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Sustainable Extraction Limits Derived from the Recharge Risk Assessment Method – South Australia

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Report to Murray-Darling Basin Authority

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Description: Windmill pumping water from the River Murray near Purnong, SA. September 2007

Photographer: Greg Rinder

Acknowledgments

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Abbreviations

CSIRO	Commonwealth Scientific and Industrial Research Organisation
DWLBC	Department of Water, Land and Biodiversity Conservation
GL	Gigalitre
GS1*	Groundwater SDL area 1
km^2	kilometres squared
m	metres
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
mg/L	Milligrams per Litre
mm	Millimetres
N/A	Not Applicable
PWA	Prescribed Wells Area
RRAM	Recharge Risk Assessment Method
SA	South Australia
SDL	Sustainable Diversion Limit
SF	Sustainability Factor
SKM	Sinclair Knight Merz
TDS	Total Dissolved Solids
WAVES	Water Atmosphere Vegetation Energy Soil

*The number at the end of the GS code is unique for each groundwater SDL area

Executive Summary

The Murray-Darling Basin Authority has responsibility for development of the Basin Plan for the Murray-Darling Basin (MDB) as specified under the *Water Act 2007*. The Basin Plan must include a number of mandatory conditions, including the development of a sustainable diversion limit (SDL) for the MDB's water resources. SDLs must encompass both surface water and groundwater. The SDL will limit the take of water for consumptive uses and is expressed as a volume.

The Recharge Risk Assessment Method (RRAM) was developed to derive preliminary SDLs to inform the Basin Plan development process.

The RRAM is based on the requirements of the *Water Act 2007* and the expectation that SDLs will reflect an environmentally sustainable level of take. According to the RRAM, the level of take must not compromise the following characteristics of the resource; key environmental assets, key ecosystem functions, the productive base and key environmental outcomes. In general terms, the RRAM is based on setting an extraction limit by applying a sustainability factor to groundwater recharge. For more information regarding the methodology, refer to CSIRO (2010).

In summary, for South Australia, the preliminary RRAM derived extraction limits that were calculated to inform the Basin Plan included:

- extraction limits that are greater than the volume of current groundwater use and therefore there is a volume of unassigned water associated with such units (i.e. the SA Murray SDL area) and
- extraction limits that were set to equal the Plan Limit for that area (i.e. the Marne Saunders SDL area).

1 Sustainable extraction limits derived from the RRAM – South Australia

1.1 Angas Bremer (GS1)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the recharge risk assessment method (RRAM) for the Angas Bremer sustainable diversion limit (SDL) area.

1.1.1 Background

The Angas Bremer SDL area sits in the west of the Murray Basin, on a natural floodplain between the Eastern Mount Lofty Ranges and Lake Alexandrina.

The SDL area contains uppermost Quaternary and Tertiary sediments underlain by the Pre-Cambrian basement rock of the Kanmantoo Group (Cresswell & Herczeg, 2004). There are two main aquifers in the SDL area. The Quaternary sediments comprise 10-35 m of sands, silts and clays which contain discontinuous and inter-lensing aquifers (Cresswell & Herczeg, 2004), which are confined in some areas and unconfined in others (Zulfic & Barnett, 2007). Groundwater resources are mostly contained within the Murray Group Limestone aquifer, of the Tertiary sediments; a semi-confined aquifer, up to 100 m thick which varies in character between clayey soft limestone, a hard sandy limestone and soft bryozoal limestone (Cresswell & Herczeg, 2004).

The Tertiary aquifer is the most extensively used in the area, with extractions generally concentrated around the Angas and Bremer Rivers where salinity ranges from 1,500 to 3,000 mg/L. Salinities as high as 10,000 mg/L have been recorded towards the margins of the SDL area. The superficial aquifer typically has poor water quality (ranging from approximately 1,000 to 80,000 mg/L), lower yields and hence limited use.

The aquifers extend from the plains in the south of the SDL area to the margin joining Kanmantoo Group aquifer and Murray Group Limestone aquifer. This interface defines the northern boundary of the sedimentary basin (AWE, 2005). The topographic orientation of the Murray Group Limestone aquifer makes it artesian in the south of the area. The 2007/2008 use is 6.6 GL/year (Table 1). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 1 Groundwater Take Summary for the Angas Bremer SDL area

Angas Bremer SDL area	GL/year*
Total 2007/2008 Entitlement	6.3
2007/2008 Metered and Estimated Use for Entitlement Bores	6.5
2007/2008 Estimated Use for Stock & Domestic Bores	0.05
Total 2007/2008 Use	6.6

*Entitlement and use information was provided by DWLBC

1.1.2 Salinity zoning

Groundwater of the Murray Group Limestone within the Angas Bremer SDL area has been characterised by two salinity zones (Figure 1 and Table 2).

There is a lack of salinity data on the edges of the area (shown in white in Figure 1), which have been incorporated into the most appropriate (adjacent) salinity zone (approximately 50 percent in zone 2 and 50 percent in zone 3).

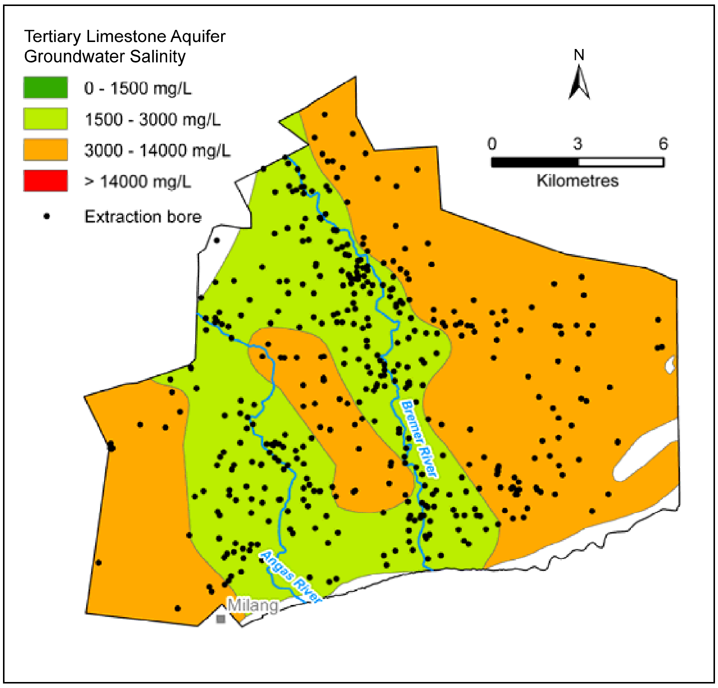

Figure 1. Angas Bremer Murray Group Limestone aquifer salinity distribution, from the Murray Group Limestone salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 2. Summary of salinity zones in the Angas Bremer Murray Group Limestone aquifer

Murray Group Limestone salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	N/A	N/A
Zone 2 (1500–3000 mg/L TDS)	41	102
Zone 3 (3000–14,000 mg/L TDS)	59	147
Zone 4 (>14,000 mg/L TDS)	N/A	N/A
Total	**100**	**249**

1.1.3 Key environmental assets

There are no known groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Angas Bremer SDL area.

1.1.4 Key ecosystem function

The Angas and Bremer rivers reaches and their tributaries are generally considered to be unregulated. The SDL area includes only the lowland reaches of Angas and Bremer catchments, which are ephemeral in nature, with flow dependent on rainfall events. When the Angas and Bremer rivers cross the plains, they are thought to change from gaining to losing systems; recharging the underlying Quaternary aquifers (and not the deeper Murray Group Limestone aquifer), with depths to watertable near the rivers ranging from 2 to >6 m below ground surface.

Groundwater pumping is unlikely to impact upon the hydrological function of the river reaches because extraction is from the deeper confined Murray Group Limestone aquifer. Ecosystem function is therefore considered to be low risk for the Angas Bremer SDL area.

1.1.5 Productive base

Recharge

Groundwater recharge to the aquifers of the Angas Bremer SDL area has been investigated on a number of occasions over the years and has resulted in different interpretations of the dominant recharge mechanisms to the Murray Group Limestone aquifer. The findings of some of these studies have been summarised below.

Australian Water Environments (2000) indicated that the main source of recharge to the Murray Group Limestone aquifer was lateral recharge at the north-western boundary with the Mount Lofty Ranges.

REM (2008) developed a numerical model of the area and had a similar conceptualisation to that of AWE (2000) with a dominant recharge mechanism of lateral inflow from the adjacent eastern Mount Lofty Ranges fractured rock. Recharge via leakage through the Angas and Bremer River beds was also recognised as an important recharge process. The REM (2008) report included hydrographs of nested observation bores that monitor the Quaternary and Murray Group Limestone aquifers and indicated almost identical response to rainfall and pumping, which supports the inference that the confining bed is very leaky or absent in some places. REM (2008) concluded that under 7 GL/year of extraction the aquifer pressures equilibrate; however, some of the resource continues to be salinised.

Cresswell and Gibson (2004) investigated the area using airborne geophysical techniques and concluded that the major recharge process to the Murray Group Limestone aquifer is vertical leakage from the overlying Quaternary aquifer and that this recharge occurs on a time-scale of thousands of years.

Zulfic and Barnett (2007) developed the groundwater status report for the Angus Bremer Prescribed Wells Area (PWA) and agreed with the findings of Cresswell and Gibson (2004) (and also Cresswell and Herczeg (2004)) that current lateral groundwater flow from the ranges is not a significant contributor to recharge to the Murray Group Limestone aquifer. Zulfic and Barnett's interpretation of the groundwater system also supports a primary groundwater recharge mechanism of slow downward leakage from the Quaternary aquifer across the aquitard, to the Murray Group Limestone aquifer within a time-scale of a few hundred to a few thousand years.

Recharge to the Murray Group Limestone aquifer is also augmented via injection of low salinity water such as lake water, or imported water from outside the PWA. Injection of supplies of surface water from the Angas and Bremer Rivers also occurs when there is flow. This Aquifer Storage and Recovery (ASR) scheme started in the early 1980s. The amount of surface water injected into the confined Murray Group Limestone aquifer every year varies significantly, depending on the availability of surface water with salinities less than 1500 mg/L. Between 1983 and 2006 the annual volume of injected water ranged from 0.036 GL to 2.4 GL and averaged 0.47 GL (Zulfic and Barnett, 2007).

The DWLBC's current understanding of the resource is consistent with that of Zulfic and Barnett (2007) and hence natural (i.e. not considering ASR derived) recharge to the Murray Group Limestone aquifer is considered to be negligible in the Angas Bremer SDL area.

Storage relative to recharge

As recharge to the main aquifer in the Angas Bremer SDL area is considered to be zero, there is a very low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.1.6 The risk matrix

Table 3 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that there are unregulated river reaches in this unit
- the SDL area is ranked low risk in terms of the productive base
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)

- there is a low uncertainty associated with this SDL area, given that groundwater recharge has been well investigated and documented.

Table 3. Risk matrix

<table>
<tr><th>Risk ranking</th><th>Environmental assets (EAs)</th><th>OR</th><th>Ecosystem function</th><th>OR</th><th>Productive base</th><th>Sustainability factor (SF)</th><th>Key environmental outcome</th><th>Degree of uncertainty</th></tr>
<tr><td>High</td><td>EA that is highly groundwater dependent and highly sensitive to take</td><td rowspan="3"></td><td>In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion</td><td rowspan="3"></td><td>Storage/ recharge <20</td><td>0.10</td><td rowspan="3">Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes

Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made:

Salinity class 1: reduce SF by 20%

Salinity class 2: reduce SF by 10%

Salinity classes 3 & 4: no reduction</td><td rowspan="2">Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%</td></tr>
<tr><td>Medium</td><td>EA that is highly groundwater dependent and is moderately sensitive to take

EA that is moderately groundwater dependent and is highly sensitive to take</td><td>The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge 20–40</td><td>0.50</td></tr>
<tr><td>Low</td><td>EA that has a low groundwater dependence and low sensitivity to take

EAs do not exist in the SDL area</td><td>The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge >40</td><td>0.70</td><td>Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%</td></tr>
</table>

1.1.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Angas Bremer SDL area is 0 GL/year. This reflects the confined nature of the productive aquifer in this unit and the slow rate of leakage from the (often more saline) overlying aquifer.

This preliminary extraction limit has been superseded by an extraction limit of 4 GL/year, which was based on advice from local experts in the area and a final decision made by the Murray-Darling Basin Authority.

1.2 SA Murray Salt Interception Schemes (GS8)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the SA Murray Salt Interception Schemes SDL area.

1.2.1 Background

The SA Murray Salt Interception Schemes SDL area incorporates the River Murray floodplain and adjacent areas extending from the South Australian/Victorian border to the east of Morgan.

The Monoman Formation (or Channel Sands) lies beneath the floodplain and is predominantly re-worked sediments of the Loxton-Parilla Sands that the river has incised over time. The Monoman Formation consists of fine to coarse-grained, fluvial sands that are hydraulically connected to the regional groundwater flow system.

In the eastern half of the area, the watertable is located within the Loxton-Parilla Sands aquifer, which is separated from the underlying confined Murray Group Limestone aquifer by the poorly consolidated plastic silts and shelly clays of the Bookpurnong Beds. The Loxton-Parilla Sands aquifer is variable in consistency with coarser sands in the upper sequence, and finer sediments with increasing depth. Thickness varies from approximately 30 to 100 m. Moving west, the Bookpurnong Beds pinch out completely, leaving Murray Group Limestone hydraulically connected to the overlying sand aquifers. In the west of the region west of Loxton, the watertable is mostly contained within the Murray Group Limestone.

The unit currently includes several salt interception schemes, with an annual groundwater extraction volume (in 2007/2008) of approximately 11 GL/year (MDBC, 2008). The majority of groundwater in the area is hyper saline and hence unusable.

1.2.2 Salinity zoning

Groundwater of the watertable aquifer within the SA Murray Salt Interception Schemes SDL area has been characterised by three salinity zones (Figure 2 and Table 4).

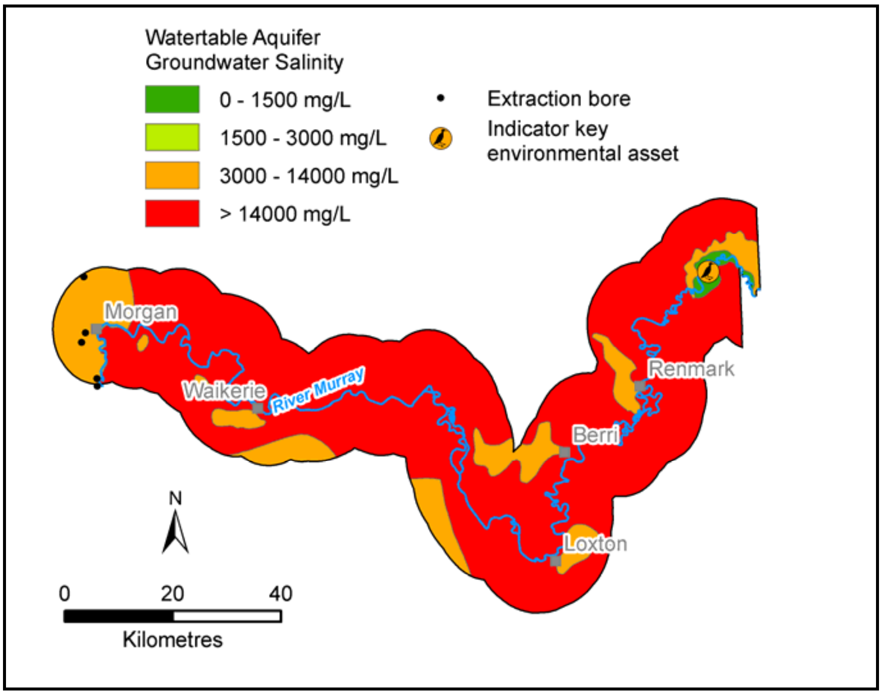

Figure 2. SA Murray Salt Interception Schemes watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 4. Summary of salinity zones in the SA Murray Salt Interception Schemes SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	1	42
Zone 2 (1500–3000 mg/L TDS)	N/A	N/A
Zone 3 (3000–14,000 mg/L TDS)	16	643
Zone 4 (>14,000 mg/L TDS)	83	3307
Total	**100**	**3993**

1.2.3 Key environmental assets

The *Water Act 2007* requires that assessment of environmental water needs of the Murray-Darling Basin (MDB) must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 key environmental asset–hydrologic indicator sites that drive the environmental hydrology of the MDB (MDBA, 2010). These 18 hydrologic indicator sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the MDB.

The SA Murray Salt Interception Schemes SDL area encompasses the Riverland-Chowilla Floodplain, which is one of the 18 key environmental asset–hydrologic indicator sites identified by the Murray-Darling Basin Authority. This key environmental asset is not considered to be adversely impacted by groundwater extraction from current salt interception schemes.

1.2.4 Key ecosystem function

There are no unregulated rivers in the SA Murray Salt Interception Schemes SDL area. The River Murray in this region is known to be highly connected to the Monoman Sands and therefore the regional watertable aquifer of the Loxton-Parilla Sands and the Murray Group Limestone. The River Murray receives significant inflows from the groundwater system, resulting in high salinity groundwater increasing the salinity of the River Murray itself. The salt interception schemes were put in place as a means of controlling this influx and have succeeded in reducing local groundwater-derived salt loads where they occur (MDBC, 2008).

The only groundwater extraction in the SDL area is that of the salt interception schemes, which are in place to locally reduce the influx of saline groundwater to the River Murray and hence have positive impact on ecosystem function. For this reason the SDL area is ranked low in terms of impact on ecosystem function.

1.2.5 Productive base

Recharge

Recharge in the SA Murray Salt Interception Schemes SDL area occurs via infiltration of rainfall and downward percolation of irrigation water. Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie and McCallum, 2009) has been used to calculate recharge to the unconfined aquifer. The historical climate scenario for a median 15-year period results in recharge rates ranging from 0.043 mm/year to 34 mm/year and equates to a total recharge rate of 40 GL/year (Table 5).

Approximately 460 km^2 of the Murray Salt Interception Schemes SDL area is irrigated and although it is recognised that surface water derived irrigation accessions are a significant input to groundwater recharge in this unit, the information was not available to account for it in this assessment.

-

Table 5. Recharge calculation for the SA Murray Salt Interception Schemes SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	42	N/A	643	3307
Diffuse recharge (mm/yr)	1.0	N/A	10	10
Total recharge (GL/yr)	**0.043**	**N/A**	**6.5**	**34**

Storage

Aquifer storage has not been calculated in order to indicate how much groundwater can be extracted from the aquifer. It has been calculated such that a comparison between the volume of water held in the aquifer and the annual volume of groundwater recharge can be made. This comparison will indicate how vulnerable the aquifer is to climate change and in particular to a reduction in rainfall recharge. For this reason the storage volume of all aquifers has been calculated as the product of aquifer area, saturated aquifer thickness and specific yield. This approach is used for confined aquifers as well as unconfined aquifers as the volume of water stored in a confined aquifer that is drained under gravity in most cases far exceeds that released due to expansion of water as the aquifer is depressurised.

A specific yield of 0.15 was adopted for the unconfined aquifer, which has been used to calculate storage volume. The saturated thickness of the unconfined aquifer varies across the area. In the eastern section of the SDL area where the watertable is found within the Pliocene Sands, the average thickness has been estimated to range from a few metres to around 50 m. Where the watertable lies within the Murray Group Limestone the saturated thickness ranges between 50 and 100 m.

A value of 50 m has been adopted in the storage calculations (Table 6).

Table 6. Storage calculation for the SA Murray Salt Interception Schemes SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	42	N/A	643	3,307
Saturated thickness (m)	50	N/A	50	50
Specific yield	0.15	N/A	0.15	0.15
Total storage (GL)	**315**	**N/A**	**4,823**	**24,803**

Storage relative to recharge

The ratio of storage to recharge for the SA Murray Salt Interception Schemes SDL area ranges from 730 to 7,326 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.2.6 The risk matrix

Table 7 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that unregulated river reaches do not exist in this unit
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a no risk to the key environmental outcomes (i.e. groundwater salinity)
- there is a low level of uncertainty given that models were used to design the salt interception schemes.

Table 7. Risk matrix

<table>
<tr><th>Risk ranking</th><th>Environmental assets (EAs)</th><th>OR</th><th>Ecosystem function</th><th>OR</th><th>Productive base</th><th>Sustainability factor (SF)</th><th>Key environmental outcome</th><th>Degree of uncertainty</th></tr>
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Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%</td></tr>
<tr><td>Medium</td><td>EA that is highly groundwater dependent and is moderately sensitive to take

EA that is moderately groundwater dependent and is highly sensitive to take</td><td>The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge 20–40</td><td>0.50</td></tr>
<tr><td>Low</td><td>EA that has a low groundwater dependence and low sensitivity to take

EAs do not exist in the SDL area</td><td>The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge >40</td><td>0.70</td><td>Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%</td></tr>
</table>

1.2.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the SA Murray Salt Interception Schemes SDL area is 29 GL/year (Table 8). This is greater than the estimated salt interception scheme extraction (11 GL/year).

Groundwater extraction estimates for the South Australian salt interception schemes predict significant increases in the next few decades (approximately 20 GL/year by 2015 and approximately 23 GL/year by 2050 (P Pfeiffer, 2008, pers. comm.). The beneficial outcomes associated with salt interception schemes means it is advantageous to set an extraction volume to account for the long-term requirements of the current and proposed salt interception schemes.

Table 8. Preliminary extraction limit summary for the SA Murray Salt Interception Schemes SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	0.043	N/A	6.5	34
Sustainability factor	0.70	N/A	0.70	0.70
Extraction limit (GL/yr)	**0.030**	**N/A**	**4.6**	**24**

1.3 Eastern Mount Lofty Ranges (GS2)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Eastern Mount Lofty Ranges SDL area.

1.3.1 Background

The Eastern Mount Lofty Ranges SDL area is the most westerly unit in the Murray Basin, forming part of the central portion of the Adelaide Geosyncline.

The SDL area generally contains two topographical regions: the highland (hills) region, associated with the fractured basement outcrops of the Adelaide Geosyncline, and the lowland (plains) region of the Murray Basin. The Fractured Rock in the hills region consists of rocks of a number of different geological units including the Barossa Complex, Kanmantoo Group, Normanville Group and Adelaidean Sedimentary Rocks, which form the Fractured Rock aquifer of the area. The plains region, which makes up a relatively small portion of the SDL area, is underlain by unconsolidated sediments which form the sedimentary aquifers of the Murray Basin. These include the Murray Group Limestone and Quaternary Sediments.

On the plains, the Quaternary sediments contain discontinuous, inter-lensing aquifers, which are separated from the underlying Murray Group Limestone aquifer by a confining layer of silt and clay. Groundwater resources of the Eastern Mount Lofty Ranges SDL area are mostly contained within Fractured Rock aquifer (the Adelaidian and Normanville Groups containing the most important), with shallow alluvial aquifers in the valley bottoms (Green and Stewart, 2008). The Fractured Rock aquifer is the most developed aquifer in the SDL area, with 2007/2008 use at 20 GL/year (Table 9). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 9. Groundwater take summary for the Eastern Mount Lofty Ranges SDL area

Eastern Mount Lofty Ranges SDL area	GL/yr*
Total 2007/2008 entitlement	**N/A**
2007/2008 metered use for entitlement bores	0.0
2007/2008 estimated use for entitlement bores	19
2007/2008 estimated use for stock and domestic bores	0.74
Total 2007/2008 use	**19**

*Entitlement and use information was provided by DWLBC. Entitlement volumes were not available at the time of reporting.

1.3.2 Salinity zoning

Groundwater of the Fractured Rock aquifer within the Eastern Mount Lofty Ranges SDL area has been characterised by four salinity zones (Figure 3 and Table 10).

There is a lack of salinity coverage along the western side and a small area in the north-eastern corner of the SDL area (shown in white in Figure 3). In the absence of other groundwater salinity information, the groundwater in these areas has been assigned to the most appropriate salinity zone – the western section added to zone 2, and the small area incorporated into zone 3.

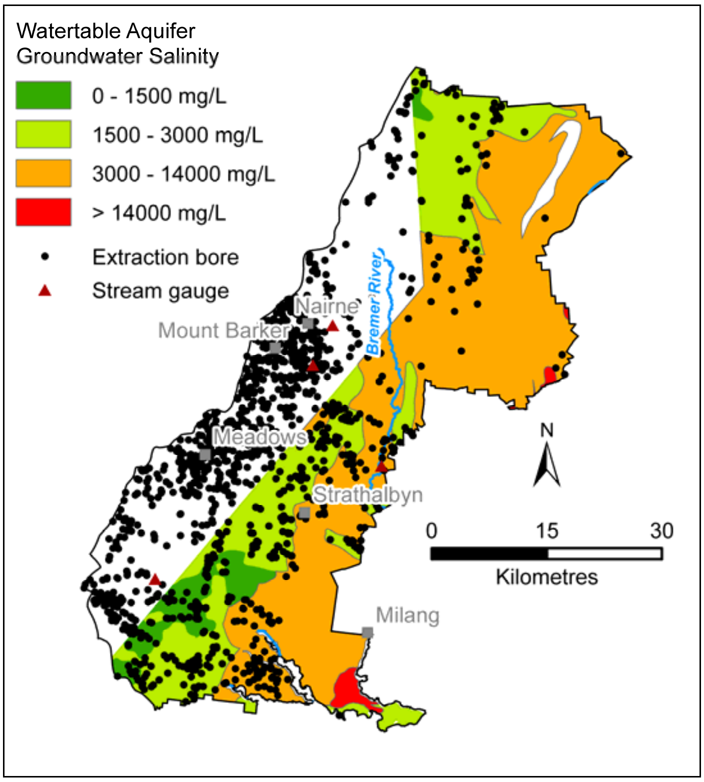

Figure 3. Eastern Mount Lofty Ranges watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 10. Summary of salinity zones in the Eastern Mount Lofty Ranges SDL area

Watertable salinity zone	Portion of total area	Total area	Area of Fractured Rock aquifer
	percent	km^2	km^2
Zone 1 (0–1500 mg/L TDS)	4	105	81
Zone 2 (1500–3000 mg/L TDS)	56	1447	1266
Zone 3 (3000–14,000 mg/L TDS)	39	1018	484
Zone 4 (>14,000 mg/L TDS)	1	22	15
Total	**100**	**2592**	**1846**

1.3.3 Key environmental assets

There are no groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Eastern Mount Lofty Ranges SDL area.

1.3.4 Key ecosystem function

In the hills region the watertable aquifer lies in the fractured rock and moves from the higher points in the landscape to the lowest, where discharge to streams provides baseflow which dominates flow for most of the year. Groundwater–surface water interactions have been shown to occur mostly in the upper reaches of the stream catchments, particularly in the upper Angas Bremer, the south-western Finniss River Catchment and Northern Tookayerta Creek Catchment (Green and Stewart, 2008). Permanent pools are also present in the SDL area, which are maintained by groundwater inflows (CSIRO, 2007). Investigations into the connectivity of streams to the groundwater system have acknowledged that there may be reaches that interact with groundwater which have not been identified (Green and Stewart, 2008).

The connected nature of the streams within the Fractured Rock aquifer in the Eastern Mount Lofty Ranges SDL area means that groundwater extraction could potentially impact on the river system. The SDL area is therefore considered high risk in terms of key ecosystem function as unregulated rivers exist.

1.3.5 Productive base

Recharge

Recharge to these aquifers occurs directly from rainfall where a proportion of rainfall percolates down to the watertable through the soil profile. Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie and McCallum, 2009) has been used to calculate recharge to the unconfined area. The historical climate scenario for a medium 15-year period results in a recharge rate of 125 mm/year for salinity zone 1, 114 mm/year for zone 2, 39 mm/year for zone 3 and 32 mm/year for zone 4. This results in a total recharge of 174 GL/year across the Fractured Rock aquifer within the SDL area (Table 11).

Table 11. Recharge calculation for the Eastern Mount Lofty Ranges SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	81	1266	484	15
Diffuse recharge (mm/yr)	125	114	39	32
Total recharge (GL/yr)	**10**	**145**	**19**	**0.48**

Storage

The storage parameters used in the calculation for the Fractured Rock aquifer include a specific yield of 0.1 and saturated depth of 100 m (as used elsewhere in the Murray Basin; R Evans, 2010, pers. comm.) (Table 12).

Table 12. Storage calculation for the Eastern Mount Lofty Ranges SDL area – Fractured Rock Aquifer

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	81	1,266	484	15
Saturated thickness (m)	100	100	100	100
Specific yield	0.1	0.1	0.1	0.1
Total storage (GL)	**807**	**12,663**	**4,839**	**154**

Storage relative to recharge

The ratio of storage to recharge for the Eastern Mount Lofty Ranges SDL area ranges from 81 to 321 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.3.6 The risk matrix

Table 13 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked high risk in terms of ecosystem function, given that there are unregulated river reaches in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with this SDL area, given that extensive research into the contribution of baseflow and the impacts of pumping on water-dependent ecosystems in the Eastern Mount Lofty Ranges SDL area has been undertaken (e.g. Banks et al., 2007; Green and Stewart, 2008).

Table 13. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.3.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Easter Mount Lofty Ranges SDL area is 16 GL/year (Table 14). The key ecosystem function component of the assessment has a considerable impact on the extraction limit (currently assumed to be at high level of risk due to the presence of unregulated rivers). The South Australian Government is currently developing planning arrangements for this SDL area which will seek to preserve baseflow and groundwater throughflow to protect ecosystem function. It is expected that the State planning arrangements will also include local management rules that seek to provide additional protection to key ecosystem function through the use of buffer zones around streams, thereby limiting the volume of extraction near a stream.

Given the existence of local management rules it is possible to lower the risk ranking associated with the key ecosystem function from high to medium. This would result in an extraction limit equivalent to 79 GL/year (Table 15).

A draft Eastern Mount Lofty Ranges Plan exists and is expected to be adopted by the end of 2010. The extraction limit defined in the plan is 33 GL/year (including stock and domestic use).

This RRAM extraction limit has been superseded by the plan limit, given that the plan limit represents the best available knowledge and that the plan limit will define planned environmental water (which cannot be reduced).

Table 14. Preliminary extraction limit summary for the Eastern Mount Lofty Ranges SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	10	145	19	0.48
Sustainability factor	0.08	0.09	0.10	0.10
Extraction limit (GL/yr)	**0.81**	**13**	**1.9**	**0.05**

Table 15. Preliminary extraction limit summary for the Eastern Mount Lofty Ranges SDL area – with local management rules

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	10	145	19	0.48
Sustainability factor	0.40	0.45	0.50	0.50
Extraction limit (GL/yr)	**4.0**	**65**	**9.4**	**0.24**

1.4 Mallee (GS3)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Mallee SDL area.

1.4.1 Background

The Mallee SDL area is located in the south-eastern area of the Murray Basin, in South Australia.

There are five main hydrogeological units in the Mallee SDL area, including aquifers and confining layers (Barnett and Osei-bonsu, 2006). The uppermost Pliocene Sands aquifer, consisting of weakly cemented fine to coarse sand, is approximately 0 to 15 m thick and is absent in the west of the Mallee (Barnett, 2006). The layer is underlain by the Bookpurnong Beds, which is only present across the eastern portion of the SDL area and decreases in thickness from up to 30 m near the eastern boundary and pinching out between Geranium and Lameroo. The layer consists of plastic silts, clays and sands and acts as a confining layer to underlying Murray Group Limestone, where it exists.

The Murray Group Limestone aquifer contains consolidated, highly fossiliferous, fine to coarse bioclastic limestone, with an average thickness of 100 m (Barnett and Osei-bonsu, 2006). The aquifer is confined across the majority of the area, but unconfined in the west where the Bookpurnong Beds pinch out and the watertable is continuous between the Murray Group Limestone and the Pliocene Sands aquifers.

Beneath the Murray Group Limestone lies the confining Ettrick Formation, which consists of glauconitic and fossiliferous marl with a typical thickness of 15 m and separates the upper aquifers from the Renmark Group; an unconsolidated carbonaceous sands, silt and clay layer of approximately 150 m in thickness (Barnett and Osei-bonsu, 2006).

The Murray Group Limestone aquifer is the most highly developed aquifer in the SDL area, due to the higher quality and quantities of extractable groundwater, and will therefore be the focus of this assessment. Total 2007/2008 usage is 24 GL/year (Table 16) and is used mainly for irrigation in the east of the region. For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 16. Groundwater take summary for the Mallee SDL area

Mallee SDL area	GL/yr*
Total 2007/2008 entitlement	**41**
2007/2008 metered use for entitlement bores	14
2007/2008 estimated use for entitlement bores	8.5
2007/2008 estimated use for stock and domestic bores	1.9
Total 2007/2008 use	**24**

*Entitlement and use information was provided by DWLBC.

1.4.2 Salinity zoning

Groundwater of the Murray Group Limestone within the Mallee SDL area has been characterised by four salinity zones (Figure 4 and Table 17).

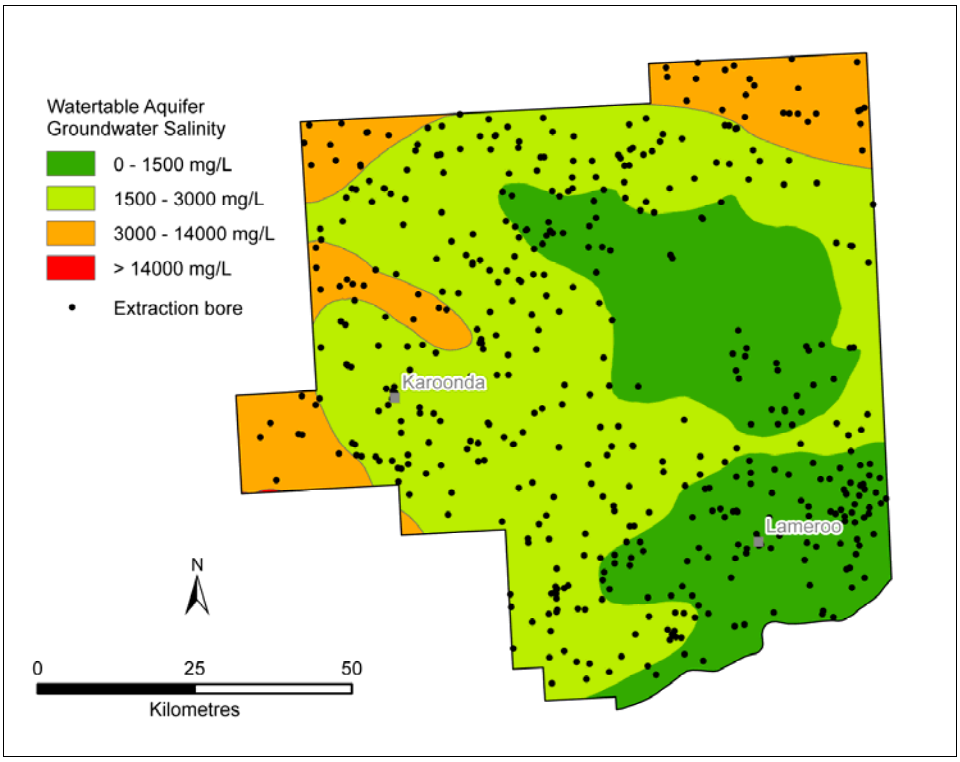

Figure 4. Mallee SDL area Murray Group Limestone salinity distribution, from the Murray Group Limestone salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 17. Summary of salinity zones in the Mallee Murray Group Limestone

Murray Group Limestone salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	32	2458
Zone 2 (1500–3000 mg/L TDS)	55	4218
Zone 3 (3000–14,000 mg/L TDS)	13	956
Zone 4 (>14,000 mg/L TDS)	0.0013	1.0
Total	**100**	**7633**

1.4.3 Key environmental assets

There are no groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Mallee SDL area.

1.4.4 Key ecosystem function

There are no unregulated rivers or surface water features considered to be in connection with the groundwater system in the Mallee SDL area. The risk to the key ecosystem function is therefore low.

1.4.5 Productive base

Recharge

Recharge to the Mallee SDL area occurs from rainfall recharge in the unconfined portion of the area and leakage from the unconfined aquifer in the remaining portion.

The groundwater resource of the Mallee PWA has been modelled by Barnett and Osei-bonsu (2006) and indicates that the Murray Group Limestone aquifer receives 2.5 GL/year recharge in the unconfined part of the SDL area. Leakage from the overlying Pliocene Sands was modelled and estimated at 3.5 GL/year.

Recharge volumes from the Barnett and Osei-bonsu (2006) numerical model have been used to estimate recharge in this SDL area.

The recharge rate for the SDL area was estimated through spatially distributing the modelled recharge volumes (from rainfall and leakage) across the associated portion of the PWA and applying those numbers to the SDL area. This resulted in an approximate recharge of 0.5 mm/year across the SDL area and a total recharge rate of 3.8 GL/year (Table 18).

Table 18. Recharge calculation for the Mallee SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	2458	4218	956	1
Diffuse recharge (mm/yr)	0.5	0.5	0.5	0.5
Total recharge (GL/yr)	**1.2**	**2.1**	**0.48**	**0.00050**

Storage

The specific yields adopted in the Mallee PWA – Murrayville Water Supply Protection Area numerical model for the Murray Group Limestone aquifer was 0.1 and 0.15. An average of 0.125 has been used to calculate storage volume. The average thickness of the Murray Group Limestone is 100 m in this area. The estimated thickness across the SDL area differs between each salinity zone (Table 19).

Table 19. Storage calculation for the Mallee SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	2,458	4,218	956	1
Saturated thickness (m)	100	80	80	65
Specific yield	0.125	0.125	0.125	0.125
Total storage (GL)	**30,725**	**42,180**	**9,560**	**8**

Storage relative to recharge

The ratio of storage to recharge for the Mallee SDL area ranges from 16,000 to 25,604 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.4.6 The risk matrix

Table 20 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that unregulated river reaches do not exist in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with this SDL area, given that the area is represented by a numerical model.

Table 20. Risk matrix

<table>
<tr><th>Risk ranking</th><th>Environmental assets (EAs)</th><th>OR</th><th>Ecosystem function</th><th>OR</th><th>Productive base</th><th>Sustainability factor (SF)</th><th>Key environmental outcome</th><th>Degree of uncertainty</th></tr>
<tr><td>High</td><td>EA that is highly groundwater dependent and highly sensitive to take</td><td rowspan="3"></td><td>In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion</td><td rowspan="3"></td><td>Storage/ recharge <20</td><td>0.10</td><td rowspan="3">Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes

Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made:

Salinity class 1: reduce SF by 20%

Salinity class 2: reduce SF by 10%

Salinity classes 3 & 4: no reduction</td><td rowspan="2">Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%</td></tr>
<tr><td>Medium</td><td>EA that is highly groundwater dependent and is moderately sensitive to take

EA that is moderately groundwater dependent and is highly sensitive to take</td><td>The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge 20–40</td><td>0.50</td></tr>
<tr><td>Low</td><td>EA that has a low groundwater dependence and low sensitivity to take

EAs do not exist in the SDL area</td><td>The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)</td><td>Storage/ recharge >40</td><td>0.70</td><td>Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF

Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%</td></tr>
</table>

1.4.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Mallee SDL area is 2.4 GL/year (Table 21).

The extraction limit defined in the state plan is 41 GL/year. This RRAM extraction limit has been superseded by the plan limit, given that the plan limit represents the best available knowledge and that the plan limit will define planned environmental water (which cannot be reduced).

Table 21. Preliminary extraction limit summary for the Mallee SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	1.2	2.1	0.48	0.00050
Sustainability factor	0.56	0.63	0.70	0.70
Extraction limit (GL/yr)	**0.69**	**1.3**	**0.34**	**0.00035**

1.5 Mallee Border Zone (GS4)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Mallee Border Zone SDL area.

1.5.1 Background

The Mallee Border Zone SDL area is located in the south-east of the Murray Basin, in South Australia, adjacent the Victorian border.

There are five main hydrogeological units in the Mallee Border Zone SDL area, including aquifers and confining layers (Barnett and Osei-bonsu, 2006). The uppermost Pliocene Sands aquifer, consisting of weakly cemented fine to coarse sand, is approximately 50 m thick. The watertable in this aquifer is typically between 40 and 60 m below ground level. The Pliocene Sands aquifer is underlain by the Bookpurnong Beds, which acts as a confining layer to the underlying Murray Group Limestone. The Bookpurnong Beds have an average thickness of approximately 20 m, and consist of plastic silts, clays and sands.

The confined Murray Group Limestone aquifer consists of consolidated, highly fossiliferous, fine to coarse bioclastic limestone (Barnett and Osei-bonsu, 2006) with thickness ranging from 80 to 140 m (Barnett 2006). Beneath the Murray Limestone lies the confining Ettrick Formation, which consists of glauconitic and fossiliferous marl of 15 m average thickness which separates the upper aquifers from the Renmark Group; an unconsolidated carbonaceous sands, silt and clay layer of approximately 150 m in thickness (Barnett and Osei-bonsu, 2006).

The Murray Group Limestone aquifer is the most highly developed aquifer in the SDL area, due to the higher quality and quantities of extractable groundwater compared to that of the Pliocene Sands. Usage data suggests total use in the SDL area to be 16 GL/year, which is mainly used for irrigation (Table 22). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 22. Groundwater take summary for the Mallee Border Zone SDL area

Mallee Border Zone SDL area	GL/yr*
Total 2007/2008 entitlement	**20**
2007/2008 metered use for entitlement bores	16
2007/2008 estimated use for entitlement bores	0.0
2007/2008 estimated use for stock and domestic bores	0.40
Total 2007/2008 use	**16**

*Entitlement and use information was provided by DWLBC.

1.5.2 Salinity zoning

Groundwater of the Murray Group Limestone within the Mallee Border Zone SDL area has been characterised by three salinity zones (Figure 5 and Table 23).

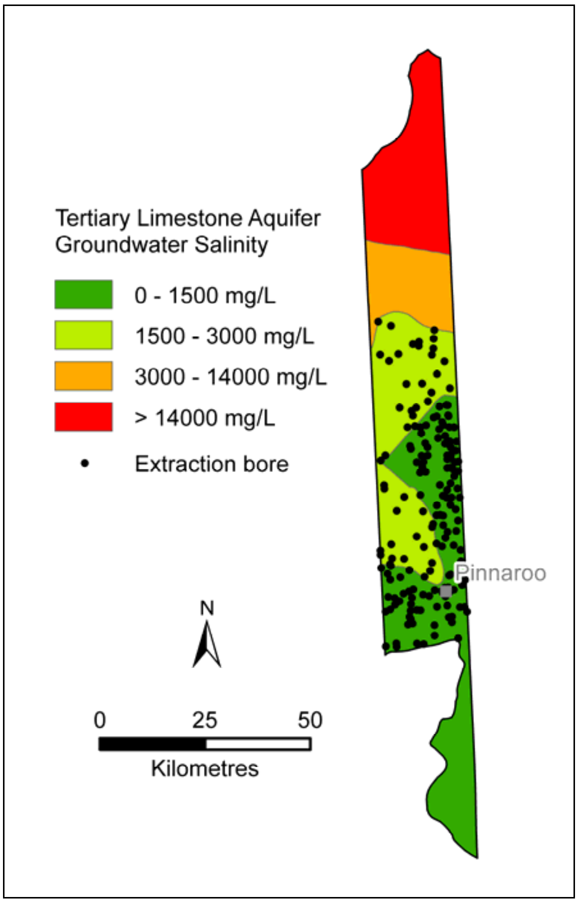

Figure 5. Mallee Border Zone Murray Group Limestone salinity distribution, from the Murray Group Limestone salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 23. Summary of salinity zones in Murray Group Limestone aquifer of the Mallee Border Zone SDL area

Murray Group Limestone salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	35	997
Zone 2 (1500–3000 mg/L TDS)	18	533
Zone 3 (3000–14,000 mg/L TDS)	13	375
Zone 4 (>14,000 mg/L TDS)	34	968
Total	**100**	**2873**

1.5.3 Key environmental assets

There are no groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Mallee Border Zone SDL area.

1.5.4 Key ecosystem function

There are no unregulated rivers or surface water features considered to be in connection with the groundwater system in the Mallee Border Zone SDL area. Therefore the risk to the key ecosystem function is low.

1.5.5 Productive base

Recharge

The Murray Group Limestone in the Mallee Border Zone SDL area is not recharged via direct infiltration of rainfall, due to the confining nature of the overlying Bookpurnong Beds. However, modelling of Mallee PWA, by Barnett and Osei-bonsu (2006) estimates downward leakage to the Murray Group Limestone at approximately 0.85 GL/year.

The recharge rate for the SDL area was estimated via spatially distributing the modelled recharge volumes (from leakage) across the associated portion of the PWA area and applying those numbers to the SDL area. This resulted in an approximate recharge of 0.43 mm/yr across the SDL area and a total recharge volume of 1.2 GL/year (Table 24).

Table 24. Recharge calculation for the Mallee Border Zone SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	997	533	375	968
Estimated recharge (mm/yr)	0.43	0.43	0.43	0.43
Total recharge (GL/yr)	**0.43**	**0.23**	**0.16**	**0.42**

Storage

The specific yields adopted in the Mallee PWA – Murrayville Water Supply Protection Area numerical model for the Murray Group Limestone aquifer was 0.1 and 0.15. An average of 0.125 was used to calculate storage volume. The estimated average saturated thickness of the Murray Group Limestone varies across the SDL area (Table 25).

Table 25. Storage calculation for the Mallee Border Zone SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	997	533	375	968
Saturated thickness (m)	130	130	130	130
Specific yield	0.125	0.125	0.125	0.125
Total storage (GL)	**16,201**	**8,661**	**6,563**	**16,940**

Storage relative to recharge

The ratio of storage to recharge for the Mallee Border Zone SDL area ranges from 37,657 to 41,019 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.5.6 The risk matrix

Table 26 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that unregulated river reaches do not exist in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with this SDL area, given that the area is represented by a numerical model.

Table 26. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.5.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Mallee Border Zone SDL area is 0.79 GL/year (Table 27). This volume is less than the sum of 2007/2008 entitlements (20 GL/year) and use (16 GL/year).

The extraction limit defined in the state plan for the Mallee Border Zone is 22 GL/year. This RRAM extraction limit has been superseded by the plan limit, given that the plan limit represents the best available knowledge and that the plan limit will define planned environmental water (which cannot be reduced).

Table 27. Preliminary extraction limit summary for the Mallee Border Zone SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	0.43	0.23	0.16	0.42
Sustainability factor	0.56	0.63	0.70	0.70
Extraction limit (GL/yr)	**0.24**	**0.14**	**0.11**	**0.29**

1.6 Marne Saunders (GS5)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Marne Saunders SDL area.

1.6.1 Background

The Marne Saunders catchment is located in the west of the Murray Basin, northeast of Adelaide in South Australia. The area stretches from the southern Barossa Highlands to the northern extents of the Eastern Mount Lofty Ranges and across the plains, to the River Murray.

The SDL area can be divided into two distinct geological regions: the highland (hills) region, associated with the fractured basement outcrops of the Adelaide Geosyncline, and the lowland (plains) region of the Murray Basin. The regions are separated by the Palmer Fault Scarp.

The hills zone is made up of rocks of the Kanmantoo Group including sandstone, siltstone, marble and greywacke with inliers of granite (SAMDBNRMB, 2009), which form Fractured Rock aquifers. Alluvial Quaternary sediments also contain groundwater in the valleys. The rocks of this region have low permeability and contain limited fractures and joints where groundwater can be stored leading to limited recharge (Richardson et al., 2008). Bore yields are typically poor and groundwater salinities variable, which has lead to generally low extraction in this region (DWR, 2001).

The plains region is underlain by unconsolidated sediments, which form the sedimentary aquifers of the Murray Basin, underlain by the basement rocks typical of the hills zone. The uppermost unconfined Quaternary-aged sediments, range from wind-blown sands in the uplands to alluvial sediments of the modern drainage channel and vary in thickness from 60 m near the Palmer Fault to a few metres close to the River Murray (DWR, 2001).

The Quaternary sediments on the plains are only saturated in the west where the interbedded clays and clayey sands of the Pooraka Formation act as a confining layer to the underlying Tertiary sediments. In the east of the region, the Pooraka pinches out thereby allowing hydraulic connection between the Quaternary sands and the Tertiary Murray Group Limestone aquifer.

The Murray Group Limestone aquifer consists of highly fossiliferous limestone that varies in thickness from a few metres in the west to approximately 50 m on the eastern boundary (DWR, 2001). The Murray Group Limestone is underlain by the Ettrick Formation; a layer of grey-green sandy marls of varying thickness which acts as a confining layer to the underlying confined Renmark Group aquifer.

The Murray Group Limestone is the most productive aquifer in the system, having better quality water with more reliable yields than the Renmark Group. A preliminary extraction limit has been determined for the Murray Group Limestone aquifer, given it is the most developed in this area. 2007/2008 groundwater use in the Marne Saunders SDL area is 2.5 GL/year (Table 28). For more information regarding the source of the entitlement and use information, refer to CSIRO (2010).

Table 28. Groundwater take summary for the Marne Saunders SDL area

Marne Saunders SDL area	GL/yr*
Total 2007/2008 entitlement	**3.9**
2007/2008 metered use for entitlement bores	2.2
2007/2008 estimated use for entitlement bores	0.0
2007/2008 estimated use for stock and domestic bores	0.27
Total 2007/2008 use	**2.5**

*Entitlement and use information was provided by DWLBC.

1.6.2 Salinity zoning

Groundwater of the Murray Group Limestone aquifer within the Marne Saunders SDL area has been characterised by three salinity zones (Figure 6 and Table 29).

There is a lack of data for the Murray Group Limestone in part of the Marne River plains zone, which has been incorporated in the most appropriate (adjacent) salinity zone; zone 3.

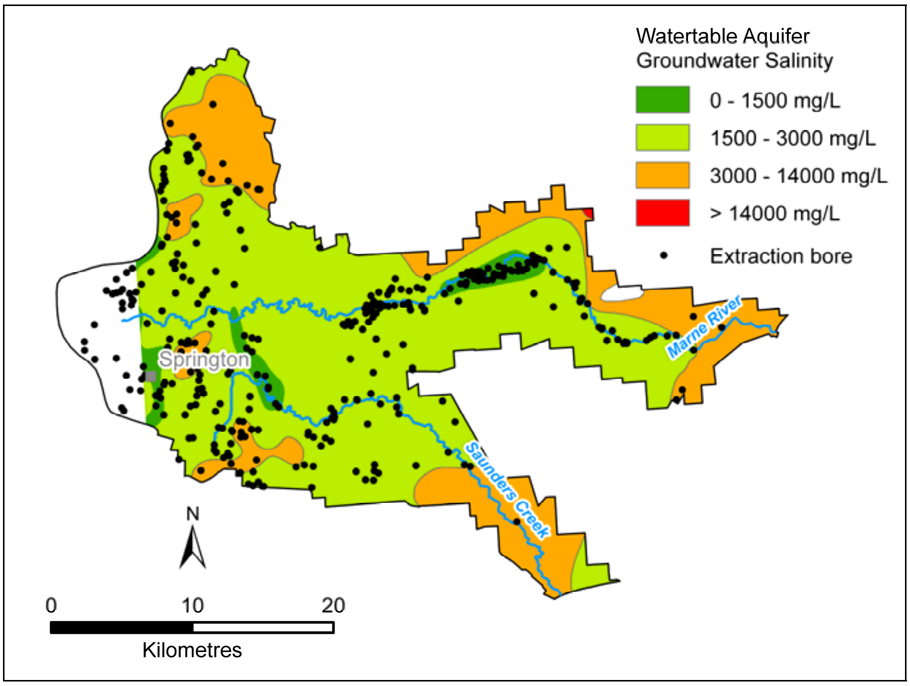

Figure 6. Marne Saunders watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 29. Summary of salinity zones in the Murray Group Limestone within the Marne Saunders SDL area

Murray Group Limestone salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	4	29
Zone 2 (1500–3000 mg/L TDS)	70	535
Zone 3 (3000–14,000 mg/L TDS)	26	181
Zone 4 (> 14,000 mg/L TDS)	N/A	N/A
Total	**100**	**745**

1.6.3 Key environmental assets

There are no groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Marne Saunders SDL area.

1.6.4 Key ecosystem function

The main channels and smaller tributaries of the Marne River and Saunders Creek are unregulated and generally considered to be gaining river reaches in the highland region of the catchments and losing across the plains region (Zulfic and Barnett, 2002; Harrison, 2004). In the hills zone, groundwater drains from the higher points to the lowest where it discharges to streams and often constituting baseflow which can dominate flow for most of the year, especially in dryer periods (Zulfic and Barnett, 2002). In the plains region, the creeks are highly ephemeral and lose water to the underlying sedimentary aquifer system when they flow, with the watertable occurring below the creek beds for the majority of the plains reaches (Harrison, 2004), and in particular where current groundwater extraction wells exist.

Groundwater extraction is concentrated in areas of fresher groundwater, mainly in the general vicinity of the River Marne Channel (Figure 6). It is thought that the impact of this groundwater extraction and extraction elsewhere in the SDL area would be to increase the difference in water levels from the river to the groundwater. Hence, the rates of loss along losing reaches on the plains will increase and the length of maximum losing reaches will increase.

Groundwater extraction in the Marne Saunders SDL area is therefore considered to have high impact in terms of key ecosystem function. It is possible to argue that a medium risk should be applied since the impact of groundwater extraction may have a lag time greater than 50 years (see Table 32). However, further investigation would be required to make this assessment which determined the degree of connection along the length of the rivers and the changes in the groundwater levels as a result of groundwater extraction.

1.6.5 Productive base

Recharge

The majority of the groundwater extraction in the Marne Saunders SDL area is from the Murray Group Limestone in the plains region. There is extraction from the Fractured Rock aquifer however it is assumed to be less significant than extraction from the plains. Recharge to the plains aquifer occurs via three main mechanisms: direct rainfall recharge, lateral throughflow from the Fractured Rock aquifer in the hills zone across the Palmer Fault, and flood recharge (which is outside the scope of this assessment) (DWR, 2001).

Total recharge to the Marne Saunders SDL area is estimated to be 8.0 GL/year which has been distributed to the most appropriate salinity zones. Throughout the plains, recharge is approximately 5.0 GL; 4.0 GL from streams (allocated to salinity zone 1) and 1.0 GL/year from lateral flow (salinity zone 2). Recharge to the hills face zone is 3.0 GL/year (Barnett and Zulfic, 2001). This has been allocated to salinity zone 2 (Table 30).

Table 30. Recharge calculation for the Marne Saunders SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Total recharge (GL/yr)	**4.0**	**4.0**	**0**	**N/A**

Storage

The specific yield adopted for the storage calculation of the Murray Group Aquifer is 0.15 (as used in the Marne River Catchment Plains Zone groundwater modelling; DWR, 2001.) The average aquifer thickness of the aquifer is thought to be between 25 and 35 m (DWR, 2001). Average saturated thickness was taken to be 30 m in the absence of further data, which was used in the storage calculations (Table 31).

Table 31. Storage calculation for the Marne Saunders SDL area – Murray Group Limestone and Fractured Rock aquifer

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	29	535	181	N/A
Saturated thickness (m)	30	30	30	N/A
Specific yield	0.15	0.15	0.15	N/A
Total storage (GL)	**131**	**2408**	**815**	**N/A**

Storage relative to recharge

The ratio of storage to recharge for the Marne Saunders SDL area ranges from 33 to 602 for each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.6.6 The risk matrix

Table 32 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked high risk in terms of ecosystem function, given that there are unregulated river reaches in this SDL area
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40

- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with this SDL area given that a numerical model exists and good monitoring and metering data is available.

Table 32. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.6.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Marne Saunders SDL area is 0.68 GL/year (Table 33).

The key ecosystem function component of the assessment has a considerable impact on the extraction limit (currently ranked as a high risk resource characteristic due to the presence of unregulated rivers). The South Australian Government is currently developing planning arrangements for this SDL area which will seek to preserve baseflow and groundwater throughflow to protect ecosystem function. It is expected that the State planning arrangements will also include local management rules that seek to provide additional protection to key ecosystem function through the use of buffer zones around streams, thereby limiting the volume of extraction near a stream.

Given the existence of local management rules it is possible to lower the risk ranking associated with the key ecosystem function from high to medium. This would result in an extraction limit equivalent to 3.5 GL/year (Table 34).

The extraction limit defined in the state plan for Marne Saunders is 4.7 GL/year (including stock and domestic use). The RRAM extraction limit has been superseded by the plan limit, given that the plan limit represents the best available knowledge and that the plan limit will define planned environmental water (which cannot be reduced).

Table 33. Preliminary extraction limit summary for the Marne Saunders SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	4.0	4.0	N/A	N/A
Sustainability factor	0.08	0.09	N/A	N/A
Extraction limit (GL/yr)	**0.32**	**0.36**	**N/A**	**N/A**

Table 34. Revised preliminary extraction limit summary for the Marne Saunders SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	4.0	4.0	N/A	N/A
Sustainability factor	0.40	0.45	N/A	N/A
Extraction limit (GL/yr)	**1.5**	**2.0**	**N/A**	**N/A**

1.7 Peake-Roby-Sherlock (GS6)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the Peake-Roby-Sherlock SDL area.

1.7.1 Background

The Peake-Roby-Sherlock SDL area is located in the south-east of the Murray Basin, ~130 km southeast of Adelaide in South Australia.

The SDL area consists of two regions: the Mallee Highlands in the eastern portion of the SDL area, and the Coastal Plain which occupies the majority of the area.

In the highlands, the Loxton-Parilla Sands form the unconfined aquifer and overlie the Murray Group Limestone. On the lowland plains, the Murray Group Limestone, consisting of highly fossiliferous limestone and dissolution cavities in some areas, is overlain with Quaternary limestone. The watertable is continuous between the Murray Group Limestone in the highland area (where it can be up to 50 m below ground level) and the Quaternary limestone in the lowland region of the SDL area (where watertable depths range from 3 to 8 m below ground level) (SAMDBNRM, 2009).

The unconfined aquifer is hydraulically separated from the underlying confined aquifer by the Ettrick Formation; a confining layer of low permeability dark-brown carbonaceous clay that is approximately 20 m in thickness (SAMDBNRM, 2009). Groundwater resources of the confined aquifer are contained within the Buccleuch Group (bryozoal limestone) and underlying sands of the Renmark Group.

On the Coastal Plain, groundwater salinity in the unconfined aquifer is typically in excess 15,000 mg/L TDS and therefore unsuitable for general use. The lower salinity groundwater of the Murray Group Limestone in the highland region (~ 2000–3000 mg/L TDS) is used for irrigation, stock and domestic purposes.

The confined aquifer is the most developed aquifer in the SDL area. On the coastal plain, the greatest metered groundwater extraction occurs from the Buccleuch Formation (or 'the coral'), which lies 90 to 100 m below the surface with varying thickness (5 to 25 m) and limited lateral extensiveness (SAMDBNRM, 2009). In the east of the SDL area, the Buccleuch Formation merges with the Renmark Group and groundwater flows between these two units.

2007/2008 groundwater extraction from the Peake-Roby-Sherlock was 1.7 GL/year (Table 35) and for more information regarding the source of the entitlement and use information, refer to CSIRO (2010). Most extraction is from the confined aquifer. Only small volumes of groundwater is sourced from the unconfined aquifer, mainly for stock and for irrigating olives. Production wells are generally centred in the Peake area and mostly used for irrigation (Barnett and Yan, 2008).

Table 35. Groundwater take summary for the Peake-Roby-Sherlock SDL area

Peake-Roby-Sherlock SDL area	GL/yr*
Total 2007/2008 entitlement	**N/A**
2007/2008 metered use for entitlement bores	1.4
2007/2008 estimated use for entitlement bores	0.0
2007/2008 estimated use for stock and domestic bores	0.30
Total 2007/2008 use	**1.7**

*Entitlement and use information was provided by DWLBC. Entitlement information was not available at the time of reporting.

1.7.2 Salinity zoning

Groundwater of the confined aquifer within the Peake-Roby-Sherlock SDL area has been characterised by three salinity zones (Figure 7 and Table 36).

There is a lack of salinity data in a small portion of the area (shown in white in Figure 7), which have been incorporated into salinity zone 4.

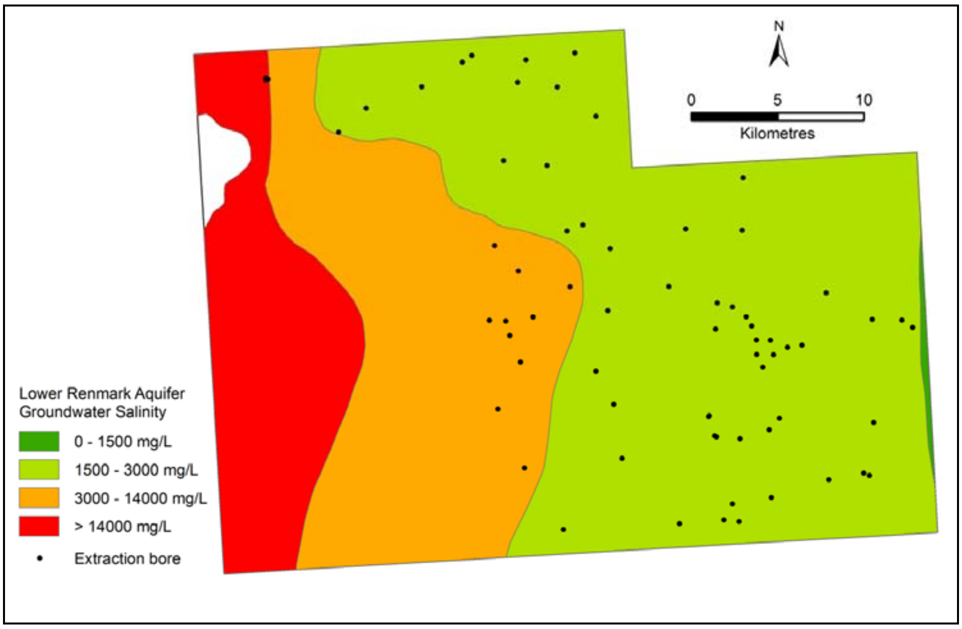

Figure 7. Peake-Roby-Sherlock Renmark Group aquifer salinity distribution, from the Lower Renmark salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 36. Summary of salinity zones in the Peake-Roby-Sherlock SDL area

Renmark Group salinity zones	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	0.5	4
Zone 2 (1500–3000 mg/L TDS)	55	621
Zone 3 (3000–14,000 mg/L TDS)	28	318
Zone 4 (>14,000 mg/L TDS)	16	189
Total	**100**	**1133**

1.7.3 Key environmental assets

There are no groundwater-dependent key environmental assets that are sensitive to groundwater extraction associated with the Peake-Roby-Sherlock SDL area.

1.7.4 Key ecosystem function

There are no streams in the Peake-Roby-Sherlock SDL area and hence impact of groundwater extraction on ecosystem function is low.

1.7.5 Productive base

Recharge

The confining Ettrick Formation that overlies the Buccleuch and Renmark Group aquifers is very effective, allowing negligible leakage to the underlying units (Barnett and Yan, 2008).

Rainfall recharge to the Murray Group Limestone does occur to the east of the region; however, in this area, the dominant aquifer is the confined Renmark Group.

Rainfall recharge within this SDL area is therefore considered negligible.

Storage relative to recharge

Recharge derived from either rainfall infiltration or leakage from overlying units is negligible in the Peake-Roby-Sherlock SDL area is considered to be zero. Therefore there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.7.6 The risk matrix

Table 37 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of key environmental assets, given none exist that have been identified as groundwater dependent in this area
- the SDL area is ranked low risk in terms of ecosystem function, given that unregulated river reaches do not exist in this unit
- the SDL area is ranked low risk in terms of the productive base
- there is a risk to the key environmental outcomes (i.e. groundwater salinity)
- a low uncertainty is associated with this SDL area given that it is well documented and understood that recharge to the developed aquifer is negligible.

Table 37. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.7.7 Preliminary RRAM extraction limit

The preliminary estimated extraction limit resulting from the RRAM for the Peake-Roby-Sherlock SDL area is zero GL/year. This reflects the confined nature of the productive aquifers in this unit.

The Peake-Roby-Sherlock groundwater model estimates lateral throughflow under current pumping conditions to be 1.1 GL/year (Barnett and Yan, 2008). Under natural conditions, groundwater flow occurred from the east of the unit towards the River Murray where it discharges. However, extraction wells for irrigation concentrated in the Peake area have caused localised drawdown and changes in groundwater flow direction, resulting in increased flow (of more saline groundwater) to the area through lateral inflow.

It is this lateral inflow on which entitlements are partially based, in addition to an accepted increase in drawdown due to use of storage (Barnett and Yan, 2008). In the draft water allocation plan for the area, allocations are based on ensuring salinity does not rise above the tolerance levels for stock within an accepted time frame.

The preliminary RRAM extraction limit has been superseded by the limit defined in the Draft Water Allocation Plan for Peake-Roby-Sherlock. This limit equates to 5.2 GL/year and represents the best available knowledge of the area and also defines planned environmental water (which cannot be reduced).

1.8 South Australian Murray (GS7)

This chapter describes the derivation of the preliminary estimated extraction limit resulting from the RRAM for the South Australian Murray SDL area.

1.8.1 Background

The South Australian Murray SDL area incorporates the majority of the Murray-Darling Basin in South Australia, stretching from the border with Victoria in the east to the edge of the plains of the Mount Lofty Ranges and south-east to the coast (Figure 8).

The South Australian Murray SDL area consists of two contrasting regions: the hills zone of the Olary Ranges and Mount Lofty Ranges along the north/north-eastern boundary of the area; and the more topographically homogenous plains region, which accounts for the majority of the area.

The upland reaches are formed from outcropping Cambrian basement rocks, forming Fractured Rock aquifers of varying yields. On the plains the upper most quaternary sediments of the SDL area mainly consists of the Aeolian Sands of the Woorinen Formation, underlain by Blanchetown Clay in some areas, which acts as a localised semi-confining layer to the underlying Tertiary sediments that contain the most significant aquifers of the system. The uppermost of these is the mostly unconfined Pliocene Sands aquifer (mainly composed of Loxton-Parilla Sands), consisting of fine to course grained sands. In the central areas and east of the SDL area, the Pliocene Sands is separated from the underlying Murray Group Limestone aquifer, by the consolidated plastic silts and clays of the Bookpurnong Beds. The Murray Group Limestone is unconfined and contains the watertable across much of the plains, other than in the east where the watertable is within the Loxton-Parilla Sands.

Beneath the Murray Group Limestone, the Ettrick Formation acts as a confining layer to the underlying Renmark Group aquifer.

Extraction in the South Australian Murray SDL area is relatively minor, mainly due to the high salinity of the groundwater in the region. There are no licensed entitlements in this unit and no metered use. Stock and domestic use is estimated at approximately 1.8 GL/year (S Barnett, 13 January 2010, pers. comm.).

1.8.2 Salinity zoning

Groundwater of the watertable aquifer of the South Australian Murray SDL area has been characterised by three salinity zones (Figure 8 and Table 38).

There is a lack of salinity data in the northern extremes of the SDL area (shown in white in Figure 8), which has been inferred to occur in salinity zone 3.

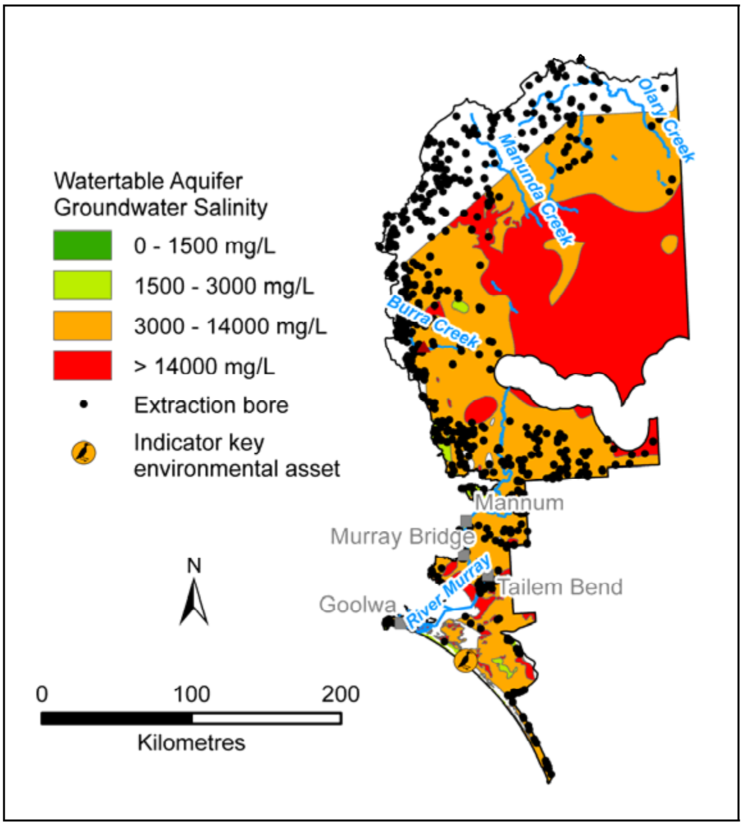

Figure 8. South Australian Murray watertable aquifer salinity distribution, from the shallow salinity layer of the MDBA Basin in a Box dataset (MDBA, 2000)

Table 38. Summary of salinity zones in the South Australian Murray SDL area

Watertable salinity zone	Portion of total area	Area
	percent	km^2
Zone 1 (0–1500 mg/L TDS)	N/A	N/A
Zone 2 (1500–3000 mg/L TDS)	2	860
Zone 3 (3000–14,000 mg/L TDS)	68	33,630
Zone 4 (>14,000 mg/L TDS)	30	15,156
Total	**100**	**49,646**

1.8.3 Key environmental assets

The Water Act requires that assessment of environmental water needs of the MDB must encompass key environmental assets, including water-dependent ecosystems, ecosystem services, and sites with ecological significance.

The Murray-Darling Basin Authority has identified 18 key environmental asset–hydrologic indicator sites that drive the environmental hydrology of the MDB (MDBA, 2010). These 18 key environmental asset–hydrologic indicator sites have been assessed to determine the objectives, targets and flow regimes required to sustain them. This information was input to the generation of an estimate of the long-term average sustainable diversion limits that will not compromise the water requirements for the rivers, wetlands and floodplains of the MDB.

The South Australian Murray SDL area encompasses the Coorong, Lower Lakes and Murray Mouth, which is one of the 18 key environmental asset–hydrologic indicator sites identified by the Murray-Darling Basin Authority. This asset is not groundwater dependent or sensitive to groundwater take.

1.8.4 Key ecosystem function

The key ecosystem function in the South Australian Murray SDL area is considered to be low. Braaten and Gates (2002) indicated that in the Lower Murray, the low connectivity between groundwater and surface water, the greater distance between bores and connected reaches of the river and the alternate sources of recharge/discharge (i.e. playa lakes and wetlands act as sinks and irrigation areas provide additional recharge) means that the proportion of groundwater pumping derived from reduced streamflow, will be low and the response times long. The risks to ecosystem function are also considered low due to the low rate of extraction.

1.8.5 Productive base

Recharge

Recharge in the South Australian Murray SDL area is assumed to occur through infiltration of rainfall. Modelled dryland diffuse groundwater recharge derived from WAVES modelling (Crosbie and McCallum, 2009) has been used to calculate recharge to the unconfined aquifer. The historical dry climate scenario for a median 15-year period, results in recharge rates of between 3.4 mm/year and 27 mm/year depending on the salinity zone (Table 39). Total recharge for the SDL area is 382 GL/year.

Table 39. Recharge calculation for the South Australian Murray SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Area (km^2)	N/A	860	33,630	15,156
Diffuse recharge (mm/yr)	N/A	27	9.1	3.4
Total recharge (GL/yr)	**N/A**	**24**	**307**	**51**

Storage

The specific yield of 0.125 adopted for the storage calculations is an average of values applied for the Murray Group Limestone aquifer and Loxton-Parilla Sands aquifer elsewhere in the Murray Basin (ranging between 0.1 and 0.15). The saturated thickness of the unconfined aquifer was inferred from geological maps of the region and has been averaged across the basin to be 60 m. Total storage for the SDL area is approximately 372,000 GL (Table 40).

Table 40. Storage calculation for the South Australian Murray SDL area

	Salinity Zone 1	Salinity Zone 2	Salinity Zone 3	Salinity Zone 4
Area (km^2)	N/A	860	33,630	151,56
Saturated thickness (m)	N/A	60	60	60
Specific yield	N/A	0.125	0.125	0.125
Total storage (GL)	**N/A**	**6,448**	**252,229**	**113,670**

Storage relative to recharge

The ratio of storage to recharge for the South Australian Murray SDL area ranges freom 269 to 2,229 fore each of the salinity zones. This indicates that there is a low risk of the productive base of the aquifer being jeopardised by factors such as climate change and the short-term over extraction of the groundwater resource.

1.8.6 The risk matrix

Table 41 provides a summary of the risk ranking associated with: key environmental assets, key ecosystem function, the productive base, the key environmental outcome and the uncertainty inherent in the RRAM calculation. In summary:

- the SDL area is ranked low risk in terms of environmental assets, given none exist in this unit
- the SDL area is ranked low risk in terms of ecosystem function, given that unregulated river reaches do not exist in this unit
- the SDL area is ranked low risk in terms of the productive base, given that the storage/recharge ratio far exceeds 40

- there is no risk to the key environmental outcome (i.e. groundwater salinity is already high in this unit)
- there is a high level of uncertainty given that the RRAM is derived from diffuse groundwater recharge derived from WAVES modelling only. It does not include other potential components of groundwater recharge, including river leakage, irrigation returns, throughflow etc.

Table 41. Risk matrix

Risk ranking	Environmental assets (EAs)	OR	Ecosystem function	OR	Productive base	Sustainability factor (SF)	Key environmental outcome	Degree of uncertainty
High	EA that is highly groundwater dependent and highly sensitive to take		In the current state, groundwater discharge provides baseflow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion		Storage/ recharge <20	0.10	Where there is no risk to the key environmental outcome (i.e. uniform groundwater salinity) there is no reduction to the SF for any of the salinity classes Where there is a risk to the key environmental outcome, as a measure to reduce risk to groundwater quality, the following reductions are made: Salinity class 1: reduce SF by 20% Salinity class 2: reduce SF by 10% Salinity classes 3 & 4: no reduction	Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 50%
Medium	EA that is highly groundwater dependent and is moderately sensitive to take EA that is moderately groundwater dependent and is highly sensitive to take		The rivers in the SDL area are regulated and they are highly connected to the groundwater system (i.e. >50% impact of pumping on streamflow within 50 years)		Storage/ recharge 20–40	0.50		
Low	EA that has a low groundwater dependence and low sensitivity to take EAs do not exist in the SDL area		The rivers in the SDL area are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on streamflow within 50 years)		Storage/ recharge >40	0.70		Where the uncertainty is low (e.g. good quality time series data, recharge well understood, metered extraction) there is no further reduction to the SF Where there is high uncertainty associated with the SDL (e.g. no numerical model available for comparison, uncertain hydrogeology, poor extraction data) the SF is further reduced by 25%

1.8.7 Preliminary RRAM extraction limit

The extraction limit resulting from the RRAM for the South Australian Murray SDL area is 203 GL/year (Table 42).

Where the volume of unassigned water is greater than 50 GL/year and greater than one-hundred times the volume of current use, the preliminary RRAM derived extraction limit is superseded by an extraction limit equivalent to the high sustainability factor applied to recharge for that particular SDL area. The South Australian Murray SDL area falls into this classification and the revised extraction limit is equal to 19 GL/year (Table 43).

Table 42. Preliminary extraction limit summary for the South Australian Murray SDL area

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	N/A	24	307	51
Sustainability factor	N/A	0.53	0.53	0.53
Extraction limit (GL/yr)	**N/A**	**123**	**163**	**27**

Table 43. Preliminary extraction limit summary for the South Australian Murray SDL area – with local management rules

	Salinity zone 1	Salinity zone 2	Salinity zone 3	Salinity zone 4
Recharge (GL/yr)	N/A	24	307	51
Sustainability factor	N/A	0.05	0.05	0.05
Extraction limit (GL/yr)	**N/A**	**1.2**	**15**	**2.6**

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