The SDL Assessment: Groundwater Technical Methods

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin
We acknowledge the Traditional Owners and Custodians of Country throughout the Murray–Darling Basin and their continuing connection to land, waters and community. We offer our respects to the people, the cultures and the Elders past and present.

Aboriginal people should be aware that this publication may contain images, names or quotations of deceased persons.

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Glossary

Alluvial systems - Alluvium refers to unconsolidated sediments like gravel, sand, silt, and clay deposited by rivers and streams. Alluvial aquifers hold groundwater and allow it to flow freely as they are typically shallower than other types of aquifers. Recharge mechanisms in alluvial systems includes diffuse, flood (also called over-bank) and in-stream where the latter two only applies to alluvial groundwater systems.

Aquifer storage - The storage volume of the aquifer provides indication of its sensitivity to a change in either an understanding of recharge or an actual change in recharge, before an impact on the ESLT characteristics occurs.

Asset area - The asset area is determined for each ESLT characteristic using a 5km radius around production bores as well as other filters specific to the various characteristics.

Aquifer buffering capacity - Buffering refers to the aquifer's resilience to changes in recharge rates with respect to the storage capacity

Basin Plan Review (BPR) - Under the *Water Act 2007* (Cth) (**Water Act**) the Authority is required to review the *Basin Plan 2012* (Cth) (**Basin Plan**) in 2026.

Climate change - A change in the state of the climate identified (e.g., through statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Includes natural internal climate processes or external climate forcings such as modulations in solar cycles, volcanic eruptions and persistent anthropogenic changes in the atmosphere or in land use[1].

Chloride mass balance (CMB) – A method of estimating recharge through the analysis of chloride in groundwater and rainfall (Lee et al. 2024)[2] used a chloride mass balance method to estimate recharge rates across Australia.

Diffuse recharge - Recharge due to rainfall infiltrating through the soil.

Environmentally Sustainable Level of Take (ESLT) – is defined by the Water Act, for a water resource means the level at which water can be taken from that water resource which, if exceeded, would compromise:

(a) key environmental assets of the water resource; or

(b) key ecosystem functions of the water resource; or

(c) the productive base of the water resource; or

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[1] IPCC (Intergovernmental Panel on Climate Change) (2022) 'Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change' [H-O, Pörtner, DC, Roberts, M, Tignor, ES, Poloczanska, K, Mintenbeck, A, Alegría, M, Craig, S, Langsdorf, S, Löschke, V, Möller, A, Okem, B, Rama (eds), Cambridge University Press, Cambridge, UK and New York, NY, USA, doi:10.1017/9781009325844.
[2] Lee S, Irvine DJ, Duvert C, Rau GC, and Cartwright I (2024) 'A high-resolution map of diffuse groundwater recharge rates for Australia', *Hydrology and Earth System Sciences*, *28*(7): 1771-1790.

(d) key environmental outcomes for the water resource

Groundwater - refers to: (a) water occurring naturally below ground level (whether in an aquifer or otherwise); or (b) water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works[3].

Groundwater Dependent Ecosystem (GDE) - refers to Basin ecosystems that are either completely groundwater dependant, or that rely on groundwater for part of the time.

Groundwater Dependent Ecosystem (GDE) potential - The groundwater assessment method used the Groundwater Dependent Ecosystems Atlas[4] to locate potential GDEs. GDEs are categorised in the Atlas as low/moderate/high potential for groundwater interaction.

In-stream recharge - Recharge due to stream losses through the bed and banks – only in alluvial systems

Lines of enquiry (Groundwater) – three approaches to assessing the effectiveness of the Basin Plan[5] in achieving its environmental objectives (do the SDLs reflect an ESLT) under current and full implementation of settings and under the current and future climate scenarios.

Line of Enquiry 1 (Groundwater) – Current implementation of the Basin Plan (and level of use) as at June 2024 – to explore the outcomes of Basin Plan implementation to date, recognising implementation is ongoing.

Line of Enquiry 2 (Groundwater) – Full Basin Plan implementation (and full use of the SDL) – to assess whether, under a fully implemented Basin Plan, the SDLs continue to reflect an ESLT and support the Basin Plan environmental outcomes.

Line of Enquiry 3 (Groundwater) – Full implementation under a range of plausible future hydroclimates – to provide a view of potential long-term impacts of climate change under full Basin Plan implementation, full use of the SDL and plausible future hydroclimate sequences, through to the next Basin Plan (2036 using hydroclimate sequences centred around 2030) and a planning horizon centred around 2050.

Non-alluvial system - Recharge mechanisms in non-alluvial systems includes diffuse and transfers from another groundwater sources (alluvium or other).

Flood (over-bank) recharge - Recharge due to inundation from rivers breaking their banks – only in alluvial systems.

Productive base – equates to ecosystem support services, comprising provisioning, regulating, supporting and cultural services.

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[3] Section 4 of the *Water Act 2007* (Cth)
[4] BOM (Bureau of Meteorology) (2026) *Groundwater Dependent Ecosystems Atlas Map*, BOM website, accessed 15 January 2026.
[5] Murray-Darling Basin Authority, (2012). Basin Plan 2012.

Recharge - Recharge is the inflow of water, including precipitation, to a groundwater resource. Sustainable Yields 2 in Module 3a[6] investigated the impact of future climate on three forms of recharge; diffuse, in-stream or flood. Improved historical estimates of diffuse recharge were also developed through this project.

Surface water - includes: (a) water in a watercourse, lake or wetland; and (b) any water flowing over or lying on land: (i) after having precipitated naturally; or (ii) after having risen to the surface naturally from underground[3].

Surface water – groundwater connectivity - Surface water – groundwater connectivity is the interpreted ESLT characteristic of key ecosystem function (KEF). There is connectivity where there is a zone of continuous saturation between a stream and the aquifer. If the connection between these components is significant, groundwater use may directly affect surface stream flow by inducing leakage into the groundwater system. Similarly, groundwater use may intercept potential groundwater-derived base flows to streams. The different levels of connectivity can be understood as follows:

- gaining stream: groundwater flows to surface water;
- losing stream: surface water flows to groundwater;
- maximum losing stream: surface water flows to groundwater, however, the groundwater and stream are not connected; and
- disconnected stream: there is no connection between the surface water and groundwater

Sustainable Diversion Limit (SDL) – The maximum long-term annual average quantity of water that can be taken, on a sustainable basis, from the Basin water resources as a whole, and the water resources, or particular parts of the water resources, of each water resource plan area.

Sustainable Diversion Limit (SDL) Assessment – the process of assessing whether the SDLs reflect an ESLT and, ultimately, their effectiveness in supporting the environmental outcomes of the Basin Plan.

Sustainable Diversion Limits Assessment and Response Framework – the document that explains the process which has informed the initial SDL Assessment.

Sustainable Yields (SY) - SY 1 refers to Murray-Darling Basin Sustainable Yields 1 which provided the historical recharge estimates that informed the establishment of the SDL. SY 2, refers to Murray-Darling Basin Sustainable Yields 2 module 3a, which provides improved historical diffuse recharge estimates, and future plausible changes in recharge for diffuse, flood and instream recharge[6].

Water quality – water quality is the interpreted ESLT characteristics of key environmental outcomes (KEO). For Basin groundwater resources, the KEO is the protection of groundwater resources from increased salinisation. Groundwater salinisation can occur via multiple processes including excessive groundwater take.

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[6] Crosbie R, Doble R, Fu G, Teixeira PC, Pickett T, Devanand A, Ticehurst C, Gibbs M, Gunner W, and Gonzalez D (2025) 'Groundwater recharge modelling of the Murray-Darling Basin under historical and future climate conditions: CSIRO report from Module 3a of the MDBA Sustainable Yields Project', CSIRO, Australia.

Trend assessment – Groundwater and salinity trends were analysed under Line of Enquiry 1 using bore data within 5km of production bores. A Mann-Kendall trend analysis was undertaken to determine if there was a declining or increasing/stable trend in the water or salinity levels.

Foreword

The Basin Plan sets long-term average sustainable diversion limits (Sustainable Diversion Limits or SDLs) which determine how much surface and groundwater can be taken by towns and communities, farmers and industries in the Murray-Darling Basin, while keeping the rivers and environment healthy. Each SDL resource unit in the Basin has its own limit on water take.

As part of the statutory review of the Basin Plan, the Murray–Darling Basin Authority (the MDBA) is assessing whether the SDLs continue to reflect an environmentally sustainable level of take (ESLT). For groundwater, the four components of the ESLT are interpreted as the following ESLT characteristics:

- **Groundwater Dependent Ecosystems** (GDEs), relating to Basin ecosystems that are dependent on groundwater.
- **Connectivity**, relating to groundwater – surface water connectivity (for example groundwater discharge to streams or springs).
- **Water quality**, relating to the protection of the groundwater resource from salinisation.
- **Productive base**, relating to the maintenance of the groundwater resource volume and quality.

The technical methods for conducting the SDL Assessments are described in several documents (refer Figure 1 below) and sits within the broader *Sustainable Diversion Limit Assessment and Response Framework.*

This document describes the ***technical methods for groundwater*** that enabled an initial assessment of the 80 groundwater SDLs. Technical methods were developed and applied to three Lines of Enquiry that support the initial groundwater SDL Assessment. Line of Enquiry 1 considers the potential risks of current use to the achievement of the ESLT, while Lines of Enquiry 2 and 3 consider those same risks assuming full use of the SDL, under historical and a range of possible future climates, respectively. Consistent with the MDBA's approach to science and knowledge[7], best available science and knowledge have been used in the groundwater technical method, including modelling informed by climate science; groundwater monitoring and reporting sources; scientific knowledge generated from hydrogeological/ hydrology research, and expert elicitation.

The management arrangements for the 80 groundwater SDL resource units differ from those for surface water. There were only two groundwater SDL resource units for which water recovery was required under the Basin Plan, and water take is significantly lower than the SDLs in many groundwater SDL resource units (take is currently less than half of the SDL in nearly 70% of SDL resource units). Further, there were no 'fit for purpose' groundwater models available at the time of the assessment to evaluate the impact of full use of the SDL.

[7] MDBA (Murray-Darling Basin Authority) (2025) *Our science and knowledge approach*, MDBA website, accessed 21 January 2026.

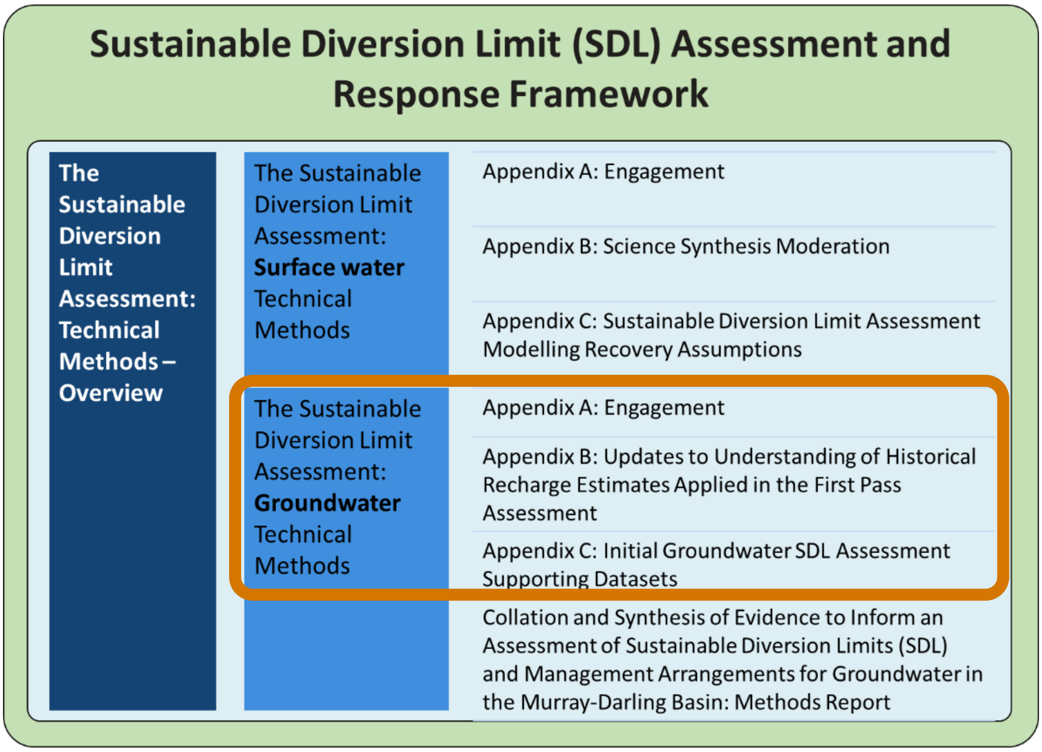

Figure 1. Structure of the SDL Technical Assessment Methods Reports

Other reports that provide further context relevant to this report are:

- Sustainable Diversion Limit Assessment and Response Framework[8]
- The Basin Plan Review: Early Insights Paper[9]
- The Sustainable Yields (SY) Report/s[10]

[8] MDBA (Murray-Darling Basin Authority) (2026a) *Sustainable Diversion Limit Assessment and Response Framework: An approach developed for the Basin Plan Review.*

[9] MDBA (Murray-Darling Basin Authority) (2024) Early Insights Paper | Murray–Darling Basin Authority MDBA website, accessed 8 January 2026.

[10] MDBA (Murray-Darling Basin Authority) (2025c) 2025 Sustainable Yields | Murray–Darling Basin Authority MDBA website, accessed 8 January 2026.

1 Summary of the SDL Assessment: Groundwater Technical Methods

To determine whether the groundwater SDL reflects an ESLT, the technical method involved a three-step approach - a “first pass” and “second pass” assessment that established if there is a potential risk to the ESLT, which was then followed by a panel assessment of SDL resource units where a high potential risk was identified from the second pass assessment.

- Chapter 1.1 describes the method for the first pass assessment. This applied a consistent approach across the 80 groundwater SDL resource units to determine if there is any potential risk to ESLT characteristics in any SDL resource unit.
- Chapter 1.2 details the method for the second pass assessment. The second pass focused only on those SDL resource units where a potential risk in Line of Enquiry 1 was indicated in the first pass assessment. The MDBA engaged with relevant Basin state governments to further assess the available evidence indicating a risk to the ESLT. Basin state governments were invited to provide their expertise, local knowledge as well as any additional evidence if it existed.
- A panel then reviewed identified at-risk SDL resource units from the second pass assessment.

1.1 First Pass Assessment Method

The first pass assessment method identified potential risks to the ESLT using a common method that could be implemented across the 80 groundwater SDL resource units in the Murray-Darling Basin. It used multiple lines of evidence and the best available science to identify and assess potential risk to groundwater ESLT characteristics. The MDBA engaged the National Centre for Groundwater Research and Training (NCGRT) to develop the method and Australasian Groundwater and Environmental Consultants (AGE) to implement the analysis. The technical details of the method can be found in the report produced by AGE (2025)[11].

1.1.1 Line of Enquiry 1: At the Time of the Review Based on Use at Current Levels

In the first pass assessment, Line of Enquiry 1 indicated potential risk to groundwater ESLT characteristics at the time of the review, drawing on information regarding historical and current use, and groundwater level and salinity trends.

Groundwater bore monitoring data from the last 50 years was the primary data source of data for Line of Enquiry 1, where both short-term water level and salinity trends (i.e. since the Basin Plan in 2012) and long-term water level and salinity trends (approx. 50 years) were considered. These trends provided an

[11] AGE (Australasian Groundwater and Environmental) (2025) *Collation and Synthesis of Evidence to Inform an Assessment of Sustainable Diversion Limits (SDL) and Management Arrangements for Groundwater in the Murray-Darling Basin (ID: BPR202411): Methods Report.*

insight into whether the ESLT characteristics are being maintained under the current levels of groundwater extraction.

To analyse groundwater and salinity trends, the method examined areas within 5 km of a licensed point of extraction to establish the defined extraction region or “asset area”. This 5 km criterion was used uniformly across all SDL resource units as drawdown from groundwater pumping could cause an impact within that distance and is unlikely to cause impact at a greater distance[12]. Using a variable buffer zone was explored by AGE, but it was not feasible due to time constraints and the preference to use a consistent approach and to focus in on more specific SDL resource unit information for the areas that were found to be at higher risk.

In addition to the 5 km radius around production bores, other filters specific to the various ESLT characteristics were used (as per Table 1). Resource condition indicators (RCIs) were then analysed for all monitoring bores within this region to ascertain trends in groundwater levels and thus possible threats to productive base associated with extraction. Additional filters were applied to further constrain the areas of the extraction regions relevant to key environmental assets (KEAs) (expressed as GDEs); key ecosystem functions (KEFs) (expressed as surface water-groundwater connectivity); and key environmental outcomes (KEOs) (expressed in terms of groundwater quality (i.e. salinity). The method proposed a suite of RCIs which are indicators of aquifer conditions that relate to the ESLT characteristics (Table 1). Further details of this method can be found in AGE (2025)[11].

Table 1 Spatial filters used to define the areal extent of RCI analysis in the method and the Resource Condition Indicators (RCIs) for the four ESLT characteristics. For further details refer to AGE (2025)[11]

<table>
<tr><th>ESLT characteristics</th><th>Spatial filters used to define area for analysis</th><th>Resource Condition Indicator (RCI)</th></tr>
<tr><td>Productive Base
(expression of Productive Base)</td><td>Areas within 5 km of licensed extraction.</td><td rowspan="3">A declining trend in groundwater levels over the short-term (2012-2024, 12 years) and long-term (data dependent, ~50 years)</td></tr>
<tr><td>GDEs
(expression of Key Environmental Asset)</td><td>Areas within 5 km of licensed extraction and within 5 km of a mapped GDE. Excluding areas where depth to water is greater than 15 metres.</td></tr>
<tr><td>Connectivity
(expression of Key Ecosystem Function)</td><td>Areas within 5 km from a gauged river reach that are within 5 km of licensed extraction.</td></tr>
<tr><td>Water quality
(expression of Key Environmental Outcome)</td><td>Areas within 5 km of licensed extraction, AND where groundwater salinity < 3,000 mg/L.</td><td>An increasing trend in groundwater salinity over the short-term (2012-2024, 12 years) and long-term (data dependent, ~50 yrs)</td></tr>
</table>

[12] NCGRT (National Centre for Groundwater Research and Training) (2024) *Development of a Method for the Review of the Environmentally Sustainable level of take for Groundwater: Prepared for the Murray-Darling Basin Authority [unpublished report]*, NCGRT.

Within the area of analysis (following spatial filtering of the full SDL resource unit area as described in Table 1), the Mann-Kendall Test and linear regression analysis were used to assess trends in the RCIs (water level and salinity level data). This determined whether the trend was improving, declining, or if there was insufficient data for a trend analysis. For each ESLT characteristic, the proportional areas of improving or declining trends and insufficient data were evaluated to determine if a risk is indicated or not and the uncertainty of the assessment. For further details refer to AGE (2025)[11].

Based on statistically significant changes in groundwater and salinity levels, a risk is indicated where, for that ESLT characteristic, more than 30% of the asset area has a declining trend. The confidence of the assessment is determined from the proportion of the asset area for which a trend cannot be calculated and described as follows:

- low confidence – where the area for which a trend cannot be calculated is > 70% of the asset area
- moderate confidence – where the area for which a trend cannot be calculated is 30 - 70% of the asset area
- high confidence – if trend can be calculated for where the area for which a trend cannot be calculated is <30 % of the asset area.

The trend assessment was based on statistically significant changes in groundwater and salinity levels, resulting in an identified trend for the ESLT characteristic asset area in the SDL resource unit. The trend was identified based on the percentage asset area with declining trend, where more than 30% declining is a concern and raises a potential risk to consider further in the second pass assessment. Where the proportion of the asset area that has a declining trend was 30% or more, further analysis and investigation was undertaken in the second pass assessment.

AGE developed additional quantitative products assessments for all SDL resource units to assist the MDBA in analysing the groundwater use in the units and any potential risk to ESLT characteristics. These products included:

- maps displaying the magnitude of trends
- cross-sections illustrating historical drawdown and groundwater fluctuation zones
- the correlation between groundwater use and rainfall data
- spatial interpolation of depth-to-water, groundwater elevation, salinity classes.

Additionally, for units that were identified as having a declining trend of 30% or more for any ESLT characteristic, AGE produced qualitative reports to synthesise the data and technical knowledge of the unit (from Basin state governments and other reports). These reports summarised the potential risks to the ESLT characteristics currently and under future climate. The MDBA drew on these reports during the second-pass assessment.

1.1.2 Line of Enquiry 2: Fully Implemented Basin Plan Assuming Full Use of the SDL

In the first pass assessment, Line of Enquiry 2 indicated potential risk to groundwater ESLT characteristics assuming full use of the SDL under the historical climate. There were no ‘fit for purpose’ groundwater models available at the time of the assessment to evaluate the impact of full use of the

SDL. Instead, the assessment approach considered any updates to the estimates of recharge used to set the existing groundwater SDLs.

The groundwater SDLs were informed by either modelling or an analytical risk assessment, known as the recharge risk assessment method (RRAM) [13]. The RRAM used diffuse recharge estimates that had been derived using the WAVES model developed by CSIRO for Sustainable Yields 1[14]. The model was subsequently refined and used to calculate recharge estimates for establishing the Basin Plan[15]. The RRAM established a sustainability factor that incorporated an assessment of the level of risk that groundwater use posed to the ESLT characteristics, and uncertainty in the recharge estimate, this factor was applied to the recharge estimates. This then determined a preliminary extraction limit (PEL) upon which a Groundwater Analytical Framework of policy positions was applied to give the existing SDL[16].

The 2025 Murray–Darling Basin Sustainable Yields (SY2) program provided updated diffuse recharge estimates based on historical climate conditions[6]. The SY2 estimates considered the influence of rainfall, clay content, vegetation and land use on diffuse recharge[6]. The SY2 estimates of diffuse recharge are an improvement on the estimates that were used in establishing the SDLs due to improvements in the method and validation of the results. For further details on updates to the understanding of historical recharge refer to Appendix B: Recharge .

As the SY2 recharge estimates represent new science and provide more spatially robust and validated recharge estimates, the SY2 recharge estimates were used in this method where they represent best available science[6]. However, the SY2 recharge estimates only provide a baseline estimate of the diffuse recharge, they do not provide estimates for other types of recharge. Some groundwater systems receive a significant amount of recharge from other mechanisms such as recharge from flooding. Also, where numerical groundwater models were used to estimate recharge during the establishment of the SDLs, this was deemed to be the best available information. Given these different considerations, the best available information varies depending on the SDL resource unit, as shown in Figure 2.

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[13] MDBA (Murray-Darling Basin Authority) (2020a) *Groundwater report cards,* Murray–Darling Basin Authority, Canberra, CC BY 4.0.
[14] Crosbie R, McCallum J, Walker G and Chiew FHS (2008) *Diffuse groundwater recharge modelling across the Murray-Darling Basin*, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australian Government.
[15] CSIRO (Commonwealth Scientific and Industrial Research Organisation) and Sinclair Knight Merz (SKM) (2010) *Dryland diffuse groundwater recharge modelling across the Murray-Darling Basin: A report to the MDBA from the CSIRO/SKM Groundwater SDL Project,* CSIRO (Water for a Healthy Country National Research Flagship), Australian Government.
[16] MDBA (Murray-Darling Basin Authority) (2020b) *Murray-Darling Basin Plan Groundwater Methods Report: Determining the groundwater baseline and sustainable diversion limits,* MDBA Publication no: 42/20, Australian Government.

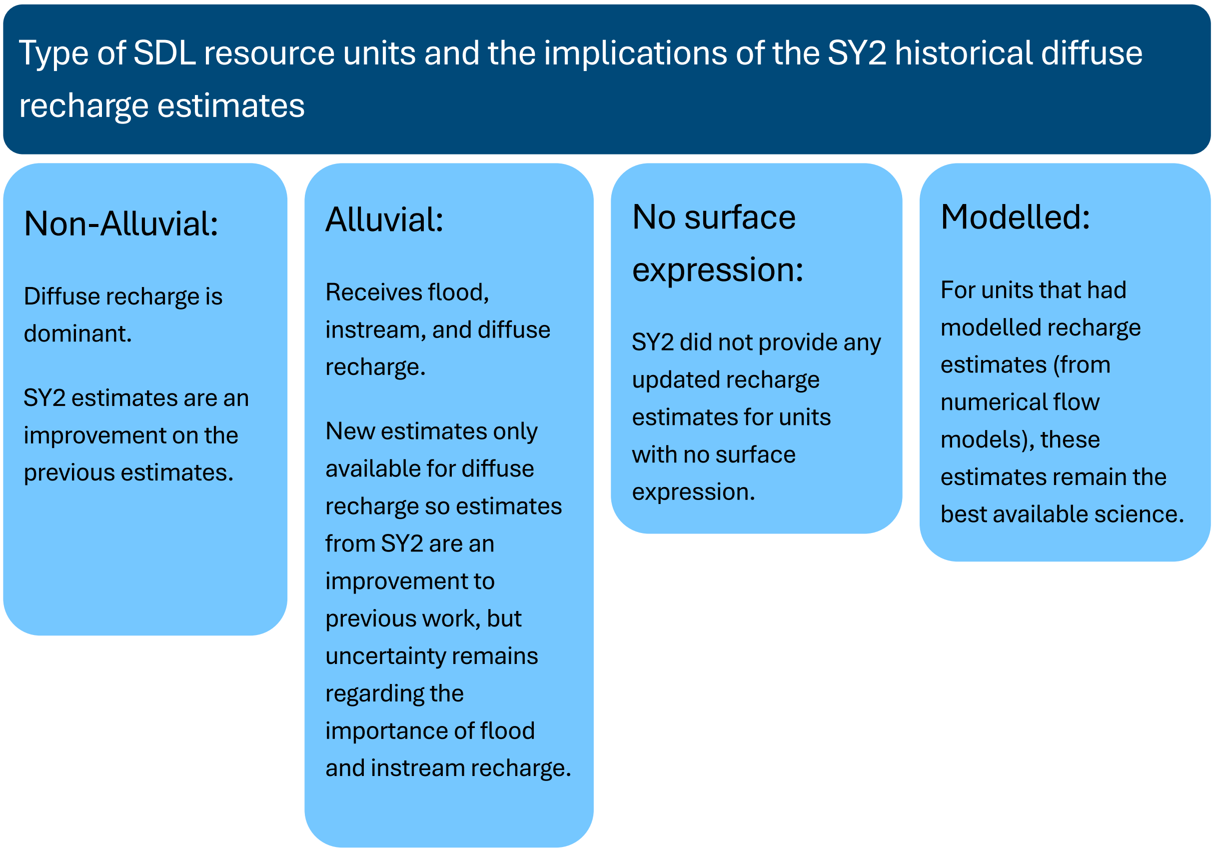

Figure 2. Consideration of SY2 recharge estimates for different types of SDL resource units

The current groundwater SDLs were set in 2012 based on both recharge information and the level of risk to ESLT characteristics. To provide an initial indication of potential risk of whether the SDLs still reflect an ESLT, the ratio of the SDL with the best available recharge estimate (“R”, either the SY2 diffuse recharge estimate or modelled estimate) was used as a basis to indicate potential risk to the ESLT (SDL / R). A potential risk is indicated if the ratio of SDL / R is greater than or equal to a threshold of 0.9 as this indicates that the SDL is close to or greater than the recharge estimate.

The threshold of 0.9 was selected to allow room for buffering and to account for the inherent uncertainty in the data. It is a practical approach that: provides a 10% buffer within the recharge estimate; is close enough to the SDL to indicate a risk before a 1:1 ratio, which assumes all recharge is taken; is not a more conservative threshold that could result in risks possibly being overstated, noting the limited information available and ongoing uncertainties in recharge estimates.

Noting the low degree of confidence associated with the recharge estimates based on the aquifer system (refer Figure 2), the method for Line of Enquiry 2 considered the ratio of recharge to SDL in the context of the following analysis, which informed any potential risk:

- **Level of current use in relation to the SDL -** use is currently less than half of the SDL in nearly 70% of SDL resource units.
- **Potential likelihood of full utilisation of the SDL -** The likelihood of current use increasing between now and the next Basin Plan review is considered by analysing limitations that may exist to slow or

prevent groundwater use from reaching the full SDL volume. This assessment is based on information about the hydrogeology of the resource as well as patterns of historical use and water quality. This assessment also considered information from Basin state governments about whether groundwater use was likely to increase. The likelihood analysis used the IPCC likelihood scale[17].

- **Ratio of the SDL with the chloride mass balance (CMB) recharge estimate from (Lee et al. 2024)[2].** CMB recharge estimate was an alternative line of evidence that provides additional context about recharge.
- **Ratio of aquifer storage with the recharge estimate** (where the ratio was calculated as storage over recharge – either SY2 diffuse estimate[6] or modelled). This ratio provided an estimate of buffering; that is the aquifer's resilience to changes in recharge rates with respect to the storage capacity. Low buffering = 29 to 111, moderate buffering = >111 to 333, and high buffering = >333[18].
- **Ratio of average annual take with the recharge estimate -** Average annual take (GL/y) was calculated over the 10-year period 2012/13–2022/23.

Using the analysis above, the Line of Enquiry 2 finding indicated any potential risk to ESLT characteristics assuming full use of the SDL but in the context of current levels of use and the potential likelihood of full use of the SDL and considering the uncertainty related to the recharge estimates.

1.1.3 Line of Enquiry 3: What Does the Future Hold, Assuming Full Use of the SDL

In the first pass assessment, Line of Enquiry 3 indicated the level of potential risk to groundwater ESLT characteristics from full use of the SDL under future climate scenarios.

The SY2 project modelled the impact of climate change on groundwater recharge in 2030 and 2050 under drier, much drier, and wetter hydroclimate scenarios. The relative changes to future recharge were estimated for three types of recharge: diffuse, flood and in-stream. The estimates of the change in future recharge could not be calculated for groundwater systems that do not have any surface expression, of which, there are 12 SDL resource units in the MDB. For these 12 SDL resource units, the Line of Enquiry 3 assessment used a qualitative approach to analyse potential risk using information about the hydrogeology of the system, groundwater take data and information from the WRP risk assessments.

For the remaining 68 SDL resource units, AGE used available recharge information to calculate recharge estimates which were used to determine potential risk from climate change. The estimates incorporated both the SY2 diffuse recharge data[6] and additional estimates (Lee et al. 2024)[2], which provided information about other forms of recharge. Using both sources of information recognised that flood and instream recharge contribute to alluvial systems and was more representative of the potential data variance for these estimates. SY2 also provided the future change in recharge due to climate change in the form of proportional increases or decreases in recharge for diffuse, flood, and in-stream recharge.

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[17] Mastrandrea MD, Field CB, Stocker TF, Edenhofer O, Ebi KL, Frame DJ, Held H, Kriegler E, Mach KJ, Matschoss PR, Plattner G-K, Yohe GW, and Zwiers FW (2010) *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on the Consistent Treatment of Uncertainties*, 3, table 1, accessed 14 January 2026.

[18] Rojas R, Gonzalez D, and Fu G (2023) 'Resilience, stress and sustainability of alluvial aquifers in the Murray-Darling Bain, Australia: Opportunities for groundwater management', *Journal of Hydrology: Regional Studies*, 47(2214-5818): 101419.

The proportions of total recharge were estimated for each recharge type by converting these three components into a single weighted expected change (see AGE (2025)[11] for more detail).

Using the recharge estimates from the AGE analysis, the ratio of a plausible range of future recharge estimates with the SDL was examined. Where assumed use (i.e. the SDL) approaches or exceeds the recharge estimates under the future climate scenarios (i.e. SDL/recharge >0.9 or above), there is a potentially higher risk to ESLT characteristics. This assessment gives a possible indication of the sensitivity of the SDL resource unit to a range of plausible climate change futures.

Where use was >50% of the SDL, consideration of the potential pressure from climate change was also taken into account in the assessment. The potential pressure was determined using a decision tree which considered the rate of use, the rate of replenishment, climate change impacts and RCI trends. More detail about the climate analysis, the decision tree and how recharge estimates were calculated is provided in AGE (2025)[11].

The assessment for Line of Enquiry 3 describes potential risk to the resource in future climates in the context of full use of the SDL and considering the high uncertainty related to the recharge estimates.

1.1.4 Basin Governments engagement on the First Pass Method and Results

The groundwater assessment method was developed through a contractual arrangement between the MDBA and the National Centre for Groundwater Research and Training (NCGRT). The Basin state governments through members of the Groundwater Advisory Panel (GAP) were engaged during this process, with MDBA providing a method overview and eliciting feedback. Adjustments were made to the method in response to feedback, where possible and appropriate.

During the method implementation phase, Basin state governments were engaged at multiple stages, this included:

- At the outset of project implementation, the MDBA provided an overview of the SDL Assessment process and expected timelines
- Seeking verification of data inputs for the SDL Assessment
- Sharing results from the assessment and receiving feedback.

1.2 Second Pass Assessment Method

The second pass assessment involved a more detailed assessment for the 19 SDL resource units where potential risks had been identified in the first pass assessment under Line of Enquiry 1. As mentioned in the sections above, risk was flagged based on the percentage asset area with declining groundwater level trend; where more than 30% asset area with a declining groundwater level trend was identified as a concern and raised a potential risk to consider further in the second pass assessment.

While the first pass assessment used a common method across the 80 groundwater SDL resource units, the second pass assessment used context specific information and knowledge to better understand the nature of the risk that had been identified. This also considered the risk in terms of likelihood and consequence. The outcomes from the second pass assessment led to the categorisation of the 19 SDL resource units as ***at-risk***, ***localised moderate risk*** or ***low risk*** to ESLT characteristics. At-risk SDL resource units were then considered at a MDBA panel review in preparation for the assessments.

1.2.1 Additional Analysis Where Declining Trends Identified

Where a declining trend of 30% or more was identified from the first pass assessment in Line of Enquiry 1, additional analysis was undertaken to better understand the nature of the declining trend. This included:

- The identification of bores where ***low*** or ***moderate to high*** rates of decline were observed, and if the trend had persisted in the long-term as well as the short-term. If only a low rate of decline was being observed and/or the trend had stabilised in the short term, the preliminary finding led to reevaluating the risk from potentially high to potentially low.
- The identification of whether the declining trends were a risk to ESLT characteristics. This was done in a more detailed manner than under the first pass assessment, with further analysis of the GDE and connectivity maps, and other literature identifying GDE values in the resource unit. The second pass assessment also looked in more detail at the GDEs that were included in the analysis for the high-risk units and considered the impact of using high potential vs high and moderate potential GDEs in the assessment (as per the BOM GDE Atlas categorisation). More detail about this GDE analysis is included in AGE (2025)[11]. Based on the findings of this step, risk was again maintained at potentially high or downgraded to potentially low.
- The identification of the scale of the area affected by the identified groundwater level trend. At this step, it was identified if impacts were localised or were more widespread across the SDL resource unit. It also considered whether use in the SDL resource unit was close to the SDL or if there was a buffer between SDL and average take. If use was close to the SDL, or the impacts were not localised, the risk was maintained at potentially high. If the use was high, however the impacts were localised, localised moderate risk was identified.

1.2.3 Basin Governments Engagement to Inform Second Pass Assessment Findings

Effective groundwater management requires volumetric limits that apply alongside suitable local management arrangements that can effectively engage with risk and modify patterns of groundwater take. Effective management settings can mitigate risks to ESLT characteristics from localised use that may still be within the SDL. Basin state governments include rules in water resource plans to mitigate identified risks of use to the groundwater ESLT characteristics.

In this context, the first pass assessment findings were presented and discussed with the Basin governments in a workshop. The objective was to ensure that Basin government expertise was used, that knowledge being used for the assessment is fit for purpose, and that as far as possible:

- Basin governments and the MDBA developed a common view of the risks relevant to each SDL resource unit; and
- these were appropriately reflected in the assessments.

Where Basin governments had undertaken analysis of groundwater resources and risks to ESLT characteristics, these were considered and included within the assessment.

1.2.4 Basin Government Information on Recharge

Basin governments provided additional recharge information that was incorporated in the second pass assessments to ensure that the assessments aligned with the Basin government understandings of the system. This allowed for the MDBA to be adaptable and ensure that the SDLRUs were assessed using multiple lines of evidence.

The New South Wales recharge data represented new and comparable recharge information and these numbers were included in the SDL Assessment and the reports that were utilised were referenced. The Victoria recharge data was deemed to be incomparable with the recharge data used in the MDBA's technical groundwater method and was therefore included in the appendix of the relevant assessments to be considered as another line of evidence.

2 Engagement Approach

2.1 Basin Government Engagement

Basin governments were involved in all steps of the groundwater SDL assessment technical methods including:

- Providing feedback on the development of technical methods for the first pass assessment. This was canvassed through bilateral meetings and at groundwater advisory panel (GAP) meetings.
- Providing feedback on the draft results from the first pass assessments.
- Consultation through bilateral meetings and workshops on second pass assessment analysis
- Feedback on final published initial groundwater SDL Assessments

A detailed list of external meetings is provided in Appendix A.

Appendix A: Engagement

Meaningful engagement is critical to refining ecological and hydrological analyses, ensuring that evolving insights directly inform more responsive and robust decision-making and promote stakeholder buy in. MDBA is committed to fostering ongoing collaborative relationships that will help in improving our methods and ultimately support more effective decision-making and outcomes. Below is a summary of consultative meetings with Basin state governments and key forums regarding method development and result review.

Table A- 1 External meeting history of ground water

Date	Stakeholder	Content
24/08/2023	Groundwater Advisory Panel (GAP)	Introduction of the requirements under the BPR and establishing the role of GAP in this process
21/09/2023	NSW Government	Initial engagement to discuss upcoming groundwater modelling projects and their potential use in the SY and ESLT assessments
19/10/2023	VIC Government	Discuss using the Goulburn-Murray groundwater model for the SY project and ESLT assessments
27/10/2023	NSW Government	Overview of SY, ESLT, SDL methods and next steps. Including modelling requirements, consultation process and next steps
11/01/2024	QLD Government	Discuss using the Condamine Alluvium model for the SY project and ESLT assessments
04/03/2024	QLD Government	Update on QLD modelling pathway and planning for ESLT assessments
05/03/2024	NSW Government	Overview of SY and ESLT GW programs
17/04/2024	VIC Government	VIC groundwater model discussion for SY and ESLT assessments
01/05/2024	NSW Government	Updates for model funding and the SY and ESLT review projects
16/05/2024	NSW Government	Bilateral meeting for groundwater recharge conducted in SY2 and to be used in the ESLT method
16/05/2024	NSW Government	Bilateral meeting for groundwater recharge conducted in SY2 and to be used in the ESLT method
04/06/2024	SA Government	Bilateral meeting for groundwater recharge conducted in SY2 and to be used in the ESLT method
04/07/2024	QLD Government	Bilateral meeting for groundwater recharge conducted in SY2 and to be used in the ESLT method
23/07/2024	ALL	Presentation of ESLT review method including feedback and discussions
11/09/2024	Groundwater Advisory Panel (GAP)	Presentation on the NCGRT method, the ESLT review, and Crosbie et al (2025)[66] recharge data and models for SY2
10/12/2024	SA Government	Discussing the next phase of the SDL review and ESLT assessments. Introducing AGE and Basin state governments Representatives

Date	Stakeholder	Content
11/12/2024	VIC Government	Discussing the next phase of the SDL review and ESLT assessments. Introducing AGE and Basin state governments Representatives
18/12/2024	QLD Government	Discussing the next phase of the SDL review and ESLT assessments. Introducing AGE and Basin state governments Representatives
18/12/2024	NSW Government	Discussing the next phase of the SDL review and ESLT assessments. Introducing AGE and Basin state governments Representatives
19/12/2024	ACT Government	Discussing the next phase of the SDL review and ESLT assessments. Introducing AGE and Basin state governments Representatives
06/02/2025	NSW Government	Discuss ESLT assessment results and consider additional lines of NSW evidence
06/02/2025	QLD Government	Discuss ESLT assessment results and consider additional lines of QLD evidence
07/02/2025	VIC Government	Discuss ESLT assessment results and consider additional lines of VIC evidence
07/02/2025	SA Government	Discuss ESLT assessment results and consider additional lines of SA evidence
12/02/2025	NSW Government	NSW monitoring bores meeting to determine differences between BoM and NSW data
17/02/2025	QLD Government	Groundwater ESLT review of QLD draft outputs. Discussing more detail of the ESLT review assessment
20/02/2025	SA Government	SDL Assessment method run through and demonstration of pilot studies
21/02/2025	NSW Government	SDL Assessment method run through and demonstration of pilot studies
25/02/2025	QLD Government	Insight into draft SDL Assessment method and second stage of discussions on the pilot studies
04/03/2025	ACT Government	Insight into draft SDL Assessment method and second stage of discussions on the pilot studies
07/03/2025	VIC Government	Insight into draft SDL Assessment method and second stage of discussions on the pilot studies
20/03/2025	Groundwater Advisory Panel (GAP)	Discussion of 2022-23 water take reports and the Registers of Take for the ESLT review, SY2 and models where relevant
24/03/2025	NSW Government	Overview of group 1 groundwater ESLT assessments and changes to the method
25/03/2025	SA Government	Overview of group 1 groundwater ESLT assessments and changes to the method
26/03/2025	VIC Government	Overview of group 1 groundwater ESLT assessments and changes to the method
31/03/2025	QLD Government	Overview of group 1 groundwater ESLT assessments and changes to the method
17/06/2025	Groundwater Advisory Panel (GAP)	Overview of SDL Assessment approach and breakdown of the 3 lines of enquiry

Date	Stakeholder	Content
30/06/2025	NSW Government	SDL Assessment discussion – Warrumbungle Basalts
08/08/2025	NSW Government	Test approach for groundwater rules effectiveness
22/08/2025	NSW Government	Discussing trend data for southern NSW SDLRUs
25/08/2025	QLD Government	Discussing trend data for QLD units
27/08/2025	NSW Government	Discussing trend data for northern NSW SDLRUs
01/09/2025	ACT Government	Meeting to discuss stage 1-4 output from AGE
09/09/2025	SA Government	SDL Assessment method meeting and discussion of the latest updates to the groundwater assessment method
12/09/2025	VIC Government	Victorian Groundwater Recharge Estimates and SDL Assessments
22/09/2025	SA Government	SDL Assessment discussion – Marne Saunders
24/09/2025	VIC Government	Discussion about VIC recharge data
24/09/2025	QLD Government	QLD SDL Assessment workshop
30/09/2025	VIC Government	Discussion of the assessment of the management rules for VIC
14/10/2025	NSW Government	Discussion of the assessment of the management rules for NSW
10/11/2025	VIC Government	Discussion about VIC recharge data
17/11/2025	NSW Government	In person meeting with NSW to discuss the SDL Assessments, the assessment method, and any other ongoing concerns
28/11/2025	VIC Government	Groundwater SDL Assessment workshop
05/12/2025	SA Government	Marne Saunders groundwater SDL workshop
08/12/2025	QLD Government	Follow-up on high-risk SDL Assessments and finalising information for reports

Appendix B: Recharge Estimates

A key component for estimating sustainable groundwater use is understanding how much recharge the system receives. Modelling groundwater recharge is highly complex, however, as it uses multiple parameters which all contain some degree of uncertainty. The 2025 Murray–Darling Basin Sustainable Yields (SY2) program estimated groundwater recharge in the Basin using WAVES which is a Soil-Vegetation-Atmosphere-Transfer model. This model estimates recharge at a point-scale which is then upscaled over a larger area using information about soil, vegetation and annual average rainfall. Though WAVES recharge estimates have been shown to be quite reliable, there is inherent uncertainty in producing this type of modelled data on a scale as large as the Murray Darling Basin.

The SY2 estimates considered the influence of rainfall, clay content, vegetation information and land use on diffuse recharge. The SY2 diffuse recharge estimates represent new science and provide more spatially robust and validated recharge estimates. These updated recharge estimates were used where they represent best available science. The previous estimates used for the RRAM[13] to determine existing SDLs lacked reliability compared to the SY2 estimates[6], due to the absence of validation. An allowance for this uncertainty in the recharge estimate was included in the RRAM[13].

Recharge estimates from the groundwater numerical flow models (modelled for the Basin Plan) were used preferentially to the SY2 recharge estimates in the groundwater SDL Assessment. This is due to the groundwater flow models being calibrated to the specific SDL resource unit area and including a calculation of the recharge from sources other than rainfall (diffuse recharge). The SY2 recharge estimates only include a baseline calculation of diffuse recharge and therefore, for alluvial systems, can significantly under-represent the volume of recharge that is entering the system. As such, the advice from AGE and CSIRO was that where it existed, the original modelled recharge estimates represent the best available information, not the SY2 recharge estimates.

Appendix C: Initial Groundwater SDL Assessment Supporting Datasets

Multiple sources of information and datasets have contributed to the SDL Assessment of surface water and groundwater. Additionally, during this assessment process the MDBA and AGE have created new datasets and produced results for various components of the technical methods that have contributed to the assessments. To make as much of this data available as possible the majority of it has been placed into an online library, available by searching using key words at https://library.mdba.gov.au. Broadly, results have been placed into the MDBA online library.

Below is the link to the published results for groundwater outputs:

https://library.mdba.gov.au/group/sdl-groundwater-assessment-data[19]

https://library.mdba.gov.au/group/sustainable-diversion-limit-assessments-groundwater[20]

[19] MDBA (Murray-Darling Basin Authority) (2026b) https://library.mdba.gov.au/group/sdl-groundwater-assessment-data, library.mdba.gov.au, accessed 27 January 2026.

[20] MDBA (Murray-Darling Basin Authority) (2026c) https://library.mdba.gov.au/group/sustainable-diversion-limit-assessments-groundwater, library.mdba.gov.au, accessed 27 January 2026.

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