Summary of Estimated Impact of Groundwater Use on Streamflow in the Murray-Darling Basin

Report prepared for the Murray-Darling Basin Commission

Resource and Environmental Management

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Murray-Darling Basin Commission
Values Statement

We will manage and conduct our business in a highly professional and ethical manner, and according to the values jointly agreed with the Community Advisory Committee. These values require particular behaviours that will cement our relationships with our stakeholders and the wider community, and will underlie all decisions, actions and relationships we enter into. We will promote the values so that all people and organisations which have dealings with the Commission know what to expect from us and what we expect from them.

Our values

We agree to work together, and ensure that our behaviour reflects the following values.

Courage

We will take a visionary approach, provide leadership and be prepared to make difficult decisions.

Inclusiveness

We will build relationships based on trust and sharing, considering the needs of future generations, and working together in a true partnership.
We will engage all partners, including Indigenous communities, and ensure that partners have the capacity to be fully engaged.

Commitment

We will act with passion and decisiveness, taking the long-term view and aiming for stability in decision making.
We will take a Basin perspective and a non-partisan approach to Basin management.

Respect and honesty

We will respect different views, respect each other and acknowledge the reality of each other's situation.
We will act with integrity, openness and honesty, be fair and credible, and share knowledge and information.
We will use resources equitably and respect the environment.

Flexibility

We will accept reform where it is needed, be willing to change, and continuously improve our actions through a learning approach.

Practicability

We will choose practicable, long term outcomes and select viable solutions to achieve these outcomes.

Mutual obligation

We will share responsibility and accountability, and act responsibly, with fairness and justice.
We will support each other through necessary change.

Executive Summary

ES1. Background

Increasing groundwater use is one of six developing issues likely to have significant impact on the surface water resources in the basin. These six issues are referred to collectively as the “risks to the shared water resources”, and include: climate change, reafforestation, groundwater use, farm dams, bushfires and return flows.

Appropriate and reliable data on these issues is not readily available. While at this stage, it is not possible to make any predictions with certainty on possible impacts on streamflow by these risks, there is sufficient information on emerging trends to warrant their closer examination. An understanding of the cumulative impacts of these issues, with the continuing pressure on our water resources, would appear to be fundamental to effective water resources management in the basin, particularly in regard to maintaining the integrity of the Cap.

This report is part of the work program agreed by the Murray-Darling Basin Ministerial Council (MDBMC), which aims to refine our understanding of these risks, strategically fill knowledge gaps and develop appropriate advice to the Murray-Darling Basin Commission (MDBC) and MDBMC to address these issues.

This report provides an overview of groundwater use and management within the basin. The purpose of this report is to assess the current and future trends in groundwater use, to more clearly understand the significance of groundwater use and management as a risk to the surface water resources within the basin.

ES2. Objectives

There are two overarching objectives of this study:

- **Objective 1**: Provide an overview of the current (2002/03) knowledge of Groundwater Management Units (GMUs) of the basin with an emphasis on those units where current or future use may impact on streamflow; and

- **Objective 2**: Provide a summary of the current management arrangements within each of the jurisdictions to jointly manage surface and groundwater resources to maintain the integrity of the Cap.

ES3. Method

Responses from the jurisdictions were provided to the Office of the MDBC, based on a template developed by the Groundwater Technical Reference Group. It was intended the jurisdiction’s responses be used as the primary source of information for this report. The current reporting approach was adopted based on feedback from the Integrated Catchment Management Policy Committee.

Responses were compiled and supplemented with information from previous investigations identified in Section 2 of this report and follow-up discussions occurred with jurisdictions when clarification was needed.

This report was prepared and reviewed by the Groundwater Technical Reference Group and the Office of the MDBC.

ES4. Key Findings and Conclusions

ES4.1 Key findings

This overview has focused on GMUs that are potentially connected to stream flow. The Great Artesian Basin GMUs and Unincorporated Areas have not been included within the study.

The key findings from this overview are detailed below.

ES4.2 Groundwater use

Groundwater use was analysed at both a jurisdiction scale and at a GMU scale. In terms of timeframes, historical use, current use (2002/03) and projected future use (2012/13 and 2052/53) were documented. The key findings related to groundwater use are presented below.

Historical groundwater Use (pre 2002/03)

- There is limited data available for historical use of groundwater, prior to 1999/00, particularly at a GMU scale.
- Based on limited available information it is estimated that groundwater annual use increased by approximately 180 GL (20%) from 894 GL to 1074 GL between 1983/84 and 1999/00. There was a further increase in use of approximately of 476 GL/yr between 1999/00 and 2002/03, with the most dramatic increase in use occurring after 2000/01. Most of the increase in use occurred in NSW.
- Only limited data is available for groundwater use in 1993/94 (the Cap reference conditions) at the GMU scale.

Current Groundwater Use (2002/03)

- There remains 34 GMUs (of a total of 69 GMUs with current use reported by jurisdictions) where current use is not metered or partially metered on an annual basis.
- Groundwater use across the basin and across the GMUs within individual jurisdictions is not uniform, thus the presentation of groundwater use at a jurisdiction scale will not reflect the extent of use relative to sustainable yield within individual GMUs.
- Groundwater use currently exceeds the estimated sustainable yield level in 18 GMUs.

Future groundwater use

- Future groundwater use across the Basin is projected to rise by 17% (272 GL/yr) from 1550 GL/yr to 1822 GL/yr between 2002/03 and 2052/53. Most of this increase in use is expected to occur by 2012/13, based on current trends.

- The largest growth in groundwater use is anticipated to occur (on a volumetric basis) in the Upper Lachlan and Mid-Murrumbidgee GMUs.

ES4.3 Influence of groundwater use on streamflow

The extent of connectivity between the aquifer and the stream was assessed for the major streams within each GMU. The following key findings related to the influence of groundwater use on stream flow are detailed below:

- There is a limited understanding of the extent of connectivity between the groundwater system and stream flow. A range of local conditions, including geology and the siting of the production bore relative to the stream, influence the extent to which groundwater use will influence stream flow.

- There are different approaches to determining the extent of connectivity across the jurisdictions.

- Streamflow will be reduced where there is an increase in groundwater use in connected GMUs.

- The Border Rivers alluvium (Qld and NSW), Upper Lachlan, Mid Murrumbidgee, Upper Macquarie, Upper Murray, Upper Namoi, Lower Murray, Murmungee, Mid Loddon, Campaspe and Katunga GMUs are considered to be the priority GMUs based on possible current and/or future streamflow impacts.

- The impact of the current level (2002/03) of groundwater use on stream flow is assessed as reducing stream flow by 327 GL across the basin.

- Reduction in stream flow is projected to rise by nearly 77% (to a stream flow reduction of 572 GL) by 2012/13 and by 85% (to a stream flow reduction of 603 GL) by 2052/53.

- Approximately 44 % of future stream flow reduction is expected to occur within the southern connected river system by 2052/53.

- Erosion to stream flow that is not evident to date is expected to occur from the delay or ‘lagged’ impact of the rise in groundwater use prior to 2002/03. Any additional increase in groundwater use in the connected GMUs where current use is below the estimated sustainable yield or groundwater allocation will lead to further erosion of stream flow.

ES4.4 Management arrangements to protect the integrity of the Cap on surface water diversions

There has been a long held view from the GTRG that there should be a Cap on total (surface water and groundwater) diversions within the basin and that the water resource should be managed in an integrated manner.

A compilation of information describing management arrangements put in place by each of the jurisdictions to protect the integrity of the Cap on surface water use was undertaken and an assessment made of the impact of increasing groundwater use on the surface water Cap.

The key findings are detailed below;

- Each jurisdiction has legislative and policy that allows for the integrated management of surface water and groundwater, but implementation of the integrated approach has not occurred to-date.

- The intended outcomes of the Cap on surface water diversions have been compromised as a result of the increased groundwater use since 1993/94.

- The extent to which the intended outcomes of the Cap have been influenced is uncertain due to the uncertainty of the critical data sets required to make the assessment, namely historical groundwater use, extent of connectivity and the extent to which stream flow is sourced from the groundwater system where connectivity exists.

- Taking into account the delayed or ‘lagged’ impact of the historic, current and future levels of groundwater use in the connected GMUs, further erosion of the intended outcomes of the surface water Cap is expected to occur. The estimated impact on the Cap from the anticipated increase in groundwater usage beyond 2002/03 will be up to 276 GL/yr greater in 2052/53 than in 2002/03.

- The largest future impacts are expected to occur in the large connected under developed GMUs such as Mid Murrumbidgee and Upper Lachlan. These two systems are expected to account for more than 40% of the estimated future impact on the Cap.

- There is a range of approaches being taken by each of the jurisdictions regarding current and intended future management of groundwater to ensure the integrity of the surface water Cap is retained.

- The jurisdictions have identified technical and planning investigations that will be undertaken and investigations that are needed to reduce the uncertainty, although the implementation plan for these investigations has not been made clear.

ES5. Conclusions

In the context of the identified risks to the shared water resource, the following conclusions have been made with respect to current and future groundwater management within the Murray Darling Basin.

- There is limited data available for historic and current groundwater use. This together with a poor understanding of the extent of hydraulic connectivity between the groundwater system and stream flow has made it difficult to estimate with confidence, the impact of increasing groundwater use on the intended outcomes of the surface water Cap.

Groundwater use

- With an 44% increase in groundwater use from 99/00-02/03 and predicted further increases of 17% predominantly in the next 10 years, it would appear that policy and regulation are the only mechanisms that can limit use to sustainable levels, as market forces are acting to increase groundwater use.

- The future sustainability of groundwater resources is threatened by current levels of use in 18 GMUs.

Streamflow

- With stream flow reductions already assessed at 327 GL/yr across the Basin and an expectation of a total reduction of 603 GL/yr by 2052/53 (according to the methodology described in this report) further action is required to determine how to distribute the impacts of this increase between surface water and groundwater users, and the environment.

Integrity of the Cap

- The consequential reductions in streamflow due to the significant rise in groundwater use are likely to already have had an impact on the intended outcomes of the Cap. This, together with a further impact of 315 GL/yr on the Cap outcomes by 2052/53 (of which 39 GL/yr is associated with salt interception schemes) will erode the reliability of future water availability for both surface water irrigation and environmental requirements unless there is a Cap on total diversions.

Management Arrangements

- Each jurisdiction has management arrangements to achieve conjunctive (joint) management of both surface and groundwater, however the implementation of a conjunctive resource management approach has not been initiated. If the current management arrangements are maintained, then the continued losses of streamflow will need to be addressed in terms of appropriate trade-offs to achieve a key objective of the MDB *Initiative,* specifically the equitable, efficient and sustainable use of water resources.

- Each jurisdiction has identified studies required to be undertaken to improve the level of confidence in the estimates made of current use, the extent of connectivity and the impact of increasing groundwater usage on the surface water Cap. Further delays in the commencement of these studies will continue to result in low levels of confidence in both the progress made and the support for changes to management arrangements.

- Any action to address the future impacts on streamflow and the sustainable use of the groundwater resource identified in this report will need to take into account the likelihood, severity and cumulative impacts associated with other risk factors including climate change, reafforestation, farm dams, bushfires and return flows

- The development and implementation of effective management arrangements are also dependent on improved information gathering linked to continued assessment of sustainable yield issues, including data collected at the appropriate time and spatial scales.

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1 ABOUT THIS REPORT

1.1 Background

1.1.1 Risks to the shared water resources

Increasing groundwater use is one of six developing issues likely to have significant impact on the surface water resources in the Basin. These six issues are referred to collectively as the “risks to the shared water resources”, and include: climate change, reafforestation, groundwater use, farm dams, bushfires and return flows.

The Murray-Darling Basin Ministerial Council (MDBMC) at it’s meeting on 26 March 2004:

- noted the potential impact of six key risks which, if not addressed, could cause the flow and quality in the Murray-Darling Basin to decrease; and
- endorsed the Commission’s proposed work plan to address these issues with immediate priority given to bushfires and groundwater use, and through medium term strategies for climate change, farm dams, reafforestation and return flows from irrigation.

This report is part of the work program agreed by MDBMC, which aims to refine our understanding of these risks, strategically fill knowledge gaps and develop appropriate advice to the Murray-Darling Basin Commission (MDBC) and MDBMC to address these issues.

The purpose of this report is to assess the current and future trends in groundwater use, to more clearly understand the significance of groundwater use and management as a risk to the surface water resources within the basin.

The subsequent integration of this information with the knowledge developed for the other five identified risks will enable a greater understanding of the cumulative impacts of these issues to be developed. This overall knowledge would appear to be fundamental to effective water resources management in the basin, particularly in regards to maintaining the integrity of the Cap on surface water diversions (referred subsequently as the Cap).

1.1.2 Risk of impacts to streamflow by pumping groundwater

A number of studies have highlighted the potential for increasing groundwater use to adversely impact stream flow and impact on initiatives such as the Cap and the Living Murray aimed at protecting the environmental values of the river systems within the basin.

In recognition of the importance of this issue, the connection and interaction between surface water and groundwater resources, and the need to manage these resources in an integrated way, has been explicitly recognised by the Coalition of Australian Governments (COAG), and reinforced through the National Water Initiative (NWI).

The most recent estimate of the severity of the potential impact of future groundwater pumping indicates that annual average streamflow may be reduced by 510 GL/yr by 2023 owing to groundwater pumping (Earth Tech, 2003).

As a consequence of these studies, increased groundwater use has been identified by the MDBC and MDBMC as one of the six key threats to the shared water resources of the basin. In response, the MDBMC has requested a Groundwater Report be submitted to MDBC and MDBMC which:

- …*identifies those groundwater management units where future growth in use is likely to have a significant impact on streamflow*; and
- …*to* [report to] *Commission by September 2004 on how they propose to jointly manage groundwater and surface resources to maintain the integrity of the Cap.*

A framework to coordinate the jurisdiction's responses, requested as the basis that this report was developed by the MDBC's jurisdictionally based Groundwater Technical Reference Group (GTRG). The framework was designed to be complemented by work already obtained through MDBC investment in knowledge generation and managed by the GTRG.

This report presents a synthesis of the jurisdiction's responses and outcomes from previous investigations to support the production of a comprehensive Groundwater Report for MDBC and MDBMC on increased groundwater development and the associated impact on surface water flows.

While the focus of this report is the potential impact that groundwater extraction can have on streamflow, it needs to be recognised that changes to the surface water flow regime (e.g. through the development of farm dams) can also impact on recharge to the aquifer. There is a risk that a reduction in recharge due to reduced streamflow will result in a reduction in the availability of groundwater for consumptive and environmental uses.

The information in this report does not address additional impacts which may arise from:

- Climate change;
- Reafforestation;
- Farm dams;
- Bushfires; and
- Return flows.

1.2 Objectives

There are two overarching objectives of this study.

Objective 1: Provide an overview of the current (2002/03) knowledge of GMUs of the MDB with an emphasis on those units where current or future use may impact on streamflow. The overview must:

- synthesise and summarise all currently available information including the material provided by the jurisdictions and the results of previous MDBC research related to groundwater;
- determine and explain the current understanding of connectivity between surface and groundwater systems on a GMU by GMU basis;
- prioritise GMUs according to the potential impact of groundwater use impacting on surface water resources; it is likely this prioritisation will focus on areas where connectivity is significant or where there is potential for over allocation and/or overuse;
- describe, and quantify wherever possible, the levels of confidence in the groundwater data currently available;
- identify key issues and knowledge gaps in the understanding of current and future use of groundwater where there are implications for surface water resources; and
- summarise current relevant work being undertaken within the jurisdictions. Outline what information will be provided by this work and when this information will be available.

Objective 2: Provide a summary of the current management arrangements within each of the jurisdictions to jointly manage surface and groundwater resources to maintain the integrity of the Cap. The overview should:

- summarise the current and proposed management arrangements that would support the management of groundwater use to ensure that that Cap on surface water diversions is not eroded;
- identify the information required to enable the implementation of these management arrangements; and
- identify key risks associated with the impact of groundwater use on the shared water resources of the Murray-Darling Basin.

1.3 Method

The method described below was developed to meet the required project objectives.

1. A request was received by the Office of the Murray-Darling Basin Commission (OMDBC) from the MDBMC to prepare the Groundwater Report;

2. The objectives of the study were established by the OMDBC;

3. A framework was established by the GTRG to identify consistent information to be provided by each of the jurisdictions. The GTRG's framework requested information on:

- a summary of management arrangements implemented to protect the Cap;
- current and future groundwater use at the GMU scale required for 2002/03 and projected future use estimates were required for 2012/13 and 2052/53; and
- quantification of the current and future impacts to streamflow volume per annum for each GMU.

4. The current reporting approach was adopted based on feedback from the Integrated Catchment Management (ICM) Policy Committee on jurisdiction's initial responses;

5. Responses from jurisdictions were compiled and a summary of the data was prepared (Appendix A);

6. Gaps were identified and additional sources of information were identified (Section 2);

7. Follow-up discussions occurred with key contacts within the jurisdictions; and

8. A report was prepared and reviewed by the OMDBC.

9. The report was presented to the GTRG and comments received from each jurisdiction have been incorporated on the report.

1.4 Report Structure

Section 1 of this report sets out the background, objectives and methodology. A summary of the key sources of information and data is provided in Section 2.

The report summarises current levels of groundwater use and future levels of groundwater use on a GMU by GMU basis in Section 3. Knowledge gaps associated with groundwater use data are also described.

In Section 4, links are drawn between increasing groundwater use and the potential impact on streamflow by describing the connectivity between streams and aquifers and the likely volumetric impacts. The priority GMUs are identified in Section 4, and knowledge gaps associated with the interaction between streamflow and aquifers are also described.

A summary of current groundwater management arrangements is provided in Section 5 and the capacity of these arrangements to manage groundwater within a surface water Cap is discussed.

Key findings, conclusions and recommendations are provided in Sections 6 and 7, respectively.

2 SUMMARY OF CONTRIBUTING REPORTS

This section contains a summary of information that is used to support the information provided by the jurisdictions.

Title: Australian water resources assessment 2000

Author National Land and Water Resources Audit

Date 2000

Objectives refer to www.nlwra.gov.au

Key findings refer to www.nlwra.gov.au

Title: Survey of baseflows in unregulated catchments in the Murray-Darling Basin. Prepared for the Murray-Darling Basin Commission.

Date 2001

Author: Sinclair Knight Merz (SKM)

Objectives: Determine the baseflow contribution to unregulated streams in the Murray-Darling Basin

Key Findings: Annual baseflow indices ranged from 0.04 (almost no baseflow contribution) to 0.76 (around three quarters of the total flow is baseflow). The indices are mapped across the basin

Median annual baseflow index was 0.25.

Title: Groundwater – surface water interaction in NSW: a discussion paper.

Date: 2002

Author: Braaten and Gates (Department of Infrastructure, Planning and Natural Resources)

Objectives: Assess the significance of surface water – groundwater interaction for water allocation in NSW, particularly with respect to the surface water Cap.

Key Findings: The main areas of surface water and groundwater connection occur in the mid and upper aquifers of the basin's major rivers, where floodplains are narrow, rainfall is high and groundwater shallow, however, these are generally not the major groundwater extraction zones.

Until 2002, the 'Cap' was likely to have been undermined by a maximum of approx 15 GL, mainly due to increases in groundwater extraction in the Upper Lachlan alluvium since 1993/94.
If all connected surface water and groundwater systems were developed up to their sustainable yield, the maximum depletion of river flow would be 307 GL (in NSW).

Title:	Water audit monitoring report (GMU scale groundwater use data)

Date 2002/03

Author MDBC

Data used 2002/03 GMU scale groundwater use data for New South Wales and Victoria

Title:	Integrated water management in the Murray-Darling Basin: the role of groundwater. Prepared for the MDBC

Date: 2003 (draft)

Authors: Evans, Ife, Powell, Richardson and Walker

Objectives: Summarise the current state of knowledge concerning the status of groundwater resources in the MDB, interactions between surface water and groundwater, the water-related effects of land use change in dryland areas, and their implications for the Cap and MDBC water recovery initiatives.

Key Findings: At current estimates of sustainable yield, the MDB is at the limit of allocation in many groundwater systems. About 50% of GMUs within the MDB are over-allocated, and groundwater is over-used in about 15% of GMUs based on 2000/01 data.
There are declining groundwater pressures in all major regional aquifer systems due to over-extraction and increasing salinity in parts of the Murray Group Limestone, Gunnedah Formation, and Calivil Formation aquifers.
There is evidence of declining groundwater flows to rivers and increasing leakage from rivers to groundwater. Both processes affect river ecosystem health by altering the surface water flow regimes.
There is capacity for groundwater use to increase in some developing GMUs.

Title:	Projections of groundwater extraction rates and implications for future demand and competition for surface water. Prepared for the MDBC.

Date: 2003

Author: SKM

Objectives:

Project future groundwater extraction rates.
Identify extraction and quality thresholds for groundwater resources in the MDB.
Predict trends for subsequent displacement of groundwater use to surface water demand.
Provide an estimate of the economic cost of potential loss to industry due to limited access to groundwater.
Outline potential for disputes resulting from increased demand on surface water due to loss of groundwater resources.
Define the degree of connection between surface water and groundwater for given river reaches.

Key Findings:

Groundwater resources in the MDB in many areas are currently (1999/00) highly or over-allocated.
Over-allocated GMUs account for 80% of the total allocations in GMUs in the MDB.
Considering all MDB GMUs (excluding the GAB), 134% of the sustainable yield volume has been allocated.
By 2050 the sustainable yield was predicted to have been reached in virtually all GMUs, placing significant additional pressures on the Cap. This is an increase in groundwater use, which in 1999/00 was 58% of the sustainable yield.
Growth in groundwater usage between 1993/94 and 1999/00 represents a 2% undermining of the Cap by capturing baseflow (potential groundwater discharge to river flow). Insufficient data exists to accurately quantify the volume of groundwater pumped derived from surface water; however, for planning purposes a figure of 60% was adopted as an overall estimate.
It was estimated that 186 GL/yr of river flow was captured via groundwater pumping.
Assuming that groundwater usage increases up to the sustainable yield in GMUs that are currently partly developed and groundwater usage decreases down to the sustainable yield in GMUs that are currently over developed, then the loss of river water via groundwater pumping will be 711 GL/year (or 7% of total surface water usage).
In the long term groundwater should be fully integrated into an expanded Cap.

Title:	Final Report. Preliminary review of selected factors that may change future flow patterns in the River Murray system

Date: 2003

Authors: Resource & Environmental Management (REM, as reported by Earth Tech).

Objectives: Estimate of the likely impact to future flow patterns of the key factors on the period between the introduction of the Cap and today.

Nominated factors are climate change, reafforestation, groundwater extraction, changes to irrigation return flows from irrigation areas, farm dams, vegetation regrowth in the upper catchment following the 2003 bushfires, industry change and water trade.

Key Findings: The impact of groundwater pumping over the 20-year to 50-year period will be in the range of 275 to 550 GL/yr with a “likely” impact of 330 GL/yr for the entire basin.

Title:	Groundwater flow systems framework: Essential tools for planning salinity management

Authors: Walker, Gilfedder, Evans, Dyson and Stauffacher

Date: 2003

Objectives: Interpret relation between landscapes and groundwater systems leading to dryland salinity, taking into account the different geologies and landforms found throughout the basin

Key findings: Synthesis document presenting an overview of the use of the catchment classification (groundwater flow system framework) for salinity management in the basin.

Title:	Groundwater status report

Author: URS

Date: 2004

Objectives: Groundwater status report aimed to provide:

- an assessment of the current extent and condition of groundwater resources in the basin;
- an assessment of the extent to which groundwater conditions (salinity and head) have changed;
- a review of groundwater management arrangements and proposes changes where appropriate; and
- current levels of groundwater stress in the basin.

Key findings: Groundwater levels have been impacted by a sequence of drier than average years since the mid 1990s. This is because of increased groundwater extraction and a reduction in groundwater recharge and hence a decline in groundwater levels in parts of the basin.

Rising groundwater levels resulting in salinity is an ongoing problem and is of particular focus in the dryland regions around the margins of the basin.

State monitoring networks are an invaluable tool to assist in managing the hidden groundwater resources.

Close correlation between groundwater systems and surface water systems indicates the need to adopt a single resource management approach to the basin's water resources.

Groundwater resources have been impacted by anthropogenic activities such as land clearing, irrigation, maintenance of lock levels in rivers, groundwater pumping, capping and pipping programs and salt interception schemes.

Title: WATERMARK: Sustainable groundwater use within irrigated regions. Final report from Stage 1. Prepared for the MDBC.

Date: 2004

Authors: REM

Objectives: Summarise the status of groundwater use, allocation and yield across the MDB. Create a consistent approach to calculating sustainable groundwater yields for aquifers within the basin.

Define a process for managing the combined use of groundwater and surface water. Develop tools to help manage external groundwater impacts from irrigated areas. Establish an evaluation process to help monitor and report progress against benchmarks and targets for managing groundwater resources.

Key Findings: Presentation of a framework for conjunctive water resources management within irrigated regions of the Murray-Darling Basin. The framework recognises the need for appropriate investment in knowledge generation and analysis, and the need to manage surface water and groundwater as a single resource.

Produced the guiding principles for estimation of sustainable yield.

Summarised the status groundwater use, allocation and yield for GMUs across the basin.

Estimated a potential 275 to 550 GL/yr future impact on streamflow based on 2000/01 data.

Developed a monitoring and evaluation framework and developed an approach to managing irrigation impacts.

Recommendations for the implementation of a conjunctive management framework are provided.

Title:	Lagging behind: Exploring the time lag in river-aquifer interaction. Proceedings of the 9th Murray-Darling Basin Groundwater Conference, 17-19 February, Bendigo.

Date: 2004

Author: Braaten and Gates (Department of Infrastructure, Planning and Natural Resources)

Objectives: Investigate which aquifer and river parameters (via numerical simulation) affect the time lag between groundwater pumping and reductions in stream flow.

Key Findings: Stream flow reductions in response to groundwater pumping have a wide range of time lags depending on the characteristics of the aquifer system. Distance between groundwater pumping and river channels is generally considered to be one of the major causes of time lag, however, the methodology used indicated that distance had no effect on the lag time in narrow semi-confined valleys. Classification of river – aquifer systems needs to account for whether aquifers are semi-confined or unconfined wide or narrow, whether the river is regulated or unregulated, or whether it flows continuously or intermittently.

Title:	Queensland jurisdiction's response

Date: 2004

Author: Natural Resources and Mines (NRM)

Objectives: Summarise current and projected future groundwater use, identifying GMUs where future growth would be likely to have a significant impact on river flow.

Key Findings: There is limited potential for the expansion of groundwater use in Queensland GMUs in the basin, because current management arrangements cap allocations at agreed levels at early stages of aquifer development.
River water – groundwater connectivity was recognised in the Border Rivers GMU and some Upper Condamine GMUs.
The Border Rivers GMU has been capped since 1990, but groundwater use has not reached allocation levels. Increasing groundwater use has potential to impact river flow.
Upper Condamine groundwater use has reached allocation level and no further impact on river flow is anticipated.
All other GMUs where groundwater use was expected to increase in the future were classified as disconnected river - groundwater systems and no impact on river flows were predicted.

Title:	New South Wales jurisdiction's response

Date: 2004

Authors: Department of Infrastructure, Planning and Natural Resources (DIPNR).

Objectives: Summarise current and projected future groundwater use, identifying GMUs where future growth would be likely to have a significant impact on river flow.

Key Findings: Sustainable yield for each GMU is a social construct whereby groundwater entitlement, environmental water and impacts including those on stream flow is negotiated with all stakeholders and is applied for the term of the Water Sharing Plan.

The impact of stream flow on groundwater is seen as of equal importance. Changes in stream regulation and operation have a marked long term impact on groundwater systems that are often lagged by many decades.

Increasing water use efficiency may also indirectly impact on stream flow as 'deep drainage' from irrigation is recharge to the groundwater system and has been included in groundwater entitlements.

Integrity of the 'Cap' has been addressed in all inland surface water sharing plans.

Resource management in all of the water sharing plans is based on an estimate of sustainable yield that has been derived (in most cases) independently of the Cap.

This approach has no implications for 'Cap' management in areas where the river water and groundwater systems are disconnected (i.e. Lower Murray, Lower Murrumbidgee, Lower Lachlan, Lower Namoi, and Lower Gwydir).

For water sharing plans where river water and groundwater are hydraulically connected (i.e. Lower Macquarie and Upper Namoi), Cap management is a significant issue and will require further technical and modelling work to progress.

Upper Lachlan and Mid Murrumbidgee alluvial aquifers are the main areas of concern.

Title:	Victoria jurisdiction's response

Date: 2004

Author: Department of Sustainability and Environment (DSE)

Objectives: Summarise current and projected future groundwater use, identifying GMUs where future growth would be likely to have a significant impact on river flow.

Key Findings: Estimates of the impacts to streamflow were not provided.

The policy for groundwater allocation in relation to its impact on surface water resources and the environment was released in the White Paper "Securing our water future together" in June 2004.
The paper states that for any new allocation where there is a high degree of connectivity between surface water and groundwater the Government will ensure that any allocation of new groundwater licences does not undermine the Environmental Water Reserve or surface water allocations.

Title:	South Australia jurisdiction's response

Date: 2004

Author: Department of Water Land and Biodiversity Conservation (DWLBC)

Objectives: Summarise current and projected future groundwater use, identifying GMUs where future growth would be likely to have a significant impact on river flow.

Key Findings: There are no GMUs where current or projected groundwater extraction is likely to have a significant impact on river flow in the main Murray River channel.
Groundwater extraction for salt interception schemes may reduce river flow by <1%, however, these are saline groundwater flows prevented from entering the river rather than flows induced out of the river.
Several tributary streams that intermittently enter the River Murray and Lake Alexandrina gain groundwater from the Mt Lofty Ranges highlands, but lose surface water to groundwater recharge when they flow across the plains. These are generally ungauged, but their total flow is approximately 30 GL/year. These flows are not accounted under the Cap on water diversions.

3 GROUNDWATER USE IN THE MURRAY-DARLING BASIN

3.1 Introduction

This section contains a summary of the available data on historic use, current use and future use reported at a basin, jurisdiction and GMU scale (Sections 3.3 to 3.5) and a discussion of the data (Section 3.6).

The primary data source for this section was the data provided by each of the jurisdictions in response to the request from MDBC and MDBMC to report on groundwater issues (the data tables submitted are provided in Appendix A). The jurisdiction's responses were supported with additional information from reports summarised in Section 2.

3.2 Groundwater resources of the Murray-Darling Basin

Groundwater is used extensively throughout the basin and contributes around 10 to 15% of the basin water resource. Around 65% of groundwater is used for irrigation (**Figure 3.1**), which is taken from an area covering less than 20% of the basin (SKM, 2003)

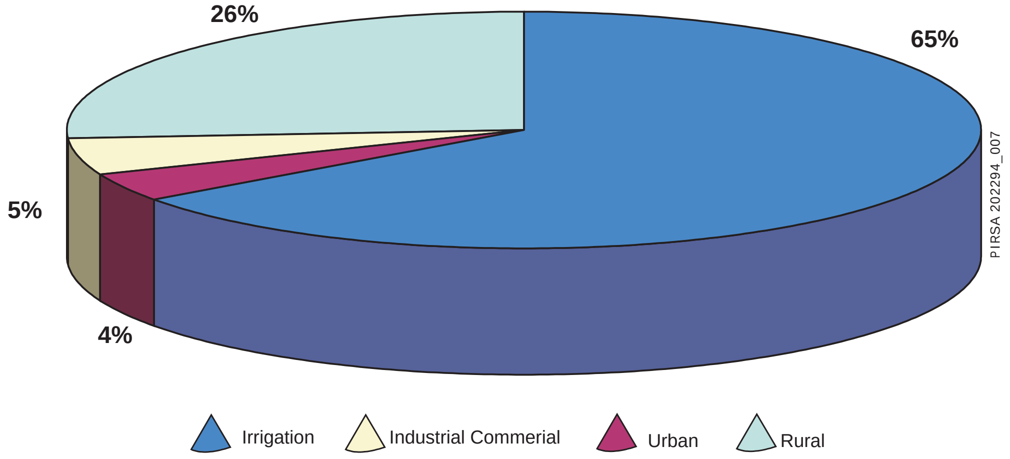
There are three aquifer types within the basin – basinal sediments of the Murray Geological Basin and associated deposits in the Darling River Drainage Basin; porous sandstones within the Great Artesian Basin; and aquifers within the fractured rocks of the highlands (Lachlan Fold Belt, New England Block, and Mt Lofty Ranges, Evans *et al*., 2004).

The basinal aquifers are regional in extent and granular in nature, whereas individual fractured rock aquifers are much smaller and more localised (although in total, fractured rock aquifers cover a larger area). Basinal aquifers provide most of the basin's groundwater resources. The GAB sandstones are extensive but occur at depth and generally have no influence on stream flow in the basin and hence are disregarded in this report.

There is a detailed description of the basin's groundwater systems in the Groundwater Status Report (GSR, refer Section 2), including analysis of trends in groundwater levels and salinity, and a description of inter-aquifer connections. This information can be used to support the analysis of stream-aquifer interaction.

Groundwater flow systems (GFS) have also been defined throughout the basin as an aide to the management of dryland salinity (refer to Section 2).

The National Land and Water Resource Audit (NLWRA, 2000) defined a Groundwater Management Unit (GMU) as a "hydraulically connected groundwater system that is defined and recognised by Territory and State agencies". Unincorporated areas (UA) are the parts of groundwater provinces



Types of groundwater use (%) in the Murray-Darling Basin for 1999/2000 (taken from SKM, 2003)

Figure 3.1

that are not designated as GMUs. There is limited potential for use to increase in UAs.

New GMUs are being proclaimed in NSW as pressure on the use of existing water resources increases and the potential for adverse impacts on streamflow and quality.

A breakdown of the number of GMUs and UAs in each jurisdiction is provided in **Table 3.1**.

Table 3.1 Summary of number of groundwater management units and unincorporated areas by jurisdiction.

Jurisdiction	Number of GMUs (excluding GAB)	Number of GMUs in the GAB	Number of unincorporated areas (UA)
Queensland	26[2]	6	1
New South Wales	26[1]	4	7
Victoria	22[3]	0	4
South Australia	12[3]	0	4
Total	86	10	16

[1] Includes a GMU for the Border Rivers alluvium.

[2] Includes Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs.

[3] Includes GMUs outside the Murray drainage basin but within the Murray geological basin.

This report focuses on the GMUs and excludes GAB GMUs and UAs on the basis of the likely impact of groundwater pumping on streamflow.

The operation of salt interception schemes (SIS) provide a benefit to river water quality by intercepting salt within the aquifer before it discharges to the river. Data for salt interception schemes is also provided in the report.

3.3 Groundwater management and sustainable yield

All basin jurisdictions are committed to managing groundwater resources according to a sustainable yield approach. The National definition of sustainable yield is:

Sustainable groundwater yield is defined as the groundwater extraction regime, measured over a specified timeframe that allows acceptable levels of stress and protects dependent economic, social and environmental values.

This definition is normally accompanied by explanatory notes for extraction regime, acceptable levels of stress, storage depletion and protecting dependent economic, social and environmental values which are provided in Section 8

A key component of the definition of sustainable yield is the trade-offs that can occur between various users, usually between consumptive and environmental users on the basis that a balance is needed to maintain the social and economic development that has occurred with the use of groundwater. In this sense the value of sustainable yield can change over time as social values change so that GMUs that are currently over-used with respect to sustainable yield could be seen as being sustainable at some point in the future.

There are variations between jurisdictions in the approach to definition of sustainable yield and there are also variations in approaches to how sustainable yield is used in the context of water sharing and water allocation plans.

3.4 Historical use in the Murray-Darling Basin

Historical groundwater use data are summarized in Section 3.4.1 and data qualifications are described in Section 3.4.2.

3.4.1 Data

A compilation of historical use data is provided in Table 3.2. The data is based on information from the sources identified in this report (Section 2) with the exception of sources listed in the footnotes to Table 3.2.

In general, the history of use at the GMU scale falls into two broad categories - one where the use has continued to increase, but with possible minor fluctuations around the trend line (e.g. Lower Murrumbidgee, **Figure 3.2**); and another where use was relatively constant (usually capped) but again with fluctuations (sometimes the fluctuations are large, e.g. Condamine).

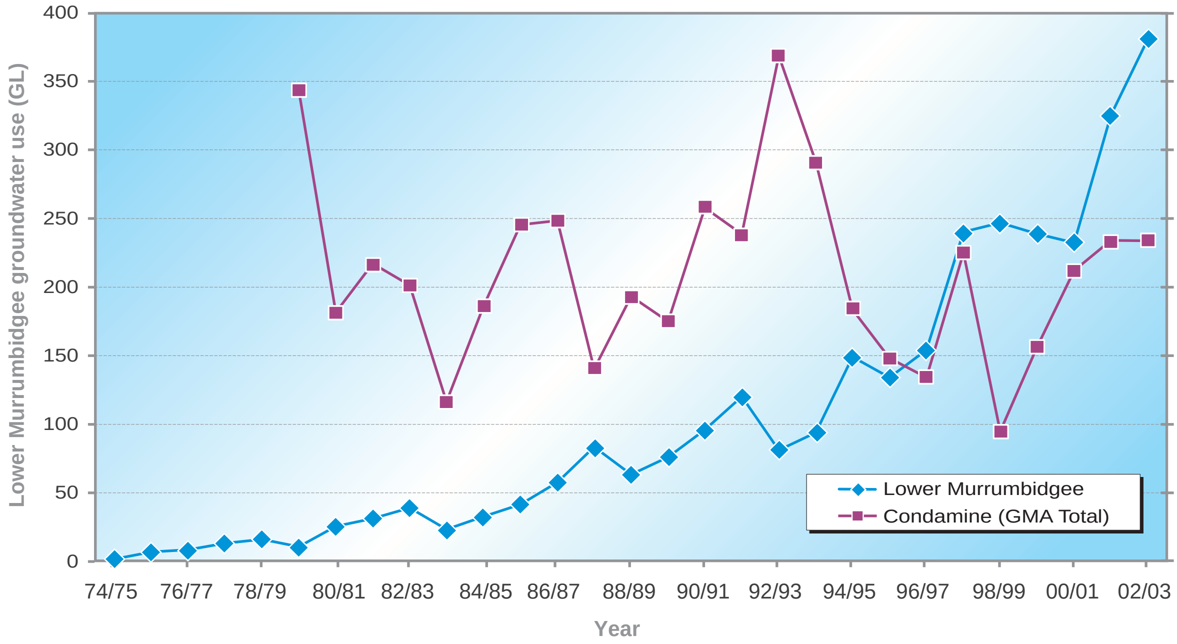
There is additional groundwater use, sustainable yield and allocation data from the MDBC Water Audit Monitoring reports which are summarised in Appendix B.

Table 3.2

Jurisdiction	1983/84 (GL, Water Review 1985)	1996/97 (GL, National Land and Water Resources Audit)	1999/00 (GL, SKM, 2003)	2000/01 (GL, Watermark)
Queensland		[2]1623	[3]92	[4]129
New South Wales		[2]1009	[5]742	[5]667
Victoria		[9]622	[6]217	[6]212
South Australia		[8]430	[7]23	[6]213
Total	[1]894	[2]3684	1074	1033

Compilation of historical groundwater use data.

[1] Data provided by MDBC. The authors have not reviewed the report and it is not known whether the value includes all GMUs.



Trends in groundwater use in the Lower Murrumbidgee and Condamine GMUs

Figure
3.2

[2] Values include GAB aquifers and unincorporated areas. The NLWRA website was experiencing difficulties and access to GMU-scale information was not possible.

[3] Data not available for Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs. Data excludes GAB GMUs.

[4] Data includes Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs. Data excludes GAB GMUs.

[5] Data includes Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and excludes Border Rivers alluvium and GAB GMUs.

[6] Data excludes Telopea Downs, Lillimur, Neuarpur, Boikerbert, Moolort, Bungaree, Glengower, Bullarook and Tourello GMUs.

[7] Data includes values for Angas Bremer and Mallee GMUs.

[8] This value is larger than the SKM and Watermark values because it includes values for the GMUs that are within the Murray geological basin, but outside the Murray drainage basin. This value also includes unincorporated areas.

[9] Includes unincorporated areas.

3.4.2 Data qualification

Compilation of historical groundwater use data for trend analysis is made difficult because of differences in the GMUs reported between data sources and the incomplete datasets (e.g. missing years).

There is no information readily available that describes the reliability of the Water Review 1985 and NWLRA (2000) datasets. A comparison of the different datasets raises some issues such as the 400 GL difference between the NLWRA and later datasets which appears to be assigned to unincorporated areas in Victoria and South Australia.

There are reliable historical datasets available for some GMUs with records that go back 20 to 30 years. However there are other data sets where use has not been metered but instead estimated. These historical datasets are currently being collated as part of the Watermark project (Stage 2).

3.5 Current (2002/03) groundwater use in the Murray-Darling Basin

The available groundwater use data for 2002/03 has been compiled and summarised in Section 3.5.1 and data qualifications are described in Section 3.5.2.

3.5.1 Data

A compilation of current use data for each jurisdiction is provided in **Table 3.3**. A composite set of values of groundwater use for 2002/03 has been constructed and presented in **Table 3.3 (last column)** based on the range of available data.

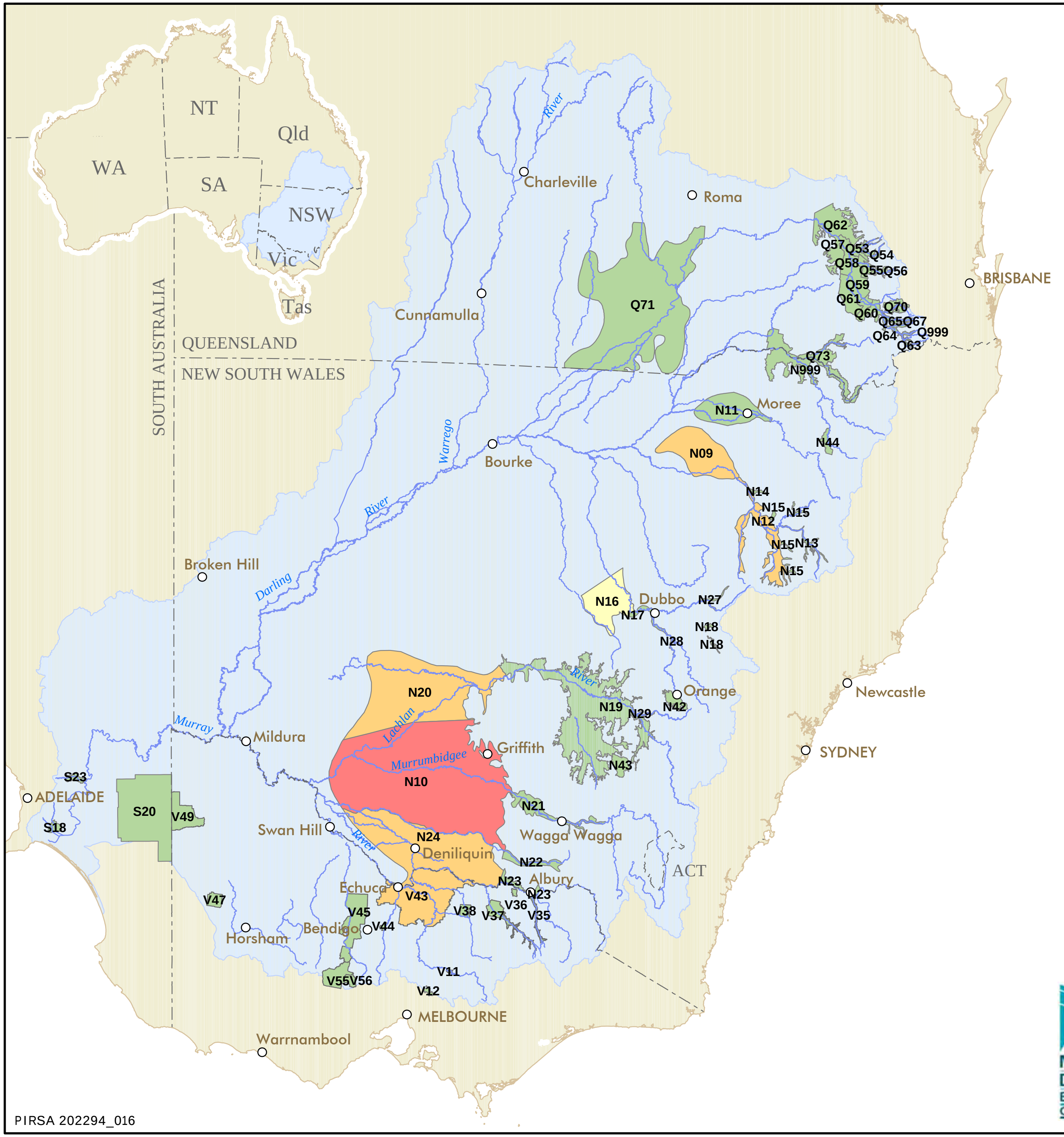
A compilation of current volumes of groundwater extracted from salt interception schemes is provided in **Table 3.4**.

The volume of groundwater use in each GMU (excluding GAB aquifers) in 2002/03 is mapped in **Figures 3.3 and 3.4.** The extent of GMUs has to be presented using two maps because of some GMUs overlap each other in the vertical profile. The first map (**Figure 3.3**) shows the extent of those GMUs that are not overlain by other GMUs and the second map **(Figure 3.4)** shows the extent of those GMUs that are partly or wholly overlain by other GMUs.

The extent of the GMUs in Figures 3.3 and 3.4 is based on the information available in October 2004, however, it is recognised that new GMU boundaries are being identified in NSW as part of the macro water sharing planning process.

The GMUs with largest volumes of groundwater use in 2002/03 (greater than 50 GL) are:

- Lower Murrumbidgee (381 GL);
- Lower Murray (134 GL);
- Upper Namoi (132 GL);
- Lower Lachlan (123 GL);
- Shepparton (120 GL);
- Lower Namoi (119 GL); and
- Lower Macquarie (54 GL).



GMU key and name

N09, Lower Namoi Alluvium
N10, Lower Murrumbidgee Alluvium
N11, Lower Gwydir Alluvium
N12, Upper Namoi Alluvium
N13, Peel River Alluvium
N14, Maules Creek Alluvium
N15, Miscellaneous Tributaries of the Namoi River (Alluvium)
N16, Lower Macquarie Alluvium
N17, Upper Macquarie Alluvium
N18, Cudgegong Valley Alluvium
N19, Upper Lachlan Alluvium
N20, Lower Lachlan Alluvium
N21, Mid Murrumbidgee Alluvium
N22, Billabong Creek Alluvium
N23, Upper Murray Alluvium
N24, Lower Murray Alluvium
N27, Coolaburragundy - Talbragar Valley Alluvium
N28, Bell Valley Alluvium
N29, Belubula River Alluvium
N42, Orange Basalt
N43, Young Granite
N44, Inverell Basalt
N999, Border River
Q53, Myall / Moola Creek North
Q54, Myall Creek
Q55, Lower Oakey Creek Alluvium
Q56, Oakey Creek Management Area
Q57, Condamine - Condamine Groundwater Management Area Sub-Area 1
Q58, Condamine - Condamine Groundwater Management Area Sub-Area 2
Q59, Condamine - Condamine Groundwater Management Area Sub-Area 3
Q60, Condamine - Condamine Groundwater Management Area Sub-Area 4
Q61, Condamine - Condamine Groundwater Management Area Sub-Area 5
Q62, Condamine River (Down-river of Condamine Groundwater Management Area)
Q63, Condamine River Alluvium (Killarney to Murrays Bridge)
Q64, Condamine River Alluvium (Murrays Bridge to Cunningham)
Q65, Condamine River Alluvium (Cunningham to Ellangowan)
Q66, Glengallan Creek
Q67, Dalrymple Creek Alluvium
Q68, Kings Creek Alluvium
Q69, Swan Creek Alluvium
Q70, Nobby Basalts
Q71, St. George Alluvium
Q73, Border River
Q999, Emu Creek Alluvium
S18, Angas Bremer
S20, Mallee - 1
S23, Marne
V11, Alexandra
V12, King Lake
V35, Mullindolingong
V36, Barnawartha
V37, Murmungee
V38, Goorambat
V43, Shepparton Groundwater Supply Protection Area
V44, Ellesmere
V45, Mid Loddon
V47, Balrootan (Nhill)
V49, Murrayville Groundwater Supply Protection Area
V55, Upper Loddon
V56, Spring Hill Groundwater Supply Protection Area

Groundwater Use (GL)

- Less than 50
- 50 - 100
- 100 - 200
- 200 - 400
- No Data

- Murray Darling Basin
- Murray-Darling River System

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that are not overlain by any other GMUs

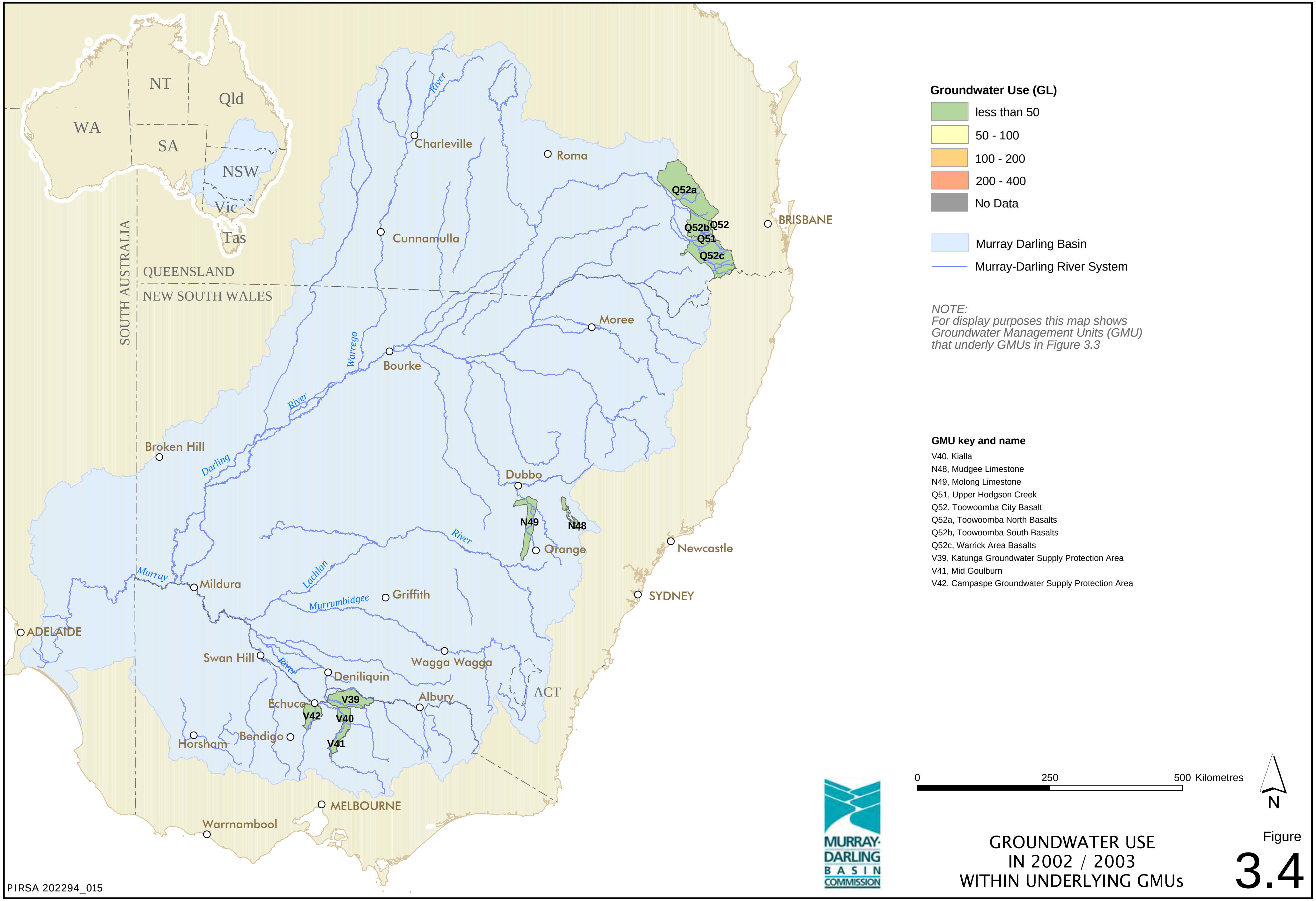
0 250 500 Kilometres

N

MURRAY-DARLING BASIN COMMISSION

GROUNDWATER USE IN 2002 / 2003 WITHIN EACH GMU

Figure 3.3



GROUNDWATER USE IN 2002 / 2003 WITHIN UNDERLYING GMUs

Figure 3.4

Table 3.3 Compilation and summary of the data available describing current (2002/03) groundwater use.

Jurisdiction	Number of GMUs with current use data provided in the jurisdiction's responses	Current use (GL, provided in the jurisdiction's responses)	Current use (GL, from adjusted jurisdiction's responses)	[1]Current use (GL, taken from the Water Audit Monitoring Report 2002-03)	[2]Current use (GL, used in the Watermark project)	Current use data (GL, based on an evaluation by the authors)
Queensland	26[3]	151[3]	151[3]	Not available at the GMU scale	154[3]	151[3]
New South Wales	25	1008[4]	[11]855	1290	1120[5]	1126[10]
Victoria	15	310[6]	234[7]	Only available for metered GMUs	Only available for metered GMUs	239[7]
South Australia	3	44[8]	[12]34	Not provided	34[9]	34[9]
Total	69	1513	1274			1550

[1] Use data for NSW was provided to REM by MDBC taken from the Water Auditing Monitoring Report for 2002/03.

[2] Queensland and SA data provided to REM for the Watermark project.

[3] Data from Watermark was added for the Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs, but excludes the six GAB GMUs (pers. comm. David Free, NRM). The difference between the 154 GL (Watermark) and 151 GL (jurisdiction's response) values occurs because of round-off.

[4] NSW data for current use not necessarily for 2002/03 and in some GMUs the data is based on information used in model calibration runs. Data excludes Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and includes four GAB GMUs.

[5] NSW data provided to REM for the Watermark project excludes GAB aquifers and the Border Rivers alluvium, but includes estimates for Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone and Molong limestone GMUs.

[6] Victorian data does not include GMUs located in western Victoria (Balrootan, Murrayville, Telopea Downs, Lillimur, Neuarpur, Boikerbert). Excludes SIS.

[7] Victorian data does not include GMUs located in western Victoria (Telopea Downs, Lillimur, Neuarpur, Boikerbert). Excludes groundwater use in UAs and SIS.

[8] Use value based on volume pumped from the Waikerie, Woolpunda and Qualco-Sunlands salt interception schemes and Angas Bremer, Marne and Mallee GMUs. The SA contact suggested not including SA GMUs that lie outside the drainage basin (pers. comm. Steve Barnett, DWLBC).

[9] SA values for Angas Bremer, Marne and Mallee GMUs.

[10] Includes a 5.5 GL (rounded up to 6 GL) volume for the NSW part of the Border Rivers (pers. comm. David Free) added to the 1120 GL from Watermark.

[11] Excludes values for GAB, use in UAs and SIS.

[12] Excludes SIS and use in UAs.

Table 3.4 Compilation and summary of the data available describing current (2002/03) groundwater extraction from salt interception schemes.

Jurisdiction	Current volume of groundwater extracted (GL)
Queensland	0
New South Wales	7.7[1]
Victoria	7.3[2]
South Australia	9.8[3]
Total	24.8

[1] Data provided by DIPNR

[2] Data provided by River Murray Water and does not include value for SIS at Pyramid Creek.

[3] Data provided in SA jurisdiction's response

3.5.2 Data qualifications

Queensland

The jurisdiction's response (Appendix A) contains data for 26 GMUs. The response did not include the GAB aquifers in their response because the GAB aquifers are not connected to surface water systems (pers. comm. David Free, NRM).

Eight of the 26 GMUs for which data was supplied have metered data, which is supplemented with estimates for stock and domestic use. Use values for the remaining 18 GMUs are estimates only. There is no information presented which allows an assessment of the accuracy of the estimated use values.

Data from the Water Audit Monitoring Reporting process was not included because the data provided was based on Cap catchments rather the GMUs.

New South Wales

The jurisdiction's response (Appendix A) contains use data for 25 metered GMUs. Data for the Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone and Molong limestone GMUs was not provided because use in these GMUs is small (pers. comm. George Gates, DIPNR). The NSW response does not contain data for the NSW part of the Border Rivers alluvium, although data provided by Queensland indicates NSW metered use to be around 5.5 GL/yr (pers. comm. David Free, NRM).

NSW provided estimates of current use that didn't necessarily correspond with the 2002/03-year and were derived from datasets used in groundwater flow model calibration. In some cases the volume of current use provided by NSW related to a year other than 2002/03. This was done because the estimates of impact on streamflow (refer Section 4) are taken from model output (in 10 GMUs) and the presentation of model input data in the jurisdiction's response therefore made the response internally consistent (pers. comm. Mike Williams, DIPNR).

The reason for differences in current use values in non-modelled GMUs is not known.

NSW advised that groundwater use data from the Water Audit Monitoring process could be used to report use in 2002/03. There is a difference of 265 GL between the use values provided in the adjusted NSW jurisdiction's response and the use values in the Water Audit Monitoring Report (2002/03) datasets.

Victoria

The jurisdiction's response (Appendix A) contains data for 15 GMUs. There are six GMUs (of the 15 GMUs in the response) with metered data only and the remaining nine GMUs have estimated use values or a combination of metered and estimated values.

Groundwater use in most unmetered GMUs is relatively small and these unmetered GMUs are therefore less important when discussing basin-scale impacts. The Shepparton GMU is the exception with an estimated 2002/03 use of around 120 GL, which is a large part of the total volume reported in the jurisdiction’s response (310 GL).

South Australia

The data on 2002/03 use in the jurisdiction’s response was for the three GMUs within the Murray-Darling drainage basin (Angas Bremer, Marne and Mallee GMUs). Data for salt interception schemes along the River Murray was also included.

3.6 Future use

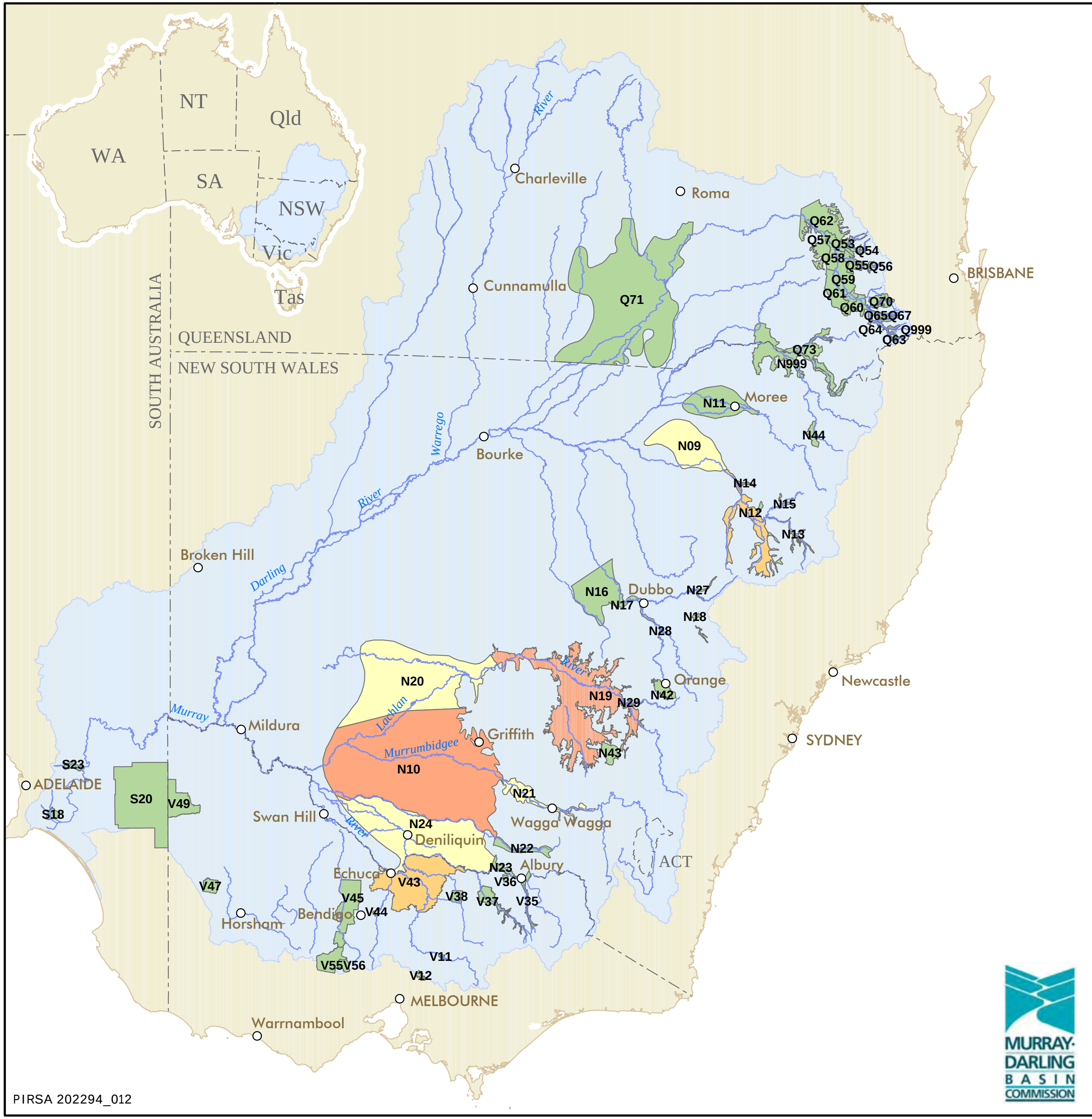
A compilation of the future use data for each jurisdiction is provided in **Table 3.5**. A composite set of values of groundwater use for 2002/03 is also presented in **Table 3.5 (last column)**.

The volume of groundwater estimated to be used in each GMU (excluding GAB aquifers) in 2052/53 is mapped in **Figures 3.5 and 3.6.**

The rate of growth varies between GMUs and between jurisdictions with use in NSW expected to plateau at sustainable yield within 10 years. Growth in Queensland is limited by a groundwater cap that is in place for most GMUs. The rate of rise in use is not expected to be large because use in many of the GMUs is capped.

Future growth in Victoria is expected to increase significantly. Use in South Australia is not expected to increase significantly because of limits to the availability of low salinity water in the Mallee GMU.

The largest projected increases in groundwater use over the 50-year period are in the Upper Lachlan (161 GL) and Mid Murrumbidgee (53 GL) GMUs. For the Upper Lachlan and Mid Murrumbidgee, the sustainable yield estimates are preliminary and may be revised downwards over the next 10 years prior to these projected increases actually occurring. In other GMUs such as the Lower Murrumbidgee and Upper Namoi, use is expected to fall back to the sustainable yield over the next 50-years as regulatory controls take effect.



GMU key and name

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N10, Lower Murrumbidgee Alluvium
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Q70, Nobby Basalts
Q71, St. George Alluvium
Q73, Border River
Q999, Emu Creek Alluvium
S18, Angas Bremer
S20, Mallee - 1
S23, Marne
V11, Alexandra
V12, King Lake
V35, Mullindolingong
V36, Barnawartha
V37, Murmungee
V38, Goorambat
V43, Shepparton Groundwater Supply Protection Area
V44, Ellesmere
V45, Mid Loddon
V47, Balrootan (Nhill)
V49, Murrayville Groundwater Supply Protection Area
V55, Upper Loddon
V56, Spring Hill Groundwater Supply Protection Area

Groundwater Use (GL)

- less than 50
- 50 - 100
- 100 - 200
- 200 - 400
- No Data

- Murray Darling Basin
- Murray-Darling River System

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that are not overlain by any other GMUs

0 250 500 Kilometres

N

MURRAY-DARLING BASIN COMMISSION

PROJECTED GROUNDWATER USE IN 2052/2053 WITHIN EACH GMU

Figure 3.5

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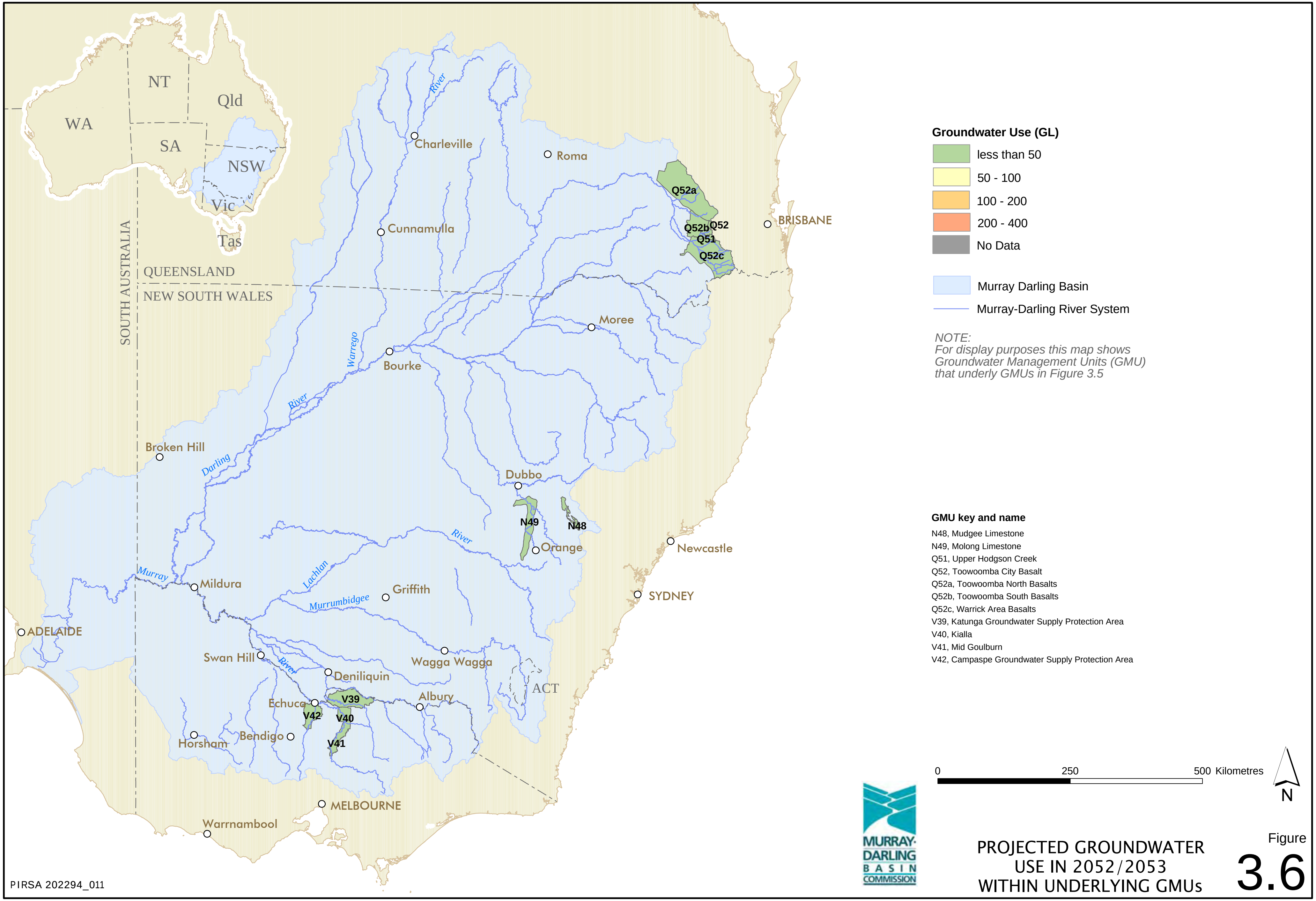


PROJECTED GROUNDWATER USE IN 2052/2053 WITHIN UNDERLYING GMUs

Figure 3.6

Table 3.5 Compilation and summary of the data available describing projected groundwater use.

Jurisdiction	Number of GMUs with future use data in the jurisdiction's responses	Estimated future use (GL, from the jurisdiction's response)		Estimated future use (GL, from adjusted jurisdiction's responses)		Estimated future use (GL, based on an evaluation by the authors)	
		2012/13	2052/53	2012/13	2052/53	2012/13	2052/53
Queensland	26	181[1]	215[1]	181[1]	215[1]	181[1]	215[1]
New South Wales	25	1312[2]	1312[2]	1203[8]	1203[8]	1251[6]	1251[6]
Victoria	15	378[3]	445[3]	263[4]	293[4]	2703[4]	304[4]
South Australia	3	77[5]	95[5]	42[7]	52[7]	42[6]	52[6]
Total	69	1948	2067	1689	1763	1744	1822

[1] Data from Watermark was added for the Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs, but excludes the six GAB GMUs and use in UAs (pers. comm. David Free). It was assumed the upper limit was the estimated sustainable yield. It was assumed that 50% of the available increase would occur in the first 10 years and the remaining 50% of the available increase would occur in the remaining 40 years.

[2] Data excludes Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and includes four GAB GMUs.

[3] Victorian data does not include GMUs located in western Victoria (Balrootan, Murrayville, Telopea Downs, Lillimur, Neuarpur, Boikerbert). Excludes SIS.

[4] Victorian data does not include GMUs located in western Victoria (Telopea Downs, Lillimur, Neuarpur, Boikerbert). Excludes groundwater use in UAs and SIS.

[5] Use value based on volume pumped from the Waikerie, Woolpunda, Qualco-Sunlands, Pike River, Murtho, Loxton, Bookpurnong and Chowilla salt interception schemes and values for Angas Bremer, Marne and Mallee GMUs. Excludes groundwater use in UAs.

[6] Data from Watermark added for Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and excludes four GAB GMUs, SIS and UAs. The upper limit to use for the additional GMUs is the estimate of sustainable yield provided for the Watermark project.

[7] Excludes values for UAs and SIS.

[8] Data excludes Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs. Excludes GAB GMUs, UAs and SIS.

Table 3.6. Compilation and summary of the data available describing projected groundwater extraction from salt interception schemes.

Jurisdiction	Volume of groundwater extracted (GL)	
	2012/13	2052/53
Queensland	0	0
New South Wales	8.2[1]	8.2[1]
Victoria	7.3[2]	7.3[2]
South Australia	34.6[3]	43.4[3]
Total	50.1	58.9

[1] Data provided by DIPNR

[2] Data provided by River Murray Water and does not include value for SIS at Pyramid Creek.

[3] Data provided in SA jurisdiction's response

3.6.1 Data qualification

Queensland

The addition of the data for the GMUs not originally included in the jurisdiction's response (refer to footnote 1 to **Table 3.5**) is not expected to change the overall outcome from the analysis because these GMUs are relatively small (total of 39 GL allocated).

New South Wales

The addition of data for those small GMUs not included in the response increase the estimate of future use by around 48 GL/yr.

Victoria

The estimates of future use provided within the jurisdiction's response are based on the assumption that use will reach the upper limit (permissible annual volume) in 50-years, with half the increase occurring in the next 10-years and the remaining increase in the following 40-years.

Future use in metered GMUs are described in the response as having a "medium confidence" and future use in unmetered GMUs are described as having a "low confidence".

South Australia

Data was provided for relevant GMUs and for salt interception schemes

3.7 Key findings and discussion

The collation of jurisdiction and basin scale datasets confirms that groundwater use has increased significantly within the basin over the last 20-years. The Water Review (1985) report estimated groundwater use to be 894 GL in 1983/84. Groundwater use increased gradually to 1033 GL in 2000/01, and then increased more rapidly to 1550 GL in 2002/03. There was an additional 24.8 GL extracted by salt interception schemes in 2002/03.

There is no basin-scale dataset that describes use in 1993/94, although it has been estimated that total groundwater use rose by 310 GL/yr between 1993/94 and 1999/00 (SKM, 2003). It is not clear from the SKM report whether the 310 GL applies to all groundwater resources in the basin or just GMUs.

Groundwater use has increased in nearly all GMUs in the basin since 2000/01 and the only GMUs where use has been stable are those where use is at or above the sustainable yield. The largest increase in use between 2000/01 and 2002/03 occurred in the alluvial plain GMUs mostly in southern New South Wales (450 GL).

The rapid rise is considered to be due mainly to new development of irrigated areas, the implementation of the Cap on surface water diversions which is limited to 1993/94 development levels, and the continuing dry climatic conditions.

There are very few GMUs that have shown a falling trend, even where use exceeds sustainable yield. Capital investment in infrastructure for the use of groundwater is likely to mean that groundwater use will not decline significantly.

Figure 3.7 provides a summary of (approximated) basin scale historical trends in groundwater use. The groundwater use trend line shown in the figure is stylised based on only a few pieces of data. **Figure 3.7** also provides a trend line that represents the growth in the diversion of surface water.

The rapid increase in groundwater use since 2000/01 indicates that the sustainable yield of the basin's groundwater resources will be reached within the next 5 to 10 years. Use in 2002/03 was 1550 GL which is around 80% of the sustainable yield for the basin. This contrasts with the situation in 2000/01 when use was 58% of the sustainable yield.

The ratio of use in 2002/03 to estimated sustainable yield in each GMU is mapped in **Figure 3.8 and 3.9**. The estimates of sustainable yield are taken from datasets provided to REM for the Watermark project. There are 18 GMUs within the basin where current use is greater than the estimated sustainable yield. There are three large GMUs; the Lower Lachlan, Lower Murrumbidgee, Lower Murray where use in 2002/03 exceeded the sustainable yield. Water sharing plans are being introduced across NSW to keep average groundwater use (over a 10-year period) at a level at, or below, sustainable yield. Over used GMUs exist in Queensland (Condamine Sub area 3).

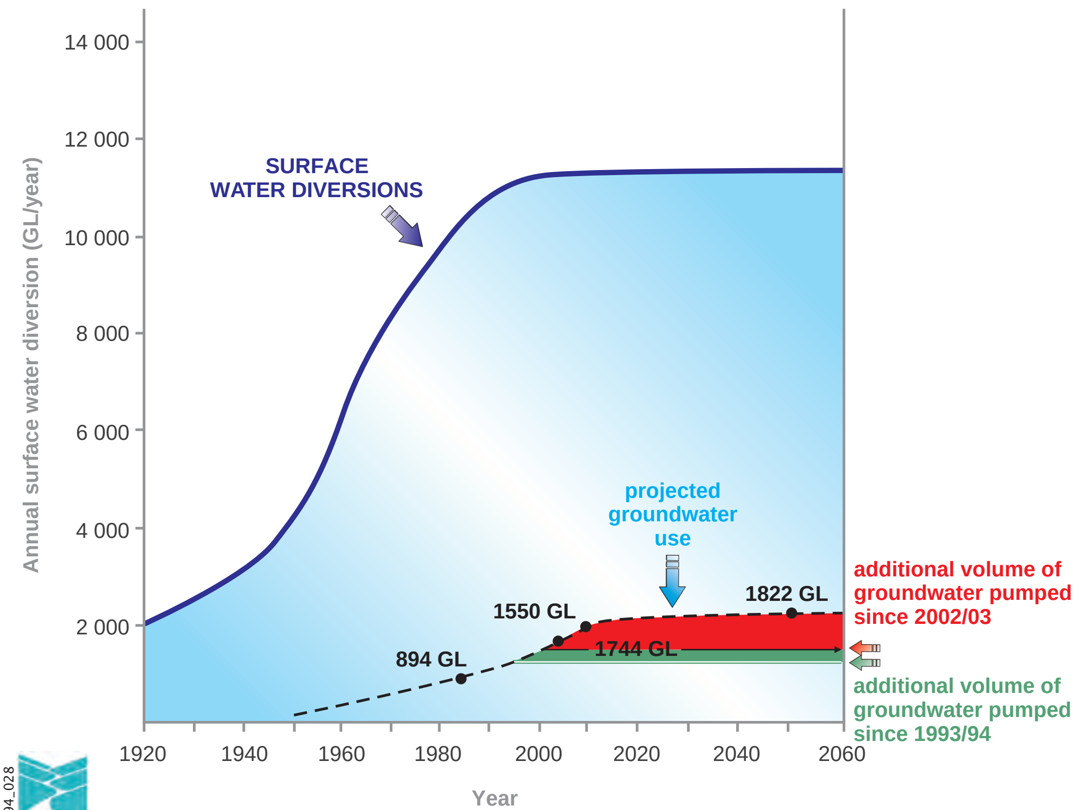
Groundwater use is estimated to increase by 17% (to 1822 GL/yr) over the 50-year timeframe. The volume of groundwater extracted by salt interception schemes is estimated to increase by nearly 140% (to around 59 GL/yr) over the 50-year timeframe. Most of this increase is estimated to occur when new salt interception schemes are commissioned along the South Australian reach of the River Murray.

With respect to future groundwater use, most of the increase in groundwater use can be expected in the 10-year rather 50-year timeframe recognising the rapid growth seen since 2000/01. This conclusion is in stark contrast to previous studies that have suggested a gentler rise over the next 50 years or so (SKM, 2003). It is expected that reduced allocations and the introduction of trading of groundwater licences in NSW GMUs will further accelerate groundwater use.

The largest growth is anticipated to occur (on a volumetric basis) in the Upper Lachlan and Mid-Murrumbidgee GMUs (based on current sustainable yield estimates). However other factors such as market forces and climate change will also be important. The overriding factor is likely to be revised management plans at the GMU scale.

There is limited scope for further development of groundwater resources in South Australia and Queensland.

The level of confidence in the current groundwater use data varies between GMUs. There is no readily available data to determine the accuracy of estimated or metered use values, but some semi-quantitative observations can be made.



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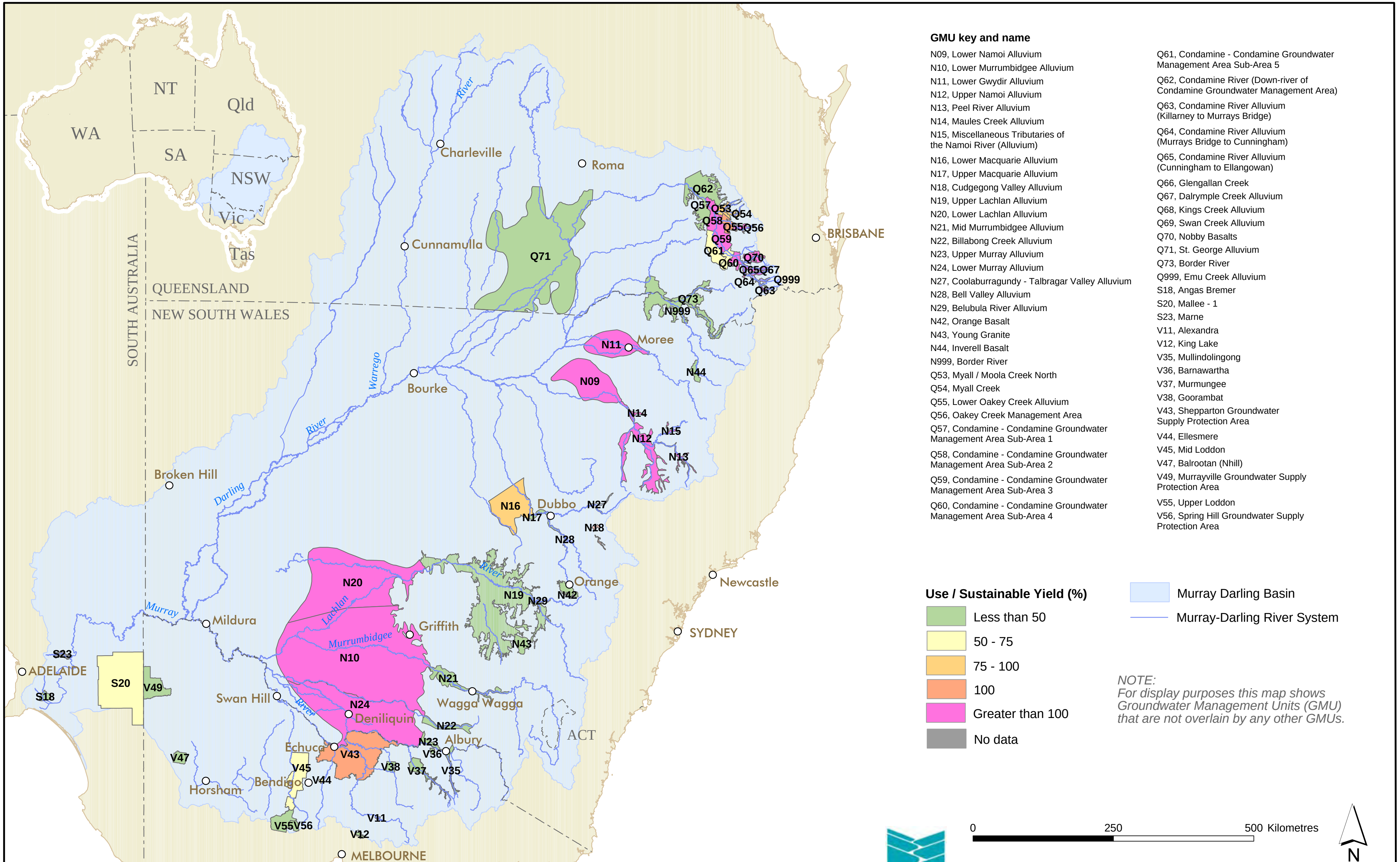
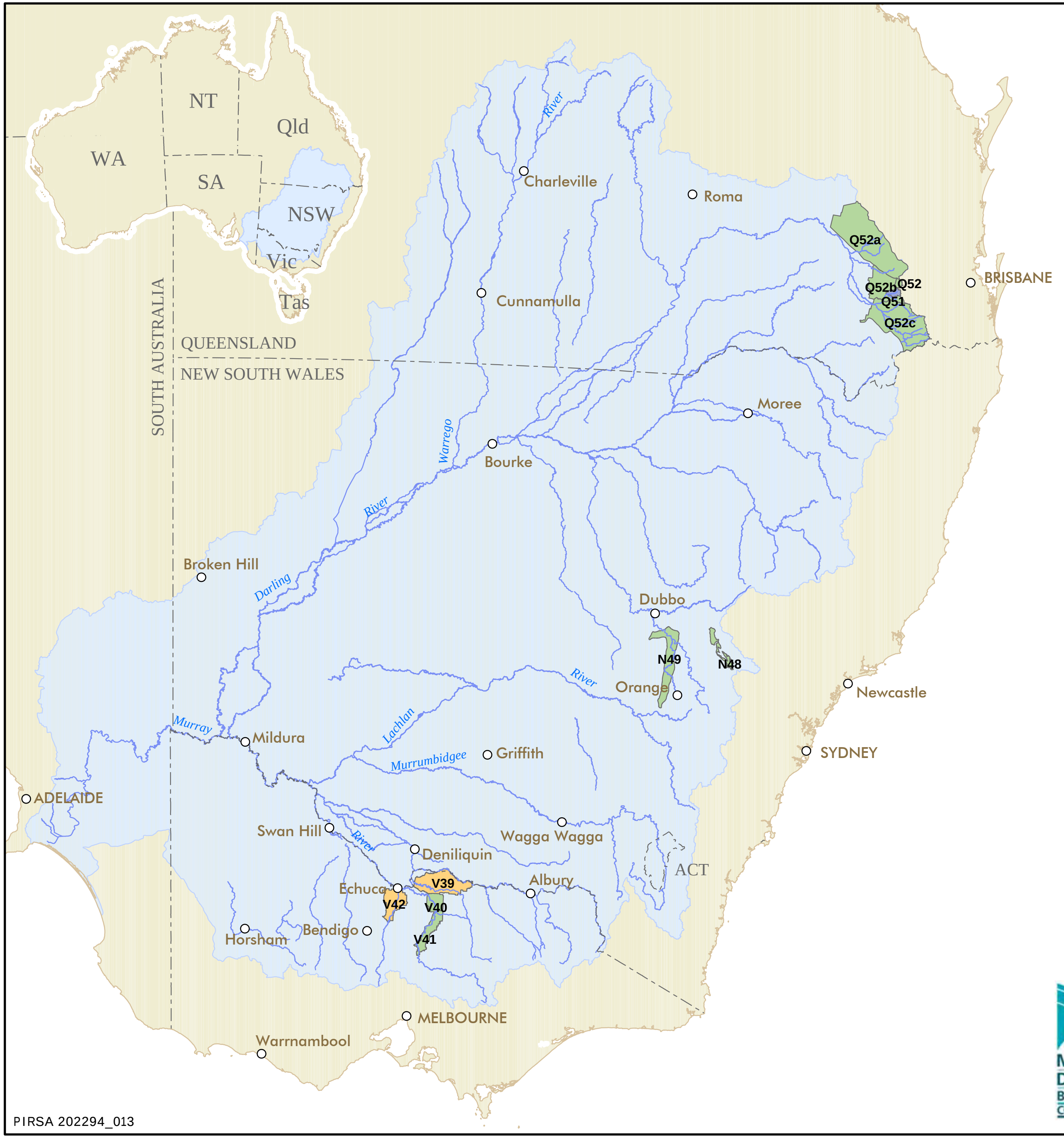
Trends in surface water and groundwater use for the basin

Figure 3.7



RATIO OF GROUNDWATER USE IN 2002/2003 TO SUSTAINABLE YIELD WITHIN EACH GMU

Figure 3.8



Use / Sustainable Yield (%)

- Less than 50
- 50 - 75
- 75 - 100
- 100
- Greater than 100
- No data

- Murray Darling Basin
- Murray-Darling River System

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that underly GMUs in Figure 3.8

GMU key and name

N48, Mudgee Limestone
N49, Molong Limestone
Q51, Upper Hodgson Creek
Q52, Toowoomba City Basalt
Q52a, Toowoomba North Basalts
Q52b, Toowoomba South Basalts
Q52c, Warrick Area Basalts
V39, Katunga Groundwater Supply Protection Area
V40, Kialla
V41, Mid Goulburn
V42, Campaspe Groundwater Supply Protection Area

0 250 500 Kilometres

N

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RATIO OF GROUNDWATER USE IN 2002/2003 TO SUSTAINABLE YIELD WITHIN UNDERLYING GMUs

Figure 3.9

In some jurisdictions there are a high number GMUs where use is estimated rather than metered. For example in Victoria only six of the 15 GMUs reported in the jurisdiction response have been metered. GMU scale analysis of use is hampered by the lack of metered groundwater use data. Similar issues occur in Queensland.

Most jurisdiction’s responses did not include a small number of GMUs. In some cases (e.g. in Victoria) this is because a number of smaller GMUs have been consolidated to form larger GMUs.

The use data for 2002/03 (the benchmark year agreed by GTRG) in the NSW jurisdiction’s response did not match data provided by NSW to the Water Audit Monitoring report process. The difference in 10 of the NSW GMUs were because the use numbers in the jurisdiction’s response was taken from groundwater model calibration runs, which didn’t necessarily include 2002/03.

The usage data from NSW prepared for groundwater flow modelling requires verification of the metered pumping information lodged for the full period of record. The data is examined on a bore by bore basis for consistency and filed checked with groundwater users and compliance officers. It is considered highly reliable.

The difference between the two NSW use values was around 20% (265 GL) of the adjusted jurisdiction’s response, which is significant. The differences at the GMU scale were more significant, for some GMUs such as Upper Lachlan where the NSW jurisdiction’s response had a current use value of 12.5 GL and the data from the Water Audit Monitoring Report shows a value of 44.1 GL for 2002/03. A difference of this significance needs to be resolved.

It will be difficult to develop and implement management arrangements where accurate groundwater use data is of low reliability. There is a need to comprehensively meter the use of groundwater to implement a monitoring and evaluation strategy as part of a continued assessment of sustainable yield issues. However, there is also a need to establish clear objectives for the design of a metering program so that data is collected at the appropriate time and spatial scales.

The uncertainty in future use values is recognized by the Victorian response which includes either a “low confidence” (for unmetered GMUs) or “medium confidence” (for metered GMUs) tag against each GMU. There is no indication of the accuracy of these estimates in other jurisdiction’s responses, although the NSW response indicates a tag of “regional best guess” for 14 GMUs.

Equally uncertain is the time it will take to reach the higher level of usage. Jurisdictions have assumed that the rate of increase in use will be greatest in the next 10 years. This is considered a reasonable assumption given the rapid growth in use seen over the last 2 to 3 years.

It is clear from historical trends in groundwater use that the simple linear average rate of rise model of projected groundwater use (SKM, 2003) does not hold and that large upward steps in groundwater use can occur over short periods. A more comprehensive assessment of the factors that can affect future use in high priority GMUs would provide a higher level of certainty of estimated future use. The factors involved are likely to include physical, policy and regulatory settings, and market and social factors that drive patterns in use. Failure to adequately understand these drivers could result in actual use increasing more rapidly than anticipated before appropriate management arrangements have been implemented.

4 CONNECTIVITY OF THE SURFACE AND GROUNDWATER RESOURCES

4.1 Introduction

This section contains a summary of the available information on current and future impacts of groundwater pumping on streamflow reported on a jurisdictional and GMU basis.

The primary data source for this section is the data provided by each of the jurisdictions in response to the request from MDBC and MDBMC to report on groundwater issues (the data submitted is collated in Appendix A). Additional sources of information and data are summarised in Section 2.

An overview of the connectivity of surface water and groundwater is provided in Section 4.2 and a more detailed description of data provided by jurisdictions is provided in Section 4.3 (historic impacts), Section 4.4 (current impacts), Section 4.5 (future impacts) and a discussion of key findings and knowledge gaps is provided in Section 4.6.

4.2 Overview of connectivity of surface water and groundwater resources of the basin

4.2.1 When are surface water and groundwater systems hydrologically linked

Surface water and groundwater are considered to be *connected* when there is a saturated zone that links the river (or lake) bed to groundwater in the adjacent aquifer system (**Figure 4.1**). When an unsaturated zone exists between the river channel and groundwater in the adjacent aquifer system, the groundwater and surface water systems are considered to be *disconnected*.

The degree of connectivity between rivers and their adjacent aquifer systems and the direction of water exchange (i.e. gaining or losing) is often driven by their position in the landscape. Typical interactions between rivers and adjacent aquifers relative to their positions in the landscape are summarised in **Figures 4.2 and 4.3**.

There are a range of conceptual models represented schematically in **Figure 4.3** which characterise the main connected systems within the basin (the upland fractured rock system is not shown and the volumes in these systems are not large when considered at the basin-scale).

The type 1 system (**Figure 4.3**) contains the largest volumes of groundwater, but the impact from groundwater pumping is buffered by downward leakage from groundwater mounds beneath irrigated areas. **Figure 4.3** shows that the river and shallow aquifer are connected, but there are long reaches in the mid

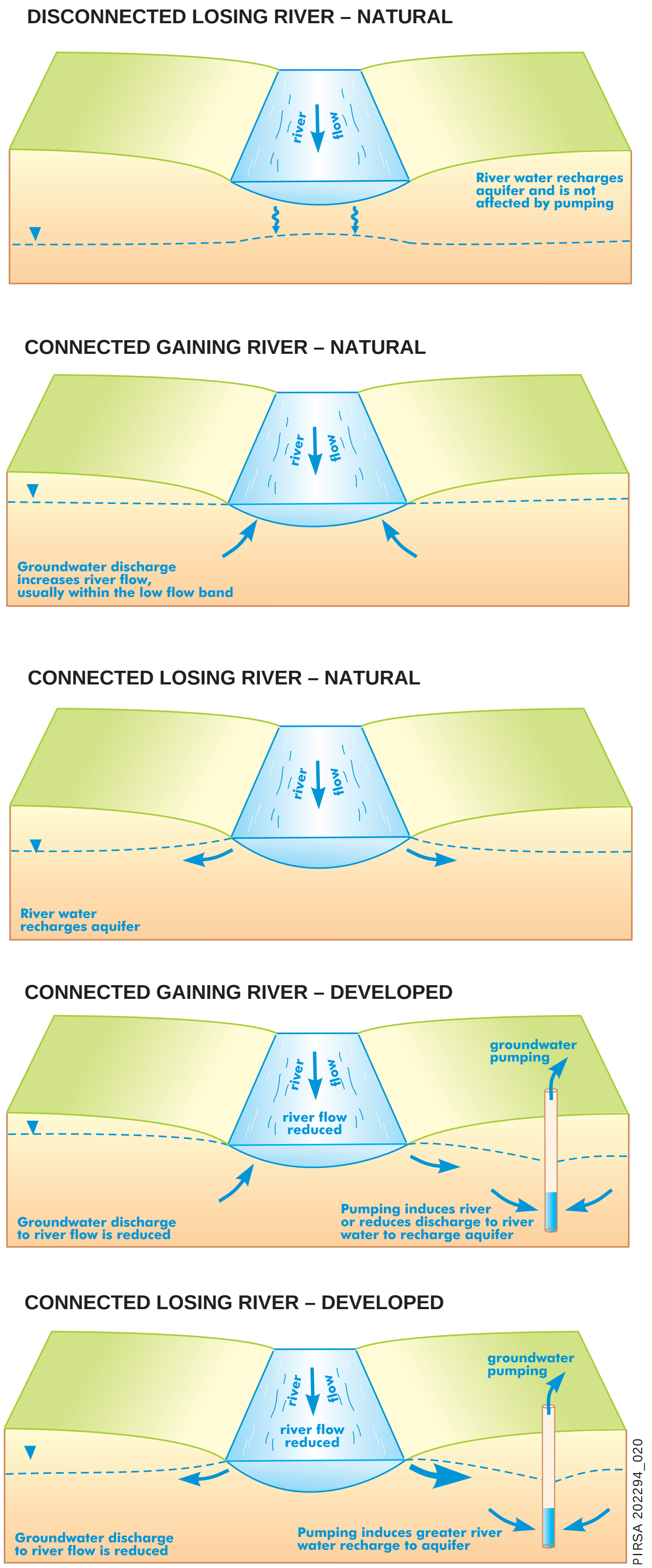

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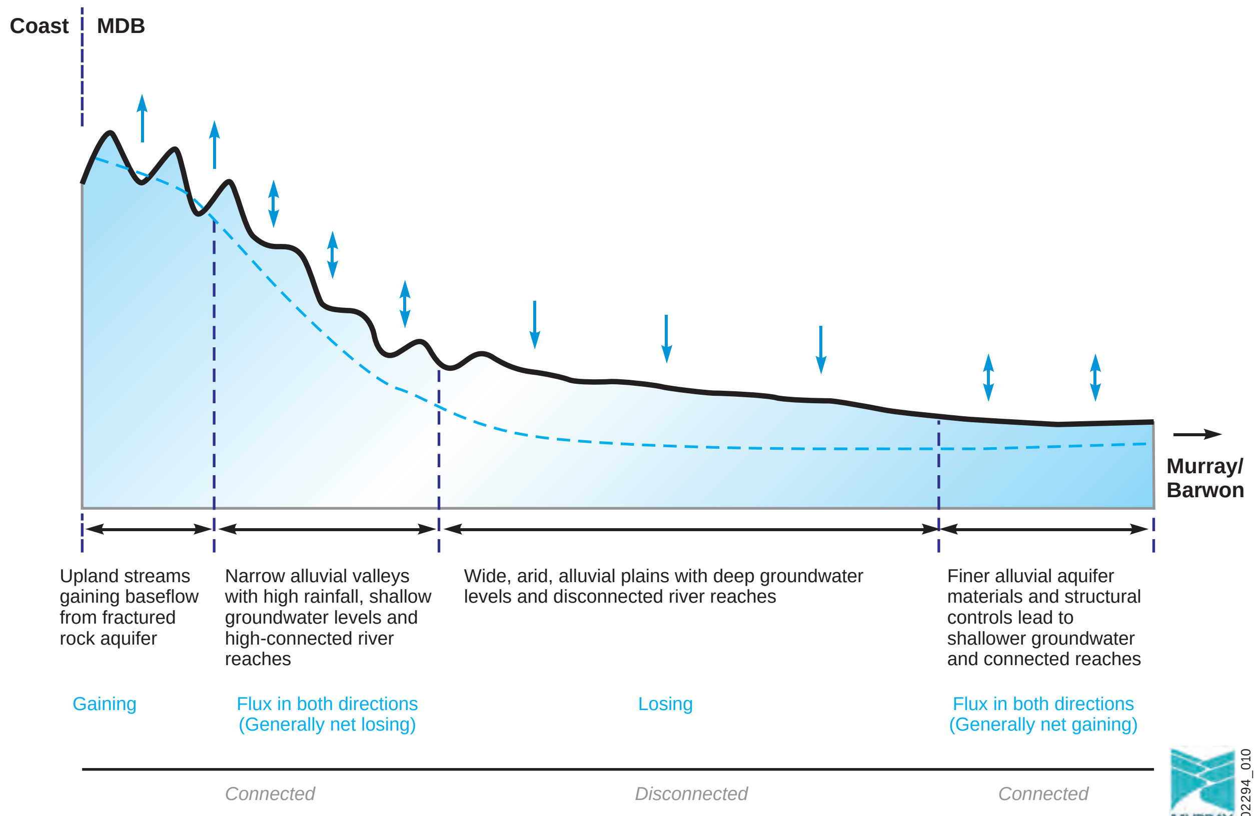
Figure 4.1

Schematic of river–aquifer interactions



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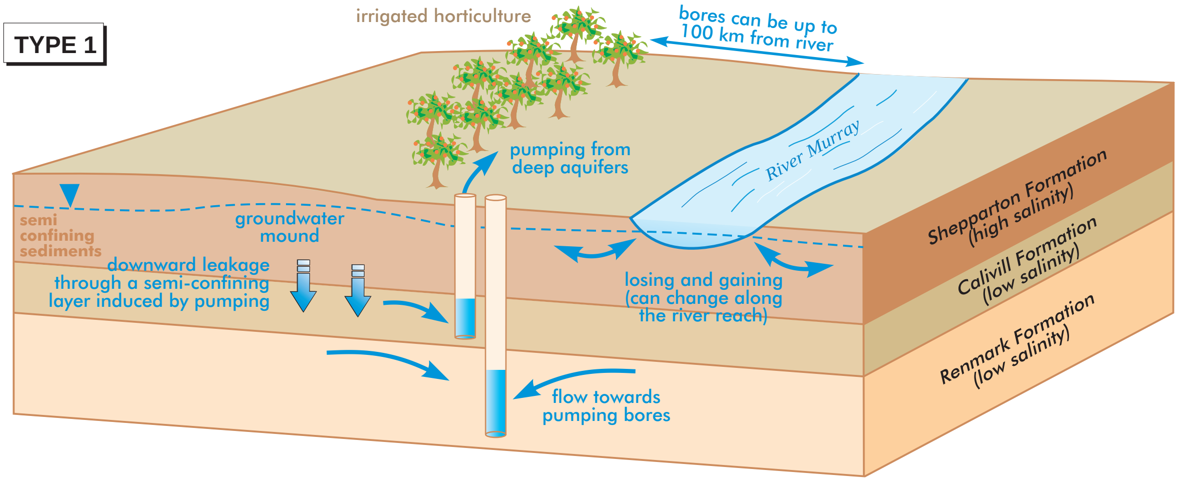
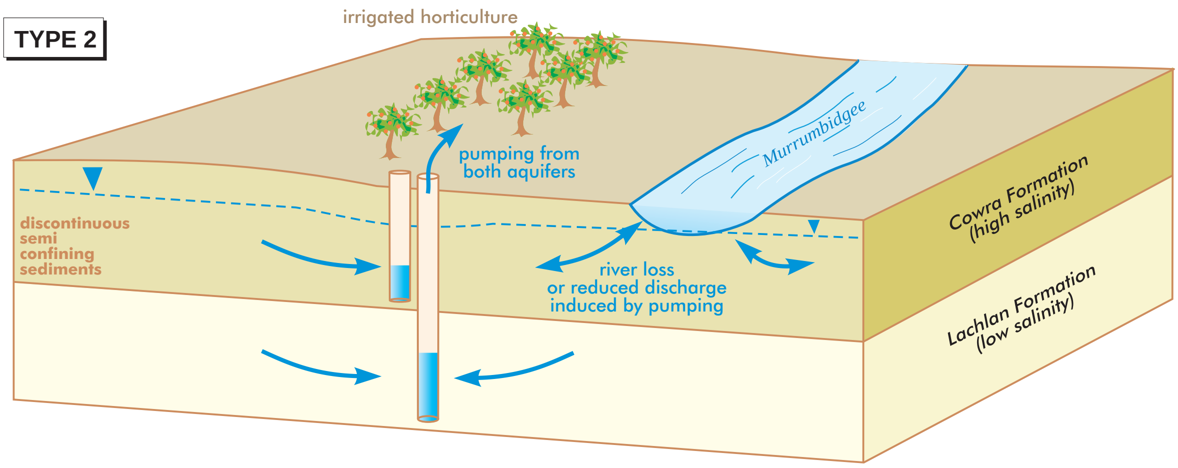
Transect of Murray–Darling Basin showing relationship between river–aquifer connection and landscape position. Blue arrows indicate the direction of river–aquifer flux (Braaten and Gates, 2002)

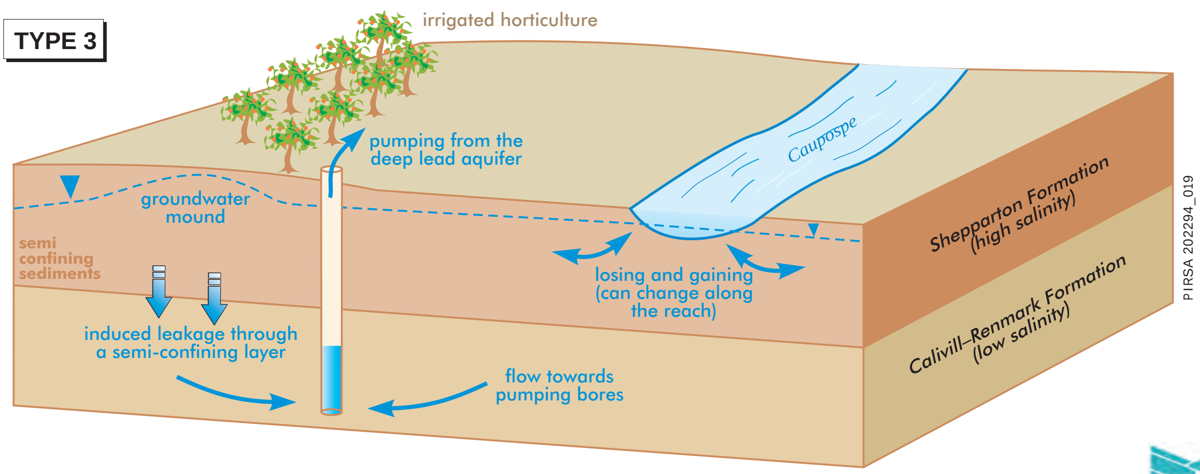
Figure
4.2



The type 1 systems occur within the mid-section of the alluvial plains such as the Lower Murray and Lower Murrumbidgee regions. Groundwater pumping induces downward leakage from irrigation mounds through a confining layer. To a large extent this leakage offsets impacts to the river. The connectivity between the river and aquifer will change along the river reach. The example shown occupies the southern portion of the basin. There are long reaches in the mid sections of these systems where groundwater in the Shepparton Formation is disconnected from the river.



The type 2 systems occur within the upper and mid sections of the basin with narrow alluvial valleys such as Upper Lachlan and Mid Murrumbidgee. In these systems the lower aquifer occurs within a paeleo-valley. Pumping induces leakage from the river and/or reduces groundwater discharge to the river through the discontinuous semi-confining layer.



The type 3 systems represent a combination of types 1 and 2 and occur within the Victorian part of the basin such as the Shepparton GMU. Pumping induces leakage from the mound in the upper aquifer through a semi-confining layer which off-sets impacts to the river. The connectivity between the river and aquifer will change along the reach. In these systems the lower aquifer occurs within a paeleo-valley.

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Figure
4.3

Conceptual models where rivers and aquifers are connected (losing or gaining) sections of these systems where the river is disconnected (refer to Section 4.2.2).

Type 2 systems are highly connected and sit at the head of the alluvial plains, and within the uplands and narrow alluvial valleys of the basin. Type 3 systems are a combination of types 1 and 2, where the impact of pumping is also buffered by downward leakage from irrigation mounds and the presence of semi-confining layers.

The distinction between disconnected and connected systems should not be mis-interpreted to infer that disconnected systems are not important to the conjunctive management of surface water - groundwater systems. Reduced groundwater recharge due to reduced streamflow in disconnected systems can impact on the availability of groundwater for consumptive and environmental uses.

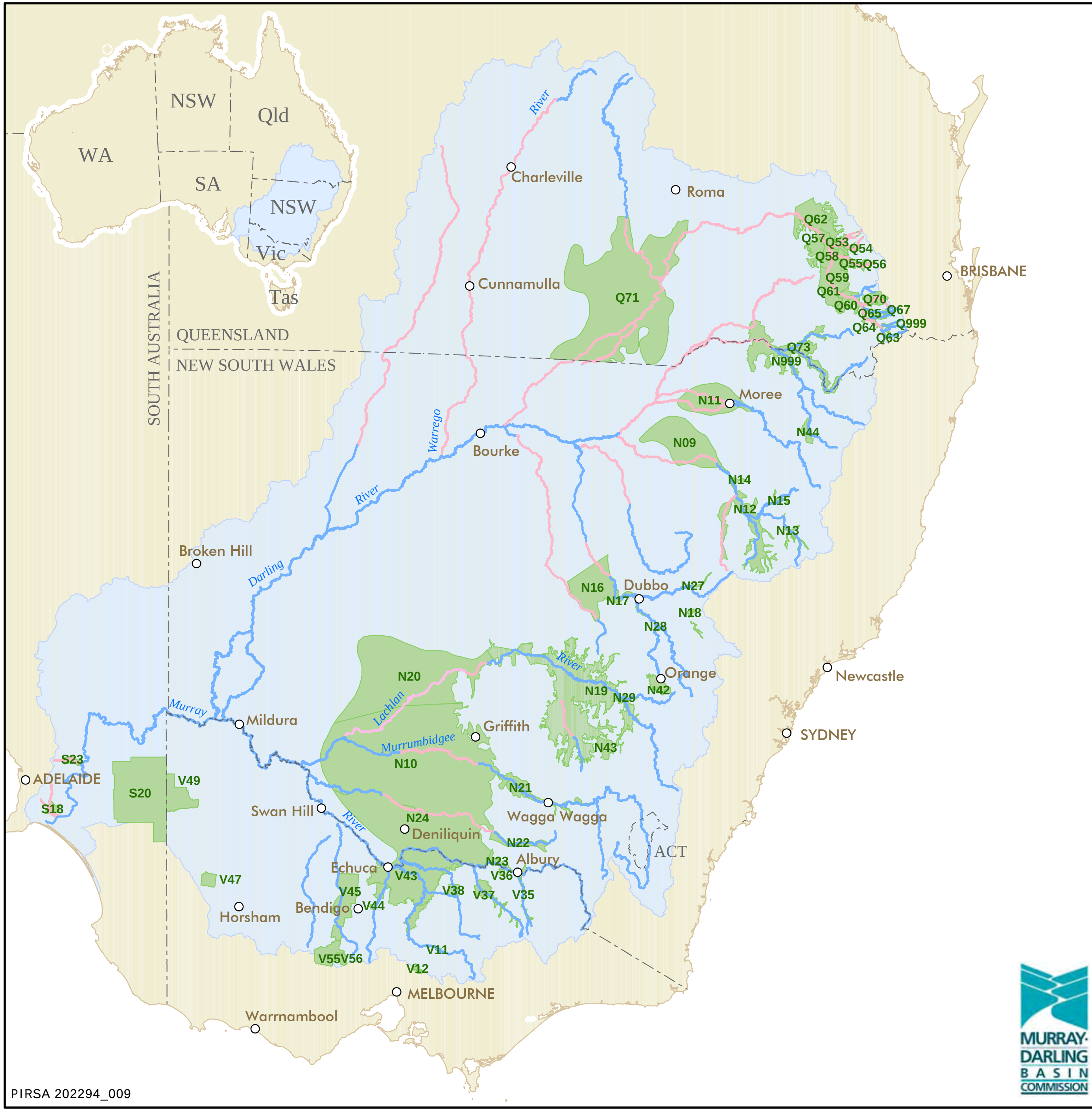
4.2.2 Basin-scale view of river – aquifer connections

The information in this section is sourced from the Watermark project, which included references to work by SKM (2003) and Braatan and Gates (2002). The information taken from Watermark provides a basin scale view only and it needs to be made clear that there is considerable uncertainty regarding the location and degree of connectivity between rivers and aquifers at the GMU scale. Additional work is required to build this analysis.

A map (**Figures 4.4 and 4.5**) showing the connected and disconnected reaches was developed by REM (2004) which has been updated following discussion with each of the jurisdictions. The map has been altered in the Queensland part of the basin to show that the upland tributaries are disconnected (pers. comm., David Free). Modifications to the map of connectivity in the Victorian part of the basin have also occurred. The River Murray has been characterised as being connected based on advice from Victoria, however it is recognised that NSW characterised the reach between Barham and near a point just west of Tocumwal as being disconnected.

Figures 4.4 and 4.5 indicate that most connected systems lie within the upland catchments and narrow alluvial valleys as classified in **Figure 4.3.** GMUs with the potential for substantial growth in usage (based on current sustainable yield projections) are typically in these connected upland GMUs.

Most of the large GMUs with current high usage levels are in the alluvial plain areas within NSW where groundwater systems and streams are mostly disconnected.



GMU key and name

N09, Lower Namoi Alluvium
N10, Lower Murrumbidgee Alluvium
N11, Lower Gwydir Alluvium
N12, Upper Namoi Alluvium
N13, Peel River Alluvium
N14, Maules Creek Alluvium
N15, Miscellaneous Tributaries of the Namoi River (Alluvium)
N16, Lower Macquarie Alluvium
N17, Upper Macquarie Alluvium
N18, Cudgegong Valley Alluvium
N19, Upper Lachlan Alluvium
N20, Lower Lachlan Alluvium
N21, Mid Murrumbidgee Alluvium
N22, Billabong Creek Alluvium
N23, Upper Murray Alluvium
N24, Lower Murray Alluvium
N27, Coolaburragundy - Talbragar Valley Alluvium
N28, Bell Valley Alluvium
N29, Belubula River Alluvium
N42, Orange Basalt
N43, Young Granite
N44, Inverell Basalt
N999, Border River
Q53, Myall / Moola Creek North
Q54, Myall Creek
Q55, Lower Oakey Creek Alluvium
Q56, Oakey Creek Management Area
Q57, Condamine - Condamine Groundwater Management Area Sub-Area 1
Q58, Condamine - Condamine Groundwater Management Area Sub-Area 2
Q59, Condamine - Condamine Groundwater Management Area Sub-Area 3
Q60, Condamine - Condamine Groundwater Management Area Sub-Area 4
Q61, Condamine - Condamine Groundwater Management Area Sub-Area 5
Q62, Condamine River (Down-river of Condamine Groundwater Management Area)
Q63, Condamine River Alluvium (Killarney to Murrays Bridge)
Q64, Condamine River Alluvium (Murrays Bridge to Cunningham)
Q65, Condamine River Alluvium (Cunningham to Ellangowan)
Q66, Glengallan Creek
Q67, Dalrymple Creek Alluvium
Q68, Kings Creek Alluvium
Q69, Swan Creek Alluvium
Q70, Nobby Basalts
Q71, St. George Alluvium
Q73, Border River
Q999, Emu Creek Alluvium
S18, Angas Bremer
S20, Mallee - 1
S23, Marne
V11, Alexandra
V12, King Lake
V35, Mullindolingong
V36, Barnawartha
V37, Murmungee
V38, Goorambat
V43, Shepparton Groundwater Supply Protection Area
V44, Ellesmere
V45, Mid Loddon
V47, Balrootan (Nhill)
V49, Murrayville Groundwater Supply Protection Area
V55, Upper Loddon
V56, Spring Hill Groundwater Supply Protection Area

Groundwater Management Unit
Murray Darling Basin

Stream-Aquifer Connectivity

Connected
Disconnected

*NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that are not overlain by any other GMUs.*

0 250 500 Kilometres
N

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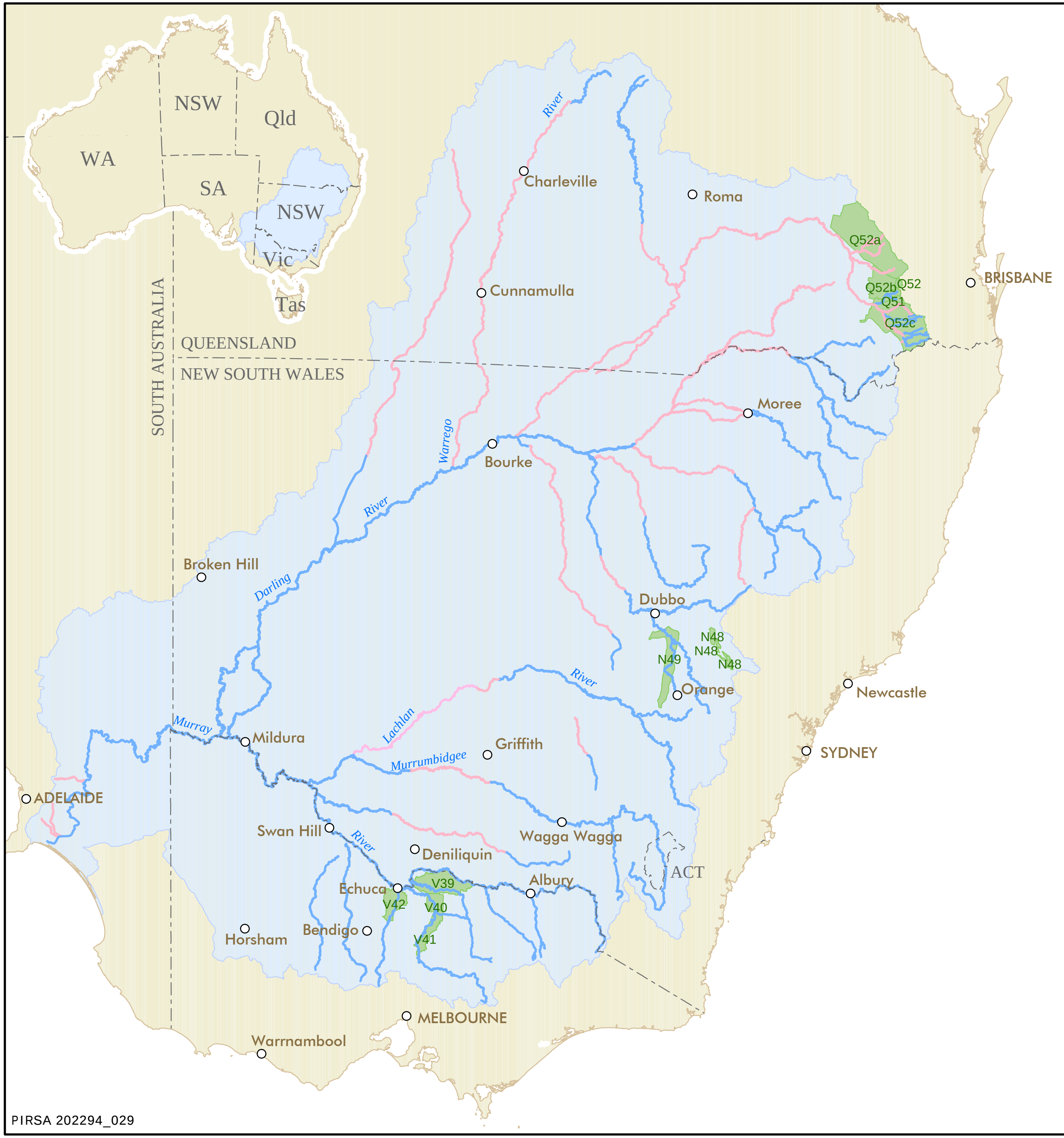
Figure 4.4

RIVER-AQUIFER CONNECTIVITY
(modified after REM, 2004)



GMU key and name

N48, Mudgee Limestone
N49, Molong Limestone
Q51, Upper Hodgson Creek
Q52, Toowoomba City Basalt
Q52a, Toowoomba North Basalts
Q52b, Toowoomba South Basalts
Q52c, Warrick Area Basalts
V39, Katunga Groundwater Supply Protection Area
V40, Kialla
V41, Mid Goulburn
V42, Campaspe Groundwater Supply Protection Ar

Groundwater Management Unit
Murray Darling Basin

Stream-Aquifer Connectivity

Connected
Disconnected

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that underlie GMUs in Figure 4.4

0 250 500 Kilometres

N

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RIVER-AQUIFER CONNECTIVITY WITH THE AREAS OF UNDERLYING GMUs

Figure 4.5

4.3 Historic impact of groundwater pumping on streamflow

4.3.1 Data

SKM (2003) estimated that, on average, 60% of the groundwater pumped from the basin's groundwater resources were derived from streamflow. In this broad context, streamflow is taken as including flooding and riverbed leakage to disconnected systems. Historic impacts from application of the 60% value to basin-wide historic use values (**Table 3.2**) are collated in **Table 4.1**.

Table 4.1 Compilation of the derived data describing the historic impact of groundwater pumping on streamflow across the basin.

Year	[1]Groundwater use (GL/yr)	% groundwater pumped derived from streamflow (taken from SKM, 2003)	Volume of groundwater pumped derived from streamflow (GL/yr)
1983/84	894	60	536
1999/00	1074	60	644
2000/01	1033	60	620

[1] groundwater use data taken from **Table 3.2**.

4.3.2 Data qualification

In reality the volume of streamflow impacted by groundwater pumping will vary greatly between GMUs. It is estimated, for example, that streamflow losses due to groundwater pumping within the large GMUs in New South Wales are negligible, whereas up to 90% of the groundwater pumped from the Mid-Murrumbidgee GMU is estimated to be derived from streamflow.

The 60% value (SKM, 2003) was at the time a best overall estimate adopted for planning purposes. This value has been used in this report (Table 4.1) only to assist in establishing a trend in the likely impact of groundwater use and in no way infers that the value is necessarily correct. GMU specific investigations are required to provide a more accurate estimate of the impact of groundwater pumping.

4.4 Average stream flow, natural stream loss and current (2002/03) impacts of groundwater pumping on streamflow

4.4.1 Data

The available data on average streamflow, natural stream loss or gain, and current impact of groundwater pumping on streamflow have been compiled and summarised in **Table 4.2**. The available data of the current impact of salt interception schemes on streamflow is summarised in **Table 4.3**.

The following GMUs are recognized as being connected (based on jurisdiction's responses, REM (2004) and SKM (2003)).

<u>Queensland</u>

- Upper sections of Glengallan Creek Alluvium, Emu Creek, Dalrymple Creek alluvium, King's Creek alluvium and Swan Creek alluvium, throughout the Border Rivers alluvium, Condamine River alluvium (Killarny to Murray Bridge) and Toowoomba City basalts.

<u>New South Wales</u>

- Upper Namoi, Lower Gwydir (upstream of Moree), Upper Murray, Peel River, miscellaneous tributaries of Namoi, Lower and Upper Macquarie, Cudgegong Valley, Billabong Creek, Upper Murray, Bell Valley, Belubula River, Orange Basalt, Young Granite, Inverell Basalt, Upper Lachlan, Molong Limestone, Mudgee Limestone, Coolaburragundy-Talbrager Valley and Mid Murrumbidgee.

<u>Victoria</u>

- Upper Loddon, Katunga, Campaspe, Shepparton, Ellesmere, Kialla, Mullindolingong, Mid Loddon, Spring Hill, Nagambie (Mid Goulburn), Murmungee, Goorambat, Alexandra and Barnawartha GMUs.

<u>South Australia</u>

- There are no GMUs with significant connection.

Table 4.2 Compilation and summary of the data available describing average stream flow, natural stream loss and current (2002/03) impacts of groundwater pumping on streamflow.

State	Number of GMUs with current net annual river loss data in the jurisdiction's responses	Average stream flow (GL/yr, provided in the jurisdiction's responses)	Natural stream loss (GL/yr, provided in the jurisdiction's responses)	Current net annual river loss (GL, provided in the jurisdiction's responses)	[11]Current net annual river loss (GL, from the adjusted jurisdiction's responses)	Current net annual river loss (GL, provided by authors of this report)
Queensland	0	[1]50.8	Not known	Not known	Not known	15[7]
New South Wales	25	15291[2]	361[3,4]	92[5]	92	172[8]
Victoria	0	Not provided	Not provided	Not provided	Not provided	140[9]
South Australia	0	4800	Not provided	7[6]	0	0[10]
Total	25					327

[1] Data provided for tributaries associated with Toowoomba City Basalt (0.3 GL/yr) and Lower Oakey Creek alluvium (50.5 GL/yr) GMUs.

[2] Data excludes data for the Misc. Tributaries of the Namoi, Upper Murray, Lower Murray, Orange Basalt, Young Granite, Inverell Basalt, Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and GAB GMUs.

[3] Estimates based on unaccounted stream losses.

[4] Data excludes Misc. Trib of Namoi, Mid Murrumbidgee, Billabong Creek, Upper Murray, Coolaburragundy-Talbrager Valley, Bell Valley, Orange Basalt, Young Granite, Inverell Basalts, Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and GAB GMUs.

[5]Data does not include Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, but includes GAB GMUs.

[6] Values provided for the Waikerie, Woolpunda and Qualco-Sunlands salt interception schemes, which are operated along the River Murray.

[7] Queensland recognises connectivity in Toowoomba City Basalt, Condamine River alluvium (Killarny to Murry Bridge), upper sections of Glengallan Creek alluvium, upper sections of Dalrymple Creek alluvium, upper sections of Kings Creek alluvium, upper sections of Swan Creek alluvium and Border Rivers alluvium. The current net river loss or gain is estimated to be 15 GL based on a total current use in the connected systems of 25.5 GL and assuming 60% of groundwater pumped comes from streamflow.

[8] Calculated based on the 2002/03 use data taken from Water Audit Monitoring report process and the % of groundwater pumped derived from streamflow provided in the jurisdiction's response. Value includes estimate for Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs using data from Watermark and the assumption that 60% of pumped groundwater is derived from streamflow (SKM, 2003). Values exclude GAB GMUs

[9] The current net river loss is estimated from a current use value of 234 GL in connected systems and assuming 60% of groundwater pumped comes from streamflow across all GMUs.

[10] Excludes data for salt interception schemes and recognises that impacts from groundwater pumping are zero in the Mallee GMU and negligible in the Angas Bremer GMU (pers. comm. Steve Barnett, DWLBC).

[11] Excludes values for GAB GMUs, UAs and SIS.

Table 4.3 Compilation and summary of current data available describing impact of salt interception schemes on streamflow.

Jurisdiction	Current (2002/03)[3] impact on streamflow (GL)
Queensland	0
New South Wales	1.7[1]
Victoria	7.1[2]
South Australia	6.9[4]
Total	15.7

[1] No data for Rufus River and Mallee Cliffs.

[2] No data for Pyramid Creek.

[3] Data provided by River Murray Water.

[4] Jurisdiction’s response.

4.4.2 Data qualification

Queensland

The response contained average streamflow for two GMUs and did not contain estimates of natural or current net river losses. This was partly because the integrated surface water - groundwater models (IQQM) are not aligned with GMU boundaries. There are seven GMUs where some degree of connectivity between streams and aquifers is recognised.

Estimates of impact on streamflow in the GMUs with recognized connectivity have been provided by the authors of this report using the "60% value" used as part of a basin scale assessment by SKM (2003). In reality, the 60% value may be a low estimate for well connected systems for the Border Rivers alluvium, but it may be a high estimate for GMUs such as Dalrymple Creek alluvium, Kings Creek alluvium and Swan Creek alluvium where the connectivity exists in the upper section only and the potential to develop viable surface water or groundwater projects is very limited due to the size of the resource (refer to jurisdiction's response in Appendix A).

This estimate is provided only as a guide and should be viewed as an 'order of magnitude estimate' only. The reliability of these estimates is considered to be low.

New South Wales

Estimates of current annual river loss or gain are based on modelling of 10 of the 25 GMUs reported and "regional best guesses" for the remaining 15 GMUs. The regional best guesses have assumed a certain percentage of pumped groundwater is derived from streamflow. The percentage ranges from 40 to 80%. Several GMUs have been assigned a 60% value, which is taken from SKM (2003).

The most critical issue relates to the uncertainty around the groundwater use values provided for the benchmark year and the impact this has on estimates of net river loss. The estimate for current net loss or gain is based on a current use value which does not necessarily correspond with the chosen benchmark year of 2002/03. This occurs in most GMUs listed in the NSW response. The current net river loss is estimated by the authors of this report to be 172 GL based on the use data taken from the 2002/03 Water Audit Monitoring report and the estimate of the degree of impact that groundwater extraction has on streamflow within each GMU (expressed as a percentage in the jurisdiction's response). The revised value of 172 GL is significantly different to the 92 GL provided in the jurisdiction's response.

This report has not indicated GAB GMUs, but it is recognised by NSW that some connection exists between GAB aquifers in the intake areas and streams.

Victoria

There are no estimates of average streamflow, natural net river loss, or current net river loss gain in the Victorian response. The lack of data is a significant issue since there are some well-developed GMUs (e.g. Katunga and Shepparton) which are considered to be connected to the River Murray system (SKM, 2003 and REM, 2004).

A number of projects are in-place to provide this information over the medium (5 year) term (pers. comm. Gordon Walker, DSE).

Estimates of future use estimates provided by the authors of this report were calculated based on the future use data provided by the jurisdiction and the assumption that 60% of the volume of groundwater pumped from all connected GMUs.

There is a high degree of uncertainty regarding the impact on streamflow in the Shepparton GMU. This system is recognized as being connected, but it is likely that the impact of groundwater pumping on streamflow is buffered by the downward percolation of excess irrigation water.

South Australia

There are no data qualifications for the South Australian data.

4.5 Impacts of future groundwater pumping on streamflow

4.5.1 Data

The available data describing the future impact that groundwater pumping could have on streamflow have been compiled and summarised in **Table 4.4**. Available data of potential future impacts of salt interception schemes on streamflow is summarised in **Table 4.5**.

Table 4.4 Compilation and summary of the data describing future impacts of groundwater pumping on streamflow.

State	Number of GMUs with future net annual river loss in the jurisdiction's responses	Future net river loss (GL, provided in the jurisdiction's responses)		[9] Future net river loss (GL, adjusted from the jurisdiction's responses)		Future net river loss (GL, provided by the authors of this report)	
		2012/13	2052/53			2012/13	2052/53
Queensland	25[1]	No change[1]	No change[1]	No change[1]	No change[1]	23[5]	30[5]
New South Wales	25	369[2]	369[2]	369	369	397[6]	397[6]
Victoria	0	Not provided	Not provided	Not provided	Not provided	158[7]	176[7]
South Australia	0[3]	24[4]	30[4]	[10]0	[10]0	0[8]	0[8]
Total	50					578	603

[1] Data includes the Toowoomba North Basalt, Toowoomba South Basalt, Warwick Area Basalt, Emu Creek alluvium GMUs, but excludes the six GAB GMUs and the Border Rivers Alluvium

[2] Data excludes Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs, and includes GAB GMUs.

[3] The South Australian response focused on salt interception schemes within the Riverland region. The aquifers in this area are saline and not designated as a GMU.

[4] Values provided for the Waikerie, Woolpunda, Qualco-Sunlands, Pike River, Murtho, Loxton-Bookpurnong and Chowilla salt interception schemes.

[5] Queensland recognises connectivity in Toowoomba City Basalt, Condamine River alluvium (Killarny to Murry Bridge), upper sections of Glengallan Creek alluvium, upper sections of Dalrymple Creek alluvium, upper sections of Kings Creek alluvium, upper sections of Swan Creek alluvium and Border Rivers alluvium. The future net river loss is calculated assuming current use in the connected systems of 39 GL in 2012/13 and 51 GL in 2052/53, and assuming 60% of groundwater pumped comes from streamflow (SKM, 2003).

[6] Value based on the value provided in the jurisdiction's response and an estimate for the Mid and Upper Murrumbidgee fractured rock, the Mudgee limestone, Molong limestone and Border Rivers alluvium GMUs calculated from the future use values and assuming that 60% of groundwater pumped comes from streamflow.

[7] The current net river loss is estimated from future use values in connected GMUs of 263 GL and 293 GL for 2012/13 and 2052/53, respectively and assuming 60% of groundwater pumped comes from streamflow (SKM, 2003).

[8] Excludes data for salt interception schemes and recognises that impacts from groundwater pumping are zero in the Mallee and negligible in the Angas Bremer (pers. comm. Steve Barnett, DWLBC).

[9] Excludes values for the GAB GMUs, UAs and SIS.

[10] Excludes values for the UAs and SIS.

Table 4.5 Compilation and summary of the data available describing potential future impact of salt interception schemes on streamflow.

Jurisdiction	Future (2012/13)[3] impact on streamflow (GL)	Future (2052/53)[3] impact on streamflow (GL)
Queensland	0	0
New South Wales	1.7[1]	1.7[1]
Victoria	7.1[2]	7.1[2]
South Australia	24.2[4]	30.3[4]
Total	33.0	39.1

[1] No data for Rufus River and Mallee Cliffs.

[2] No data for Pyramid Creek.

[3] Data provided by River Murray Water.

[4] Jurisdiction's response.

4.5.2 Data qualifications

Queensland

The response did not include data for the Border River Alluvium which is recognised as a connected system. There is a program in-place to assess the impact in this GMU (pers. comm., David Free, NRM). There is a groundwater model developed, but waiting for more aquifer stress data before quantifying impacts and developing cross border management strategies.

Estimates of impact on streamflow in the GMUs with recognized connectivity have been provided by the authors of this report using the “60% value” used as part of a basin scale assessment by SKM (2003). This estimate is provided only as a guide and should be viewed as an ‘order of magnitude estimate’ only. The reliability of these estimates is considered to be low. Refer to Section 4.4.2 for additional qualifications regarding this calculation.

New South Wales

Estimates of future annual river loss or gain are based on modelling for 10 of the 25 GMUs reported and regional best guesses for the remaining 15 GMUs. The regional best guesses have assumed a certain percentage of baseflow is affected by pumping. The percentage ranges from 40 to 80%. Several GMUs have been assigned a 60% value, which is taken from SKM (2003). The reliability of these estimates is considered to be medium.

Victoria

There are no estimates of projected net river loss in the Victorian response. The lack of data is considered to be significant issue since there are some well developed GMUs (e.g. Katunga and Shepparton) which are considered to be connected to the river, based on work from SKM (2003) and REM (2004).

Estimates of future use provided by the authors of this report were calculated based on the future use data provided by the jurisdiction and the assumption that 60% of the volume of groundwater pumped from all connected GMUs. The 60% value was originally applied across all GMUs (connected and disconnected) by SKM (2003) however the values provided by the authors in Table 4.4 are based on groundwater use in connected GMUs only (as listed in Section 4.4.1).

This estimate is provided only as a guide and should be viewed as an ‘order of magnitude estimate’ only. The reliability of these estimates is considered to be low. Refer to Section 4.4.2 for additional qualifications regarding this calculation.

A number of projects are in-place to provide GMU specific information (pers. comm. Gordon Walker).

South Australia

There are no data qualifications for the South Australian data.

4.5.3 Key findings and discussion

A compilation of previous assessments and the jurisdiction's responses has provided a basin, jurisdictional and GMU scale view of where streams are connected to productive aquifers. A basin overview (**Figures 4.4 and 4.5**) indicates that most connected systems lie in the upland and mid-sections of the basin. The larger GMUs situated in the lower more arid sections of the basin tend to be disconnected or connected in discharge areas where groundwater is saline. SKM (2003) noted that 17 GMUs had a "high" level of connection with streams within the basin.

The degree of connectivity between streams and aquifers (and the impact pumping will have on streamflow) varies greatly between GMUs. It is clear that site specific approaches are needed to better understand the hydraulic connectivity. This point was demonstrated by Braatan and Gates (2002) who were able to draw distinctions between regulated and unregulated streams, semi confined and unconfined aquifers, ephemeral and perennial streams, and narrow and wide valleys.

It is estimated that streamflow within the basin is currently eroded by 327 GL/yr due to groundwater pumping (**Table 4.6**) and that streamflow losses will increase by nearly 77% (to 578 GL/yr) over the next 10-years and by around 85% (to 603 GL/yr) over the next 50-years. The impact on the southern rivers of the basin is expected to rise from the current 167 GL/yr to 268 GL/yr in 2052/53.

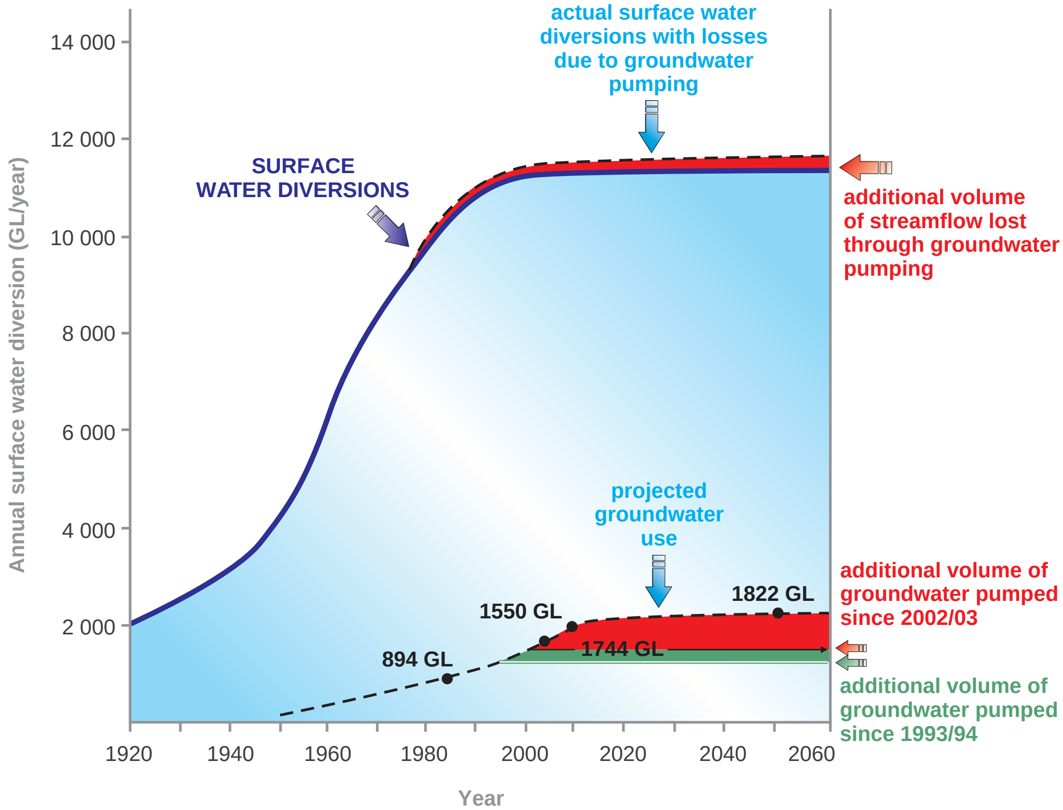
The impact of groundwater pumping is small in relation to surface water diversions (around 6%) at the basin scale. However, the volumetric impact may be significant relative to water recovery programs and water requirements of dependent ecosystems at the GMU scale. There are also some individual GMUs where the current sustainable yield is high relative to surface water diversions (e.g. Upper Lachlan).

The impact of groundwater pumping on streamflow is demonstrated in **Figure 4.6** which indicates that actual surface water diversions will increase by an amount equal to the volume of streamflow removed through groundwater pumping.

Table 4.6 Summary of current and projected net river loss associated with changes in groundwater use.

Jurisdiction	Net annual river loss (GL)		
	2002/03	2012/13	2052/53
Queensland	15	23	30
New South Wales	172	397	397
Victoria	140	158	176
South Australia	0	0	0
Total	327	578	603

The data in Table 4.4 is drawn from Tables 4.1 and 4.2



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Trends in surface water and groundwater use for the basin
and implications for streamflow
(the values do not include extraction from
salt interception schemes)

Figure
4.6

It is evident from the jurisdiction's responses and previous investigations that the interactions between surface water and groundwater systems are poorly understood at the GMU and river-reach scale, and that the relationship between groundwater pumping and streamflow is generally poorly understood.

As such the level of confidence in the estimates of current and future impacts on streamflow is low.

Use of the 60% value to estimate streamflow impact (where other estimates are not available) is based on an earlier assessment that needed a number for planning purposes (SKM, 2003). The earlier assessment recognised that the value could vary significantly between GMUs. The NSW response indicates variations in values from less than 5% to 80%, with a jurisdiction average of nearly 17%.

The authors of this report stress the use of the 60% value is a guide only and should not replace comprehensive site specific investigations required to provide a more accurate value. Further qualification of the use of this value is provided in Sections 4.4.2 and 4.5.2.

A more accurate estimate of the level of groundwater use through the 1990s, especially for 1993/94 needs to be considered.

The information in **Table 4.1** is supported with information from SKM (2003) which estimated that streamflow had been reduced by around 186 GL/yr between 1993/94 and 1999/00, based on the assumption that 60% of groundwater pumping is derived from streamflow. Use has increased by around 476 GL/yr in GMUs between 1999/00 and current (2002/03), which means that streamflow has been eroded by 472 GL/yr between 1993/94 and 2002/03 assuming that 60% of groundwater pumping is derived from streamflow. These numbers do not agree with the values in Table 4.6 most likely because the 60% is, on average, too high and that most of the growth in recent years is in the disconnected GMUs in the alluvial plain areas. Also the 186 GL/yr (impact on streamflow between 93/94 and 99/00; SKM, 2003) is likely to account for more GMUs than considered in this report.

It is not appropriate to use the 186 GL/yr value to derive a current position until more investigation of this value can be undertaken.

An overlay of the stream connectivity with current use for each GMUs provided in **Figures 4.7 and 4.8**, highlights where streams are connected to GMUs with high current rates of groundwater pumping. It is evident from this figure that the largest volumes of groundwater are pumped from systems such as the Lower Murrumbidgee and Lower Namoi that are disconnected.

In some systems, the connections between streams and aquifers occur at the downstream end of the aquifer unit (e.g. Lower Murray), where the groundwater salinity tends to be higher. In these situations there may be benefits from increased groundwater use that reduces saline groundwater discharge to rivers.

The future increases in impact to streamflow are summarised in **Figures 4.9 and 4.10**. The highest risk of streamflow impacts in areas where there is high

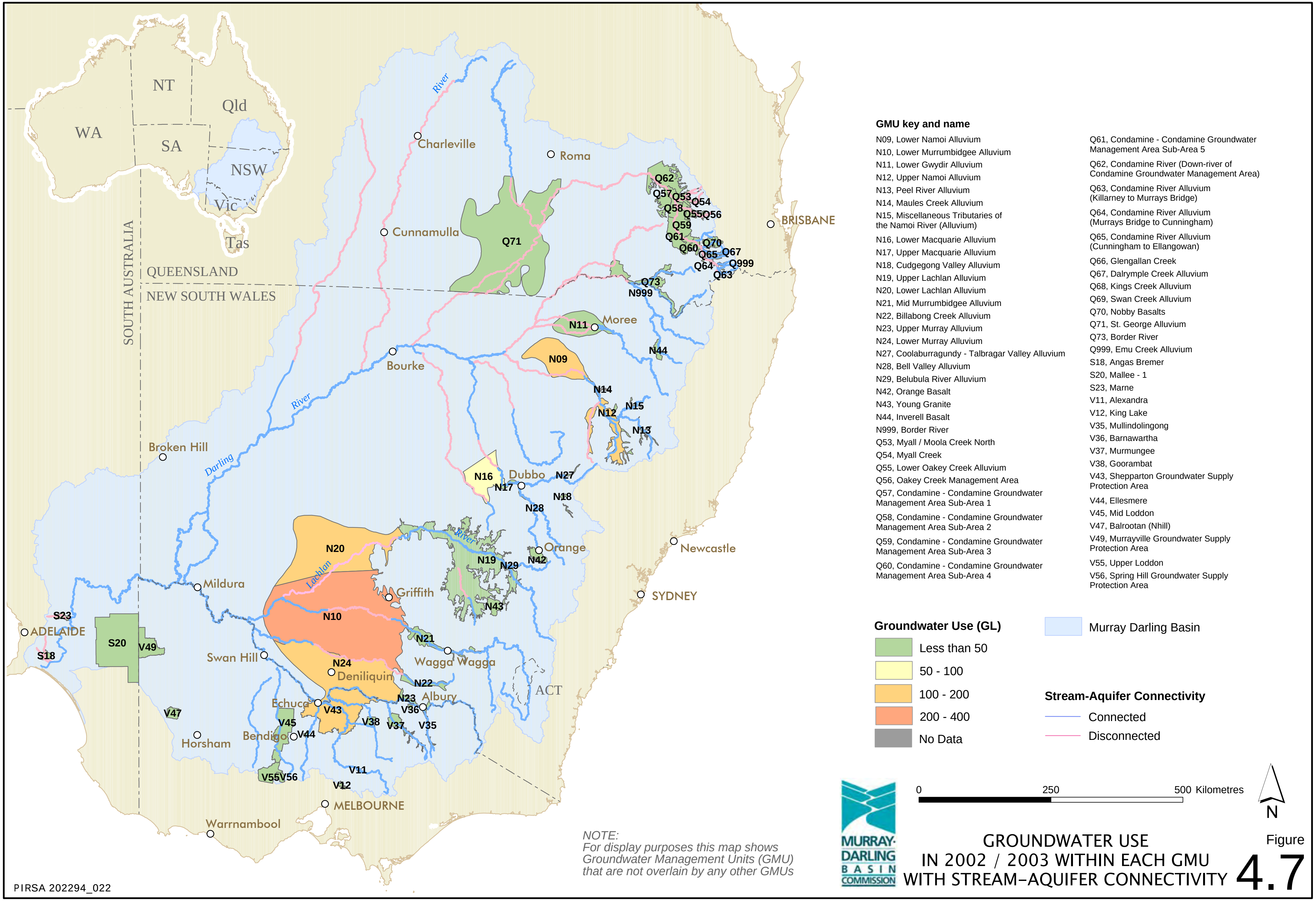
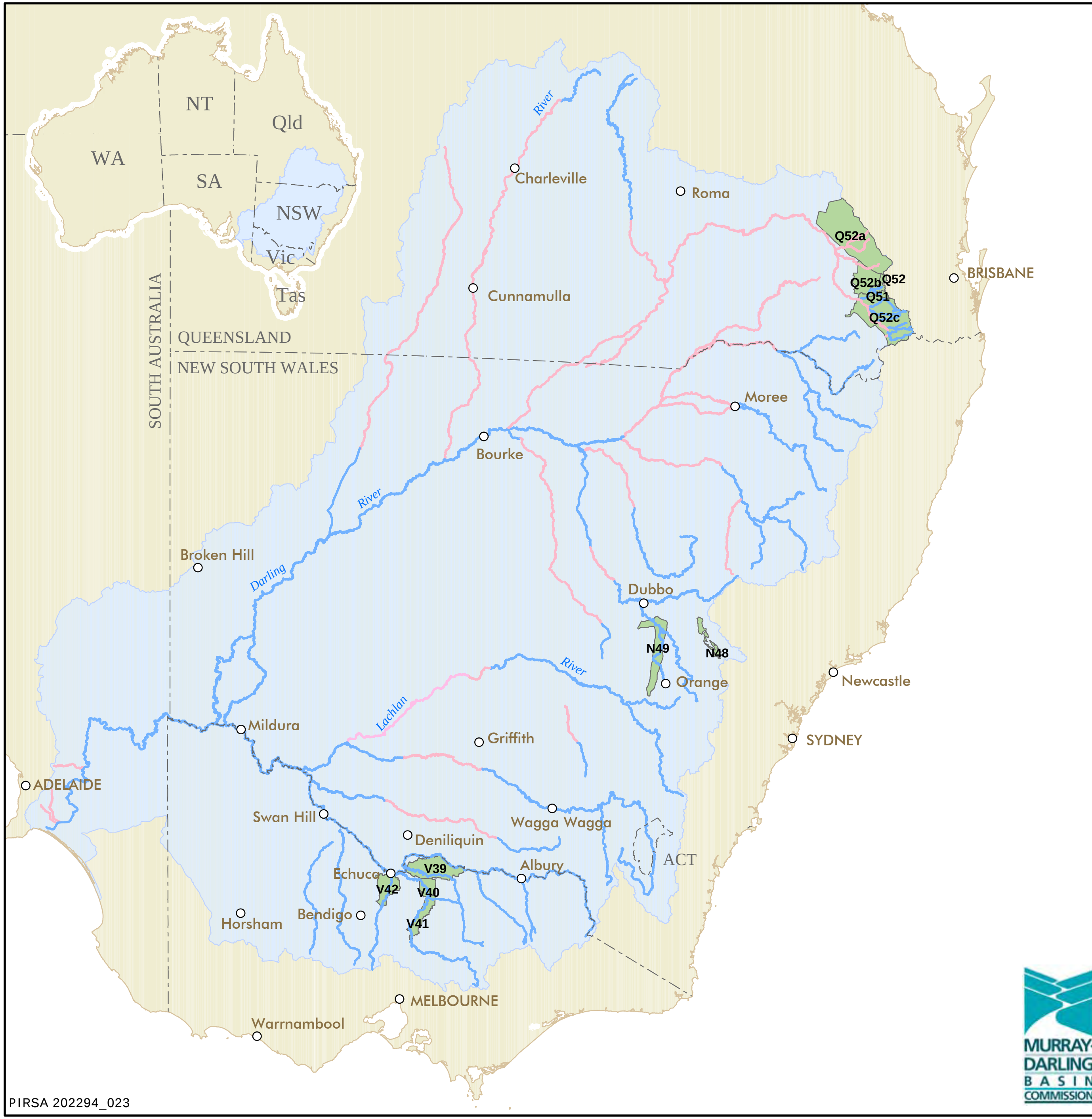


Figure 4.7
GROUNDWATER USE IN 2002 / 2003 WITHIN EACH GMU WITH STREAM-AQUIFER CONNECTIVITY



Groundwater Use (GL)

- less than 50
- 50 - 100
- 100 - 200
- 200 - 400
- No Data

Murray Darling Basin

Stream-Aquifer Connectivity

- Connected
- Disconnected

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that underly GMUs in Figure 4.7

GMU key and name

N48, Mudgee Limestone
N49, Molong Limestone
Q51, Upper Hodgson Creek
Q52, Toowoomba City Basalt
Q52a, Toowoomba North Basalts
Q52b, Toowoomba South Basalts
Q52c, Warrick Area Basalts
V39, Katunga Groundwater Supply Protection Area
V40, Kialla
V41, Nagambie
V42, Campaspe Groundwater Supply Protection Area

0 250 500 Kilometres

N

MURRAY-DARLING BASIN COMMISSION

GROUNDWATER USE
IN 2002 / 2003
WITHIN UNDERLYING GMUs
WITH STREAM–AQUIFER CONNECTIVITY

Figure 4.8

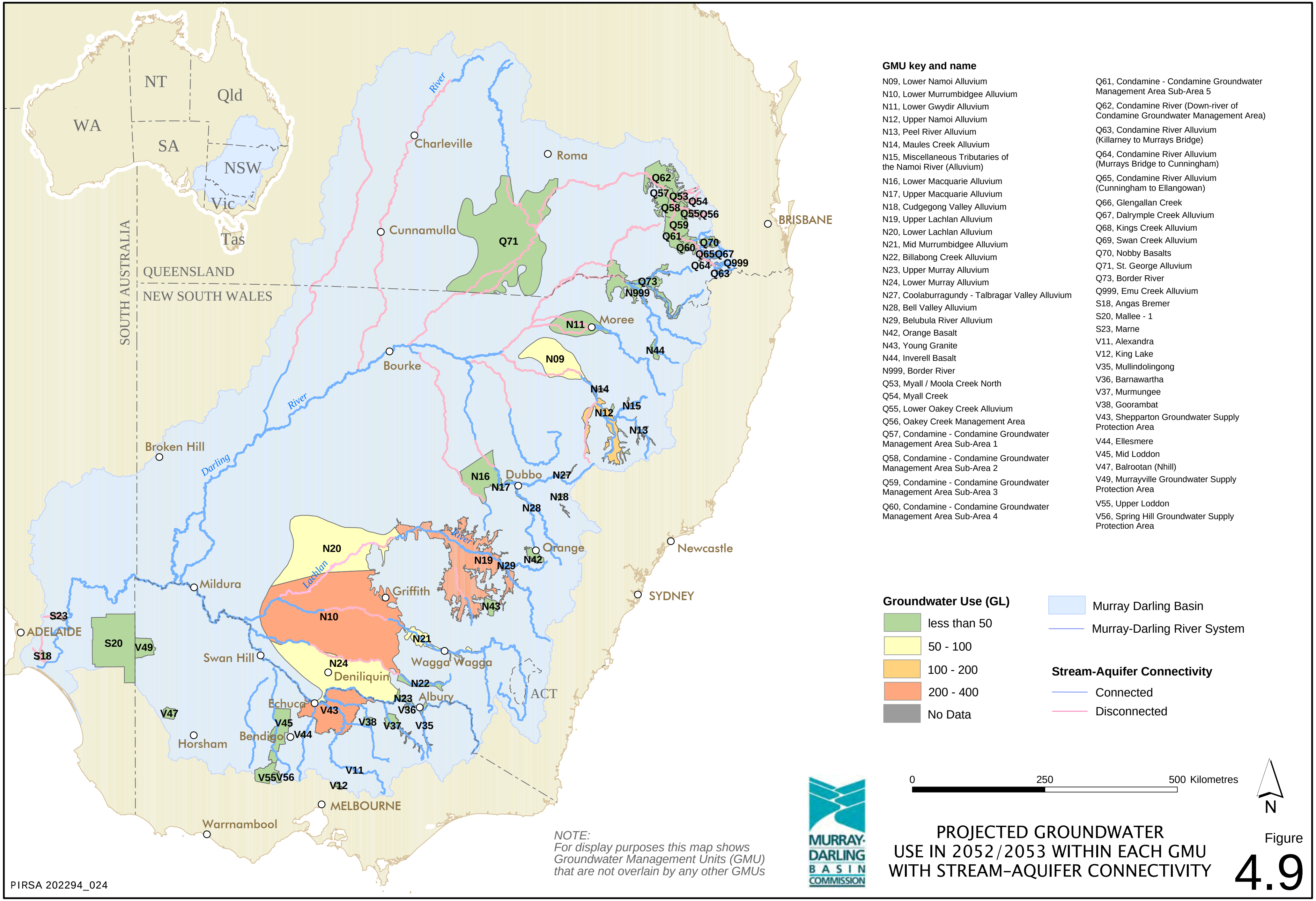
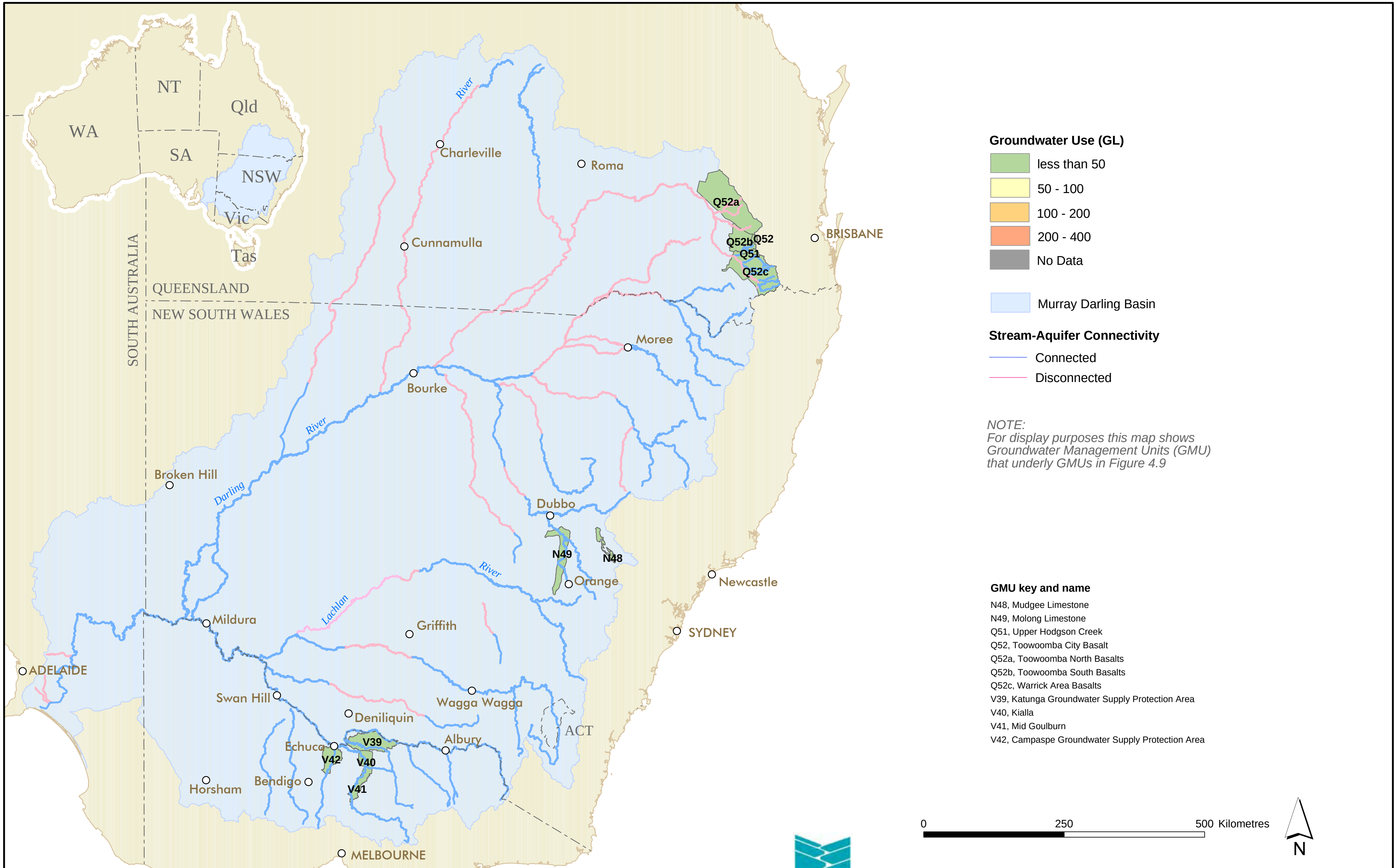


Figure 4.9
PROJECTED GROUNDWATER USE IN 2052/2053 WITHIN EACH GMU WITH STREAM-AQUIFER CONNECTIVITY



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PROJECTED GROUNDWATER USE IN 2052/2053 WITHIN UNDERLYING GMUs WITH STREAM-AQUIFER CONNECTIVITY

Figure 4.10

connectivity between rivers and their adjacent aquifer systems, and where there is capacity for use to increase significantly. **Figures 4.9 and 4.10** indicate that increases are expected in several of the large GMUs in Victoria and New South Wales. The future impact in well developed GMUs such as Lower Murrumbidgee and Lower Gwydir is expected to fall as use decreases to the sustainable yield.

The GMUs where an increase in streamflow loss is expected over the next 50-years are shown in **Figures 4.11 and 4.12**.

The priority GMUs are sorted into two types. The first type of priority GMUs are those connected GMUs where use has increased since 1999/00. The second type of priority GMUs are those connected GMUs where current usage is less that the upper limit to use defined in the jurisdictions responses for 2052/53.

The following priority GMUs are defined on the basis of the above criteria.

<u>Priority GMUs – connected systems where use has increased since 1999/00</u>

<u>Queensland</u>

- Throughout the Border Rivers, upper sections of King’s Creek alluvium, St George alluvium, Condamine River alluvium (Killarny to Murry Bridge) and Toowoomba City basalts.

  The impact in King’s Creek alluvium is limited because the connections exist in the upper reaches where there is less opportunity for development of water resources (Appendix A).

<u>New South Wales</u>

- Tier 1 – Peel River, Lower and Upper Macquarie, Cudgegong Valley, Lower Murray, Bell Valley and Inverell Basalt, Border River alluvium and Upper Namoi.

- Tier 2 – Mudgee Limestone and Molong Limestone.

<u>Victoria</u>

- Alexandra, Mullindolingong, Barnawartha, Goorambat, Katunga, Nagambie (Mid Goulburn), Campaspe, Ellesmere, Mid Loddon, Upper Loddon and Spring Hill.

  A significant level of uncertainty exists with the Shepparton GMU where the impact of pumping on streamflow may be buffered by downward percolation of excess irrigation water. The groundwater extraction scheme in the Shepparton GMU was designed to manage a salinity and waterlogging problem. However, it is not clear what volume of groundwater needs to be pumped to attain the benefits in terms of salinity and waterlogging management before groundwater extraction will impact on streamflow.

<u>South Australia</u>

- There are no GMUs with significant connection.

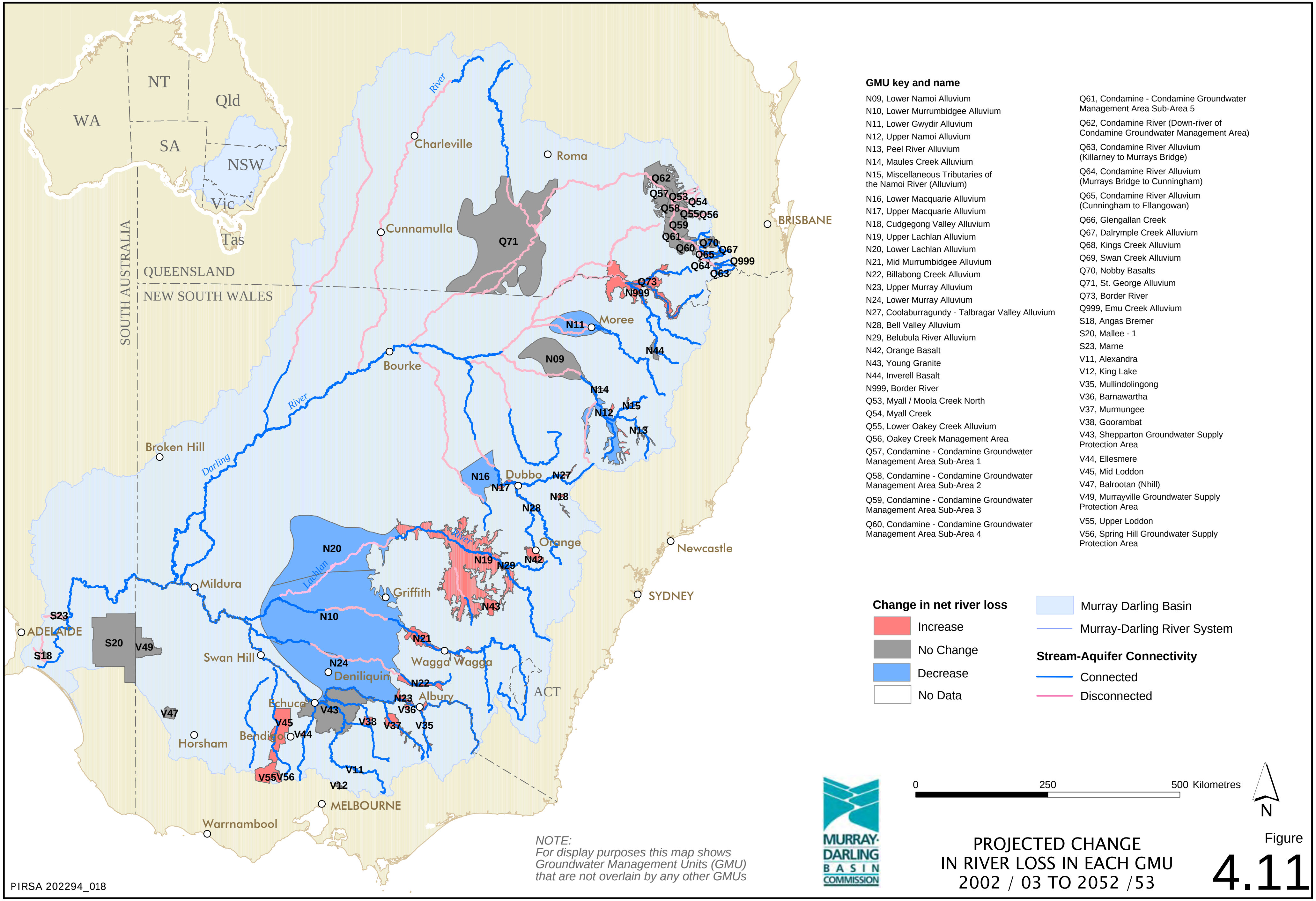
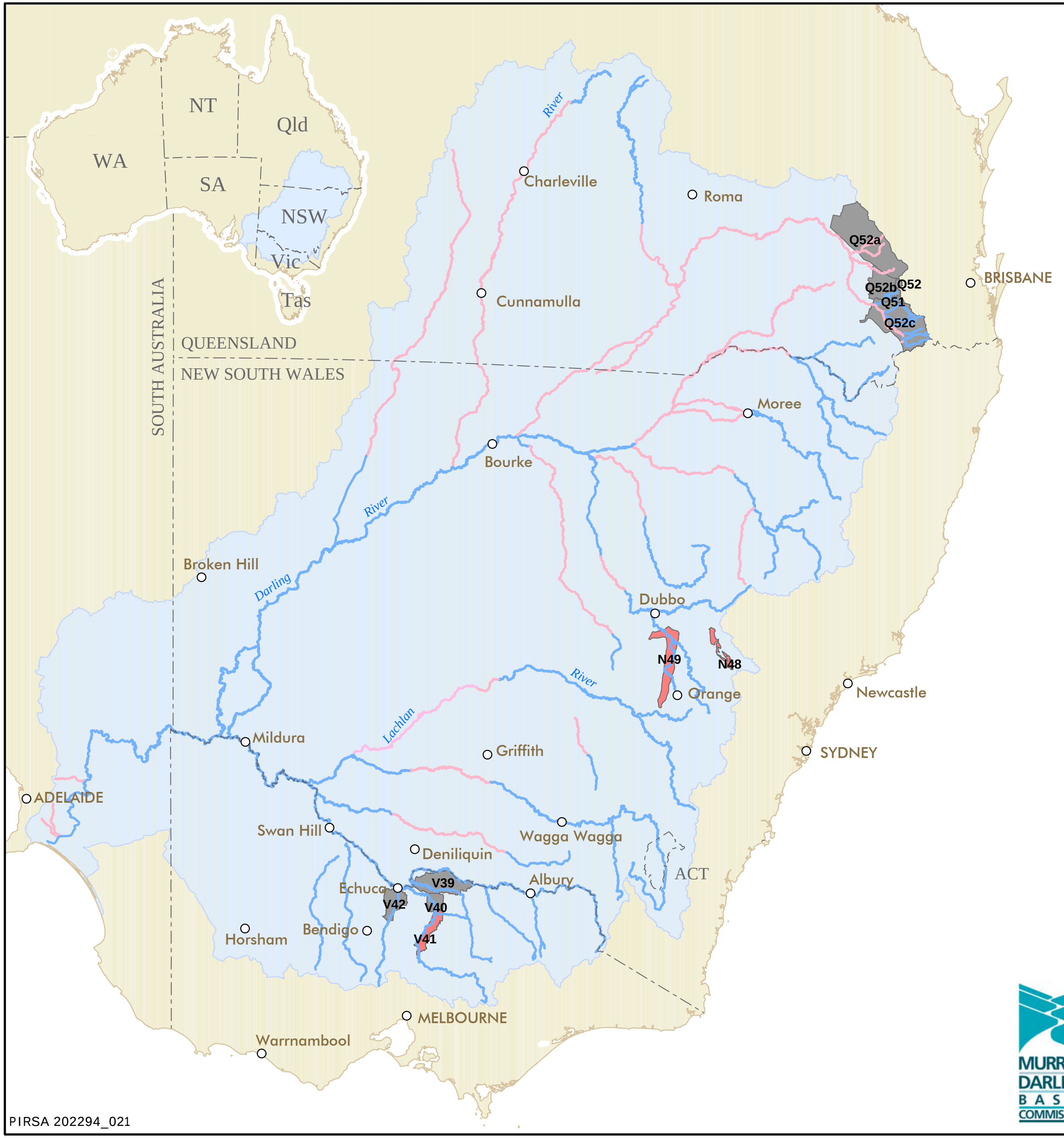


Figure 4.11

PROJECTED CHANGE IN RIVER LOSS IN EACH GMU 2002 / 03 TO 2052 /53



Change in net river loss

- Increase
- No Change
- Decrease
- No Data

Murray Darling Basin

Stream-Aquifer Connectivity

- Connected
- Disconnected

NOTE:
For display purposes this map shows Groundwater Management Units (GMU) that underly GMUs in Figure 4.11

GMU key and name

N48, Mudgee Limestone
N49, Molong Limestone
Q51, Upper Hodgson Creek
Q52, Toowoomba City Basalt
Q52a, Toowoomba North Basalts
Q52b, Toowoomba South Basalts
Q52c, Warrick Area Basalts
V39, Katunga Groundwater Supply Protection Area
V40, Kialla
V41, Mid Goulburn
V42, Campaspe Groundwater Supply Protection Area

0 250 500 Kilometres

N

MURRAY-DARLING BASIN COMMISSION

PROJECTED CHANGE IN RIVER LOSS WITHIN UNDERLYING GMUs IN 2002 / 2003 TO 2052 / 2053

Figure 4.12

Priority GMUs – connected systems where current use is less than the upper limit to use

Queensland

- Upper sections of Emu Creek alluvium, Dalrymple Creek alluvium, Swan Creek alluvium, Kings Creek alluvium, Border Rivers alluvium and Toowoomba City basalt.

The impact in these GMUs is limited because the connections exist in the upper reaches where there is less opportunity for development of water resources (Appendix A).

New South Wales

- Tier 1 - Miscellaneous tributaries of the Namoi, Upper Lachlan, Mid Murrumbidgee, Billabong Creek, Upper Murray, Coolaburragundy – Talbragar Valley, Belubula, Orange Basalt and Young Granite, Inverell Basalt, Cudgegong Valley, Bell Valley, Upper Macquarie, Border Rivers alluvium and Mid and Upper Murrumbidgee fractured rock.
- Tier 2 – Mudgee Limestone and Molong Limestone.

It is worthwhile noting that the Lachlan River does not discharge into the Murrumbidgee or Murray River. Rather, most flows that reach the end of the valley discharge into the Great Cumbung Swamp. If flows are impacted in this system, it is local baseflow and GDEs that will most likely be affected.

Victoria

- Murmungee, Mullindolingong, Barnawartha, Goorambat, Ellesmere, Mid and Upper Loddon, Spring Hill, Kialla and Nagambie (Mid Goulburn).

South Australia

- There are no GMUs with significant connection.

In connected systems, groundwater use does not result in an instantaneous impact on surface water resources. It may be years or decades before impacts are felt in large systems like the Lower Murray, but in narrow systems such as the Upper Lachlan, the response time will be one year or less. The question about impacts from groundwater pumping often relates to the impact of future increases in use, however in some systems it may be more important to consider future impacts from a past increase in groundwater use.

The length of time taken for the new equilibrium to be reached will vary greatly between GMUs because it depends on aquifer properties and the distance between the pumping bore and the stream.

The lag time also dictates the part of the river flow regime that could be impacted (Braatan and Gates, 2002), and it may be that a lag forces the impact from a critical low flow period to a less critical high flow period.

There has been some preliminary assessment of lag times under various hydrogeological settings (e.g. Braatan and Gates, 2004) which indicates the full impact of pumping within 1 km of a connected river will occur within a few years, but pumping 100 km from the river could take more than 50 years to fully impact the river.

5 GROUNDWATER MANAGEMENT ARRANGEMENTS TO RETAIN THE INTEGRITY OF THE CAP

5.1 How does the Cap on surface water diversions work?

The MDBMC introduced a permanent Cap on the diversion of water from the Basin's river system from 1 July 1997. The two primary objectives driving the decisions to implement the Cap were:

- To maintain and, where appropriate improve existing flow regimes in the waterways of the Murray-Darling Basin to protect and enhance the riverine environment; and
- To achieve sustainable consumptive use by developing and managing basin water resources to meet ecological, commercial and social needs.

The Cap is defined as:

"The volume of water that would have been diverted under 1993/94 levels of development."

For reasons of equity, the Cap may be adjusted for certain additional development that occurred after 1993/94 in terms of each State.

Diversions under the 1993/94 levels of development is not necessarily the same as the volume of water that was diverted in 1993/94. Rather, the Cap in any year is the volume of water that would have been diverted with infrastructure (pumps, dams, channels, areas developed for irrigation etc) and management rules that existed in 1993/94, assuming climatic and hydrologic conditions to those experienced in the year in question. Thus, the Cap provides scope for greater water use in certain years and lower use in other years. The Cap itself does not attempt to reduce basin diversions, merely prevent them from increasing. New developments are possible under the Cap provided that the water from them is obtained by improving water use efficiency or by purchasing water from existing developments.

The Cap is managed in accordance with the set of formal rules in Schedule F to the *Murray-Darling Basin Agreement*, which was adopted in August 2000. Schedule F requires an approved Cap model to be used for determination of an annual diversion Cap target for each of 22 designated Cap valleys. The development of Cap models for each of the valleys is the responsibility of the respective jurisdiction.

Implementation of the Cap within each valley is also the responsibility of the respective jurisdictions. The MDBC is responsible for auditing and reporting on compliance with the Cap. An Independent Audit Group (IAG) conducts an annual audit of the diversion in every designated Cap valley of the Basin in October every year, comparing the observed diversion against annual targets determined by the valley Cap models. In addition to the annual IAG Report the

Commission also prepares an annual Water Audit and Monitoring Report on Cap Implementation which includes the Diversion Cap Register, a formal record of diversions and Cap compliance in the Basin.

Based on the findings from a review of the Operation of the Cap, the MDBMC agreed in August 2000 to the following recommendations of the MDBC related to groundwater:

- *Groundwater be managed on an integrated basis with surface water within the spirit of the Cap (Recommendation 20); and*
- *A Murray-Darling Basin Groundwater Management Strategy be developed by the Groundwater Technical Reference Group (GRTG) that is based on jurisdiction's management of groundwater through sustainable yields and include investigations clarifying how groundwater management practices may impact upon the integrity of the Cap in future (Recommendation 21).*

Since this decision the annual Water Audit and Monitoring Report on Cap Implementation has reported on groundwater use in the Basin with intent to establish an integrated reporting framework for surface and groundwater in line with *Recommendation 20*.

There has been a long held view from the GTRG that there should be a Cap on total (surface water and groundwater) diversions and that the water resource should be managed in an integrated manner.

5.2 Groundwater management arrangements to protect the Cap

A summary of the current groundwater management arrangements relevant to protection of the Cap on surface water diversions is provided in this section. It is based on the information provided in jurisdiction's responses and the information sources listed in Section 2.

<u>Queensland</u>

The Water Act 2000 provides the primary framework for water management in Queensland. Water Resource Plans (WRP) which are catchment based subordinate legislation provide the means for integrating surface water and groundwater management into a regulatory framework. WRPs covering surface water resources for the entire Queensland section of the basin and are in place as final plans for the Moonie, Border Rivers, Warrego/Paroo/Bulloo/Nebine and Condamine -Balonne valleys.

Administrative holds have been progressively applied in Queensland to over 90% of the GMU's in the basin since 1970 as system allocations reached agreed yield levels or as systems exhibited signs of over-development. In the Condamine tributary GMU's, where some degree of connectivity has been recognised, administrative holds that effectively cap groundwater allocations have been in place since the early 1990's.

Groundwater resources will be progressively integrated into this planning framework as a second stage process. WRPs do not currently apply to groundwater extraction in the plan areas, although in some streams there are some interactions between stream flow and alluvial aquifers that underlie those streams and these were considered during hydrologic modelling studies. Where required, the WRP's will be amended during their 10-year life to include the management of groundwater systems.

A number of national level, and inter-governmental natural resource planning and management initiatives further provide the planning framework for the development of water resource plans in Queensland Murray-Darling valleys. For example the governments of New South Wales and Queensland are developing the New South Wales - Queensland Border Rivers Agreement. This agreement will be important in providing a pathway for integrated management of rivers in the Border Rivers region. There will be scope to include groundwater at a later date (pers. comm. David Free, Queensland NRM).

New South Wales

The Water Management Act (2000) specifically states that its objective is to provide for the integrated management of water sources within the state. The Act sets out that all water resources in the state should be classified according to whether they are at risk and the completion of statutory water sharing plans for priority sources of water. The priority aquifers are usually over allocated and sometimes over used.

The Act is supported by a range of policy and guidelines. A draft policy has been developed for the conjunctive management of unregulated surface/groundwater systems. It is currently under review.

New South Wales has been moving towards integrated groundwater - surface water management for the last few years. Water managers have had a broad understanding of the hydraulic connection between surface and groundwater sources. However it was not until the completion of several large groundwater flow models (Lower Namoi, Lower Murray and Lower Murrumbidgee) coupled with an assessment of groundwater-surface water interaction (Braaten and Gates 2002) that the consequences on the Cap of managing water surface and groundwater sources separately was understood.

Integrity of the Cap has been addressed in all inland surface water sharing plans. These plans commenced operation on 1st July 2004. The groundwater sharing plans for the 6 major inland aquifers (Lower Gwydir, Namoi, Lower Macquarie, Lower Lachlan, Lower Murrumbidgee, and Lower Murray) will commence on 1st July 2005. Once in-effect the plans have a 10-year life. At this stage the development of WSP's has involved preparation of separate surface water and groundwater plans, each overseen by separate stakeholder committees.

The groundwater sharing plans have identified in them a sustainable yield figure that is the basis for resource management. For the most part the estimate of sustainable yield has been derived independently of the Cap. For groundwater systems that do not have significant hydraulic connection to rivers (eg. Lower Murray, Lower Murrumbidgee, Lower Lachlan, Lower Namoi and Lower Gwydir (downstream of Moree)) this approach has negligible implications for Cap management.

For water sharing plan areas (eg. Upper Namoi) that are hydraulically connected to rivers, Cap management is a significant issue and will require further technical and modelling work to progress. Likewise for aquifers in the upstream parts of catchments that have been broadly identified as hydraulically connected to rivers.

Arrangements have been made in respective groundwater sharing plans, to reduce groundwater entitlements in over allocated aquifers and to compensate affected licence holders.

The NSW Government recognised the potential impacts and move to suspend the granting of further groundwater entitlements (except for town and domestic and stock supplies) in all groundwater sources within the basin until a policy on the impact of further groundwater development on the Cap is established.

NSW, through the macro water sharing plan is defining sustainable yield for all aquifers in the state and stream-aquifer interactions will be considered in all basin aquifers.

<u>Victoria</u>

Groundwater and surface water in Victoria is allocated under the Water Act *1989*. The legislation provides for the setting of an upper limit to the volume of groundwater that can be extracted. Groundwater Supply Protection Areas are invoked where the volume of groundwater allocated exceeds 70% of the sustainable yield. These areas require a groundwater management plan which demands a higher level of investigation and management intervention.

The policy context for groundwater allocation in relation to its impact on surface water resources and the environment has been laid out in the Victorian Government White Paper ‘Securing our Water Future Together’ that was released in June 2004. The White Paper states in relation to new allocation that, where there is a high degree of connectivity between groundwater and surface water the Government will ensure that allocation of new groundwater licences does not undermine the Environmental Water Reserve or surface water allocations.

In relation to existing allocation, the White Paper has established a process for reviewing the balance between consumptive use and the environment. It will require:

- Expert assessment at 15-year intervals;
- Extension of the current moratorium on new entitlements in fully allocated systems;
- The establishment of Environmental Water Reserves which take into account the need to protect the integrity of the aquifer and the interaction between surface water and groundwater and the needs of groundwater dependent ecosystems where appropriate; and

- Establish water supply protection areas and prepare Management Plans in highly allocated aquifers, stressed aquifers and aquifers with strong interconnections with stressed surface water systems.

There is less certainty with the way existing licences will be managed in systems where there is an acknowledged issue with the Cap. A number of approaches are currently being considered for example, the use of surface water restrictions to groundwater users where groundwater pumping occurs close to streams. Groundwater level targets are also being (or have been) defined across the State and groundwater pumping will be maintained at a level that will result in the groundwater target level being met.

<u>South Australia</u>

In South Australia the Water Resources Act (1997) requires the preparation of a water allocation plan for prescribed wells areas. The water allocation plan sets the rules for the extraction of groundwater and must consider the sustainable yield for the aquifers and take into account the requirements of all users of the resource, which means taking into account the linkages between the rivers and aquifers.

Water allocation plans are in place for the Angas-Bremer and Mallee GMUs and in development for the aquifers linked to tributary streams along the eastern Mount Lofty Ranges. Surface water resource management is not part of the Angas Bremer water allocation plan.

Rules within the plans will ensure that groundwater pumping does not impact on river flow.

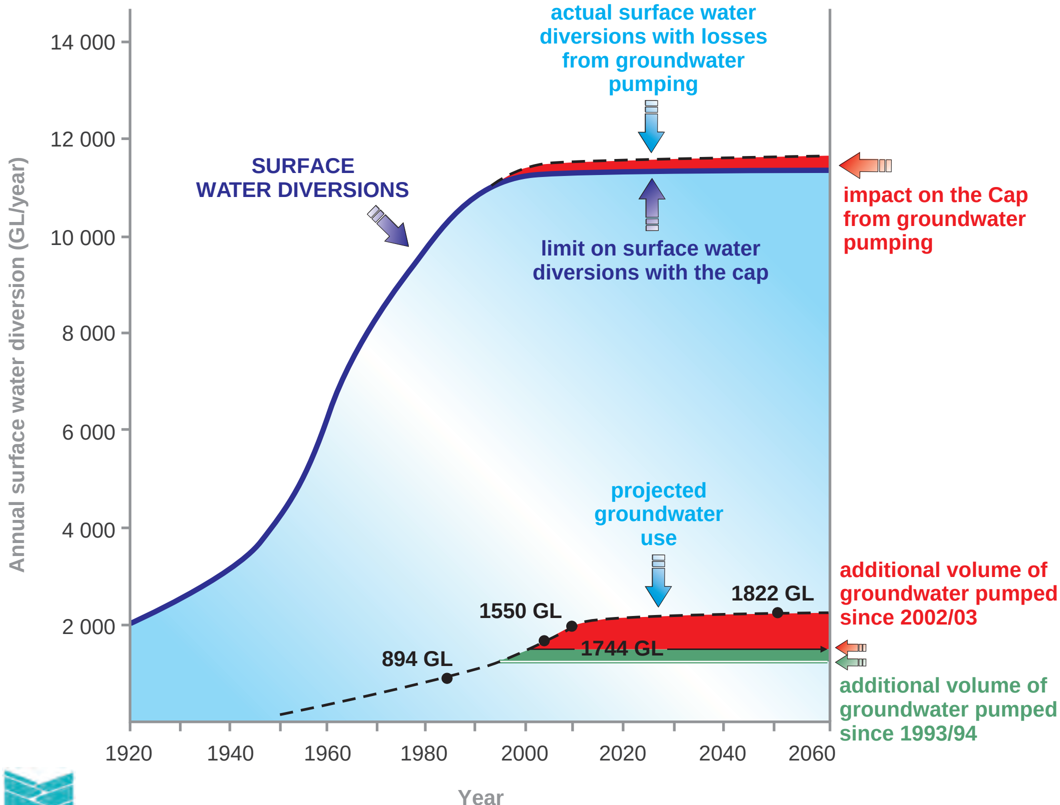
The future water allocation planning process for the eastern Mount Lofty Ranges (to be undertaken over the next 2 years) will take into account the interaction between groundwater and surface water mainly to protect surface water ecosystems. Flow from these tributary streams is not accounted for under the Cap on water diversions.

5.3 Impact on the Cap on surface water diversions

For those GMUs that are hydraulically connected to rivers in the basin, any increase in groundwater extraction since 1993/94 will result in a decrease in streamflow. This will impact on the anticipated outcomes of the Cap (REM, 2004).

The impact of current groundwater use on streamflow across the basin is estimated to be 327 GL/yr in 2002/03 (excluding the impact of SIS) and is estimated to increase to 603 GL/yr in 2052/53. The major increase in groundwater use is expected to occur in the 10 years to 2012, to an upper limit established within the respective water sharing plans. The upper limit is set at the estimated sustainable yield or allocation. Although there is uncertainty regarding the level of groundwater use in many GMUs it is likely that groundwater use will increase in most under-developed GMUs.

The effect of increased groundwater use is demonstrated in **Figure 5.1** this shows that the actual volume of surface water diverted will rise above the limit on



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MURRAY-DARLING BASIN COMMISSION

Trends in surface water and groundwater use for the basin and implications for the Cap

Figure 5.1

surface water diversions set by the Cap. The trends shown in this figure infer that the intended outcomes of the Cap will be compromised over the next 10 to 50 years.

SKM (2003) estimated the impact of groundwater pumping on the Cap in 1999/00 to be 186 GL/yr based on a broad understanding of the relationship between groundwater pumping and streamflow. This overview has not quantified the impact on the Cap prior to 2002/03 due to the limitations of the data, particularly the known impact of the groundwater pumping on streamflow in 1993/94.

The future impact on the Cap can be more clearly quantified by using current groundwater use (2002/03) as a benchmark. Any additional increase in groundwater use will be a direct reduction in the Cap. Based on the estimates made for current and future groundwater use, the impact of increased groundwater use on the Cap beyond 2002/03 will be 276 GL/yr over and above the impact that has occurred prior to 2002/03.

The impact on the Cap will occur in the GMUs listed in Section 4.5.3.

The largest future impacts to occur are expected to be in the large connected under-developed GMUs such as, Mid-Murrumbidgee and Upper Lachlan. The estimated future impact in these two systems alone could account for more than 70% of the estimated future impact on the Cap for the basin.

There is a high degree of uncertainty regarding the impact on the Cap in the Shepparton GMU. This system is recognized as being connected, but it is likely that the impact of groundwater pumping on streamflow is buffered by the downward percolation of excess irrigation water. It is possible that the impact on streamflow may increase as the irrigation efficiency increases resulting in a smaller contribution of excess water back to the aquifer.

There are also well developed connected GMUs that have experienced growth in groundwater use since 1993/94 but reached an upper limit by 2002/03. In these systems there has been an impact on the Cap created by the growth in use since 1993/94 which may or may not have been expressed as reduced streamflow due to a lag effect, but there will be no additional future impact.

Some jurisdictions expressed a desire to take into account the impact of salt interception schemes within the Cap, recognising the substantial benefits these schemes provide. New South Wales has indicated it will require a licence to operate salt interception schemes within a groundwater allocation.

5.4 Key Findings and Discussion

The review of existing management arrangements has highlighted that institutional controls are available to manage surface water and groundwater in an integrated way in each jurisdiction. This has not occurred to date due partly to limitations associated with knowledge of the technical issues and due to the process used in recent years to determine which GMUs were of higher priority.

Both NSW and Victoria have previously adopted a risk assessment approach for management of GMUs based on managing the use of groundwater. NSW has given priority to those GMUs where groundwater use has been significant and exceeded the estimated sustainable yield or where allocations exceeded sustainable yield. These GMUs have been lower in the landscape where extent of stream-aquifer connectivity is low. As such the priority GMUs addressed by the jurisdictions to date have primarily been those GMUs that do not impact on streamflow. Priority GMUs in Victoria have been those where allocation has reached 70% of the estimated sustainable yield.

All jurisdictions have plans in place to manage groundwater resources to the estimated sustainable yield. Each jurisdiction has developed groundwater management plans for priority GMUs. However, the potential impact on the Cap, will only be addressed where this planning process involves the integration of surface and groundwater. Almost all groundwater sharing plans are currently being developed and implemented in isolation of the surface water plans.

Many of the water sharing plans implemented (or being implemented) have relatively long lives. The NSW WSPs have a 10 year review period and the Victorian government White Paper refers to a 15 year review period. While this provides certainty for water users it creates difficulties for Government. A mid term review or adjustment to the sharing arrangements may trigger a compensation claim by those landholders affected.

In a number of regions, the total surface and groundwater resources are fully committed. The rapid increase in groundwater use since 1999/00 will have undermined the anticipated outcomes from introducing the Cap at 1993/94 levels of diversion. With the introduction of the surface water Cap on diversions there is no longer an option to offset the increase in groundwater use with surface water allocations in most GMUs.

At a policy level there is concern regarding how to share the impacts between surface water and groundwater users, recognising the security that the groundwater resource provides during periods of low streamflow. The options for the connected GMUs include reducing groundwater use to those levels of use in 1993/94, reducing the allowable surface water diversions or setting a new benchmark for total diversions that recognises the increased groundwater usage since 1993/94.

There are actions planned to investigate this issue further at the jurisdiction’s level (refer to Section 5.2), however at this stage there is no evidence of a policy position with respect to growth in groundwater use and the Cap.

There are some over-developed GMUs where use may decline over the 10 to 50-year timeframe. However, background research undertaken in the Watermark project indicates that market forces are acting to increase groundwater use in nearly all GMU’s. There are no market forces acting to reduce use due to unsustainable practices at this stage.

Policy and regulation appear to be the only forces that can limit use to sustainable levels, but these approaches have not met with success in the GMUs where use is exceeding sustainable yield. This generally stems from the compensatory tension between the invested capital and wealth generation associated with current irrigation activities, and the desire to reduce access to the resource for environmental or long term economic reasons.

There has been a long held view from the GTRG that there should be a Cap on total (surface water and groundwater) diversions and that the water resource should be managed in an integrated manner.

The Watermark project developed a framework to the conjunctive management of surface water and groundwater within the basin. It was proposed that the framework be used as guide to water managers charged with the investigations and development of integrated water management plans. The framework is supported by a number of guiding principles some of which are listed below:

- Recognise that surface water and groundwater are two inter-related components of a single resource;
- Groundwater use can impact on streamflow and surface water use can impact on the availability of groundwater;
- All planning processes must be underpinned by knowledge of all elements of the integrated water balance, also recognizing the transient effects within the water balance;
- Recognize that the integrated approach will vary between connected and disconnected systems and, between regulated and unregulated streams;
- Predictive modeling tools (supported with appropriate data) are required for priority systems;
- There are minimum requirements for data that vary depending on the status of the resource;
- Transparent quality assurance procedures need to be built into the planning process;
- There is a need to consider uncertainty and variability when defining user provisions;
- There is a need for appropriate rules for trade between surface water and groundwater users;
- Application of “surface water rules” to groundwater users where groundwater pumping can impact on streamflow;
- Consider the lag between groundwater pumping and impact on streamflow; and
- Incorporate agreed monitoring and evaluation programs into plans to allow for periodic improvement to water management approaches.

6 KEY FINDINGS AND CONCLUSIONS

6.1 Key findings

This report of groundwater use and management in the Murray-Darling Basin has drawn on information provided by the jurisdictions and supplemented with information from sources identified in Section 2 of this report.

This overview has focused on Groundwater Management Units (GMUs) that are potentially connected to streamflow. The Great Artesian Basin GMU's and Unincorporated Areas have not been included within the study.

The key findings from this overview are detailed below.

6.1.1 Groundwater Use

Groundwater use was analysed at both a jurisdiction scale and at a GMU scale. In terms of timeframes, historical use, current use (2002/03) and projected future use (2012/13 and 2052/53) were documented. The key findings related to groundwater use were:

- There is limited data available for historical use of groundwater, prior to 1999/00, particularly at a GMU scale. Data is not readily available for groundwater use in 1993/94 at the GMU scale.
- There remains 34 GMUs (of 69 GMUs with current use reported by the jurisdictions) where current use is not metered or partially metered on an annual basis. It will be difficult to develop and implement management arrangements where accurate groundwater use data is of low reliability. Without accurate groundwater use records it will be difficult to develop, implement and review appropriate management arrangements. There are programs to increase the metering of groundwater use in Qld (over 7 years) and Victoria (over 3 years).
- There has been a significant increase in groundwater use since 2000/01. Based on limited available information, annual use increased by approximately 180 GL/yr between 1983/84 and 1999/00. There was a further increase in use of approximately of 476 GL/yr between 1999/00 and 2002/03, with most of the increased use occurring in NSW.
- The volume of groundwater extracted from salt interception schemes is expected to increase from around 25 GL/yr to 59 GL/yr over the next 50 years.
- Groundwater use across the basin and across the GMU's within individual jurisdictions is not uniform, thus the presentation of groundwater use at a jurisdiction scale will not reflect the extent of use relative to sustainable yield within individual GMUs

- Groundwater use currently exceeds the estimated sustainable yield level for 18 GMUs. The location of these GMUs is shown in **Figures 3.8 and 3.9**. It should be noted that the comparison between use and sustainable yield is for a “snapshot in time” and that mechanisms are in-place in NSW and Victoria to maintain use within the sustainable yield for the medium and long term. Groundwater use has been capped in most over-used GMUs in Queensland. However, it is also recognised that sustainable yield is a social construct and that an estimate of sustainable yield derived from a technical process can be altered to account for the balance needed between consumptive and environmental uses.

- Future groundwater use is projected to rise by 17% across the basin (272 GL) between 2002/03 and 2052. Most of this increase in use is expected to occur by 2012, based on current trends. However, there will be a high level of uncertainty in regard to the future patterns of groundwater use without GMU-specific investigation of the key drivers to groundwater use.

- The largest growth in groundwater use is estimated to occur (on a volumetric basis) in the Upper Lachlan and Mid-Murrumbidgee GMUs.

6.1.2 Influence of groundwater use on stream flow

The extent of connectivity between aquifers and the streams was assessed for the major streams within each GMU. The key findings related to the influence of groundwater use on stream flow are detailed below:

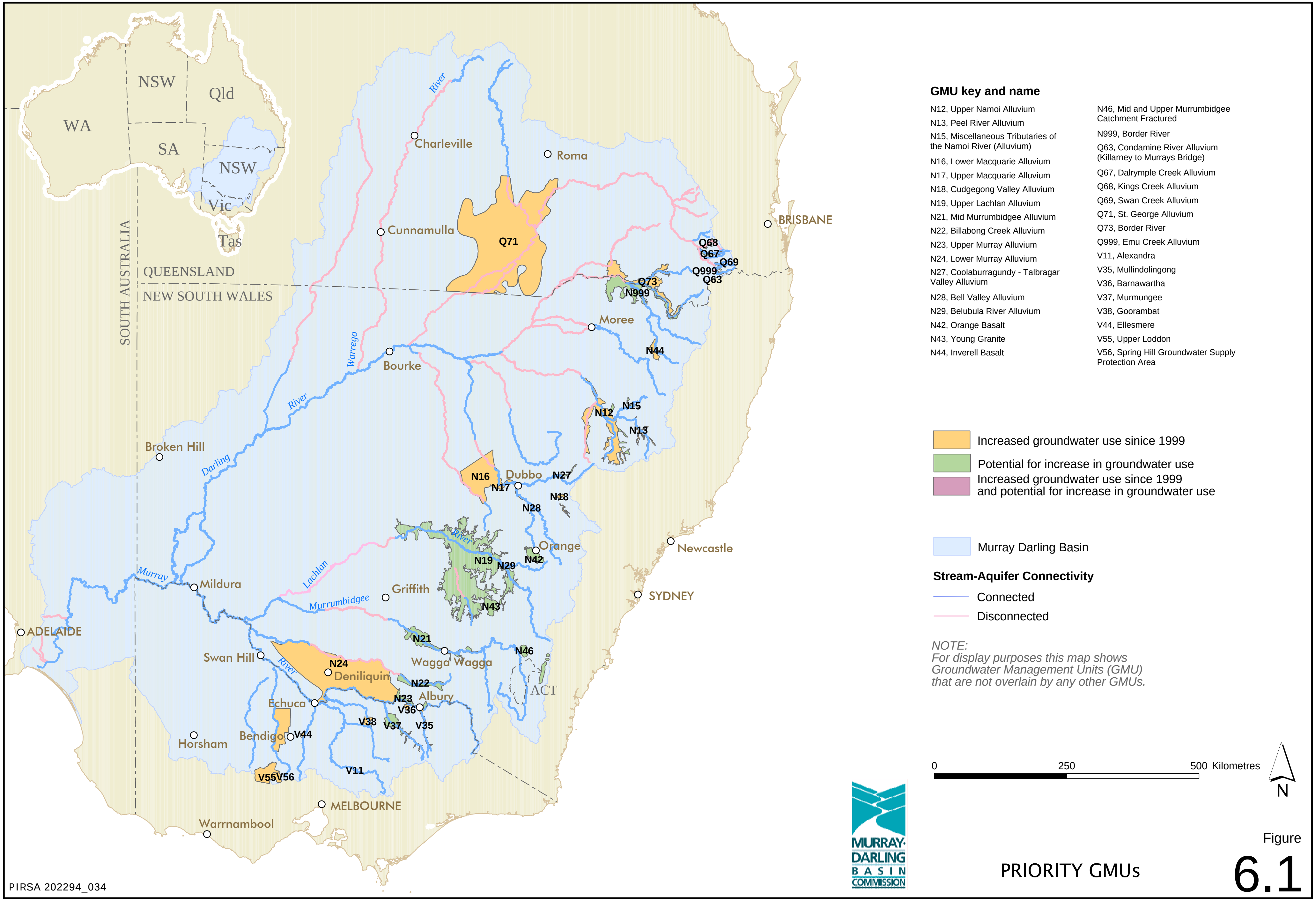
- There is a limited understanding of the extent of connectivity between the groundwater system and stream flow. A range of local conditions, including geology and the siting of the production bore relative to the stream, influence the extent to which groundwater use will reduce stream flow.

- There are different approaches to determining the extent of connectivity across the jurisdictions.

- Streamflow will be reduced where there is an increase in groundwater use in connected GMUs. Recharge of stream water to an underlying aquifer may fall if streamflow is reduced.

- The priority GMUs (based on current or future impact on streamflow) are shown in **Figure 6.1** and **Figure 6.2**. The GMUs with the largest potential impact are Upper Lachlan alluvium, Mid Murrumbidgee alluvium, Upper Namoi alluvium, Lower Murray alluvium, Border Rivers alluvium, Lower Macquarie alluvium, Upper Murray alluvium, Mid Loddon, Billabong Creek alluvium, Young Granite, Orange Basalt and Katunga GSPA.

- The impact of the groundwater use on stream flow in 2002/03 is assessed as reducing stream flow by 327 GL across the basin. This reduction in stream flow is projected to rise by nearly 77% (to a stream flow reduction of 572 GL) by 2012 and by 85% (to a stream flow reduction of 603 GL) by 2052. Approximately 45% of this stream flow reduction is expected to occur within the southern connected river system by 2052/53.



PRIORITY GMUs

Figure 6.1

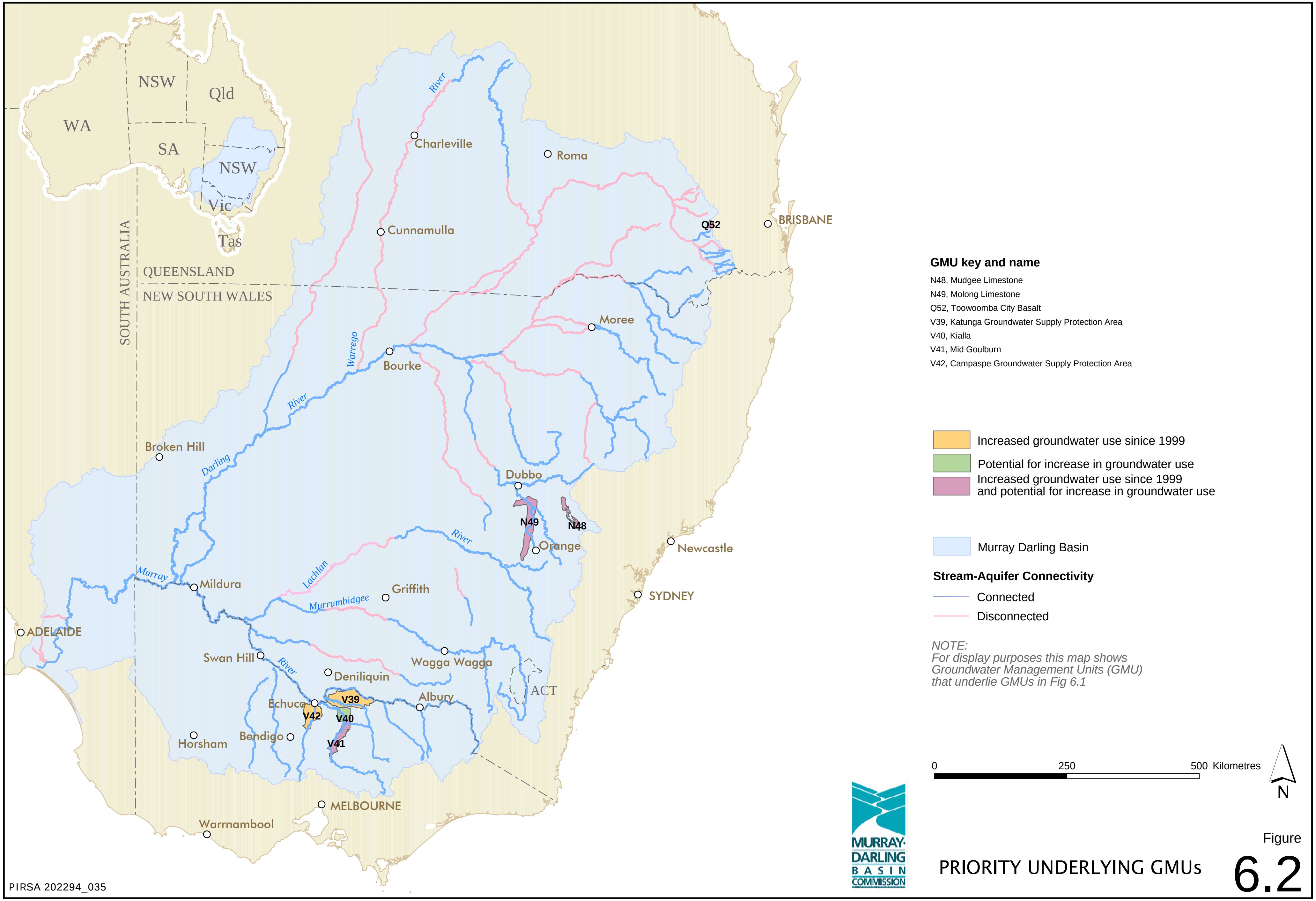


Figure 6.2

PRIORITY UNDERLYING GMUs

- The impact of groundwater extraction by salt interception schemes in 2002/03 is assessed as reducing streamflow by 15.7 GL across NSW, Victoria and South Australia. The reduction in streamflow is projected to rise by 110% (to a streamflow reduction of 33 GL) by 2012 and by 150% (to a streamflow reduction of 39.1 GL) by 2052/53. Salt interception schemes are operated to reduce the impact of discharge of saline groundwater to the River Murray so there is trade-off between the benefits from a reduced salt load in the river and the volumetric impact to streamflow that will occur.

- Erosion to stream flow that is not evident to date from the recent rise in groundwater use is expected to occur from the delay or ‘lagged’ impact of the current levels of groundwater use as well as any additional increase in groundwater use in the connected GMUs where current use is below the estimated sustainable yield or groundwater allocation.

6.1.3 Management arrangements to protect the integrity of the Cap on surface water diversions

A compilation of information on management arrangements put in place by each of the jurisdictions to protect the integrity of the Cap on surface water use was undertaken and an assessment made of the impact of increasing groundwater use on the surface water Cap.

The key findings are detailed below:

- Each jurisdiction has legislative and policy that allows for the integrated management of surface water and groundwater, but implementation of the integrated approach has not occurred to-date.

- The intended outcomes of the Cap on surface water diversions have been compromised as a result of the increased groundwater use since 1993/94.

- The extent to which the intended outcomes of the Cap have been influenced is uncertain due to the uncertainty of the critical data sets required to make the assessment, namely historical groundwater use, extent of connectivity and the extent to which streamflow is sourced from the groundwater system where connectivity exists.

- Taking into account the delayed or ‘lagged’ impact of the current and future levels of groundwater use in the connected GMU’s further erosion of the intended outcomes of the surface water Cap is expected to occur. The estimated impact on the Cap from the anticipated increase in groundwater usage beyond 2002/03 will be up to 276 GL/yr greater in 2052/53 than in 2002/03.

- The largest future impacts are expected to occur in the large connected under developed GMUs such as Mid Murrumbidgee and Upper Lachlan. These two systems are expected to account for more than 40% of the estimated future impact on the Cap.

- There is a range of approaches being taken by each of the jurisdictions regarding current and intended future management of groundwater to ensure the integrity of the surface water Cap is retained.

- The jurisdictions have identified technical and planning investigations that will be undertaken and investigations that are needed to reduce the uncertainty, although the implementation plan for these investigations has not been made clear.

6.2 Groundwater Management as a Risk to the Shared Water Resource

Increasing groundwater use is one of six developing issues likely to have significant impact on the surface water resources in the Basin. These six issues are referred to collectively as the “risks to the shared water resources”, and include:

- Climate change – There is a consensus among climate experts that global warming is occurring. The impacts in the basin are predicted to include a decrease in rainfall, reducing system inflows, and an increase in temperature and evaporation, leading to increased supply demands for existing activities.

- Reafforestation – Forecasts indicate that the area of plantation forests in the basin will increase by 140,000 ha over the next 20 years. As a result there will be less run off which is expected to impact on flows, the extent of which would depend on the rainfall of the respective locations.

- Groundwater Use – Groundwater and surface water systems are connected to differing extents in different locations in the basin. As a result extractions from groundwater can reduce streamflow. As all surface water in the Basin was capped permanently from 1 July 1997, extractions from groundwater pumping that reduce streamflow are compromising the intended outcomes of the surface water Cap.

- Farm Dams – These are defined as storages developed to harvest run-off from individual properties rather than on-farm storages associated with regulated and unregulated diversion licences. There is considerable uncertainty regarding the impact that future growth in these dams will have on streamflows largely because of the lack of data on current status and current levels of growth in storage capacity.

- Bushfires – A consequence of fire in forests is a reduction in water yield as the forest regenerates which affects run off for over 50 years. The reduction is dependent on the age of the original forest and whether the trees were killed by the fire. In 2002/03 bushfires burnt 50% of Hume catchment and 20% of the catchments of the Kiewa and Ovens Rivers.

- Return Flows –The *‘Register of Diversion Definitions in the Murray-Darling Basin’* contains the definitions of diversions used to monitor Cap compliance. Where practical, diversion is defined as off takes from the river less the return flows since this reflects a more accurate impact of the diversion on river flow. In many cases however, it has not been practicable to measure the return flows which include irrigation supply system overflows or escapes, drainage flows and returns from sewerage treatment plants. Returns via groundwater flow are also not included. The increasing scarcity of water since the Cap was introduced has encouraged improved watering systems, recycling systems, better management of distribution systems to reduce channel escapes and increased diversions from drains. These changes since 1993/94 are understood to have already had an impact on the Cap.

Appropriate and reliable data on these issues is not readily available. While at this stage, it is not possible to make any predictions with certainty on possible impacts on streamflow by these risks there is sufficient information on emerging trends to warrant their closer examination.

Closer examination of these risks requires much more than an issue by issue approach. Water managers in the basin can be faced with more than one of these risks at different times, intensity and locations. An understanding of the cumulative impacts of these events with the continuing pressure on our water resources is fundamental to effective water resources management in the basin, particularly in regards to maintaining the integrity of the Cap.

The risk factors associated with the availability of surface water can also impact on the availability of groundwater in connected and disconnected GMUs that rely on recharge from streams. While this report notes the risk of current use on future sustainable yield it does not describe additional impacts associated with: climate change; reafforestation; farm dams; bushfires; and return flows.

The MDBMC at its meeting on 26 March 2004:

- noted the potential impact of six key risks which, if not addressed, could cause the flow and quality in the Murray-Darling Basin to decrease; and

- endorsed the Commission's proposed work plan to address these issues with immediate priority given to bushfires and groundwater use, and through medium term strategies for climate change, farm dams, reafforestation and return flows from irrigation.

This report is part of the work program agreed by MDBMC, which aims to refine our understanding of these risks, strategically fill knowledge gaps and develop as appropriate advice to MDBC and MDBMC to address these issues.

6.3 Conclusions

Based on the findings from a review of the Operation of the Cap, the Murray Darling Basin Ministerial Council agreed (in August 2000) to recommend that groundwater be managed on an integrated basis with surface water within the spirit of the Cap (Recommendations 20). There has also been a long held view by the MDBC's Groundwater Technical Reference Group that there should be a Cap on total (surface water and groundwater) diversions and that the water resource should be managed in an integrated manner.

The conclusions provided in this section are based on the best available current information and the assumptions and data qualifications detailed in the relevant sections of this report.

In the context of the identified risks to the shared water resource, the following conclusions have been made with respect to current and future groundwater management within the Murray-Darling Basin.

There is limited data available for historic and current groundwater use. This together with a poor understanding of the extent of hydraulic connectivity between the groundwater system and streamflow makes it difficult to estimate with confidence, the impact of increasing groundwater use on the intended outcomes of the surface water Cap. Without clear management objectives for the appropriate collection and availability of data, appropriate management information will continue to be a problem.

Groundwater use

- With an 44% increase in groundwater use from 99/00-02/03 and predicted further increases of 17% predominantly in the next 10 years, it would appear that policy and regulation are the only mechanisms that can limit use to sustainable levels, as market forces are acting to increase groundwater use.

- The future sustainability of groundwater resources is threatened by current levels of use in 18 GMUs.

Streamflow

- With stream flow reductions already assessed at 327 GL/yr across the Basin and an expectation of a total reduction of 603 GL/yr by 2052/53 (according to the methodology described in this report) further action is required to determine how to distribute the impacts of this increase between surface water and groundwater users, and the environment.

Integrity of the Cap

- The consequential reductions in streamflow due to the significant rise in groundwater use are likely to already have had an impact on the intended outcomes of the Cap. This, together with a further impact of 315 GL/yr on the Cap outcomes by 2052/53 (of which 39 GL/yr is associated with salt interception schemes) will erode the reliability of future water availability for both surface water irrigation and environmental requirements unless there is a Cap on total diversions.

Management Arrangements

- Each jurisdiction has management arrangements to achieve conjunctive (joint) management of both surface and groundwater, however the implementation of a conjunctive resource management approach has not been initiated. If the current management arrangements are maintained, then the continued losses of streamflow will need to be addressed in terms of appropriate trade-offs to achieve a key objective of the MDB *Initiative,* specifically the equitable, efficient and sustainable use of water resources.

- Each jurisdiction has identified studies required to be undertaken to improve the level of confidence in the estimates made of current use, the extent of connectivity and the impact of increasing groundwater usage on the surface water Cap. Further delays in the commencement of these studies will continue to result in low levels of confidence in both the progress made and the support for changes to management arrangements.

- Any action to address the future impacts on streamflow and the sustainable use of the groundwater resource identified in this report will need to take into account the likelihood, severity and cumulative impacts associated with other risk factors including climate change, reafforestation, farm dams, bushfires and return flows

- The development and implementation of effective management arrangements are also dependent on improved information gathering linked to continued assessment of sustainable yield issues, including data collected at the appropriate time and spatial scales.

7 ACKNOWLEDGEMENTS

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The Office of the Murray-Darling Basin Commission would like to acknowledge the contribution the following people have made to this report:

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- Gordon Walker (Victorian Dept Sustainability and Environment)

8 GLOSSARY

Allocation	Water declared to be available to a water user, normally expressed as a proportion of a licensed entitlement. NSW also uses the term entitlement, which is the volume authorised historically under groundwater management policies for different GMUs. In NSW the licensee does not have an automatic right to the volume groundwater defined by the entitlement and must work within an announced allocation.
Aquifer	A geological formation that contains sufficient saturated permeable material to yield economic quantities of water to wells and springs. Aquifers generally occur in sands, gravels, limestone, sandstone or in highly fractured rocks.
Cap	The limit placed on taking water from rivers in the Murray-Darling Basin, equivalent to the water demands at 1993 – 94 levels of development.
Cone of depression	A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone, and develops around a well from which water is being withdrawn. It defines the area of influence of a well.
Confined aquifer	An aquifer that lies below a low permeability material. The piezometric surface in confined aquifers is above the base of the confining material.
Connected system	River (or lake) section that is linked to groundwater by a continuous saturated zone.
Conjunctive management	Combined management of surface water and groundwater resources that considers water as one resource.
Disconnected system	River (or lake) sections that are separated from the groundwater in the adjacent aquifer system by an unsaturated zone.
Ecosystem	Term used to describe species in an environment and their relationship with one another and the non-living (abiotic) community.
Gaining river	A river section that receives groundwater discharge from the adjacent aquifer system.
Gigalitre (GL)	One thousand megalitres.
Groundwater	Water that is held in saturated soil, rock medium, fractures

	or other underground cavities.
Groundwater Management Unit (GMU)	Hydraulically connected groundwater system that is defined and recognised by Territory and State agencies. Also referred to as GMAs (Groundwater Management Areas) in Victoria. GMUs were initially defined during the National Land and Water Resources Audit.
Groundwater Supply Protection Area	A locally designated aquifer that is moved to a higher level of management because it is anticipated that additional management will be required to achieve sustainability (in Victoria). In South Australia these areas are referred to as Prescribed Wells Areas (PWA).
Hydrogeologic	Those factors that deal with subsurface waters and related geologic aspects of surface waters.
Hydrograph	A graph that shows water table trends.
Living Murray	A Murray-Darling Basin Ministerial Council initiative about what is required for restoring the health of the River Murray and the Murray-Darling Basin.
Losing river	A river section that loses water into the adjacent aquifer system.
Megalitre (ML)	One million litres.
Model - Conceptual	Identifies hydrogeologic units and boundary conditions for a particular study area.
Model - Numerical	Simulates groundwater flow indirectly by means of a governing equation considered representative of the physical process occurring in the system, in addition to equations describing heads of flow along the model boundaries.
Permeability	The property or capacity of a porous rock, sediment or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.
Potentiometric surface	The level to which water will rise in wells screening a discrete aquifer. The water table is a particular potentiometric surface for an unconfined aquifer.
Recharge	Water that drains through the soil and reaches the water table.
Saturated zone	The sone in which the voids in the rock or soil are filled with water.
Sustainable yield	Sustainable groundwater yield is defined as the groundwater extraction regime, measured over a specified

	timeframe that allows acceptable levels of stress and protects dependent economic, social and environmental values.[1]
Unincorporated Area (UA)	Areas of aquifers that have not been defined as Groundwater Management Units.
Unconfined aquifer	An aquifer that has the water table at its upper surface.
Unsaturated zone	The zone between the land surface and the water table that is not saturated with water.
Water table	The upper level of unconfined groundwater, where the water pressure is equal to the atmosphere and below which the soils and rocks are saturated.
Well	A borehole that has been cased with pipe, usually steel or PVC plastic, in order to keep the bore hole open in unconsolidated sediment or unstable rock. Often used interchangeably with the term bore.

[1] Explanatory notes for definition of sustainable yield.

Extraction regime

It is recognised that sustainable groundwater yield should be expressed in the form of an extraction regime, not just an extraction volume. The concept is that a regime is a set of management practices that are defined within a specified time (or planning period) and space. Extraction limits may be expressed in volumetric quantity terms and may further specify the extraction or withdrawal regime by way of accounting rules and/or rates of extraction over a given period and/or impact, water level or quality trigger rules. The limits may be probabilistic and/or conditional.

An often-used means of defining the extraction regime has been by way of a maximum volume that may be taken in any single year. In some cases, where draw beyond the rate of recharge may be acceptable, it may be only for a specified period, after which time the rate may be less than the rate of recharge to compensate. In some cases and under specific circumstances (for example, high or low rainfall years) the amount of water that may be taken may be greater or less than the longer-term value and the conditions for this can be specified.

Acceptable levels of stress

The approach recognises that any extraction of groundwater will result in some level of stress or impact on the total system, including groundwater dependent ecosystems. The concept of acceptable levels of stress as the determining factor for sustainable yield embodies recognition of the need for trade-offs to determine what is acceptable. How trade-offs are made is a case and site-specific issue and a matter for the individual States to administer. The trade-offs will often involve balancing between environmental, social and economic needs. In some cases, the stress may be temporary as the system adjusts to a new equilibrium.

The definition should be applied in recognition of the total system. That is, it should recognise the interactions between aquifers and between surface and groundwater systems and associated water dependent ecosystems. The definition implies that integrated management decisions must be taken to fully satisfy its spirit.

In calculating sustainable yield, a precautionary approach must be taken with estimates being lower where there is limited knowledge. Application of the calculated sustainable yield as a limit on extractions must be applied through a process of adaptive management involving monitoring impacts of extraction. Sustainable yields should be regularly reassessed and may be adjusted in accordance with a specified planning framework to take account of any new information, including improved valuations of dependent ecosystems.

Storage depletion

The approach recognises that extraction of groundwater over any timeframe will result in some depletion of groundwater storage (reflected in a lowering of water levels or potentiometric head). It also recognises that extracting groundwater in a way that results in any unacceptable depletion of storage lies outside the definition of sustainable groundwater yield.

Where depletion is expected to continue beyond the specified planning timeframe, an assessment needs to be made of the likely acceptability of that continuation and whether intervention action might be necessary to reduce extraction. If intervention is likely to be necessary, then planning for that action should be undertaken so that it can be implemented at the end of the specified time-frame.

Major considerations in determining the acceptability of any specific level of storage depletion should be “inter-generational equity”, and a balance between environmental matters identified in the *National Principles for Provision of Water for Ecosystems*, social and economic values.

Protecting Dependent Economic, Social and Environmental Values

The definition recognises that groundwater resources have multiple values, some of which are extractive while others are *in-situ* (eg. associated water-dependent ecosystems) and all have a legitimate claim on the water resource.

In considering trade-offs in resource values, due recognition should be given to environmental dependencies, the risk of irreversible impacts and any decisions shall be made in accordance with the principles of ecological sustainable development.

NOTE: When this definition is reproduced, it should be accompanied with the above explanatory notes to maximise understanding of the definition.

Appendix A

Compilation of data from jurisdiction’s responses

				Current as at 2002/03		2012/13		2052/53				
GMU	Groundwater Management Area	Average Stream Flow (GL/year)	Natural Stream Loss (GL/year)	Benchmark current use 02/03 (GL/year)	Net River Loss or Gain 02/03 (GL/year)	Projected future use (GL/year)	Projected net river loss or gain (GL/year)	Projected future use (GL/year)	Projected net river loss or gain (GL/year)	Steady State	Source of Estimates	Additional Comments including caveats and confidence in data
SA	Morgan to SA Border	*4800										
SIS	Waikerie			3.8	2.7	4.7	3.3	7.5	5.2			
SIS	Woolpunda			4.4	3.1	6.3	4.4	7.6	5.3			
SIS	Qualco-Sunlands			1.6	1.1	1.6	1.1	4	2.8			
SIS	Pike River					4.7	3.3	4.7	3.3			
SIS	Murtho					4.7	3.3	6.3	4.4			
SIS	Loxton / Bookpurnong					6.3	4.4	7	4.9			
SIS	Chowilla					6.3	4.4	6.3	4.4			
SA	Estimated Total	*4800		9.8	6.9	34.6	24.2	43.4	30.3			
V11	Alexandra			0.9		0.9		0.9			02/03 use estimated at 50% of allocation	Low confidence
V12	King Lake			1.4		2.6		3.8			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V35	Mullindolingong			1		4		7			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V36	Barnawartha			0.3		1.2		2.1			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V37	Murmungee			7.3		12		16.7			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V38	Goorambat			0.8		2.9		5			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence

V39	Katunga Groundwater Supply Protection Area			40.5		40.5		40.5			02/03 use metered	Medium confidence
V40	Kialla (Zone 1)			1.1		1.95		2.8			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V41	Nagambie (Mid Goulburn)			1.9		3.8		5.7			02/03 use metered. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V42	Campaspe Deep Lead WSPA			31		31		31			02/03 use metered	Medium confidence
V43	Shepparton WSPA			120		120		120			Metered use 01/02.	Low confidence
V44	Ellesmere			1.2		1.55		1.9			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
V45	Mid Loddon WSPA (Bridgewater)			18.8		28		37.2			02/03 use metered. Future use difference between 02/03 use and PAV divided equally between each future reporting time	Medium confidence
V55	Upper Loddon (Ascot)			5.7		8.8		11.9			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Medium confidence
V56	Spring Hill WSPA			2.2		4.1		6			02/03 use metered. Future use - difference between 02/03 use and allocation divided equally between each future reporting time	Medium confidence
Vic	Unincorporated Area			76.2		114.3		152.4			02/03 use estimated at 50% of allocation. Future use - difference between 02/03 use and PAV divided equally between each future reporting time	Low confidence
N09	Lower Namoi	868	31.9	101.6	0	95	0	95	0	0	Numerical Model	Aquifer is largely disconnected from the River system
N10	Lower Murrumbidgee	3365	142.2	326.3	5	270	4.8	270	4.8	4.8	Numerical Model	
N11	Lower Gwydir	862	12	58.5	15.2	35	4.3	35	4.3	4.3	Numerical Model	

N12	Upper Namoi (including Maules Creek)	775	40.4	148.6	-5.4	125	-6.5	125	-6.5	-6.5	Numerical Model	
N13	Peel River	208	6	9.4	7.5	10	8	10	8	8	Regional 'Best Guess'	Provide baseflow to river. Assume 80% of outflow
N15	Miscellaneous Tributaries of Namoi	n/a	n/a	4.3	2.6	5	3	5	3	3	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N16	Lower Macquarie	1381	20.4	30.5	12.2	48.2	19.3	48.2	19.3	19.3	Regional 'Best Guess'	Assume 40% of outflow
N17	Upper Macquarie	1258	6.7	7.3	5.8	30	24	30	24	24	Regional 'Best Guess'	Provide baseflow to river Assume 80% of outflow
N18	Cudgegong Valley	46	2.2	1.2	1	12	9.6	12	9.6	9.6	Regional 'Best Guess'	Provide baseflow to river Assume 80% of outflow
N19	Upper Lachlan	897	45.3	12.5	10	205	164	205	164	164	Regional 'Best Guess'	Provide baseflow to river Assume 80% of outflow
N20	Lower Lachlan	744	13.4	50.1	13.4	94	13.4	94	13.4	13.4	Modelling	Aquifer is largely disconnected from the River System
N21	Mid Murrumbidgee	4355	to be advised	25.3	20.2	89	71.2	89	71.2	71.2	Regional 'Best Guess'	Provide baseflow to river. Assume 80% of outflow
N22	Billabong Creek	160	n/a	0.6	0.18	16	4.8	16	4.8	4.8	Modelling	Assume 30% of outflow
N23	Upper Murray	(MDBC)	(MDBC)	2.5	1.3	30.3	15.2	30.3	15.2	15.2	Regional 'Best Guess'	Provide baseflow to river. Assume 50% of outflow
N24	Lower Murray	(MDBC)	38	71	0.4	83.7	0.5	83.7	0.5	0.5	Numerical Model	Impact on the river are for the freshwater areas only
N27	Coolaburragundy-Talbragar Valley	58	n/a	1.8	1.1	3	1.8	3	1.8	1.8	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N28	Bell Valley	115	n/a	1.1	0.6	7	4.2	7	4.2	4.2	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N29	Belubula River	209	2.6	0.6	0.3	6	3.6	6	3.6	3.6	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N42	Orange Basalt	n/a	n/a	0.1	0	13.7	8.2	13.7	8.2	8.2	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N43	Young Granite	n/a	n/a	0.2	0.1	16.8	10.1	16.8	10.1	10.1	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
N44	Inverell Basalt	n/a	n/a	1.7	1	8.6	5.1	8.6	5.1	5.1	Regional 'Best Guess'	Provide baseflow to creeks. Assume 60% of outflow MDBC (2003)
NSW	GAB - Surat		0	36.9	0	10.1	0	10.1	0	0	Models	Any river losses are accounted for in those aquifers that have direct connection with the river systems. All outflow is presumed to be diffuse sources or unconnected to streams
NSW	GAB - Southern Recharge		0	70.8	0	53.6	0	53.6	0	0	Models	Any river losses are accounted for in those aquifers that have direct connection with the river systems. All outflow is presumed to be diffuse sources or unconnected to streams
NSW	GAB - Central		0	6.6	0	5.8	0	5.8	0	0	Models	Any river losses are accounted for in those aquifers that have direct connection with the river systems. All outflow is presumed to be diffuse sources or unconnected to streams

NSW	GAB - Warrego		0	44.4	0	38.8	0	38.8	0	0	Models	Any river losses are accounted for in those aquifers that have direct connection with the river systems. All outflow is presumed to be diffuse sources or unconnected to streams
NSW	GAB - Total			158.6		108.3		108.3				
Q51	Upper Hodgson Creek Basalt	not determine d	not known	2	not known	4	no change	7.5	no change		Metered plus estimated 100 ML stock and domestic	Ephemeral stream transects GMU. No direct connection between groundwater and surface water. Groundwater levels well below stream bed level.
Q52	Toowoomba City Basalt	0.3	not known	4	not known	5	no change	6.5	no change		Some meters majority use estimated	GMU is drained by two effluent streams. Baseflow is groundwater dependant. Streamflow is supplemented with urban runoff. Urban runoff is increasing over time.
Q53	Myall / Moola Creek North Alluvium	not determine d	not known	3	not known	3	no change	3.5	no change		Groundwater use based on estimates only	No significant surface water groundwater interaction. Groundwater levels are below stream bed level. Groundwater cap in place.
Q54	Myall Creek Alluvium	not determine d	not known	5	not known	5	no change	5	no change		Water use estimated	No significant surface water groundwater interaction. Groundwater levels are below stream bed level. Groundwater cap in place.
Q55	Lower Oakey Creek Alluvium	50.5	not known	6.5	not known	6.5	no change	6.5	no change		Water use estimated	No significant surface water groundwater interaction. Groundwater levels are below stream bed level. Groundwater cap in place.
Q56	Oakey Creek Management Area	not determine d	not known	9.5	not known	9.5	no change	9.5	no change		Metered plus estimated 270 ML stock and domestic	Ephemeral stream transects GMU. No direct connection between groundwater and surface water. Groundwater levels well below stream bed level. Groundwater cap in place.
Q57	Condamine (CGMA) Sub-Area 1	not determine d	not known	4	not known	4	no change	4	no change		Metered plus estimated 130 ML stock and domestic	Groundwater levels have been disconnected from surface stream bed levels for at least 40 years. Groundwater cap in place.
Q58	CGMA Sub-Area 2	not determine d	not known	8	not known	8	no change	8	no change		Metered plus estimated 290 ML stock and domestic	Groundwater levels have been disconnected from surface stream bed levels for at least 40 years. Groundwater cap in place.
Q59	CGMA Sub-Area 3	not determine d	not known	32	not known	32	no change	32	no change		Metered plus estimated 670 ML stock and domestic	Groundwater levels have been disconnected from surface stream bed levels for at least 40 years. Groundwater cap in place.
Q60	CGMA Sub-Area 4	not determine d	not known	1	not known	1	no change	1	no change		Metered plus estimated 240 ML stock and domestic	Groundwater levels have been disconnected from surface stream bed levels for at least 40 years. Groundwater cap in place.
Q61	CGMA Sub-Area 5	not determine d	not known	1	not known	1	no change	1	no change		Metered plus estimated 150 ML stock and domestic	Groundwater levels have been disconnected from surface stream bed levels for at least 40 years. Groundwater cap in place.

Q62	Condamine D/S CGMA	not determined	not known	0.5	not known	2.5	no change	3.5	no change		Water use estimated	Groundwater levels are below the bed level and considered disconnected from a management perspective. Groundwater development has been slow due to poor quality water. Open Cut coal and coal seam gas developments are expected to impact on groundwater use levels over the next 20 years. Groundwater cap in place.
Q63	Condamine River Alluvium (Killarny to Murry Bridge)	not determined	not known	2	not known	2	no change	2	no change		Water use estimated	Connectivity would exist throughout most of this GMU. However groundwater allocation and future development has been capped with no further expansion possible. Therefore no potential to increase impact on stream losses into the future.
Q64	Condamine River Alluvium (Murry Bridge to Cunningham)	not determined	not known	4	not known	4	no change	4	no change		Water use estimated	Groundwater levels generally below stream bed levels and no direct connectivity recognised. Future groundwater resource plans are likely to reduce levels of groundwater use consequently there should be no adverse impact on surface water security into the future. Groundwater cap in place
Q65	Condamine River Alluvium (Cunningham to Ellangowan)	not determined	not known	6.5	not known	6.5	no change	6.5	no change		Water use estimated	Groundwater levels generally below stream bed levels and no direct connectivity recognised. Future groundwater resource plans are likely to reduce levels of groundwater use consequently there should be no adverse impact on surface water security into the future. Groundwater cap in place.
Q66	Glengallan Creek Alluvium	not determined	not known	6	not known	6	no change	6	no change		Water use estimated	Ephemeral stream transects GMU. Connectivity exists in the upper section only and the potential to develop viable groundwater or surface water projects is very limited due to size of the resource. In the downstream section there is no direct connection between groundwater and surface water. Groundwater levels are below stream bed level. Groundwater cap in place.
Q67	Dalrymple Creek Alluvium	not determined	not known	3	not known	3.5	no change	4	no change		Water use estimated	Ephemeral stream transects GMU. Connectivity exists in the upper section only and the potential to develop viable groundwater or surface water projects is very limited due to size of the resource. In the downstream section there is no direct connection between groundwater and surface water. Groundwater levels are below stream bed level. Groundwater cap in place.

Q68	King's Creek Alluvium	not determine d	not known	2	not known	3	no change	4	no change		Water use estimated	Ephemeral stream transects GMU. Connectivity exists in the upper section only and the potential to develop viable groundwater or surface water projects is very limited due to size of the resource. In the downstream section there is no direct connection between groundwater and surface water. Groundwater levels are below stream bed level. Groundwater cap in place.
Q69	Swan Creek Alluvium	not determine d	not known	1	not known	2	no change	2.5	no change		Water use estimated	Ephemeral stream transects GMU. Connectivity exists in the upper section only and the potential to develop viable groundwater or surface water projects is very limited due to size of the resource. In the downstream section there is no direct connection between groundwater and surface water. Groundwater levels are below stream bed level. Groundwater cap in place.
Q70	Nobby Basalts	not determine d	not known	2.5	not known	2.5	no change	2.5	no change		Water use estimated	Nobby Basalt aquifers are at depth and not drained by any surface feature. Groundwater cap in place.
Q71	St. George Alluvium	not determine d	not known	3	not known	10	no change	18	no change		Water use estimated	Possible connection exists. Further assessment required to confirm and quantify. Very little development has occurred due to variable water quality and a wait and see approach by applicants. Not enough aquifer response data available at this point in time to assess potential for adverse impact on surface water supplies.
Q73	Border Rivers Alluvium			7.5		10		15			Metered system	Connectivity exists over the entire GMU. Currently assessing the impact. Groundwater model developed and awaiting more aquifer stress data before quantifying impacts and developing cross border management strategies. Groundwater cap in place.

* 2002/2003 stream flow
SIS: Salt Interception Schemes

Appendix B

Groundwater data from the MDBC Water Audit Monitoring Reports

Additional data sourced from the MDBC Water Audit Monitoring Report

Year	1999/00	2000/01	2001/02	2002/03
Groundwater use (GL/yr)	1052*	1024	1329	1632
Sustainable yield (GL/yr)	2326	2786	2626	2356
Allocation (GL/yr)	2806	3014	3009	2868
Groundwater use as % of surface water use		10	11.5	20.2

* Victorian data not provided