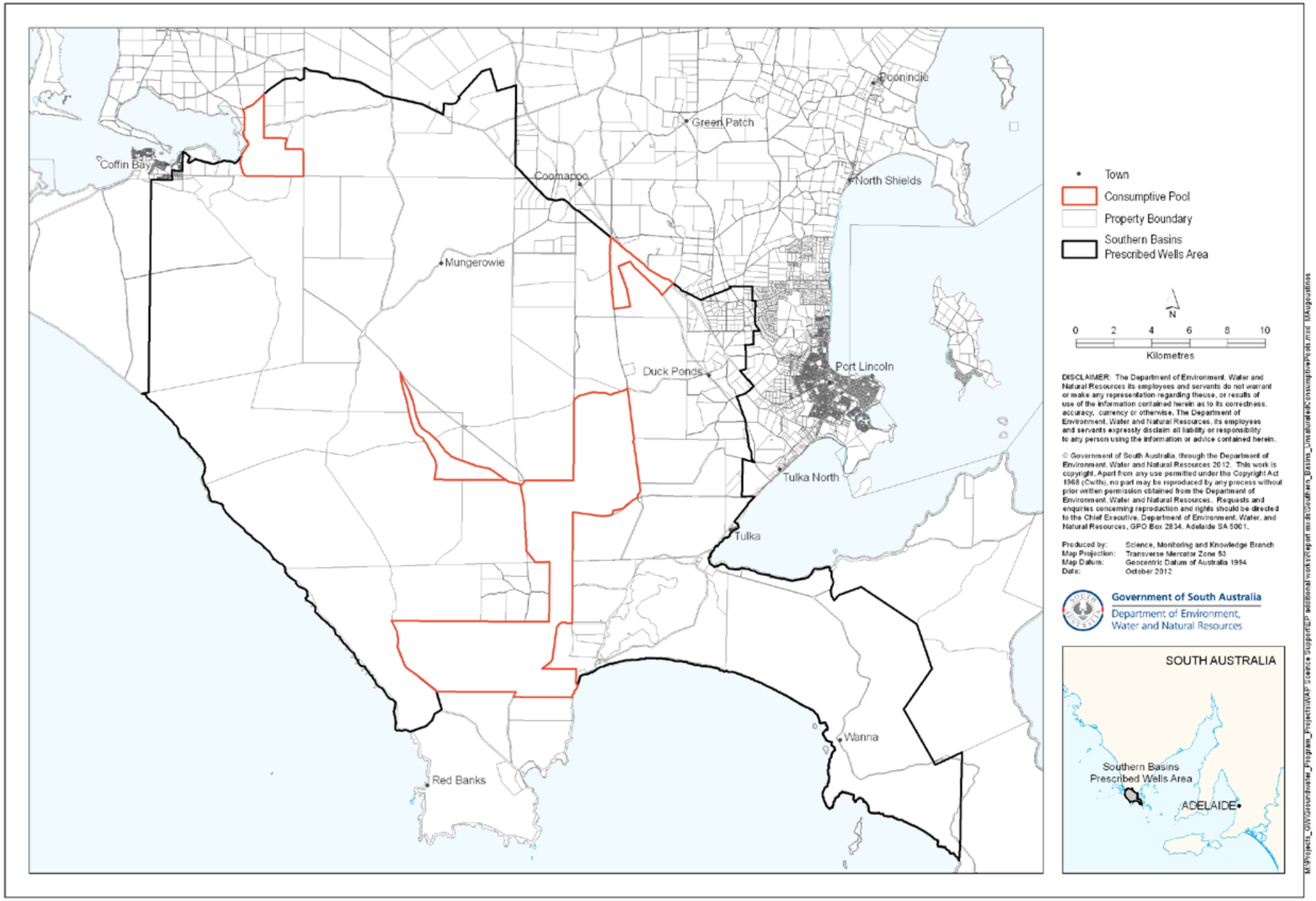

Figure 3. Consumptive Pool boundary for the Unsaturated Quaternary Limestone of the Southern Basins PWA

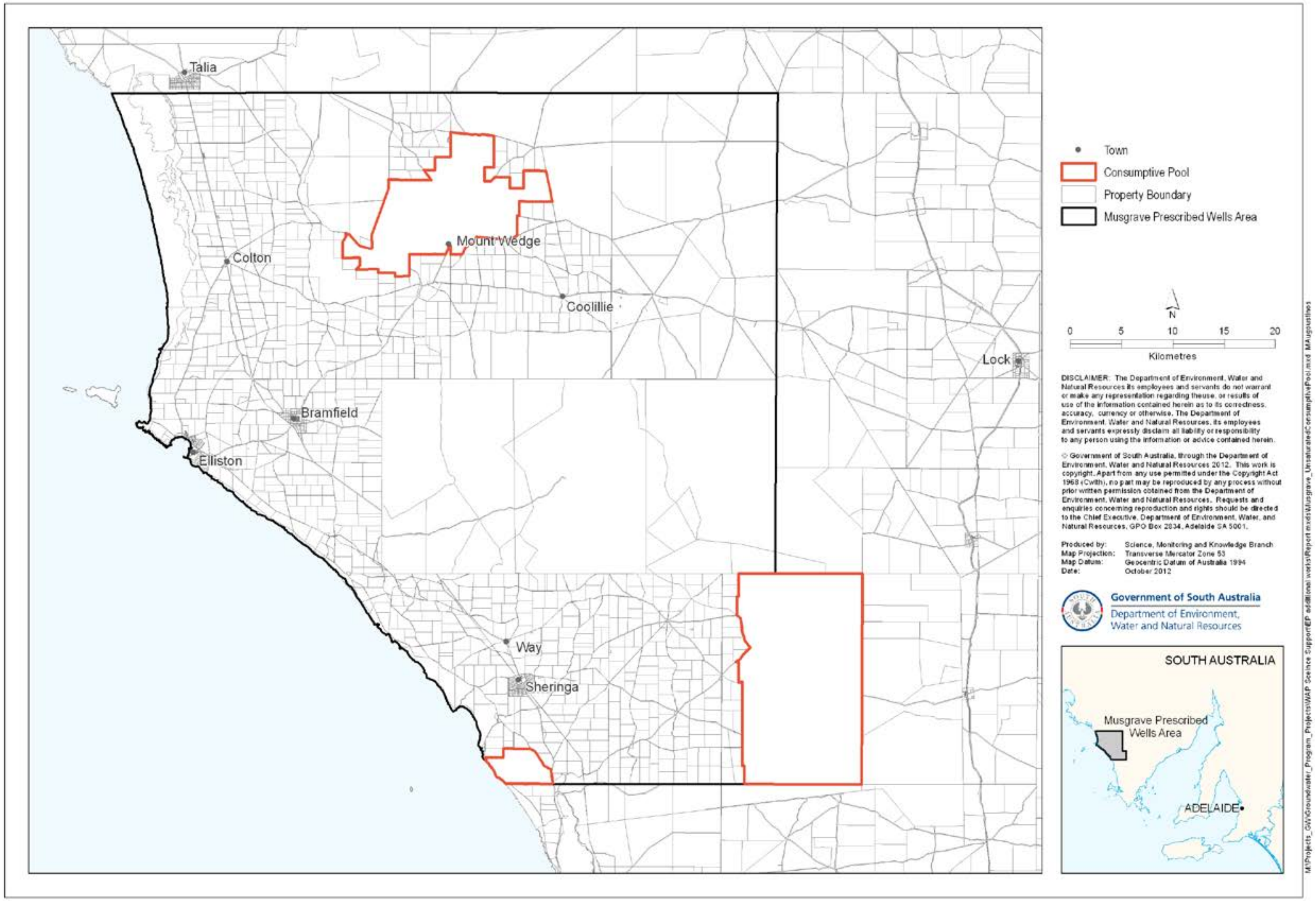

Figure 4. Consumptive Pool boundary for the Unsaturated Quaternary Limestone of the Musgrave PWA

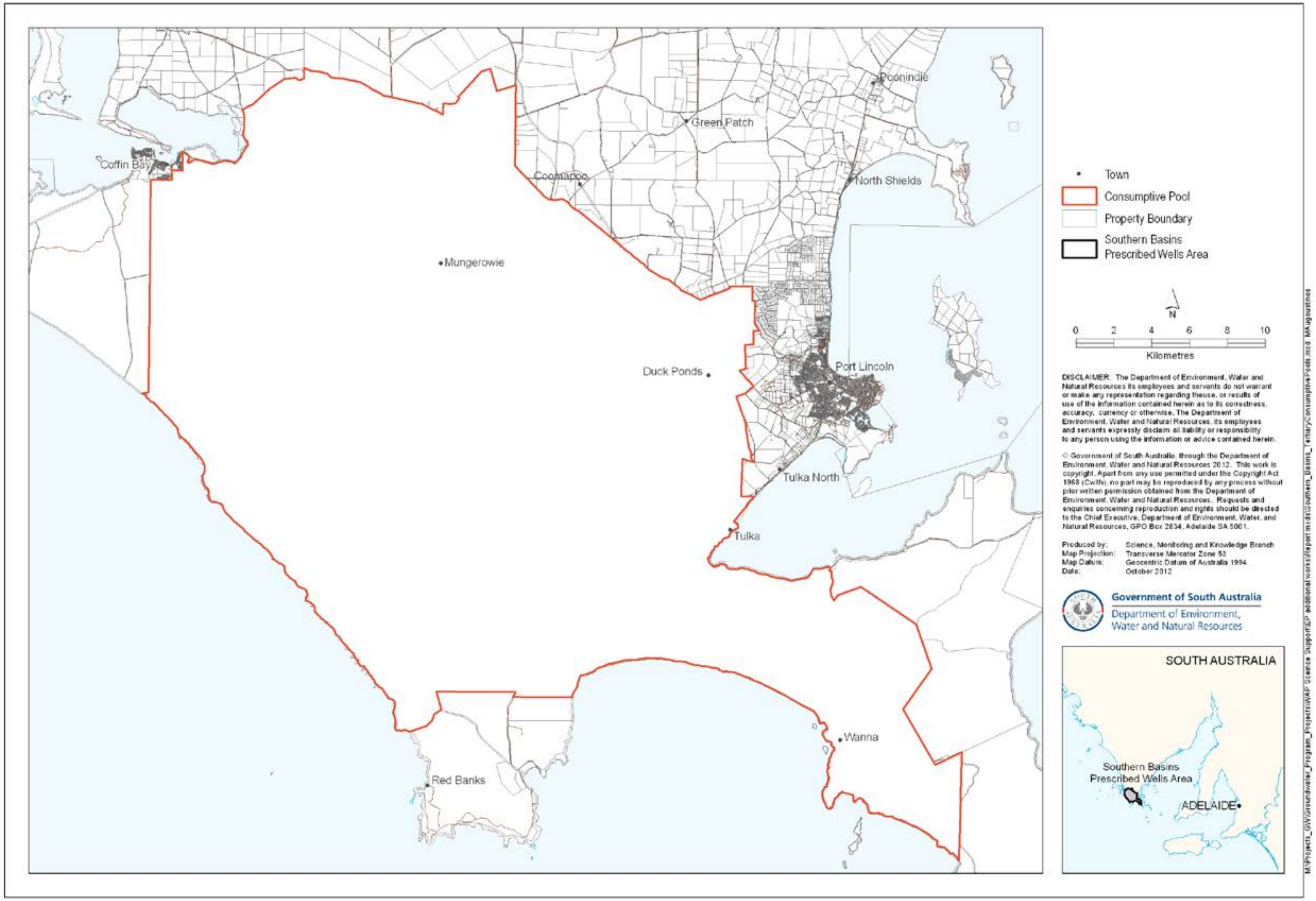

Figure 5. Consumptive Pool boundary for the Tertiary aquifer of the Southern Basins PWA

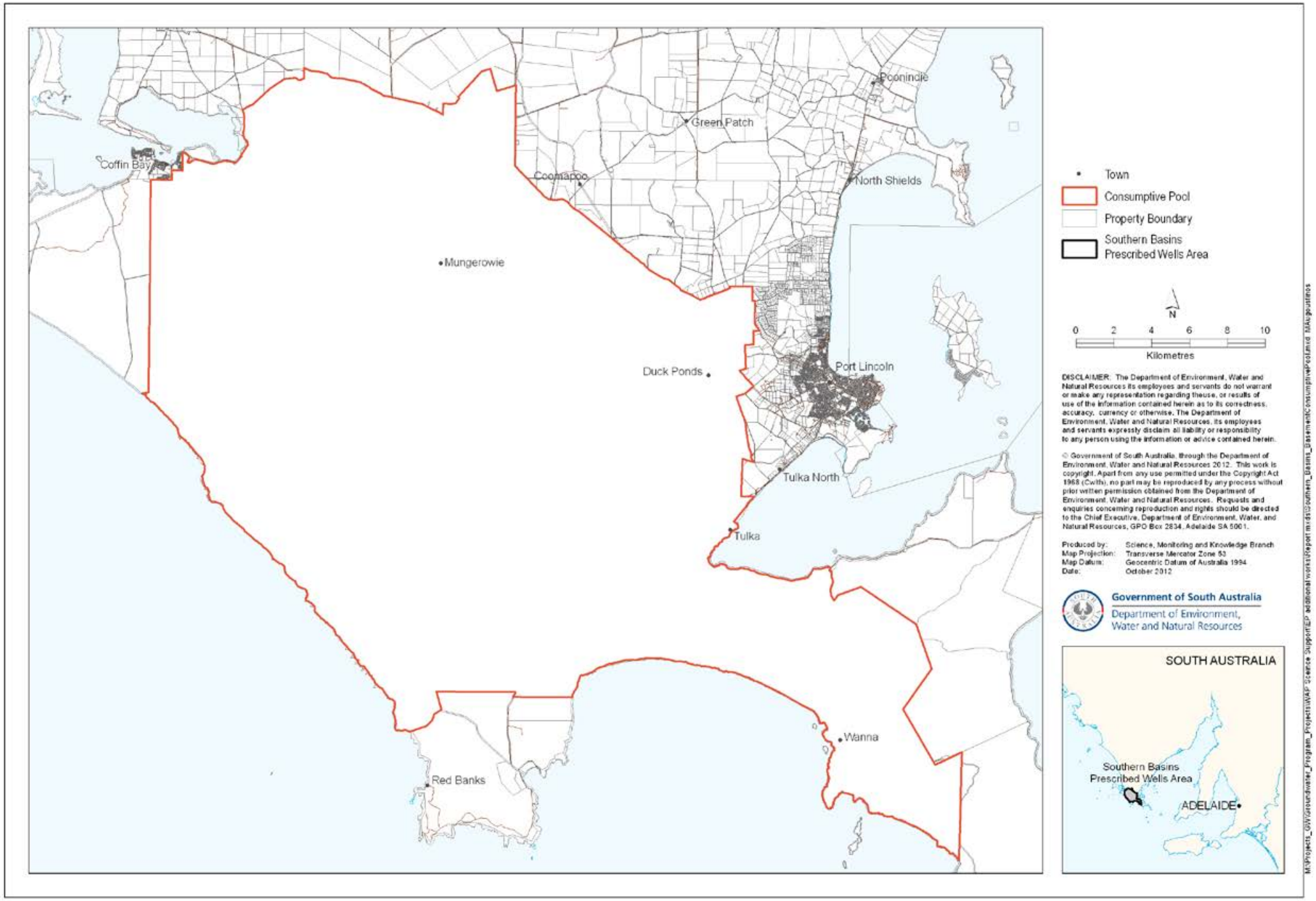

Figure 6. **Consumptive Pool boundary for the Basement aquifer of the Southern Basins PWA**

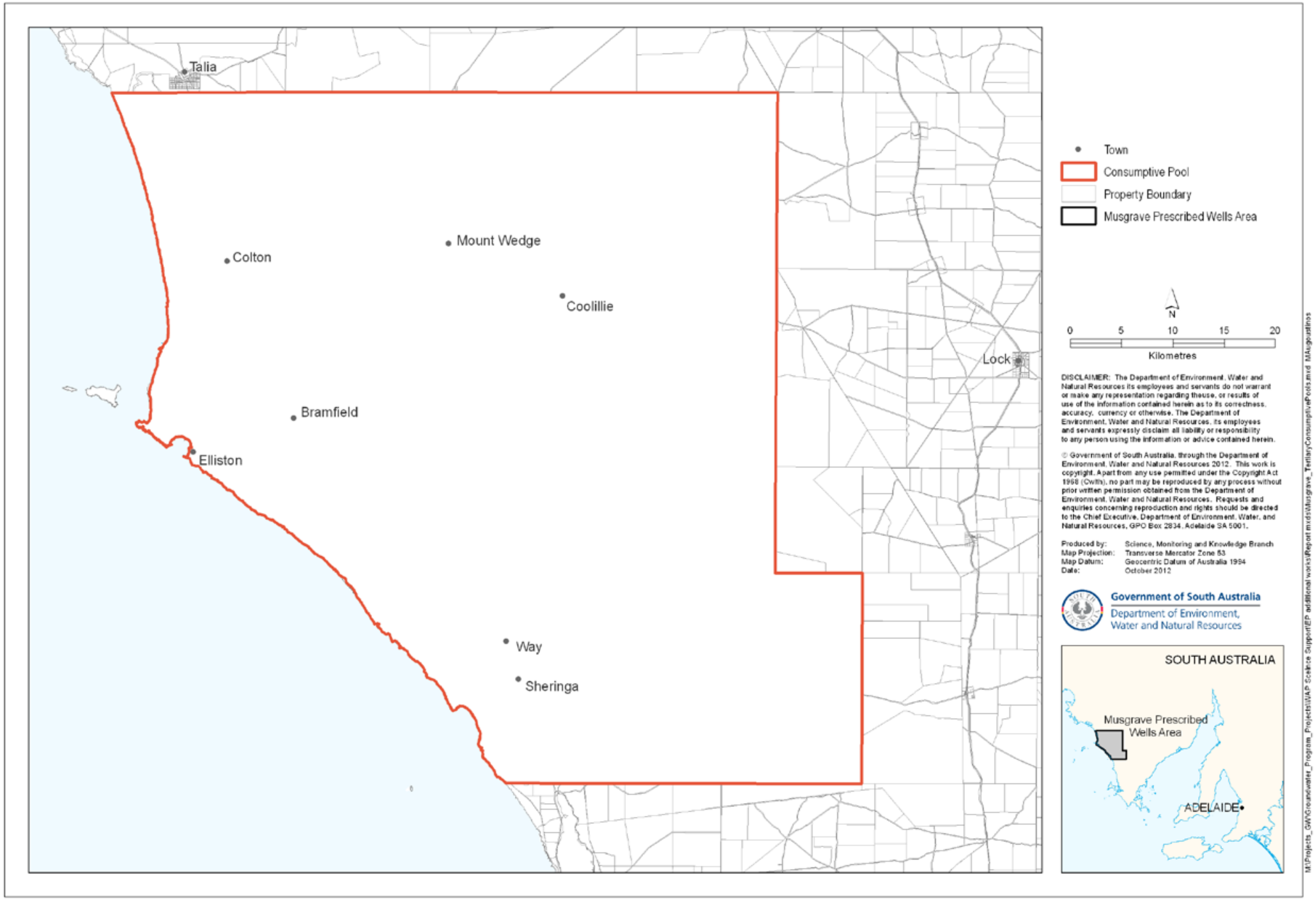

Figure 7. Consumptive Pool boundary for the Tertiary aquifer of the Musgrave PWA

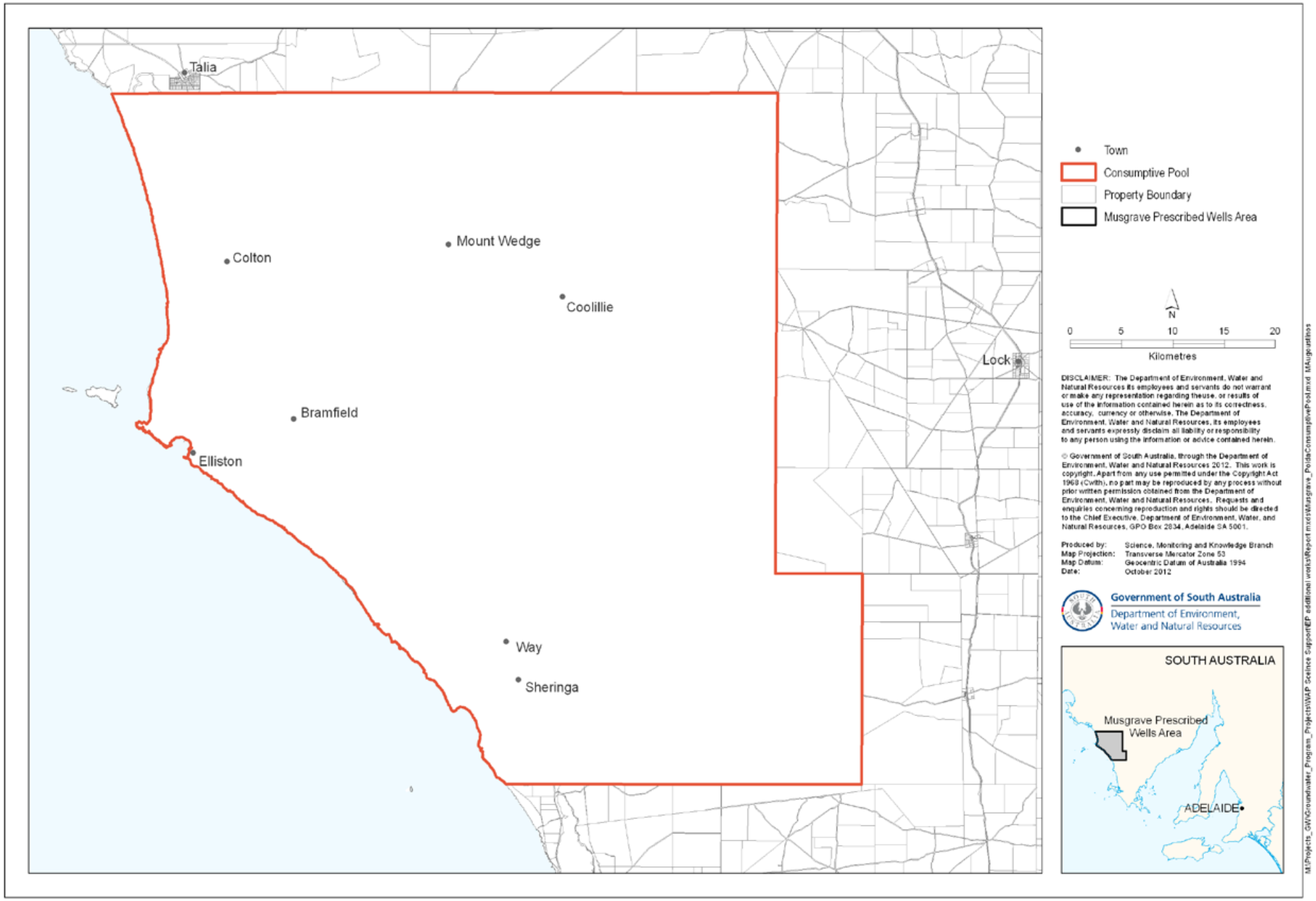

Figure 8. Consumptive Pool boundary for the Jurassic aquifer of the Musgrave PWA

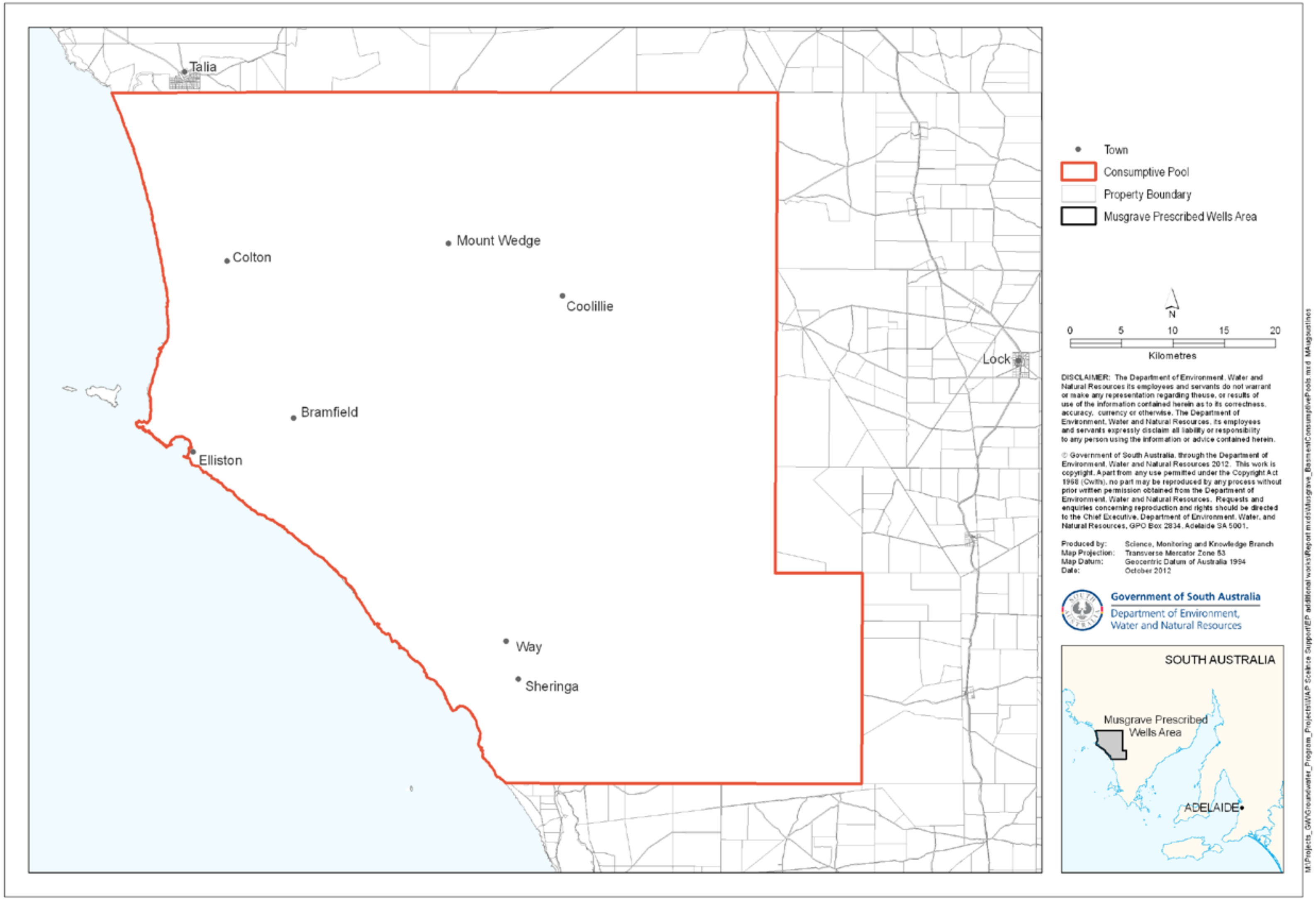

Figure 9. Consumptive Pool boundary for the Basement aquifer of the Musgrave PWA

1.2. RECHARGE ZONES FOR THE QUATERNARY LIMESTONE AQUIFER

The recharge zones for the consumptive pools are represented by a combination of (a) the extents of the relevant fresh groundwater lenses as derived from information available for April 2011 (Stewart, Alcoe and Risby 2012) and (b) the saturated extent of the remaining brackish Quaternary Limestone aquifer as measured at April 2011 (Figures 10 and 11). Table 1 outlines the relevant recharge zones for the consumptive pools. An exception to this is the Lincoln North consumptive pool where there is very limited information on the lens and extent of the brackish Quaternary aquifer, and consequently this area will be treated in a similar manner to the Tertiary, Jurassic and Basement aquifers as discussed in later sections of this report.

Within the Uley South lens, Harrington, Evans and Zulfic (2006) have postulated there to be an upward leakage of groundwater from the Tertiary Sands into the Quaternary Limestone aquifer at a rate of 14 mm/y where the Tertiary clay is absent. This area is not mapped on Figure 10 but the volume of recharge has been included in the resource capacity calculations and is considered a recharge zone.

Table 1. Recharge Zones comprising consumptive pool boundaries of the Quaternary Limestone aquifer for the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Recharge Zone
Southern Basins	Coffin Bay	Coffin Bay A lens
	Uley Wanilla Public Water Supply	Uley Wanilla lens
		Uley Wanilla brackish
	Uley North	Coffin Bay B lens
		Coffin Bay C lens
		Uley East A lens
		Uley East B lens
		Uley North brackish
	Uley South Public Water Supply	Uley South lens
		Uley South brackish
		Uley South Tertiary Leakage
		Pantania lens
		Mikkira lens
	Lincoln South Public Water Supply	Lincoln A lens
		Lincoln B lens
		Lincoln C lens
		Lincoln South brackish
Musgrave	Polda	Polda lens
		Polda East A lens
		Polda East B lens
		Polda brackish
		Tinline lens
		Talia East lens
	Bramfield	Bramfield lens
		Bramfield brackish
		Talia lens
	Sheringa	Sheringa A lens
		Sheringa B lens
		Kappawanta lens
		Sheringa brackish

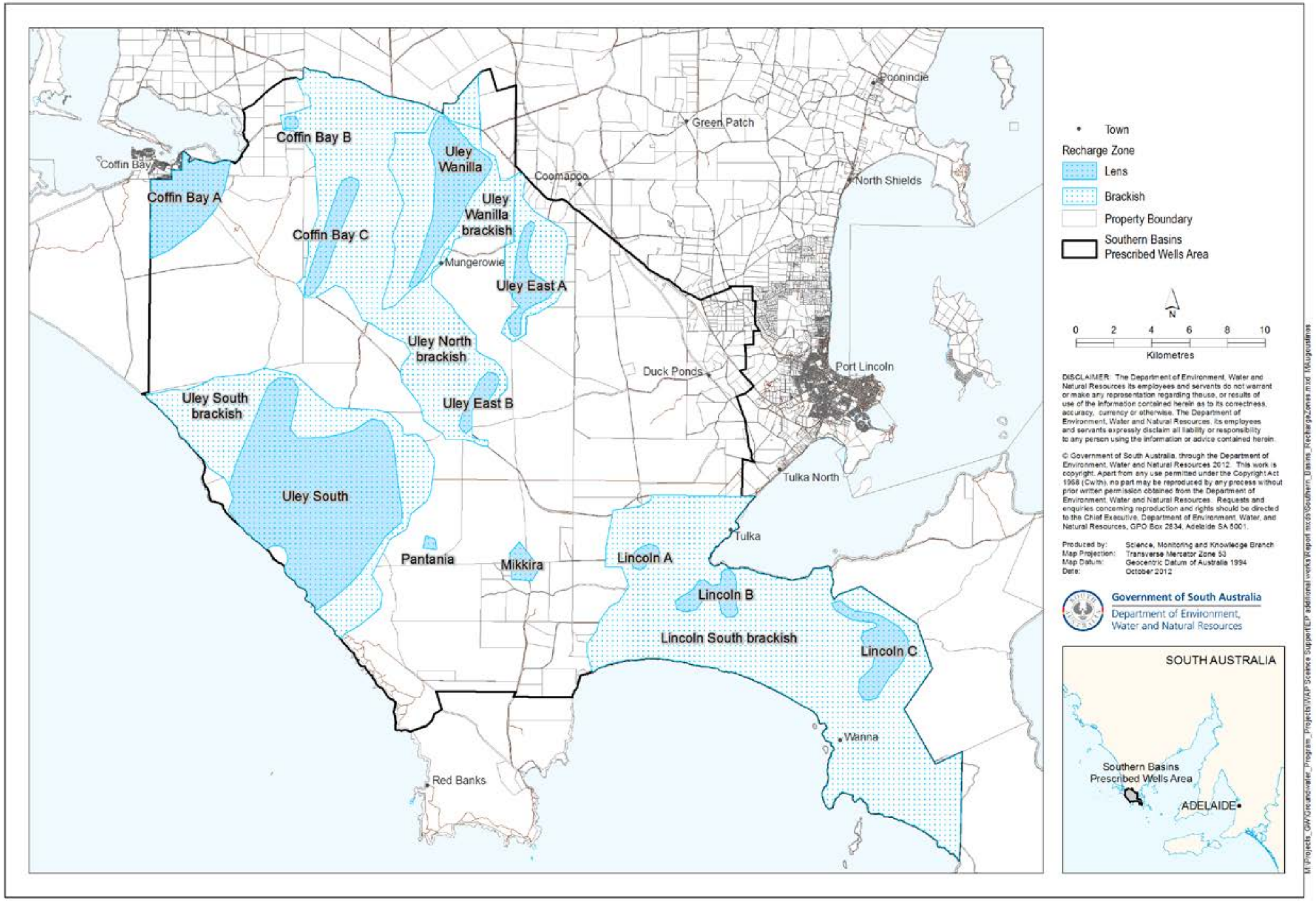

Figure 10. Recharge Zones for the Southern Basins PWA

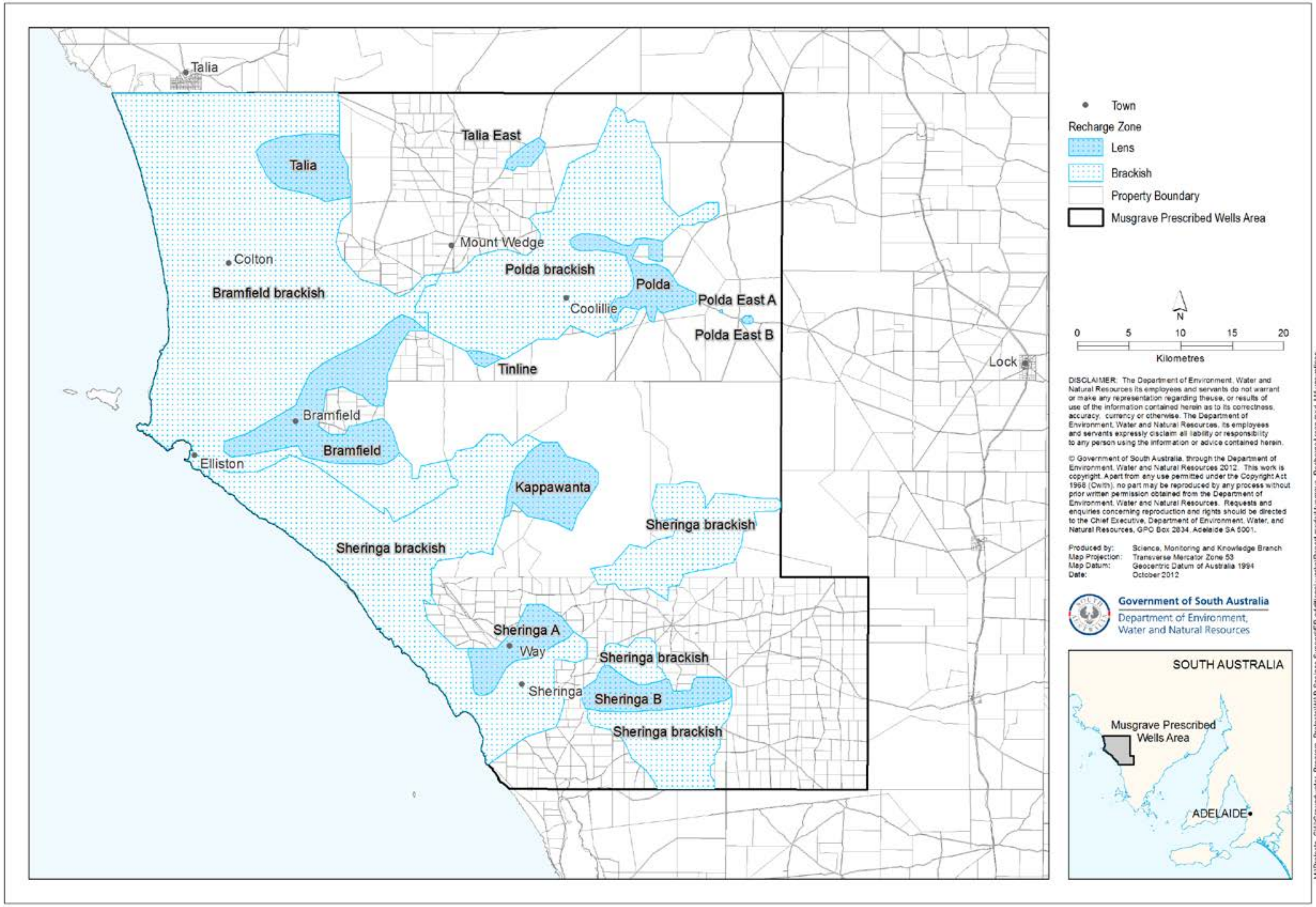

Figure 11. Recharge Zones for the Musgrave PWA

1.3. MAXIMUM HISTORICAL SATURATED EXTENT

The maximum historical saturated extent of the Quaternary Limestone aquifer (Figures 12 and 13) was estimated by searching Obswell data for the highest watertable elevation on record for each observation well. A point shapefile was created for these wells and a water level surface was interpolated using the Inverse Distance Weighted (IDW) tool in ArcGIS® to create a Reduced Standing Water Level raster. The water level raster was overlayed on a raster which represents the elevation of the Tertiary Clay aquitard and the Cut/Fill tool was used to identify a theoretical maximum possible saturated extent of the Quaternary Limestone aquifer. An exception to this is the Lincoln D lens and Lincoln North brackish areas, where there was limited data available toward the south. In this case because the consumptive pool boundary is based on the maximum historical saturated extent, the boundary to the west in the south has been assumed based on the likely extent due to topographic divides.

The estimates of the capacity of the resources for the Quaternary aquifer have been made based on the 2011 saturated extent as described in Stewart, Alcoe and Risby (2012) and as used to represent the total extent of the recharge zones for 2011 (Figures 10 and 11). However future variations of allocations will employ the maximum historical saturated extent boundary as the spatial extent for which to calculate the aquifer thickness annually. The variability of the aquifer thickness from one year to the next will lead to variations in allocations. This process allows for potential increases in allocations in future years if water levels rise above the levels observed in April 2011.

1.4. BOUNDARIES FOR THE WATER ALLOCATION PLAN

Figures 14 and 15 are the maps that may be inserted into the Water Allocation Plan. The figures not only display the consumptive pool boundaries, but also the maximum historical saturated extent and the recharge zones for the Quaternary Limestone aquifer.

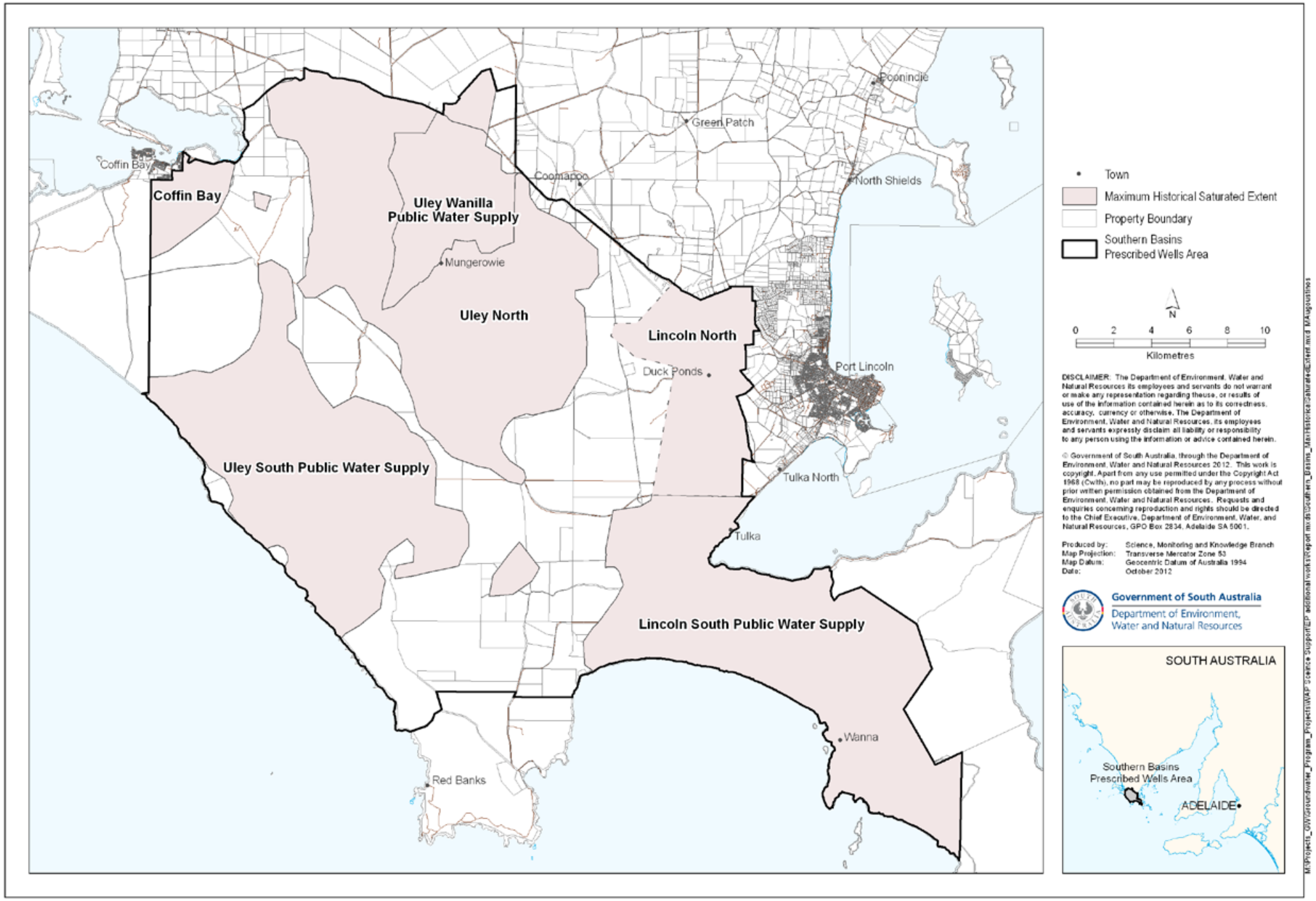

Figure 12. Maximum historical saturated extent of the Quaternary Limestone aquifer for the Southern Basins PWA

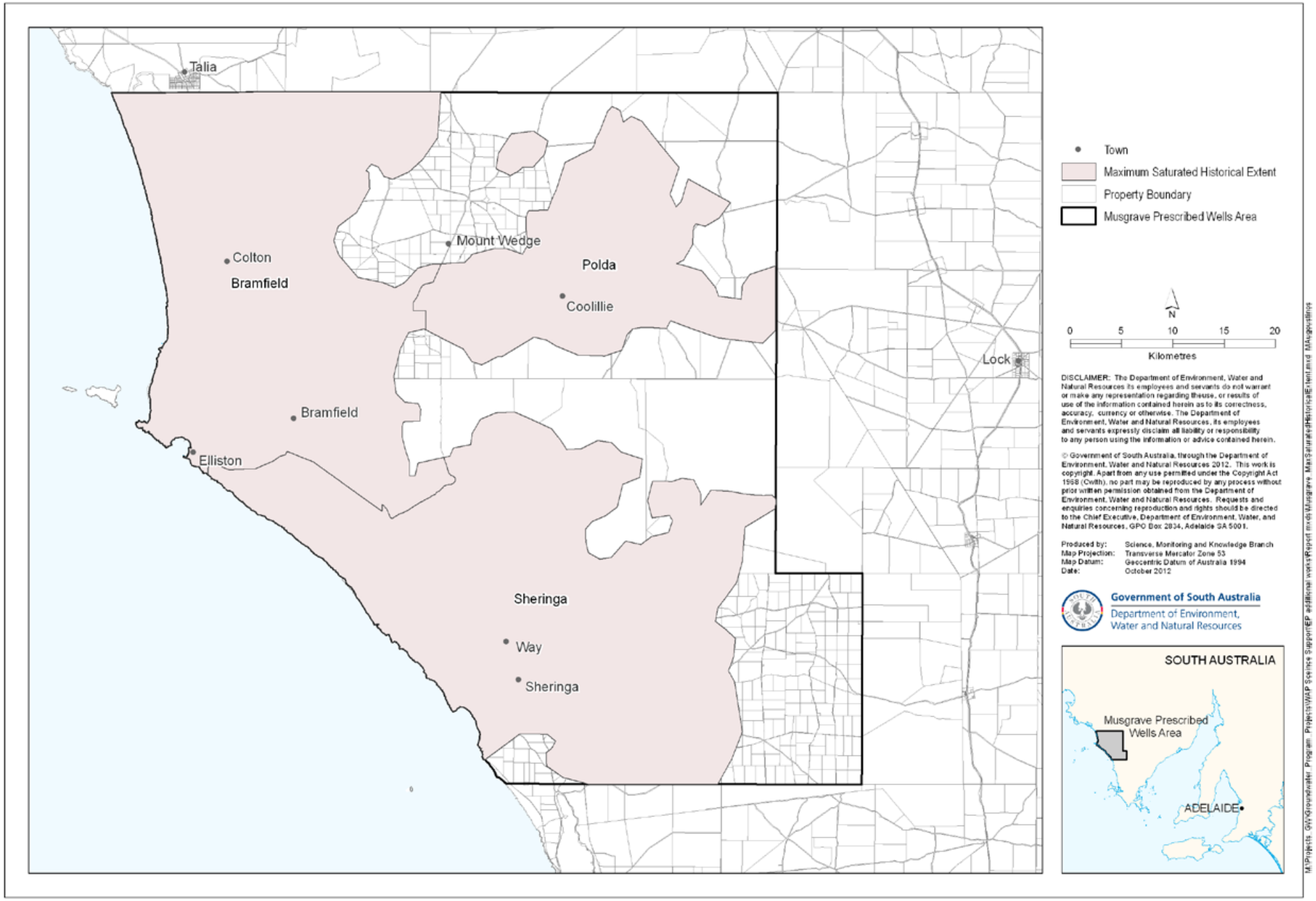

Figure 13. Maximum historical saturated extent of the Quaternary Limestone aquifer for the Musgrave PWA

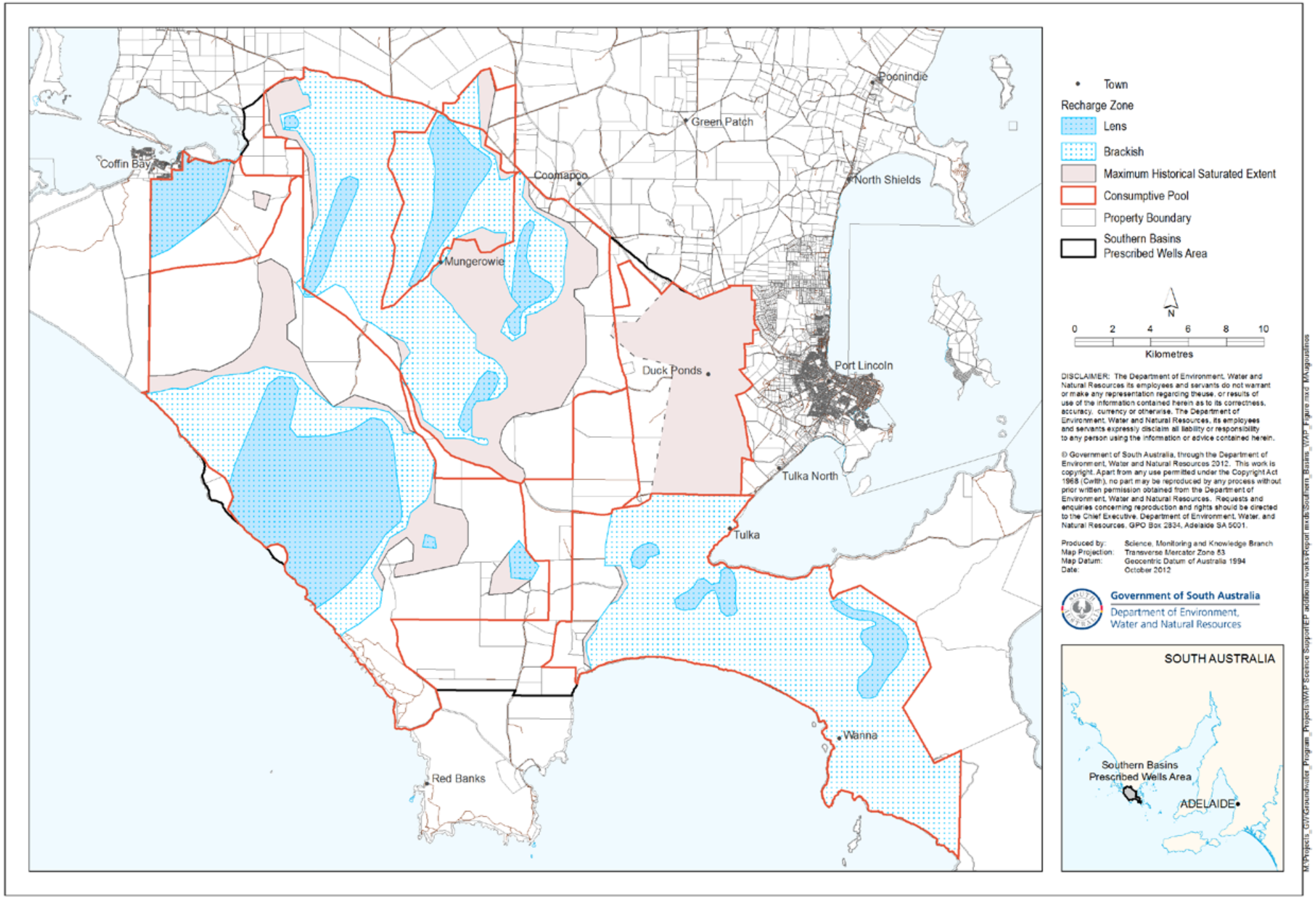

Figure 14. Recharge zones, maximum historical saturated extent and consumptive pool boundaries for the Southern Basins PWA

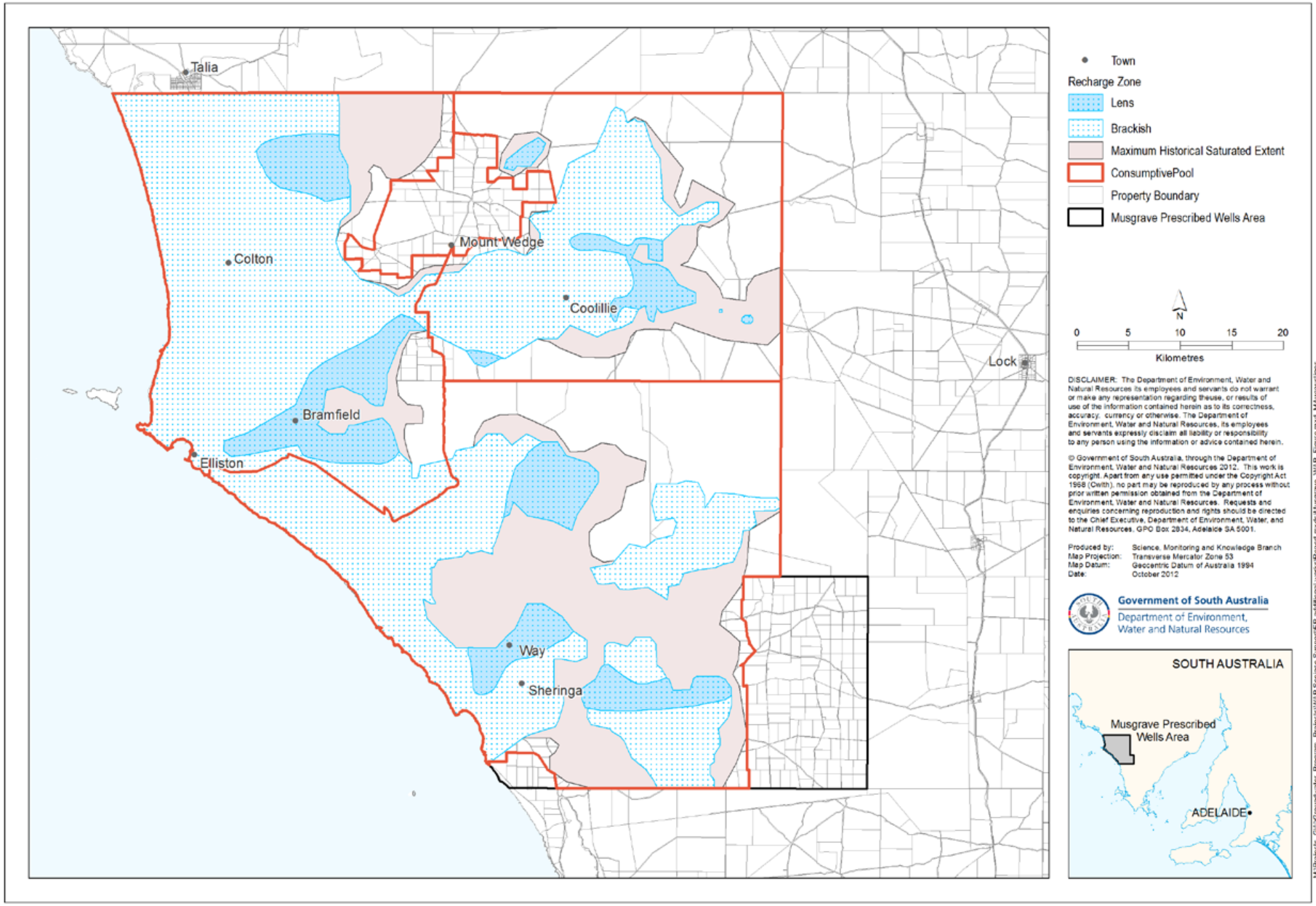

Figure 15. **Recharge zones, maximum historical saturated extent and consumptive pool boundaries for the Musgrave PWA**

1.5. RESOURCE CAPACITY & CONSUMPTIVE POOL VOLUMES

The following section describes the methodology for calculating the resource capacity and consumptive pool volumes for each consumptive pool and, in turn, the water available for licensed requirements.

The **resource capacity** is the volumetric capacity of the groundwater resources that is available for all uses (i.e. licensed, non-licensed, the environment and aquifer maintenance) on a continuing basis. The demands on the resource can be described as both consumptive and non-consumptive. Consumptive demands include licensed water use (irrigation and public water supply) and non-licensed water use such as stock and domestic use. Non-consumptive demands include water for maintaining natural processes such as aquifer throughflow and discharge, and water for groundwater dependent ecosystems where present.

The **consumptive pool volume** is calculated as the resource capacity (as defined above) less the volume of water required by non-consumptive demand in the Quaternary Limestone aquifer (with the exception of the Lincoln North consumptive pool). Due to the lack of sufficient data, the consumptive pool volumes in the Quaternary Lincoln North, Tertiary, Jurassic and Basement consumptive pools is proposed to be limited to the entitlements to be licensed at the adoption of the revised WAP.

The consumptive pool volume is comprised of the water available for licensed requirements and non-licensed purposes, section 128 authorisations and any water held by the Minister.

1.5.1. SATURATED QUATERNARY LIMESTONE CONSUMPTIVE POOLS

1.5.1.1. Resource capacity

The capacity of the resource has been estimated for each recharge zone using the 2013/14 Recent Recharge Rate of the Lens as outlined in the South Australian Government Gazette (Musgrave page 865, 21st March 2013 and Southern Basins page 946, 4th April 2013).

The Understanding the Southern Basins Prescribed Wells Area (2001, page 28) guide notes that "*The Recent Recharge Rate of each lens takes into account the actual recharge that has occurred to the underground water resource over the previous ten year period. It is deemed that, as these resources are responsive to rainfall variations, the most appropriate management should be attuned to the current conditions of the resource*." Furthermore the Southern Basins Water Allocation Plan (2000, page 11) states "... *the recharge rate which forms the basis of allocation in Part 5 of this Plan reflects annual underground water level responses to precipitation less precipitation lost to evaporation and transpiration averaged over the preceding ten years*."

The "Recent Recharge Rate of the Lens" is calculated using the hydrograph method. The hydrograph method is based on the fact that changes in groundwater levels in unconfined aquifers are due to the amount of recharge water reaching the watertable. Recharge water that reaches the watertable is the amount of precipitation on the land above the recharge area of the lens minus the amount lost to evapotranspiration. The recent recharge for any given year is calculated from the water level responses over the preceding ten years, providing a recharge rate for the current condition of the resource, reflecting the most recent climatic conditions.

An exception to this is the Uley South and Uley South Brackish recharge zones (Table 2).

A recent study (Ordens *et al.* 2011), which aimed to refine the existing long-term average annual recharge estimates for the Uley South lens, reports that recharge ranges between 47 and 129 mm/y (estimated by the chloride mass balance and watertable fluctuation methods). The upper limit of 129 mm/y by the watertable fluctuation method has been selected as the recharge rate for the Uley

South lens and Uley South brackish area because water levels are currently displaying stable or rising trends, indicating that the current levels of extraction (around 5717 ML/y) are sustainable. These trends could not be sustained if the lower range of the new recharge estimates were applicable. The Uley South lens and Uley South brackish equate to an area of 108.48 km^2. When multiplied by the recharge rate this equates to an annual recharge of 13 994 ML. Additionally, 14 mm/y over an area of 9.29 km^2 is contributed to the Quaternary aquifer through upward leakage from the underlying Tertiary aquifer (discussed further below). This equates to an additional volume of 130.06 ML.

Werner (2010) constructed a numerical groundwater flow model based on an existing Uley South lens extent 124.04 km^2. Calibration of the model indicated that under contemporary conditions inflows from recharge equalled 17 994.5 ML/y and outflows to the ocean equalled 12 373.5 ML/y, resulting in 5621 ML/y difference which could be available for extraction given that no ecosystems are dependent on groundwater within this lens. This value closely correlates to the average extraction for the past 5 years (2007/08 to 2011/12) of 5717 ML/y. The recharge rate used for the contemporary conditions scenario of the model equates to 145 mm/y. Whilst Werner's recharge rate (145 mm/y) is slightly higher than that suggested by Ordens (129 mm/y), the modelled area was larger (124.04 km2) than that outlined in section 1.2 of this report (108.45 km2). When compared to a similar area, the volume of recharge is very similar which further supports the proposed recharge rate is sustainable.

Within the Uley South recharge zone, groundwater levels suggest there is potential for upward leakage from the underlying Tertiary Sands into the Quaternary Limestone aquifer. Harrington, Evans and Zulfic (2006) estimated this leakage to be about 14 mm/y and whilst it is a small component of the overall water balance, it is an additional inflow component for Uley South. In areas where the Tertiary Clay is thought to be absent (Figure 26), an estimated inflow of 14 mm/y has been applied to the area of absent aquitard (9.29 km^2). Whilst there are areas in the remainder of the Musgrave and Southern Basins PWAs which have an absence of clay, there is no evidence that indicates potential for upward leakage from the Tertiary aquifer into the Quaternary Limestone aquifer.

In all other cases, the area of the recharge zones are outlined in Figures 10 and 11, and the fresh groundwater lenses have been assigned the 2013/14 Recent Recharge Rate of the Lens as outlined in the South Australian Government Gazette. The brackish areas have either been assigned the same recharge rate as the adjacent fresh lens or if they represent a more regional area (Uley North brackish, Bramfield brackish, Sheringa brackish and Polda brackish), the recharge rate for the minor lenses from the 2013/14 Government Gazette of the Recent Recharge Rate of the Lens has been applied.

Table 2. Recharge rates for the Quaternary Limestone aquifer of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Recharge Zone	2013/14 Recharge Rate of the Lens (mm/y)	Recently documented recharge rates (mm/y)
Southern Basins	Coffin Bay	Coffin Bay A	29	
	Uley Wanilla Public Water Supply	Uley Wanilla lens	13	
		Uley Wanilla brackish	13	
	Uley North	Coffin Bay B lens	6	
		Coffin Bay A lens	9	
		Uley East A lens	22	
		Uley East B lens	22	
		Uley North Brackish	13	
	Uley South Public Water Supply	Uley South lens	133	129
		Uley South brackish	133	129
		Uley South Tertiary Leakage		14
		Pantania lens	13	
		Mikkira lens	13	
	Lincoln South Public Water Supply	Lincoln A lens	35	
		Lincoln B lens	35	
		Lincoln C lens	35	
		Lincoln South brackish	35	
Musgrave	Polda	Polda lens	15.8	
		Polda East A lens	6.8	
		Polda East B lens	6.8	
		Polda brackish	14.1	
		Tinline lens	17.5	
		Talia East lens	15.8	
	Bramfield	Bramfield lens	25	
		Bramfield brackish	14.1	
		Talia lens	15.8	
	Sheringa	Sheringa A lens	16.3	
		Sheringa B lens	15.8	
		Kappawanta lens	22	
		Sheringa brackish	14.1	

1.5.1.2. Non-consumptive demands

The capacity of the resource outlines the volume of water available for licensed, non-licensed use and non-consumptive demand. Consideration has been given to allocating only a percentage of any derived volume and setting aside the remainder for aquifer maintenance and to meet the needs of groundwater dependent ecosystems (GDEs).

There is a need to maintain natural flows through the aquifer, including natural discharge. If too much water is made available for licensed and non-licensed purposes, there may be impacts on the water balance in other areas, such as reducing natural discharges and altering flow directions. These natural discharges occur not only to marine environments, such as Coffin Bay, but also to water-dependent ecosystems. Aquifer maintenance includes maintaining groundwater flow gradients, which is particularly important in coastal lenses such as Uley South to help manage the risk of sea water intrusion.

Ultimately, the percentage of water set aside for aquifer maintenance and GDEs depends upon the various management objectives from a resource perspective balanced against social and economic considerations. The percentage of the recharge that is set aside for non-consumptive purposes for the various Quaternary consumptive pools has been determined through a risk assessment undertaken by Sinclair Knight Merz (SKM 2013). The Risk assessment took into consideration the Accessibility Risk: The risk to users (licenced and non-licensed) of restricting water for consumptive use, that is risks to social, cultural and economic values of not getting groundwater, and the Environmental Risk: The risks to the aquifer and environment of extracting water for consumptive use.

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

1) Users are not allocated sufficient groundwater to meet their consumptive needs

2) There is no alternate water supply available to meet user needs

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

1) Groundwater Dependent Ecosystems are present and impacted by extraction

2) Aquifer integrity (salinity) is affected by extraction

3) Aquifer integrity (groundwater levels) is affected by extraction

By considering the likelihood and consequence of the different risks, scores for individual consumptive pools were able to be determined ranking the Accessibility and Environmental risks as either High, Moderate or Low. A risk matrix was then used to define the portion of the resource capacity to be reserved for to meet non-consumptive requirements (Table 3).

Table 3. Portion of Quaternary Limestone consumptive pools set aside for non-consumptive demands for the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Portion of resource capacity set aside for non-consumptive demands (%)
Southern Basins	Coffin Bay	60
	Uley Wanilla Public Water Supply	60
	Uley North	50
	Uley South Public Water Supply	30
	Lincoln South Public Water Supply	60
Musgrave	Polda	60
	Bramfield	60
	Sheringa	60

1.5.1.3. Domestic Demands

While domestic water use is not licensed in the PWAs, it is important to account for domestic water use and set this amount aside to avoid possible over use of the groundwater resources. Domestic demands have been calculated by multiplying the number of domestic wells by the average water consumption per household (Table 4, Figures 16 and 17). The SA Geodatabase maintains a record of the intended purpose of all wells via the Department's permitting system. Wells that have been assigned the purpose 'domestic use' have been used in the assessment. Any wells with a null reading for aquifer monitored were assumed to be completed in the Quaternary Limestone aquifer.

The State's water plan, Water for Good, reports that average household mains water consumption in the greater Adelaide Region, prior to water restrictions, was 280 kL/y.

On Eyre Peninsula, particularly in rural areas, anecdotal evidence suggests that most households use rainwater tanks for drinking water and some household tasks. Houses in urban areas also have access to mains water. For these reasons, it could be assumed that groundwater represents half of the domestic household water budget. However, homes in rural Eyre Peninsula are generally set on larger block sizes than expected in urban settings and therefore may have higher water requirements. Combined with the uncertainty surrounding the number of domestic wells, an annual water consumption of 280 kL per domestic well represents a conservative approach to estimating domestic water demand.

Table 4. Domestic demands for the recharge zones of the Quaternary Limestone aquifer of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Recharge Zone	Domestic Wells	Domestic consumption (ML/y)
Southern Basins	Coffin Bay	Coffin Bay A	1	0.28
	Uley Wanilla Public Water Supply	Uley Wanilla lens	5	1.4
		Uley Wanilla brackish	0	0
	Uley North	Coffin Bay B lens	0	0
		Coffin Bay C lens	0	0
		Uley East A lens	0	0
		Uley East B lens	0	0
		Uley North Brackish	2	0.56
	Uley South Public Water Supply	Uley South lens	0	0
		Uley South brackish	0	0
		Uley South Tertiary Leakage	0	0
		Pantania lens	0	0
		Mikkira lens	0	0
	Lincoln South Public Water Supply	Lincoln A lens	0	0
		Lincoln B lens	0	0
		Lincoln C lens	0	0
		Lincoln South brackish	5	1.4
Musgrave	Polda	Polda lens	3	0.84
		Polda East A lens	0	0
		Polda East B lens	0	0
		Polda brackish	6	1.68
		Tinline lens	0	0
		Talia East lens	0	0
	Bramfield	Bramfield lens	27	7.56
		Bramfield brackish	48	13.44
		Talia lens	2	0.56
	Sheringa	Sheringa A lens	1	0.28
		Sheringa B lens	1	0.28
		Kappawanta lens	0	0
		Sheringa brackish	10	2.8

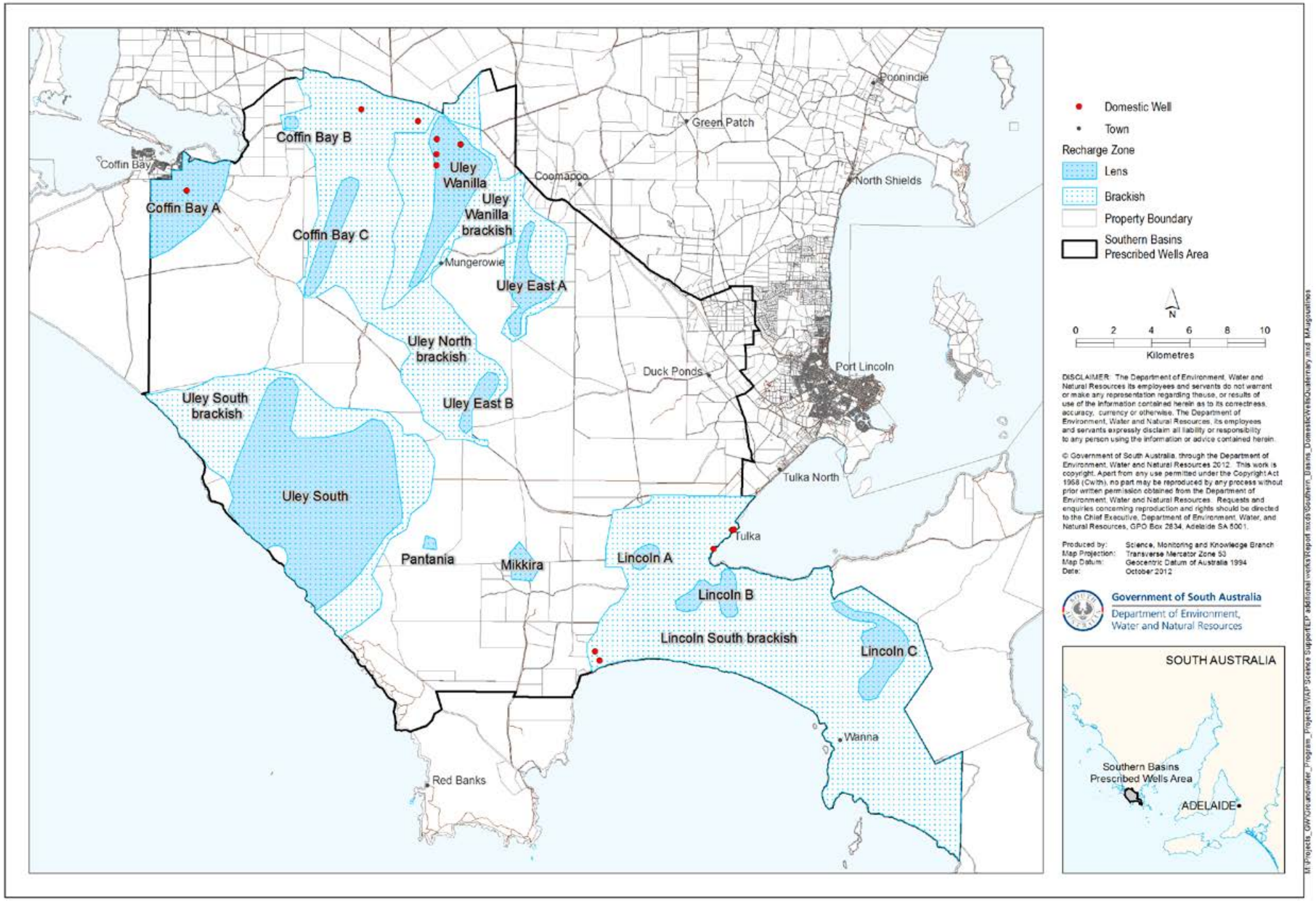

Figure 16. Domestic wells completed in the Quaternary Limestone aquifer of the Southern Basins PWA

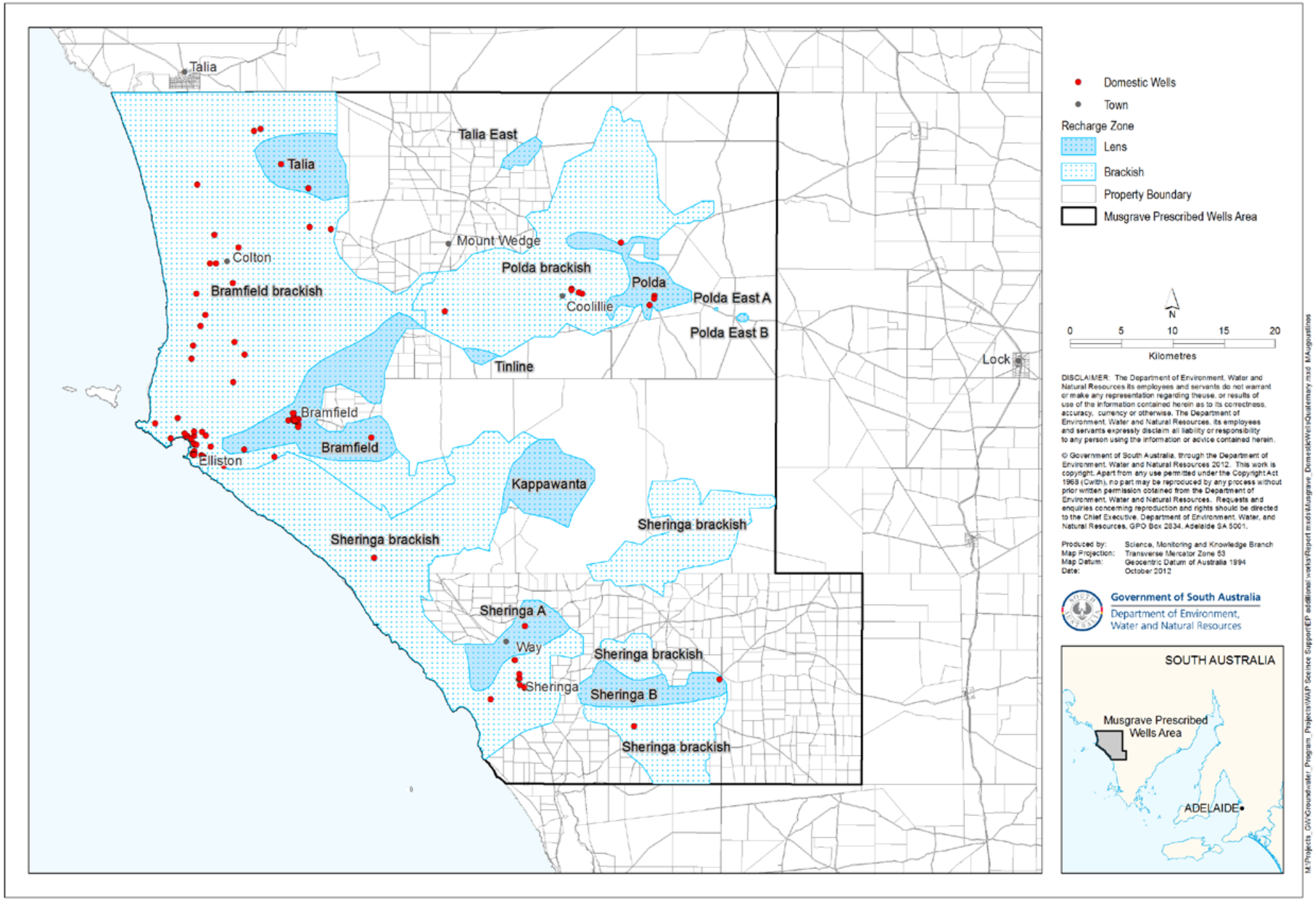

Figure 17. Domestic wells completed in the Quaternary Limestone aquifer of the Musgrave PWA

1.5.1.4. Stock Demands

Whilst stock water use is not licensed in the PWAs, it is important to account for stock water use and set this amount aside to avoid possible over use of the groundwater resources.

Primary Industries and Regions South Australia (PIRSA) collect information from properties with current registrations under the Livestock Act 1997. The Primary Industries Information System (PIIMS) provides a spatially referenced data set of stock numbers for the PWAs. The spatial nature of the dataset allows water to be assigned to different lenses or aquifers.

Stewart, Alcoe and Risby (2012) state that to estimate stock water use, the number of stock held on any given parcel of land are normalised to a standard unit – the Dry Sheep Equivalent (DSE) (Table 5). The DSE is a standard unit used to estimate feed requirements of different classes of stock (McLaren 1997). Normalising absolute stock numbers to DSEs enables water demand estimates to be calculated based on estimated water consumption per unit DSE (Luke 2003).

Table 5. Dry Sheep Equivalents (DSEs) for different classes of stock

Stock type	Conversion factor (DSE per head of stock)	Reference
Cattle, buffalo	13	Dry sheep equivalents for comparing different classes of livestock (McLaren 1997) Mary Chirgwin [PIRSA Biosecurity] 2010, pers. comm., September)
Sheep	1.4	Mary Chirgwin [PIRSA Biosecurity] 2010, pers. comm., September)
Deer, goats alpaca	1	Grazing livestock – a sustainable and productive approach (AMLRNRMB 2010)
Chickens	0.2	Brown (2004)
Pigs, horses	10	Luke (2003)

The Department for Water's Eyre Peninsula Demand and Supply Statement estimates the water use of sheep located on the Eyre Peninsula to be 10 L/sheep/d (or 7.14 L/DSE/d) (DFW 2011). This estimate of water use is based on advice from PIRSA and includes an allowance for on-farm losses.

Stock water use was estimated by overlying the spatially referenced PIIMS parcel data on the recharge zones. The PIMMS data required some filtering to remove all references to aquatic breeding and to remove duplications associated with stock that served two purposes (i.e. wool and meat) such that the stock were only counted once. The proportion of each PIIMS parcel that overlies a recharge zone was then calculated (a detailed description of the stock analysis can be seen in Appendix).

The area of the parcel that overlies the recharge zone was then divided by the area of the whole PIIMS parcel to result in a proportionate factor. This factor was then applied to the stock numbers for that particular parcel. It should be noted that the PIIMS data set links all parcels owned by one land holder into one record, therefore there were some cases where a person's land was located both inside and outside of the PWA. In these cases the stock were split proportionally between the land inside the PWA/recharge zone and the land outside the PWA. This does not account for times when all stock are rotated onto the parcel within the PWA. However it is unlikely that this would occur for the entire year as there would likely be a rotation of stock to the parcel which sits outside of the PWA at some time during the year also. Therefore this is considered a reasonable approximation of the annual stock numbers for these particular parcels.

Once stock numbers for each recharge zone were identified, they were multiplied by the DSE as outlined in Table 5 for the relevant stock, and the DSE was then converted into a water use consumption by multiplying by 7.14 L/d (Table 6).

An assumption was made that all PIIMS parcels that overly the saturated Quaternary Limestone access water from the Quaternary aquifer. In areas where the PIIMS parcel overlies the unsaturated Quaternary Limestone, water was considered to be sourced from either the Tertiary or Basement aquifer. As there is no way to determine the proportion of water being accessed for stock purposes from the Tertiary or Basement aquifers, the volume of water apportioned to parcels overlying the unsaturated Quaternary Limestone have been split evenly between the Tertiary and Basement aquifers. No stock water use was assigned to the Jurassic aquifer in the Musgrave PWA.

Table 6. Stock demands for the recharge zones of the Quaternary Limestone aquifer of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Recharge Zone	DSE	Stock consumption (ML/y)
Southern Basins	Coffin Bay	Coffin Bay A	0	0
	Uley Wanilla Public Water Supply	Uley Wanilla lens	0	0
		Uley Wanilla brackish	0	0
	Uley North	Coffin Bay B lens	0	0
		Coffin Bay A lens	166	0.43
		Uley East A lens	1268	3.31
		Uley East B lens	28	0.07
		Uley North Brackish	7093	18.49
	Uley South Public Water Supply	Uley South lens	391	1.02
		Uley South brackish	542	1.41
		Uley South Tertiary Leakage	0	0
		Pantania lens	0	0
		Mikkira lens	273	0.71
	Lincoln South Public Water Supply	Lincoln A lens	4	0.01
		Lincoln B lens	0	0
		Lincoln C lens	0	0
		Lincoln South brackish	542	1.41
Musgrave	Polda	Polda lens	1382	3.6
		Polda East A lens	0	0
		Polda East B lens	0	0
		Polda brackish	8924	23.34
		Tinline lens	11	0.03
		Talia East lens	91	0.24
	Bramfield	Bramfield lens	3664	9.57
		Bramfield brackish	51551	134.4
		Talia lens	3545	9.24
	Sheringa	Sheringa A lens	339	0.88
		Sheringa B lens	223	0.58
		Kappawanta lens	0	0
		Sheringa brackish	17057	44.45

The existing WAP estimates average stock capacity as 1 and 2 DSE/ha for the Musgrave (3595 km^2) and Southern Basins (870 km^2) PWAs respectively. Assuming all land is capable of being effectively grazed, stock numbers of 360,000 DSE for the Musgrave PWA and 174,000 DSE for the Southern Basins PWA were estimated. Assuming the conversion factors listed in Table 5, the PIIMS data indicates that for all aquifers stock estimates are approximately 134,549 DSE in the Musgrave PWA and 39,855 DSE in the Southern Basins PWA. These are significantly different from the numbers estimated in the existing WAP, however the methodology used in this instance is more robust and is likely to provide more accurate estimates of DSE numbers. Additionally it aligns well with anecdotal evidence (Stewart, Alcoe and Risby 2012).

1.5.2. UNSATURATED QUATERNARY LIMESTONE CONSUMPTIVE POOL

Based on the current knowledge, there is unlikely to be any significant volumes of water available for consumptive purposes on an ongoing basis from the unsaturated Quaternary Limestone consumptive pool. Any such supplies are likely to be highly unreliable. Consequently, it is suggested the unsaturated Quaternary Limestone be assigned a small nominal volume of water from the consumptive pool for potential stock and domestic purposes only and a zero allocation limit.

1.5.2.1. Stock and Domestic Demands

Stock and domestic demands were calculated as outlined in sections 1.5.1.3 and 1.5.1.4, however an assumption was made for stock estimates, that in areas where the PIIMS parcel overlies the unsaturated Quaternary Limestone, water is sourced from either the Tertiary or Basement aquifers and therefore there is no stock estimate for the unsaturated Quaternary Limestone consumptive pools.

It is possible that the unsaturated Quaternary Limestone may be able to provide limited water for domestic purposes in small isolated pockets where the Arc Hydro modelling did not identify the presence of groundwater. All wells assigned a purpose of domestic which were present in the unsaturated Quaternary Limestone were assumed to be accessing groundwater from these areas for the purpose of domestic supply (Table 7, Figures 18 and 19).

Table 7. Domestic demands for the unsaturated Quaternary Limestone of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Domestic Wells	Domestic consumption (ML/y)
Southern Basins	Unsaturated Quaternary Limestone	7	1.96
Musgrave	Unsaturated Quaternary Limestone	20	5.6

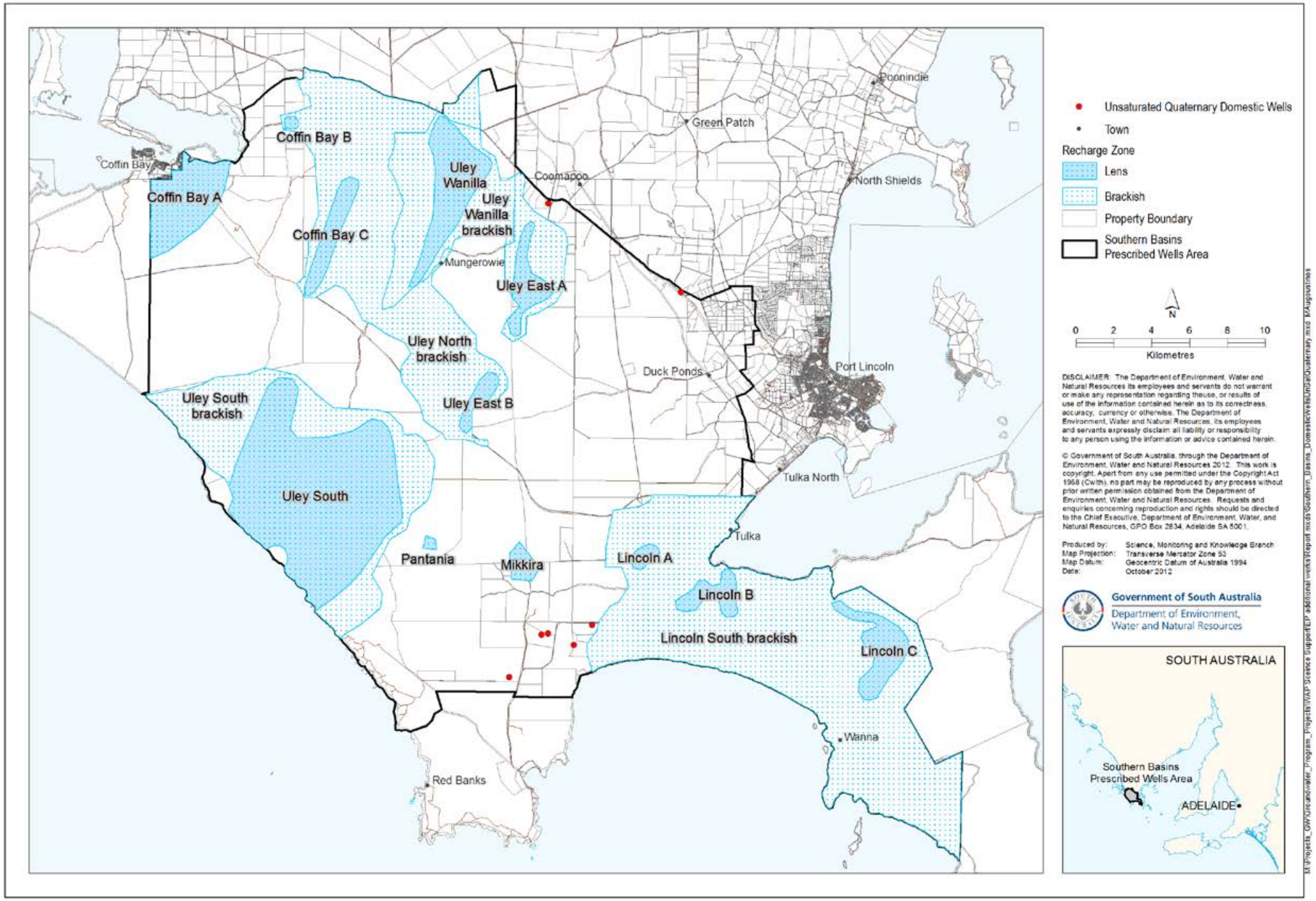

Figure 18. Domestic wells completed in the unsaturated Quaternary Limestone of the Southern Basins PWA

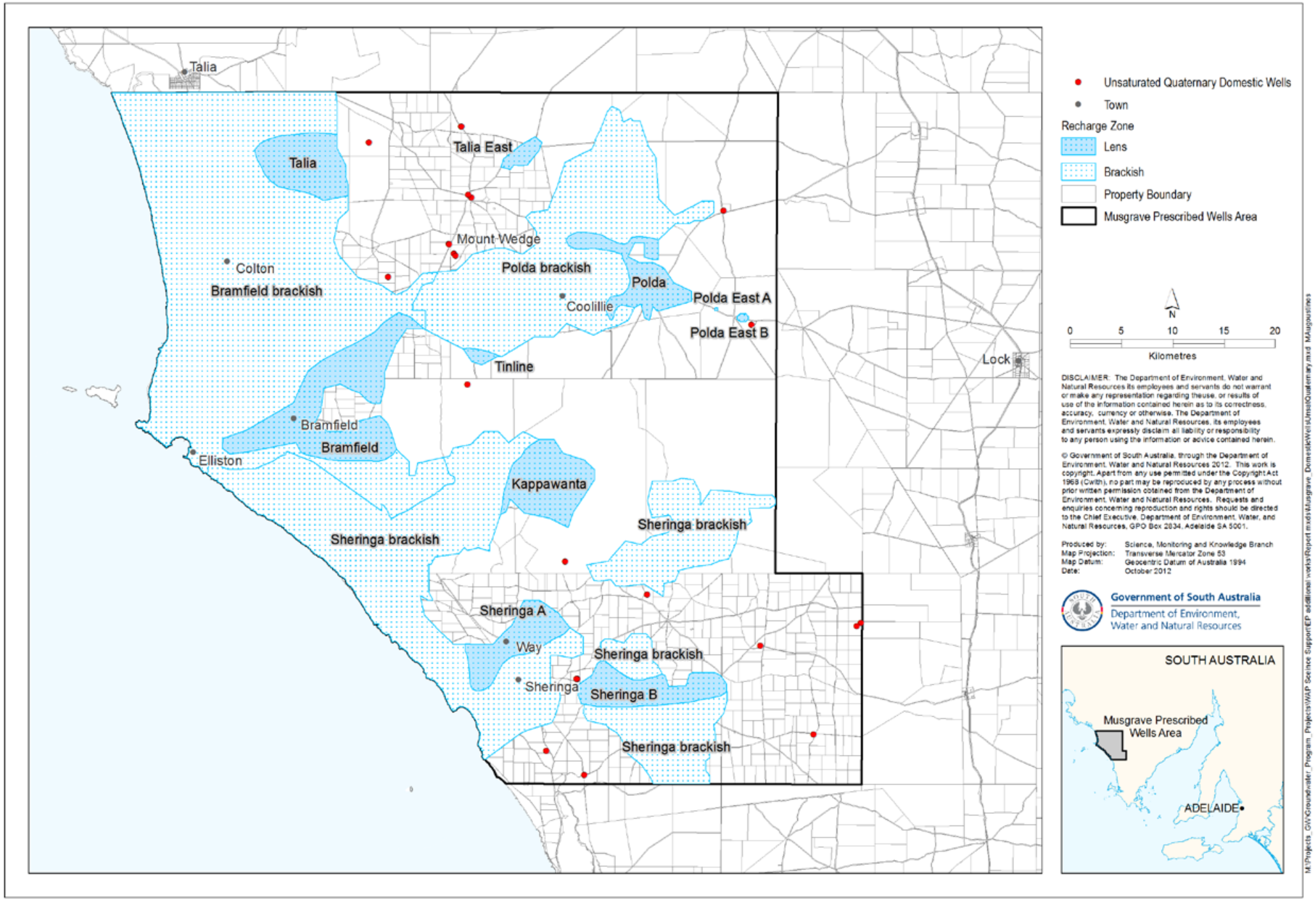

Figure 19. **Domestic wells completed in the unsaturated Quaternary Limestone of the Musgrave PWA**

1.5.3. TERTIARY, JURASSIC AND BASEMENT AQUIFERS AND QUATERNARY LINCOLN NORTH CONSUMPTIVE POOLS

1.5.3.1. Resource capacity

Due to the limited knowledge to support more refined resource capacity information in relation to the Tertiary, Jurassic and Basement aquifers, and the Quaternary Lincoln North region, it is proposed that a set volumetric limit not be applied to these consumptive pools. The NRM Act does not require a consumptive pool to be determined as a volume. Only the water that is available for allocation from time to time is required to be defined as a volume, by a Notice published in the South Australia Government Gazette by the Minister. It is therefore possible for the revised WAP to provide rules or a formula to calculate the volume of water in the consumptive pool for each water use year. Therefore it might be possible to allow any proponent interested in being granted an allocation from the deeper aquifers to satisfactorily demonstrate that taking a given allocation would not have a negative or detrimental impact on other water resources, existing water users or GDEs.

This would require investigations including an aquifer test and monitoring of neighbouring wells both within the target aquifer and adjacent aquifers. Depending on the location, wells may need to be drilled specifically for the purpose of undertaking an initial assessment of the proposal's viability.

It is proposed that there be a requirement for different levels of investigations depending on the proposed extraction volumes (and associated level of risk) to the resources, including GDEs and existing water users. For example, allocations less than 5 ML could require an aquifer test and localised monitoring pre-development, whereas proposed allocations in excess of 5 ML would require ongoing monitoring as a licence condition to ensure the extraction of additional water will not negatively impact upon existing users, GDEs or adjacent aquifers.

It is proposed that in the absence of more refined information on the resource capacity, the initial water available for licensed requirements for the Lincoln North, Tertiary, Jurassic and Basement consumptive pools be set to the volume currently on licence. The volume of water available for licensed requirements would change as new applications for allocations are approved.

1.5.3.2. Non-consumptive demands

Whilst the risk assessment undertaken by Sinclair Knight Merz (2013) outlines the portion of the resource capacity to be set aside for non-consumptive demands, the resource capacity of the Lincoln North, Tertiary, Jurassic and Basement consumptive pools was not able to be calculated due to limited information. The non-consumptive demand is therefore not required for the determination of the consumptive pool volume for these pools, however is it provided in Table 8 for information only.

Table 8. Portion of Lincoln North, Tertiary, Jurassic and Basement consumptive pools set aside for non-consumptive demands for the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Portion of resource capacity set aside for non-consumptive demands (%)
Southern Basins	Lincoln North	40
	Tertiary Sand	40
	Basement	60
Musgrave	Tertiary Sand	50
	Polda Formation	50
	Basement	50

1.5.3.3. Domestic Demands

As outlined in section 1.5.1.3 domestic demands have been calculated by multiplying the number of domestic wells within the relevant aquifer by the average water consumption per household (Table 9, Figures 20 and 21).

Table 9. Domestic demands for the Lincoln North, Tertiary, Jurassic and Basement consumptive pools of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Domestic Wells	Domestic consumption (ML/y)
Southern Basins	Lincoln North	12	3.36
	Tertiary Sand	4	1.12
	Basement	1	0.28
Musgrave	Tertiary Sand	4	1.12
	Polda Formation	0	0
	Basement	0	0

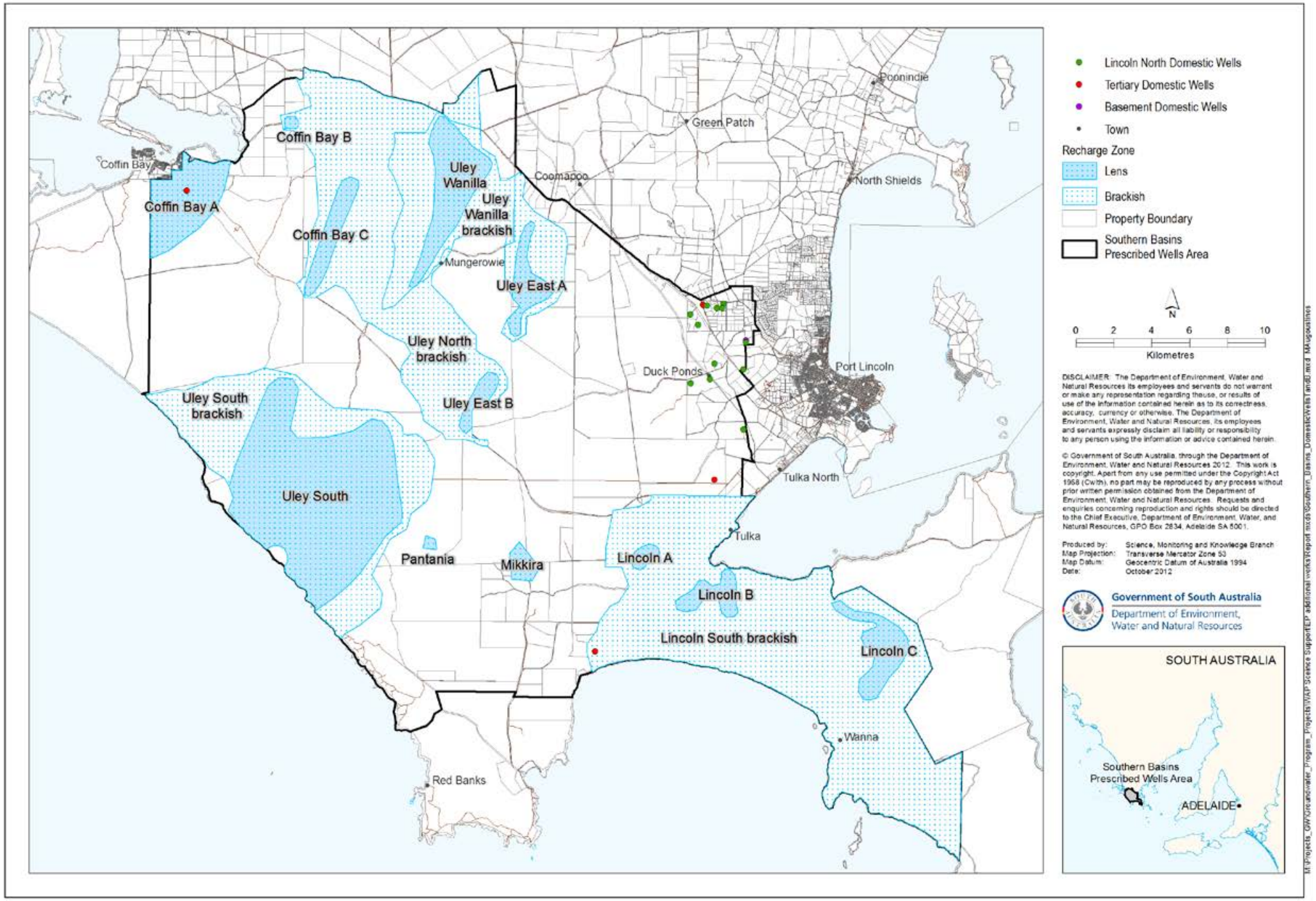

Figure 20. **Domestic wells completed in the Lincoln North, Tertiary and Basement consumptive pools of the Southern Basins PWA**

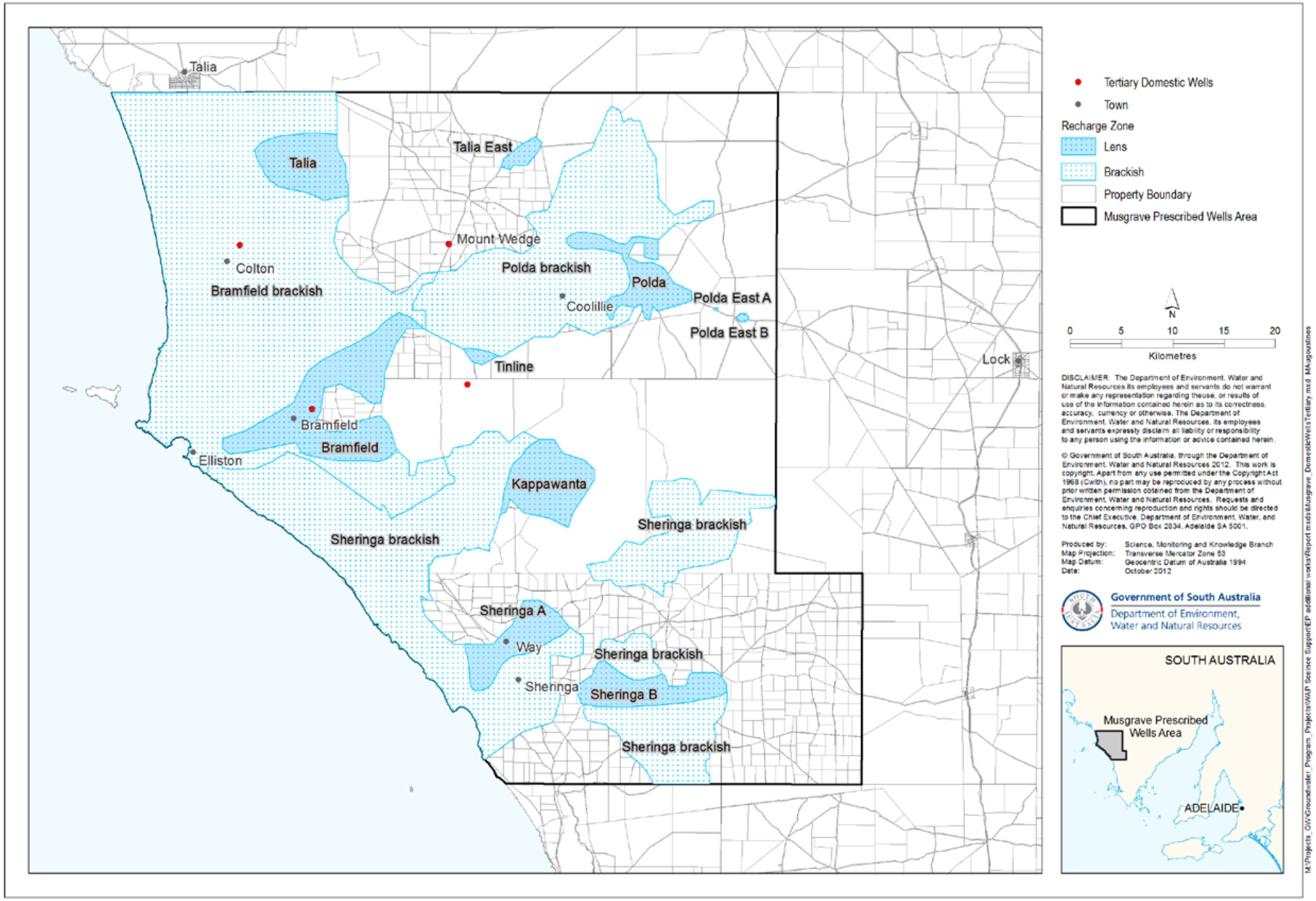

Figure 21. **Domestic wells completed in the Tertiary consumptive pool of the Musgrave PWA**

1.5.3.4. Stock Demands

The methodology for determining the stock demands for the Lincoln North consumptive pool follows that outlined in section 1.5.1.4. As before, the assumption was made that in areas where the PIIMS parcel overlies the unsaturated Quaternary Limestone, water is sourced from either the Tertiary or Basement consumptive pools. As there is no way to determine the proportion of water being access for stock purposes from the Tertiary or Basement pools, the volume of water apportioned to parcels overlying the unsaturated Quaternary Limestone have been split evenly between the Tertiary and Basement aquifers (Table 10). No stock water was apportioned to the Jurassic consumptive pool in the Musgrave PWA.

Table 10. Stock demands for the Lincoln North, Tertiary, Jurassic and Basement consumptive pools of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	DSE	Stock consumption (ML/y)
Southern Basins	Lincoln North	11878	30.95
	Tertiary	8834	23.02
	Basement	8834	23.02
Musgrave	Tertiary	23881	62.27
	Jurassic	0	0
	Basement	23881	62.27

1.5.4. CONSUMPTIVE POOL VOLUMES

Table 11 outlines the consumptive pool boundary, the recharge zone, the adopted recharge rate, the resource capacity, non-consumptive and non-licensed demands and the water available for all licensed requirements for each recharge zone, and consumptive pool within the two Prescribed Wells Areas. It also summarises the water available for licensed requirements for each consumptive pool.

As the calculations reveal that some consumptive pools have some unallocated water, it is proposed that allocation of this water be subject to the proponent demonstrating that the extraction would not negatively impact other water resources, existing water users or GDEs.

This would require investigations including an aquifer test and monitoring of neighbouring wells both within the target aquifer and adjoining aquifers. The proposed extraction point would need to be set back from any existing users' access points so as not to cause negative impacts to the existing user and throughout the life of the plan, regular salinity monitoring would be required to ensure that the extraction of water is not negatively impacting upon the beneficial use of the aquifer. An exception to this is extraction points in borefields for Public Water Supply which would require no specific set back distance. This is because in many cases it is more beneficial to the aquifer to extract a small portion of water from a number of wells in close proximity than to extract a larger volume of water from one well which may result in a localised cone of depression.

The preferred approach is to allow the formation of a new consumptive pool in the Quaternary Limestone aquifer if future work carried out indicates that the extent of saturation is larger than that outlined in this document, as this would identify water previously not accounted for. It is proposed that, if such an instance arises, the additional water should form part of a new consumptive pool called 'Found Water' and the same application processes would be required to be undertaken as outlined above.

Table 11. Assessment of the capacity and demands of the consumptive pools of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Recharge Zone	Adopted recharge rate (mm)	Recharge area (km2)	Resource Capacity (ML)	Non-Consumptive Demand %	Water Available for Consumptive Demands (ML)	Non-Licensed Use Requirements		Water Available for Licensed Requirements (ML)	Water Available for Licensed Requirements Consumptive Pool boundary(ML)
								Domestic Demands (ML)	Stock Demands (ML)		
Southern Basins	Coffin Bay	Coffin Bay A lens	29	13.82	400.7	60	160.3	0.28	0	160.0	160.0
	Uley Wanilla Public Water Supply	Uley Wanilla lens	13	14.33	186.3	60	74.5	1.4	0	73.1	206.3
		Uley Wanilla brackish	13	25.61	332.9	60	133.2	0	0	133.2	
	Uley North	Coffin Bay B lens	6	0.42	2.5	50	1.3	0	0	1.3	694.1
		Coffin Bay C lens	9	5.47	49.2	50	24.6	0	0.43	24.2	
		Uley East A lens	22	5.48	120.5	50	60.2	0	3.31	56.9	
		Uley East B lens	22	2.42	53.2	50	26.6	0	0.07	26.5	
		Uley North brackish	13	92.97	1208.6	50	604.3	0.56	18.49	585.2	
	Uley South Public Water Supply	Uley South lens	129	65.42	8439.5	30	5907.6	0	1.02	5906.6	9907.0
		Uley South brackish	129	43.06	5555.3	30	3888.7	0	1.41	3887.3	
		Uley South Tertiary Leakage	14	9.29	130.1	30	91.0	0	0	91.0	
		Pantania lens	13	0.38	4.9	30	3.4	0	0	3.4	
		Mikkira lens	13	2.13	27.6	30	19.3	0	0.71	18.6	
	Lincoln South Public Water Supply	Lincoln A lens	35	1.20	42.0	60	16.8	0	0.01	16.8	2125.0
		Lincoln B lens	35	3.95	138.2	60	55.3	0	0	55.3	
		Lincoln C lens	35	7.92	277.4	60	110.9	0	0	110.9	
		Lincoln South brackish	35	138.92	4862.0	60	1944.8	1.4	1.41	1942.0	
	Lincoln North							3.36	30.95	53.9	53.9
	Unsaturated Quaternary Limestone							1.96	0	0	0
	Tertiary Sand							1.12	23.02	0	0
	Basement							0.28	23.02	100.2	100.2
Musgrave	Polda	Polda lens	15.8	37.21	587.9	60	235.2	0.84	3.6	230.7	1812.8
		Polda East A lens	6.8	0.07	0.5	60	0.2	0	0	0.2	
		Polda East B lens	6.8	0.72	4.9	60	2.0	0	0	2.0	
		Polda brackish	14.1	273.84	3861.1	60	1544.5	1.68	23.34	1519.4	
		Tinline lens	17.5	3.13	54.7	60	21.9	0	0.03	21.8	
		Talia East lens	15.8	6.15	97.1	60	38.9	0	0.24	38.6	
	Bramfield	Bramfield lens	25	99.46	2486.4	60	994.6	7.56	9.57	977.4	4708.1
		Bramfield brackish	14.1	639.93	9023.0	60	3609.2	13.44	134.41	3461.3	
		Talia lens	15.8	44.17	697.9	60	279.2	0.56	9.24	269.4	
	Sheringa	Sheringa A lens	16.3	36.23	590.5	60	236.2	0.28	0.88	235.1	3795.0
		Sheringa B lens	15.8	38.99	616.0	60	246.4	0.28	0.58	245.5	
		Kappawanta lens	22	48.86	1074.8	60	429.9	0	0	429.9	
		Sheringa brackish	14.1	519.82	7329.4	60	2931.8	2.8	44.45	2884.5	
	Unsaturated Quaternary Limestone							5.6	0	0	0
	Tertiary Sand							1.12	62.27	0	0
	Polda Formation							0	0	0	0
	Basement							0	62.27	0	0

1.6. CONSUMPTIVE POOLS RESERVED FOR PUBLIC WATER SUPPLY

Within the Southern Basins PWA a number consumptive pools have been reserved for Public Water Supply purposes in an effort to secure fresh groundwater now and into the future for critical human needs. Within these pools (Uley South Public Water Supply, Uley Wanilla Public Water Supply and Lincoln South Public Water Supply), new allocations will only be granted if the purpose is for Public Water Supply.

1.7. GROUNDWATER MANAGEMENT ZONES

Ground Water Management Zones (GWMZs) have been assigned to the Tertiary and Basement consumptive pools of the Southern Basins PWA (Figures 22 and 23) where the aquifers are overlain by publically owned land which falls within a Public Water Supply consumptive pool. Within these GWMZs, the extraction limit will be set to 0 ML/y to ensure that pumping from the deeper aquifers does not have the potential to cause downward leakage and losses from the Quaternary Limestone aquifer into the Tertiary or Basement aquifers. Confining the GWMZ to the publicly owned land does not limit private users from accessing the deeper aquifers to provide a water resource for licensed purposes.

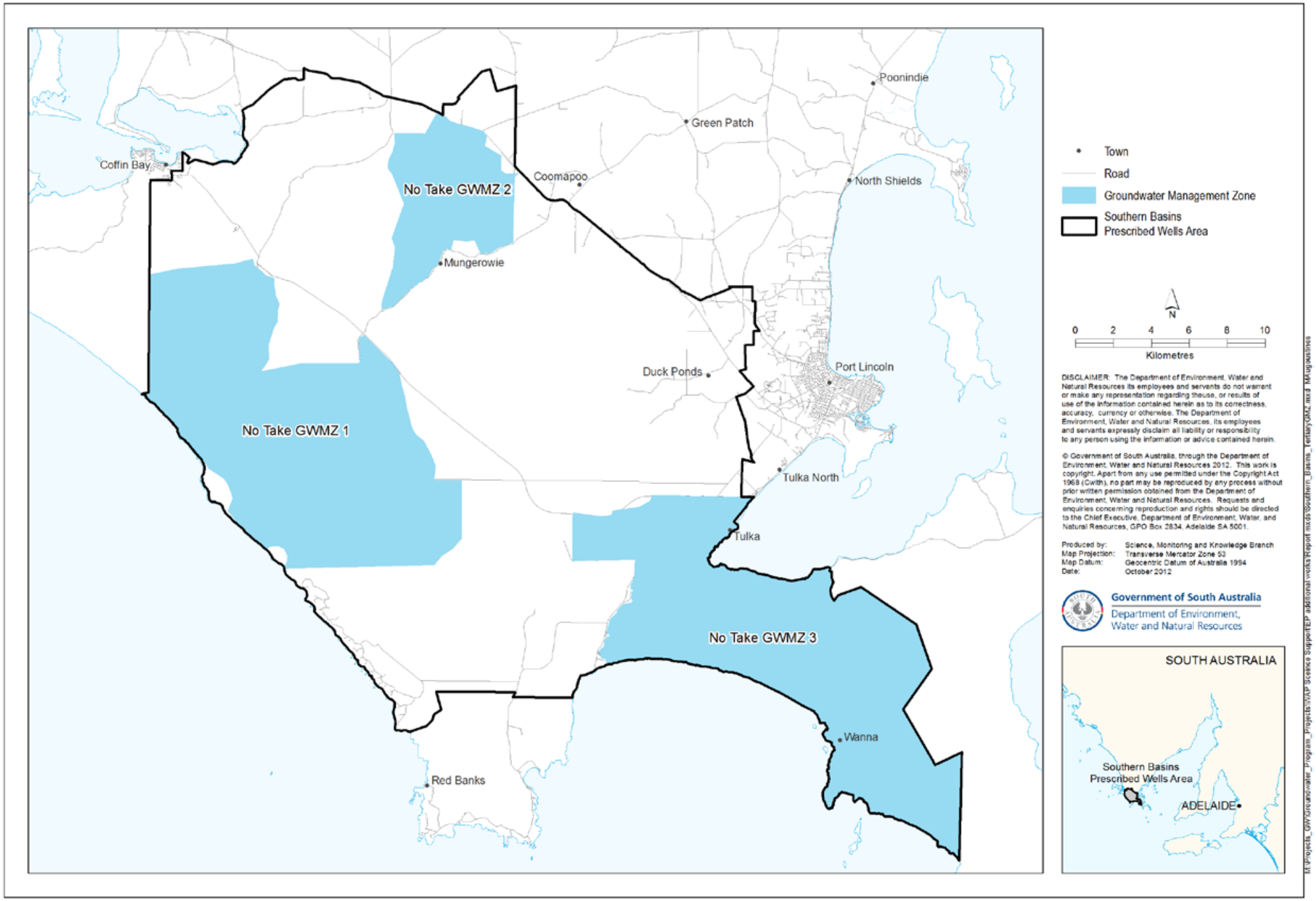

Figure 22. Groundwater Management Zones of the Tertiary consumptive pool in the Southern Basins PWA

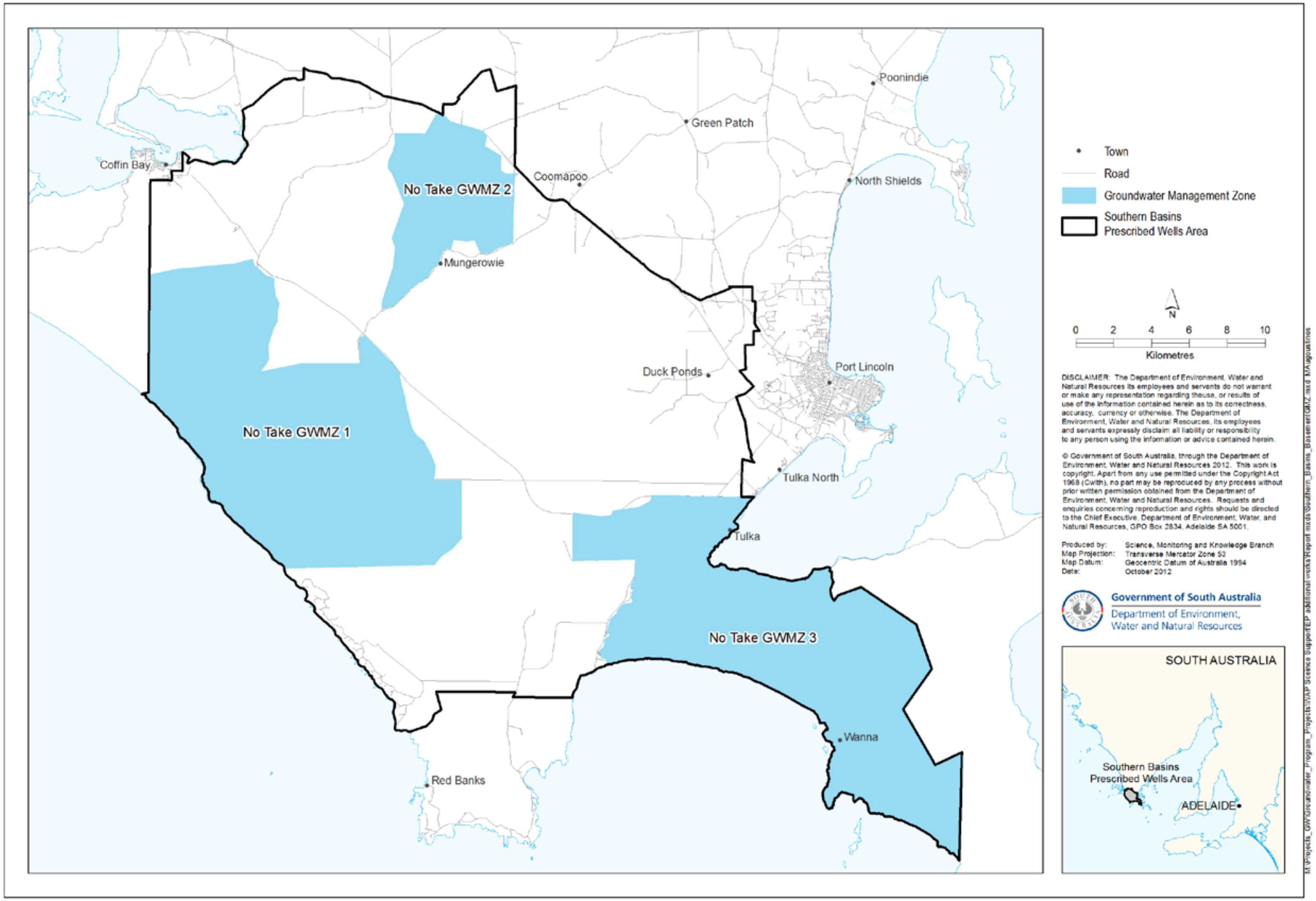

Figure 23. **Groundwater Management Zones of the Basement consumptive pool in the Southern Basins PWA**

2. PROTECTION OF RESOURCES

2.1. ENVIRONMENTAL PROTECTION ZONES

A range of policy options are available, which are aimed at protecting GDEs. Environmental buffers, now termed Environmental Protection Zones (EPZs) (Howe & Howieson 2006), is one option that has been adopted by the South East Natural Resources Management Board (SENRMB) in their draft WAP for the Tintinara Coonalpyn Prescribed Wells Area (SENRMB 2011). Howe and Howieson (2006) define an EPZ as "*…the desirable set-back distance that any water affecting activity must be from a GDE so as to mitigate the effect of groundwater use on maintenance of GDE access to groundwater*". The EPZ approach to GDE protection proposed by the SENRMB is considered transferable to Eyre Peninsula's PWAs due to the similarities in geology and hydrogeology i.e. both regions rely on groundwater resources, which reside primarily within Quaternary Limestone aquifers, despite the lenses of the Eyre Peninsula being much thinner than the aquifers of the South East.

The formula that is used to calculate environmental protection zone distances is based on the (non-equilibrium) Theis Solution (Fetter 1994). Details of the Theis Solution and its associated assumptions can be seen in Stewart, Risby and Alcoe (2012).

Although Theis' analytical solution describes flow of water to wells which are fully screened within confined aquifers, his method is commonly applied to unconfined aquifers by substituting the confined aquifer storage parameter 'specific storage' (Ss) for the unconfined aquifer storage parameter 'specific yield' (Sy) (Freeze & Cherry 1979). The Theis Solution is reliable in predicting water level drawdowns in unconfined aquifers contingent on the drawdown being small relative to the saturated thickness of the aquifer (Jacob 1950). Drawdowns in the unconfined Quaternary Limestone aquifer are likely to be relatively small relative to saturated thickness due to the aquifer's high transmissivities, as indicated by aquifer tests undertaken in the area (Stewart, Risby and Alcoe 2012, Table 21).

Aquifer parameters for the Eyre Peninsula's groundwater basins have been estimated based on a review of the published literature. The range of measured transmissivities and specific yields are summarised in Table 12.

Table 12. Range of specific yield (Sy) and transmissivity (T) for the Southern Basins and Musgrave PWAs

PWA	Lens/area	Minimum Sy	Maximum Sy	Minimum T (m^2/d)	Maximum T (m^2/d)
Southern Basins	Coffin Bay A		0.172		
	Uley South	0.007	0.72	680	1300
	Uley Wanilla	0.02	0.28	252	1612
Musgrave	Bramfield	0.005	0.032		
	Kappawanta	0.022	0.11		
	Musgrave (regional)	0.00003	0.11	750	3450
	Sheringa A	0.0051	0.0052		
	Sheringa B	0.012	0.036		
	Polda	0.00002	0.28	1370	4150

Doeg *et al* (2012) identifies the following groundwater dependent ecosystems within the PWAs:

Southern Basins PWA – Pillie Wetland Group, Sleaford Wetland Group and Wanilla Wetland Group; Musgrave PWA – Newland Wetland Group, Hamilton Wetland Group and Poelpena Wetland.

Given that the distribution of phreatophytes such as Red Gums is quite regional and that any inferred mapping such as NDVI or aerial photography has yet to be ground-truthed, protection zones have not been applied to Red Gum communities. Analysis of the regional geology, lithological logs and depth to groundwater (SKM 2009) suggests that both Big and Little Swamps are disconnected from the Quaternary Limestone aquifer and consequently, they have not been considered as GDEs.

EPZs have been calculated from the range of transmissivity and specific yield values stated in Table 12, assuming a pumping rate of 133 kL/d (i.e. an annual allocation of 10 ML, used in its entirety and extracted continuously over an irrigation season of 75 days). The maximum allowable watertable drawdown at the full extent of the zone is 0.1 m.

Table 13 outlines the minimum and maximum specific yield and transmissivity values for the relevant GDEs. The table summarises information sourced from Tables 21 and A1 from Stewart, Alcoe and Risby (2012). GDEs have been assigned different maximum and minimum values based on their location within the PWA.

The Pillie and Sleaford Wetland Groups are located near the Lincoln lens, and as there is no specific yield or transmissivity data specific to this area, the GDEs have been assigned the maximum and minimum ranges for all Southern Basins data in Table 12. However, the Wanilla Wetland Group is generally located in the Coffin Bay/Wanilla area and therefore the maximum and minimum specific yield and transmissivity values adopted have been sourced from the values for the Coffin Bay and Uley Wanilla properties as outlined in Table 12. The Uley South values were not taken into account for this GDE.

As the Newland Wetland Group is not located near any of the lenses, the regional Musgrave data was assigned to this GDE. The Poelpena Wetland is located in the vicinity of the Polda lens and therefore has been assigned the maximum and minimum specific yield and transmissivity values identified for Polda. The Hamilton Wetland Group is located in the Bramfield and Sheringa region and the minimum and maximum specific yield values for this GDE have been taken from the Bramfield and Sheringa values in Table 12. As there is no transmissivity data available specific to Bramfield or Sheringa, the minimum and maximum transmissivity values have been taken from the regional Musgrave data.

Table 13. Range of specific yield (Sy) and Transmissivity (T) for relevant Groundwater Dependent Ecosystems

PWA	GDE	Minimum Sy	Maximum Sy	Minimum T (m^2/d)	Maximum T (m^2/d)
Southern Basins	Pillie Wetland Group	0.007	0.72	252	1612
	Sleaford Wetland Group	0.007	0.72	252	1612
	Wanilla Wetland Group	0.02	0.28	252	1612
Musgrave	Newland Wetland Group	0.00003	0.11	750	3450
	Hamilton Wetland Group	0.0051	0.036	750	3450
	Poelpena Wetland	0.00002	0.28	1370	4150

The pumping rate of 133 kL/d (10 ML/y) is assumed to be a good approximation of the likely allocations that new users may apply for within the PWAs. Excluding allocations for Public Water Supply (PWS), the average allocation since 2004 for the Southern Basins and Musgrave PWAs is 9.8 and 21 ML respectively (Table 14). Whilst average annual allocations within the Musgrave PWA is nearly twice that of the allocations in the Southern Basins PWA, average annual extraction remains very similar at 2.4 and 2.16 ML for the Southern Basins and Musgrave PWAs respectively (Table 15). Given the above data, a conservative pumping rate of 10 ML/y was chosen as a precaution from which to define the GDE buffers.

Tables 16 - 20 display the range of applicable protection zone distances based on the Theis Solution for an unconfined aquifer, considering the ranges of transmissivity and specific yield for each groundwater dependent ecosystem as outlined in Table 13. The largest protection zone distance identified for each GDE is summarised below and the spatial extent of the protection zones can be viewed in Figures 24 and 25.

Table 14. Average annual allocations (excluding PWS) for the Southern Basins and Musgrave PWAs

PWA	Average Annual Allocation (ML)						
	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Southern Basins	10.3	10.3	10.3	10.3	10.3	8.8	8.8
Musgrave	22	23	23	23	22	17	17

Table 15. Average annual extraction (excluding PWS) for the Southern Basins and Musgrave PWAs

PWA	Average Annual Extraction (ML)						
	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Southern Basins	2.1	2.5	3.2	3.2	2.8	2.4	1.9
Musgrave	2.19	1.34	7.33	2.14	1.36	1.43	1.21

Table 16. Pillie and Sleaford Wetland Group EPZ distances (m)

T (m^2/d) /Sy	0.007	0.01	0.05	0.1	0.25	0.5	0.72
252	751	628	281	199	126	89	74
500	329	275	123	87	55	39	32
750	124	104	46	33	21	15	12
1000	44	37	16	12	7	5	4
1500	5	4	2	1	1	1	1
1612	3	3	1	1	1	0	0

Table 17. Wanilla Wetland Group EPZ distances (m)

T (m^2/d) /Sy	0.02	0.05	0.1	0.15	0.2	0.28
252	444	281	199	162	140	119
500	194	123	87	71	62	52
750	73	46	33	27	23	20
1000	26	16	12	10	8	7
1500	3	2	1	1	1	1
1612	2	1	1	1	1	0

Table 18. Newland Wetland Group EPZ distances (m)

T (m^2/d) /Sy	0.00003	0.00005	0.0001	0.0005	0.001	0.005	0.01	0.05	0.11
750	1894	1467	1037	464	328	147	104	46	31
1000	673	521	369	165	117	52	37	16	11
1500	78	61	43	19	14	6	4	2	1
2000	9	7	5	2	1	1	0	0	0
2500	1	1	0	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0	0
3450	0	0	0	0	0	0	0	0	0

Table 19. Hamilton Wetland Group EPZ distances (m)

T (m^2/d) /Sy	0.005	0.0075	0.01	0.025	0.036
750	147	120	104	66	55
1000	52	43	37	23	19
1500	6	5	4	3	2
2000	1	1	0	0	0
2500	0	0	0	0	0
3000	0	0	0	0	0
3500	0	0	0	0	0
4000	0	0	0	0	0

Table 20. Poelpena Wetland EPZ distances (m)

T (m^2/d) /Sy	0.00002	0.00005	0.0001	0.001	0.01	0.1	0.15	0.28
1370	169	107	75	24	8	2	2	1
1500	96	61	43	14	4	1	1	1
2000	10	7	5	1	0	0	0	0
2500	1	1	0	0	0	0	0	0
3000	0	0	0	0	0	0	0	0
3500	0	0	0	0	0	0	0	0
4000	0	0	0	0	0	0	0	0
4150	0	0	0	0	0	0	0	0

Table 21. Adopted EPZ distances for the relevant groundwater dependent ecosystems

PWA	GDE	EPZ (m)
Southern Basins	Pillie Wetland Group	750
	Sleaford Wetland Group	750
	Wanilla Wetland Group	450
Musgrave	Newland Wetland Group	1900
	Hamilton Wetland Group	150
	Poelpena Wetland	170

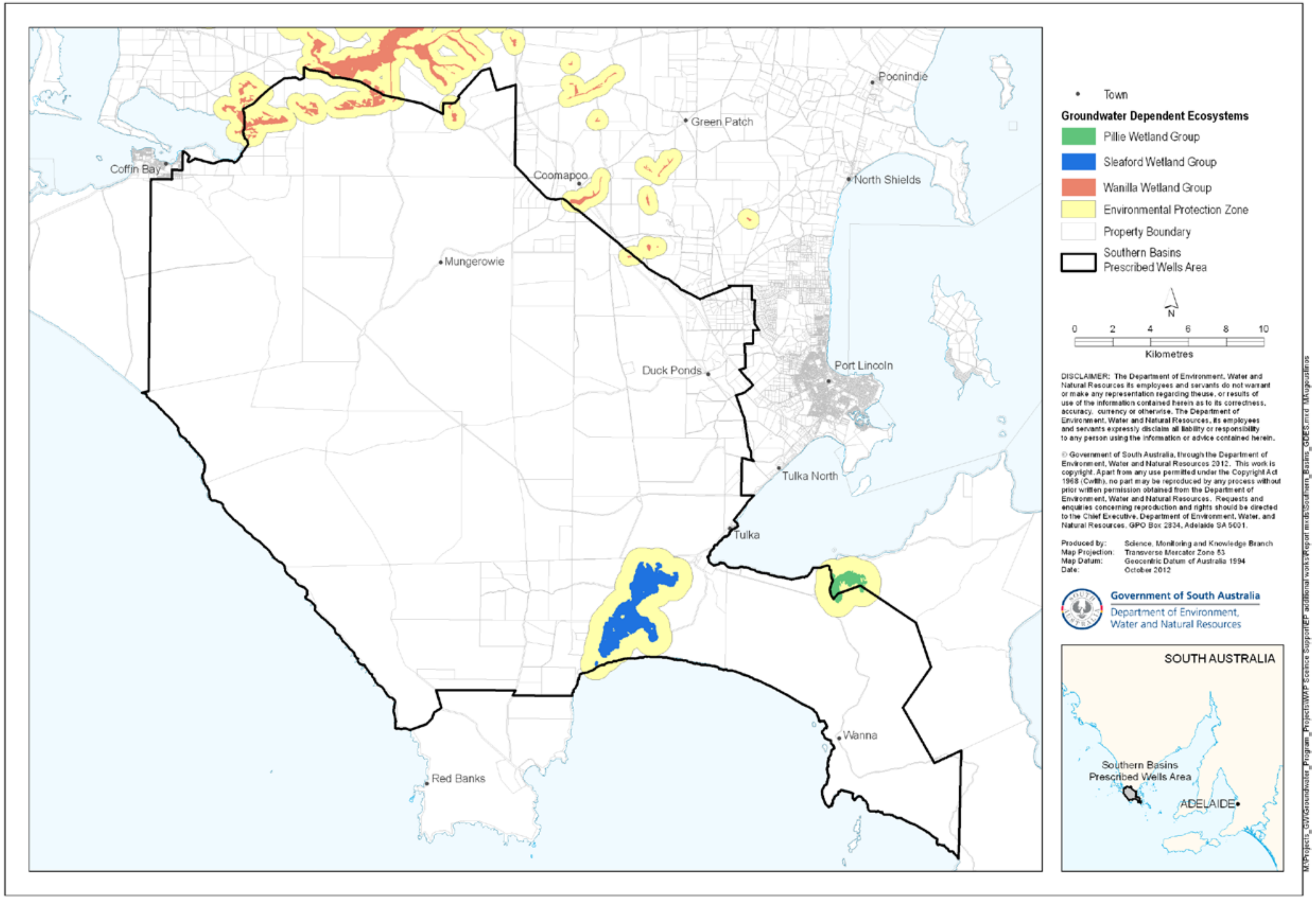

Figure 24. **Groundwater dependent ecosystems of the Southern Basins PWA and Environmental Protection Zones**

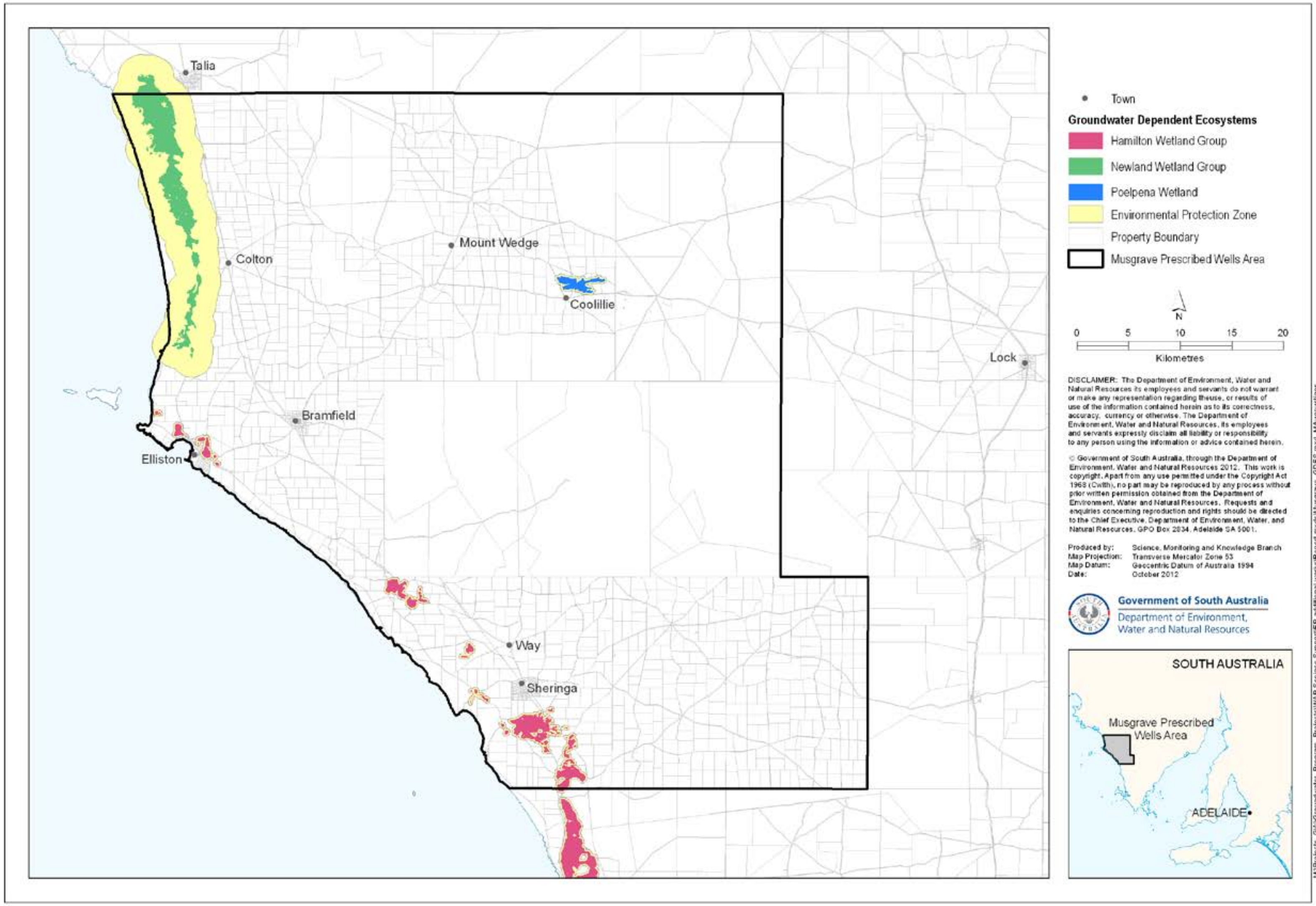

Figure 25. **Groundwater dependent ecosystems of the Musgrave PWA and Environmental Protection Zones**

2.2. MARINE WATER/FRESH WATER INTERFACE MANAGEMENT

Consideration was given to applying protection zones along coastline of the Southern Basins PWA in the vicinity of Uley South where sea water intrusion has the potential to degrade the resource. However it is considered that regular monitoring of the marine water/fresh water interface would be a more suitable way to manage the interface (refer to Section 4).

2.3. TERTIARY CLAY ABSENCE BUFFERS

In locations where the Tertiary Clay aquitard is absent, there is potential for the Quaternary Limestone aquifer to be connected to the underlying Tertiary Sands or Basement aquifers. Therefore extractions from the Tertiary Sand and Basement aquifers should be limited in areas where the Tertiary Clay is absent to protect the overlying Quaternary Limestone aquifer as there is the potential for downward leakage in these areas if hydraulic head gradients are varied.

Buffers have been applied around the areas of likely aquitard absence. The buffer distance suggested for each area is based on the calculations undertaken by Stewart, Alcoe and Risby (2012) and have been applied for extraction volumes of 5 ML/y and 10 ML/y (assuming the allocation is used in its entirety and extracted continuously over an irrigation season of 75 days), as summarised below in Table 22.

Table 22. Summary of suggested Tertiary buffers for specific areas of the PWAs sourced from Table 21 in Stewart, Risby and Alcoe 2012

Region	Buffer Distance 5 ML (m)	Buffer Distance 10 ML (m)
Polda Tertiary	1727	2518
	411	427
	1245	1305
Talia Tertiary	3611	6209
	3540	3908
Uley South Tertiary	7	163

The buffer distances outlined in Table 22 have been applied to the areas where the Tertiary Clay was deemed to be absent from lithological logs. In the absence of more regional data being available, for the majority of both PWAs the average of the Polda Tertiary buffer distance was applied. Exceptions to this are in the region of Talia, where the average of the Talia buffers was applied and in Uley South where the Uley South Tertiary buffer was applied as more refined localised data was available. Adopted buffer distances for the areas of clay absence are shown in Table 23.

Table 23. Adopted Tertiary Clay buffer distances

Region	Buffer Distance 5 ML (m)	Buffer Distance 10 ML (m)
Southern Basins regional	1128	1417
Southern Basins Uley South	7	163
Musgrave regional	1128	1417
Musgrave Talia region	3576	5059

The buffers indicate the likely distance around areas of probable aquitard absence where extraction from the Tertiary Sands or Basement aquifers may have a deleterious impact on the Quaternary Limestone aquifer (Figures 26 and 27). These buffers are to be used for management purposes such as limiting new allocations from the Tertiary or Basement aquifer within the buffered region. For example, in the area identified as Clay Absence it is proposed that no allocations would be allowed from the Tertiary or Basement aquifer in this area. In the area identified as Clay Absence Buffers 5 ML it is suggested that the proponent would only be able to extract up to 5 ML annually from the Tertiary or Basement aquifer in this area. In the area identified as Clay Absence Buffers 10 ML it is suggested that the proponent would be able to extract up to 10 ML annually from the Tertiary or Basement aquifer. If the proponent wishes to extract more than 10 ML annually they would be required to sit outside of all Clay Absence Buffers.

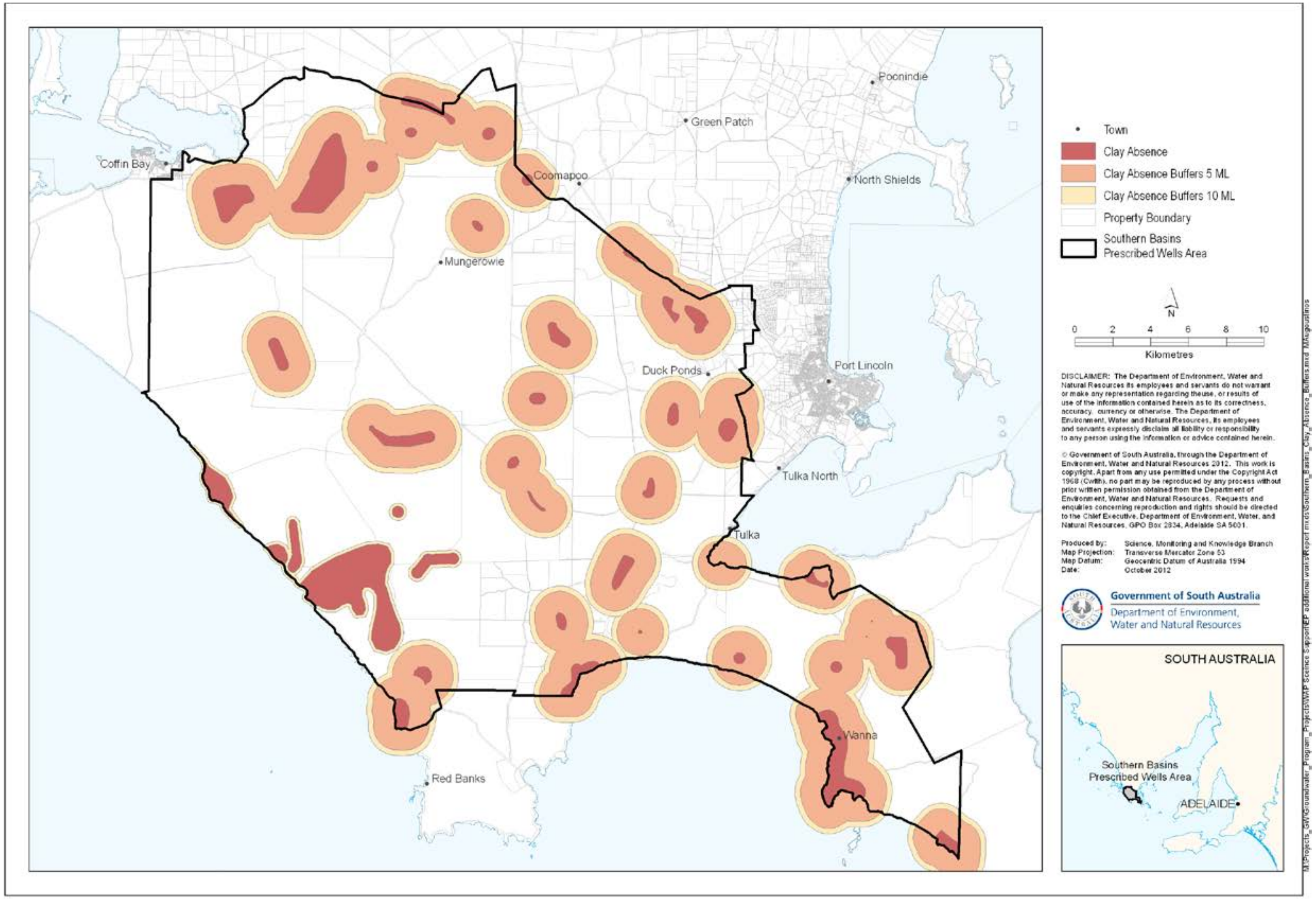

Figure 26. **Tertiary Clay absence buffers for 5ML and 10ML extraction rates for the Southern Basins PWA**

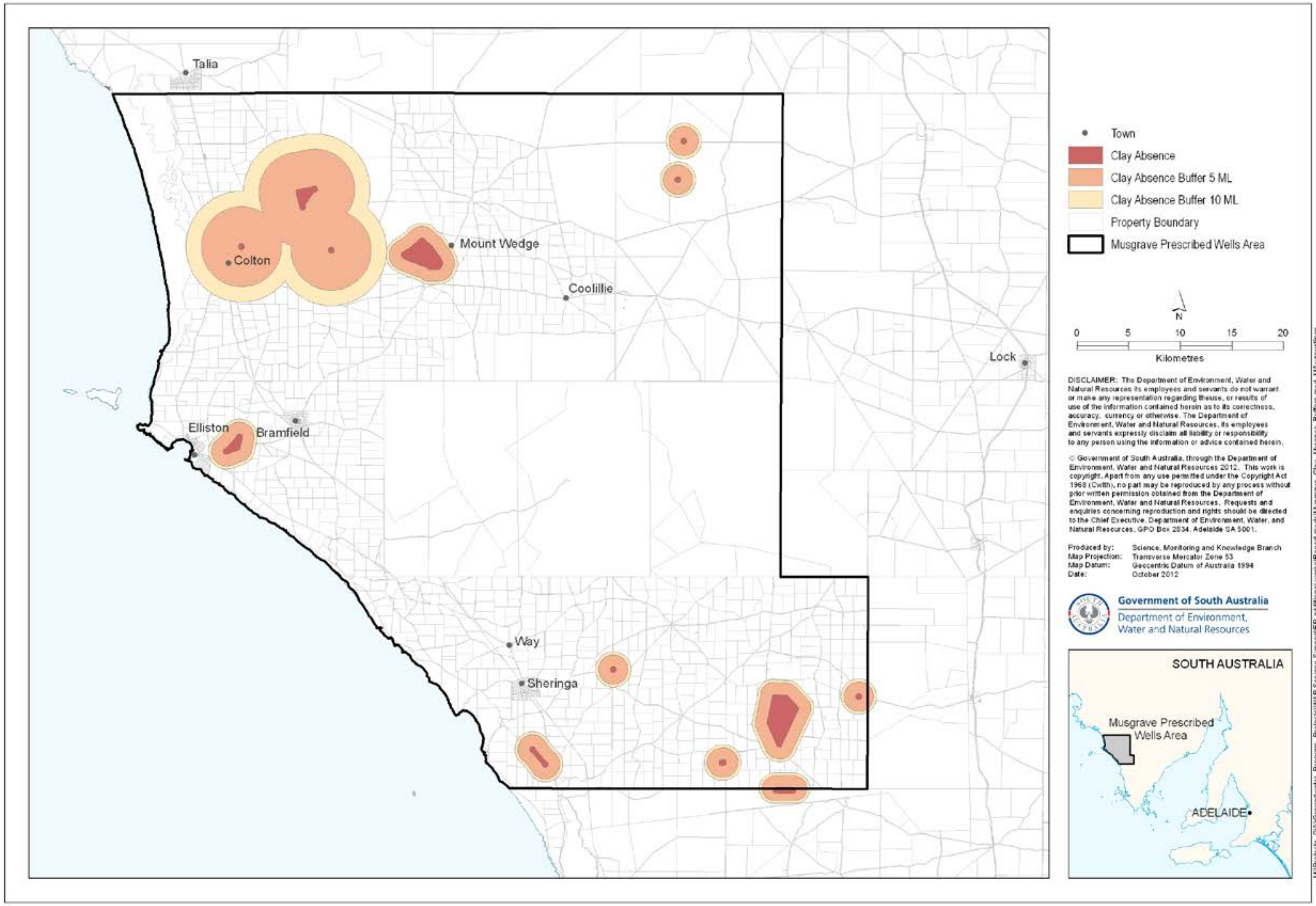

Figure 27. Tertiary Clay absence buffers for 5ML and 10ML extraction rates for the Musgrave PWA

3. VARIANCE OF ANNUAL ALLOCATIONS

In an unbundled water resource, water allocations are obtained through a water access entitlement which is the ongoing right to a share of the consumptive pool. While the share of the consumptive pool remains constant over the life of the WAP, the value of the share may be subject to variation which could be linked to the resource condition of a particular consumptive pool. In the case of the saturated Quaternary Limestone aquifer consumptive pools within the Southern Basins and Musgrave PWAs, this is to be achieved through analysing the change in storage (or aquifer saturation thickness) on an annual basis using recent monitoring data in combination with the Aquaveo™ Arc Hydro Groundwater model.

After the initial shares of the resource have been issued to licensees, their water allocations will be varied annually depending on changes in the amount of groundwater stored in the aquifer. The assessment of the level of storage (expressed as a percentage compared to a baseline) for each recharge area will be undertaken after the groundwater level monitoring is carried out in April of each year, which will then determine any changes to allocations for the next water use year commencing in June.

This methodology allows for changes in the aerial extent of the aquifer to be considered when varying allocations, not just the saturated thickness. This is particularly important for areas such as Uley South where the known maximum aerial extent of saturation is significantly larger than that observed in 2011.

3.1. AQUIFER STORAGE BASELINE

In order to vary allocations annually based on the assessed level of storage of the resource, a baseline status was required to be defined, because although allocations could be varied on the resource condition from one year to the next, this approach would not identify when the resources were becoming more stressed, and would just result in continual declines in allocations over time. A baseline was required to set triggers for change and to identify a storage trigger which would result in the complete cessation of pumping when the resource sustainability was threatened.

Choosing a baseline when water levels were at their highest historical levels would not be appropriate as it does not take into account the recent climatic conditions which have generally been drier than that observed historically. Alternatively, choosing the April 2011 aquifer storage as the baseline (Stewart, Alcoe and Risby 2012) was not feasible as it could potentially lead to increases in allocations in very wet years to volumes greater than the initial allocation set out for licensees at the adoption of the revised WAP.

It was considered that the past 20 years provides a reasonable period over which to consider the climatic conditions to be typical. Consequently, the baseline should be set as the year in which water levels were highest since 1992. Analysis of 46 observation wells across the Southern Basins PWA for the Quaternary Limestone aquifer indicated that the majority of wells observed the highest water level for the past 20 years in 1993. Therefore the saturated thickness of the aquifer for April (autumn) of 1993 is considered to be the aquifer storage baseline. April was chosen as it represents the time of year when water levels are likely to be at their lowest elevation after summer and the irrigation season, but prior to any significant recharge occurring. This is a precautionary approach to ensure water is not allocated without taking into account the seasonal declines that are observed due to the natural discharge from aquifers.

3.2. SCENARIO TESTING – LEVEL OF STORAGE

In order to determine appropriate triggers and rates of change in storage, the variability in the level of storage of the lenses and brackish areas needed to be considered. Therefore scenario testing to calculate the changes in storage over the past 10 years was undertaken.

3.2.1. METHODOLOGY

For the scenario testing to indicate a representative change from one year to the next, it was important to ensure that the inputs to the Arc Hydro model were consistent for each year. Given that the base of the Quaternary Limestone aquifer (top of the Tertiary Clay aquitard) will not change over time, it was important to ensure that the wells from which the water level rasters were interpolated were the same for every year of analysis.

Water level data for 1993 and the period 2000-2012 were extracted from Obswell for both PWAs for the autumn period (March – May). Any wells that had missing data for the autumn period in any single year were removed from the analysis. This resulted in a set of wells that had a water level reading for the autumn period for 1993 and each year from 2000-2012. April data was used where available and if not, either March or May data was used (Figures 28 and 29).

In both PWAs, there was insufficient monitoring undertaken in the autumn of 2006 for this analysis and therefore the 2006 storage data has been omitted from this analysis. There was also insufficient monitoring for this analysis in autumn of 2001 in the Southern Basins PWA and therefore there are no storage calculations for the Southern Basins PWA consumptive pools for this year.

As discussed previously, the modelling extent has been bound by the maximum historical saturated extent to account for future aerial expansion of the lenses and brackish areas. In order to observe the changes to the level of storage for the individual lenses, the modelling was completed at the lens level and then can be scaled up to the consumptive pool level as required. Figures 28 and 29 display the domains for which the modelling was conducted, and the wells used for analysis in the Southern Basins and Musgrave PWA respectively. Note that the Lincoln North area was not modelled due to limited data. There were also a number of lenses for which geovolumes could not be created because the spatial extent of the lens was too small in relation to the pixel size of the raster. This occurred for the Pantania and Mikira lenses in the Southern Basins PWA and in the Polda East A, Polda East B, Tinline and Talia East lenses in the Musgrave PWA. Due to the limited size of the Talia East lens, the volume of the Polda brackish area which surrounds the Talia East lens could also not be calculated.

Arc Hydro Groundwater was used to create 3-D geovolume features for each lens and brackish area (modelled area) for each year, which resulted in a volume calculation.

The 1993 storage volumes were taken to represent the aquifer storage baseline. The volumes for each modelled area that were calculated for the years of 2000-2012 were able to be compared with the 1993 volumes to determine the level of storage for each year in relation to the baseline. The scenario testing is a limited by the number of wells used and the data available to define the extent of saturation and fresh water lenses. The scenario testing is provided for testing purposes only and is not to be considered an indication of the likely changes to the level of storage that may be observed in the future.

3.2.2. RESULTS

Table 24 indicates the level of storage for each modelled area for each applicable year. In addition, it indicates the minimum and maximum level of storage for each modelled area. It can be seen that the minimum level of storage occurs in different years in different modelled areas. It generally occurs in

2009 with a few lenses experiencing the minimum in either 2008 or 2010. An exception to this is the Uley South lens and Uley South brackish area which experienced the minimum level of storage in 2000.

The level of storage in some lenses varies significantly over the scenario testing period, for example the Polda lens varies between 48 and 75%, with a maximum variation in one year of 13.5%. In contrast, other lenses remain fairly stable throughout the scenario testing period, for example the Coffin Bay A lens only varies from 98 to 99% with a maximum variation in one year of 0.58%. However this may be limited by the number of monitoring points available within Coffin Bay A for use in the scenario testing and their limited aerial extent within the lens. Additionally, the Coffin Bay A lens is known to be in connection the ocean which allows for buffering of the variation in water level when compared to aquifers further inland.

The scenario testing indicates that the Musgrave PWA modelled areas show significantly greater variation over the scenario testing period than those of the Southern Basins PWA, with the exception of the Uley East A lens. Again this could be due to the fact that a number of Southern Basins lenses are in connection with the ocean and the variation in water levels may be buffered by this connection.

The variability of the level of storage of the Uley East A lens could be due to its close proximity to the edge of aquifer saturation extent which would result in it being one of the first lenses impacted if the extent of saturation contracted due to below average recharge and hence falling water levels.

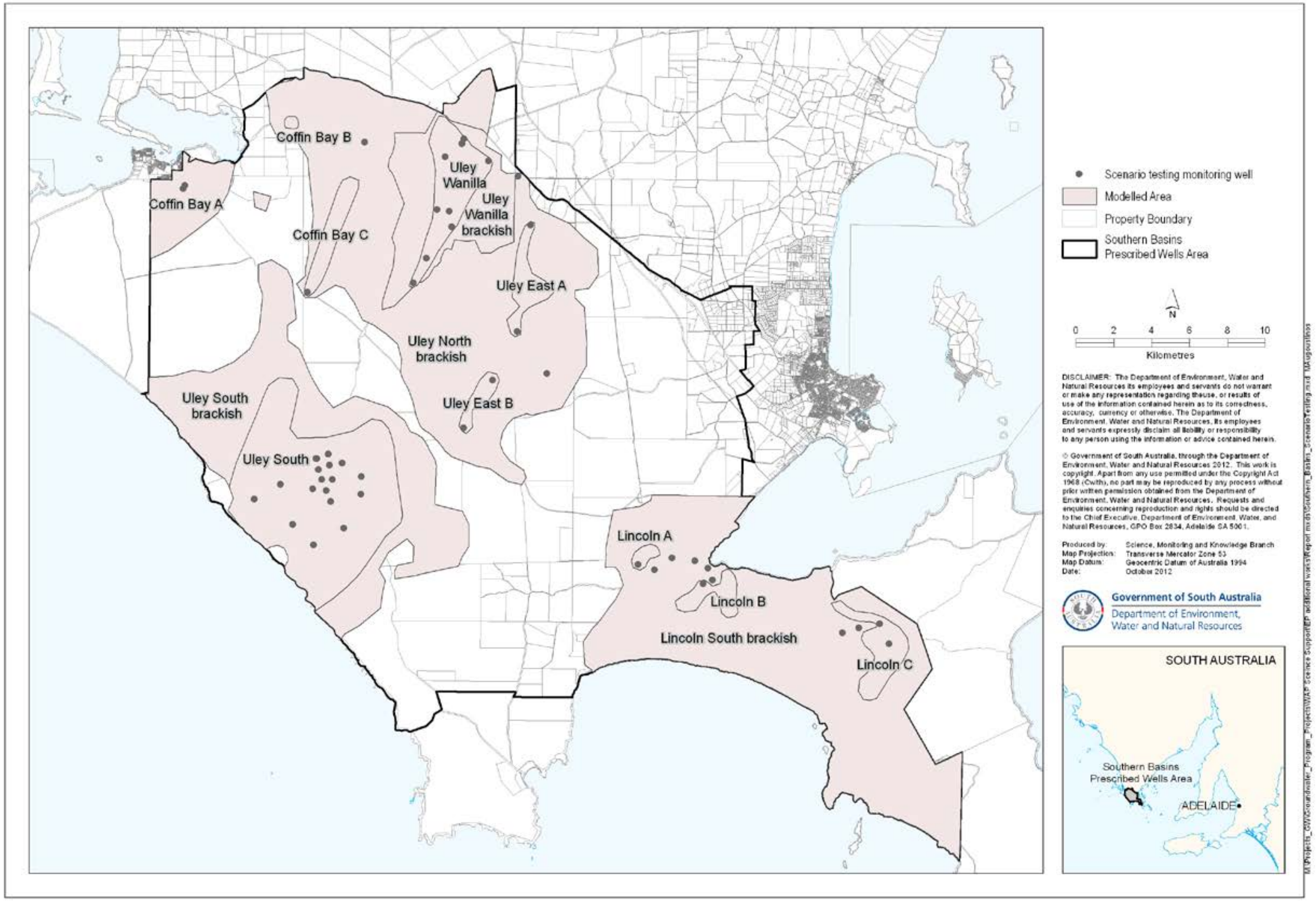

Figure 28. **Scenario testing wells and modelling domains for the Southern Basins PWA**

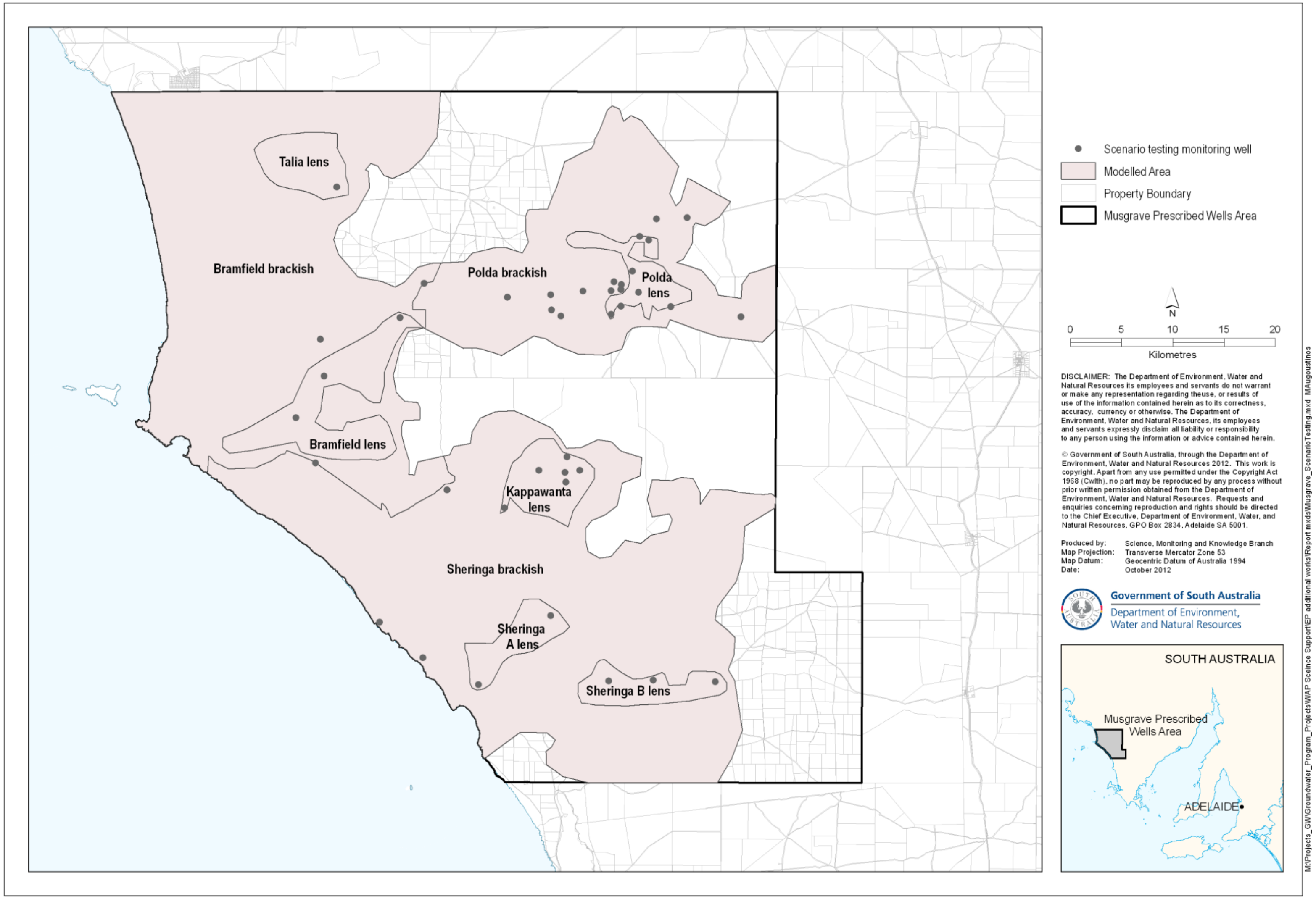

Figure 29. Scenario testing wells and modelling domains for the Musgrave PWA

Table 24. Level of storage for each modelled area for the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Modelled Area	Level of Storage (%)														
			1993	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2012	Min	Max
Southern Basins	Coffin Bay	Coffin Bay A lens	100	99		99	98	99	98	99	99	99	98	99	99	98	99
	Uley Wanilla Public Water Supply	Uley Wanilla lens	100	88		88	87	86	85	84	82	82	83	85	86	82	88
		Uley Wanilla brackish	100	81		81	79	78	78	75	74	73	75	78	79	73	81
	Uley North	Coffin Bay B lens	100	98		98	97	97	97	97	97	97	97	97	97	97	98
		Coffin Bay C lens	100	94		94	94	93	93	92	91	91	91	93	93	91	94
		Uley East A lens	100	64		65	59	61	62	54	51	52	65	70	68	51	70
		Uley East B lens	100	92		94	92	91	92	90	89	88	91	91	91	88	94
		Uley North brackish	100	92		92	91	90	90	89	88	88	90	91	91	88	92
	Uley South Public Water Supply	Uley South lens	100	87		90	89	88	87	89	89	89	91	92	92	87	92
		Uley South brackish	100	83		87	86	84	83	87	85	85	88	90	89	83	90
	Lincoln South Public Water Supply	Lincoln A lens	100	94		94	93	93	92	92	91	92	92	93	93	91	94
		Lincoln B lens	100	98		98	98	98	98	98	97	98	98	98	98	97	98
		Lincoln C lens	100	95		96	96	94	94	93	93	93	93	93	93	93	96
		Lincoln South brackish	100	96		96	95	95	95	95	94	95	95	95	95	94	96
Musgrave	Polda	Polda lens	100	68	66	75	67	70	64	58	52	48	62	72	70	48	75
		Polda brackish+	100	80	78	83	78	80	76	72	68	65	73	79	78	65	83
	Bramfield	Bramfield lens	100	80	80	81	78	80	77	74	71	69	80	83	78	69	83
		Bramfield brackish	100	89	88	89	86	88	86	84	83	81	87	89	86	81	89
		Talia lens	100	86	85	86	83	86	83	80	77	75	82	87	87	75	87
	Sheringa	Sheringa A lens	100	92	92	92	90	91	89	87	87	86	88	90	89	86	92
		Sheringa B lens	100	85	87	88	84	85	83	78	75	74	78	82	80	74	88
		Kappawanta lens	100	76	81	86	79	84	79	68	64	61	74	81	75	61	86
		Sheringa brackish	100	89	89	90	87	89	86	83	82	81	85	87	85	81	90

+this calculation does not include the brackish component around the Talia East lens

3.3. TRIGGERS

This report recommends a proportional relationship between the level of storage and the proportion of water available from a consumptive pool for allocation. The proportional relationship has set triggers that define the type of variation to water allocations that should occur. These triggers are:

- The Upper Storage Trigger. This is defined as when the water available from a consumptive pool for allocation falls below 100% of that stated in the Water Allocation Plan
- The Mid Storage Trigger. This is defined as when a variation to the rate of change to the percentage of water available, as a function of the rate of change in the assessed level of storage, will occur
- The Lower Storage Trigger. This is defined as when the water available from a consumptive pool for allocation falls to 0% of that stated in the Water Allocation Plan

It is proposed that when the level of storage for the consumptive pool is greater than the Upper Storage Trigger, the water available for allocation will be 100% of that stated in the WAP.

When the status of storage falls below the Upper Storage Trigger but remains higher than the Mid Storage Trigger, it is proposed that the volume of water available for allocation varies by the Upper Rate of Change (defined in section 3.3.4) for each 1% change in the level of storage.

When the storage level falls below the Mid Storage Trigger but remains higher than the Lower Storage Trigger, it is proposed that the volume of water available for allocation varies by the Lower Rate of Change (defined in section 3.3.5) for each 1% change in the level of storage.

When the storage level is assessed to be equal to or less than the Lower Storage Trigger, no water will be available from the consumptive pool for allocation.

Section 3.3.6 presents the triggers and rates of change for the Southern Basins and Musgrave PWA. The values chosen take into consideration the accessibility and environmental risks derived from the risk based approach to determining consumptive pools and aquifer maintenance pools (SKM 2013), the response of the different modelled areas to the scenario testing (specifically the variation in the level or storage observed) and the robustness of the lenses which fall within the consumptive pools. The defined triggers reflect the specific characteristics of the individual consumptive pools.

3.3.1. UPPER STORAGE TRIGGER

The Upper Storage Trigger was determined by considering the vulnerability of the lenses which constitute each consumptive pool. Lenses that are more variable have a greater susceptibility to rapid change or falling below critical levels with little warning. The likely degree of variability in the storage levels in each lens was able to be assessed throughout the scenario testing.

If the storage level variability was high, the Upper Storage Trigger has been set at 100% indicating that as soon as the saturated thickness falls below the baseline value, allocations will vary by the Upper Rate of Change. This prevents the need to impose significant reductions on licensees' allocations in one year and allows forward planning for licensees and time to source alternative water resources.

If the scenario testing indicated that the storage level variability is moderate, the Upper Storage Trigger was set at 90%.

If the scenario testing indicated that the variability is low, the Upper Storage Trigger was set at 85%. The criteria used to determine if the lens reflected a high, moderate or low level of storage variability can be seen below. Table 25 summarises the Upper Storage Trigger values for each consumptive pool.

Exceptions to the above are the coastal consumptive pools where up-coning or saltwater intrusion is a risk. In the Coffin Bay and Lincoln South Public Water Supply consumptive pools up-coning is a significant risk to the resource. In these consumptive pools, the fresh water portion of the aquifer is quite thin due to the stratification on saline water. Due to the connection with the ocean, these lenses are buffered from variability in the level of storage observed over the scenario testing period, however in order to minimise the risk of saltwater up-coning, in these cases the Upper Storage Trigger has been set at 95% of the baseline level.

In the Uley South Public Water Supply consumptive pool, it is not saltwater up-coning that poses a risk to the resource but rather, saltwater intrusion. Saltwater intrusion is the lateral movement of saline water into a coastal aquifer. Monitoring of the saltwater interface has been undertaken in the Uley South lens and to date no movement of the interface has been observed. However, as potential saltwater intrusion is a risk to the resource, it should be considered when assigning triggers to the consumptive pool. Again due to the connection to the ocean, the variability in the level of storage over the scenario testing period for the Uley South lens was not significant, however due to the risk of saltwater intrusion a higher Upper Storage Trigger has been set. In this case the Upper Storage Trigger has been set at 90% in order to ensure that the volume available in the consumptive pools for allocations are varied as the level of storage of the resource varies, despite the lens showing very little variation over the scenario testing period.

Storage Level Variability

Low	All modelled areas that make up the consumptive pool have a storage level variability over the scenario testing period of <10%
Moderate	One or more modelled areas that make up the consumptive pool have a storage level variability over the scenario testing period of more than 10%
High	One or more modelled areas that make up the consumptive pool have a storage level variability over the scenario testing period of more than 20%

Table 25. Analysis to determine Upper Storage Trigger

PWA	Consumptive Pool	Number of modelled areas in consumptive pool with variability of <10%	Number of modelled areas in consumptive pool with variability of more than 10%	Number of modelled areas in consumptive pool with variability of more than 20%	Scenario testing variability	Coastal aquifer	Upper Storage Trigger %
Southern Basins	Coffin Bay	1	0	0	Low	Y	95
	Uley Wanilla Public Water Supply	2	0	0	Low		85
	Uley North	4	1	0	Moderate		90
	Uley South Public Water Supply	2	0	0	Low	Y	90
	Lincoln South Public Water Supply	4	0	0	Low	Y	95
Musgrave	Polda	0	1	1	High		100
	Bramfield	1	2	0	Moderate		90
	Sheringa	2	1	1	High		100

3.3.2. LOWER STORAGE TRIGGER

The Lower Storage Trigger was determined in two ways depending on the location of the lenses within the Prescribed Wells Area.

3.3.2.1. Inland Consumptive Pools

For the inland consumptive pools, namely the Uley Wanilla Public Water Supply, Uley North, Polda, Bramfield and Sheringa consumptive pools an assessment of the aquifer robustness, which is the ratio between aquifer storage and recharge, was undertaken to provide an indication of the aquifer capability. In aquifers with a large robustness (large storage compared to recharge) there may be opportunities to use the aquifer storage to buffer natural variations in climate (IAH, 2004).

For each lens in the consumptive pools listed above, a robustness assessment was undertaken. The storage component was calculated to be the Arc Hydro 2012 volume multiplied by the specific yield as outlined in Stewart, Risby & Alcoe 2012 (Table 6), and the recharge component was the 2013/14 gazetted recharge rate multiplied by the recharge area of the lens (Table 26). To determine the Robustness Index the Storage was divided by the Recharge.

Table 26. Aquifer Robustness Test for Inland Consumptive Pools

PWA	Consumptive Pool	Lens	2012 Arc Hydro Volume (GL)	Specific Yield	Storage (GL)	Recharge Rate (mm/y)	Recharge Area (km^2)	Recharge (GL)	Robustness Index
Southern Basins	Uley Wanilla Public Water Supply	Uley Wanilla lens	147.60	0.188	27.75	13	14.33	0.19	149
	Uley North	Coffin Bay B lens	13.20	0.172	2.27	6	0.42	0.003	905
		Coffin Bay C lens	75.78	0.172	13.03	9	5.47	0.05	265
		Uley East A lens	9.57	0.188	1.80	22	5.48	0.12	15
		Uley East B lens	10.96	0.188	2.06	22	2.42	0.05	39
Musgrave	Polda	Polda lens	80.29	0.0265	2.13	15.8	37.21	0.59	4
	Bramfield	Bramfield lens	278.19	0.0135	3.76	25	99.46	2.49	2
		Talia lens	262.95	0.03	7.89	15.8	44.17	0.70	11
	Sheringa	Sheringa A lens	155.44	0.0031	0.48	16.3	36.23	0.59	1
		Sheringa B lens	145.06	0.01	1.45	15.8	38.99	0.62	2
		Kappawanta lens	179.67	0.045	8.09	22	48.86	1.07	8

While threshold values which define high and low robustness have not yet been comprehensively agreed upon, based on case studies outlined in the IAH report (2004) they suggest that an index of 100 or higher indicates high robustness, whilst an index of less than 20 indicates a low robustness. Table 26 outlines the robustness for the individual lenses, however given that the resource is to be managed on the consumptive pool level, the robustness also needs to be scaled to the consumptive pool level.

For the majority of consumptive pools this is fairly straight forward given that each lens within the pool has a similar robustness defined. An exception to this is the Uley North consumptive pool where Coffin Bay B and C lenses have a high robustness, Uley East A has a low robustness and Uley East B has a moderate robustness. In this case, taking a precautionary approach and managing the resource to the lowest robustness would be the conservative approach.

For the consumptive pools with a low robustness, it is proposed that the Lower Storage Trigger be equivalent to the level of storage which corresponds to the minimum water levels observed over the scenario testing period (2000-2012). For all lenses within the Musgrave PWA, the minimum water levels observed correspond with the lowest level of storage calculated, being 2009. For lenses within the Southern Basins PWA the minimum water levels observed occur in 2009 which corresponds to the lowest level of storage calculated, with the exception of the Uley East A lens. In this case the lowest water levels occurred in 2008 and correspond to the minimum level of storage for that lens which was calculated to be 2008.

As the triggers are applicable at the consumptive pool level, the minimum level of storage for the individual lenses (or Lower Storage Trigger) was required to be scaled up. If only one lens is present for a particular consumptive pool, the Lower Storage Trigger for that lens was applied to the whole consumptive pool. If multiple lenses were present in a particular consumptive pool, the average of the minimum level of storage for the various lenses was used to determine the Lower Storage Trigger for the consumptive pool (Table 27).

Table 27. Process of up scaling the Lower Storage Trigger for each lens to the consumptive pool

PWA	Consumptive Pool	Lens(s) used to determine consumptive pool Lower Storage Trigger
Southern Basins	Uley Wanilla Public Water Supply	Uley Wanilla lens
	Uley North	Average of Coffin Bay B and C and Uley East A and B lenses
Musgrave	Polda	Polda lens
	Bramfield	Average of Bramfield and Talia lenses
	Sheringa	Average of Sheringa A and B and Kappawanta lenses

The triggers were then rounded to the nearest whole number to attain the Lower Storage Trigger for the low robustness inland lenses (Table 28).

Table 28. Inland low robustness consumptive pool

PWA	Consumptive Pool	Lens	Robustness Index	Robustness	Consumptive Pool Robustness	Year of minimum saturated thickness	Level of storage in year (%)	Consumptive Pool Level of Storage (%)	Lower Storage Trigger
Southern Basins	Uley Wanilla Public Water Supply	Uley Wanilla lens	149	High	High	2009	81.8	n/a	n/a
	Uley North	Coffin Bay B lens	905	High	Low	2009	96.6	81.7	82
		Coffin Bay C lens	265	High		2009	91.1		
		Uley East A lens	15	Low		2008	50.9		
		Uley East B lens	39	Moderate		2009	88.3		
Musgrave	Polda	Polda lens	4	Low	Low	2009	48.0	48.0	48
	Bramfield	Bramfield lens	2	Low	Low	2009	69.4	72.2	72
		Talia lens	11	Low		2009	75.0		
	Sheringa	Sheringa A lens	1	Low	Low	2009	86.0	73.4	73
		Sheringa B lens	2	Low		2009	73.7		
		Kappawanta lens	8	Low		2009	60.7		

For the more robust systems, namely Uley Wanilla Public Water Supply, it is thought that the Lower Storage Trigger could likely be less than that minimum storage observed over the scenario testing period. Furthermore due to the aquifer geometries of the Polda lens, the values of the minimum water level observed over the scenario testing period are likely too low to maintain the aquifer on an ongoing basis. As such the Lower Storage Trigger for the Polda consumptive pool was required to be refined. In both the case of the Uley Wanilla Public Water Supply and the Polda consumptive pools it was determined that the Lower Storage Trigger should be equivalent to the depth at which the aquifer can no longer reasonably supply water for licensed purposes.

The Thies Solution (Fetter 1994) provides a mechanism by which to calculate the maximum drawdown observed at 0.1 m from a pumping well for specific extraction volumes. Details of the Theis Solution and its associated assumptions can be seen in Stewart, Risby and Alcoe (2012).

The maximum drawdown observed at 0.1 m from the extraction well has been calculated from the range of transmissivity and specific yield values specific for each consumptive pool (Table 29).

Table 29. Transmissivity and Specific Yield values for the Uley Wanilla Public Water Supply and Polda consumptive pools

PWA	Consumptive Pool	Minimum Sy	Maximum Sy	Minimum T (m^2/d)	Maximum T (m^2/d)
Southern Basins	Uley Wanilla Public Water Supply	0.02	0.28	252	1612
Musgrave	Polda	0.00002	0.28	1370	4150

A pumping rate of 133 kL/d (i.e. an annual allocation of 10 ML, used in its entirety and extracted continuously over an irrigation season of 75 days) has been assumed for the Polda consumptive pool to represent likely extractions required to meet irrigation demands (see section 2.1). It is assumed that in the future the Polda lens will not be used for the purposes of supplying water for Public Water Supply.

A pumping rate of 597 kL/d has been assumed for the Uley Wanilla Public Water Supply consumptive pool, this equates to an annual extraction of 44.8 ML used in its entirety and extracted over a period of 120 days. Within the Uley Wanilla Public Water Supply consumptive pool the maximum extraction over the life of the existing WAP occurred in the 2002/03 water use year with a total extraction from the lens of 266 ML. In 2002/03 the Uley Wanilla lens was only used in the months of November – February to supplement the reticulated supply and as such the extraction period has been broken down to 120 days. Furthermore there are 11 wells within the lens used to extract water for public water supply purposes, so the extraction rate requires some consideration of the management of the well field. The flow rate of each well in the well field is known, and by considering the maximum extraction rate of the well which displays the minimum saturated thickness (as this is likely to be the well which will go dry first if the lower storage trigger is reached) the rate of extraction could be properly considered.

Tables 30 and 31 display the applicable maximum drawdowns likely to be observed for the specified extraction volumes for the Uley Wanilla Public Water Supply and Polda consumptive pools at 0.1 m from the extraction well.

Table 30. Maximum drawdown (m) calculated for the Uley Wanilla Public Water Supply consumptive pool

T (m^2/d) /Sy	0.02	0.05	0.01	0.15	0.2	0.28
252	2	2	2	2	2	2
500	1	1	1	1	1	1
750	1	1	1	1	1	1
1000	1	1	1	1	1	1
1500	0	0	0	0	0	0
1612	0	0	0	0	0	0

Table 31. Maximum drawdown (m) calculated for the Polda consumptive pool

T (m^2/d) /Sy	0.00002	0.00005	0.0001	0.001	0.01	0.1	0.15	0.28
1370	0.22	0.21	0.2	0.18	0.17	0.15	0.15	0.14
1500	0.2	0.19	0.19	0.17	0.15	0.14	0.13	0.13
2000	0.15	0.14	0.14	0.13	0.12	0.1	0.1	0.1
2500	0.12	0.12	0.11	0.1	0.09	0.08	0.08	0.08
3000	0.1	0.1	0.1	0.09	0.08	0.07	0.07	0.07
3500	0.09	0.08	0.08	0.08	0.07	0.06	0.06	0.06
4000	0.08	0.07	0.07	0.07	0.06	0.05	0.05	0.05
4150	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05

Tables 30 and 31 indicate that the likely maximum drawdown within the aquifer at 0.1 m from an extraction well for the various transmissivity and specific yield values is 2 m for the Uley Wanilla Public Water Supply consumptive pool and 0.22 m for the Polda consumptive pool.

To gain an understanding of the actual drawdown likely to be observed within the extraction well itself, the resultant maximum drawdown at 0.1 m from the well has been multiplied by a further 50%. This is likely an over estimate but is a conservative approach (Table 32).

Table 32. Maximum drawdown at 0.1 m and within the well for the Uley Wanilla Public Water Supply and Polda consumptive pools

PWA	Consumptive Pool	Maximum drawdown at 0.1 m from the well (m)	Maximum drawdown within the well (m)
Southern Basins	Uley Wanilla Public Water Supply	2	3
Musgrave	Polda	0.22	0.33

Knowing the likely drawdown due to the possible extraction rates compared to the minimum saturated thickness observed at a licensees existing well throughout the consumptive area pool for April 2011 for the saturated portion of the consumptive pool, the minimum allowable saturated thickness was able to be determined. Assuming a consistent change in aquifer storage with changes in aquifer saturated thickness a minimum level of storage and hence Lower Storage Trigger was able to be determined for each consumptive pool (Table 33).

Table 33. Lower Storage Trigger for Uley Wanilla Public Water Supply and Polda consumptive pools

PWA	Consumptive Pool	Maximum drawdown within the well (m)	Minimum saturated thickness April 2011 (m)	Minimum allowable saturated thickness (m)	April 2011 level of storage (%)	Equivalent level of aquifer storage (m)	Lower Storage Trigger
Southern Basins	Uley Wanilla Public Water Supply	3	3.64	3	85.32	70.31	70
Musgrave	Polda	0.33	0.24	0.33	72.17	99.23	99

3.3.2.2. Coastal Consumptive Pools

For consumptive pools which are coastal, namely the Uley South Public Water Supply, Coffin Bay and Lincoln South Public Water Supply consumptive pools, the Lower Storage Trigger was determined by considering a critical minimum thickness of aquifer saturation which was based on mean sea level (0 m AHD). This is because within both the Coffin Bay and Lincoln South Public Water Supply consumptive pools, the water is saline below this level and effectively cannot be used for the purposes of irrigation, public water supply or other licensed requirements. In Uley South, this is a precautionary measure to minimise the risk of saltwater intrusion. However as passive saltwater intrusion can still occur even if the gradient of groundwater flow is towards the ocean, it is suggested that a set of saltwater interface wells (refer to Section 4) are monitored regularly as a secondary trigger for the Uley South lens. Activation of the salinity trigger would prompt an investigation into the cause of the change in location of the interface prior to the Lower Storage Trigger being reached, which when reached would require extractions for the purposes of public water supply, which provides approximately 70% of Eyre Peninsula’s reticulated water supply (Zulfic, Harrington and Evans 2007), to cease.

To determine the critical minimum thickness from which the Lower Storage Trigger can be determined for these coastal lenses, it was required to firstly create a raster using GIS which showed only the thickness of the groundwater lens above sea level. As this is a graduated thickness (e.g. in Coffin Bay the thickness ranged from 0 to 3 m), the area needed to be divided into different thickness bounds. Using GIS, the thickness contours were used to create individual polygons from which area could be calculated. By multiplying the area by the median value of the thickness bound (e.g. for 0-1 m, the median contour thickness is 0.5 m), a volume could be calculated. The area and volume of each bound was calculated and added, then by dividing the total volume by the total area, the average thickness of the lens above sea level could be calculated. A similar process was undertaken for the saline portion of water below 0 m AHD to determine the average thickness of the saline water. By adding the average thickness of the saline water to the average thickness of the fresh water, the total average thickness of the aquifer can be determined. The average thickness of the saline water determines the critical minimum thickness for the lens. By considering the level of storage for 2011 in relation to the aquifer thickness in 2011, the minimum level of storage could be determined by taking into consideration the critical minimum thickness of the lens through cross multiplication, assuming a consistent rate of change in level of storage and saturated thickness and rounding to the nearest percentage (Table 34).

Table 34. Analysis to determine Lower Storage Trigger for coastal consumptive pools

PWA	Consumptive Pool	2011 average saturated thickness 2011 (m)	2011 lens level of storage (%)	Critical minimum thickness (m)	Critical minimum status of storage (%)	Lower Storage Trigger
Southern Basins	Coffin Bay	17.66	98.86	16.50	92.38	92
	Uley South Public Water Supply	14.51	92.35	11.13	70.88	71
	Lincoln South Public Water Supply	16.38	94.4	16.10	92.79	93

3.3.3. MID STORAGE TRIGGER

The Mid Storage Trigger is set as the median value between the Upper and Lower Storage Trigger values, generally rounded up to the nearest percentage (Table 35).

Table 35. Analysis to determine Mid Storage Trigger

PWA	Consumptive Pool	Upper Storage Trigger	Lower Storage Trigger	Median between upper and lower Storage Trigger	Mid Storage Trigger
Southern Basins	Coffin Bay	95	92	93.5	94
	Uley Wanilla Public Water Supply	85	70	77.5	78
	Uley North	90	82	86	86
	Uley South Public Water Supply	90	71	80.5	81
	Lincoln South Public Water Supply	95	93	94	94
Musgrave	Polda	100	99	99.5	99.5
	Bramfield	90	72	81	81
	Sheringa	100	73	86.5	87

3.3.4. UPPER RATE OF CHANGE

The Upper Rate of Change is related to the accessibility risk to the groundwater resources of the consumptive pool as assessed in the risk assessment (SKM, 2013). If the accessibility risk is high, the Upper Rate of Change is a 1% change in allocation per 1% change in the storage level. This is because the Upper Rate of Change relates to the change in storage between the Upper Storage Trigger and the Mid Storage Trigger and within this zone, there is a low likelihood that the resource will be at risk if water is continued to be allocated. Therefore it is considered acceptable to continue to allocate water in a reasonable manner to licensees and for public water supply purposes. When the accessibility risk is low (indicating the resource is not highly essential for licensed purposes) allocations will be varied by 0.5% for every 1% of change in storage level (Table 36).

Table 36. Analysis for Upper Rate of Change

PWA	Consumptive Pool	Accessibility Risk	Upper Rate of Change
Southern Basins	Coffin Bay	high	1
	Uley Wanilla Public Water Supply	high	1
	Uley North	low	0.5
	Uley South Public Water Supply	high	1
	Lincoln South Public Water Supply	high	1
Musgrave	Polda	high	1
	Bramfield	high	1
	Sheringa	low	0.5

3.3.5. LOWER RATE OF CHANGE

The Lower Rate of Change is the rate of change required to vary the proportional relationship for each 1% change in the level of storage between the Mid Storage Trigger and the Lower Storage Trigger which results in the volume of water available in the consumptive pool becoming zero (Table 37). To determine the Lower Rate of Change the following calculation was undertaken using the Uley South Public Water Supply consumptive pool as an example:

Step 1: Determine the difference between the Upper Storage Trigger and the Mid Storage Trigger
  90 - 81 = 9
Step 2: Multiply the difference by the Upper Rate of Change to determine the percentage change in the proportional relationship between the Upper and Mid Storage Triggers.
  9 x 1 = 9
Step 3: Calculate the difference between the Mid Storage Trigger and Lower Storage Trigger
  81 - 71 = 10
Step 4: Subtract the percentage change in proportional relationship between the Upper and Mid Storage Triggers from 100%
  100 - 9 = 91
Step 5: Divide the remaining percentage available in the proportional relationship (result of step 4) by the difference between the Mid and Lower Storage Triggers
  91 / 10 = 9.10

The resultant value indicates the rate at which the variation of the proportional relationship is required to change by to ensure that when the Lower Storage Trigger is reached, the volume available for allocation from the consumptive pool equals zero.

Table 37. Analysis for Lower Rate of Change

PWA	Consumptive Pool	Upper Storage Trigger	Mid Storage Trigger	Difference between Upper and Mid Storage Triggers	Upper Rate of Change	% change in storage level between Upper and Mid Storage Triggers	Lower Storage Trigger	Difference between Mid and Lower Storage Triggers	Full storage minus storage change at Upper Rate of Change	Lower Rate of Change
Southern Basins	Coffin Bay	95	94	1	1	1	92	2	99	49.5
	Uley Wanilla Public Water Supply	85	78	7	1	7	70	8	93	11.63
	Uley North	90	86	4	0.5	2	82	4	98	24.5
	Uley South Public Water Supply	90	81	9	1	9	71	10	91	9.1
	Lincoln South Public Water Supply	95	94	1	1	1	93	1	99	99
Musgrave	Polda	100	99.5	0.5	1	0.5	99	0.5	99.5	199
	Bramfield	90	81	9	1	9	72	9	91	10.11
	Sheringa	100	87	13	0.5	6.5	73	14	93.5	6.68

3.3.6. TRIGGERS AND RATES OF CHANGE

The Upper Storage Trigger, Upper Rate of Change, Mid Storage Trigger, Lower Rate of Change and Lower Storage Trigger for the various consumptive pools of the Quaternary aquifer of the Southern Basins and Musgrave PWAs have been summarised in Table 38. Figures 30-37 demonstrate the proportional relationship for the relevant Quaternary consumptive pools.

Table 38. Proportional relationship storage triggers and rates of change for the consumptive pools of the Southern Basins and Musgrave PWAs

PWA	Consumptive Pool	Upper Storage Trigger	Upper Rate of Change	Mid Storage Trigger	Lower Rate of Change	Lower Storage Trigger
Southern Basins	Coffin Bay	95	1	94	49.5	92
	Uley Wanilla Public Water Supply	85	1	78	11.62	70
	Uley North	90	0.5	86	24.5	82
	Uley South Public Water Supply	90	1	81	9.1	71
	Lincoln South Public Water Supply	95	1	94	99	93
Musgrave	Polda	100	1	99.5	199	99
	Bramfield	90	1	81	10.11	72
	Sheringa	100	0.5	87	6.68	73

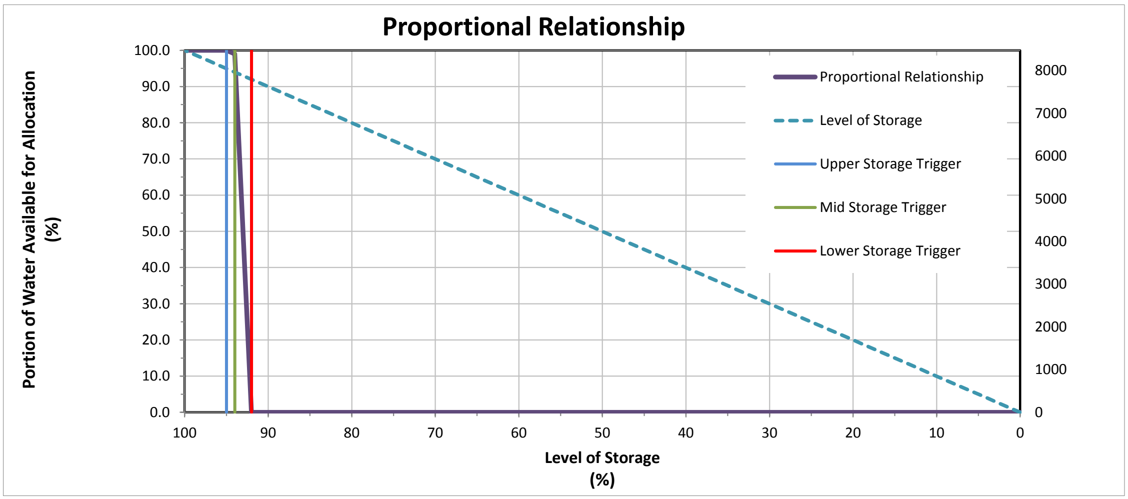

Figure 30. Proportional relationship for the Coffin Bay consumptive Pool

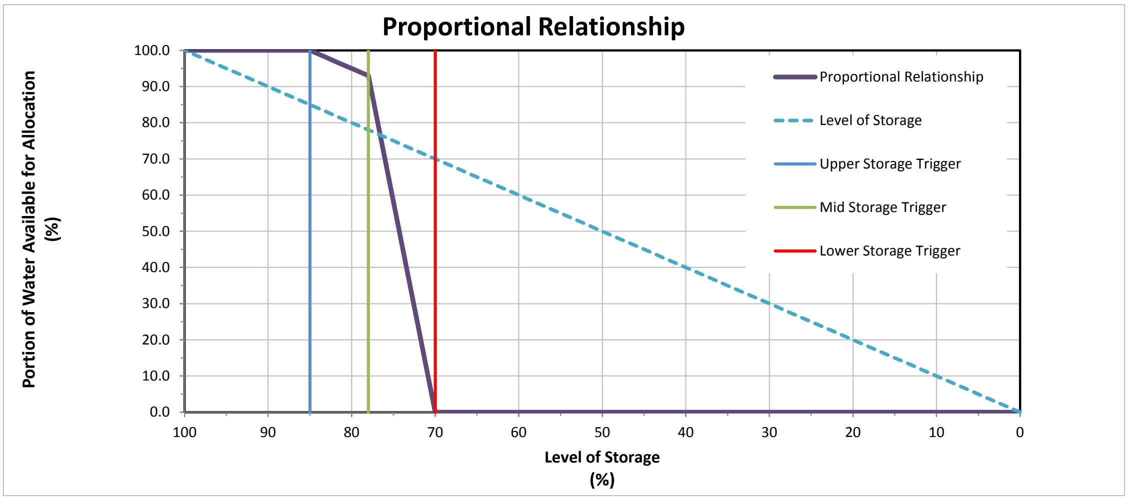

Figure 31. Proportional relationship for the Uley Wanilla Public Water Supply consumptive pool

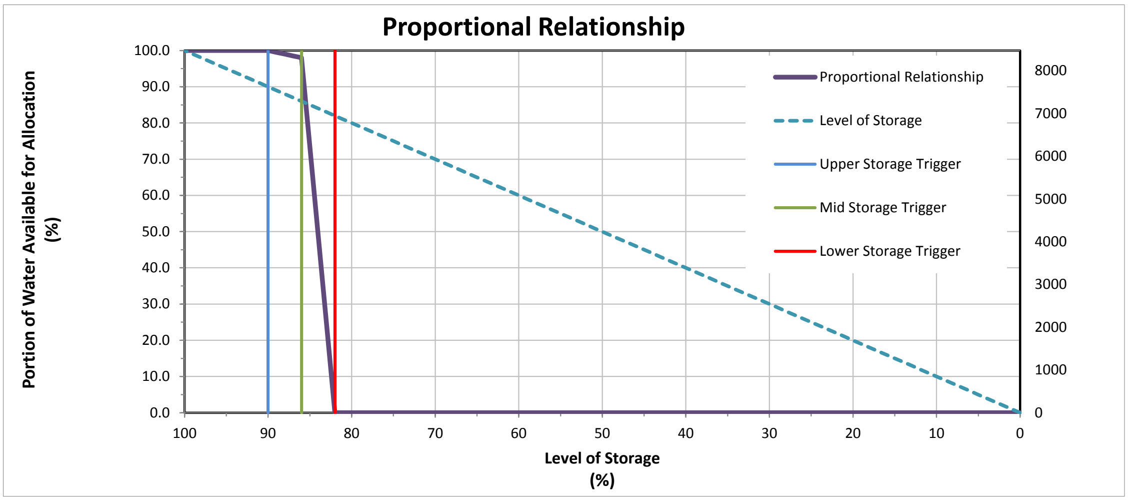

Figure 32. Proportional relationship for the Uley North consumptive pool

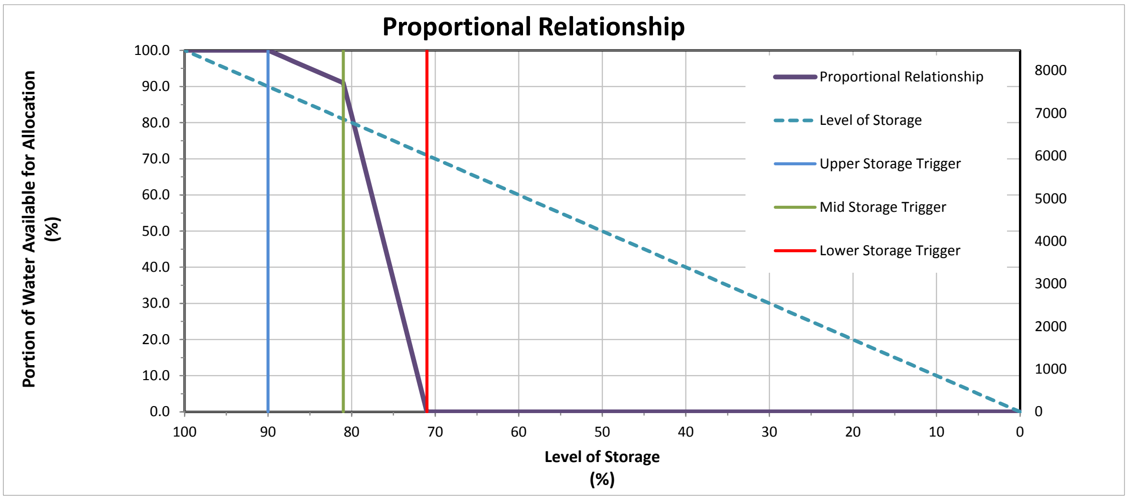

Figure 33. Proportional relationship for the Uley South Public Water Supply consumptive pool

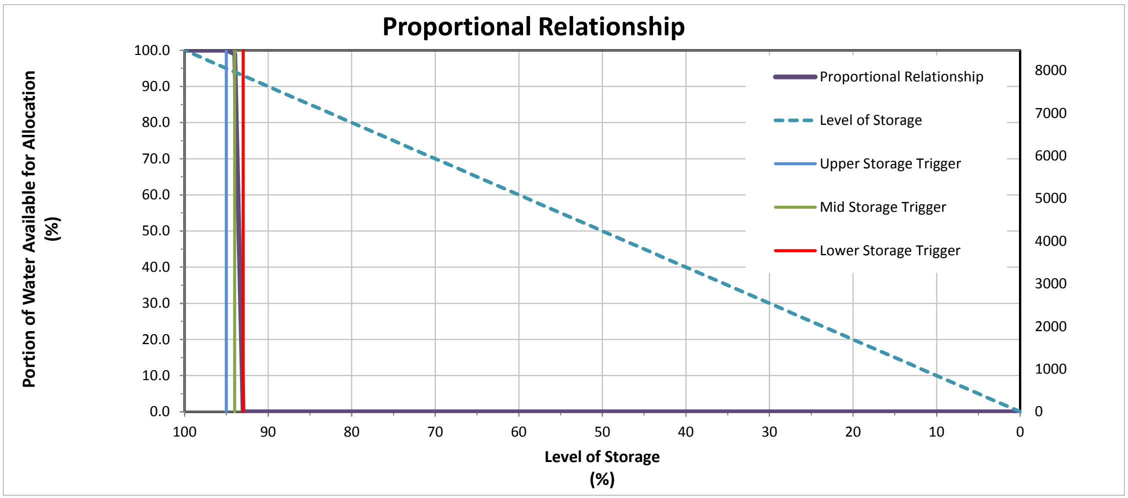

Figure 34. Proportional relationship for the Lincoln South Public Water Supply consumptive pool

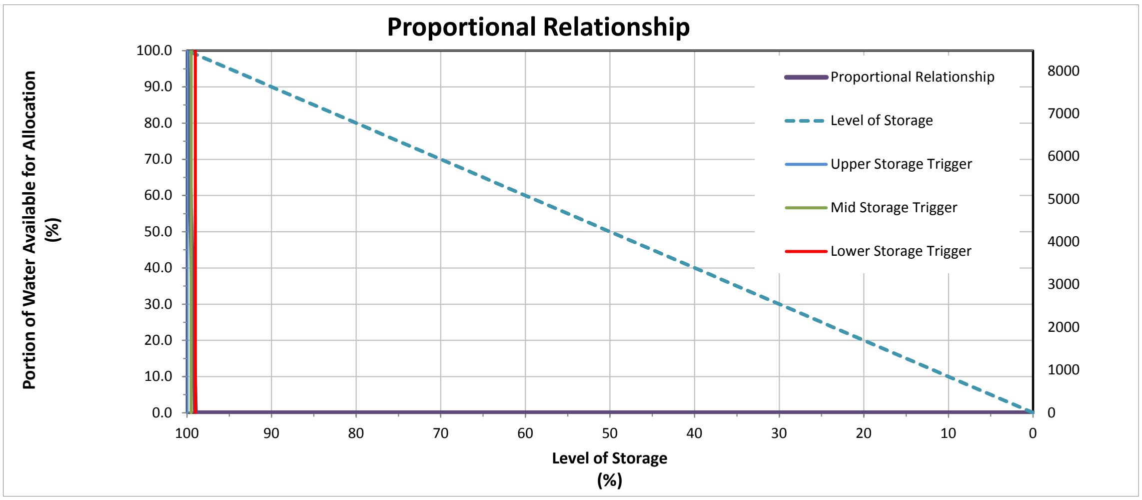

Figure 35. Proportional relationship for the Polda consumptive pool

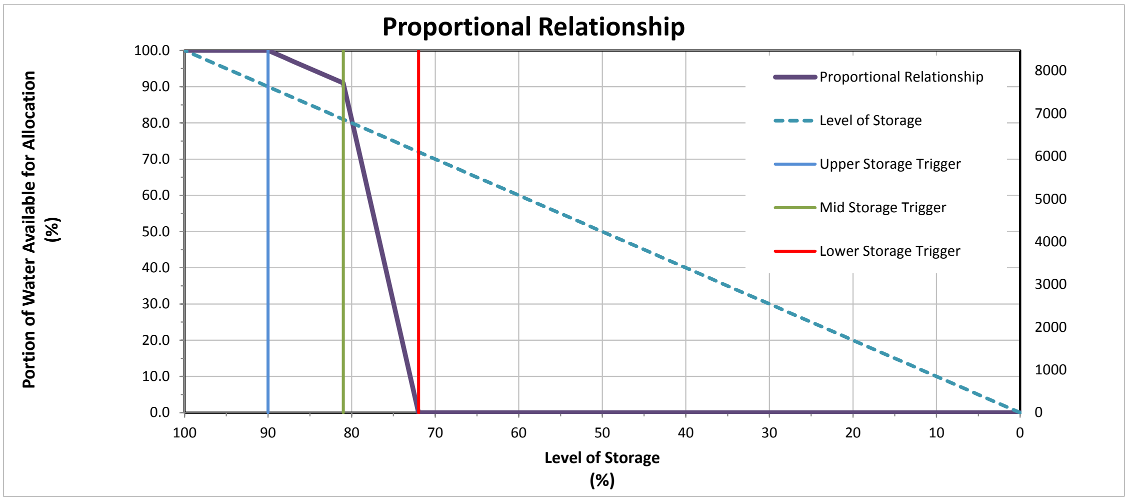

Figure 36. Proportional relationship for the Bramfield consumptive pool

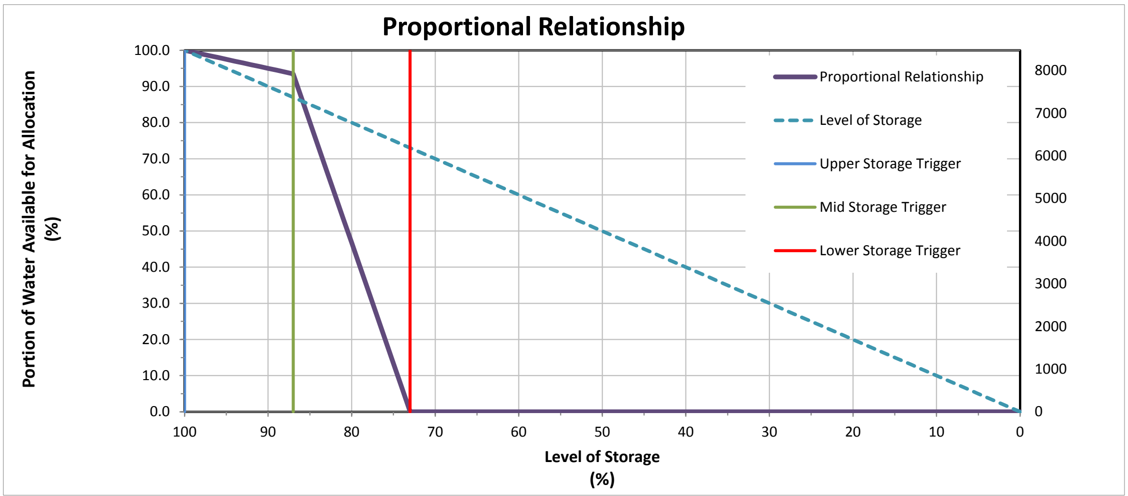

Figure 37. Proportional relationship for the Sheringa consumptive pool

3.4. POTENTIAL IMPACT TO EXISTING USERS

Using the triggers outlined in Table 38, the potential impact to existing users was able be investigated using the 2012 monitoring data. The following has been calculated assuming that at the adoption of the revised WAP licensees will be given a water access entitlement equal to the maximum allocation provided throughout the life of the existing WAP excluding any additional water that may have been approved under a Section 128 or any other agreement. An exception to this is the Uley Wanilla Public Water Supply consumptive pool which would be limited to the volume of water available for licensed demand. This is because the volume of water available for licensed demand is less than that previously held on licence within this consumptive pool, as such the limit for water access entitlements should be consistent with the ability of the resource to meet demand. The water access entitlement would equate to the baseline status of 1993 storage levels and annually allocations would be varied from this maximum volume based on the assessed level of storage within the consumptive pool.

As the triggers are applicable at the consumptive pool level, the level of storage for the individual lenses and brackish Quaternary Limestone areas from the 2012 data was required to be scaled up. As water level data for the brackish area is generally sparse or infrequent, it was considered that the lenses should be the source of the storage level for the consumptive pool. If only one lens was present for a particular consumptive pool, the level of storage for that lens was applied to the whole consumptive pool. If multiple lenses were present in a particular consumptive pool, the average of the storage level for the various lenses was used to determine the level of storage for the consumptive pool (Table 39).

Table 39. Process of up scaling the level of storage for each modelled area to the consumptive pool

PWA	Consumptive Pool	Modelled area(s) used to determine consumptive pool storage level
Southern Basins	Coffin Bay	Coffin Bay A lens
	Uley Wanilla Public Water Supply	Uley Wanilla lens
	Uley North	Average of Coffin Bay B and C and Uley East A and B lenses
	Uley South Public Water Supply	Uley South lens
	Lincoln South Public Water Supply	Average of Lincoln A, B and C lenses
Musgrave	Polda	Polda lens
	Bramfield	Average of Bramfield and Talia lenses
	Sheringa	Average of Sheringa A and B and Kappawanta lenses

The 2012 data sourced from wells listed in the Monitoring section (Section 4) of this report were modelled using Arc Hydro Groundwater to provide an assessment of the 2012 level of storage. Using these values, licensees allocations were able to be calculated for the 2012-13 water use year and compared with recent extraction and the existing licensed allocation for 2012-13 determined by the current WAP methodology.

The model indicated that allocations based on the proposed trigger methodology generally aligned well with the current 2012-13 allocations. Under the proposed mechanism for 2012-13, some licensees would have had slightly lower allocations (up to 8%), whilst some would have been entitled to slightly more water. Exceptions to this are the Polda and Sheringa consumptive pools where significant differences were observed. Within the Sheringa consumptive pool, the proposed triggers would result in licensees being allocated significantly less than they were actually allocated for 2012-13, due to the level of storage falling below the Mid Storage Trigger. The results also indicate the storage level for the Polda consumptive pool falls below the Lower Storage Trigger and consequently, allocations for 2012-13 for each licensee within the Polda consumptive pool would be required to reflect this if allocated under the proposed trigger mechanism.

3.5. EXCESS WATER

It is proposed that licensees be assigned a water access entitlement equal to the maximum volume of water allocated throughout the life of the existing WAP excluding any water approved under Section 128 of the *NRM Act 2004* or Section 13 of the *Water Resources Act 1997,* with the exception of Uley Wanilla Public Water Supply which would be limited to the volume of water available for licensed demand. When this allocated volume is compared with the total volume of water available for licensed demand, a resultant excess water volume may exist for each consumptive pool (Table 40). The excess water may be available for allocation, subject to the Minister’s discretion. It is proposed that aquifer tests and monitoring should be carried out prior to the allocation of the excess water to ensure that no adverse impacts will occur to existing users, the aquifer in question, adjacent aquifers or groundwater-dependent ecosystems.

Table 40. Excess water for each consumptive pool in the Southern Basins and Musgrave PWA

PWA	Consumptive Pool	Recharge Zone	Adopted recharge rate (mm)	Recharge area (km2)	Resource Capacity (ML)	Non-Consumptive Demand %	Water Available for Consumptive Demands (ML)	Non-Licensed Use Requirements: Domestic Demands (ML)	Non-Licensed Use Requirements: Stock Demands (ML)	Water Available for Licensed Requirements (ML)	Water Available for Licensed Requirements Consumptive Pool boundary(ML)	Water Access Entitlements (ML)	Water Access Entitlements Consumptive Pool Boundary (ML)	Excess Water (ML)
Southern Basins	Coffin Bay	Coffin Bay A lens	29	13.82	400.7	60	160.3	0.28	0	160.0	160.0	148.9	148.9	11.1
	Uley Wanilla Public Water Supply	Uley Wanilla lens	13	14.33	186.3	60	74.5	1.4	0	73.1	206.3	206.3	206.3	0
		Uley Wanilla brackish	13	25.61	332.9	60	133.2	0	0	133.2		0		
	Uley North	Coffin Bay B lens	6	0.42	2.5	50	1.3	0	0	1.3	694.1	0	238.7	455.4
		Coffin Bay C lens	9	5.47	49.2	50	24.6	0	0.43	24.2		0		
		Uley East A lens	22	5.48	120.5	50	60.2	0	3.31	56.9		8.1		
		Uley East B lens	22	2.42	53.2	50	26.6	0	0.07	26.5		188.2		
		Uley North brackish	13	92.97	1208.6	50	604.3	0.56	18.49	585.2		42.4		
	Uley South Public Water Supply	Uley South lens	129	65.42	8439.5	30	5907.6	0	1.02	5906.6	9907.0	7249.9	7249.9	2657.1
		Uley South brackish	129	43.06	5555.3	30	3888.7	0	1.41	3887.3		0		
		Uley South Tertiary Leakage	14	9.29	130.1	30	91.0	0	0	91.0		0		
		Pantania lens	13	0.38	4.9	30	3.4	0	0	3.4		0		
		Mikkira lens	13	2.13	27.6	30	19.3	0	0.71	18.6		0		
	Lincoln South Public Water Supply	Lincoln A lens	35	1.20	42.0	60	16.8	0	0.01	16.8	2125.0	0	928.6	1196.4
		Lincoln B lens	35	3.95	138.2	60	55.3	0	0	55.3		0		
		Lincoln C lens	35	7.92	277.4	60	110.9	0	0	110.9		0		
		Lincoln South brackish	35	138.92	4862.0	60	1944.8	1.4	1.41	1942.0		928.6		
	Lincoln North							3.36	30.95	53.9	53.9	53.9	53.9	0
	Unsaturated Quaternary Limestone							1.96	0	0	0	0	0	0
	Tertiary Sand							1.12	23.02	0	0	0	0	0
	Basement							0.28	23.02	100.2	100.2	100.2	100.2	0
Musgrave	Polda	Polda lens	15.8	37.21	587.9	60	235.2	0.84	3.6	230.7	1812.8	23.1	697.7	1115.1
		Polda East A lens	6.8	0.07	0.5	60	0.2	0	0	0.2		0		
		Polda East B lens	6.8	0.72	4.9	60	2.0	0	0	2.0		0		
		Polda brackish	14.1	273.84	3861.1	60	1544.5	1.68	23.34	1519.4		674.6		
		Tinline lens	17.5	3.13	54.7	60	21.9	0	0.03	21.8		0		
		Talia East lens	15.8	6.15	97.1	60	38.9	0	0.24	38.6		0		
	Bramfield	Bramfield lens	25	99.46	2486.4	60	994.6	7.56	9.57	977.4	4708.1	1201.4	1201.4	3506.7
		Bramfield brackish	14.1	639.93	9023.0	60	3609.2	13.44	134.41	3461.3		0		
		Talia lens	15.8	44.17	697.9	60	279.2	0.56	9.24	269.4		0		
	Sheringa	Sheringa A lens	16.3	36.23	590.5	60	236.2	0.28	0.88	235.1	3795.0	32.8	565.6	3229.4
		Sheringa B lens	15.8	38.99	616.0	60	246.4	0.28	0.58	245.5		0		
		Kappawanta lens	22	48.86	1074.8	60	429.9	0	0	429.9		532.8		
		Sheringa brackish	14.1	519.82	7329.4	60	2931.8	2.8	44.45	2884.5		0		
	Unsaturated Quaternary Limestone							5.6	0	0	0	0	0	0
	Tertiary Sand							1.12	62.27	0	0	0	0	0
	Polda Formation							0	0	0	0	0	0	0
	Basement							0	62.27	0	0	0	0	0

4. MONITORING

In order for the allocation variation methodology outlined previously to be successful, a select number of monitoring wells are required to be monitored annually in autumn (March, April or May) for water level. If these specific wells are not monitored, the change in storage from one year to the next may be biased by the monitoring locations rather than the condition of the resource.

The observation well number and spatial location of the Quaternary wells to be monitored annually in autumn have been provided for the Southern Basins PWA (Figure 38 and Table 41) and Musgrave PWA (Figure 39 and Table 42). These lists supersede those in Stewart, Alcoe and Risby (2012) as the modelling has now been fully developed and the list of wells required has therefore been updated.

Table 41. List of Quaternary Limestone aquifer autumn monitoring wells for the Southern Basins PWA

Observation Well Number	Easting	Northing	Observation Well Number	Easting	Northing
FLN8	579474.91	6145563.82	ULE145	552601.00	6149494.00
FLN25	580908.74	6144449.89	ULE166	558926.70	6154778.76
FLN29	581386.88	6143376.62	ULE171	556266.75	6162440.91
FLN35	579799.64	6144235.67	ULE172	558667.73	6156042.78
FLN42	581209.80	6138237.61	ULE179	562456.69	6165502.88
FLN56	578928.71	6143970.81	ULE182	563330.73	6157649.93
LKW37	544192.00	6167594.00	ULE183	561750.00	6159877.00
LKW38	544106.00	6167428.00	ULE184	551157.00	6153167.00
LKW39	544098.00	6167422.00	ULE185	551131.78	6153174.85
LKW43	543513.66	6167514.82	ULE186	551763.00	6153404.00
LNC8	568800.76	6148180.65	ULE187	551844.00	6152819.00
LNC15	569928.75	6147920.83	ULE188	551243.75	6152585.67
SLE30	569334.66	6144842.77	ULE189	553516.00	6152207.00
SLE35	571565.84	6146549.89	ULE190	551425.85	6152066.25
SLE37	572070.78	6146760.76	ULE191	551985.12	6152055.36
SLE41	572755.67	6145020.93	ULE192	551672.00	6151480.00
SLE47	568128.00	6147582.00	ULE193	551891.00	6150894.00
SLE52	569008.95	6147295.83	ULE194	547857.40	6151029.43
SLE68	571828.88	6147370.74	ULE196	551618.00	6149131.00
ULE7	556943.00	6163746.00	ULE197	552506.34	6152937.29
ULE34	558162.73	6166226.75	ULE200	558290.96	6165412.96
ULE36	557506.64	6166303.94	WNL3	557939.58	6169101.93
ULE77	550671.64	6161942.74	WNL35	553699.70	6169879.68
ULE86	560447.74	6157304.85	WNL43	558929.71	6170053.73
ULE99	549244.59	6151804.47	WNL44	560234.73	6168886.79
ULE101	549563.37	6150501.69	WNL45	561794.85	6168057.98
ULE102	549893.00	6149686.00	WNL46	558830.65	6169787.87
ULE114	550945.00	6151573.00	WNL47	557484.67	6170105.94
ULE134	550991.96	6148604.15	WNL48	557523.62	6170019.74
ULE139	553492.00	6151286.00			

Table 42. List of Quaternary Limestone aquifer autumn monitoring wells for the Musgrave PWA

Observation Well Number	Easting	Northing	Observation Well Number	Easting	Northing
HUD18	520082.49	6271194.12	SQR101	543117.00	6289799.00
KPW37	526164.78	6276147.34	SQR105	537482.80	6291748.41
KPW38	525953.64	6274663.97	SQR106	533128.66	6292171.03
KPW55	523400.56	6274832.28	SQR110	531228.55	6292471.16
KPW68	527406.54	6274828.14	SQR111	531628.65	6295621.05
KPW73	526028.74	6273671.11	SQR113	531428.68	6292921.10
PER1	540598.75	6254256.17	SQR114	535027.00	6292669.00
PER15	530227.68	6254336.21	SQR117	530994.82	6289309.34
PER30	534531.67	6254404.23	SQR118	530993.00	6289326.00
SQR2	531417.58	6292447.18	TAA5	512221.57	6293038.28
SQR3	531417.58	6292447.18	TAA29	503726.63	6302439.12
SQR8	531391.68	6290820.20	TAA57	509878.60	6289721.26
SQR9	530425.00	6291595.00	TAA58	502139.66	6287618.22
SQR10	530735.00	6293225.00	TAA59	502139.66	6287618.22
SQR21	536242.00	6290783.00	TAA61	502516.54	6284040.12
SQR28	532375.00	6291590.00	TIN20	524582.55	6291957.25
SQR30	530445.00	6292345.00	TIN41	524665.71	6290475.02
SQR31	530438.71	6290049.36	TIN42	525551.71	6289857.05
SQR37	540632.53	6290623.12	TIN61	520332.65	6291713.31
SQR74	532144.55	6299987.12	TIN79	526887.00	6297504.00
SQR75	532021.70	6298503.08	TIN96	527694.75	6292289.11
SQR77	534853.68	6299356.22	WAD17	501642.69	6275563.14
SQR79	537867.00	6299454.00	WAD31	499758.55	6279981.36
SQR85	534116.00	6297263.00	WAY9	507908.50	6260040.29
SQR86	533964.57	6296442.24	WAY15	524583.67	6260669.04
SQR88	533217.59	6297627.16	WAY31	517530.64	6253965.98
SQR95	531850.65	6293909.25	WAY55	512135.51	6256582.22
SQR97	531983.57	6291966.11	WAY56	520597.22	6258567.40
SQR100	532530.80	6294267.32			

In addition, it is recommended that throughout the life of the revised WAP, the current monitoring network is amended to undertake groundwater level and salinity monitoring in the Lincoln North consumptive pool region to better define this resource. Figure 40 and Table 43 outline the unit number and spatial location of the Quaternary wells suggested to be added to the current monitoring network. As these wells are all privately owned, landholder approval to monitor these wells will be required.

Table 43. List of Quaternary Limestone aquifer monitoring wells for the Lincoln North consumptive pool

Unit Number	Easting	Northing
6028-00132	571095	6161053
6028-00143	573108	6156575
6028-00198	572903	6159453
6028-02112	574298	6156700
6028-02202	570889	6160767

As there are already wells available which monitor the location of the salt water interface within the Uley South Public Water Supply consumptive pool (Figure 41 and Table 44), it is recommended that annual sonding of the long screened wells is undertaken for the life of the revised WAP. Additionally it is recommended that and annual salinity monitoring of the nested wells is carried out annually by pumping the wells as bailing is not a sufficient method by which to monitor salinity in these systems. It is proposed that the identification of a change in the location of the interface triggers an investigation into the cause of the variation and prompts the implementation of relevant management options.

Table 44. List of salt water interface monitoring wells within the Uley South Public Water Supply consumptive pool

Observation Well Number	Easting	Northing	Comments
ULE156	550516	6147404	Drilled into Tertiary
ULE209	550522	6147398	Drilled into Quaternary
ULE205	549935	6147386	Long screened well suitable for sonding
SLE69	551460	6145299	Long screened well suitable for sonding

It is strongly suggested that the relationship between groundwater extraction, recharge, groundwater levels, storage, GDE health and groundwater salinity be closely analysed and monitored over the life of the revised WAP, with a view to refining the consumptive pool volumes and proposed triggers in the future.

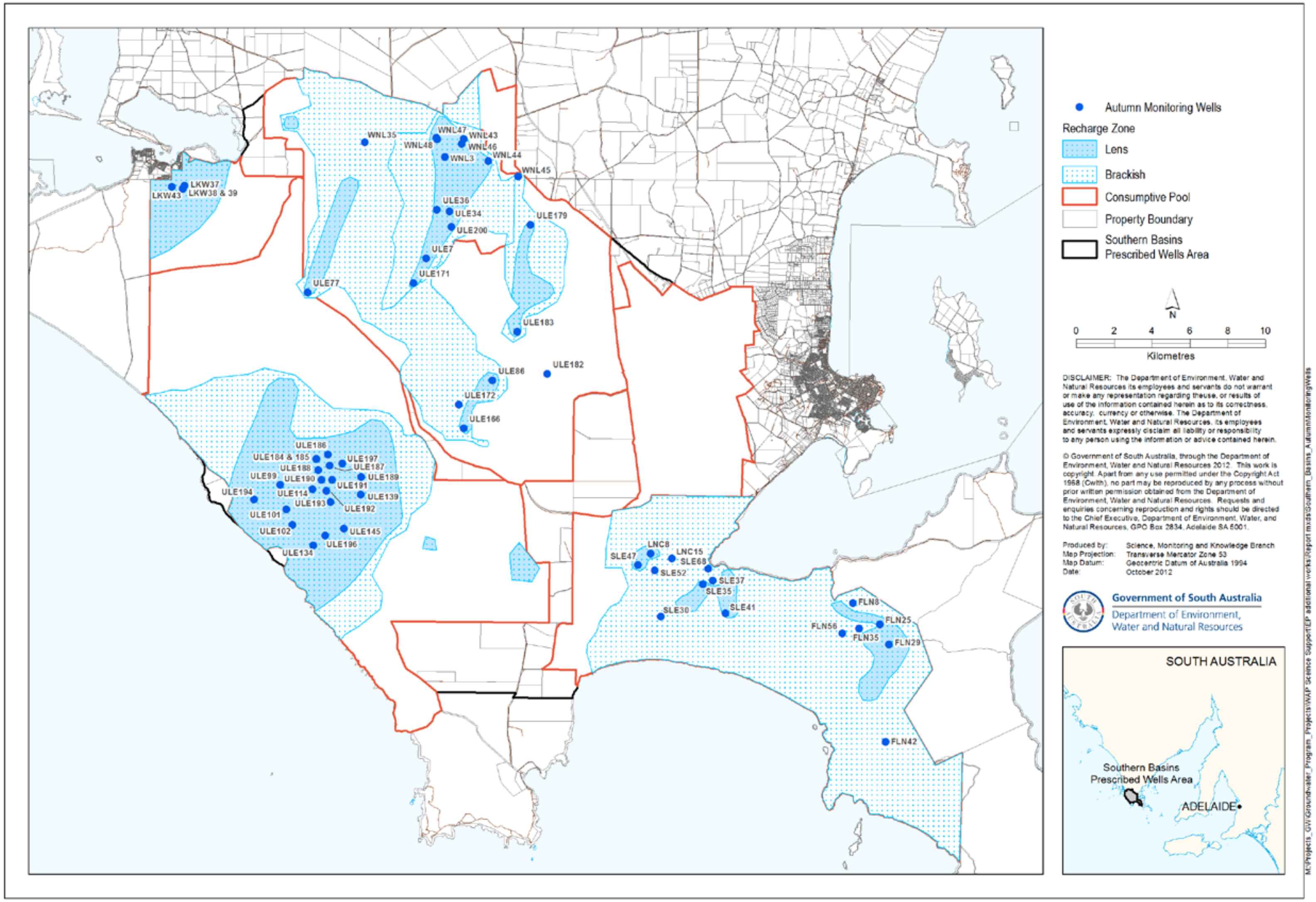

Figure 38. Location of Quaternary Limestone aquifer autumn monitoring wells for the Southern Basins PWA

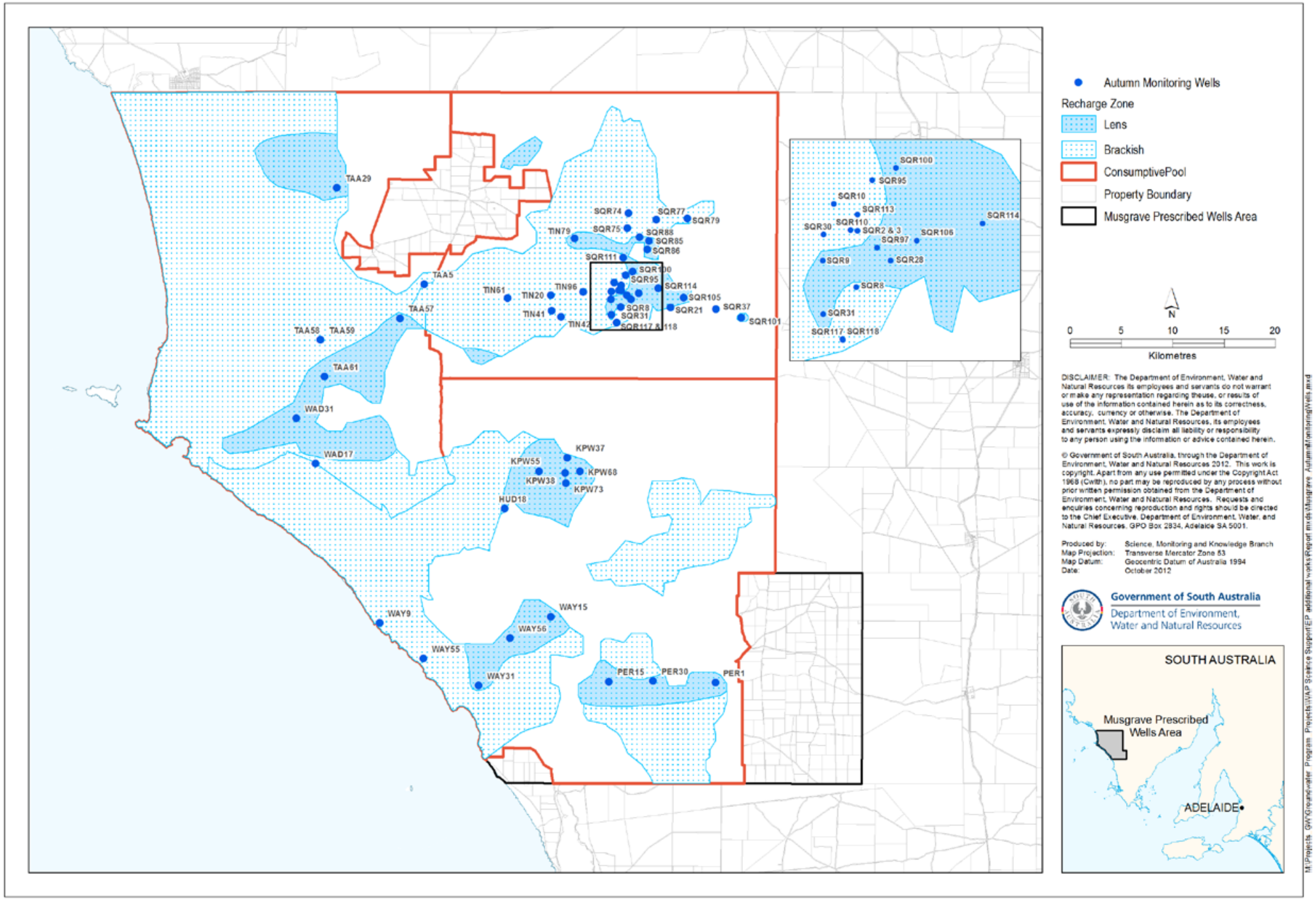

Figure 39. Location of Quaternary Limestone aquifer autumn monitoring wells for the Musgrave PWA

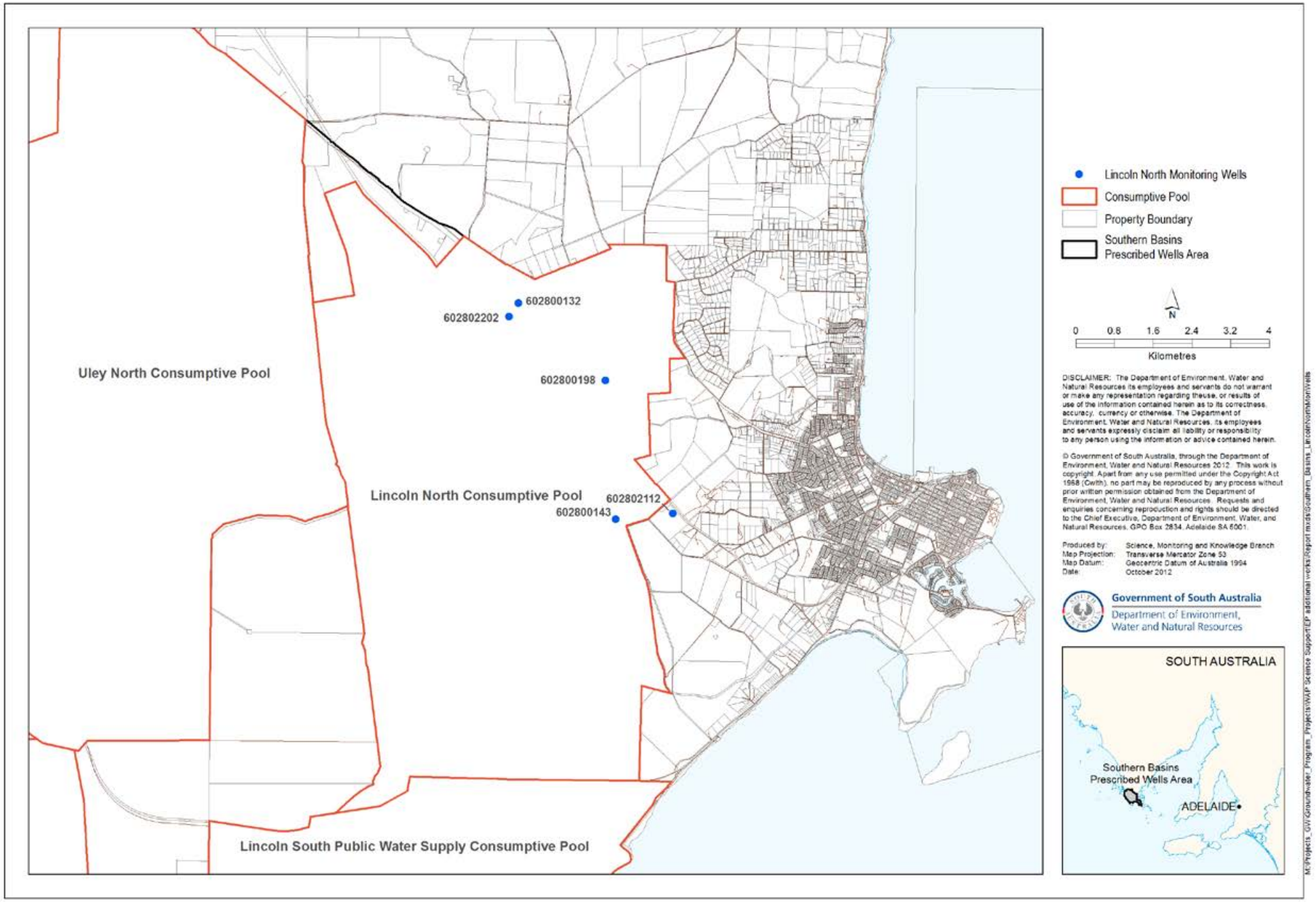

Figure 40. Location of Quaternary monitoring wells for the Lincoln North consumptive pool

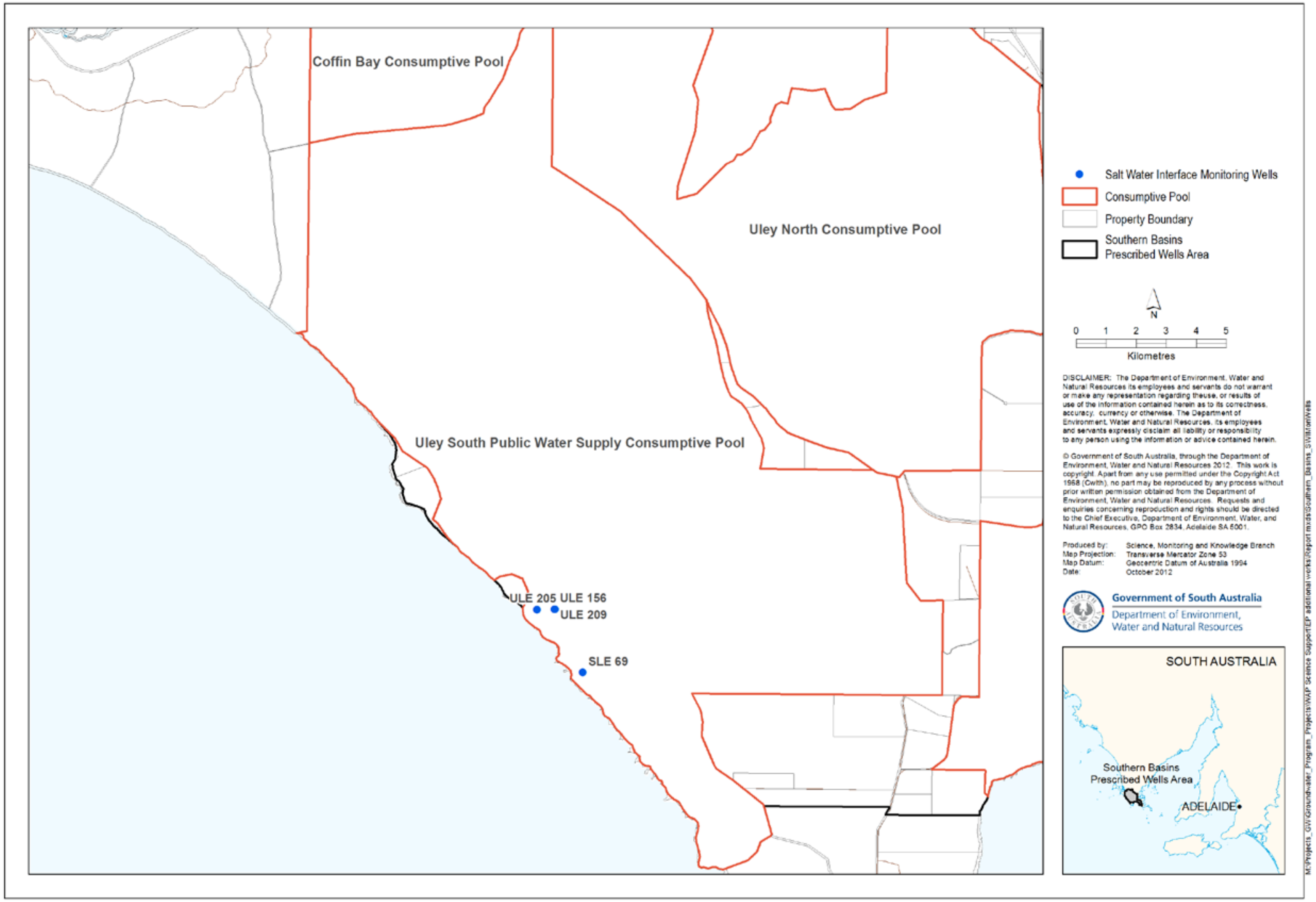

Figure 41. Location of salt water interface monitoring wells within the Uley South Public Water Supply consumptive pool

APPENDIX

METHODOLOGY FOR CALCULATING STOCK WATER REQUIREMENTS

1. Add PIMMS data to GIS
2. Remove all data that relates to oceanographic stock
3. Check data with species identified as ‘Any’ remove oceanographic ones
4. Remove doubles of stock that are used for multiple purposes (e.g. meat and wool)
5. Remove PICs which do not land at all within the PWAs. Some PICs include parcels both inside and outside the PWAs – keep these
6. Clip PIMMS parcels to PWA but retain full parcel area and add a column to calculate new parcel area therefore working out the area of the PIMMS parcel that resides within the PWA
7. Create spreadsheet with PIC number, area of whole PIC license, area in PWA, conversion factor (ratio of total area of PIC to area of PIC in the PWA) and number of animals in the whole PIC and then using the conversion factor the number of animals for that PIC in the PWA
8. Then use the Clip of the PIIMS data and clip that to the different recharge zones and create a table as outlined in step 6. This will result in a number of stock per recharge zone
9. Using the DSE conversion factors, convert all stock for each lens into DSE
10. Multiply the DSE by the water use conversion of 7.14L/day
11. Consider that all PIIMS parcels which overly the unsaturated Quaternary Limestone are accessing water from the Tertiary or Basement and apportion 50% of this to the Tertiary and 50% of this to the basement

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