



Australian Government



The proposed Groundwater Baseline and Sustainable Diversion Limits: Methods report

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1. Introduction

The Murray-Darling Basin Authority (the Authority) has a vision of a healthy working Basin that has vibrant communities, productive and resilient industries, and healthy and diverse ecosystems. One of the key actions to achieving a healthy working Basin is the need to ensure that there is balance between the water needs of communities, industries and the environment, while at the same time protecting and restoring the ecological and other values of water-dependent ecosystems so they remain healthy.

The Basin Plan aims to do this through the establishment of Long-Term Average Sustainable Diversion Limits (SDLs), which come into effect in 2019, along with a range of other measures that will improve the management of water in the Basin. The SDLs are limits on the volumes of water that can be taken for human uses (including domestic, urban and agricultural use) from both surface water and groundwater systems across the Basin. The Water Act requires that these new limits reflect an Environmentally Sustainable Level of Take (ESLT).

This report contains a summary of the methods and assessments used to determine the groundwater SDLs for the proposed Basin Plan. As well as the SDLs, the Authority has determined a baseline against which SDLs are compared. Known as the Baseline Diversion Limit (BDL), it represents the Authority's determination of the limits on groundwater use under existing water management arrangements. The proposed Basin Plan SDLs and BDLs reflect the different aquifer characteristics, levels of management and knowledge of the groundwater resources across the Basin.

Groundwater use occurs across the entire Murray-Darling Basin with an annual average extraction of approximately 1,795 GL. The majority of use (approximately 75%) is centred on a small number of large alluvial aquifers in NSW, Queensland and Victoria. Elsewhere in the Basin, groundwater is the only reliable source of water for stock and domestic (S&D) uses. There are also a number of cities or towns across the Basin that rely on groundwater for the majority of their domestic water supply. Groundwater is also important in the Basin to other industries such as food processing and mining. Furthermore, in many areas, groundwater can and has provided a buffer during surface water scarcity.

Each of the Basin states has a groundwater management framework in place. In developing the proposed Basin Plan, the Murray - Darling Basin Authority (the Authority) has considered the state frameworks and has drawn on the expertise and knowledge held by the states.

Significantly, the proposed Basin Plan is the first time that:

- a limit on groundwater use is being established across the Basin. This is in contrast to surface water, where a cap has been in place since the mid-90s; and
- a consistent management arrangement will be applied across all the Basin's groundwater resources.

The groundwater resources in the Basin have been split into 23 groundwater Water Resource Plan (WRP) areas, which are further divided into 79 SDL resource units including 2 separate deep SDL resource units. SDL resource unit boundaries were determined to accommodate the level of connectivity of various groundwater resources and state planning

boundaries. There is an SDL volume for each SDL resource unit in the proposed Basin Plan. A number of the SDL resource units have also been vertically separated, to reflect that water is or can be extracted from different aquifers within the same area. Appendix A groups all SDL resource units according to the method and/or assessment decision made to set the SDL.

The Authority has used a consistent approach across the Basin in assessing the risk of groundwater extraction on:

- the ability of aquifers to continue to be productive over time;
- groundwater dependent ecosystems;
- surface water resources that are fed from groundwater; and
- water quality (salinity) of groundwater.

The requirement to set SDLs is just one element of the Basin Plan that should be considered in parallel to the other elements (e.g. water resource plan requirements, Water Quality and Salinity Management Plan) that are required to deliver a healthy working Basin. Importantly, the SDL sets the regional upper limit for groundwater use. Within the limits set by the SDL, localised impacts will be managed through water management arrangements in water resource plans which will be developed and implemented by the Basin states and accredited by the Authority.

2. Changes since the Guide to the Proposed Basin Plan

Since releasing the Guide, in October 2010, the Authority has further considered the BDLs and SDLs and has made a number of refinements to the methodology used to calculate groundwater BDLs and SDLs.

Over the past year the states provided new and updated information that has improved the Authority's understanding of a number of groundwater issues. The new information related to current levels of entitlement and usage, the geographic distribution of entitlements, stock and domestic consumption, SDL resource unit boundaries, new groundwater models, recharge estimates, and the updated assessment of connectivity between surface water and groundwater in a number of areas. Consideration of this additional information has enabled analysis that has resulted in a different Basin-wide groundwater SDL for the proposed Basin Plan than the SDL presented in the Guide. The difference is due to:

- inclusion of aquifers not included in the Guide (3 deep groundwater resources: Gunnedah-Oxley Basin, Oaklands Basin and SA Malle: Renmark Group);
- updated and improved data on current levels of extraction to determine the baseline groundwater diversion limit;
- further assessment of the extent to which identified aquifers can sustain additional extraction; and
- consideration of existing state based groundwater reduction schemes.

The Basin wide total of BDLs is 2352 GL/year and proposed SDLs is 4340 GL/year. The SDLs in the proposed Basin Plan reflect an environmentally sustainable level of take in the view of the Authority.

Importantly, the specification of SDLs across all of the Basin's groundwater resources represents the first comprehensive limit on groundwater use from these resources. At the time of the release of the proposed Basin Plan in November 2011, 14 SDL resource units had transitional or interim water resource plans in place (covering an area representing 24% of the Basin wide total of SDLs). In the remaining 65 SDL resource units, planning is at various stages of development and implementation. In most of these areas it is expected that a plan will be in place by the time the Basin Plan is expected to be made and some areas are not expected to have a plan in place until water resource plans are developed under the Basin Plan.

3. WRP areas and SDL resource units boundaries

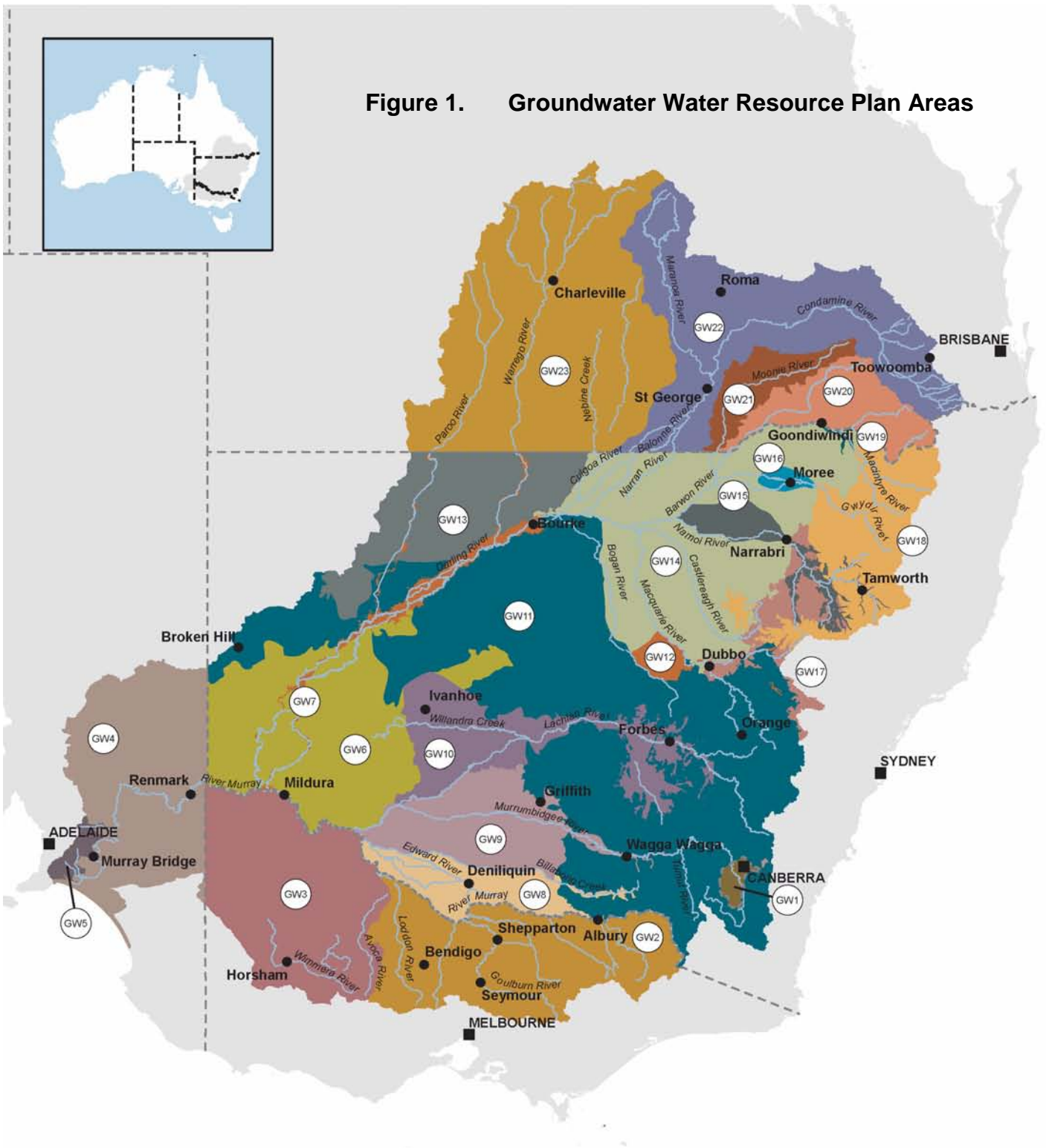
The Basin Plan's management arrangements will be implemented at a local scale through water resource plans prepared by the Basin states for accreditation by the Commonwealth Water Minister.

The Basin has been divided into 23 groundwater WRP areas. The boundaries of these areas are shown in Figure 1. Within these WRP areas there are 79 SDL resource units including 2 separate deep SDL resource units (Figures 2 & 4).

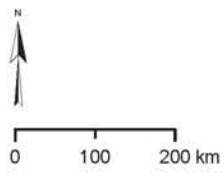
The water resource plan areas cover the entire Basin, including those areas not previously subject to water planning arrangements. The *Water Act 2007* specifically excludes Great Artesian Basin groundwater resources from being considered as a Murray-Darling Basin water resource.

The Water Act (s. 22(1) item 2) requires that boundaries of water resource plan areas must align as far as possible with existing water management boundaries. Accordingly, the Authority used existing water planning areas as a starting point in the identification of water resource plan areas. In some cases, existing state planning boundaries have been varied to include, for example, water resources that are not currently covered by water planning areas, or as a result of consultation with Basin states. Hydrologic, geological and hydrogeological units, such as river catchments, geological formations and aquifers, were also used to identify the new boundaries with groundwater areas based chiefly on hydrogeological units.

Figure 1. Groundwater Water Resource Plan Areas



- capital city
- main town
- - - state border
- main rivers



Groundwater water resource plan areas

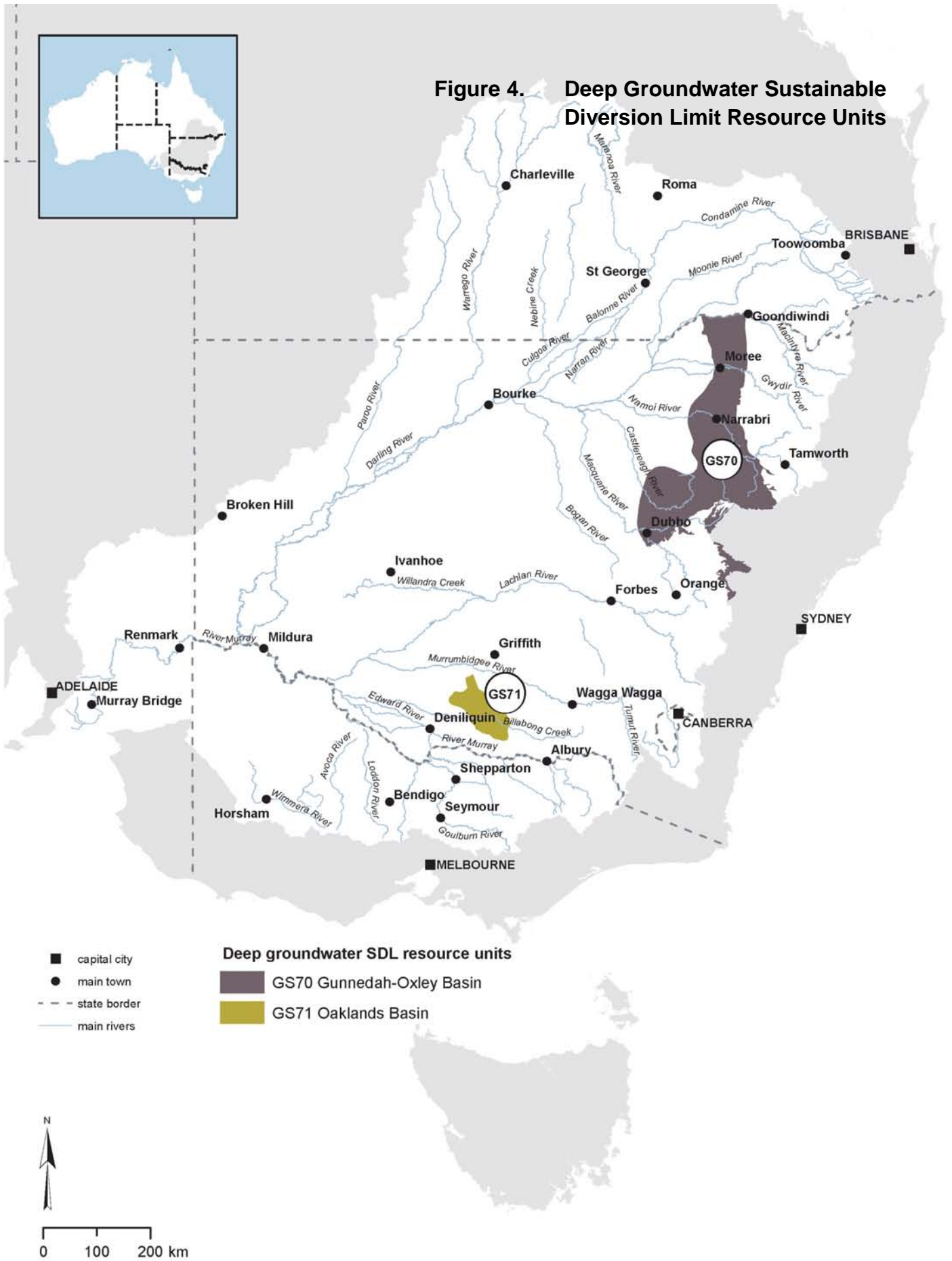
- | | |
|--|--|
| GW1 Australian Capital Territory (groundwater) | GW13 New South Wales Sediments above GAB |
| GW2 Goulburn-Murray | GW14 New South Wales Alluvium above GAB |
| GW3 Wimmera-Mallee (groundwater) | GW15 Namoi Alluvium |
| GW4 South Australian Murray | GW16 Gwydir Alluvium |
| GW5 Eastern Mount Lofty Ranges | GW17 Eastern Porous Rock |
| GW6 Western Porous Rock | GW18 New England Fractured Rock and Northern Basalts |
| GW7 Darling Alluvium | GW19 New South Wales Border Rivers Alluvium |
| GW8 Murray Alluvium | GW20 Queensland Border Rivers |
| GW9 Murrumbidgee Alluvium | GW21 Moonie |
| GW10 Lachlan Alluvium | GW22 Condamine-Balonne |
| GW11 Lachlan and South Western Fractured Rock | GW23 Warrego-Paroo-Nebine |
| GW12 Macquarie-Castlereagh Alluvium | |

Figure 3. Groundwater Sustainable Diversion Limit Resource Units (Key)

Groundwater SDL resource units, other than deep groundwater SDL resource units



Figure 4. Deep Groundwater Sustainable Diversion Limit Resource Units



4. Baseline Diversion Limit Policy

The BDL for each groundwater SDL resource unit represents the Authority's determination of the limits on groundwater use under existing water management arrangements and describes the baseline against which SDLs are assessed. Specifying BDLs is required under s78 of the *Water Act 2007* and provides a common starting point for discussions with Basin states and communities on the introduction of sustainable diversion limits under the Basin Plan. In surface water, the 1995 cap on diversions effectively provided this common starting point for much of the Basin, however in groundwater no similar arrangement was in place prior to the development of the proposed Basin Plan.

The specification of BDLs also has implications for the Commonwealth's commitment to bridge the gap through its water recovery programs. It is important to have a Basin-wide policy for setting BDLs that accurately reflects the potential limit of diversions currently in place. The BDL for each SDL resource unit has been determined on the following basis:

1. where a water management plan or proposed plan exists, the BDL is the plan limit unless the plan limit is greater than the level of entitlement, in which case the BDL is the entitlement;
2. where there is no plan, the BDL is the entitlement along with the effect of any rules managing extraction; and
3. where there is a cross-border agreement for groundwater management, the extraction limit under the agreement is the BDL.

In setting the BDLs, the Authority has included the most recent estimates of the S&D extraction volume, held by the Authority, for each SDL resource unit.

The Basin states provided the information used by the Authority to determine the BDLs. During the development of the proposed Basin Plan a number of the Basin states have reviewed and updated the baseline information that they initially provided to the Authority. This new information has been used to inform the BDL determinations as it represents the most up to date understanding of the current level of groundwater entitlements and S&D use.

5. Assessment to Determine Groundwater SDLs

Under the Water Act 2007 (s22(1) Item 6), the Basin Plan must include maximum long-term annual average quantities of water that can be taken, on a sustainable basis, from:

- a) the Basin water resources as a whole; and
- b) the water resources, or particular parts of the water resources, of each water resource plan area.

The averages are the long-term average sustainable diversion limits (SDLs) for the Basin water resources, and the water resources, or particular parts of the water resources, of the water resource plan area.

The SDLs must reflect the environmentally sustainable level of take (ESLT) for a water resource, which is defined as the level at which water can be taken from that water resource which, if exceeded, would compromise:

- a) key environmental assets (KEA) of the water resource; or
- b) key ecosystem functions (KEF) of the water resource; or
- c) the productive base (PB) of the water resource; or
- d) key environmental outcomes (KEO) for the water resource.

To meet the ESLT requirements for groundwater, the Authority has determined that a groundwater SDL must:

- a) maintain key environmental assets that have any dependence on groundwater (KEA);
- b) maintain base flow groundwater contributions to rivers and streams (KEF);
- c) ensure that productive use of the aquifer is sustainable without compromising the hydrogeological integrity of the aquifer (PB); and
- d) protect against decreasing groundwater quality, in particular salinisation of the groundwater resource (KEO).

The proposed groundwater SDLs were informed by numerical modelling or an analytical risk assessment.

Numerical modelling was carried out in 13 SDL resource units where there were fit for purpose numerical models available. Where numerical models were not available the Authority has used a recharge risk assessment method (RRAM), developed for the MDBA (CSIRO and SKM 2010), to inform the proposed SDLs. Both the numerical groundwater modelling and the RRAM provide the potential volume of water available for consumptive use (the preliminary extraction limit (PEL)).

The PEL represents the Authority's analytical assessment of the volume of water that can be extracted from a groundwater SDL resource unit. The Authority then applied an analytical framework to determine the proposed groundwater SDLs that reflect the ESLT (Section 6).

The groundwater SDLs are a limit and not a target. In some areas due to poor water quality and the difficulty in accessing groundwater, it is unlikely that extraction will approach the SDL in the life of the Basin Plan.

5.1 Modelled SDL resource units

The Authority found that within the Murray-Darling Basin there were a limited number of numerical groundwater models available to inform the determination of groundwater SDLs. In contrast to surface water, where numerical models were available for the majority of surface water catchments in the Basin, there were only 11 numerical groundwater models available that cover 13 SDL resource units.

The 11 numerical groundwater models focus on the higher use alluvial groundwater systems in NSW, Victoria and Queensland. These models were developed or modified for the CSIRO Murray–Darling Basin Sustainable Yields Project (CSIRO 2008) and all of the NSW numerical models were originally developed and calibrated by the New South Wales Office of Water or its predecessors.

The models cover all or parts of the following groundwater systems:

- Upper Condamine Alluvium (Qld)
- Lower Namoi Alluvium (NSW)
- Lower Macquarie Alluvium (NSW)
- Lower Lachlan Alluvium (NSW)
- Lower Murrumbidgee Alluvium (NSW)
- Southern Riverine Plains (NSW & Vic) including:
 - Lower Murray Alluvium(NSW)
 - Ovens-Kiewa Sedimentary Plain(Vic)
 - Victorian Riverine Sedimentary Plain(Vic)
- Lower Gwydir Alluvium (NSW)
- Upper Namoi Alluvium (NSW)
- Upper Macquarie Alluvium (NSW)
- Upper Lachlan Alluvium (NSW)
- Mid-Murrumbidgee Alluvium (NSW)

These models represented systems that covered 73% of the groundwater extracted extraction in the Murray-Darling Basin in 2007/08.

Further, South Australia made the results of the numerical model for the Angas–Bremer SDL resource unit available to the Authority and this information was used to confirm the SDL for Angas-Bremer SDL resource unit.

The Authority used the above modelling results as an input to determining the proposed SDLs. Other evidence was also considered including groundwater hydrographs, extraction information, and consultation with the states and water users.

Further explanation of the modelling method is provided at Appendix B.

5.2 Recharge Risk Assessment Method (RRAM)

The RRAM is a risk assessment process that is used to determine a PEL for an SDL resource unit. The method establishes a sustainability factor (SF), which is then applied to the recharge volume to determine the PEL. Further information on the application of the RRAM process in the development of the proposed Basin Plan is available as separate report at: <http://www.mdba.gov.au/files/bp-kid/1056-MDBA-Groundwater-SDL-Methodology.PDF>.

In summary, the first step in determining the PEL using RRAM was to determine recharge across the Basin using the Water Vegetation Energy and Solute (WAVES) model and upscaling techniques developed for the Murray-Darling Basin Sustainable Yields project and subsequently refined for the Basin Plan (Zhang and Dawes 1998 and CSIRO 2010). Additional recharge information was also used where it was made available by the states.

The next steps determined the SF using a risk matrix which assesses

- the risks to the 4 ESLT characteristics; and
- the level of uncertainty within an SDL resource unit.

Risks to the 4 ESLT characteristics

The higher the risk that groundwater extraction represents to compromising one of the ESLT characteristics, the lower the SF will be. The following SF factors were used:

- High risk – 10% of recharge
- Medium risk – 50% of recharge
- Low risk – 70% of recharge

The level of uncertainty within an SDL resource unit

The level of uncertainty reflects the information and data that is available and the level of understanding of the groundwater processes. Where there is a high degree of uncertainty regarding the groundwater system, the SF is further reduced. The reduction was determined by the level of risk to the ESLT characteristics:

- Risk to ESLT characteristics is high or medium – SF reduced by 50% groundwater
- Risk to ESLT characteristic is low – SF reduced by 25%

The SF was then applied to the recharge volume to determine the PEL.

For example, in a SDL resource unit where the Authority considered that there was a high risk of groundwater extraction impacting on surface water flows, due to the connectivity between the resources, the SF will be 10% of the recharge. If the area has a high degree of uncertainty, the SF (recharge) is reduced by a further 50%. This results in a PEL of 5% of recharge, leaving 95% of the recharge protected from further extraction.

The PEL is the starting point to which the Authority then applied an analytical framework to determine the proposed groundwater SDLs that reflect the ESLT (Section 6).

6. Authority Groundwater Assessment Framework

The Authority has developed a groundwater assessment framework that has been used to determine the SDLs in the proposed Basin Plan. In applying the framework a two- stage approach was taken. The first stage considered the characteristics of the individual groundwater resource units. Each groundwater SDL unit was characterised as either:

- Deep groundwater;
- Non-renewable groundwater;
- Connected groundwater; or
- Non-connected groundwater.

The second stage assessed the Authority's determination of the BDL and assessment of the PEL in conjunction with the current or proposed groundwater management arrangements to determine the SDL for each groundwater SDL resource unit. The assessments within each of the characterisation groups considered:

- is there an existing reduction program in place;
- is the BDL greater than the PEL;
- is the BDL equal to the PEL;
- is the BDL less than the PEL; and
- is there more up to date science or knowledge, or existing or proposed water management arrangements in place and how do they relate to the BDL and PEL considerations.

For each assessment the Authority then applied a specific approach to further refine the SDLs. The approaches applied by the Authority were:

- Connected resources (specific approach see Section 6.3);
- Existing reduction program;
- SDL resource units with proposed reductions (informed by BDL greater than PEL);
- Existing planning arrangements/ up to date science (variable BDL/PEL outcome); or
- Unassigned groundwater (BDL less than PEL).

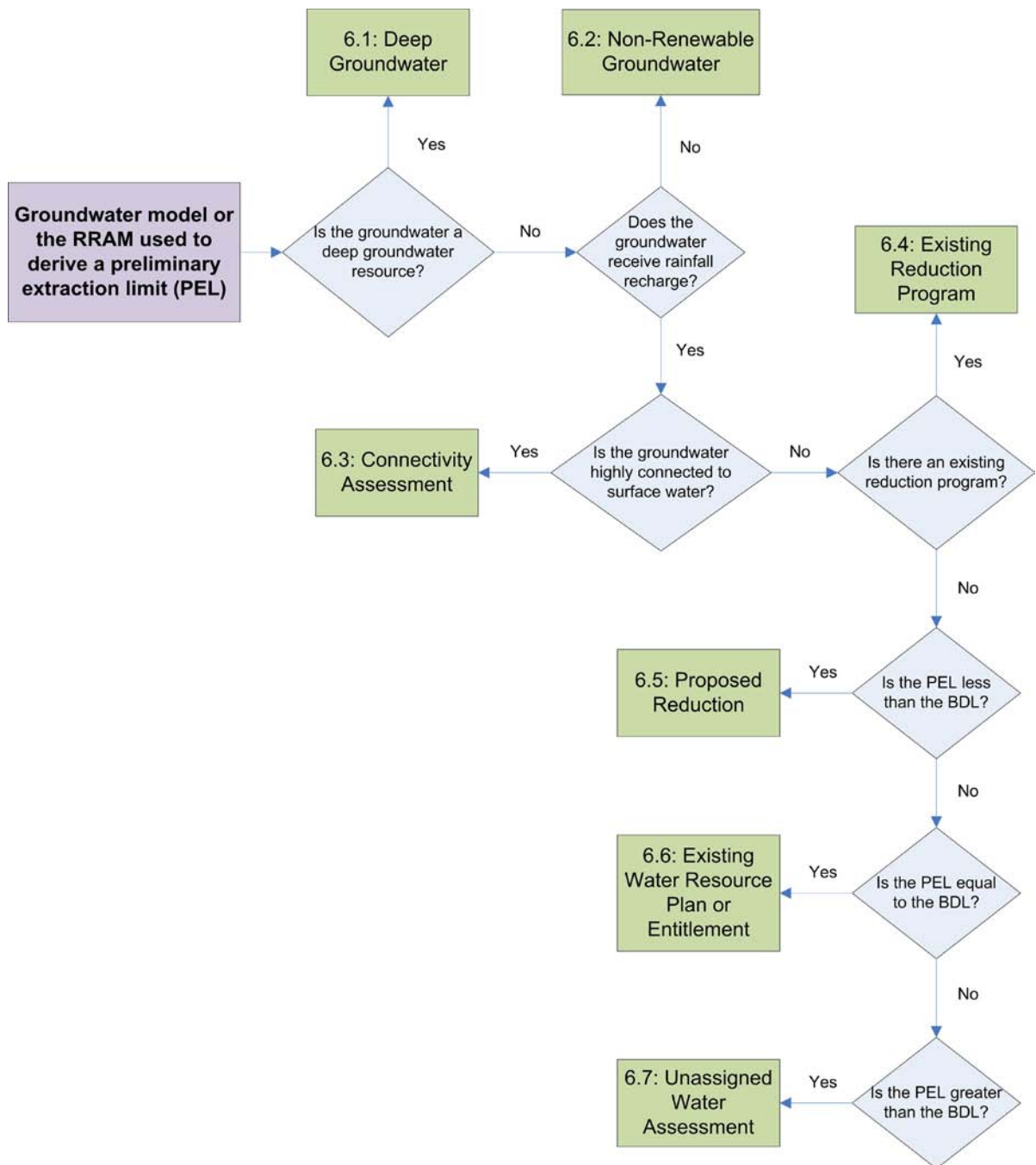
The application of the groundwater assessment framework has resulted in seven areas in which the groundwater SDL resource units can be categorised. The categories are outlined in the following sub-Sections of this report:

- 6.1 Deep groundwater
- 6.2 Non-renewable groundwater
- 6.3 Connected resources
- 6.4 Existing reduction program;
- 6.5 SDL resource units with proposed reductions;
- 6.6 Existing planning arrangements/ up to date science;
- 6.7 Unassigned groundwater

Figure 5 outlines the process of assessment that was used to determine which assessment was applied to the preliminary extraction limit for each SDL resource unit. Additionally,

Appendix A provides a summary of the predominant assessment that has been applied to individual groundwater SDL resource units.

Figure 5 Groundwater assessment framework decision tree



6.1 Deep groundwater resources

Deep groundwater resources are described as the groundwater resources below those currently accessed for productive use and S&D needs. In general, they occur deeper than 200m below the land surface. Interest in groundwater extraction has now extended to a number of the deep groundwater resources that, under the *Water Act 2007*, are considered Murray-Darling Basin water resources.

The incorporation of deep groundwater in the proposed Basin Plan is an outcome of the Authority's improved knowledge regarding these systems. These groundwater resources are not normally accessed for agricultural purposes because of the substantial depth of the water and its generally low quality make it an uneconomic proposition. Each of the Basin states has been consulted during the development of the deep groundwater assessment.

SDL resource units for known deep groundwater resources are attributed to either the WRP area where the deep groundwater resource outcrops or, if the deep groundwater is fully sub-cropped, the WRP area where the majority of the deep groundwater resource underlies. The proposed SDL volumes are based on the available knowledge of these deep aquifers and it is possible that new knowledge may inform a change to these SDLs as part of the 2015 review of the Basin Plan (proposed Basin Plan s6.06 (1)(d) and s6.07). There are 3 deep groundwater resources recognised in the proposed Basin Plan (Appendix A) that are described below.

The total SDL for the 3 deep groundwater resource units is 304.5 GL/year, representing 7.0% of the overall Basin wide total of groundwater SDLs.

6.1.1 New South Wales

In New South Wales, there are two deep groundwater SDL resource units: the Gunnedah-Oxley Basin (GS 70) and the Oaklands Basin (GS 71).

The Gunnedah-Oxley Basin lies in northern NSW (Figure 4) and it has been defined in the proposed Basin Plan as "Groundwater in the Gunnedah-Oxley Basin excluding groundwater in Eastern Porous Rock: Macquarie–Castlereagh (GS 17) and Eastern Porous Rock: Namoi–Gwydir (GS 18)". The Gunnedah-Oxley Basin has an SDL of 300 GL/year and the take from this SDL resource area will be reported through the Eastern Porous Rock WRP area.

Recharge to the Gunnedah-Oxley Basin occurs through the overlying Eastern Porous Rock (GS17 & GS18) and Liverpool Ranges Basalt (GS27) SDL resource units. The total recharge for the 3 SDL resource units is approximately 800 GL/year and the combined SDL, of the 3 overlying units and the Gunnedah-Oxley Basin is 331.06 GL/year. Additionally, it should be noted that the Gunnedah-Oxley Basin SDL represents 0.006% of the groundwater storage in the Gunnedah-Oxley Basin.

The Oaklands Basin SDL resource unit lies in southern NSW (Figure 4) and it has been defined as the water resources within the Oaklands Basin. The Oaklands Basin receives negligible volumes of recharge and could be classified as a non-renewable groundwater resource, however given its geological characteristics the Authority have classified it as a deep resource. The SDL for the resource is 2.5GL/year, which represents 0.0006% of the

storage. Extraction from Oaklands Basin will be reported through the Murray Alluvium WRP area.

6.1.2 Queensland

In Queensland, there are deep groundwater resources in the Basin that lie beneath the Great Artesian Basin. No SDL resource units are included in the proposed Basin Plan for these resources as it is highly unlikely that the resources will be developed in the period of the first Basin Plan.

6.1.3 Victoria

There have been no deep groundwater resources specified in Victoria in the proposed Basin Plan.

6.1.4 South Australia

The Renmark Group, in the existing Mallee SDL resource unit (GS 3), has an SDL of 2 GL/year as part of the deep groundwater assessment. The Authority decided not to establish an additional deep groundwater SDL resource unit and included the deep groundwater SDL component in the GS 3 Mallee SDL resource unit. This aligns with the requirement of the *Water Act 2007* that boundaries of water resource plan areas must align as far as possible with existing water management boundaries.

6.2 Non-renewable resources

A non-renewable groundwater resource is one which received recharge during a different climatic period (e.g. several thousand years ago), and is now a semi-confined or confined aquifer receiving negligible recharge. Non-renewable groundwater can have a very large storage which, to a certain point, can be extracted with minimal environmental consequences. Determinations on current extraction regimes under existing water resource plans are based on an acceptable rate of decline of the non-renewable groundwater resource.

Within the Basin, there are 3 SDL resource units that have been treated as non-renewable resources: Mallee (GS 3), West Wimmera (GS 9a) and Wimmera-Mallee Border Zone (GS 9c) (Appendix A). These SDL resource units straddle the South Australian and Victorian Border (Figure 2). The extraction of groundwater along the border is regulated by a cross-border agreement contained in both South Australian and Victorian state legislation (the *Groundwater (Border Agreement) Act 1986* (SA and Vic.)). This agreement (Border Groundwaters Agreement) allows for the groundwater in the designated area, a 40-km-wide strip centred on the South Australian – Victorian border, to be depleted by approximately 15% in 200 years.

In determining the SDL for SDL resource units with non-renewable resources, the Authority carried out its own assessment of the current extraction limits in the state water plans. The Authority determined that the extraction limits in the state plans would not compromise the ESLT characteristics within the time frame of the Basin Plan and that the state extraction limits were subsequently adopted as the SDLs.

The proposed SDLs for non-renewable groundwater in the Mallee in South Australia and in western Victoria reflect the maximum permitted rate of groundwater decline under the state Acts for the Border Groundwaters Agreement area. The principles used in the Border Groundwaters Agreement area have also been applied to the surrounding Mallee groundwater which is also considered to be non-renewable water.

The total SDL for the 3 non-renewable resource units is 110.4 GL/year, representing 2.5% of the overall Basin wide total of groundwater SDLs.

6.3 Connected Systems

The connectivity between groundwater and surface water is variable across the Basin. Within the Basin connected systems can be classified (Parsons Brinckerhoff 2009) in the following way:

- fractured rock systems (e.g. Lachlan Fold Belt: Lachlan) - variable connectivity due to the nature of the geology of these streams;
- shallow alluvial aquifers (e.g. Belubula Alluvium) – typically highly connected system with the stream gaining water from the groundwater;
- mid-valley alluvial aquifer systems (e.g. Mid-Murrumbidgee Alluvium) – generally gaining streams;
- floodplain alluvial aquifer systems (e.g. Victorian Riverine Sedimentary Plain and Lower Namoi Alluvium) – streams are mostly disconnected from the aquifer and lose water to the groundwater at a maximum rate; and
- end of system aquifers (e.g. SA Murray and NSW Western Porous Rock) – typically gaining streams but the discharge is usually saline.

For the purposes of determining the SDLs those areas that were classified as losing streams (floodplain alluvial aquifer systems) and end of system aquifers have been treated as non-connected systems. In the case of the losing streams, this is due to the fact that further groundwater extraction has no further impact on surface water resources. Saline end of system aquifers were treated in a similar manner as groundwater extraction in these systems can be beneficial to surface water resources as it reduces the volume of salt entering rivers and streams.

The Authority considered an SDL resource unit to be highly connected, if during the RRAM process, the risk to the surface water streams (key ecosystem function (KEF)) was determined to be high or medium. The criterion used to assess the risk is:

- High – In the current state, groundwater discharge provides base flow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion;
- Medium – The rivers in the SDL resource unit are regulated and highly connected to the groundwater system (i.e. >50% of the groundwater pumped would have contributed to stream flow within 50 years); or
- Low – The rivers in the SDL resource unit are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on stream flow within 50 years).

Across the Basin, 23 groundwater resource units were identified as connected systems and the SDL has been set at the BDL to ensure that the KEF (i.e. Base flows) is not compromised (Appendix A). Of these, 20 occur in NSW, 2 in Victoria and 1 in Queensland.

The total SDL for the 23 connected groundwater SDL resource units is 254.8 GL/year, representing 5.9% of the overall Basin wide total of groundwater SDLs.

There are a further 13 large fractured rock systems assessed as having a high risk to the KEF due to the presence of unregulated rivers. The Authority considered that these systems

were best addressed through the application of unassigned water assessment to set the SDL (Section 6.3.3).

6.3.1 Highly connected systems

For the proposed Basin Plan, the highly connected systems assessment is to restrict the SDL to the BDL. This ensures that, in systems that have been determined to have a high or medium risk to surface water flows, groundwater extraction will have no further impact on surface water resources beyond the level that is accounted for within the BDL.

In most cases (18 out of the 23 highly connected SDL resource units) the PEL was equal to or less than the BDL. In 15 of these SDL resource units the PEL was less than the BDL and further investigations were carried out. It was determined that river recharge (not a component of the WAVES model) was sufficient in these systems to ensure that in capping the SDL at the BDL that will be no further impact on surface water resources beyond the level of that is accounted for within the BDL. Most of these systems were narrow alluvial valleys in which recharge from rivers is a significant component of the aquifer water balance.

6.3.2 Highly connected systems with the potential for groundwater/surface water trade

Of the 23 highly connected systems, there are 5 SDL resource units (3 in NSW and 2 in Victoria) that are considered to be highly connected where the PEL is greater than the BDL. In these systems an increase in groundwater extraction would have an impact on the KEF (i.e. base flows), however the preliminary extraction limit suggests that further development could occur in the groundwater resource without compromising the other ESLT characteristics.

To allow further development of the groundwater resource there would be a need for an offsetting reduction in surface water extraction. This would ensure that the KEF values of the relevant surface water system will be maintained. Put simply, it is the Authority's view, that although the groundwater SDL is set at the BDL, further development could occur through trading surface water entitlement to the groundwater system.

In these systems there is the opportunity to increase surface water extraction through the purchase of groundwater entitlement and vice versa. For the potential trades to occur there must be an understanding of the connectivity of the system.

An example of a water management plan that deals with the issue of groundwater/surface water trade is the Victorian draft water management plan for the Upper Ovens River Water Supply Protection Area. This draft plan proposes trade between groundwater and surface water in zones within the Upper Ovens River catchment (Upper Ovens WSPA Consultative Committee 2011).

6.3.3 Large fractured rock systems

There are 13 SDL resource units (8 in NSW, 2 in Queensland and 3 in Victoria) which feature fractured rock hydrogeological formations in which connectivity to surface water is reliant on faults and fractures in the geological strata (Appendix A). These faults and fractures result in the connectivity in the systems being variable. Additionally, the localised faults and fractures, in these large systems, may have no connection to surface water

resources (e.g. a bore extracting water 4 km from a stream may have no impact on a stream as the fracture the bore is drawing water from does not intersect the stream).

The Authority had originally classified these systems as highly connected, however, after further consideration, the Authority determined that this was overly conservative, and that the consideration of the risk of groundwater extraction to surface water resources, as part of the RRAM process in these large areas would ensure that the surface water KEF, and the other ESLT characteristics, would not be compromised. Further protection of the surface water KEF is expected to be provided through the inclusion of local management rules in water resource plans.

Given this decision, these groundwater SDL resource units met the criteria for the unassigned water assessment (Section 6.7). Using the unassigned water assessment, in these fractured rock systems, the maximum volume that is allowed to be extracted in any one of the 13 resource units represents 8% of the total SDL resource unit recharge.

The SDLs for the large fractured rock systems are included within the unassigned groundwater total SDL in Section 6.7.

6.4 Adopt Existing Reduction Program

The Achieving Sustainable Groundwater Entitlements program (ASGE) was announced in 2005. The program, funded by the Commonwealth and NSW governments, was introduced to achieve the sustainable use of groundwater resources in 7 alluvial groundwater systems in NSW:

- Lower Gwydir;
- Lower Macquarie;
- Lower Murray;
- Lower Murrumbidgee;
- Lower Namoi;
- Lower Lachlan; and
- Upper Namoi.

These systems had been identified as over-allocated and over used and reductions in entitlement were required to achieve sustainable levels of entitlement and use. The program was put in place through the development and introduction of water sharing plans in the 7 areas. Table 1 details the ASGE reductions in entitlements that ranged from 46% to 69%:

The numerical groundwater modelling carried out for the Authority indicated that the PEL was less than the BDL for 4 of the SDL resource units and recommended further reductions in diversion limits in these systems. However, the Authority received feedback focused on the use of the numerical modelling and the need for further cuts when the ASGE process is yet to run its course and any outcomes have not been realised.

After receiving the feedback the Authority carried out further investigation and consideration including:

- additional consideration of the risks to the ESLT characteristics for the resources;
- the consideration of the peer reviews of the numerical models; and
- an assessment of additional information supplied by both the NSW government and water users.

In particular, the Authority considered the additional uncertainties associated with modelling groundwater systems that are undergoing a reduction program and the resultant change in groundwater extractions. Additionally, these resource units have large groundwater storages (a minimum of 200 years at current levels of use) and there is a low risk of depleting the volume of groundwater stored in these aquifers within the period of the first Basin Plan. The large storages also suggests that the overall risk to the resource is relatively low for the period of the first Basin Plan.

Table 1: Affect of the ASGE program on groundwater entitlements.

Groundwater Resource unit	Initial Entitlement (GL)	Reduction Volume (GL)	Entitlement at the completion of ASGE (GL)	Reduction (%)	Plan completion date
GS 29 Lower Gwydir Alluvium	70.7	38.4	32.3	54.3%	30 Jun 17
GS 31 Lower Macquarie Alluvium	136.8	67.5	69.3	49.3%	30 Jun 17
GS 32 Lower Murray Alluvium	267.6	183.9	83.6	68.7%	30 Jun 17
GS 33 Lower Murrumbidgee Alluvium	514.6	234.6	280.0	45.6%	30 Jun 17
GS 34 Lower Namoi Alluvium	172.2	86.2	86.0	50.1%	30 Jun 17
GS 30 Lower Lachlan Alluvium	212.3	104.3	108.0	49.1%	30 Jun 18
GS 51 Upper Namoi Alluvium	301.9	179.8	122.1	59.6%	30 Jun 17
Total	1,676.1	894.9	781.2	53.7%	

Given these factors the Authority considered that an approach should be adopted, that allowed the reduction program to be completed and the outcomes determined before any further changes to the SDL were considered at a later stage. For the 7 NSW SDL resource units where the ASGE program is in place, the SDLs in the proposed Basin Plan have been set at the final plan limit plus S&D rights. The Authority will continue to monitor and assess the impacts of groundwater take in these systems with the aim of reviewing the plan limits on an ongoing basis.

The total SDL for the groundwater SDL resource units where the Authority has adopted the reduction program is 821.6 GL/year, representing 18.9% of the overall Basin wide total of groundwater SDLs.

6.5 SDL Resource Units with proposed reductions

Under the proposed Basin Plan the Authority has assessed two SDL resource units as having a higher BDL than SDL: the Victorian Riverine Sedimentary Plain (GS 8f) and the Upper Condamine Alluvium (GS67). In both cases, the relevant state is managing groundwater extraction to ensure that water users have continued access to the resource.

The total SDL for the 2 groundwater SDL resource units where the Authority has proposed a reduction is 213.5 GL/year, representing 4.9% of the overall Basin wide total of groundwater SDLs.

6.5.1 Goulburn-Murray: Victorian Riverine Sedimentary Plains (GS8f)

The Victorian Riverine Sedimentary Plain underlies surface-water catchments in Victoria, from the Loddon in the west to the Ovens in the east. The hydrogeology of the area consists of a shallow aquifer (Shepparton formation) that overlies a number of deeper aquifers associated with the Calivil and Renmark hydrogeological formations. A number of these deeper aquifers are known as the 'deep lead' systems.

Groundwater extraction from the shallow aquifer in the area is managed to lower watertable levels and reduce the risk of salinisation. The shallow aquifers are currently managed under the Shepparton Irrigation Region Water Supply Protection Areas (WSPA) salinity management plan. This plan is currently under review and a new plan is expected to be in place prior to the end of 2012. The Authority has adopted the current level of entitlement to allow for the maximum flexibility for the management of the shallow aquifer (Section 6.6).

Victoria manages the more heavily developed parts of the deep aquifers through water management plans linked to Groundwater Management Areas (GMAs) and WSPAs (Figure 6). There are 5 Victorian GMAs and WSPAs in the SDL resource unit:

- Katunga WSPA;
- Lower Campaspe WSPA;
- Mid Loddon GMA
- Mid Goulburn GMA
- Loddon Highlands WSPA

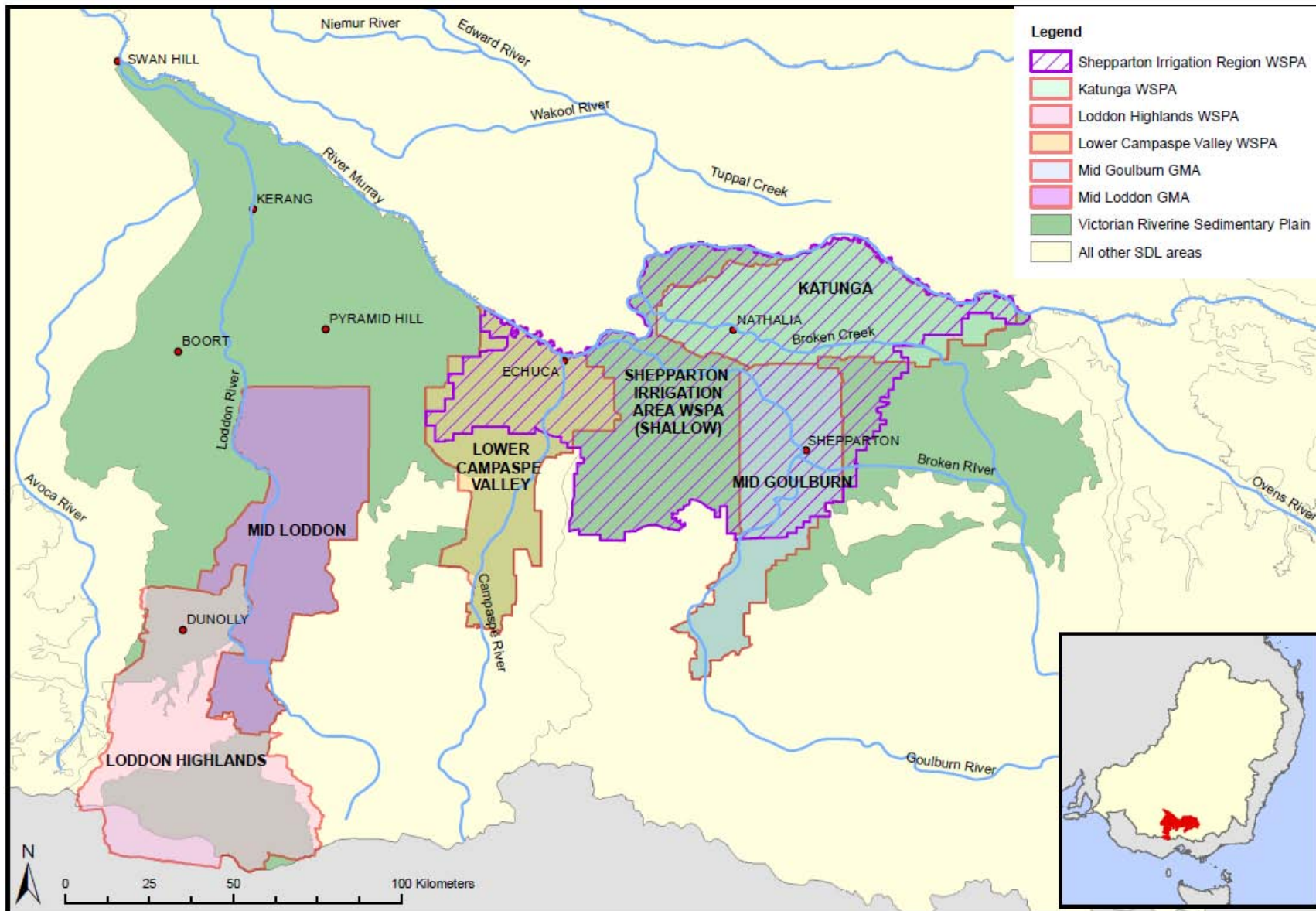
The volumes of entitlement and average consumption vary between the 5 WSPAs and GMAs.

Table 2 Proposed Victorian Riverine Sedimentary Plain BDL & SDL

	Ent. (GL/y)	S&D (GL/y)	Current use [#] (GL/y)	Proposed Basin Plan		
				BDL (GL/y)	PEL (GL/y)	SDL (GL/y)
Shallow	239.39	4.76	92.06	244.14	120	244.14
Deep	188.65	4.06	97.23	174.98	127	127

[#]Current use includes metered use and estimated S&D use.

Figure 6 Victorian Riverine Sedimentary Plain – Victorian management Units



Victorian Riverine Sedimentary Plain Deep: Calivil and Renmark Formations (GS 8f)

The Baseline Diversion Limit (BDL) of 174.98 GL/year reflects the Authority's policy of adopting the current plan limits and rules used to manage extraction. In the case of the Katunga WSPA the current water management plan restricts use to 70% of entitlement, which was incorporated by the Authority when the BDL was determined.

The proposed SDL for the Victorian Riverine Sedimentary Plain deep SDL resource unit (Calivil Formation and Renmark formations) is 127 GL/year. The SDL was derived by assessing a range of extraction scenarios in a numerical groundwater model to determine the impact on the ESLT characteristics. In considering the ESLT characteristics, the SDL resource unit was assessed as having a high levels of risk to:

- key environmental assets, with Lower Goulburn River Floodplain, Barmah-Millewa Forest and Gunbower Forest all located within the SDL resource unit.
- key ecosystem function, given there are unregulated gaining rivers and streams in the southern portion of the SDL resource unit that depend on base flow derived from groundwater.

Additionally, there is a risk of contamination of fresh groundwater from saline groundwater in the shallow Shepparton Formation and saline parts of the deeper Calivil and Renmark aquifers. The numerical groundwater model for this area has been peer reviewed (Merrick, NP et al. 2010).

The difference between the BDL and the proposed SDL is 47.98 GL/year. However, the Authority understands that the proposed SDL does not represent a reduction in groundwater use and in fact the proposed SDL of 127 GL/year is higher than the maximum use recorded across the deep resources of the SDL resource unit. The information that the Authority has in relation to use in the deep aquifers is:

- the average yearly metered use of 97.23 GL/year for 2003–04 to 2007–08; and
- maximum use for the SDL resource unit was approximately 105 GL/year in 2006–07.

The Commonwealth 'bridging the gap' commitment will apply to this area and the necessary entitlements will be purchased to ensure use stays below the SDL. The amount and location of the entitlements that need to be purchased to achieve the SDL will be the subject of further work and consultation with the Victorian government and water users in the area.

6.5.2 Upper Condamine Alluvium GS67

The Upper Condamine Alluvium SDL resource unit (GS 67) is located in the headwaters of the Condamine River, and extends from Killarney, in the south-east, to downstream of Chinchilla, in the west. It is an alluvial groundwater system that has been heavily utilised to grow irrigated crops.

For the determination of the BDL and SDL, the Authority has divided the Upper Condamine Alluvium into two areas, the Central Condamine Alluvium (CCA) which matches Queensland's management area; and the area outside the CCA (called the Tributaries). The Queensland government has managed extraction in the CCA through regulation, although a state water resource plan for the groundwater in the area is under development.

Central Condamine Alluvium (CCA) Groundwater Management Area

The CCA is made up of 8 sub-areas. Five of the sub-areas (1, 2, 3, 4 and 5) make up the former Condamine Groundwater Management Area (CGMA), which also corresponds to the model domain. The remaining three sub areas (6, 7 and 8) of the CCA are not within the model domain.

For the CCA, the BDL of 81.4 GL/year is based on the Authority BDL policy of using entitlement (plus S&D) along with the effect of any rules managing extraction (Section 4).

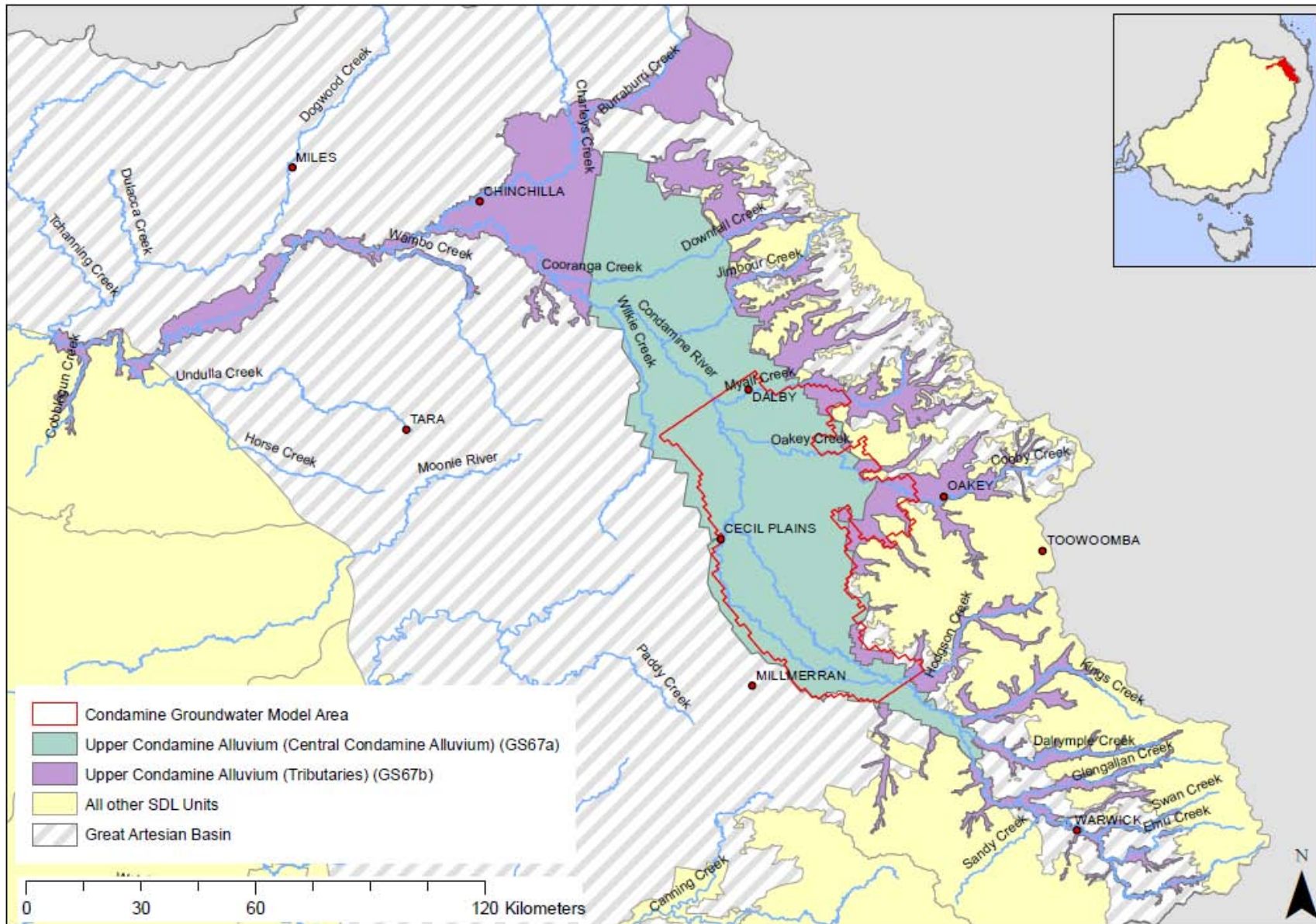
The breakdown of the BDL is:

- metered use from 2002/03 to 2007/08 for the 5 sub-areas of the former CGMA (52.6 GL/year) (metered use was used in this case to estimate the limit imposed by the current arrangements); plus
- 100% of entitlement for sub-areas 6, 7 and 8 (22.8 GL/year); plus
- S&D rights for the whole Central Condamine Alluvium (6 GL/year).

Note: Entitlement, rather than current use, was used for sub-areas 6, 7 and 8 because there is no metering in these zones.

To determine the SDL for the CCA the Authority carried out numeric groundwater modelling (Appendix B) and the Recharge Risk Assessment. The groundwater model determined that the SDL volume for the CCA is 46 GL/year (including S&D). This SDL represents a reduction of 35.4 GL/year from the BDL of 81.4 GL/year. The modelling carried out by the Authority confirmed earlier modelling carried out as part of the CSIRO Murray-Darling Basin Sustainable Yields project. The SDL concurs with an earlier proposal by the Queensland government that had been discussed with local water users but had not been adopted or ratified under the Queensland water planning process.

Figure 7 GS 67 Upper Condamine Alluvium



Tributaries outside the CCA

As there is no plan or metered use in the Tributaries, the BDL of 45.5 GL/year is based on entitlement (42 GL/year) plus S&D rights (3.5 GL/year).

For the Tributaries area, the PEL of 40.5 GL/year, was determined using the RRAM process. The PEL represents the volume which has been assessed to meet the environmentally sustainable level of take requirements and has been adopted as the SDL. This volume is 5 GL/year below the BDL and was set due to the high risk of salinisation and the high level of uncertainty associated with the Tributaries area.

Table 3 Proposed Upper Condamine Alluvium BDL & SDL

	Ent. (GL/y)	S&D (GL/y)	Proposed Basin Plan		
			BDL (GL/y)	PEL (GL/y)	SDL (GL/y)
Upper Condamine Alluvium – Central Condamine Alluvium	86.15	6	81.4	46	46.0
Upper Condamine Alluvium - Tributaries	42	3.5	45.5	40.5	40.5
Total	128.15	9.5	126.9	86.5	86.5

Overall the BDL for the Upper Condamine Alluvium is 126.9 GL/year and the SDL 86.5 GL/year, representing an overall reduction of 40.4 GL/year or 32%.

The Commonwealth 'bridging the gap' commitment will apply to this area and the necessary entitlements will be purchased to ensure use stays below the SDL. The amount and location of the entitlements that need to be purchased to achieve this outcome will be the subject of further investigation and consultation.

6.6 Existing water resource plans

There are 13 SDL resource units where the Authority has decided to adopt an existing or proposed transitional or interim water resource plan limit as the SDL. Of these, 4 occur in SA, 5 in NSW, 1 each in Victoria and the ACT, and 2 in Queensland (Appendix A).

Prior to adopting the state extraction limit the Authority assessed the plan extraction limit against the preliminary extraction limit to determine if the plan limit reflected an environmentally sustainable level of take. The assessment considered if the state extraction limit and the science underpinning it represents the most up to date scientific knowledge (i.e. a more thorough assessment than RRAM, while also being consistent with the *Water Act 2007*).

This assessment acknowledges that there are areas in the Basin where the Basin states have invested considerable resources into understanding the groundwater system and their assessment of sustainability may be more appropriate than the RRAM.

The total SDL for the 13 groundwater SDL resource units where the Authority has adopted of the existing water resource plan extraction limits is 507.0 GL/year, representing 11.7% of the overall Basin wide total of groundwater SDLs.

6.7 Unassigned water

Across the Basin there are SDL resource units with low levels of development, and in these systems there is the potential to increase groundwater extraction without compromising ESLT characteristics. SDL resource units with this potential have been termed unassigned water areas, with the unassigned water defined as the sustainable volume of water available for extraction above the BDL.

In many cases these systems have low levels of development as the groundwater can be difficult to access, or is of poor quality, and are subsequently not suitable for agricultural production. In unassigned water areas there may be water suitable for S&D or mining activities. In some situations, the taking of saline groundwater can be a beneficial use as it may reduce the volume of saline water which enters the rivers.

A total of 36 unassigned water SDL resource units were identified, including the 5 Lachlan Fold Belt resource units (Section 6.7.2) and the SA Murray salt interception scheme (Section 6.7.3). Of the 36 resource units, 15 are in NSW, 4 in SA, 7 in Victoria and 10 in Queensland.

The total SDL for all 36 groundwater SDL resource units where the Authority has adopted the unassigned water assessment is 2,127.8 GL/year and this represents 49.0% of the overall Basin wide total of groundwater SDLs.

For the SDL resource units with unassigned water, it should be noted that:

- the number (36) of SDL resource units with unassigned water (Appendix A) is a reflection of the Authority setting extraction limits for the first time for many SDL resource units across the Basin;
- for the 16 unassigned water SDL resource units with an SDL over 25% of the available recharge, the water quality is brackish to saline and the groundwater is difficult to access;
- there are 12 SDL resource units where the unassigned water volume represents less than 5% of the available recharge; and
- the remaining 8 SDL resource units have an SDL representing between 5% and 25% of the available recharge.

6.7.1 Unassigned Water Assessment

Of the 36 SDL resource units, where the unassigned water assessment has been applied (Appendix A), in 30 areas the PEL was further reduced due to ESLT considerations. The unassigned water assessment is used to determine the SDLs if the resource unit has not been the subject of one of the previous assessments or methods (Figure 5) and the PEL is greater than the BDL.

In these cases, the unassigned water assessment reduces the risks associated with further development of the groundwater resource by decreasing the PEL by 50% of the available water above the BDL to determine the SDL. It should be noted that the unassigned water assessment is applied after the RRAM process has considered the risks of groundwater extraction to the 4 ESLT characteristics and uncertainty to determine the PEL.

As noted in Section 6.3.3, there are 13 large fractured rock SDL resource units that have been assessed as having a high risk to the KEF (i.e. base flows). The connectivity to surface water in these systems relies on faults and fractures in the geological strata and this results in variable connections to surface water. For these 13 areas the Authority used the unassigned water assessment method (Section 6.3.3). Of the 13 SDL resource units, 9 have had the SDL determined by applying the methodology described in this sub-section. The remaining 4 SDL resource units are associated with the Lachlan Fold Belt as described below.

6.7.2 NSW Lachlan Fold Belt resource units

There are 5 SDL resource units associated with the NSW Lachlan Fold Belt (Lachlan, Macquarie-Castlereagh, Murray, Murrumbidgee and Western). The Lachlan Fold Belt covers the width of the Basin across parts of Victoria, southern NSW, from around Canberra to around Broken Hill.

Of these 5 SDL resource units, 4 (Lachlan, Macquarie-Castlereagh, Murray and Murrumbidgee resource units) are the remainder of the 13 large fractured rock SDL resource units discussed in Section 6.3.3. The other SDL resource unit in this category is the Lachlan Fold Belt (Western) which, while also a large fractured rock aquifer, it was not considered under Section 6.3.3 as it was considered essentially disconnected from surface water.

For the first 4 SDL resource units (Lachlan, Macquarie-Castlereagh, Murray and Murrumbidgee resource units) the Authority assessed that there was less risk to the ESLT characteristics due to the hydrogeological characteristics of these systems. The limited intersection of the faults and fractures with rivers and streams result in the connectivity in the systems being variable or there may be no connection to surface water resources. As a consequence, the unassigned water was not reduced by 50% and the SDL equals the PEL.

In the case of the Lachlan Fold Belt: Western, it has been assessed as having a low risk to the KEF (i.e. base flow). As a result, the unassigned water was not reduced by 50% and the SDL equals the PEL.

The SDL represents 5% of the available recharge for these 4 SDL resource units and 53% of the available recharge for the Lachlan Fold Belt: Western.

6.7.3 Salt Interception Schemes

The Authority and states manage a number of salt interception schemes (SISs) across the Basin that are designed to keep salt out of the Basin rivers. The schemes typically involve groundwater pumping and drainage projects that intercept saline water flows and dispose of them by evaporation.

There are several SIS across the basin. The requirements for the SISs across the Basin are accommodated within the SDL for the individual SDL resource units where the SISs are located.

There is one groundwater SDL resource unit (SA Murray SIS (GS 7)) where groundwater extraction is solely for salt interception. The BDL is 11 GL/y, reflecting the present SIS extraction. It is projected that by 2050 the SIS extraction will increase to 23 GL/year. As this

projected extraction rate is accommodated within the PEL of 28.6 GL/year, the PEL has been adopted as the SDL.

7. Groundwater BDLs and SDLs

This report provides a description of the methods and assessments used to determine the groundwater SDLs for the proposed Basin Plan. It demonstrates the logic used to determine the SDLs in the proposed Basin Plan (proposed Basin Plan, Schedule 4, p172 to 186 and the Plain English summary of the proposed Basin Plan, Schedule 4, p87 to 93). Appendix C provides a summary of Schedule 4 of the proposed Basin Plan and, to assist stakeholders, the BDLs and SDLs that were under consideration at the time of the Guide to the proposed Basin Plan.

Appendix A. Distribution of assessment application

Appendix A groups the SDL resource units into their categories within the assessment options for all of the 79 SDL resource units.

Assessment option	Category	SDL resource unit
6.1 Deep groundwater		GS 3 – Mallee (Renmark Group) GS 70 – Gunnedah–Oxley Basin GS 71 – Oaklands Basin
6.2 Non–renewable groundwater		GS 3 – Mallee (Murray Group Limestone) GS 9a – West Wimmera (Murray Group Limestone) GS 9a – West Wimmera (Tertiary Confined Sands Aquifer) GS 9c – Wimmera–Mallee Border Zone (Murray Group Limestone) GS 9c – Wimmera–Mallee Border Zone (Tertiary Confined Sands Aquifer)
6.3 Connected systems	6.3.1 Highly connected systems	GS 11 – Bell Valley Alluvium GS 12 – Belubula Alluvium GS 14 – Castlereagh Alluvium GS 15 – Collaburragundry–Talbragar Alluvium GS 16 – Cudgegong Alluvium GS 19 – Inverell Basalt GS 35 – Manilla Alluvium GS 36 – Mid–Murrumbidgee Alluvium GS 38 – NSW Border Rivers Alluvium GS 39 – NSW Border Rivers Tributary Alluvium GS 45 – Peel Valley Alluvium GS 47 – Upper Gwydir Alluvium GS 48 – Upper Lachlan Alluvium GS 49 – Upper Macquarie Alluvium GS 50 – Upper Murray Alluvium GS 52 – Upper Namoi Tributary Alluvium GS 55 – Young Granite GS58 – Queensland Border Rivers Alluvium
	6.3.2 Highly connected systems with the potential for groundwater/surface water trade	GS 8c – Murray Highlands GS 8d – Ovens Highlands GS 27 – Liverpool Ranges Basalt GS 44 – Orange Basalt GS 53 – Warrumbungle Basalt

Assessment option	Category	SDL resource unit
6.4 Adopting existing or proposed reduction program		GS 29 – Lower Gwydir Alluvium GS 30 – Lower Lachlan Alluvium GS 31 – Lower Macquarie Alluvium GS 32 – Lower Murray Alluvium (deep) GS 33 – Lower Murrumbidgee Alluvium GS 34 – Lower Namoi Alluvium GS 51 – Upper Namoi Alluvium
6.5 SDL resource units with proposed reductions		GS 8f – Victorian Riverine Sedimentary Plains (deep) GS 67a – Upper Condamine Alluvium (Central Condamine Alluvium) GS 67b – Upper Condamine Alluvium (Tributaries)
6.6 Existing water resource plan		GS 1 – Angas Bremer (Murray Group Limestone) GS 2 – Eastern Mount Lofty Ranges GS 4 – Marne Saunders (all layers) GS 5 – Peake–Roby–Sherlock (all layers) GS 8f – Victorian Riverine Sedimentary Plains (shallow) GS 13 – Billabong Creek Alluvium GS 18 – Eastern Porous Rock: Namoi–Gwydir GS 26 – Lake George Alluvium GS 28 – Lower Darling Alluvium GS 32 – Lower Murray Alluvium (shallow) GS 56 – ACT (groundwater) GS 64 – St George Alluvium: Condamine–Balonne (deep) GS 68 – Upper Condamine Basalt
6.7 Unassigned groundwater	6.7.1 $SDL = BDL + 50\%$ of the unassigned water	GS1 – Angas Bremer (Quaternary) GS 3 – Mallee (Pliocene Sands) GS 6 – South Australian Murray GS 8a – Goulburn–Broken Highlands* GS 8b – Loddon–Campaspe Highlands* GS 8e – Ovens–Kiewa Sedimentary Plain GS 9a – West Wimmera (Loxton Parilla Sands) GS 9b – Wimmera–Avoca Highlands* GS 9c – Wimmera–Mallee Border Zone (Loxton Parilla Sands) GS 9d – Wimmera–Mallee Sedimentary Plain GS 10 – Adelaide Fold Belt GS 17 – Eastern Porous Rock: Macquarie–Castlereagh* GS 20 – Kanmantoo Fold Belt GS 37 – NSW Alluvium above the Great Artesian Basin GS 40 – NSW Sediments above the Great Artesian Basin GS 41 – New England Fold Belt: Border Rivers* GS 42 – New England Fold Belt: Gwydir* GS 43 – New England Fold Belt: Namoi* GS 46 – Upper Darling Alluvium GS 54 – Western Porous Rock GS 57 – Condamine Fractured Rock* GS 59 – Queensland Border Rivers Fractured Rock*

Assessment option	Category	SDL resource unit
		GS 60 – Sediments above the Great Artesian Basin: Border Rivers GS 61 – Sediments above the Great Artesian Basin: Condamine–Balonne GS 62 – Sediments above the Great Artesian Basin: Moonie GS 63 – Sediments above the Great Artesian Basin: Warrego–Paroo–Nebine GS 64 – St George Alluvium: Condamine–Balonne (shallow) GS 65 – St George Alluvium: Moonie GS 66 – St George Alluvium: Warrego–Paroo–Nebine GS 69 – Warrego Alluvium
	6.7.2 SDL = BDL + 100% of the unassigned water	GS 21 – Lachlan Fold Belt: Lachlan* GS 22 – Lachlan Fold Belt: Macquarie–Castlereagh* GS 23 – Lachlan Fold Belt: Murray* GS 24 – Lachlan Fold Belt: Murrumbidgee* GS 25 – Lachlan Fold Belt: Western
	6.7.3 SDL = RRAM (SIS scheme)	GS 7 – SA Murray SIS

* Large fractured rock system with connectivity (Section 6.3.3)

Appendix B. Modelled SDL resource units

As discussed in Section 5.1 of the report, there were only 11 numerical groundwater models available that cover 13 SDL resource units.

Approach

The modelling approach adopted for the proposed Basin Plan included the formulation of a series of standard predictive scenarios run over a fifty-year period. The scenarios were designed to test possible future extraction limits under different climatic conditions and were compared to a scenario with no groundwater extraction.

Model uncertainty was considered explicitly to account for the fact that all groundwater models will include inaccuracies. Eight criteria were used to rank the level of model uncertainty and this included: the spatial and temporal coverage of groundwater level observations, the accuracy of extraction data, accuracy of recharge estimation, length of calibration period, calibration statistics, accuracy at key indicator sites, representation of the physical process of importance in the catchment and whether the model had been peer reviewed.

The sum of the model uncertainties were converted to a PEL scaling factor by assuming a linear progression from the least uncertain model (scaling factor of 90%) to the most uncertain model (scaling factor of 75%) (i.e. the larger the uncertainty with the model, the larger the reduction made to the recharge potentially available for extraction). The linear scaling and uncertainty factor limits were based on expert opinion. The use of a model uncertainty factor as an input to determining the SDL is a precautionary approach that recognises that there are limitations to the use of numerical models to represent the behaviour of groundwater systems. There are additional modelling uncertainties associated with groundwater systems that are undergoing a reduction program, such as those in the ASGE areas (Section 6.4).

Numerical models have the ability to directly relate extraction scenarios to impacts on ESLT characteristics by the use of Resource Condition Limits (RCLs). RCLs define an acceptable upper limit to the impact on the groundwater resource and are typically described as water levels at key monitoring sites, which might include sites in stressed parts of the aquifer or sites near key environmental assets. A series of sites were established in each model, that are considered to be representative of the aquifer and for which historical records are available. The sites can be considered as barometers of aquifer condition and were used to determine SDLs that did not compromise the watering needs of the ESLT characteristics.

It should be noted that the Authority used the modelling results as an input to determining the preliminary extraction limit and subsequent proposed SDLs. Other lines of evidence, where available, were also considered including: groundwater hydrographs; extraction information; and consultation with the states and water users..

Appendix C. Groundwater BDLs and SDLS

SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)
South Australia								
GS1	Angas Bremer (Quaternary)	6.5	4.0	38.5	0.00	2.18		
GS1	Angas Bremer (Murray Group Limestone)				6.57	6.57		
GS2	Eastern Mount Lofty Ranges	19.3	33.5		34.7	38.5		
GS3	Mallee (Pliocene Sands)	63.4	63.4		0.00	82.8		
GS3	Mallee (Murray Group Limestone)				65.7	65.7		
GS3	Mallee (Renmark Group)				0.00	2.00		
GS4	Marne Saunders (fractured rock)	4.7	4.7		2.09	2.09		
GS4	Marne Saunders (Murray Group Limestone including overlying Quaternary sediments)				2.38	2.38		
GS4	Marne Saunders (Renmark Group)				0.50	0.50		
GS5	Peake–Roby–Sherlock (unconfined limestone)	5.2	5.2		3.41	3.41		
GS5	Peake-Roby-Sherlock (confined strata - Buccleuch formation and Renmark Group)				2.58	2.58		
GS6	SA Murray (Groundwater)	1.8	19.0		1.80	127.8		
GS7	SA Murray Salt Interception Schemes	11.1	28.3		11.1	28.6		

SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)
Victoria								
GS8a	Goulburn-Murray: Goulburn-Broken Highlands	9.8	9.8		15.2	35.8		
GS8b	Goulburn-Murray: Loddon-Campaspe Highlands	9.4	9.4		13.0	16.8		
GS8c	Goulburn-Murray: Murray Highlands	4.4	4.4		5.44	5.44		
GS8d	Goulburn-Murray: Ovens Highlands	3.2	3.2		4.67	4.67		
GS8e	Goulburn-Murray: Ovens-Kiewa Sedimentary Plain	14.7	14.7		28.5	30.5		
GS8f	Goulburn-Murray: Victorian Riverine Sedimentary Plains (deep; Renmark Group and Calivil Formation)	89.6	127.0		175.0	127.0	48.0	27.4
GS8f	Goulburn-Murray: Victorian Riverine Sedimentary Plains (shallow; Shepparton Formation)	83.3	85.0		244.1	244.1		
GS9a	Wimmera-Mallee: West Wimmera (Loxton Parilla Sands)	0.0	12.0		0.00	22.1		
GS9a	Wimmera-Mallee: West Wimmera (Murray Group Limestone)	1.9	25.5		25.5	25.5		
GS9a	Wimmera-Mallee: West Wimmera (Tertiary Confined Sands Aquifer)	0.8	4.0		4.00	4.00		
GS9b	Wimmera-Mallee: Wimmera-Avoca Highlands	0.2	0.2		1.26	3.02		
GS9c	Wimmera-Mallee: Wimmera-Mallee Border Zone (Loxton Parilla Sands)	0.0	9.7		0.00	9.37		
GS9c	Wimmera-Mallee: Wimmera-Mallee Border Zone (Murray Group Limestone)	8.8	14.1		14.1	14.1		
GS9c	Wimmera-Mallee: Wimmera-Mallee Border Zone (Tertiary Confined Sands Aquifer)		1.1		1.10	1.10		
GS9d	Wimmera-Mallee: Wimmera-Mallee Sedimentary Plain	0.6	27.0		24.2	236.2		

SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)
New South Wales								
GS10	Adelaide Fold Belt	3.0	3.3		3.61	5.25		
GS11	Bell Valley Alluvium	2.2	2.2		2.21	2.21		
GS12	Belubula Alluvium	1.9	1.9		2.90	2.90		
GS13	Billabong Creek Alluvium	2.0	6.1		7.50	7.50		
GS14	Castlereagh Alluvium	0.4	0.4		0.63	0.63		
GS15	Collaburragundy-Talbragar Alluvium	3.7	3.7		2.76	2.76		
GS16	Cudgegong Alluvium	1.6	1.6		2.54	2.54		
GS17	Eastern Porous Rock: Macquarie-Castlereagh	5.2	5.2		6.20	13.4		
GS18	Eastern Porous Rock: Namoi-Gwydir	10.3	10.3		15.5	15.5		
GS19	Inverell Basalt	2.9	2.9		4.15	4.15		
GS20	Kanmantoo Fold Belt	8.2	27.5		8.91	28.5		
GS21	Lachlan Fold Belt: Lachlan	23.1	23.1		36.9	123.6		
GS22	Lachlan Fold Belt: Macquarie Castlereagh	47.7	47.7		51.2	89.3		
GS23	Lachlan Fold Belt: Murray	5.1	5.1		14.3	31.9		
GS24	Lachlan Fold Belt: Murrumbidgee	30.9	30.9		26.3	133.4		
GS25	Lachlan Fold Belt: Western	1.2	13.0		13.7	230.6		
GS26	Lake George Alluvium	1.1	0.8	31.8	1.30	1.30		
GS27	Liverpool Ranges Basalt	2.7	2.7		2.16	2.16		
GS28	Lower Darling Alluvium	1.4	1.9		1.78	1.78		
GS29	Lower Gwydir Alluvium	32.3	32.3		32.9	32.9		
GS30	Lower Lachlan Alluvium	108.0	64.8	40.0	123.4	117.0		

GS31	Lower Macquarie Alluvium	69.3	41.9	39.5	70.7	70.7		
GS32	Lower Murray Alluvium (Shallow)	40.0	40.0		81.9	81.9		
SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)

New South Wales

GS32	Lower Murray Alluvium (Deep)	83.7	83.7		88.8	88.8		
GS33	Lower Murrumbidgee Alluvium (shallow)	280.0	280.0		26.9	26.9		
GS33	Lower Murrumbidgee Alluvium (deep)				273.6	273.6		
GS34	Lower Namoi Alluvium	86.0	75.0	12.8	88.3	88.3		
GS35	Manilla Alluvium	1.9	1.9		0.42	0.42		
GS36	Mid-Murrumbidgee Alluvium	44.0	44.0		48.1	48.1		
GS37	NSW Alluvium above the GAB	1.2	29.0		1.28	22.5		
GS38	NSW Border Rivers Alluvium	6.6	6.6		8.39	8.39		
GS39	NSW Border Rivers Tributary Alluvium	0.5	0.5		1.73	1.73		
GS40	NSW Sediments above the GAB	1.0	46.0		0.92	80.0		
GS41	New England Fold Belt: Border Rivers	3.4	3.4		6.31	15.3		
GS42	New England Fold Belt: Gwydir	4.1	4.1		6.45	22.2		
GS43	New England Fold Belt: Namoi	15.6	15.6		18.3	39.4		
GS44	Orange Basalt	6.9	24.0		10.7	10.7		
GS45	Peel Valley Alluvium	9.3	7.3	21.5	9.34	9.34		
GS46	Upper Darling Alluvium	2.4	4.8		6.72	7.10		
GS47	Upper Gwydir Alluvium	0.8	0.8		0.72	0.72		
GS48	Upper Lachlan Alluvium	77.1	63.0	18.3	94.1	94.1		
GS49	Upper Macquarie Alluvium	13.7	13.7		18.0	18.0		

GS50	Upper Murray Alluvium	11.0	11.0		14.1	14.1		
GS51	Upper Namoi Alluvium	122.1	95.0	22.2	123.4	123.4		
SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)

New South Wales

GS52	Upper Namoi Tributary Alluvium	2.0	2.0		0.37	0.37		
GS53	Warrumbungle Basalt	0.5	0.6		0.55	0.55		
GS54	Western Porous Rock	29.3	71.0		48.7	225.9		
GS55	Young Granite	4.3	4.3		7.09	7.09		
GS70	Gunnedah-Oxley Basin	NA	NA		NA	300.0		
GS71	Oaklands Basin	NA	NA		NA	2.50		

Australian Capital Territory

GS56	Australian Capital Territory (Groundwater)	7.3	4.4	39.3	1.70	7.25		
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SDL ID	SDL Resource Unit Name	Guide BDL	Guide SDL	Guide % Reduction (BDL-SDL Proposal)	Proposed BDL	Proposed SDL	Volumetric Reduction (CDL-SDL)	% Reduction (BDL-SDL)
Queensland								
GS57	Condamine Fractured Rock	2.1	2.1		0.81	2.14		
GS58	Queensland Border Rivers Alluvium	13.4	13.4		13.8	13.8		
GS59	Queensland Border Rivers Fractured Rock	6.8	6.8		10.1	11.0		
GS60	Sediments above the Great Artesian Basin: Border Rivers	0.1	42.0		0.04	28.7		
GS61	Sediments above the Great Artesian Basin: Condamine–Balonne	0.3	5.0		0.66	35.6		
GS62	Sediments above the Great Artesian Basin: Moonie	0.5	9.0		0.10	64.9		
GS63	Sediments above the Great Artesian Basin: Warrego–Paroo–Nebine	1.1	25.4		1.21	197.1		
GS64	St George Alluvium: Condamine–Balonne (shallow)	2.5	40.0		0.77	54.6		
GS64	St George Alluvium: Condamine–Balonne (deep)	7.5	12.6		12.6	12.6		
GS65	St George Alluvium: Moonie	0.5	1.7		0.01	1.37		
GS66	St George Alluvium: Warrego–Paroo–Nebine	0.3	6.5		0.12	49.1		
GS67a	Upper Condamine Alluvium (Central Condamine Alluvium)	117.1	76.8	34.4	81.4	46.0	35.40	43.5
GS67b	Upper Condamine Alluvium (Tributaries)				45.5	40.5	5.00	11.0
GS68	Upper Condamine Basalts	76.1	61.1	19.7	79.0	79.0		
GS69	Warrego Alluvium	0.7	26.6		0.70	19.8		

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