Queensland Department of Environment and Resource Management

Queensland Murray Darling Basin

Methodology for estimating the take of groundwater for stock and domestic purposes

December 2011

B2130_ 2114790A

PARSONS BRINCKERHOFF

Methodology for estimating the take of groundwater for stock and domestic purposes in the Queensland Murray Darling Basin

December 2011

Queensland Department of Environment and Resource Management

PARSONS BRINCKERHOFF

Parsons Brinckerhoff Australia Pty Limited
ABN 80 078 004 798

Level 27, Ernst & Young Centre
680 George Street
SYDNEY NSW 2000
GPO Box 5394
SYDNEY NSW 2001
Australia
Telephone *+61 2 9272 5100*
Facsimile *+61 2 9272 5101*
Email *sydney@pb.com.au*

Certified to ISO 9001, ISO 14001, AS/NZS 4801
A+ GRI Rating: Sustainability Report 2009

2114790A/PR_5550_RevD

Revision	Details	Date	Amended By
00	Working Draft	24/6/2011	CC
01	Final Draft	25/7/2011	CC
02	Client Revisions	30/9/2011	CC & LW
03	Rev A – Final draft to client	10/10/11	MP, CC, LW
04	Rev B – Final to client	21/10/2011	CC, LW
05	Rev C – Final to client	13/11/2011	LW, MP
06	Rev D – Final to client	02/12/2011	MP, CC

Author: .... Chiara Callipari

Signed: ....

Reviewer: .... Liz Webb

Signed: ....

Approved by: .... Margie Parmenter

Signed: ....

Date: .... 2 December, 2011

Distribution: .... DERM (1), PB (1)

Contents

List of tables

List of figures

Appendices

Executive summary

Queensland, like most Murray Darling Basin (MDB) states, manages groundwater on a risk based approach that assesses the likely level of impacts. In the Queensland MDB (QMDB), the take of groundwater for stock and domestic (S&D) purposes is often considered to be a small component of the overall use of a water source and is generally not metered or licensed. The main risk to the resource is in regard to the total volume of groundwater extracted for high yield irrigation, industrial or mining licences. Therefore the management focus and measurement of extractions, to date, has been on these significant extractors.

However as many water sources approach full allocation and given the effects of the drought in recent years, there has been an increasing recognition of the need to account for all forms of take from water resources across the Basin.

The Basin Plan being developed by the Murray Darling Basin Authority (MDBA) will establish a sustainable diversion limit (SDL) that will apply to all water taken from a basin water resource, including the volume of groundwater currently taken for S&D purposes. Queensland water resource plans (WRPs) will be required to include methods for accounting for this take and reporting to the MDBA on an annual basis.

Currently Queensland does not have a standard methodology or consistent approach for estimating the take of groundwater for S&D purposes. However, the effects of the drought in recent years and the approach taken by the MDBA to include S&D take in the SDLs has led to more focussed thinking about how this component of take can be better assessed, monitored and managed within the SDLs.

Queensland Department of Environment and Resource Management (DERM) have made initial estimates of the volume of groundwater take for S&D purposes in the QMDB. However, these are indicative only and improved estimates are required to inform the development of the Basin Plan.

Parsons Brinckerhoff (PB) was engaged by DERM to develop a methodology to estimate the existing take of groundwater for S&D purposes in the QMDB. This methodology needed to be practical, yet robust and defendable to the MDBA. PB was also required to apply the methodology to each of the SDL areas within the QMDB to estimate the volumes of groundwater currently taken for S&D purposes and provide recommendations for annual reporting.

The methodology developed by PB was a multifaceted approach including a number of techniques. One of the key techniques was a landholder survey which provided a mechanism to quality assure DERMs existing database of S&D bores and collect the data and information required to effectively implement the estimation method across a large area within a short period of time.

The number of responses received from the landholder surveys varied across SDL areas. Of the 249 landholders contacted over the two week period, around 50% provided the required information. These responses accounted for 148 S&D bores across the QMDB which relates to 1.6% of the total number of registered bores within the QMDB.

The type and level of information gathered from the survey provided a solid foundation for the application of the estimation methodology.

Key general observations from the survey responses included;

- The number of S&D bores reported to PB by landholders differed from those contained in DERMs Groundwater Database. The difference ranged from 43% less bores being reported in the Warrego and St George Alluvium to 21% more bores being reported in the Upper Condamine Basalts.

- Five of the eight SDL source 50% or more of their S&D use from groundwater.
- There is no clear definition or delineation of peri-urban areas across the QMDB. This lead to a generally low percentage of peri-urban landholders in the sample survey.
- Further survey in key priority areas would address the level of uncertainty in the data collected for some SDL areas.

The volume of groundwater taken per annum for S&D purposes was estimated for each SDL area by utilising the information obtained via the landholder survey and applying the methodology developed by PB. The total estimated take presented in Section 5 of this report is further divided into urban, peri-urban and rural land zones for each SDL area.

When comparing with the DERM estimates, the PB estimates suggest that groundwater take for the purposes of S&D were over-estimated in the eastern parts of the QMDB and under-estimated in the western parts of the QMDB. Thus suggesting a greater range in the usage of groundwater in the QMDB from east to west. This is further discussed in Section 6 of this report.

The limitations and level of uncertainty associated with this methodology and associated resultant estimates are outlined in Section 7 of this report. The level of uncertainty largely relates to the following key aspects:

- The small sample size, particularly in the peri urban category,
- Not having a fixed definition for 'peri urban', and not having a repeatable method to delineate this on an annual or bi-annual basis, and
- Not selecting properties without registered bores to assess the percentage of properties that in reality do have and use S&D groundwater. The groundwater database contains the "known" bores only.

Recommendations for further work to address these uncertainties include:

- Increased sample sizes in future surveys, particularly in areas where growth in peri urban is occurring (such as outside of major centres),
- Increased sample sizes in the Upper Condamine Alluvium, Upper Condamine Basalts, Qld Border Rivers Alluvium, Qld Border Rivers Fractured Rock, Sediments above the GAB, St George Alluvium and Warrego Alluvium SDL areas,
- A fixed definition of the term 'peri urban' and to develop a method (either collaboration with councils, or remote sensing/aerial photography) to be able to delineate peri urban areas in a repeatable manner over time,
- Further survey of all SDL areas during periods of varying climatic conditions,
- Further investigation of the Qld Border Rivers Fractured Rock area to better understand the number of bores, the extent of groundwater interception activities and the volumes taken from the groundwater source, and
- Selection of properties that do not have "known", registered bores. This is another measure of database accuracy that will help to reduce the uncertainty in the total number of S&D bores

However, in conclusion, the study has been found to provide an effective and robust methodology that can be used to better quantify and refine the estimation of take from groundwater for S&D use across the large geographic area of the QMDB. The study has addressed a number of concerns and limitations of earlier estimation methods and has also improved the understanding of take from groundwater for S&D purposes in each SDL area in the QMDB. This improved understanding will assist in determining the significance of S&D water in respect of the overall take of groundwater for purposes such as irrigation and industry, thereby allowing DERM to take a pragmatic approach for future management.

The focus of this study was to identify a method to estimate the take of groundwater for stock and domestic purposes in the Queensland Murray Darling Basin. The secondary focus was to implement the developed method and estimate the take. A new and extensive dataset has resulted from the project which would benefit from a more detailed analysis to enhance the statistical validity of the report and project results. Using a statistical package would generate results and statistics that would further guide the prioritisation of groundwater SDLs and build on the findings of this study.

1. Introduction

1.1 Background

Groundwater resources in the Queensland Murray Darling Basin (QMDB) are managed and allocated by the Queensland Department of Environment and Resource Management (DERM) in accordance with the Queensland *Water Act 2000.*

Queensland, like most Murray Darling Basin states, manages groundwater on a risk based assessment of likely impacts. In the QMDB the main risk is in regard to the total volume of groundwater extracted for high yield irrigation, industrial or mining licences. Stock and Domestic (S&D) groundwater extraction is often considered to be a small component of the overall use of a water source. This combined with the fact that water for S&D use is considered a 'basic right' means most of the management focus and measurement of extractions, to date, has been on the more significant extractors with groundwater for S&D use generally not been metered and in some cases, not licensed.

However, given the effects of the drought in recent years and the recognition that many water sources are approaching full allocation (and beyond in some cases), the Murray-Darling Basin Authority (MDBA) in conjunction with basin states are moving toward full accountability of systems. This movement toward accounting for all water taken from a system is driving the need to estimate previously unmeasured S&D extraction.

The MDBA is currently developing a Basin Plan under the Commonwealth *Water Act 2007* which will set limits on the amount of water that can be taken from basin water resources. These sustainable diversion limits (SDLs) represent the long-term average volume of water that can be taken for consumptive use while still maintaining the required water for the environment. All water taken from an SDL area, including the extraction of water for S&D purposes will be required to be accounted for, and Basin State Water Resource Plans (WRPs) will be required to include methods for accounting for this take and reporting this to the MDBA on an annual basis. QMDB WRPs will need to comply with the relevant SDLs, among other requirements, to qualify for accreditation under the *Commonwealth Water Act 2007*.

Accounting for S&D presents challenges for many jurisdictions in the basin, as in most water source areas take for S&D purposes is not metered or directly measured. A review of methods across Australian and internationally demonstrates there is no consistent approach across jurisdictions nor within jurisdictions.

DERM has undertaken an initial assessment to provide estimates of S&D use across the QMDB which have been used for the development of the proposed Basin Plan. However, these estimates are indicative only and DERM have determined the need for further detailed assessment to build on the initial figures and determine a more robust methodology for estimating the use of S&D groundwater in the QMDB to inform both the development of the Basin Plan and meet the associated reporting requirements.

An improved understanding of the take from groundwater for S&D purposes in each groundwater SDL area within the QMDB will also assist DERM in understanding the significance of S&D water in respect of the overall take of groundwater for purposes such as irrigation and industry. Any growth in use or total take which is currently above the SDL will require active management to ensure compliance with the SDL. An improved understanding of the current volumes used for S&D purposes is a key component for this management to ensure an informed and pragmatic approach can be applied.

DERM engaged Parsons Brinckerhoff (PB) to develop a methodology to estimate the take of groundwater for S&D purposes across the QMDB. This included a review of DERMs initial assessment approach and providing recommendations for future management and reporting.

1.2 Project objectives

The objectives of the project are to:

- Develop a methodology to estimate the existing take of groundwater for S&D purposes in the QMDB. The methodology needs to be practical yet robust and defendable to the MDBA.
- Apply the methodology to estimate the volumes of groundwater currently taken for S&D purposes within the QMDB.
- Undertake field visits within the QMDB to confirm the quality of the data collected through the phone interviews.
- Develop a process for monitoring, accounting and annual reporting of the take of groundwater for stock and domestic purposes in the QMDB. The process needs to be reported and presented with options for repeating the assessment to monitor and account for S&D usage in subsequent years.

1.3 Report structure

This report sets out the methodology developed by PB and the estimates calculated by applying the method to the SDL areas of the QMDB. Recommendations for future management and meeting reporting requirements have also been provided.

- Section 1 provides an introduction to the project, including the project objectives and an overview of the QMDB.
- Section 2 provides an overview of methods currently being used around Australia and internationally to estimate S&D (or unmetered) use. These methods are reviewed in the context of the requirement to estimate S&D use in the QMDB, undertaken in this project.
- Section 3 outlines the method developed by PB to estimate groundwater S&D take in the QMDB. This section also outlines the source of the data required to carry out the method developed, primarily from the landholder survey.
- Section 4 describes the purpose of the landholder survey and how it was developed and carried out by PB.
- Section 5 provides the results of the landholder survey and estimation method for each SDL area in the QMDB. Results are analysed for each area and an estimated take of groundwater for S&D purposes is provided.
- Section 6 summarises the findings of the estimate of groundwater S&D take and provides a comparison to previous DERM estimates.
- Section 7 discusses the limitations of the method and of the results obtained.

- Section 8 discusses the annual reporting of S&D groundwater take to the MDBA and provides recommendations to meet future reporting requirements.
- Section 9 provides the conclusions of the project and recommendations for future work to improve the level of certainty and use of the estimates for future groundwater management approaches.

1.4 Queensland Murray Darling Basin

The QMDB is located in southern Queensland and covers an area of over 260,000 km^2. It represents 15% of Queensland's surface area and approximately 25% of the Murray Darling Basin surface area. The groundwater areas of the QMDB cover an area of over 135,000 km^2 (Refer Figure 1-1).

The QMDB is characterised by significant diversity from the fertile Darling Downs in the east through to the mulga lands in the west. The economic base of the QMDB is founded on agriculture, though in recent times the region has seen the emergence of a significant energy industry, based on coal and gas, in the eastern part of the region.

Groundwater is a valuable and significant resource within the QMDB and it is used for various purposes including irrigation, town water and S&D water supply.

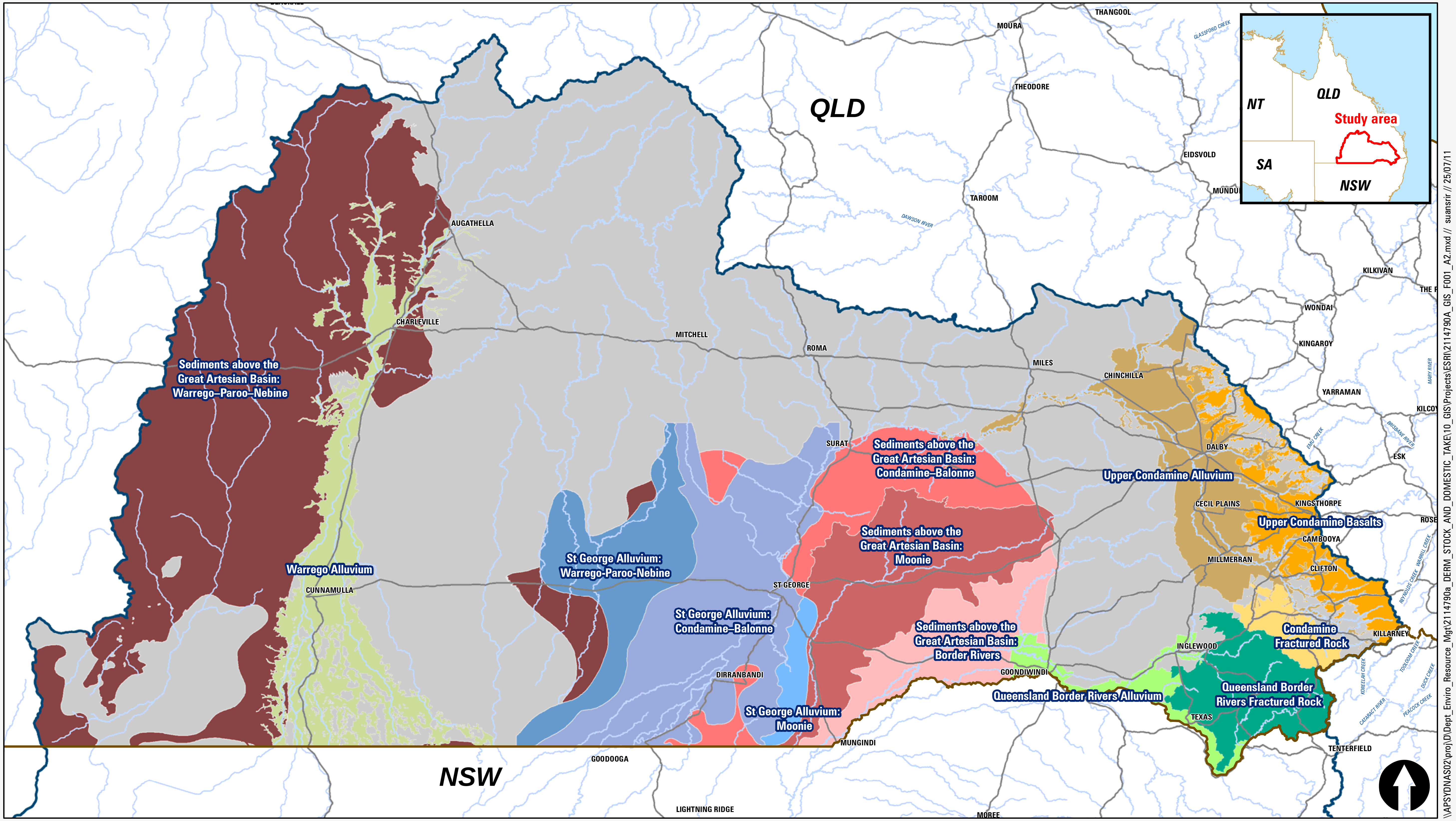
As defined in the MDBA's *Guide to the proposed Basin Plan* (MDBA 2010), the QMDB comprises the following 13 SDL areas:

1. Condamine Fractured Rock
2. Upper Condamine Alluvium
3. Upper Condamine Basalts
4. Qld Border Rivers Alluvium
5. Qld Border Rivers Fractured Rock
6. Sediments above the Great Artesian Basin (Moonie)
7. Sediments above the Great Artesian Basin (Border Rivers)
8. Sediments above the Great Artesian Basin (Condamine-Balonne)
9. Sediments above the Great Artesian Basin (Warrego Paroo Nebine)
10. St George Alluvium (Moonie)
11. St George Alluvium (Condamine-Balonne)
12. St George Alluvium (Warrego Paroo Nebine)
13. Warrego Alluvium

For the purposes of this study DERM requested that the four SDL areas associated with the Sediments above the Great Artesian Basin (GAB) SDL be combined, and the three SDL areas associated with the St George Alluvium be combined, resulting in estimates being determined and presented for a total of eight SDL areas. This approach was taken and considered reasonable given the small number of responses received during the survey for the individual SDL areas as well as the fact that the estimations of take by individual landholders did not vary considerably across the different SDL areas (see Section 5.8 and 5.9). DERM are also likely to take a similar approach for management of these groundwater areas in the future.

The groundwater resource that forms part of the GAB is excluded by the *Water Act 2007 (Cth)* from the Basin Plan process and thus was not part of this study.

Figure 1-2 shows the extent of the groundwater bores "known" to DERM as used for S&D use across the QMDB. The majority of known groundwater bores are located in the eastern parts of the QMDB – that is, in the Upper Condamine Alluvium, the Upper Condamine Basalts and the Condamine Fractured Rock SDL areas.

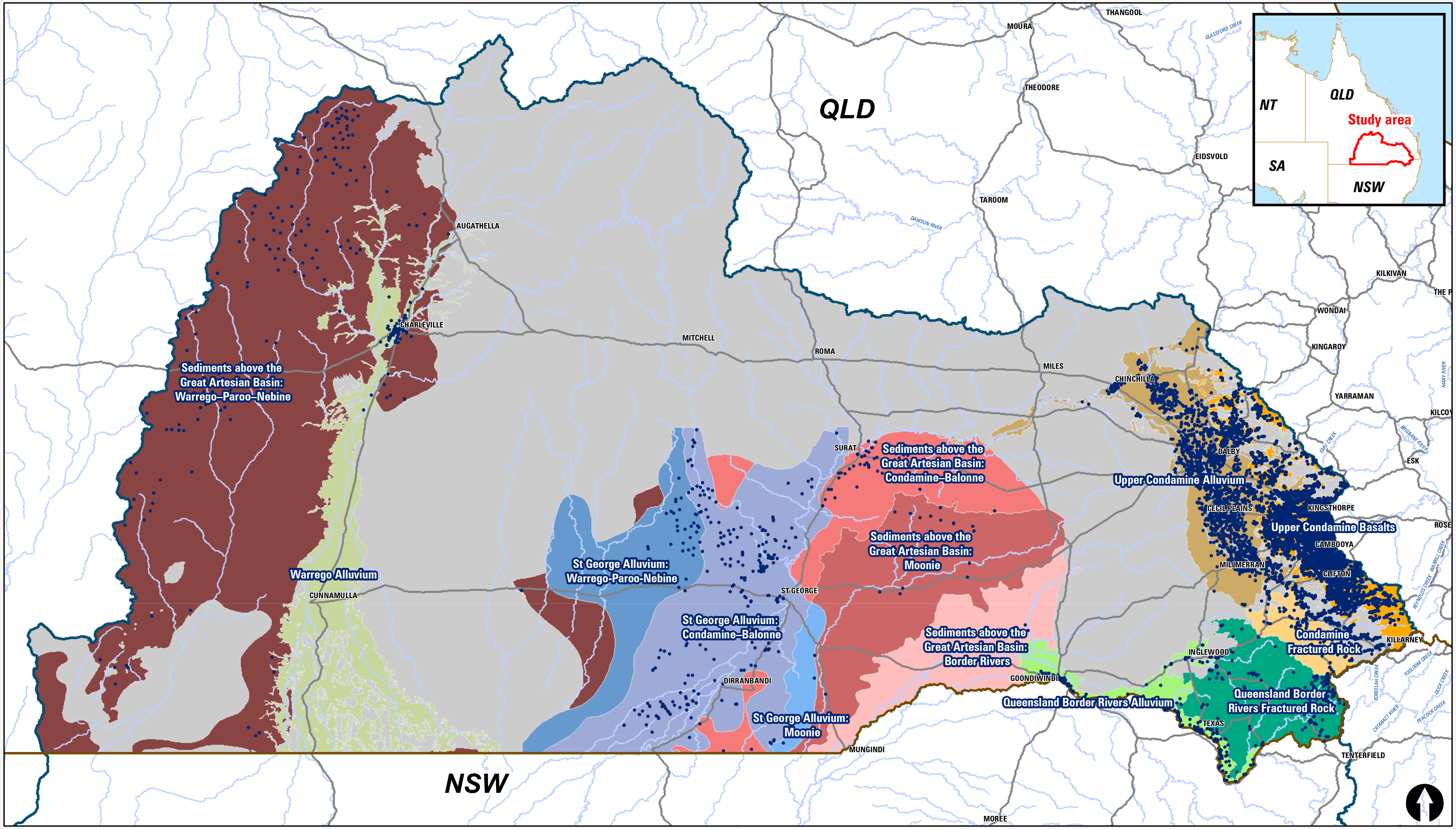


Major Road
Major River/Creek
Murray-Darling Basin boundary
GAB Outcropping - not part of project
Condamine Fractured Rock
Queensland Border Rivers Alluvium
Queensland Border Rivers Fractured Rock
Upper Condamine Alluvium
Upper Condamine Basalts
Warrego Alluvium

Combined Sediments above the Great Artesian Basin
Sediments above the Great Artesian Basin: Border Rivers
Sediments above the Great Artesian Basin: Condamine–Balonne
Sediments above the Great Artesian Basin: Moonie
Sediments above the Great Artesian Basin: Warrego–Paroo–Nebine

Combined St George Alluvium
St George Alluvium: Condamine–Balonne
St George Alluvium: Moonie
St George Alluvium: Warrego-Paroo-Nebine

Figure 1.1 QMDB groundwater SDL areas



- S&D bore
- Major Road
- Major River/Creek
- Murray-Darling Basin boundary
- GAB Outcropping - not part of project
- Condamine Fractured Rock
- Queensland Border Rivers Alluvium
- Queensland Border Rivers Fractured Rock
- Upper Condamine Alluvium
- Upper Condamine Basalts
- Warrego Alluvium

Combined Sediments above the Great Artesian Basin
- Sediments above the Great Artesian Basin: Border Rivers
- Sediments above the Great Artesian Basin: Condamine–Balonne
- Sediments above the Great Artesian Basin: Moonie
- Sediments above the Great Artesian Basin: Warrego–Paroo–Nebine

Combined St George Alluvium
- St George Alluvium: Condamine–Balonne
- St George Alluvium: Moonie
- St George Alluvium: Warrego-Paroo-Nebine

Figure 1.2
S&D bores within the QMDB groundwater SDL areas

\\APSYDNAS02\proj\D\Dept_Enviro_Resource_Mgt\2114790a_DERM_STOCK_AND_DOMESTIC_TAKE\10_GIS\Projects\ESRI\2114790A_GIS_F002_A3.mxd // SuansriR // 30/11/11

2. Current practices for estimating groundwater take for stock and domestic purposes

S&D groundwater extraction is often considered to be a small component of overall use of a water source. It is also generally considered a "basic right" and is often not metered or, in many cases, not licensed. This section provides an overview of methods currently being used around Australia and internationally to estimate S&D (or unmetered) use. These methods are reviewed in the context of the requirement to estimate S&D use in the QMDB, undertaken in this project

The suitability of applying each of these methods to estimate the S&D groundwater take in the QMDB has also been considered in terms of the amount of data required to carry out the method; the level of resources/staff required, and the time taken to implement the method. A summary of this assessment is provided in Table 2-1.

The methods employed to estimate S&D groundwater take across Australia and internationally can be broadly grouped into the following methods or approaches;

1. Direct assessment, which include:
    a. Measurement of all use
    b. Estimation by user surveys.
2. Demand based assessments, which include:
    a. Estimation of total S&D take for a water source, split into groundwater take and surface water take
    b. Estimation of groundwater take for a water source, split into various uses, e.g. S&D use, town water supply, irrigation, etc.
    c. Estimation of the number of households and stock that rely on S&D water, and multiply by their expected requirements (Lowe et al, 2009).
3. Supply/source based assessments which include determination of the number and volume of S&D licences issued and assess in combination with information on the use of farm dams (Lowe et al, 2009).

These methods are based on different assumptions and therefore the estimates determined have different levels of certainty and accuracy. This is also discussed in the following sections.

2.1 Australia

2.1.1 Queensland

S&D bores in Queensland are not required to be metered. Management of S&D groundwater use focuses on risk based approaches, such as water level decline and water quality deterioration, rather than the estimation of groundwater take volumes. However, an assessment of S&D requirements is generally undertaken during the development of water resource plans and considered in the overall limit to extraction (O'Keefe et al, 2011). The history of unlicensed and unmetered use, combined with the large number of S&D bores, i.e. in excess of 12,500, presents a difficult task in accurately estimating the take of groundwater from S&D bores.

In 2010 SKM estimated S&D bore numbers for the whole of Queensland based on the Queensland Government's Groundwater Database (GWDB) (SKM et al, 2010). Over 36,000 standalone (i.e. not used in conjunction with another water source, such as a licensed irrigation bore) bores were estimated to be present within Queensland. The number of bores was then multiplied by an estimate of use per bore of 1ML/year, estimated using allocation volumes (SKM et al, 2010). However, the number of S&D bores in the QMDB was not reported. It is important to note that the 36,000 bores estimated to be present are bores that are contained within the database; i.e. the "knowns". It is understood in DERM that many "unknown" S&D bores exist within the state. Another limitation of this method is that the constant use of 1ML/year per bore does not adequately reflect the differing climatic conditions across the state or the varying use of bores in different land use areas.

A more recent estimation of S&D use has been carried out by DERM, specifically focussed on the QMDB (DERM, 2011) to inform the MDBA's development of SDLs for the Basin Plan. This methodology reassessed the number of S&D bores within the QMDB by undertaking a thorough interrogation of the Queensland's GWDB, removing non-S&D bores (such as monitoring and abandoned bores) and assigning each bore to the correct SDL area. The number of bores identified across the QMDB totalled 9,255. However given the understanding of previous legislative arrangements, misreporting and non-reporting of drilled S&D bores, DERM developed a 'reliability factor' for each SDL to adjust bore numbers to account for uncertainty in the data. DERM then categorised bores as either urban or rural, based on the following parameters:

- Rural classification was applied to bores located on lots greater than 5,000 m^2 categorised as rural.
- Urban classification was applied using the following process:
  - Lots smaller than 5,001 m^2 selected,
  - Lots of certain tenure codes removed,
  - 100m buffer applied to all remaining lots, and
  - Lots of contiguous groups of 10 or more selected.

Average volumes extracted from each bore were then estimated based on departmental knowledge and experience of average urban and rural usage. Unit take volumes, in ML/year, were approximated for urban and rural bores, for each SDL area, and multiplied by the number of bores (including the reliability factors).

A local estimation of unmetered groundwater use has also been carried out by DERM for the Callide Valley Alluvium, in the Fitzroy Basin (DERM, 2009). The method estimates the area of the alluvium used for grazing purposes via satellite imagery in order to approximate stock numbers (actual stock numbers unavailable). Stock numbers were then multiplied by the average daily water consumption for beef cattle. There are several uncertainties inherent in this method. Firstly, the area grazed varies from year to year due to crop rotation. Secondly, differing stock water requirements are not considered, as are changes in climatic conditions.

The take of water from surface water sources is also not considered, and groundwater is assumed to be the primary source of water for stock watering and domestic purposes.

Domestic groundwater take in the Callide Alluvium was estimated by determining the number of households within the area, again with satellite imagery. Each household was then multiplied by a constant volume of 2ML/year. Further limitations and uncertainties noted for this method include the difficulty in distinguishing houses from sheds with available imagery, the application of a constant volumetric use without surveyed data, and the potential double counting of domestic take from metered/non-S&D bores. This method is not a particularly suitable management option to use to estimate the groundwater S&D take for the whole QMDB, primarily due to the large area involved, and the corresponding imagery, spatially varying stock watering information and staff time required.

2.1.2 New South Wales

In NSW the *Water Management Act 2000* (WMA 2000) governs the drilling and use of bores for S&D purposes under the basic landholder rights provisions in Section 52, domestic and stock watering. Section 52 allows landholders to extract water without a licence provided a works and use approval has been granted. The Water Act 1912, which no longer applies for basic rights bores, historically required all basic rights bore drilling and extraction to obtain a licence. Therefore many old S&D bores in NSW may still be 'licensed'.

In the WMA 2000, stock use is defined as *'…the watering of stock animals being raised on the land, but does not include the use of water in connection with the raising of stock animals on an intensive commercial basis that are housed or kept in feedlots or buildings for all (or a substantial part) of the period during which the stock animals are being raised'*. Domestic consumption is defined by Section 52 as *'…consumption for normal household purposes in domestic premises situated on the land'*.

NSW water sharing plans(WSPs) limit the overall extraction volume by setting a long term average annual extraction limit (LTAAEL), which includes S&D use under Basic Landholder Rights estimated as part of the plan preparation (O'Keefe et al, 2011). Methods for estimation are not specified but will be standardised and contained in the 'Reasonable Use Guidelines' currently under development (O'Keefe et al, 2011). The Reasonable Use Guidelines are being developed as a way of estimating unlicensed and unmetered S&D use on an individual landholding basis. This draft policy approach is essentially a demand based method like type 2(c) listed in Section 2. The method estimates the stock carrying capacity (in Dry Sheep Equivalent) for each landholding in the state, and multiplies each area by stock watering volumes, varying spatially with climatic zones. Domestic use is estimated using a constant volumetric rate per landholding, with an allowance for rural or peri urban areas (PB, 2008).

The proportion of the approximately 100,000 S&D bores in the NSW groundwater database that are operational is unknown (O'Keefe et al, 2011). However the number of S&D bores in the database provides an indication as to the proliferation of S&D bores across the state. In light of the number of bores, and given the allowance for varying climatic conditions and rural and peri urban areas, the method to estimate S&D use described above is considered suitable for similar estimation of usage in the QMDB.

2.1.3 Australian Capital Territory

The ACT *Water Resources Act 2007* requires all bores in the ACT, including those for S&D use, to be metered. As such the estimation of groundwater take for S&D purposes is undertaken through examination of metered data.

SKM et al (2010) estimates only 150 standalone S&D bores (i.e. bores only used for S&D) to be located within the ACT. Therefore metering all bores is deemed a suitable management approach for the ACT. The small number of S&D bores reflects the availability of alternative water sources in the ACT, particularly considering most of the ACT has access to reticulated water supplies.

While this approach provides data on all S&D extractions in the region, allowing a more accurate water balance, it does not lend itself to the conditions of the QMDB as the area of application is significantly greater, as is the reliance on groundwater for S&D purposes.

2.1.4 Victoria

S&D use is defined in Victoria by the *Water Act 1989* as water for: household purposes; watering of animals kept as pets, cattle and other stock; watering an area not exceeding 1.2ha for fire prevention where water is obtained from a spring, soak or dam; and, for irrigation of a kitchen garden. S&D use does not include water for dairies, piggeries, feed lots, poultry or any other intensive or commercial use. The *Water Act 1989* allows landholders to take water for S&D purposes free of charge (Section 8.1).

S&D bores in Victoria are not metered. To estimate the groundwater take from S&D bores, a nominal volume of 2ML/year is assigned to each bore, based on a Rural Water Corporation assessment of farm dams for S&D use (O'Keefe et al, 2011). This method of assessment is understandable given the number of S&D bores in the state. The Victorian Department of Primary Industries estimates the number of S&D bores within the state to be 45,000 (VDPI, 2010). SKM et al (2010) estimate the number of standalone S&D bores to be similar, at 41,989.

SKM (2007) estimated S&D water use in the Unincorporated Areas of Greater Melbourne. The method involved the use of aerial photography to identify bores used for S&D purposes, to provide an indication of what bores were in use, separate S&D water used for different purposes and to estimate the area irrigated with S&D water within each property. This method was applied to a 10km^2 sample area within each groundwater zone. The final S&D irrigation volume for each bore was calculated using the total estimated irrigation area, pan evaporation and rainfall deficit data. However a limitation to applying this method is evident particularly regarding the difficulty in separating the sources of the irrigation water, whether it be from rainfall-runoff dams, reticulated supplies, etc. Given the significantly larger size of the QMDB, the uncertainty in the source of the water, and the resource requirements necessary, this method is not considered particularly suitable to estimating S&D groundwater take in the QMDB.

For south eastern Melbourne, PB (2010) estimated the volume extracted from S&D bores by assuming that only bores installed after 1980 were in service. Estimated rates of extraction differed from those made by SKM (2007). Where SKM (2007) assumed a use of 0.6ML/year per S&D bore in the Mentone area, and 1.5ML/year in the Mornington area, PB (2010) expect usage to be lower, closer to 0.2ML/year, as bores in these areas have generally been installed recently and are more likely to be used for domestic purposes rather than traditional uses such as stock watering. The reliability of the estimates could have been improved through water use surveys or metering of a sample population.

On behalf of the Victorian Department of Sustainability and Environment (DSE), Bartley Consulting (2009) carried out a mail-out/mail-back questionnaire to more accurately determine S&D groundwater use in Western Victoria. The questionnaire was sent to 1,818 landholders, and 186 were completed and returned (i.e. 10% response rate). Information was obtained on a number of areas and included a conservative water use estimate of 1.32ML/year per S&D bore. Key recommendations from the study included:

1. Survey via telephone would likely yield a higher response rate, and a higher quality of results;

2. Time should be spent matching land parcels to actual landholders, so the survey is directed to the right owners;

3. Future mail out surveys should contain contact details landholders can use if they have queries about the survey, facilitating survey completion and quality; and,

4. Adequate promotion of the survey should be carried out prior to its dissemination, for example, to local politicians and media, to ensure the best response possible.

PB considered these recommendations in the development of the methodology for estimating the take of groundwater for S&D purposes in the QMDB.

2.1.5 Tasmania

In Tasmania the construction and operation of S&D bores is governed under the *Water Management Act 1999*. All new bores are required to have a well works permit for construction by a licensed driller. However the extraction of groundwater for S&D use does not necessarily require a licence. Licences are only required within a water management plan area that specifies this requirement. Even where licensed, bores are not required to be metered. Licences are volumetric, but there is generally no compliance reporting undertaken.

The estimation of S&D is required to be determined via a water use survey as groundwater management plans are developed. However no estimations have yet been carried out to date (O'Keefe et al, 2011). The Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) are currently in the process of developing a groundwater management plan that considers groundwater S&D use (O'Keefe et al, 2011).

There are currently around 4,500 S&D known bores in Tasmania (SKM et al, 2010). However the DPIPWE estimates this number to be growing by around 300 bores per year (O'Keefe et al, 2011). If extraction from each S&D bore, on average, is estimated to be 2ML/year (SKM et al, 2010) then a total of 9,000ML per year is taken from groundwater for S&D use in Tasmania. The groundwater management framework currently being developed by the DPIPWE will set out the direction for S&D groundwater management in Tasmania in the coming years.

Estimating S&D take through a water use survey is considered an appropriate approach to apply to the QMDB, as it allows water use to be estimated at the source and can cover large areas in a short amount of time.

2.1.6 South Australia

The South Australian *Natural Resource Management Act 2004* does not require S&D bores to be licensed to be constructed or to extract groundwater from. S&D use is estimated during the preparation of Water Allocation Plans (O'Keefe et al, 2011).

In a water resources assessment for the Tatiara Prescribed Wells Area, Cobb and Brown (2000) estimated S&D water use. Estimated stock water use and corresponding approximate stock numbers were sourced from the Australian Bureau of Statistics (ABS), with daily stock consumption figures based on data from the NSW Department of Agriculture. There was no data on domestic groundwater use, but the use was considered to be minor because of the extensive use of rainwater tanks.

Estimates of S&D water demand were also carried out by the South Australian Murray Darling Basin NRM Board for the Eastern Mount Lofty Ranges Prescribed Water Resources Area (SA MDB NRM Board, date unknown). The take of surface water and groundwater for S&D use has been estimated using a GIS approach to locate which households/properties have access to the existing water sources, and then estimating the demand on each water source. The estimation of take for domestic purposes is then calculated by determining the number of households in the prescribed water resource area, estimating the average annual use per household, and determining which water sources (surface water, groundwater or both) are being used to obtain the water for each household. Different proportions of take from groundwater and/or surface water are assigned to different areas. Similarly, the estimation of take for stock watering purposes is estimated by determining the stock carrying capacity of each property, estimating the annual total stock water demand for each property, determining which water sources are available to each property and the proportions of take from groundwater and surface water sources.

While this method is relatively straightforward in nature, several limitations to the study were present including uncertainty in stock numbers and location (recorded every two years, and movement can occur within this period); uncertainty in the separation of stock between sub catchments where properties straddle catchment boundaries; error in the correct identification of household numbers; and, error in the accuracy of groundwater and surface water locations, etc.

A telephone survey was undertaken as part of the study where 56 users provided information about where they source their water from and how they use it. The survey gathered the proportion of rainwater tanks, dams or bores for stock and domestic purposes households surveyed used. However, the variation in the proportions of each source highlighted the difficulty involved in using this method to estimate total use.

Despite these limitations, the study provides a useful estimate of S&D water demand in the Eastern Mount Lofty Ranges prescribed water resources area, in an efficient way by using available data and being desk based. Assuming information data sets on the number of households, water extraction methods (i.e. dams, bores, and tanks), stock rates and town water supply were available; a similar study could be undertaken for the QMDB to estimate the take of groundwater for S&D purposes. The study could be improved (in line with the recommendations from SA MDB NRM Board) by corroborating estimated take volumes with volumes estimated by each user within a water source area.

2.1.7 Western Australia

Licences in Western Australia are not specifically required for non-artesian S&D bores under the *Rights in Water and Irrigation Act 1914*. Section 26C of the *Rights in Water and Irrigation Exemption and Repeal Order 2010* states that water may be taken from such bores without a licence for the purposes of: domestic and ordinary use; fire fighting purposes; watering of non-intensive stock, and watering of lawns and gardens up to 0.2ha (pers. comms, R. Thorpe, June 2011). However licences to construct and operate a bore, S&D or otherwise, are required in some areas.

The groundwater take for S&D purposes is estimated (for both licensed and unlicensed S&D bores) as part of the preparation of water management plans. Use is estimated by the WA Department of Water for a water resource through surveys and local knowledge, estimates of the number of properties likely to have domestic bores (by looking at land zoning and local government plans), and information on the subdivision potential (both current and future) of the properties (O'Keefe et al, 2011). The Department of Water may also consider areas with access to reticulated water, the use and future requirements for water by the federal government, and practical access to local aquifers (O'Keefe et al, 2011).

The take of groundwater via domestic bores in the Perth area was estimated through a phone survey undertaken by Research Solutions in 2009. In their report Research Solutions estimate almost 177,000 homes use a bore for garden watering. However, an estimate of volumes used was not made as the purpose of the study was to determine the incidence and distribution of garden bores in the Perth area; to improve the calibration of the Perth Regional Aquifer Modelling System model; and, to determine allocation limits for the superficial aquifer (Research Solutions, 2009).

The WA Department of Water is currently carrying out a metering project in the Perth Metropolitan area, involving meters and loggers on some domestic garden bores. To date the Department estimates that the volume of water used is lower than expected, around 0.44ML/year per bore instead of an expected 0.8 ML/year per bore, totalling over 73,000ML/year from domestic garden bores (pers. comms, R. Thorpe, June 2011).

2.1.8 Northern Territory

A licence is not required to extract groundwater for S&D purposes in the Northern Territory under the *Water Act 1992*. S&D bores are therefore not generally metered. However the Department of Natural Resources, Environment and the Arts (NRETA) has completed a voluntary metering project in the outer Darwin area that helped to verify estimates of S&D use (O'Keefe et al, 2011).

A method to estimate S&D use is provided in the Draft Water Allocation Plan for the Western Davenport Water Control District (NRETA, 2010). This Plan estimates stock use by multiplying the maximum stock carrying capacity of the district by 50L/head/day. Domestic use is estimated by multiplying the number of people in the district by an average use of 1,000L/person/day. This is an estimate of total S&D use and is not split into surface water and groundwater takes.

S&D use is estimated in a similar fashion for the Tindall Limestone Aquifer Water Allocation Plan (NRETA, 2009). Stock use considers 50L/head/day at maximum stocking rate of the land. Household use is estimated at 4.5ML/year, based on the domestic requirements for four people (380L/person/day) and watering of 0.5ha of garden (NRETA, 2009).

S&D groundwater extraction has also been estimated in the Northern Territory by assuming 3.5ML/year per bore (pers. comm. NRETA, 2010; as cited in SKM et al, 2010).

Estimation methods such as those implemented by NRETA are considered suitable for application within the QMDB, especially if modified to allow stock watering requirements to vary over climatic zones.

2.2 International

Many countries around the world also attempt to estimate groundwater extraction where use is unmetered. A summary of some of these methods is discussed below.

2.2.1 New Zealand

In New Zealand, the taking and using of water for S&D drinking purposes is allowed under the *Resource Management Act 1991* without the need for a licence or permit. Section 14(3)(b) of the *Resource Management Act* allows the taking and using of water for household use and animals drinking water as long as there is no adverse effect on the environment. Since the vast majority of take for S&D supplies do not require a licence, there is little information on potential use or demand, and even less information on the actual use. In response to this problem the Waikato Regional Council developed a model for predicting peak summer permitted and S&D surface water use. The model calculated water use by multiplying the number of humans or animals in a catchment by corresponding variables relating to how much water each uses (Environment Waikato, 2007). While similar to the constant volume per stock head and household method, this estimation technique is driven toward surface water estimation, and cannot easily distinguish between surface water and groundwater take.

2.2.2 India

In India, groundwater abstraction is estimated using a combination of well census figures, average well commands, crop areas, water duties, well yields and pumping hours (Moench 2003). The Groundwater Resource Estimation Committee (1997) recommended calculating abstraction by multiplying the average area irrigated by each well by the average annual irrigation depth. In practice, the precise method used to calculate extraction varies in different states and localities (Moench 2003). The use of similar information to inform the development of the methodology to estimate the take of groundwater for S&D purposes in the QMDB has been considered.

2.2.3 United States of America

In the Yakima River Basin of Washington, USA, electrical power consumption data has been used to estimate agricultural groundwater withdrawals (Ripich, 2003). Power consumed during season was provided by the well owner. This approach is not well-suited to estimating groundwater take for S&D purposes in the QMDB, as many of the pumps used to extract groundwater are windmill and engine (mostly diesel) driven. This method may be applied with amendment; for example if pump diesel use information were collected, it could be used in conjunction with data on other pump types.

In New York State, USA, when registering water withdrawal, irrigators are encouraged to report a direct measurement of water use. Where this is not possible, some irrigators estimate extraction by multiplying the area of land irrigated and the depth of water applied. Non-agricultural irrigators (e.g. golf courses) may use a similar method (New York State Department of Environmental Conservation, 2011).

2.3 Summary

2.3.1 Summary of estimation methods

The methods to estimate groundwater take for S&D purposes reviewed in this section are summarised in Table 2-1. The applicability of these methods to the QMDB has been assessed, including assessment of the method’s resource and data requirements and timeframe required to implement the method.

Table 2-1 Summary of estimation methods

Method	Location	Time to implement	Resource requirements	Data requirements	Suitable to QMDB?	Comment
Direct measurement (all bores metered)	ACT (all)[1]	Long term	High	High	No	Costly to install collect and manage data. Effort to effectively utilise meters may not be commensurate with the potential impact compared to irrigation or other high use industries.
Constant volumetric rate per bore	Northern Territory[2], Victoria	Short term	Low	Low	Yes	Suitable, but more accurate methods available
Constant volumetric rate per stock head & constant volumetric rate per person	Northern Territory[3]	Short term	Medium	Medium	Yes	Suitable, but more accurate methods available
Constant volumetric rate per stock head & constant volumetric rate per person, plus water source determination	South Australia[4]	Short term	Medium	Medium	Yes	Somewhat suitable, but water source determination (i.e. groundwater or surface water source) impractical over large area of QMDB
Constant volume per area unit based on climate and stocking rates, constant volumetric rate per landholding	New South Wales[5]	Short term	Medium	Medium	Yes	Yes, but estimated volumes per unit area not currently available for QMDB. QMDB S&D water take needs to be split between groundwater and surface water
Usage based on aerial photography, rainfall & evaporation	Unincorporated areas of Greater Melbourne[6]	Medium term	High	High	Yes	Could be used, but time consuming, due to size of QMDB & more accurate methods available. QMDB S&D water take needs to be split between groundwater and surface water
Land zoning & stocking rates	Callide Valley Alluvium, Queensland[7]	Short term	Low	Low	Yes	Land zoning & stocking rates suitable, but blanket domestic volume not suitable. QMDB S&D water take needs to be split between groundwater and surface water
Landholder survey	Western Victoria[8], Western Australia (Perth)[9]	Short term	Low	Medium	Yes	Preferred method, as information is obtained from source
Power consumption	Washington, USA[10]	Medium term	Medium	Medium	Yes	Suitable, with amendment to method to review wind and pump diesel use information
Irrigable land x depth of water applied	New York State, USA[11]	Short term	Low	Low	No	Does not consider other uses of S&D water
Combination of well census, average well commands, crop areas, water duties, well yields & pumping hours	India[12]	Medium term	Medium	High	Yes	Suitable, but time and data requirements very high

1: ACT Water Resources Act (2007)
2: Draft Water Allocation Plan for the Western Davenport Water Control District (NRETA, 2010)
3. Tindall Limestone Aquifer Water Allocation Plan (NRETA, 2009)
4. Estimates of Stock and Domestic Water Demand for the Eastern Mount Lofty Ranges Prescribed Water Resources Area (SA MDB NRM Board, date unknown)
5. Unpublished 'Reasonable Use Guidelines'
6. Groundwater Allocation in the Unincorporated Areas of Greater Melbourne – Estimates of Recharge and Use (SKM, 2007)
7. Estimation of unmetered groundwater use for the Callide Valley Alluvium (DERM, 2009)
8. Western Victoria – Domestic and Stock Groundwater Bore Survey (Bartley Consulting, 2009)
9. Incidence of bores in the Perth Metropolitan Area (Research Solutions, 2009)
10. Methods to estimate unmetered ground-water withdrawals in the Yakima River Basin, Washington (Ripich, 2003)
11. Determining Non-Agricultural Water Loss in the Great Lakes Basin (New York State Department of Environmental Conservation, 2011)
12. Rethinking the approach to groundwater and food security (Moench, 2003)

2.3.2 Summary of domestic use estimations

A summary of the various domestic use estimations used by various organisations and across various Australian locations is outlined below. These estimations were considered in the development of the methodology for estimating groundwater use for domestic purposes in the QMDB.

- SA MDB NRM Board (date unknown) estimates household water use at 0.14ML/year, including garden use, for the Eastern Mount Lofty Ranges Prescribed Water Resource Area of South Australia. This equates to 384L/day per household, or approximately 192L/person/day based on two-person household.
- A S&D bore survey carried out for Western Victoria (Bartley, 2009) assumes average household consumption to be 0.3ML/year (excluding garden use)- equating to 274L/person/day based on their finding of three people per household on average.
- The Victorian Government (2002) cites the Australian Urban Water Industry (WSAA Facts, 2000) estimate of average household (excluding garden use) of 0.63ML/year, equating to approximately 575L/person/day for a three-person household.
- SKM (2007) estimate domestic and garden use to be between 0.5 – 2.9ML/year for urban and peri urban properties (with urban properties likely to be at the lower end of this range).
- DERM (2009) assume household and outdoor use to be 2ML/year per household. While this value is significantly higher than assumed for other studies, DERM (2009) anticipate average use would be lower than this.
- Brisbane City Council (2000) estimate household and outdoor use to be approximately 1,100L/day for a house of four, i.e. 275L/person/day.
- The NWC (2007) provide per capita household consumption by state (Refer Figure 2-1), with Queensland approximately 145kL/capita in 2000-01 and 125kL/capita in 2004-05. This equates to an approximate volume of 375L/person/day in 2000-01 and 342L/person/day in 2004-05.

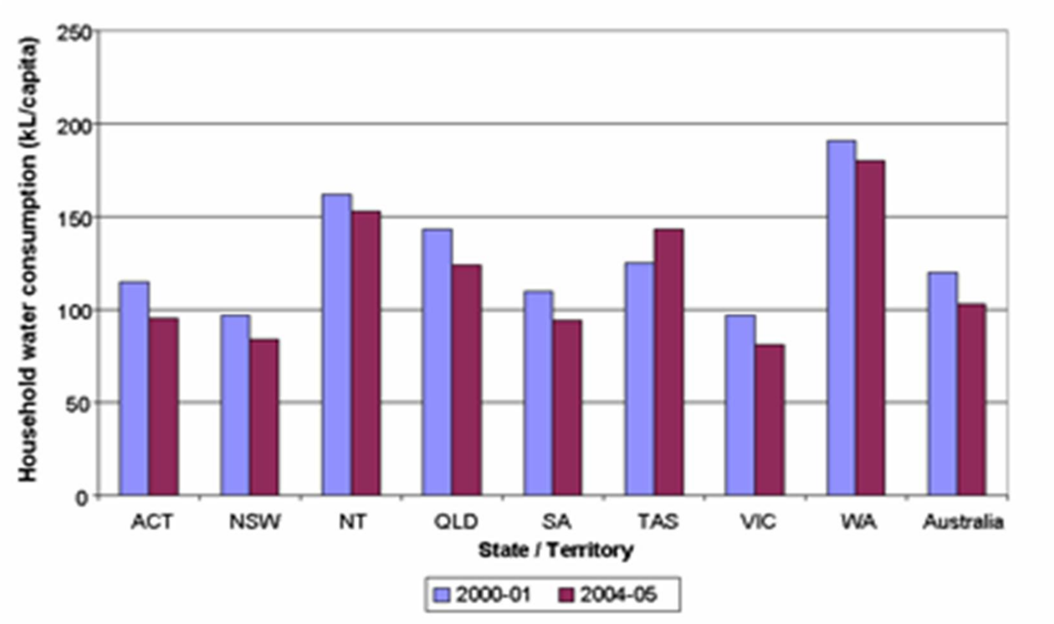


Figure 2-1 Per capita household water consumption by jurisdiction in Australia, 2000-01 and 2004-05. (Source: NWC, 2007)

3. Method to estimate stock and domestic groundwater take

This section outlines the methodology developed by PB to estimate groundwater take for S&D purposes in the QMDB. The application of the method and results obtained are documented in Section 5.

3.1 Estimation method

The method developed to estimate S&D groundwater take from the QMDB builds upon the draft methodology developed by DERM (outlined in Section 2.1.1). The draft methodology developed by DERM greatly improved on previous estimates of groundwater S&D take, particularly with the refinement of S&D bore information in the Queensland Groundwater Database (GWD). The method applied by PB in this project extends the DERM method, and incorporates valuable concepts derived from other methods reviewed in Section 2. Some of the more appropriate concepts and recommendations made in other studies considered in the methodology include:

- Collection of S&D bore extraction data through landholder survey: Western Victoria (Bartley, 2009) and Perth (Research Solutions, 2009);
- Estimation of domestic use by determining the number of households in the water source area, estimating the average annual use per household and determining which water sources are being used to supply each household: South Australia (SA MDB NRM Board, date unknown);
- Delineation of the water source area into three land use zones: urban, peri urban and rural: NWC Waterlines (O'Keefe et al, 2011);
- Consideration of pump usage to estimate volumes extracted: Washington, USA (Ripich, 2003) and India (Moench, 2003); and,
- Consideration of varying climatic conditions across the water source area: New South Wales (unpublished 'Reasonable Use Guidelines').

The method outlined in this section draws upon these concepts to add value to the draft DERM method (DERM, May 2011), by improving the accuracy of the estimation through the collection of information and additional data via the landholder survey. The key steps in the methodology applied are shown in Figure 3-1, along with the data and information required as key inputs for each stage and the source of this data and information. Each step of the methodology is discussed in further detail in the sections following.

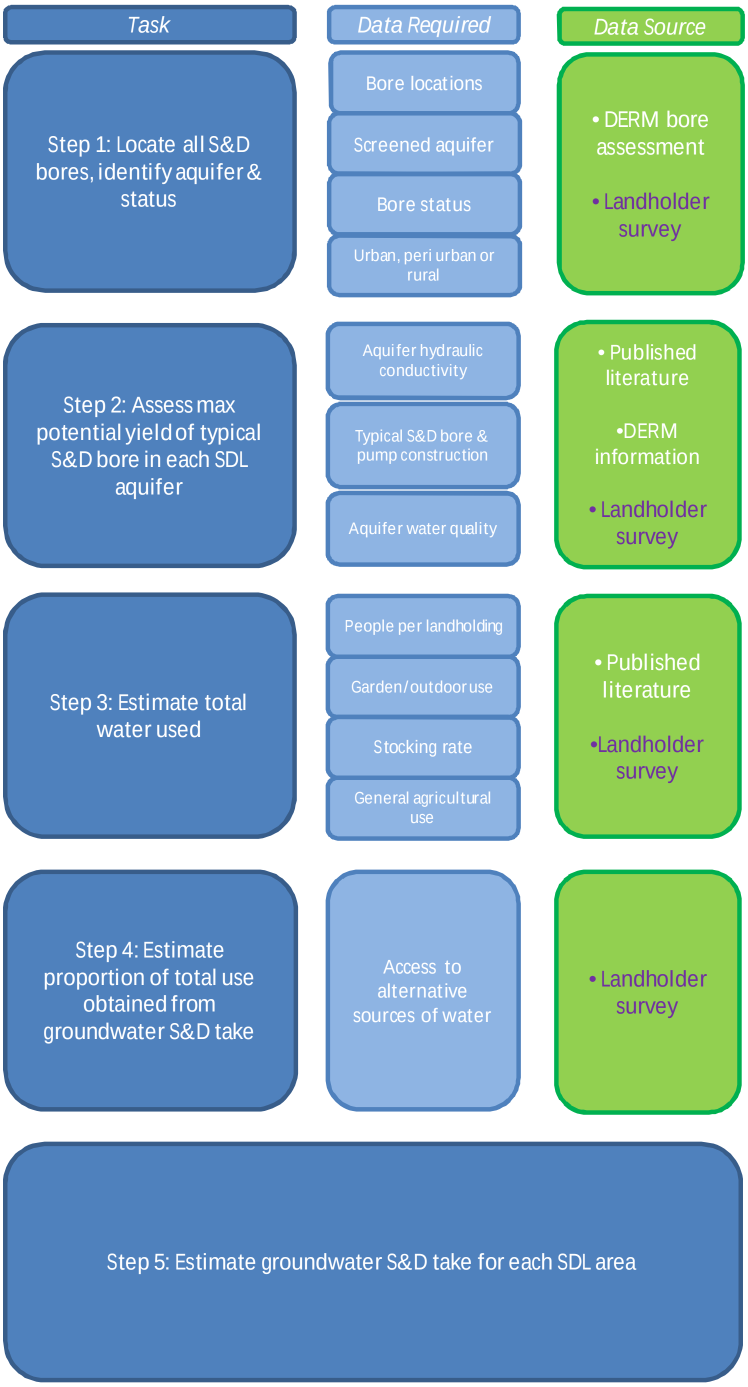


Figure 3-1 Estimation method and data sources

3.1.1 Step 1: Determine bore locations in each SDL area

Information on the number of bores and their target aquifer(s) was obtained from the DERM groundwater database. It should be noted that the number of bores contained in the estimation method detailed in Attachment 6.2 of the draft DERM (May 2011) report is based on numbers derived by SKM in 2009, and has since been refined by DERM. The refined database is used in this project.

In addition, survey information was collected from landholders to confirm bore locations and status. Landholder survey results were analysed, and where possible trends of data gaps or deviation from the database records developed. The ground-truthed information fed into the development of database accuracy values, used to adjust bore numbers based on the assessed uncertainty in the database. The database accuracy value is calculated as part of Step1, and implemented in Step 5, when final estimations for each SDL area are made.

Bores in each SDL area are then further delineated into urban, peri urban and rural zones. The draft DERM method categorised S&D bores as either rural or urban based on land zoning. The inclusion of the new peri urban category correlates with the findings of the NWC Waterlines Project, *Defining the Significance of Stock and Domestic Groundwater Use in Australia* (O'Keefe et al, 2011).

Bores within the QMDB have been categorised by land zone, using the following method:

1. Interrogation of GIS spatial information provided by DERM of the urban and rural delineated land areas.

2. Compare these areas against council planning maps with delineated land zones.

3. Re-categorise urban and rural areas into peri urban areas where aerial photography and planning maps indicate areas of peri urban properties.

4. Overlay the actual bore locations with the map of rural, urban and peri urban areas.

5. Sum the number of bores that are identified as being within rural, urban and peri urban areas for each SDL.

3.1.2 Step 2: Assess maximum potential yield for a typical S&D bore within each SDL area

The amount of water that may be extracted from each SDL area through S&D take may be physically limited by the aquifer properties and capacity of the bore and pump infrastructure to extract the water (Figure 3-2). An assessment of these factors is relatively simple and it provides benefit in 'upper limiting' the likely extraction from each S&D user.

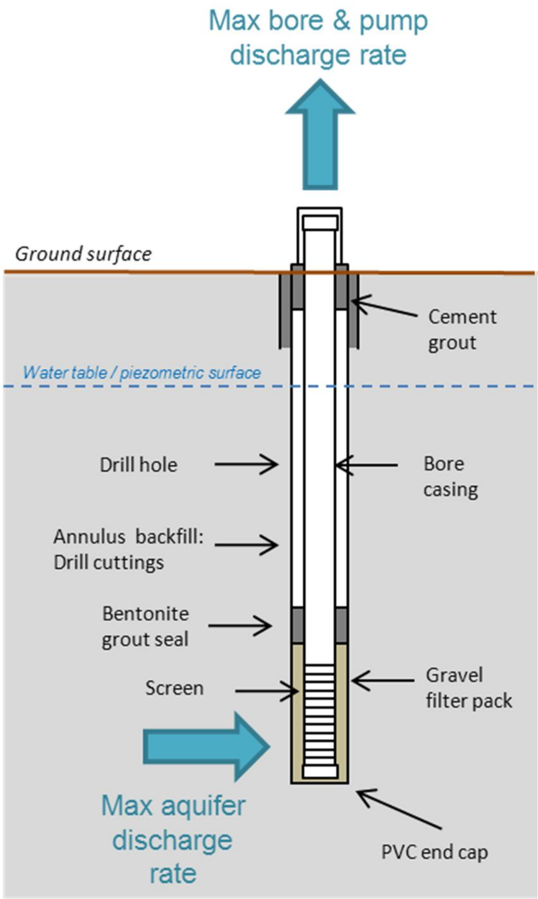


Figure 3-2 Limit to physical S&D groundwater yield & typical bore construction

The maximum potential yield available to S&D bores within each SDL area is limited firstly by the properties of the target aquifer. The rate with which water can move through the aquifer matrix influences the maximum rate at which water may be withdrawn, that is the hydraulic conductivity. The maximum rate at which water may be extracted from a bore is limited by the hydraulic conductivity of the aquifer. Recognising the hydraulic conductivity of each SDL source aids in the determination of potential maximum extraction yields for individual bores. Values for hydraulic conductivity for typical aquifer formation materials (such as gravel, sandstone, etc.) are available in published literature, and an approximate value was determined for each SDL aquifer source in the QMDB.

The maximum rate groundwater can be extracted is further restricted by the bore and pump infrastructure. The diameter of the bore, bore casing material, type and depth of the pump, depth of screening, gravel pack around the screening and sealing of the headworks all influence the effectiveness of the infrastructure to extract water.

In addition to the physical limitations on groundwater extraction, the water quality of the aquifer has some bearing on the amount of water extracted. For example, some landholders extracting from slightly saline aquifer(s) may only extract when fresher water from other sources is available for shandying or replacement. Alternatively, landholders may vary their extraction of slightly saline groundwater depending on stock tolerance. It is proposed to consider the water quality aspect in this step, estimating quality on an aquifer scale for each SDL area. This parameter is considered qualitatively, as its influence on volumes extracted is considered inherent in the estimated use approximated by landholders.

The combination of the aquifer hydraulic conductivity, the typical bore construction and likely water quality is compared to the results of the landholder survey. This comparison enhances the project results for each SDL area, and allows a 'reality check' on the estimated information obtained through the landholder survey.

3.1.3 Step 3: Estimate total amount of water used per landholding

3.1.3.1 Landholding type

Step 1 and Step 2 in the method of estimating S&D groundwater take focus on estimating the ability of landholders to extract groundwater based on the number of bores and the aquifer properties. Step 3 aims to estimate the total water use of each landholding. Landholdings in each SDL have been delineated into three categories, urban, peri urban and rural, as part of Step 1. The estimation of total water used for each landholding has been carried out on this basis.

Urban properties

The water requirements of an urban property in the QMDB are estimated by undertaking a review of previous studies completed for other parts of Australia (see Section 2) and the results obtained from the landholder survey. It is assumed that the water requirements of an urban home are domestic only, that is, there is no stock component.

Peri urban properties

Peri urban properties are commonly located on the fringes of towns and regional centres and typically consist of larger blocks of land compared to those in urban areas. For the purposes of this assessment peri urban areas have been delineated as outlined in Section 3.1.1.

The domestic use of a peri urban property is generally similar to that of an urban household, often with larger gardens. Peri urban water use is also likely to include a small stock component.

Rural properties

The domestic use for properties with S&D bores classed as rural may be assumed to be very similar to both urban and peri urban properties in the QMDB. The major differentiator for rural properties is the agricultural component of water use. It is assumed that properties which use S&D water for agricultural purposes use it primarily for stock watering and general agricultural requirements (such as vehicle wash down, spraying, etc.). The volume required is likely to increase further westward as climatic conditions become drier. However, this may be offset somewhat by reduced stocking rates.

3.1.3.2 Domestic use

Domestic use is considered to have two main components- household use (such as kitchen and bathroom use), and outdoor use (such as garden use). To estimate total household use by urban landholders in the QMDB, the number of people on each property surveyed is multiplied by an average use per person. Several studies have been carried out throughout Australia to estimate domestic water use. Section 2.3.2 summarises a selection of domestic estimations made throughout Australia, with estimations ranging between 192L/person/day to 575L/person/day. A value of 300L/person/day for household (excluding outdoor use) consumption has been assumed in this method. This is considered to be a reasonable value in light of the estimates listed in Section 2.3.2 particularly given the range in estimated domestic usage both with and without outdoor use included and given the similarity to the estimates provided for Queensland.

The outdoor component of domestic use is estimated for each landholder by multiplying the surveyed garden size by the average rainfall deficit. Average rainfall deficit information is available from Jacobson & Lau (1987) (see Figure 3-3). The QMDB essentially falls within two zones of rainfall deficit. The eastern portion is zoned as an 800-1,600mm rainfall deficit area, and the western portion as 1,600-2,400mm. Each SDL area has been assigned a rainfall deficit based on these zones and the relative position of the SDL area within the zone, as follows:

- Within the rainfall deficit zone of 1,600-2,400mm, the more western SDL areas such as the Warrego Alluvium, St George Alluvium (Condamine-Balonne, Moonie and Warrego-Paroo-Nebine) and Sediments above the GAB (Warrego Paroo Nebine) are assigned a rainfall deficit of 2,150mm.

- The more eastern SDL areas such as the Sediments above the GAB (Border Rivers, Condamine-Balonne and Moonie) are assigned a value of 1,850mm.

- The SDL areas within the 800-1,600mm rainfall deficit area have each been assigned a value of 1200 mm given their close proximity to each other. These include the Qld Border Rivers Fractured Rock, Qld Border Rivers Alluvium, Upper Condamine Alluvium, Upper Condamine Basalts and the Condamine Fractured Rock.

The different values of rainfall deficit are approximated simply to take into consideration the varying climatic conditions across the extent of the QMDB.

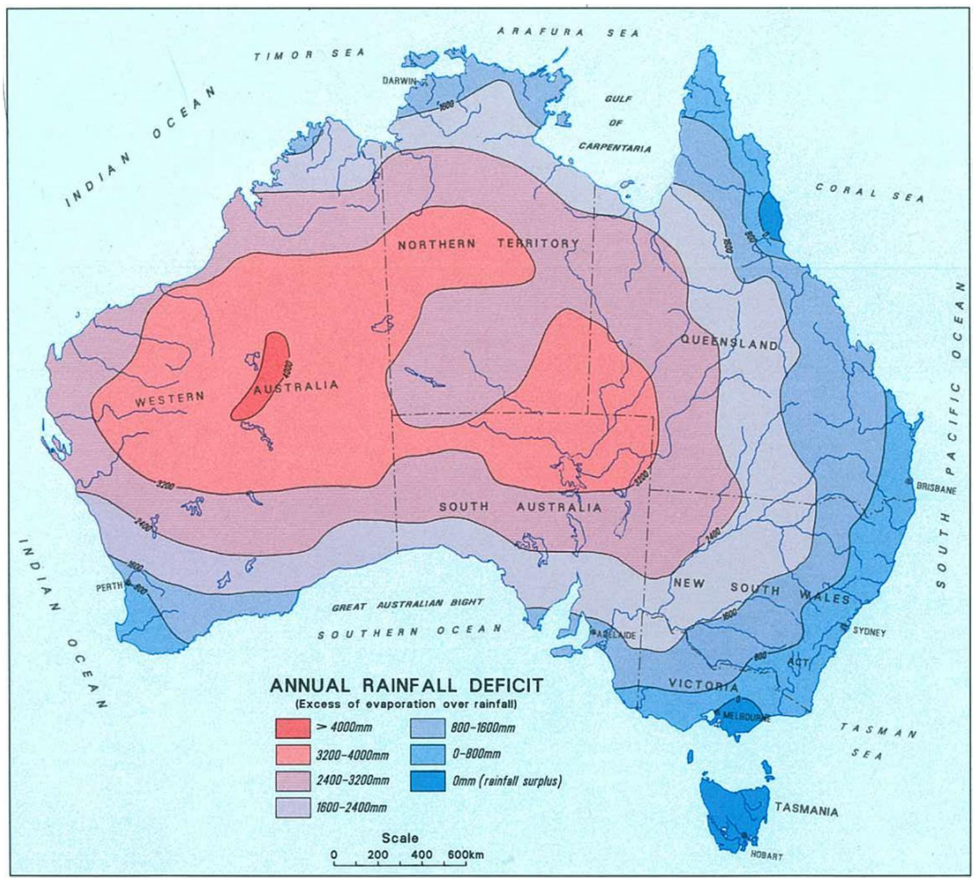


Figure 3-3 Annual rainfall deficit (Source: Jacobson & Lau, 1987)

3.1.3.3 Stock use

Water use for stock purposes is estimated by multiplying standard stock watering requirements (obtained from the Queensland Government) by the number of stock on each property as reported through landholder survey.

The following average annual consumption stock watering requirements provided by DERM were assumed in the method, and are based on Burton (1965). Note that the maximum average annual consumption volumes for each stock type were assumed.

- Sheep (nursing ewes on dry feed): 3,600L/head
- Cattle (beef): 17,000L/head
- Cattle (dairy, in milk): 20,000L/head
- Horses (working): 20,000L/head.

3.1.4 Step 4: Estimate proportion of water obtained from S&D groundwater take

The proportion of the total volume of water used by S&D landholders in each SDL is estimated in Step 3. The proportion of the total volume obtained from S&D groundwater take is estimated by assessing access to alternative sources of water. Water sources considered in this method include:

- Reticulated/mains access water: Where present, a proportion of total use is estimated through the landholder survey.
- Rainwater tanks: Where present, a proportion of total use is estimated through the landholder survey.
- Rivers, creeks or springs: Properties with extraction access to a river, creek or spring are identified and a proportion estimated through the landholder survey.
- Dams: Properties with extraction access to rainfall runoff harvesting dams are identified and a proportion estimated through the landholder survey.

The volume estimated for each landholder surveyed is then multiplied by the proportion obtained through S&D groundwater take for that property to obtain an estimated take of groundwater through S&D bores. The average value of groundwater S&D take for rural, urban and peri urban areas is then calculated for each SDL area.

3.1.5 Step 5: Estimate total groundwater S&D take for each SDL area

The information gathered was collated and used to calculate an estimate for the S&D groundwater take for each property and summed for each SDL area. This was carried out by:

(a) Gathering all data for each property and calculating an average use per bore;

(b) Multiplying the average use per bore by the number of bores in the SDL area;

(c) Adjusting the take in each SDL area by the calculated database accuracy value; and,

(d) Calculating groundwater S&D take using totals from (a) for each SDL area.

The estimation of groundwater S&D take using the methodology outlined here is discussed in Section 5.

4. Landholder survey

4.1 Purpose of survey

The method to estimate groundwater take for S&D purposes outlined in Section 3 draws heavily upon gathering information from a landholder survey. This method of data collection has been favoured as it provides realistic and current information of groundwater extraction for S&D purposes from the users themselves.

The purpose of the survey is two-fold. Firstly, to confirm and quality assure the existing database of S&D bores in the QMDB (thereby allowing a database accuracy value to be calculated for each SDL), and secondly to collect the data necessary to implement the estimation method described in Section 3.

4.2 Development of survey approach

Recommendations put forward from previous similar studies were taken into account by PB when developing the survey methodology and approach. In particular the recommendations put forward by Bartley (2009) were considered. The Bartley (2009) survey was carried out via mail out (see Section 2) for the Victorian Department of Environment and Sustainability Table 4-1 lists Bartley's (2009) key recommendations and indicates how the current project takes them into consideration.

Table 4-1 Recommendations from previous S&D bore survey and PB's response

Bartley (2009) recommendation	PB response and approach adopted for this project
Survey via telephone would likely yield a higher response rate, and a higher quality of results.	PB survey carried out via telephone. Initial telephone interviews (one from each QMDB SDL area) were followed up by site visits to those contacted, to ground-truth results received and adjust the survey as necessary.
Time should be spent matching land parcels to actual landholders, so the survey is directed to the right owners.	Information matching lot and DP numbers (identified for each S&D bore) and landholders was not available for this project. Instead landholders were asked how many S&D bores were present on the property identified by DERM and PB, and information gathered for those bores.
Future mail out surveys should contain contact details landholders can use if they have queries about the survey, facilitating survey completion and quality.	A letter was mailed out to all landholders selected for the survey, prior to the survey being conducted. The letter contained information on the project being carried out by DERM and PB, answers to a number of frequently asked questions and contact details for both DERM and PB.
Adequate promotion of the survey should be carried out prior to its dissemination, for example to local politicians and media, to ensure the best response possible.	The survey, and project objectives, were discussed with the Queensland Farmer's Federation, Queensland Dairyfarmer's Organisation and Agforce, who in turn advised their members of the survey.

The assessment of the required data and consideration of the lessons learned from the above survey approaches led to the development of the questions for the landholder survey. The questions, listed in Table 4-2, are designed to address all of the conceptual questions in the overarching approach presented in Section 3.

Table 4-2 Survey questions

1. How many stock and domestic bores or wells do you have on your property?
2. How many are operational?
3. What is the depth of each bore?
4. What is the diameter of each bore?
5. What is the maximum pump rate of each bore?
6. What is the general quality of the water extracted?
7. How are each of the bores used- for the house, garden, stock?
8. If used for the house- how many people live on the property?
9. If used for the garden- what is the approximate size of your garden?
10. If used for stock- what stock do you carry and in what numbers?
11. What is your property's maximum safe carrying capacity?
12. Do you use the stock and domestic bore water for other purposes? If so, what and how much?
13. Do you have access to alternative sources of water- mains, rainwater tanks, dams/ring tanks, spring/creeks? If so, what is each water source used for and how much?

4.3 Undertaking the survey

4.3.1 Preparation for survey

A list of landholders and their details (e.g. address, phone number and bore details) were provided to PB by DERM at the outset of the project. The landholders were selected randomly on a spatial basis by DERM from the Queensland Groundwater Database and were reviewed for suitability to the survey by DERM staff. The aim was to include approximately 25 landholders per SDL area to provide a good dataset that could be achieved within the two week timeframe. In SDLs with significantly larger numbers of bores some additional landholders were contacted to provide additional information to assess database accuracy. The number of landholders provided to PB for each SDL and the responses received are listed in Section 5.

Prior to the telephone survey a letter was sent out by DERM introducing the project, its aims, answers to some frequently asked questions. The frequently asked question list was developed by DERM during initial contact with some landholders. The letter mailed out is provided in Appendix A.

The Queensland Farmer's Federation, Queensland Dairyfarmer's Organisation and Agforce were contacted by DERM to inform them of the project and the objectives. These parties in turn advised their members of the survey. This approach assisted with the survey method as endorsement by these organisations was seen to encourage landholder response.

4.3.2 Initial testing of the phone questionnaire

Preliminary calls were made by PB, aiming for one landholder per SDL area, to test the survey's quality. These initial calls were intended to test the approach of phone calls, garner some information of the likely success of the larger phone survey, and consider adjustments that may be required either to the approach taken, or to the questions themselves.

The preliminary phone calls were undertaken with success with all landholders receiving the questions well and willing to provide information.

4.3.3 Field reconnaissance of the initial phone testing

The initial landholder phone calls were followed up by site visits, to ground-truth the information collected. This allowed the project team to ensure that the information being collected over the phone adequately reflected and represented the actual groundwater conditions at each site. It also provided an opportunity to consider whether there was the potential for ambiguity in the questions or the answers provided.

The field survey also provided the project team a first-hand appreciation of the landscapes, farming practices and how S&D groundwater was being taken and used in these SDL areas. The project team believe the inclusion of this step was a major contributing factor to the success of the overall project. The field reconnaissance confirmed that the survey questions developed were adequate to collect the information necessary to inform the proposed methodology outlined in Section 3.

4.3.4 Phone survey implementation

The telephone survey was then conducted for the remaining landholder contacts over a period of two weeks, between 6 - 17 June 2011. The telephone survey was undertaken by two people only and this allowed the approach to questioning to be consistent and somewhat controlled. The asking of questions and garnering information from landholders was a critical component of the project and the consistency of approach was a focus during the survey phone calls. The information gathered is summarised in Section 5.

5. Results and volume estimates

This section provides the results of the landholder survey and the subsequent estimation of groundwater S&D take in each SDL area of the QMDB.

5.1 Overview of survey results

The landholder survey was conducted over the two week period between 6 - 17 June, 2011.

The survey aimed to contact landholders within each SDL to obtain a dataset that would allow some estimation of the accuracy of the database to be established. Approximately 25 landholders per SDL area could be achieved within the two week timeframe. In SDLs with significantly larger numbers of bores some additional landholders were contacted to provide additional information to assess database accuracy.

Of the 9,265 bores registered in the QMDB the survey directly obtained data for 148 of them, which is a sample size of 1.6%.

The information collected from the survey was entered into Parsons Brinckerhoff's project database and utilised as the basis for the estimation calculations. The number of responses received varied across SDL areas. Table 5.1 provides a summary of the number of bores and landholders associated with these responses for each SDL area.

Table 5-1 Summary of survey responses for all known groundwater S&D users

SDL area	*Number of landholders contacted*	*Number of landholder responses*	Total number of registered bores in the SDL	DERM registered number of bores for contacted landholders who responded	Actual number of bores for contacted landholders who responded
Condamine Fractured Rock	*19*	*14*	112	15	15
Upper Condamine Alluvium	*53*	*17*	2,721	16	18
Upper Condamine Basalts	*36*	*19*	5,299	21	25
Qld Border Rivers Alluvium	*28*	*17*	247	20	22
Qld Border Rivers Fractured Rock	*37*	*13*	245	13	13
Sediments above the GAB*	*38*	*21*	363	33	30
St George Alluvium*	*22*	*11*	197	23	18
Warrego Alluvium	*16*	*7*	81	9	7
TOTAL	***249***	***119***	**9,265**	**150**	**148**

*Combined SDL areas

Given the response rate and the type and level of information obtained, the landholder survey proved to be an effective method for obtaining the required information over a large geographical area over a very short amount of time. The information obtained via this approach provided PB with a dataset which provided for the estimation of the S&D groundwater use in each SDL area in the QMDB as well as information to consider the level of certainty of the dataset for each SDL area.

The results for each individual SDL area are provided and discussed in the following sections. However some key overall observations drawn from the survey responses include;

- The number of S&D bores reported by landholders differed slightly from the number of S&D bores listed in DERM's Groundwater Database. This difference ranged from 43% less bores being reported in the Warrego and St George Alluvium to 21% more bores being reported in the Upper Condamine Basalts.
- Five of the eight SDL areas source 50% or more of their S&D use from groundwater.
- The difference in S&D groundwater use from east to west of the QMDB was greater than previously estimated by DERM.
- There is no clear definition or delineation of peri-urban areas across the QMDB. This lead to a generally low percentage of peri-urban landholders in the sample survey.

5.2 Database accuracy values

The level of accuracy of the DERM database of registered S&D bores was determined by Parsons Brinckerhoff to provide a quantitative and robust approach to address the predicted inaccuracy in the database with regard to unregistered bores that are being used to extract stock and domestic water.

The 'database accuracy values' determined by Parsons Brinckerhoff are a direct calculation between the registered and observed bores on the ground. It was achieved by calculating the ratio of the number of bores reported through the survey compared to those in the DERM database. This allowed Parsons Brinckerhoff to define those SDL's that contained unregistered bores (thus allowing an upward adjustment of the estimated use). For those SDL's that reported less actual bores than registered on the database i.e. abandoned bores that are still on the DERM database, the accuracy value allowed for a downward adjustment of the estimated use.

For example, a 'database accuracy' value of 1 indicates the same number of bores was reported by a landholder as are listed in the DERM database for that landholder and no adjustment needs to be made. However, for database accuracy values greater than 1, the actual number of bores are multiplied by that value and thus an upward adjustment is made in accordance with the actual difference between 'registered' bores and 'actual' bores. The database accuracy has been considered by Parsons Brinckerhoff for each SDL area and is reported on in the following sections.

It is important to note that the database accuracy values developed by Parsons Brinckerhoff are different to the 'reliability factors' developed and applied by DERM in their original estimates. DERM (2011) developed a range of reliability factors to reflect the reliability or accuracy of bore numbers within the DERM database. These factors were largely based on local experience, and reflected knowledge of unregistered bores and the use of groundwater for S&D purposes in combination with irrigation bores.

The database accuracy values developed by Parsons Brinckerhoff do not attempt to take into consideration other aspects previously considered in the DERM 'reliability factors'. In this way the results of the PB survey can be used and data collection can be repeated. Other 'reliability factors' can be applied to the results if deemed appropriate by DERM.

The database accuracy values are simply used to provide a greater level of accuracy to the estimate of stock and domestic use within each SDL.

5.3 Condamine Fractured Rock

The Condamine Fractured Rock SDL area lies in the north-eastern portion of the Murray Darling Basin in the shire of the Southern Downs Regional Council. Main towns include Dalveen, Pratten, Karara and others in what is a primarily rural area. Figure 5-2 shows the SDL area with S&D bores and land zones.

The Condamine Fractured Rock is in a temperate climatic zone, with wet summers and low winter rainfall (BOM, 2010), and lies within the Condamine River catchment. The hydrogeology of the SDL area is dominated by sandstones and mudstones of the Upper Devonian Texas Beds and Lower Triassic granites of the Herries Range (CSIRO and SKM, 2010). The typical hydraulic conductivity of these rocks is likely to be approximately $10 – 10^{-3}$ m/day (Driscoll, 1986). Approximate bore yields reported by landholders during the survey ranged between 0.03 – 0.8L/sec.

5.3.1 Survey responses

100% of the landholders on the contact list provided by DERM for the Condamine Fractured Rock SDL area were contacted by Parsons Brinckerhoff, with a 74% response rate. The remainder were either not willing or able to respond. The responses accounted for 13.4% of the total number of registered bores within the Condamine Fractured Rock SDL area, thus providing a good sample size for the purposes of estimating the S&D groundwater take within this SDL area. The variability in groundwater take for S&D purposes was low in this SDL area.

While the total number of bores reported by landholders were the same as are listed in the DERM groundwater database, one landholder reported having no S&D bore where the database indicated one present, and one landholder reported having three S&D bores, where the database indicates two are present.

The number of bores reported matched the number of bores listed on the DERM groundwater database thus resulting in a database accuracy value of 1, which suggests a high level of accuracy in the DERM database for this SDL area. It should be noted that complete accuracy is not expected. A database accuracy value of 1 indicates that for the ‘known’ bores surveyed in this sample selection, the number of bores in the database matched those on the ground.

The survey results are summarised in Table 5-2.

Table 5-2 Condamine Fractured Rock survey responses

Total number of registered S&D bores in the SDL	112
Total number of landholders on DERM contact list provided	19
Total number of bores associated with those landholders on the DERM contact list	20
Number of landholders contacted by PB	19
Number of landholder responses gathered by PB	14
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	15
-Reported to PB in landholder responses	15
Database accuracy value	1

5.3.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Condamine Fractured Rock area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Condamine Fractured Rock SDL area is estimated at 174ML/year. Table 5-3 provides a summary of the estimates for each of the land zones.

Table 5-3 Summary of estimated use within Condamine Fractured Rock

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/yr) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	0	ND	0	0	0
Peri-Urban	0	1.7*	5	9	9
Rural	15	1.538	107	165	165
Total – Condamine Fractured Rock					***174***

*There was not specific data from peri-urban landholders in this SDL. Therefore the average value for peri-urban use estimated during this project has been used.

5.3.3 Analysis and Discussion

The S&D groundwater use of 174 ML/ year on average estimated by PB for the Condamine Fractured Rock SDL is considerably less when compared to the DERM estimation of 664ML/year (DERM, May 2011).

The two reasons for the new much reduced estimation of S&D groundwater use from the Condamine Fractured Rock are; the original overestimate of the actual use from individual rural bores, i.e. the DERM estimate was based on 3ML/year per bore; and, the perception that the DERM database was not capturing all of the bores using groundwater for S&D purposes. These two reasons are considered legitimate and the new reduced estimate is believed to be relatively accurate. Some uncertainty does exist in the new estimate, particularly in regards to both urban and peri urban areas which were not selected as part of the survey

Landholders in the Condamine Fractured Rock SDL have a relatively moderate reliance on groundwater, (i.e. 52%) for sourcing S&D water. Refer Figure 5.1. This is likely due to the ability of landholders to obtain their water from creek and/or spring systems (reported use 19%), low bore yields in fractured rock, bores occasionally running dry and water able to be captured and stored in dams (reported use 14.5%). Most landholders surveyed reported using tanks for water storage, which has proven to be a reliable source of water (when not in drought) given the high summer rainfall under average climatic conditions (BOM, 2010).

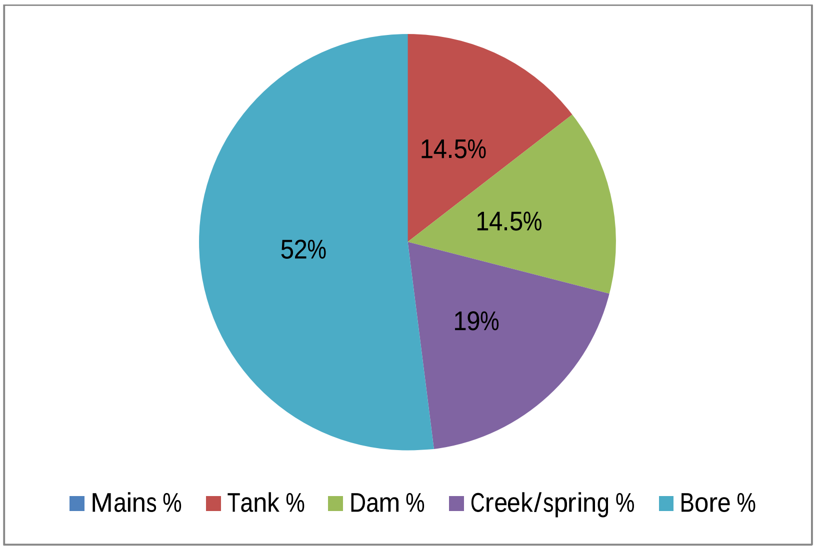


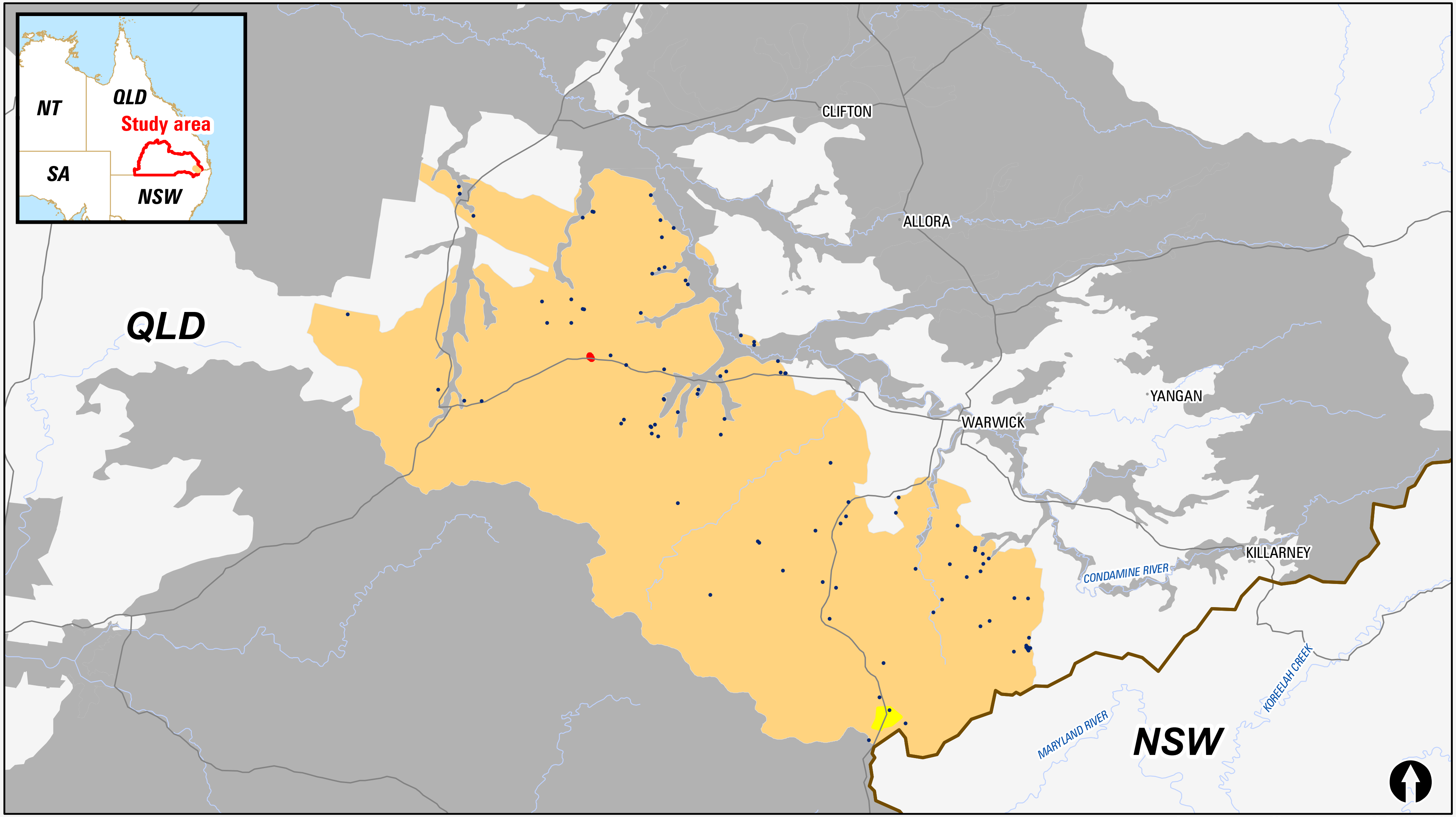
Figure 5-1 Reported use of S&D water sources in Condamine Fractured Rock

5.3.4 Conclusion

The overall assessment of S&D groundwater take from the Condamine Fractured Rock at 174ML/year is considered to be relatively accurate with 13.4% of bores in the SDL being surveyed within this project.

A slight inflation of this estimate may be required if DERM still has concerns in respect of the database accuracy. However, a reason for varying this number is not evident from the actual data collected from this survey.

Growth in use of S&D groundwater from this SDL is considered to be low risk due to the minimal potential for peri-urban areas to develop and also due to the moderate reliance on groundwater as a source of S&D water (52%).



- S&D Bore
- Urban Area*
- Condamine Fractured Rock
- Major Road
- Peri-urban Area*
- Major River/Creek
- Other SDL Areas

0 10 20 KILOMETRES

* All area outside of urban and peri-urban areas considered rural

Figure 5.2
Condamine Fractured Rock SDL area S&D bores and land zones

5.4 Upper Condamine Alluvium

The Upper Condamine Alluvium SDL area lies in the north-eastern portion of the Murray Darling Basin, covering an area of around 10,000 km^2. The northern part of the SDL area lies within the shire of Dalby and the southern area in the shire of Toowoomba. Main towns include Chinchilla, Dalby, Millmerran, Warwick, Oakey and others. Figure 5-4 shows the SDL area with S&D bores and land zones.

The Upper Condamine Alluvium is in a subtropical to temperate climatic zone, with wet summers and low winter rainfall (BOM, 2010). The SDL area lies within the Condamine-Balonne River basin. The Upper Condamine Alluvium is a highly heterogeneous alluvial deposit, with sediments up to around 140 m thick in valleys formed on weathered Palaezoic, Mesozoic and Tertiary bedrock (CSIRO and SKM, 2010). The typical hydraulic conductivity of these rocks is likely to be approximately 10^{-3} - 10^{-2} m/day (Driscoll, 1986). Approximate bore yields reported by landholders during the survey ranged between 0.01 – 1.1 L/sec, generally taken from 5 to 6 inch diameter bores with Grundfos pumps.

5.4.1 Responses

PB contacted 53 of the 54 landholders included on the DERM contact list for the Upper Condamine Alluvium Area. However responses were only received from 17 landholders who accounted for only 0.7% of the total number of registered bores within the SDL area. Despite the small sample size, variability in the reported rural and urban groundwater S&D take was relatively low; therefore the sample is thought to be reasonably representative. However the number of peri urban responses was low and the average take higher than both rural and urban take (see Table 5-5), therefore a larger sample size, particularly focused on peri urban areas, may yield a more accurate estimation of take in these areas.

In total two bores were reported in addition to those contained in the DERM groundwater database. Three additional bores were reported present and operational where the database contained no records, and one bore was reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 18 (reported) divided by 16 (listed) provided a database accuracy value of 1.125, indicating a reasonable level of accuracy in the DERM database for this SDL.

The survey results are summarised in Table 5-4.

Table 5-4 Upper Condamine Alluvium survey responses

Total number of registered S&D bores in the SDL	2,721
Total number of landholders on DERM contact list provided	54
Total number of bores associated with those landholders on the DERM contact list	53
Number of landholders contacted by PB	53
Number of landholder responses gathered by PB	17
Of those landholders who responded, the total number of bores:	
-Currently listed on DERM groundwater database	16
-Reported to PB in landholder responses	18
Database accuracy value	1.125

5.4.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Upper Condamine Alluvium area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Upper Condamine Alluvium SDL area is estimated at 3,192 ML/year. Table 5-5 provides a summary of the estimates for each of the land zones.

Table 5-5 Summary of estimated use within Upper Condamine Alluvium

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/yr) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	8	0.551	183	101	114
Peri-Urban	2	2.021	162	327	368
Rural	8	1.014	2,376	2,409	2,710
Total – Upper Condamine Alluvium					***3,192***

5.4.3 Analysis and Discussion

The estimated S&D groundwater use of 3,192 ML/year is considerably less when compared to the original DERM estimation of 9,546 ML/year (DERM, 2011).

The original DERM estimate was based on an assessment of rural use of 3ML/year per bore, and urban use of 1ML/year per bore. DERM also used a reliability factor of 1.25 based on their knowledge of the uncertainty in the database.

The PB estimate determined that an average use volume per bore ranged between 0.6 ML/year for urban properties to 2.0ML/year for peri urban properties. It is noted that the average take for rural bores is shown as 1ML/year in Table 5-5; half of that estimated for peri urban bores. Only two peri urban landholders provided responses within the SDL area, compared to 8 rural landholders. The number of rural bores identified in the SDL area is far greater than that of peri urban bores (2,376 compared to 162), and therefore have more bearing on the overall estimate. Growth in peri urban areas and use of groundwater is possible due to the proximity of this SDL to major population centres such as Toowoomba and Brisbane and this should be considered in future assessments of use in this SDL area.

The main likely reason for the reduced estimation of S&D groundwater take in the Upper Condamine Alluvium is the original overestimate of rural water use from this SDL. DERM (2011) estimated the average take of rural bores in the SDL area to be 3ML/year. The revised assessment estimates rural use from the survey is 1ML/year. The extensive spatial extent of landholders surveyed and the relatively uniform distribution of S&D bores across the SDL area provide confidence in these results However the relatively small sample size (0.7% is noted). The estimated use per bore, particularly in peri urban areas, may be refined through further survey. However this would not be a primary concern in this SDL as the majority of bores and volume extracted in the SDL are rural.

The reliance on groundwater for S&D take is calculated at 74% from the survey results for this SDL area (Figure 5-3). The high reliance on groundwater for S&D supplies in this SDL in comparison to others in the QMDB is likely due to the lack of alternative water supplies. This is illustrated in Figure 5-3, particularly in regards to the proportion of water obtained through dams (1.5%), indicative of the poor dam efficiency of the alluvial area. The very small proportion of water obtained from creek or spring systems is an unexpected result for the Upper Condamine Alluvium area. This low figure of 3% is likely a product of the landholders surveyed; that is, a more extensive survey, particularly targeting properties with river or tributary access, would most likely produce a higher estimation of water sourced from these systems.

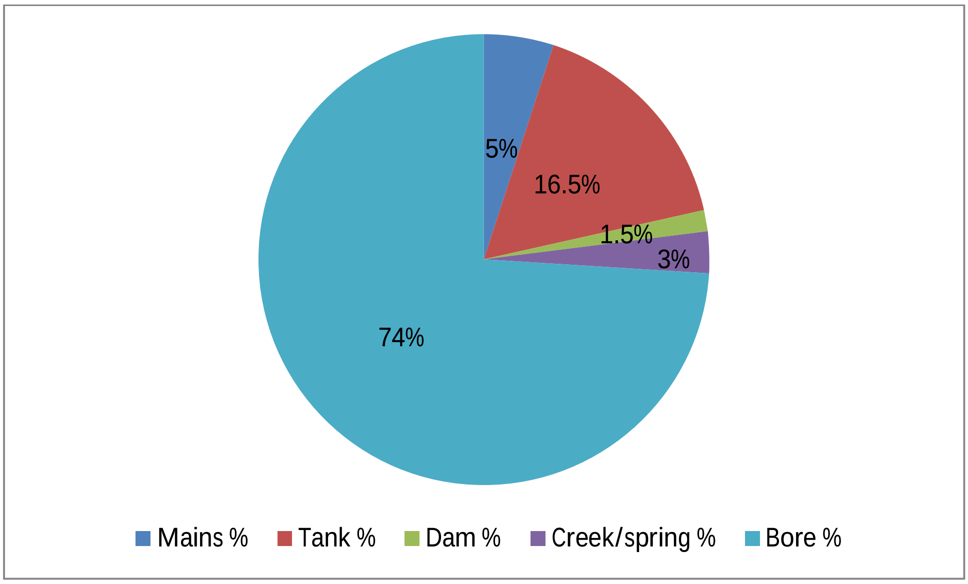


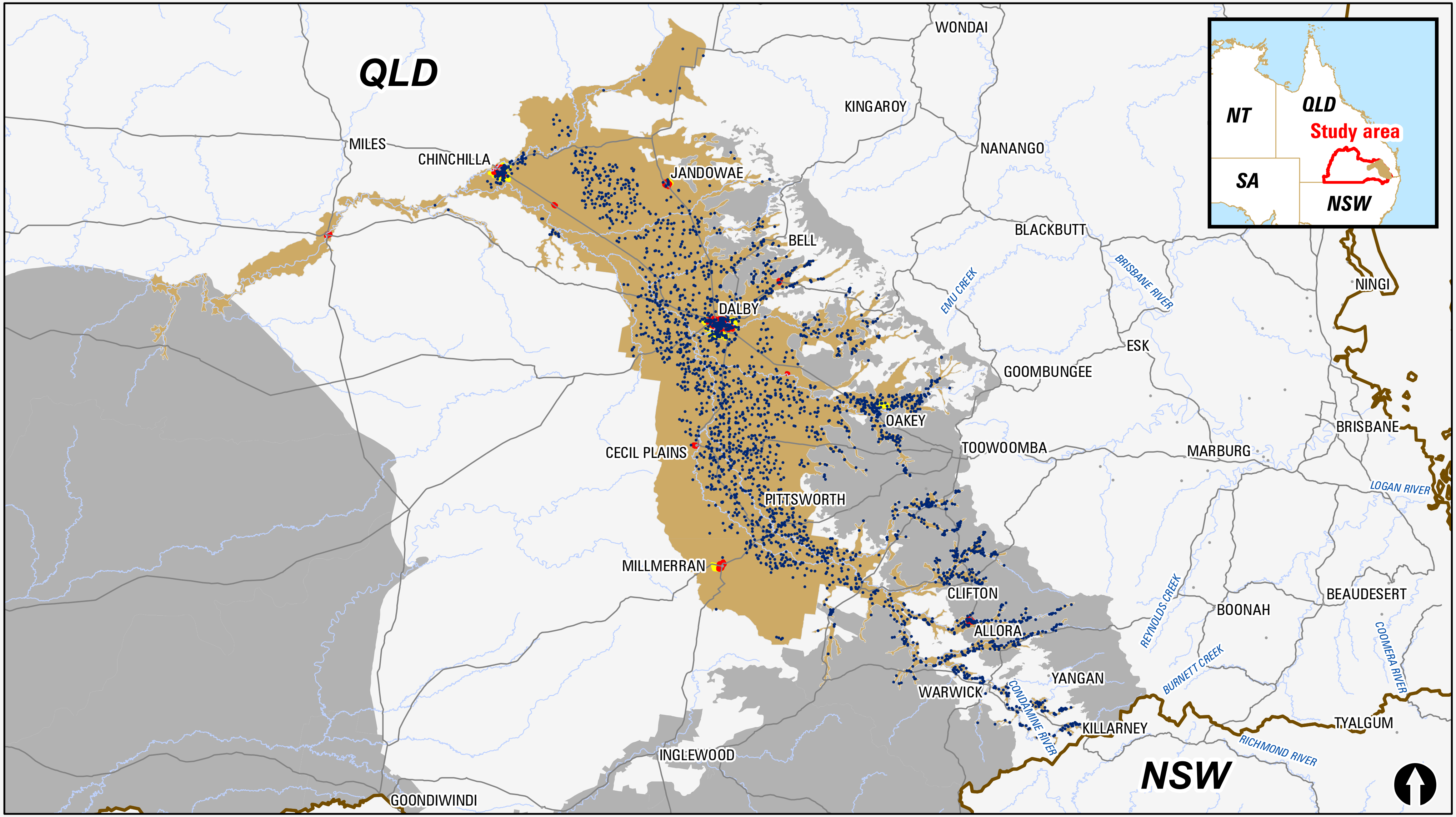
Figure 5-3 Reported use of S&D water sources in Upper Condamine Alluvium

5.4.4 Conclusion

The overall assessment of S&D groundwater take from the Upper Condamine Alluvium at 3,192 ML/year is considered to be relatively accurate based on the database accuracy value of 1.125. However, the difference between the original DERM estimate and the new revised one is large (PB estimate was around 200% higher than DERMs estimate) and the sample size is small (0.7%). It would be recommended to increase the sample size in further surveys within this SDL and also consider additional questions to further refine the data collected on the groundwater use volume per bore.

The estimated use per bore, particularly in peri urban areas, may be refined through further survey focus in these areas.

Growth in use of S&D groundwater from this SDL is considered to be a moderate risk due to the presence of significant peri-urban areas, and the high reliance on groundwater as a source of S&D water.



- S&D Bore
- Major Road
- Major River/Creek
- Urban Area*
- Peri-urban Area*
- Other SDL Areas
- Upper Condamine Alluvium

* All area outside of urban and peri-urban areas considered rural

0 25 50 KILOMETRES

Figure 5.4
Upper Condamine Alluvium SDL area S&D bores and land zones

\\APSYDNAS02\proj\D\Dept_Enviro_Resource_Mgt\2114790A_DERM_STOCK_AND_DOMESTIC_TAKE\10_GIS\Projects\ESRI\2114790A_GIS_F008_A2.mxd // SuansriR // 02/12/11

5.5 Upper Condamine Basalts

The Upper Condamine Basalts SDL area lies in the north-eastern portion of the Murray Darling Basin, covering an area of around 4,500 km^2. The Upper Condamine Basalts span three shires: Western Downs (Dalby) in the north, Toowoomba in the central area and Southern Downs in the south. Main towns include Toowoomba, Pittsworth, Cambooya, Clifton, Bell and others. Figure 5-6 shows the SDL area with S&D bores and land zones.

The Upper Condamine Basalts lies within the Condamine-Balonne River basin and is largely a temperate area with wet summers and low winter rainfall (BOM, 2010). The Upper Condamine Basalts are made up of Tertiary aged fractured basalt rock. The basalts form the highlands in the eastern waters of the Upper Condamine catchment (CSIRO and SKM, 2010). The typical hydraulic conductivity of these rocks is approximately 10 - 10^{-3} m/day (Driscoll, 1986). Approximate bore yields reported by landholders during the survey ranged between 0.1 – 3.2L/sec.

5.5.1 Responses

PB received 19 responses which accounted for 0.5% of the total number of registered bores within the SDL area. Despite the small sample size, variability in the reported rural and urban groundwater S&D take was relatively low; therefore the sample is thought to be reasonably representative. However, as in the Upper Condamine Alluvium, the number of peri urban responses was low and the average take higher than both rural and urban take (see Table 5-7), therefore a larger sample size, particularly focused on peri urban areas, may yield a more accurate estimation of take in these areas.

An additional four bores were reported when compared to those contained in the DERM groundwater database. Six additional bores were reported present and operational where the database contained no records and two bores were reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 25 (reported) divided by 21 (listed) gives a database accuracy value of 1.190, which is considered reasonable considering the very small sample size.

The survey results are summarised in Table 5-6.

Table 5-6 Upper Condamine Basalts survey responses

Total number of registered S&D bores in the SDL	5,299
Total number of landholders on DERM contact list provided	103
Total number of bores associated with those landholders on the DERM contact list	110
Number of landholders contacted by PB	36
Number of landholder responses gathered by PB	19
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	21
-Reported to PB in landholder responses	25
Database accuracy value	1.190

5.5.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Upper Condamine Basalts area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Upper Condamine Basalts SDL area is estimated at 14,670ML/year. Table 5-7 provides a summary of the estimates for each of the land zones.

Table 5-7 Summary of estimated use within Upper Condamine Basalts

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/yr) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	6	0.483	614	297	353
Peri-Urban	2	4.467	512	2,287	2,722
Rural	17	2.335	4,173	9,744	11,595
Total – Upper Condamine Basalts					***14,670***

5.5.3 Analysis and Discussion

The original DERM estimation was 17,861 ML/year (DERM, 2011) compared to 14,670ML/year estimated from the survey results.

The Upper Condamine Basalts are similar to the Upper Condamine Alluvium and the Condamine Fractured Rock areas in that the draft DERM estimate (DERM, May 2011) is based on rural use of 3ML/year per bore, and urban use of 1ML/year per bore.

The PB estimate determined that an average use volume per bore ranged between 0.5 ML/year for urban properties to 4.5ML/year for peri urban properties, with rural properties estimated to use an average of 2.3ML/year per bore. As for the Upper Condamine Alluvium, the peri urban estimated use in this SDL area is almost double the estimated rural use. It must be stressed that only two peri urban landholders provided responses within the SDL area, compared to 17 rural landholders. The number of rural bores identified in the SDL area is far greater than that of peri urban bores (4,173 compared to 512), and therefore have more bearing on the overall estimate. However, it is noted that growth in peri urban areas and subsequent growth in use of groundwater is possible.

The PB results are very similar to the draft DERM estimation. The main reason for the difference between PB and DERM estimations is the shift in where the groundwater is expected to be extracted from, combined with an increase in the number of bores identified in the SDL area. The number of peri urban bores, combined with the high estimated use, accounts for 2,722ML/year in the SDL estimate of groundwater S&D take. The similarity between the DERM and PB estimate for the Upper Condamine Basalts provides additional confidence in the current estimate, particularly considering the estimates were based on different approaches.

The low sample size of only 0.5% indicates that additional survey using a much larger sample size would reduce the uncertainty in the results. A larger sample size across rural, peri urban and urban areas would enhance both the database accuracy factor and also the estimated use per bore. This is particularly important for both the peri urban and rural areas.

The Upper Condamine Basalts has a reliance on groundwater (approximately 49%), which is lower than the Upper Condamine Alluvium, for a similar mix of rural, urban and peri urban landholders.

Water from tanks (generally holding rainwater) accounted for about a third of total S&D water use. The preference of tanks over dams is clear in this SDL area, indicating the poor dam holding capacity of basalt in the area. Water from creek/spring systems accounted for a reasonable proportion (12.5%), reflecting the regularly ephemeral nature of the surface water over the fractured basalt area.

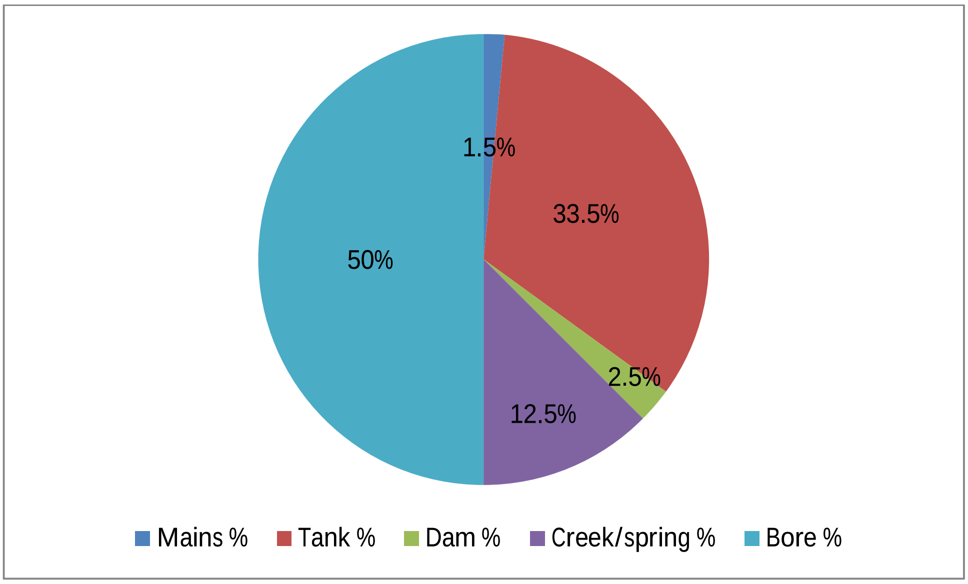
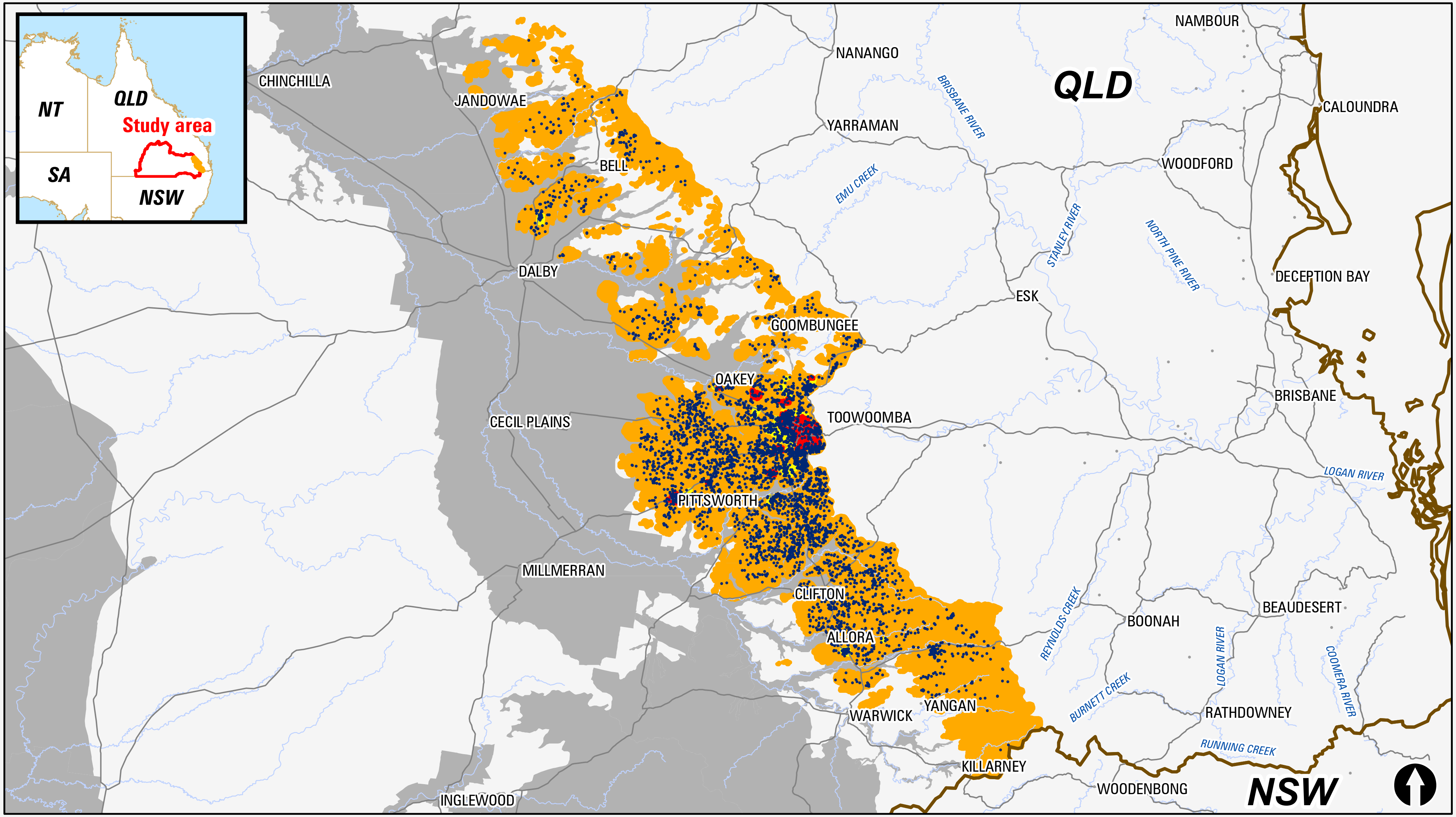


Figure 5-5 Reported use of S&D water sources in Upper Condamine Basalts

5.5.4 Conclusion

The overall estimate of S&D groundwater take from the Upper Condamine Basalts of 14,670ML/year is considered to be relatively accurate, and is similar to the previous DERM estimate of 17,861ML/year. The significance of the peri urban use proportion of the total estimate should be noted. The small sample size of 0.5% should also be noted and additional survey is recommended to improve both the estimated use per bore in peri urban and rural areas and also the database accuracy factor.

Growth in use of S&D groundwater from this SDL is considered to be a moderately high risk and monitoring the growth of peri-urban areas within this SDL may provide an indication of this potential growth in use.



S&D Bore | Urban Area* | Upper Condamine Basalts
Major Road | Peri-urban Area*
Major River/Creek | Other SDL Areas

* All area outside of urban and peri-urban areas considered rural

0 25 50 KILOMETRES

Figure 5.6
Upper Condamine Basalts SDL area S&D bores and land zones

5.6 Queensland Border Rivers Alluvium

The Queensland Border Rivers Alluvium SDL area lies in the north-eastern portion of the Murray Darling Basin, on the border with New South Wales. The SDL covers an area of around 2,200 km^2. The Queensland Border Rivers Alluvium lies almost wholly in the shire of Goondiwindi; with the main towns being Goondiwindi, Texas and Inglewood. Figure 5-8 shows the SDL area with S&D bores and land zones identified.

The Queensland Border Rivers Alluvium is a subtropical to temperate area with wet summers and low winter rainfall (BOM, 2010). The Queensland Border Rivers Alluvium comprises an upper aquifer (consisting of unconsolidated sand, clay and gravel) around 10-30 m deep, and a deeper aquifer (consisting of consolidated clay, sandstone and gravel up to 50 m thick), separated by a semi-impervious clay aquitard (CSIRO and SKM, 2010). The typical hydraulic conductivity of alluvial sediments is approximately 10^{-2} – 10^{3} m/day (Driscoll, 1986). The shallow alluvium is expected to be more permeable than the deeper aquifer. Approximate bore yields reported by landholders during the survey ranged between 0.3 – 1.6 L/sec.

5.6.1 Responses

17 (or 61%) of landholders responded to the survey which accounted for approximately 9% of the total number of registered bores within this SDL. This is considered to be a good sample size given the low variability in reported groundwater S&D take in rural and urban areas. A larger sample size within peri urban areas may yield a more accurate estimation of groundwater S&D take in these areas.

Two bores were reported in addition to those contained in the DERM groundwater database. Five additional bores were reported present and operational where the database contained no records and three bores were reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 22 (reported) divided by 20 (listed) gives a database accuracy value of 1.100. The relatively high sample size of 9% and the database accuracy of 1.100 provide additional confidence to the estimate of use from within this SDL.

The survey results are summarised in Table 5-8.

Table 5-8 QLD Border Rivers Alluvium survey responses

Total number of registered S&D bores in the SDL	247
Total number of landholders on DERM contact list provided	31
Total number of bores associated with those landholders on the DERM contact list	34
Number of landholders contacted by PB	28
Number of landholder responses gathered by PB	17
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	20
-Reported to PB in landholder responses	22
Database accuracy value	1.100

5.6.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Queensland Border Rivers Alluvium area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average annual take of groundwater for S&D purposes in the Queensland Border Rivers Alluvium SDL area is estimated at 443ML/year. Table 5-9 provides a summary of the estimates for each land zone.

Table 5-9 Summary of estimated use within QLD Border Rivers Alluvium

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/year) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	6	1.252	69	86	95
Peri-Urban	2	1.501	25	38	42
Rural	14	1.815	153	278	306
Total – QLD Border Rivers Alluvium					***443***

5.6.3 Analysis and Discussion

The DERM (May 2011) estimation of 1,442ML/year (DERM, 2011) is considerably higher than the volume estimated from the survey.

The DERM estimate for this SDL area was based on a higher assessment of rural and urban than that used for the more eastern SDL areas. The DERM (May 2011) estimate was based on an assessment of rural use being 4ML/year per bore, and urban use of 1.5ML/year per bore. DERM used a reliability factor of 2, based on an understanding of uncertainty in the database records. The database accuracy value calculated in the PB assessment used the actual ratio of the number of bores reported compared to the DERM groundwater database, and was calculated as 1.100. This value indicates a higher degree of certainty in the database records than expected from the DERM (May 2011) assessment. An additional reliability factor may be used by DERM if uncertainty in bore numbers and use for other reasons is expected by DERM for this SDL area.

Compared to the DERM estimate of urban use per bore, the PB estimate determined a similar use per bore for the urban (1.3ML/year) and peri urban bores (1.5ML/year). It should be noted that the PB estimate of 1.8ML/year for rural use was significantly lower than the DERM estimate.

The two likely reasons for the new much reduced PB estimation of S&D groundwater use from the Qld Border Rivers Alluvium are the overestimate of the actual use of rural water from this SDL, and the perception that the DERM database was not capturing all of the bores actually using groundwater for S&D purposes. The new reduced PB estimate is believed to be relatively accurate due to the relatively high level of database accuracy calculated in the survey, and the relatively high sample size of 9%. A slight inflation of this number may be required if DERM still has concerns for other reasons in respect of the database accuracy and or the estimated use per bore. However, a reason for further inflating this number is not evident from the actual data collected from the survey.

The results of the survey indicate the reliance on groundwater for S&D purposes is high in the Qld Border Rivers Alluvium; on average around 79% (Figure 5-7). The lowest proportion of water for S&D use was reported from dams and is likely due to the sandy soils where dam holding capacity is limited due to their transmissive nature.

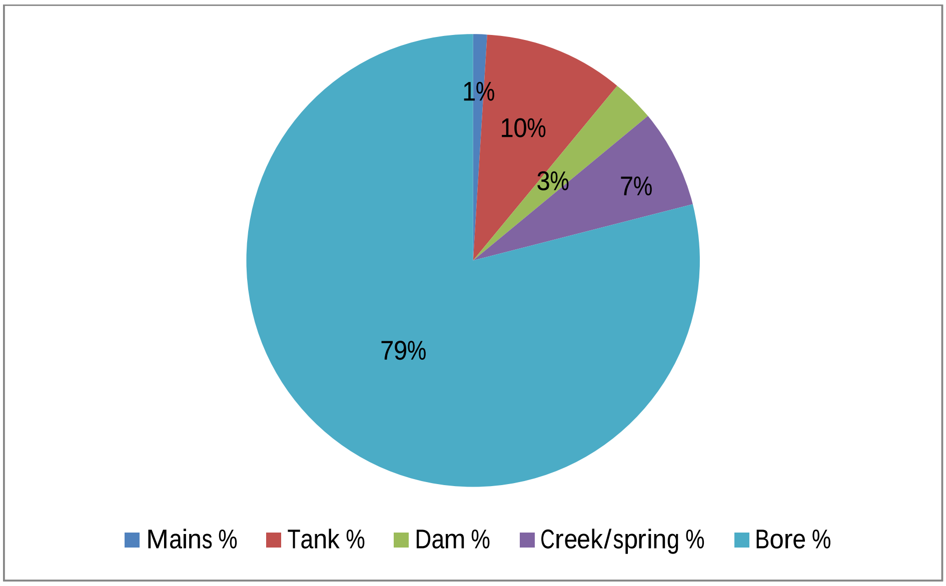
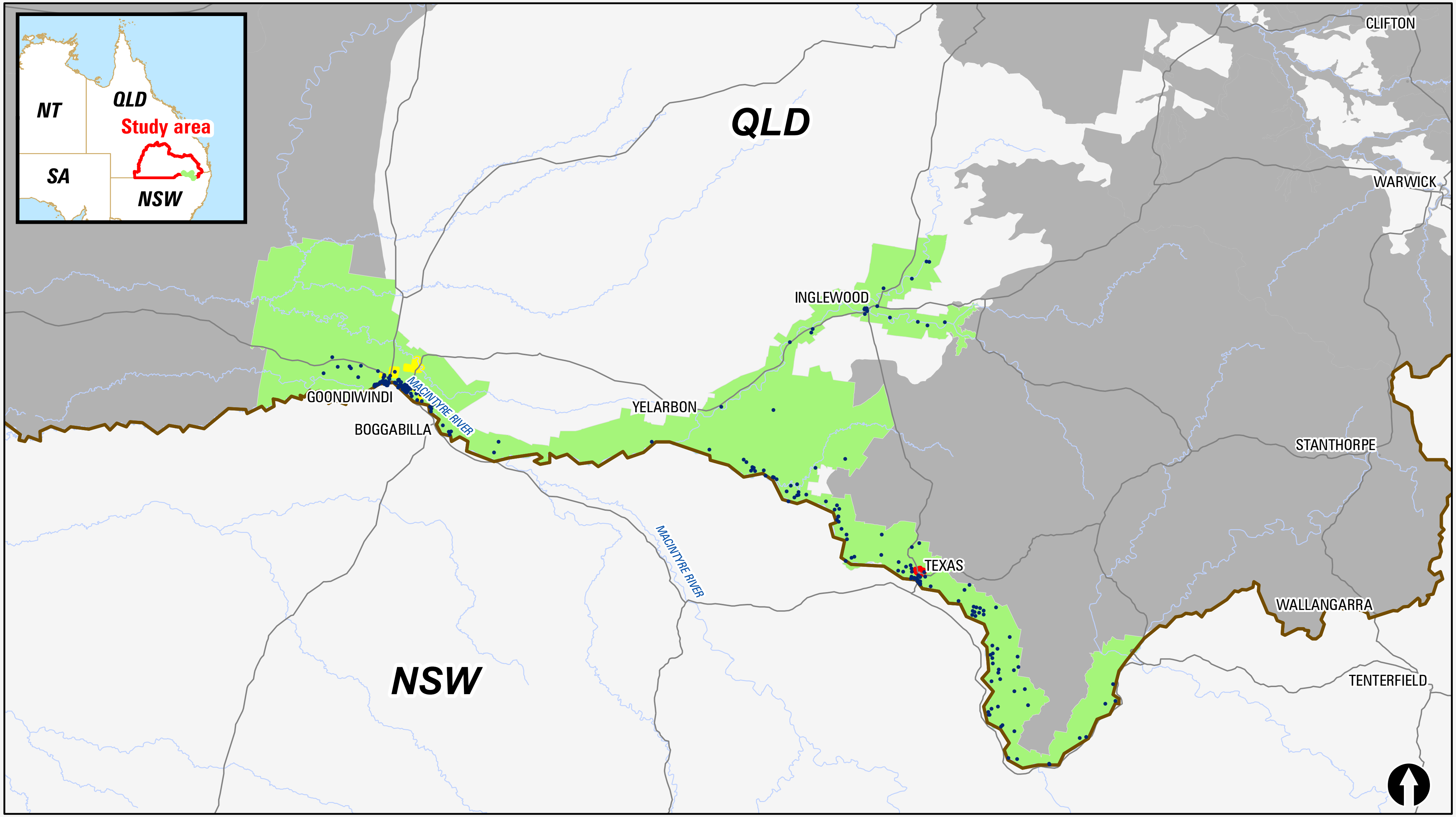


Figure 5-7 Reported use of S&D water sources in Queensland Border Rivers Alluvium

5.6.4 Conclusion

The overall estimate of S&D groundwater take from the Queensland Border Rivers Alluvium of 443 ML/year is less than a third of the previous estimate by DERM. The PB survey revealed a much lower per bore use in rural areas than has been used previously. The relatively high sample size provides some confidence in the PB estimate based on the methodology in this project.



- S&D Bore
- Major Road
- Major River/Creek
- Urban Area*
- Peri-urban Area*
- Other SDL Areas
- Queensland Border Rivers Alluvium

* All area outside of urban and peri-urban areas considered rural

0 25 50 KILOMETRES

Figure 5.8
QLD Border Rivers Alluvium SDL area S&D bores and land zones

5.7 Queensland Border Rivers Fractured Rock

The Queensland Border Rivers Fractured Rock SDL area lies in the north-eastern portion of the Murray Darling Basin, on the border with New South Wales. The SDL covers an area of around 5,600 km^2, with the eastern half in the Southern Downs Regional Council area and the western half in the Goondiwindi Regional Council area. Main towns include Stanthorpe, Wallangarra and Glen Aplin. Figure 5-10 shows the SDL area with S&D bores and land zones identified.

The Queensland Border Rivers Fractured Rock is a temperate area with warm to hot summers and mild winters (BOM, 2010). The Queensland Border Rivers Fractured Rock is dominated by sandstone and mudstone units of the Upper Devonian Texas Beds (CSIRO and SKM, 2010). A second aquifer unit is contained within the SDL area, comprised of granites that approximately align with the undeclared Stanthorpe Shire. The granite aquifers are considered to be highly connected to the surface water in the area (DERM, 2011a). The typical hydraulic conductivity of these rocks is approximately 1 – 10^{-3} m/day (Driscoll, 1986). Approximate bore yields reported by landholders during the survey ranged between 0.1 – 1.8 L/sec.

5.7.1 Responses

Responses were received from 13 (or 35%) of those landholders contacted who accounted for approximately 5.3% of the total number of registered bores in the SDL. Significant uncertainty surrounds the estimates of S&D groundwater take in the Border Rivers Fractured Rock, as is discussed further in the analysis section. Therefore a larger sample size may yield a more accurate estimate for this SDL area.

Two additional bores were reported present and operational where the DERM database contained no records, and two bores were reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 13 (reported) divided by 13 (listed) gives a database accuracy value of 1.000, indicating accuracy in the DERM database. It is noted that complete accuracy is not expected, rather, a database accuracy value of 1.000 indicates that for the ‘known’ bores surveyed, the same number of bores were reported as are in the database. The relatively high sample size of 5.3% and the database accuracy of 1.000 provide a high level of confidence to the estimate of use from within this SDL. However other factors in respect of the uncertainty of the estimated use may need to be considered for this SDL.

The survey results are summarised in Table 5-10.

Table 5-10 QLD Border Rivers Fractured Rock survey responses

Total number of registered S&D bores in the SDL	245
Total number of landholders on DERM contact list provided	38
Total number of bores associated with those landholders on the DERM contact list	39
Number of landholders contacted by PB	37
Number of landholder responses gathered by PB	13
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	13
-Reported to PB in landholder responses	13
Database accuracy value	1.000

5.7.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Queensland Border Rivers Fractured Rock area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Queensland Border Rivers Fractured Rock SDL area is estimated at 1,512ML/year. Table 5-11 provides a summary of the estimates for each land zone.

Table 5-11 Summary of estimated use within QLD Border Rivers Fractured Rock

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/yr) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	1	0.728	12	9	9
Peri-Urban	1	2.510	5	13	13
Rural	11	6.537	228	1,490	1,490
Total – QLD Border Rivers Fractured Rock					***1,512***

5.7.3 Analysis and Discussion

The DERM (May 2011) estimation of 9,525ML/year for this SDL is considerably higher than the estimate of 1,512ML/year determined from the survey.

The DERM (2011) estimate was based on an assessment of a rural use of 4ML/year per bore, and urban use of 1.5ML/year per bore. DERM used a very high reliability factor of 15. The high reliability factor for the Qld Border Rivers Fractured Rock was developed by DERM through a consideration of the following factors (taken from DERM, 2011a):

1. Uncertainty in the number of unknown S&D bores. The uncertainty associated with the number of unknown S&D bores is higher in this area than other in the QMDB due to a combination of management arrangements which did not require water licences or the

submission of drill logs, particularly in the undeclared groundwater area around Stanthorpe.

2. Uncertainty in the take of groundwater from dams or trenches. Small dams or trenches are known to intercept shallow groundwater in the QLD Border Rivers Fractured Rock area. DERM estimates around 90% of all trenches/dams in the undeclared area may intercept groundwater.

3. Uncertainty in the volume of groundwater taken for purposes other than S&D, such as irrigation, industrial use, etc. In the undeclared area there is no requirement to hold a licence to access groundwater.

The aim of the PB project was to estimate take for S&D purposes and was not focused on take for non-S&D purposes, licensed or otherwise. Therefore the database accuracy value used in this assessment only considers points 1 and 2 above, in the following manner:

1. Uncertainty in the number of unknown S&D bores: A database accuracy value of 1 can be determined from the results of the survey, calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded.

2. Uncertainty in the take of groundwater from dams or trenches: Considering that approximately 90% of dams/trenches in the undeclared portion of the SDL area are thought to intercept groundwater (pers comms O. Farrington, July 2011), the proportion of reported S&D use of dams can be added to the estimate of groundwater take through S&D bores. From Figure 5-9, 20% of S&D water was reported as being sourced from dams or trenches in the QLD Border Rivers Fractured Rock area. Therefore 18% (i.e. 90% of 20%) has been added to the estimated take of 1,512 ML/year (Table 5-11), resulting in an overall estimate of 1,784 ML/year.

It is recognised that a significant discrepancy still exists between the estimate of 1,784 ML/year and the DERM estimate of 9,525 ML/year. The main sources of discrepancy arise from the uncertainty in the number of unregistered bores, uncertainty in groundwater take through non-traditional facilities (e.g. trenches) and the lack of information on the purpose of the groundwater take (i.e. for irrigation, S&D, etc.). The PB survey and methodology did not indicate the uncertainty in bore numbers expected by DERM in their assessment. This is due to the fact that properties (regardless of whether they had a registered bore or not) were not randomly selected across the SDL area. This appears to be particularly important in this SDL, as registration of bores has not been required in the past. The selection of properties without registered bores will be an important addition for this SDL in future surveys.

Further discrepancy may exist as a result of evaporation from storages (such as dams or trenches) not being taken into account (although this volume is likely to be small compared to the overall actual take from groundwater).

The results of the survey indicate reliance on groundwater for S&D purposes is low in the Queensland Border Rivers Fractured Rock; on average around 39% (Figure 5-9). However as discussed above, total groundwater use in this area is likely to be higher due to unregistered bores and extraction via facilities other than bores alone, such as dams or trenches. The reliance on groundwater for S&D uses is likely to be greater than 39%. A considerable proportion of water was reported to be sourced from storage tanks (42%), reflecting the significant rainfall received in the area.

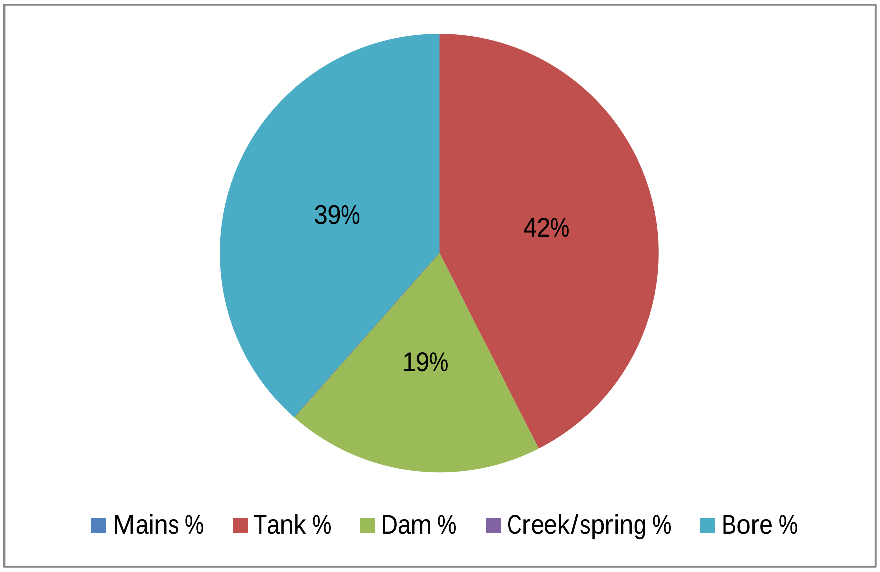


Figure 5-9 Reported use of S&D water sources in Queensland Border Rivers Fractured Rock

5.7.4 Conclusion

The current assessment estimates around 1,784 ML/year of groundwater is taken for S&D purposes in the QLD Border Rivers Fractured Rock area and this is likely to be an underestimate. The previous estimate by DERM (9,525 ML/year) takes into consideration unregistered bores and groundwater use from 'bore' sources (such as springs and trenches etc.).

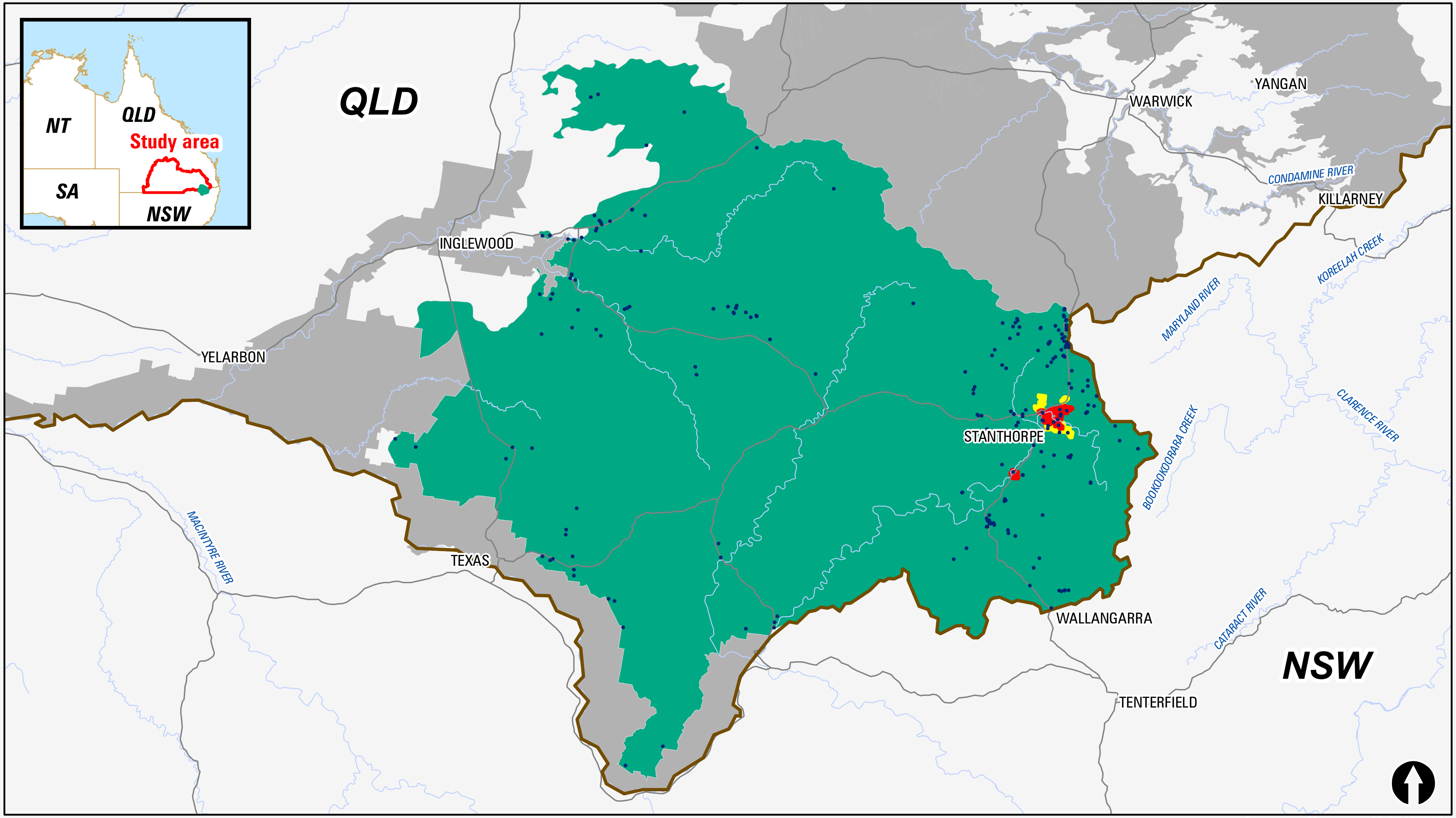
The uncertainty associated with the estimation of bore numbers and groundwater take in the QLD Border Rivers Fractured Rock may be reduced by carrying out further work, such as:

- A detailed assessment and registration of all bores in the SDL
- A study or assessment to determine a more accurate understanding of the of the number, distribution and type of groundwater interception facilities, such as dams and trenches, and an estimation of the volume of groundwater extracted via these facilities
- This SDL needs to be treated differently in future surveys. Future surveys need to tailor a method specifically for this SDL to ensure that a more accurate representation of S&D use can be obtained for this SDL.

PARSONS BRINCKERHOFF

ESTIMATION OF S&D GROUNDWATER TAKE IN QMDB

QLD DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT



\\APSYDNAS02\proj\D\Dept_Enviro_Resource_Mgt\2114790a_DERM_STOCK_AND_DOMESTIC_TAKE\10_GIS\Projects\ESRI\2114790A_GIS_F011_A2.mxd// SuansriR // 02/12/11

S&D Bore | Urban Area* | Queensland Border Rivers Fractured Rock

Major Road | Peri-urban Area*

Major River/Creek | Other SDL Areas

* All area outside of urban and peri-urban areas considered rural

0 10 20 KILOMETRES

Figure 5.10

QLD Border Rivers Fractured Rock SDL area S&D bores and land zones

5.8 Sediments above the Great Artesian Basin

The Sediments above the GAB SDL areas span a large area of the northern extent of the Murray Darling Basin, covering an area of some 75,000 km^2. The Moonie, Condamine-Balonne and Border Rivers sediments above the GAB lie in the central area of the QMDB, within the Goondiwindi Regional, Balonne Shire, Maranoa Regional and Western Downs Regional Councils. The Warrego-Paroo-Nebine Sediments above the GAB lie at the western extent of the QMDB, primarily within the Paroo and Murweh Shire Councils. Figure 5-12 shows the SDL area with S&D bores and land zones

The Moonie, Condamine-Balonne and Border Rivers Sediments above the GAB lie in a subtropical and grassland area, with persistent and distinctly dry summers (BOM, 2010). The aquifer units of these sediments may be summarised from CSIRO and SKM (2010):

- Sediments above the GAB (Moonie): alluvial, shallow and unconfined Tertiary sandstones
- Sediments above the GAB (Condamine-Balonne): Createaceous sandstone, siltstone and mudstone of the Griman Creek Formation, and
- Sediments above the GAB (Border Rivers): shallow Quaternary alluvium and undifferentiated Tertiary and Quaternary clastics.

The Warrego-Paroo-Nebine Sediments above the GAB lie within a grassland area that is persistently dry (BOM, 2010). This SDL area further west consists of shallow Quaternary and Tertiary sediments, comprised of a mix of fluvial, sheetwash and aeolian deposits (CSIRO and SKM, 2010).

Approximate bore yields reported by landholders during the survey ranged between 0.1 – 1.9 L/sec.

5.8.1 Responses

100% of the landholders on the contact list provided by DERM for the Sediments above the GAB areas were contacted by PB, with 21 (or 55%) of those landholders responding with information. These responses account for 8.3% of the total number of registered S&D bores in the SDL. Whilst this sample size may be reasonable given the low to moderate variability in reported groundwater S&D take across the combined SDL areas, an increased sample size would allow estimations of take for the individual SDL areas to be made.

Three fewer bores were reported to those contained in the DERM groundwater database. Nine additional bores were reported present and operational where the database contained no records, and 12 bores were reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 30 (reported) divided by 33 (listed) gives a database accuracy value of 0.909, indicating reasonable accuracy in the DERM database.

The survey results are summarised in Table 5-12.

Table 5-12 Sediments above the GAB survey responses

Total number of registered S&D bores in the SDL	363
Total number of landholders on DERM contact list provided	38
Total number of bores associated with those landholders on the DERM contact list	60
Number of landholders contacted by PB	38
Number of landholder responses gathered by PB	21
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	33
-Reported to PB in landholder responses	30
Database accuracy value	0.909

5.8.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Sediments above the GAB areas. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Queensland Border Rivers Fractured Rock SDL area is estimated at 1,053 ML/year. Table 5-13 provides a summary of the estimates for each land zone.

Table 5-13 Summary of estimated use within Sediments above the GAB

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/yr) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	0	*0.9**	1	1	1
Peri-Urban	0	*1.7**	5	9	8
Rural	30	3.218	357	1,149	1,044
Total – Sediments above the GAB					***1,053***

*There was not specific data from peri-urban or urban landholders in this SDL. Therefore, the average value for peri-urban and urban use estimated during this project has been used.

5.8.3 Discussion

There are four SDL areas within the Sediments above the GAB:

1. Moonie,
2. Border Rivers,
3. Condamine-Balonne, and
4. Warrego-Paroo-Nebine.

For the purposes of this project, the areas were combined into an overall SDL unit due to the total number of bores registered in the area and the small number of responses received during the survey for the individual SDL areas. This is considered a reasonable approach given that estimations of take by individual landholders did not vary considerably across the different SDL areas.

DERM (May 2011) estimated an average take of 1,692 ML/year for the combined Sediments above the GAB areas. The take in the PB assessment is reasonably similar, estimated to be 1,053 ML/year.

The DERM (May 2011) estimation of take from the combined Sediments above the GAB SDL areas was based on rural use of 4-5ML/year and urban use of 1.5-2ML/year. A reliability factor of 1.1 was used by DERM. The low adjustment factor reflects the higher degree of certainty and confidence in the DERM database records of S&D bores. The confidence is largely a result of western areas historically being licenced with owners providing drilling logs. A database accuracy of 0.909 was calculated and has been adopted in this assessment through the results of the survey, and this is comparable to the reliability factor of 1.1 used previously (DERM, 2011).

DERM (May 2011) identified two urban bores present in the combined Sediments above the GAB SDL areas. This study identified five bores in peri urban areas, and one in an urban area. Neither urban or peri urban users were selected within the survey undertaken. All 21 responses gathered from the Sediments above the GAB SDL areas were in rural areas, with use estimated to be on average 3.2ML/year per S&D bore. This average and overall estimate of groundwater S&D take is considered reasonably accurate given the reasonably good data set and similarity to the previous estimate, calculated through a separate method.

The results of the survey indicate reliance on groundwater for S&D purposes is high in the Sediments above the GAB; on average around 78% (Figure 5-11). Creeks/springs were the second most prevalent source of water for S&D purposes in the Sediments above the GAB, followed by dams. Tanks holding rainwater were the least prevalent source of water, reflective of the low rainfall area.

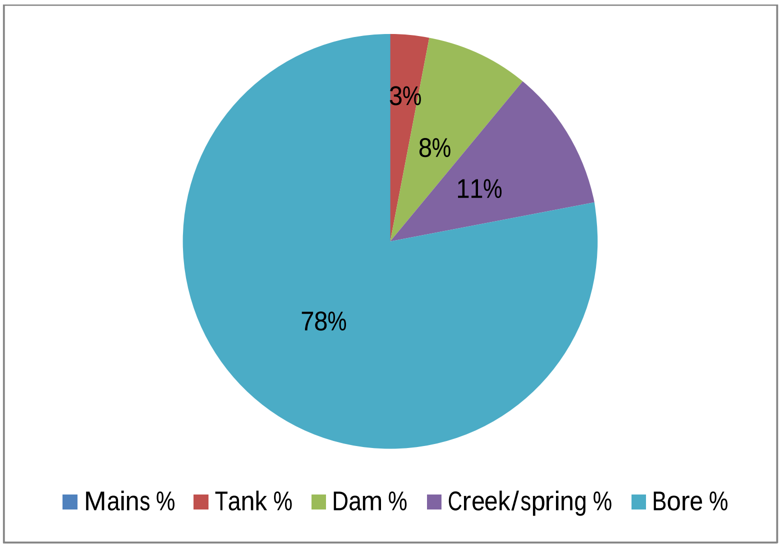


Figure 5-11 Reported use of S&D water sources in Sediments above the GAB

5.8.4 Conclusion

The overall estimate of S&D groundwater take from the Sediments above the GAB of 1,053 ML/year is considered to be reasonably accurate due to the calculated database accuracy of 0.909, the high sample size (8.3%), and the estimate being similar to the original DERM estimate of use. If refinement of this information into a volume estimate for each of the four independent SDL's within this area is required then additional survey may be undertaken.

Growth in peri urban use is expected to pose a low threat, as these SDL areas reside in predominantly rural areas of southern Queensland.

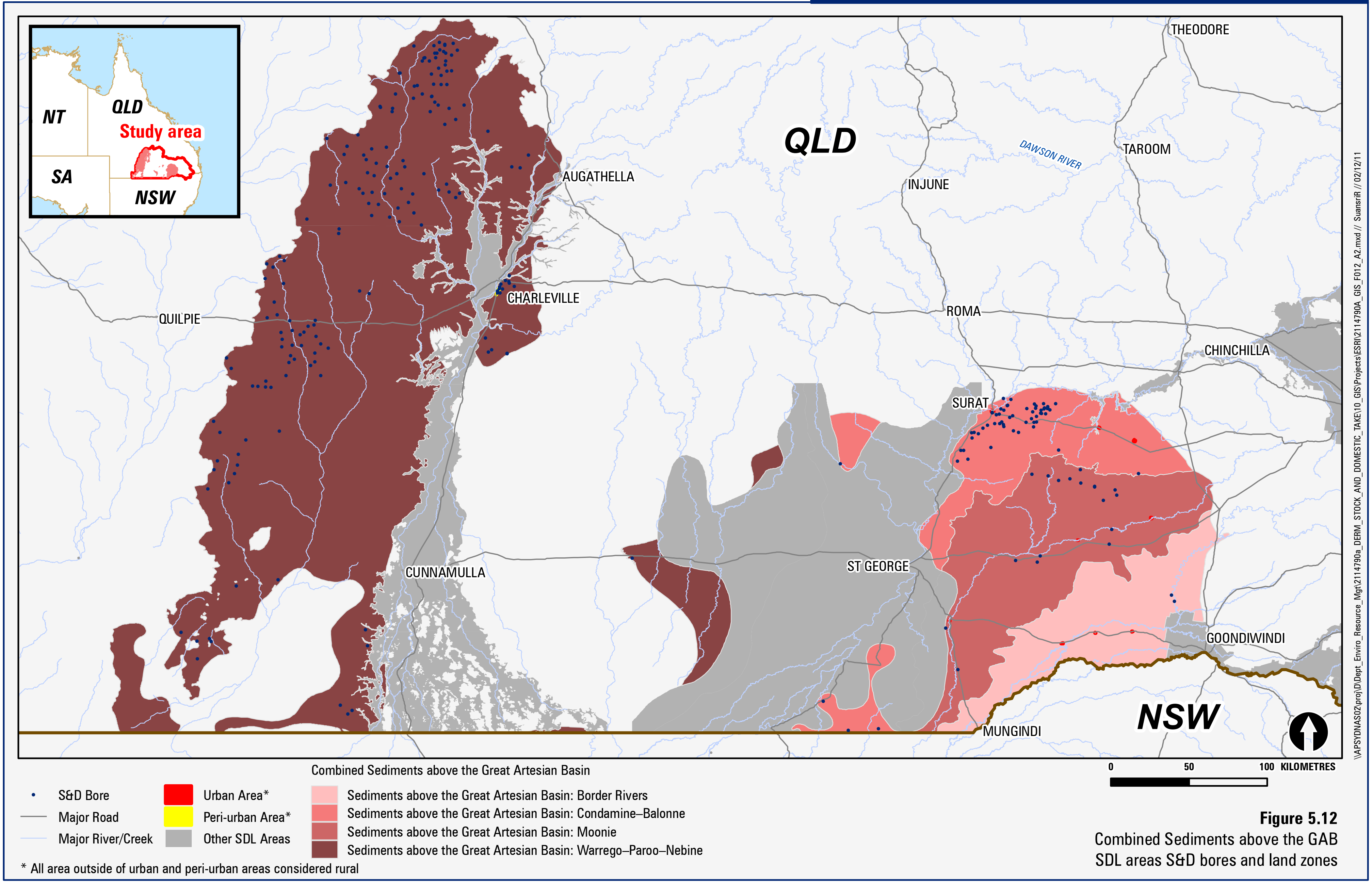


Figure 5.12
Combined Sediments above the GAB SDL areas S&D bores and land zones

5.9 St George Alluvium

The St George Alluvium SDL areas span a considerable area of the northern extent of the Murray Darling Basin, covering an area of around 26,300 km^2. The Moonie, Condamine-Balonne and Warrego-Paroo-Nebine St George Alluvium areas lie in the central area of the QMDB, within the Goondiwindi Regional, Balonne Shire, Maranoa Regional and Western Downs Regional Councils. Figure 5-14 shows the SDL area with S&D bores and land zones.

The Moonie, Condamine-Balonne and Warrego-Paroo-Nebine St George Alluvium SDL areas lie in a subtropical and grassland area, wet summers and low winter rainfall (BOM, 2010). These units are comprised of a shallow Quaternary aquifer, consisting of multiple unconsolidated fine to very coarse sand beds up to 4m thick, and a deeper unconsolidated aquifer consisting of coarse Tertiary sand beds and gravel layers (CSIRO and SKM, 2010). Approximate bore yields reported by landholders during the survey ranged between 0.3 – 1 L/sec.

5.9.1 Responses

11 (or 50%) of those landholders contacted by PB responded with information. These responses accounted for approximately 9% of the total number of registered bores in the SDL. This sample size is considered sufficient and particularly given the low to moderate variability in reported groundwater S&D take. However, an increased sample size including urban and peri urban users may yield a more complete picture of groundwater S&D take.

Five fewer bores were reported to those contained in the DERM groundwater database. Five additional bores were reported present and operational where the database contained no records, and 10 bores were reported not present where the database included them.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. 18 (reported) divided by 23 (listed) gives a database accuracy value of 0.783, indicating good alignment with the DERM database.

The survey results are summarised in Table 5-14.

Table 5-14 St George Alluvium survey responses

Total number of registered S&D bores in the SDL	197
Total number of landholders on DERM contact list provided	23
Total number of bores associated with those landholders on the DERM contact list	37
Number of landholders contacted by PB	22
Number of landholder responses gathered by PB	11
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	23
-Reported to PB in landholder responses	18
Database accuracy value	0.783

5.9.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the St George Alluvium area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Queensland Border Rivers Fractured Rock SDL area is estimated at 1,965ML/year. Table 5-15 provides a summary of the estimates for each land zone.

Table 5-15 Summary of estimated use within St George Alluvium

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/year) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	0	*0.9**	1	1	1
Peri-Urban	0	*1.7**	5	9	7
Rural	18	5.150	191	984	770
Total – St George Alluvium					***778***

*There was not specific data from peri-urban or urban landholders in this SDL. Therefore, the average value for peri-urban and urban use estimated during this project has been used.

5.9.3 Discussion

There are three SDL areas within the St George Alluvium:

1. Moonie,
2. Condamine-Balonne, and
3. Warrego-Paroo-Nebine.

For the purposes of this project, the areas were combined into an overall SDL unit due to the small number of registered bores and responses received during the survey for the individual SDL areas. This is considered a reasonable approach given that estimations of take by individual landholders did not vary considerably across the different SDL areas.

DERM (May 2011) estimated an average take of 891 ML/year for the combined St George Alluvium SDL areas which is less than the PB estimate of 778 ML/year

The DERM (May 2011) estimation of take from the combined St George Alluvium SDL areas was based on rural use of 4-5 ML/year and urban use of 2 ML/year, similar to the Sediments above the GAB areas. The PB assessment of use per rural bore of 5.150 ML/year is similar to the DERM (May 2011) estimate of rural use. A reliability factor of 1.1 was used by DERM. The low adjustment factor reflects the higher degree of certainty and confidence in the DERM database records of S&D bores. The confidence is largely a result of western areas historically being licenced with owners providing drilling logs. A database accuracy value of 0.783 was calculated and has been adopted in this assessment through the results of the survey, and this is comparable to the factor of 1.1 used previously.

DERM (2011) identified only four urban bores present in the St George Alluvium SDL areas. Refinement of their estimates identified three bores in urban areas, and 10 in peri urban areas. Nevertheless neither urban or peri urban users were picked up within the landholder survey undertaken by PB. All 18 responses gathered from the St George Alluvium SDL areas were in rural areas, with use estimated to be on average 5.150 ML/year per S&D bore. Further survey may be carried out to provide estimates for use per bore in the urban and peri urban areas of the St George Alluvium, but would not impact the result greatly due to the relatively small number of bores in peri-urban areas compared to rural.

The results of the survey indicate moderate reliance on groundwater for S&D purposes in the St George Alluvium; on average around 47% (Figure 5-13). This level of reliance is likely a product of the low bore yields reported by landholders surveyed. Stored water sourced from rainwater tanks were the second most prevalent source of water for S&D purposes in the St George Alluvium, followed by dams. Creeks/springs were the least prevalent source of water, reflecting the dry landscape of the area.

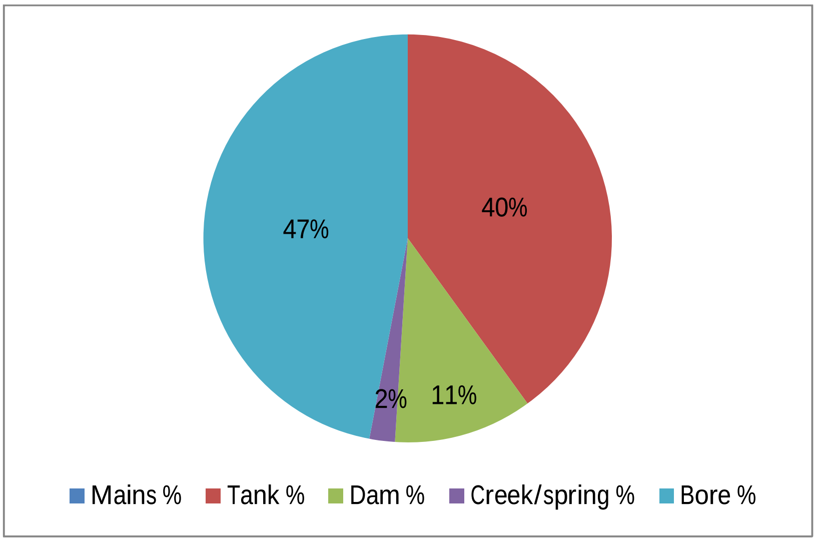


Figure 5-13 Reported use of S&D water sources in St George Alluvium

5.9.4 Conclusion

The overall estimate of S&D groundwater take from the St George Alluvium of 778 ML/year is considered to be reasonably accurate based on the sample size of 9%. The small number of respondents from this SDL should be noted, even though they formed a 9% sample size which is considered to be a relatively high percentage sample size. Further survey of the St George Alluvium, particularly the rural areas, may be carried out to refine this estimate.

Growth in peri urban use would pose a low threat, as these SDL areas reside in predominantly rural areas of southern Queensland. Further survey may be carried out to estimate use per bore in peri urban (and urban) areas but this would not significantly impact the overall estimated usage number. Volume estimates for the three SDL's within this area can be undertaken with additional survey if considered required.

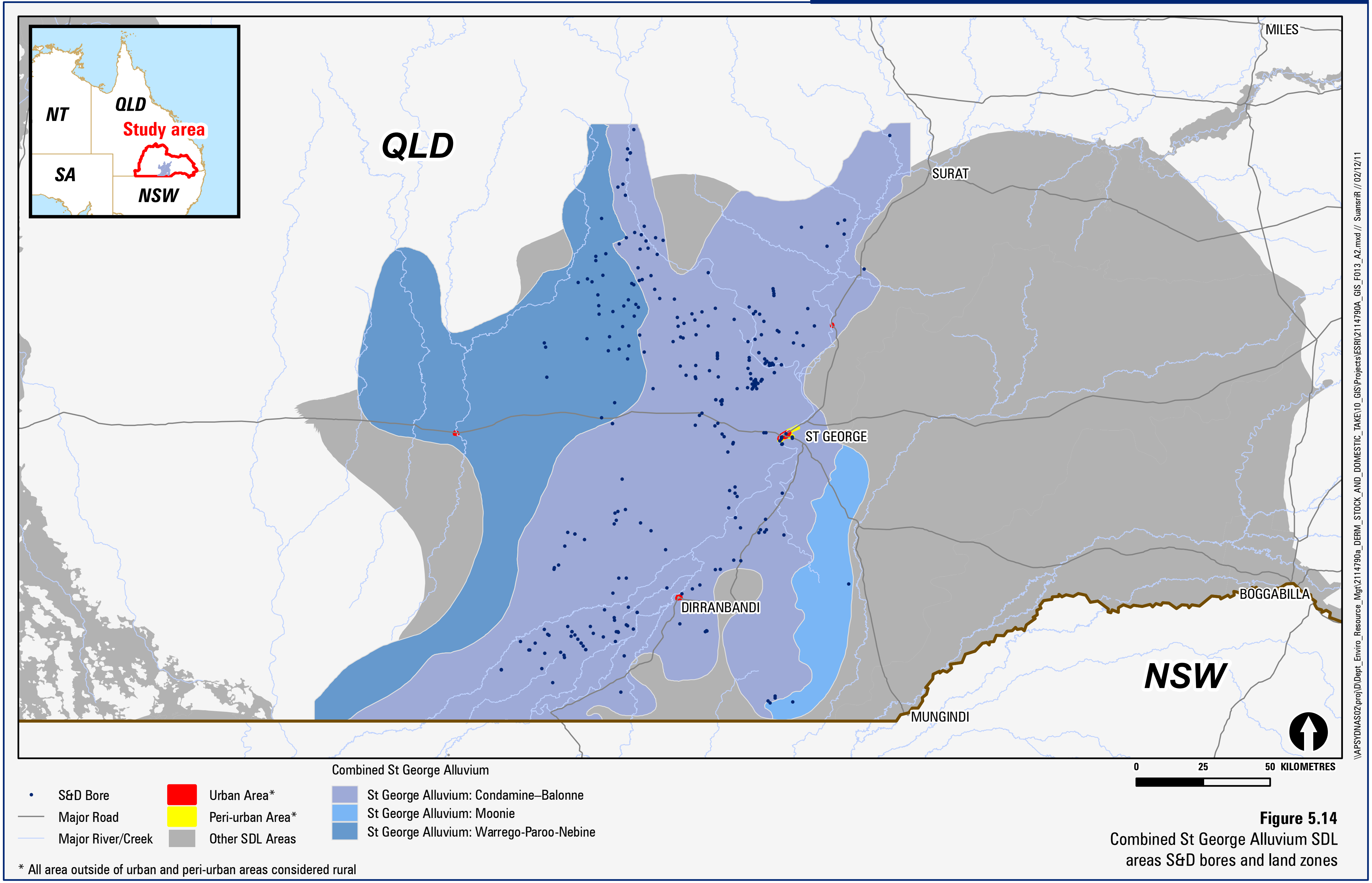


Figure 5.14
Combined St George Alluvium SDL areas S&D bores and land zones

5.10 Warrego Alluvium

The Warrego Alluvium SDL area lies in the north-western portion of the Murray Darling Basin, covering an area of around 11,300 km^2. The Warrego Alluvium lies wholly within the Murweh and Paroo Shires. Figure 5-16 shows the SDL area with S&D bores and land zones.

The Bureau of Meteorology describes the Warrego Alluvium part of QLD as a grassland area with persistently hot and dry summers (BOM, 2010). The Warrego Alluvium is comprised alluvial sediments associated with the Warrego River (CSIRO and SKM, 2010). The typical hydraulic conductivity of alluvial sediments is approximately 1 – 10^3 m/day (Driscoll, 1986). Approximate bore yields were unknown by most landholders surveyed in the Warrego Alluvium. However two landholders reported average bore yields of around 4L/sec and 11L/sec.

5.10.1 Responses

7 (or 44%) of those landholders contacted by PB responded with the required information. These responses accounted for approximately 8.6% of the total number of registered bores within the SDL area. Despite the (relatively) large sample size, variability in reported groundwater S&D take was high in this SDL area. Therefore a larger sample size may yield a more accurate estimation of groundwater S&D take across the area.

In total, two fewer bores were reported to those contained in the DERM groundwater database.

The database accuracy was calculated by taking the ratio of the number of bores reported compared to the DERM groundwater database for those who responded, i.e. seven (reported) divided by nine (listed) gives a database accuracy value of 0.778, indicating good alignment with the DERM database.

The survey results are summarised in Table 5-16.

Table 5-16 Warrego Alluvium survey responses

Total number of registered S&D bores in the SDL	81
Total number of landholders on DERM contact list provided	16
Total number of bores associated with those landholders on the DERM contact list	21
Number of landholders contacted by PB	16
Number of landholder responses gathered by PB	7
Of those landholders who responded, the total number of bores;	
-Currently listed on DERM groundwater database	9
-Reported to PB in landholder responses	7
Database accuracy value	0.778

5.10.2 Volume estimation

The information gathered from the survey responses was analysed and used to estimate the average volume extracted for each bore within the urban, peri urban and rural areas of the Warrego Alluvium area. These averages were then multiplied by the number of bores within each land zone and then multiplied by the database accuracy value to obtain the estimated annual average use within the SDL area.

The average take of groundwater for S&D purposes in the Warrego Alluvium SDL area is estimated at 468ML/year. Table 5-17 provides a summary of the estimates for each of the land zones.

Table 5-17 Summary of estimated use within Warrego Alluvium

Land zone	Number of bores with responses	Estimated average use of bores with responses (ML/year)	Total number of bores in SDL	Number of bores multiplied by estimated average use (ML/year)	Estimated Total groundwater use (ML/year) *(i.e. estimated average use multiplied by the database accuracy value)*
Urban	2	3.915	13	51	40
Peri-Urban	3	2.983	40	119	93
Rural	2	15.382	28	431	335
Total – Warrego Alluvium					***468***

5.10.3 Discussion

The average take of groundwater for S&D purposes in the Warrego Alluvium SDL area is estimated at 468ML/year (Table 5-17) which is very similar to the original DERM estimate of 403ML/year (DERM, 2011).

The PB assessment of use per rural bore is 15.4ML/year. This is significantly higher than the DERM (May 2011) estimate of rural use being 5 ML/year per bore. Use per bore for urban and peri urban areas in the PB assessment were estimated to be 3.9ML/year and 3ML/year respectively. The DERM (2011) estimate was based on a lower assessment of urban use of 2ML/year per bore. The small number of respondents from this SDL should be noted, even though they formed an 8.6% sample size which is considered to be a relatively high percentage sample size. Further survey of the Warrego Alluvium, particularly the rural areas, may be carried out to refine this estimate.

DERM (May 2011) used a reliability factor of 1.1. The low adjustment factor reflects the higher degree of certainty and confidence in the DERM database records of S&D bores. The confidence is largely a result of western areas historically being licenced with owners providing drilling logs. A database accuracy value of 0.778 was calculated and has been adopted in this assessment based on the results of the survey.

The results of the survey indicate very high reliance on groundwater for S&D purposes in the Warrego Alluvium; on average around 97% (Figure 5-15). The minor proportions of water sourced from tanks and mains, and negligible proportions sourced from dams and creeks/springs, reflect the dry landscape of the area and low use of dams due to high evaporation and the poor dam holding capacity of the alluvial soils.

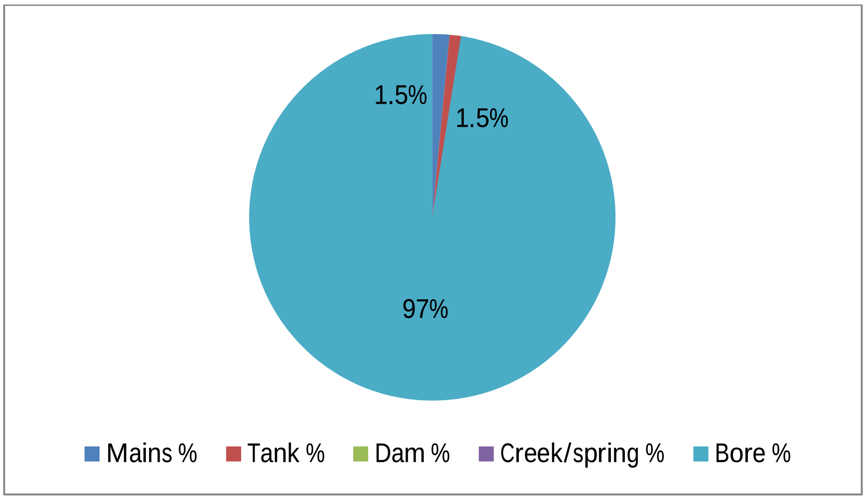


Figure 5-15 Reported use of S&D water sources in Warrego Alluvium

5.10.4 Conclusion

The current assessment estimates S&D groundwater take from the Warrego Alluvium to be 468 ML/year which is very similar to the original DERM estimate. The revised figure is based on an assessment of unit use per bore considerably higher than that estimated by DERM. The sample size of 8.6% is considered good, the actual number of bores surveyed is considered relatively small.

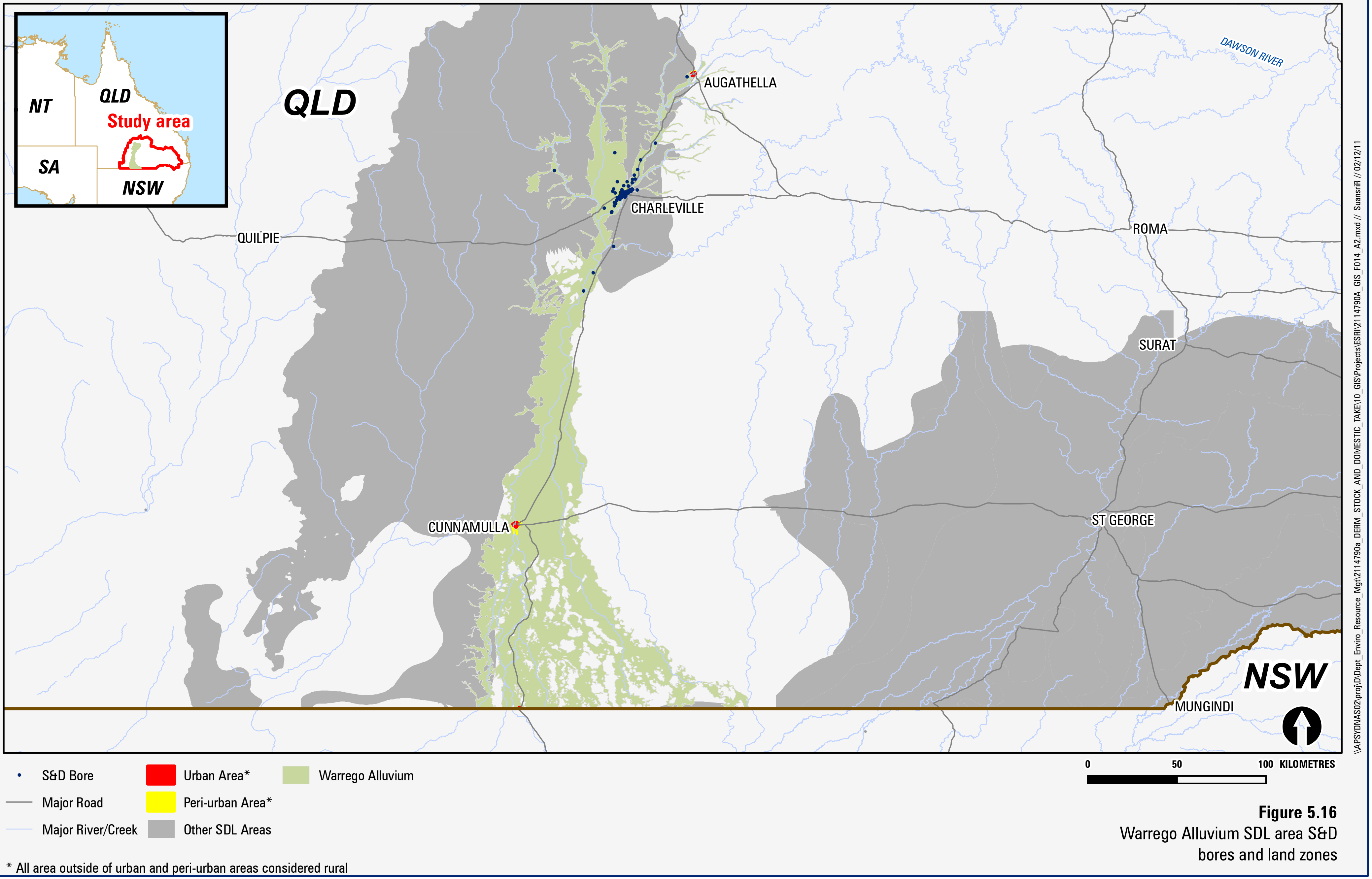


Figure 5.16
Warrego Alluvium SDL area S&D bores and land zones

6. Summary of SDL estimates

The groundwater take for S&D purposes in the QMDB SDL areas estimated from information obtained through the landholder survey is summarised in Table 6-1. Table 6-1 also compares the PB estimate with the DERM estimate for each SDL area which is also graphically represented in Figure 6-1.

Table 6-1 Summary of groundwater S&D estimates for each SDL area

SDL area	DERM Estimate (ML/year)	**PB Estimate (ML/year)**	**PB Estimate as a percentage of DERM Estimate**
Condamine Fractured Rock	664	**174**	**26%**
Upper Condamine Alluvium	9,546	**3,192**	**33%**
Upper Condamine Basalts	17,861	**14,670**	**82%**
Qld Border Rivers Alluvium	1,442	**443**	**31%**
Qld Border Rivers Fractured Rock	9,525	**1,784**	**19%**
Sediments above the GAB – Border Rivers Sediments above the GAB – Condamine-Balonne Sediments above the GAB – Moonie Sediments above the GAB – Warrego-Paroo-Nebine	1,692	**1,053**	**62%**
St George Alluvium – Condamine-Balonne St George Alluvium – Moonie St George Alluvium – Warrego-Paroo-Nebine	891	**778**	**87%**
Warrego Alluvium	403	**468**	**116%**

The results of the study indicate that historically the use of S&D was over-estimated in eastern areas and under-estimated in western areas. The trend in increasing use from east to west picked up in the current assessment can be attributed to the greater than anticipated impact that the climatic gradation had on groundwater usage for S&D purposes. The trend in increasing (overall) use from east to west is underpinned by a trend of increasing average use per bore from east to west, and not necessarily an increase in the number or density of bores. This is illustrated in Figure 6-2. Land use in the QMDB changes from more urbanised, smaller properties in the east, to larger rural properties further west.

The estimated take per bore for rural, urban and peri urban areas are illustrated in Figure 6-3. The chart shows the occurrence of urban and peri urban extraction observed in the alluvial and basalt areas of the QMDB.

The DERM (May 2011) study was based on a revision of bore numbers derived by SKM in 2009. Since this time DERM have further interrogated the groundwater database to remove non-S&D bores and bores not in the QMDB (for example removing bores within the GAB). The number of S&D bores used for this assessment is based on the groundwater database refined by DERM.

PARSONS BRINCKERHOFF

ESTIMATION ON S&D GROUNDWATER TAKE IN QMDB

QLD DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT

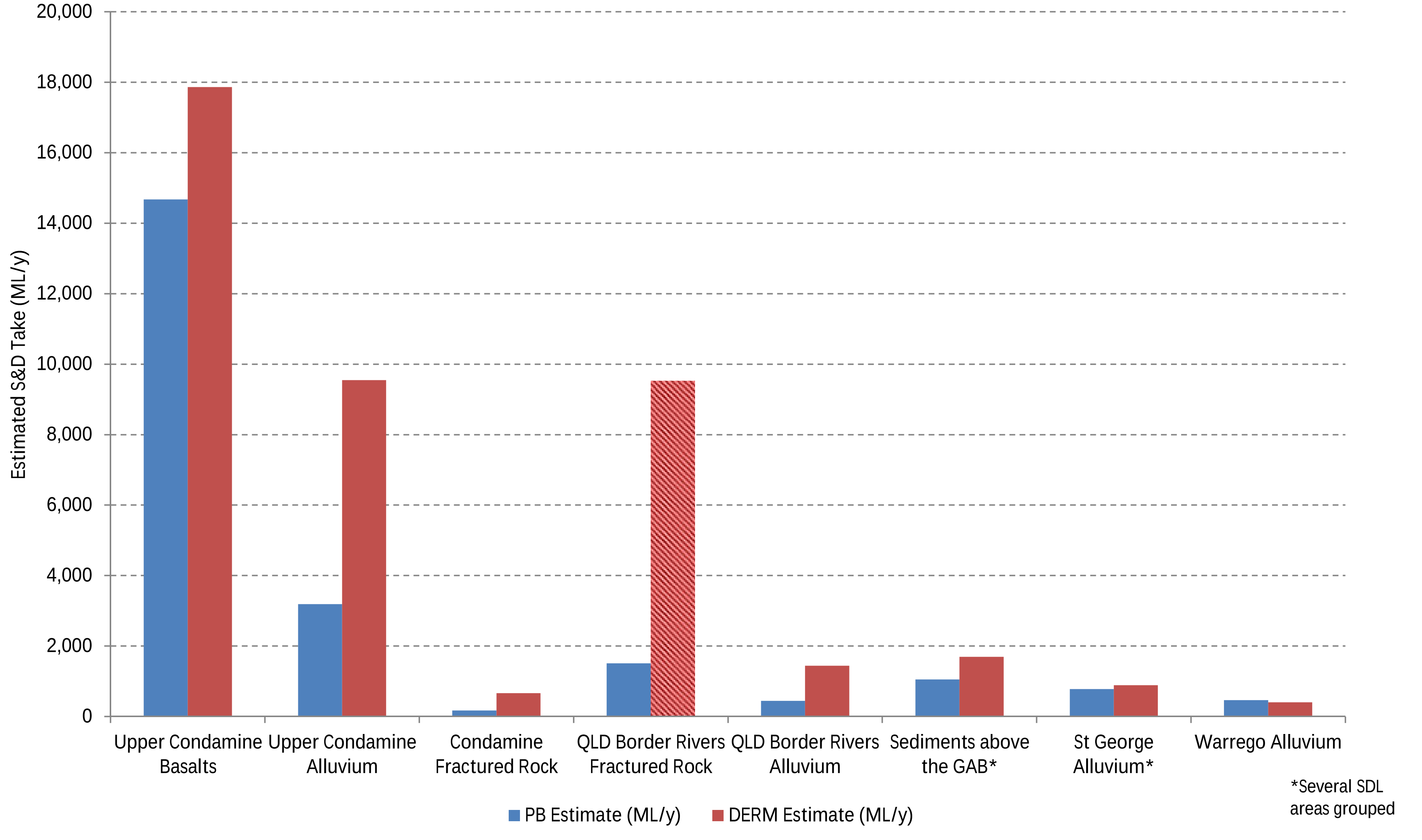
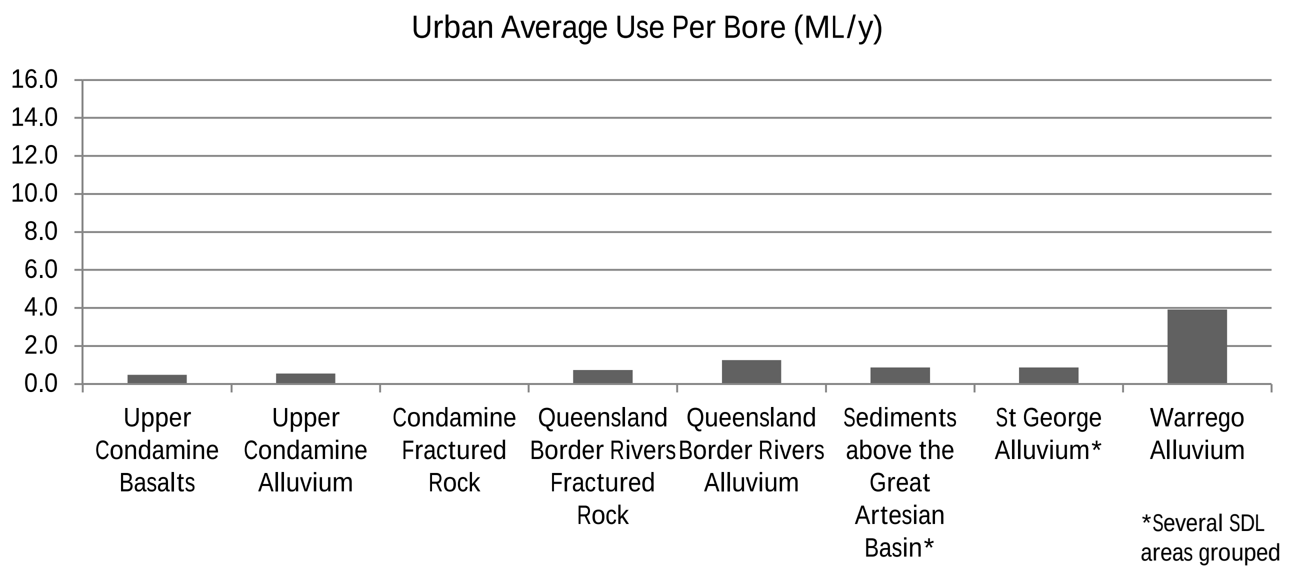
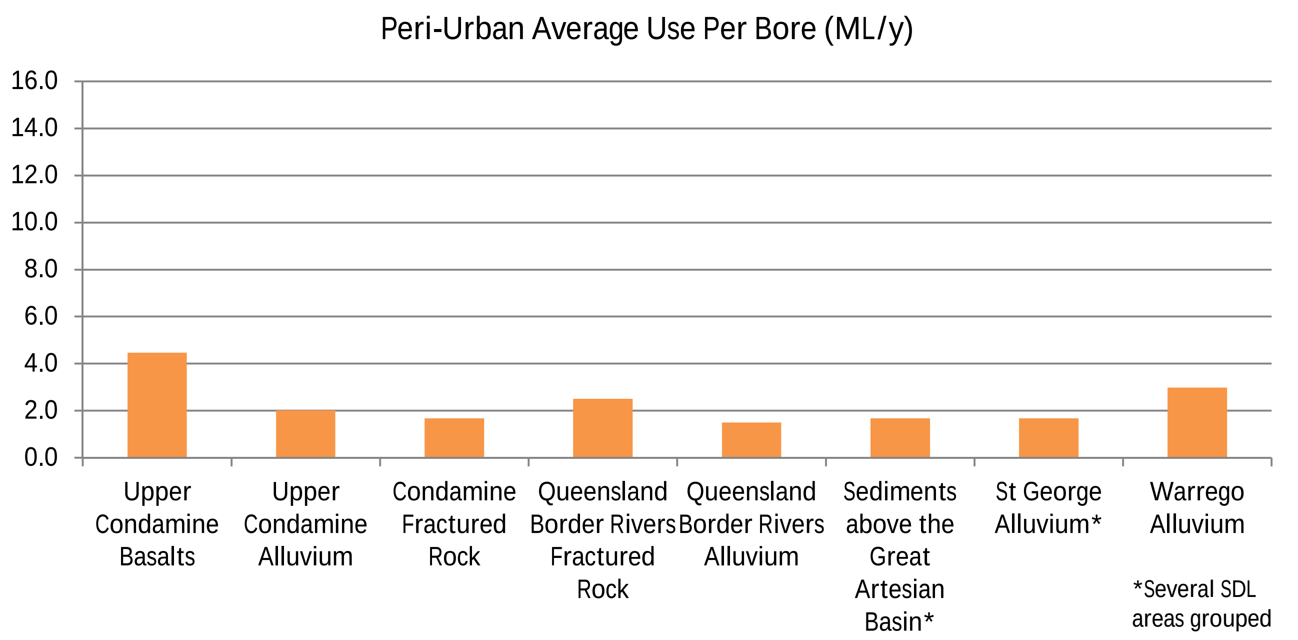


Figure 6.1 Comparison of S&D estimates





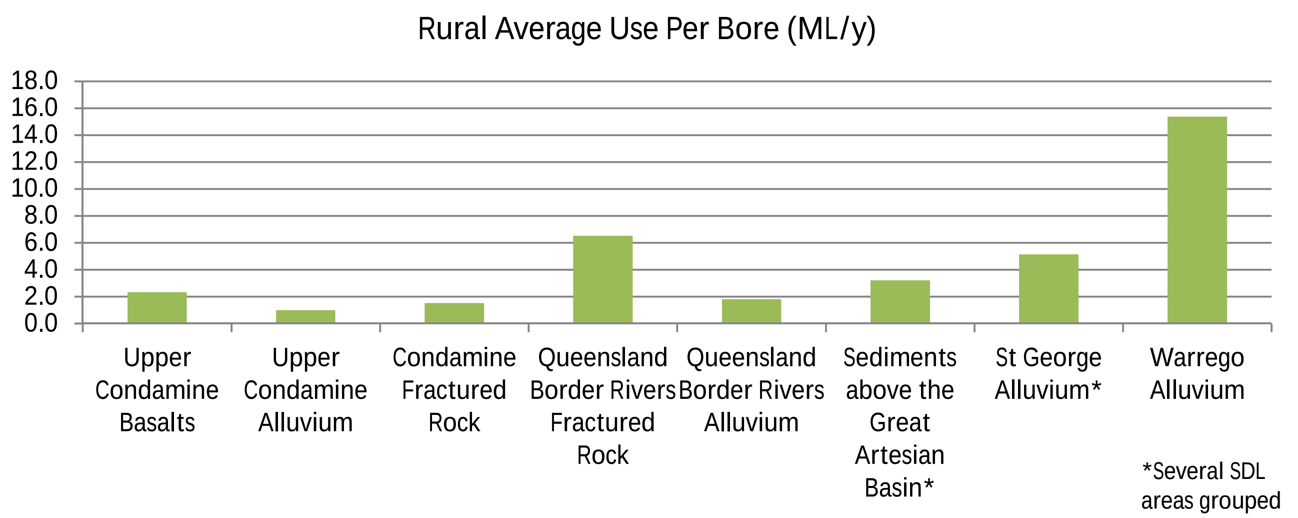


Figure 6-2 Average Use Per Bore

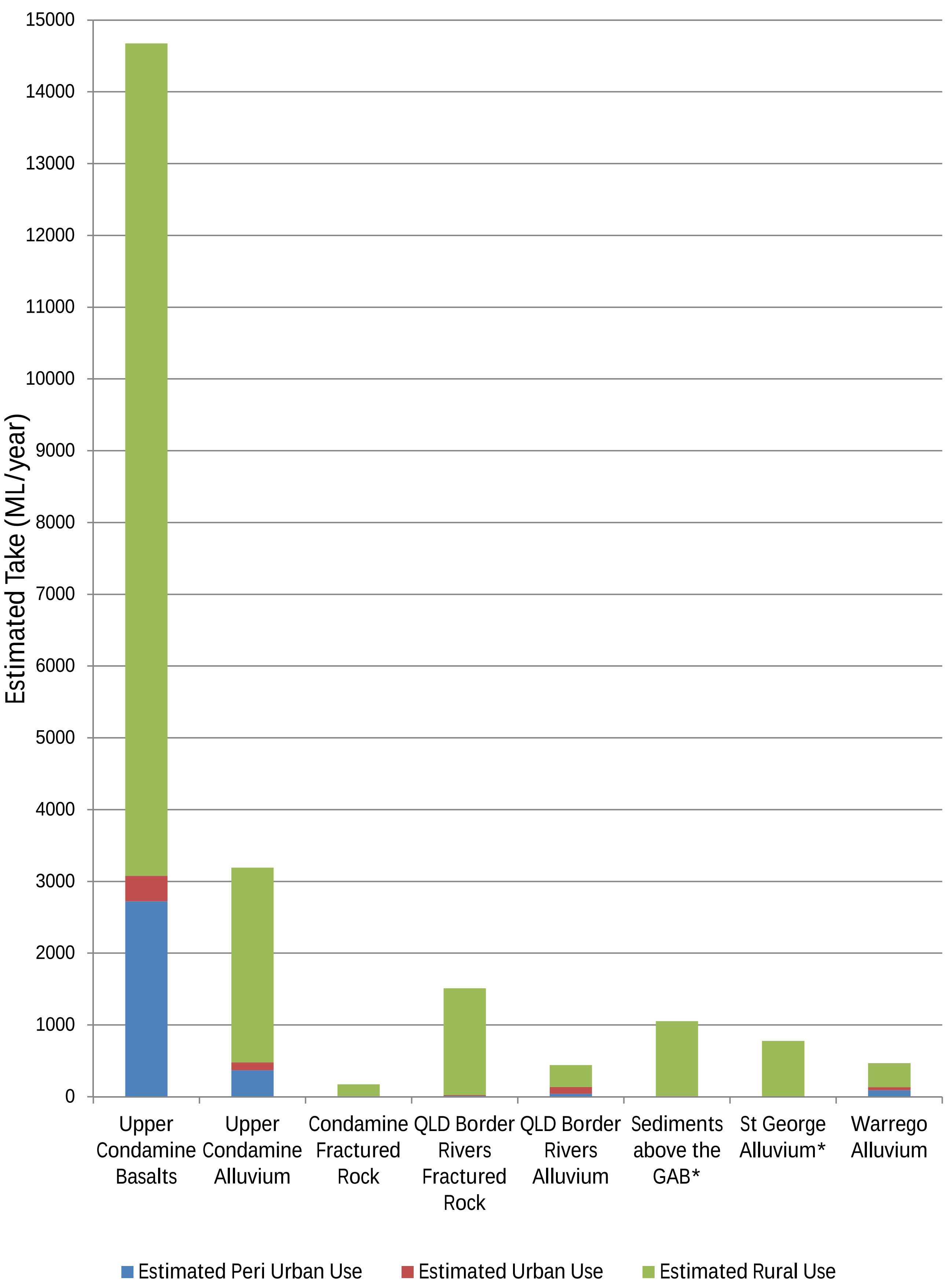


Figure 6-3 Estimated groundwater S&D take

7. Limitations of approach and results

The method implemented in this assessment contains some uncertainties as outlined below. These should be considered when applying the conclusions of this project. These include;

1. The survey undertaken to obtain estimations of S&D use in the QMDB focused on the set of registered or 'known' bores. The survey undertaken did not randomly survey landholders without a registered bore. Therefore the prevalence of unregistered S&D bores was not really addressed in this survey. However, it is thought that landholders with one registered bore are also more likely to have all bores registered. Therefore the database accuracy numbers calculated in this report are likely to be optimistic with respect to the overall accuracy of the database compared to actual bores on the ground.

   Including random surveys of landholders without registered bores in future should be considered, as it would provide a more robust approach to the definition of the database accuracy factor.

2. The database accuracy factor was a method developed and implemented in this study and was the ratio between bore numbers contained within the DERM database and those reported by landholders. This provided a measure of confidence in the actual number of bores within each SDL area. The database accuracy factor does not attempt to assess all areas of uncertainty in the use of groundwater for S&D taken in each SDL area – it only addresses the actual number of bores on the ground. This differs from the past DERM survey which used 'reliability factors' (DERM 2011) which included an assessment of bore numbers, as well as factors such as water source definition (i.e. accounting for spring fed dams). Refinement of the estimates calculated in this study for some SDL's (such as the QLD Border Rivers Fractured Rock SDL) may be carried out by DERM using the same or similar reliability factors to take account of uncertainties more broadly.

3. The selected survey data (list of landholders) provided to PB was focused toward rural areas and then on some urban areas, with bores selected by DERM randomly, yet with emphasis on clearly rural and clearly urban areas (pers comms, O. Farrington, September 2011). Thus peri urban bores were not actively targeted in the survey. As a result of this the sample sizes in peri urban areas was relatively small in most SDL's. However, the small area of peri-urban areas compared to rural means that the overall volume estimation is relatively accurate, but for future assessment of growth in use obtaining survey data from within the peri-urban areas is important. The targeted survey of peri urban areas, in conjunction with the improvement of peri urban definition (see point 4 below) would address this uncertainty in future surveys.

4. Potential changes to land use over time may provide a basis for change in the volume extracted, for example rural areas on the fringe of urban centres often transition to become peri urban with continued population growth. A limitation of this study is the definition and delineation of these peri urban areas. As discussed in Section 3.1.1, urban and peri urban areas were defined through a combination of aerial photography, lot size information and council planning maps. A more refined method would improve the robustness and repeatability of this overall project to estimate groundwater S&D take.

5. There is some uncertainty in the approximation of use by landholders. Rural landholders are generally quite aware of the volumes of water used on their properties, and a survey of these landholders as carried out in this project is considered a highly effective way to estimate use. Landholders in urban and peri urban areas generally don't need to

estimate total water use and therefore have difficulty when asked to estimate their use. For example, urban landholders often do not need to have a good understanding of the volume of water they use on their gardens, especially when the water is obtained from an unmetered source. The survey questions were designed to minimise this uncertainty. However, there are potential inaccuracies that remain. The method presented in this study is considered to provide a reasonable reflection of urban S&D use.

6. Use of groundwater for S&D purposes by landholders changes from year to year and particularly between dryer than average or wetter than average years. It is worth noting that the survey was undertaken during a period of relatively wet climatic conditions, and followed major flooding throughout Qld. A similar survey carried out under different climatic conditions (i.e. following a series of very dry years) may produce different results. This uncertainty was addressed to some extent by requesting landholders to differentiate between the volumes used and sources of water during wet and dry conditions. The maximum water use (under dry conditions) was used in the estimation of groundwater take in this assessment.

7. The focus of this study was to identify a method to estimate the take of groundwater for stock and domestic purposes in the Queensland Murray Darling Basin. The secondary focus was to implement the developed method and estimate the take. The project has resulted in a new and extensive dataset that would benefit from a more detailed statistical analysis to enhance the statistical validity of the report and project results.

8. Annual reporting of stock and domestic groundwater use to the MDBA

Under Section 71 of the *Water Act 2007 (Cth)* DERM are required to provide annual reports to the MDBA showing compliance with the long term SDLs for the groundwater SDL areas of the QMDB. The annual reports must include the volume of water available in the water resource area, the volume of water permitted to be taken, the volume actually taken and other details. The volume taken includes water for S&D purposes.

The assessment of S&D use undertaken in this project provides DERM information that can be provided directly to the MDBA to meet annual reporting requirements for this current year. Growth in use of groundwater for S&D needs to be considered on an annual basis to ensure ongoing take of S&D groundwater is considered to ensure compliance with long term SDLs.

A risk based approach is recommended for the annual accounting of groundwater take for S&D purposes. The risk based approach is recommended in part due to the relatively small volume of water taken for S&D use (in comparison to other purposes such as irrigation, mining, or town water supply) and also due to the likely relative stable take of water across most the Murray Darling Basin area that is used for rural or for urban S&D use. The 2011 report by O'Keefe et al also recommends a risk based approach to the management of groundwater taken for S&D purposes to allow areas of likely significant impact to be targeted.

The main driver for the long term growth in use of groundwater for S&D purposes is land use changes to areas of more intensive use of groundwater for these purposes such as the conversion of rural land to peri urban. Taking a risk based approach to the annual estimation of use for S&D purposes would mean that the peri urban areas of the QMDB would need to be defined and targeted for an annual or bi-annual assessment. The actual volumetric use from these areas is likely to be similar per landholding/bore over time, but the actual area of land categories as peri urban is likely to change or increase in size over time. Therefore the critical factor in reporting growth in use will be re-assessing the actual area of land classified as peri urban.

On an annual basis short term changes to the use of groundwater taken for S&D purposes is likely to be climatic conditions. Repeating the survey methodology in different climatic conditions, (or targeting questions in future surveys to try and account for recent climatic conditions) would be recommended.

The registration of existing bores, or newly constructed bores and having these entered into the DERM database is of critical importance for ongoing estimation of S&D groundwater take. The maintenance of the database system over time is a key step in being able to provide reliable and accurate information of the estimation of S&D water take. Strategies to ensure compliance with Queensland government policies in this regard are therefore important in meeting the MDBA reporting requirements.

9. Conclusions

A methodology to estimate the existing take of groundwater for S&D purposes in the QMDB has been developed and implemented. Using this method, the take of groundwater for S&D purposes has been estimated for each SDL within the QMDB, and is summarised in Table 6-1. The main conclusions that may be drawn from the project are:

- The methodology developed and applied by DERM (May 2011) provided a more accurate estimation of groundwater take for S&D purposes in the QMDB than previous methods. The PB study focused on those areas where obvious improvements could be made in the methodology, and included: the assessment of uncertainty in the number of bores in each SDL area, the estimation of use per S&D bore, and the consideration of peri urban use along with urban and rural use. These areas were the focus of the PB study, and were addressed largely through the landholder survey.

- A variety of methods are used throughout Australia and internationally to estimate S&D (or unmetered) take. However these methods are generally either too broad to accurately estimate take in the QMDB or too detailed to be applied to the QMDB area.

- The landholder survey undertaken in this study was a very effective approach to estimate the take of groundwater for S&D purposes in the QMDB. The survey gathered information on use directly from the source (landholders) and was targeted towards users across the whole QMDB.

- PB contacted 249 landholders across the QMDB via telephone to participate in the survey. The response to the survey was good with approximately 50% of those landholders contacted supplying the information required to apply the methodology for the estimation of the S&D groundwater take within each of the SDL areas. The responses related to 148 bores which accounted for 1.6% of the total number of registered bores within the QMDB.

- Responses from five SDL areas indicate 50% or more of total water use is derived through S&D groundwater,

- A trend of increasing rural use per bore is observed from east to west across the QMDB.

- The volumes of take estimated through this project suggest DERMs earlier estimates over-estimated take in the eastern SDL areas and under-estimated take in the western SDL areas. A greater range in take across the QMDB was observed in this project.

- The number of peri urban bores and estimated take from these bores in the QMDB is considerable compared to previous estimates for the QMDB that have not included peri urban areas separate from urban and rural areas.

- Several limitations are inherent in the methodology developed and applied in this project. These include bias toward the ‘known’ S&D bores in the QMDB, and potential change in average use over time due to changing climatic conditions and land use change. Despite these limitations, the method developed and implemented in this study provides a more thorough understanding of S&D groundwater take in each SDL area.

- The method developed and implemented in this study used the ratio between bore numbers contained within the DERM database and those reported by landholders as a measure of uncertainty of the actual number of bores within each SDL area. It does not attempt to assess all areas of uncertainty in the use of groundwater for S&D taken in each SDL area, included as 'reliability factors' in DERM (2011). Refinement of the estimates calculated in this study may be carried out by DERM using the same or similar reliability factors to take account of uncertainties more broadly.

- The focus of this study was to identify a method to estimate the take of groundwater for stock and domestic purposes in the Queensland Murray Darling Basin. The secondary focus was to implement the developed method and estimate the take. A new and extensive dataset has resulted from the project. This dataset would benefit from a more detailed analysis to enhance the statistical validity of the report and project results. Using a statistical package would generate results and statistics that would guide the prioritisation of groundwater SDLs.

10. Recommendations

In light of the information gathered during the project, key recommendations for future work include:

- Further survey of SDL areas where considerable growth in peri urban areas is expected and/or observed. From this project the Upper Condamine Alluvium, Upper Condamine Basalts and Qld Border Rivers Alluvium were observed to contain peri urban bores with significant average take compared to rural bores, generally thought to take larger volumes per bore.

- Further survey and investigation of the Qld Border Rivers Fractured Rock SDL area to gain a better understanding of the true number of bores, the extent and distribution of groundwater interception activities such as dams and trenches, the volume of groundwater taken and how the water is used.

- Further survey of the Sediments above the GAB to be able to estimate groundwater S&D take on an individual SDL basis.

- Further survey of the St George and Warrego Alluvium areas to reduce or better understand the variability in groundwater take for S&D purposes across these SDL areas.

- Further survey of all SDL areas under both wet and dry climatic conditions to improve the robustness of the estimation and allow further understanding of the change in use due to climatic conditions.

- Improvement to the method to delineate peri urban areas. A more refined and repeatable method would improve the robustness of and reduce uncertainty in the method in estimating groundwater S&D take.

- Development of a mechanism within the Queensland legislative/policy framework to appreciate the number of existing, operational S&D bores that are not registered within the QMDB.

- Refinement of the estimates calculated in this study may be carried out by DERM using local knowledge of the range of uncertainties particular to each SDL area that are not accounted for in this method, such as knowledge of unregistered S&D bores or use of S&D groundwater through irrigation bores.

- Assessment of the significance of S&D groundwater take in comparison to the overall take from each SDL area, to help inform a pragmatic approach to future management arrangements. For example for those SDL areas where groundwater S&D take is estimated to be only a small percentage of the total take may be considered a lower priority for assessment, compared to those areas that may require a higher level of management.

- Conduct a more detailed statistical analysis of the dataset to enhance the statistical validity of the report and project results. Using a statistical package would generate results and statistics that would guide the prioritisation of groundwater SDLs.

11. References

Bureau of Meteorology, 2010, Climate Classification of Australia, available at: http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp?maptype=kpngrp. Accessed 14/7/2011.

Bureau of Meteorology, 2011, About the National Water Account, available at: http://www.bom.gov.au/water/nwa/. Accessed 18/7/2011.

Brisbane City Council, 2000, Average Domestic Water Usage Chart, available at: http://www.thisplace.com.au/eco/tt_waterusage.htm. Accessed 22/6/2011.

Burton, J, 1965, Water storage on the farm, Bulletin 9, Volume 1, Water Research Foundation of Australia.

CSIRO and SKM, 2010, Sustainable extraction limits derived from the Recharge Risk Assessment Method – Queensland, CSIRO: Water for a Healthy Country National Research Flagship, 77pp.

Driscoll, F.G, 1986, Groundwater and Wells- Second Edition, Johnson Screens, St Paul Minnesota, USA.

Environment Waikato, 2007, Model for assessing the magnitude of unconsented surface water use in the Waikato Region. Document number 1219787. http://www.waikatoregion.govt.nz/Publications/Technical-Reports/A-Model-for-Assessing-the-Magnitude-of-Unconsented-Surface-Water-Use-in-the-Waikato-Region/

Jacobson, G and Lau, J.E, 1987, Hydrogeology of Australia 1:5 000 000 scale map. Bureau of Mineral Resources, Canberra.

Lowe, L, Vardon, M, Etchells, T, Malano, H and Nathan, R, 2009, Estimating unmetered stock and domestic water use, 18th World IMACS/MODSIM Congress, Cairns, Australia.

Moench, M, Burke, J, and Moench, Y, 2003, Rethinking the approach to groundwater and food security, prepared for the Food and Agriculture Organisation of the United Nations, in collaboration with the Institute for Social and Environmental Transition, USA.

Murray Darling Basin Authority, 2010, Guide to the proposed Basin Plan: overview and technical background, Murray Darling Basin Authority, Canberra.

National Water Commission, 2007, Australian Water Resources 2005 - Groundwater Extractions, available at http://www.water.gov.au/WaterAvailability/Waterdiversionsandextractions/Groundwaterextractions/index.aspx?Menu=Level1_3_8_2. Accessed 5/5/11.

Northern Territory Department of Natural Resources, Environment and the Arts, 2010, Western Davenport Water Control District – Draft Water Allocation Plan 2010-2020, NT Government, Australia.

Northern Territory Department of Natural Resources, Environment and the Arts, 2009, Tindall Limestone Aquifer Katherine –Water Allocation Plan 2009-2019, NT Government, Australia.

National Water Commission, 2007, Australian Water Resources 2005 – Capital City Water Use, available at: http://www.water.gov.au/WaterUse/Capitalcitywateruse/index.aspx?Menu=Level1_4_3. Accessed 22/6/2011.

O'Keefe, V, Webb, L, Woolley, D and Punthakey, J.F, 2011, Defining the Significance of Stock and Domestic Groundwater Use in Australia, Waterlines report, National Water Commission, Canberra.

Parsons Brinckerhoff, 2008, Rural Water Use Estimation- Non urban metering and inference methods, prepared for the Bureau of Meteorology, Australia.

Queensland Department of Environment and Resource Management, 2009, Estimation of unmetered groundwater use for the Callide Valley Alluvium – Callide Groundwater Information Paper 1, Queensland Government, Australia.

Queensland Department of Environment and Resource Management, May 2011, Stock and Domestic Take (Groundwater) Assessment Methodology Queensland Murray Darling Basin (draft), unpublished, Queensland Government, Australia.

Queensland Department of Environment and Resource Management, 2011 (a), Description of S&D groundwater use figures for QLD Border Rivers Fractured Rock SDL area, unpublished, Queensland Government, Australia.

Queensland Department of Environment and Resource Management, 2011 (b), Assumptions made for the S&D groundwater use figures for QLD Border Rivers Fractured Rock SDL area, unpublished, Queensland Government, Australia.

Ripich, M.A., 2003, Methods to estimate unmetered ground-water withdrawals in the Yakima River Basin, Washington [abs.]: 4th Symposium on the Hydrogeology of Washington State, April 8-10, 2003, Tacoma, Washington, Program, p. 14.

SKM, CSIRO and Bureau of Rural Sciences, 2010, Surface and/or groundwater interception activities: initial estimates, prepared for the National Water Commission as part of the Waterlines series of works, Australia.

SKM, 2007, Groundwater Allocation in the Unicorporated Areas of Greater Melbourne – Estimates of Recharge and Use for the Unincorporated Areas of Greater Melbourne, Australia.

South Australian Murray Darling Basin Natural Resources Management Board (date unknown), Estimates of Stock and Domestic Water Demand for the Eastern Mount Lofty Ranges Prescribed Water Resources Area, Australia.

Victoria Department of Primary Industries, 2010, Victorian Resources Online – Private Groundwater Extraction Bores, available at http://www.dse.vic.gov.au/dpi/vro/vrosite.nsf/pages/water-vics-gwater-extraction, accessed 5/5/11.

Appendix A

Landholder introductory letter and FAQ's

Author : Orren Farrington
Phone: (07) 4688 1299

Day Month 2011

Name
Address
Locality, QLD

Dear Sir/Madam,

The Department of Environment and Resource Management (DERM) has employed an international consultancy firm (Parsons Brinckerhoff) to assist in identification of water use for stock and or domestic purposes from groundwater sources in South-West Qld.

Our records indicate that you are the registered owner of Lot (*insert)* on Plan (*insert)* on which a stock and or domestic bore taking water from the (*insert)* aquifer exists.

This letter is to advise you that someone from Parsons Brinckerhoff will contact you during the fortnight starting June 6th regarding your bore. Contact will be by phone and is not expected to take more than 15 minutes of your time.

I would also like to take this opportunity to thank you in advance for your participation in this project.

A Frequently Asked Questions (FAQ) sheet is enclosed which provides some background to this activity.

If you have any questions please call Mr Orren Farrington at our Toowoomba office on phone (07) 4688 1299

Yours sincerely

For Manager (Water Services)
SOUTHWEST REGION
TOOWOOMBA

DPI / DNR Complex, 203 Tor Street
PO BOX 318 TOOWOOMBA
Queensland 4350 Australia

Telephone + 61 7 (07) 4688 1000
Facsimile + 61 7 (07) 4688 1188

Website www.derm.qld.gov.au

ABN 83 705 537 586

FREQUENTLY ASKED QUESTIONS FOR STOCK AND/OR DOMESTIC GROUNDWATER USE PROJECT BEING UNDERTAKEN BY PARSONS BRINCKERHOFF

Why is this project being undertaken?

The Department of Environment and Resource Management (DERM) is responsible for managing the use of water from underground water, watercourses, lakes and springs and overland flow in the state of Queensland. In the Queensland portion of the Murray Darling Basin (essentially South-West Queensland) DERM is responsible for reporting on all use from these sources to the Murray Darling Basin Authority.
The volume of water used from groundwater sources (bores/wells) for stock and/or domestic purposes has always been estimated.

Where does this estimated water use number fit into the picture?

The Murray Darling Basin Authority is in the process of finalising the 'Sustainable Diversion Limits' (SDLs) for all basin aquifers. This proposed SDL (limit) will include all use ie irrigation, urban, stock intensive, industrial, commercial and stock and/or domestic. The volume determined for stock and/or domestic use through this work by Parsons Brinckerhoff will be used to inform the SDLs in the final Basin Plan.

What is the purpose of this project?

This project aims to provide DERM with an improved system for determining the volume of water used from groundwater sources for stock and/or domestic purposes in this area.

Who are Parsons Brinckerhoff?

Parsons Brinckerhoff (PB) is one of the world's leading planning, environment and infrastructure firms, with a number of offices around Australia. The PB Water Resources Team will be carrying out the project, and comprise an integrated team of surface water, groundwater and natural resource specialists with extensive experience throughout Queensland, New South Wales, Victoria and South Australia. PB's experience includes work carried out throughout the Murray Darling Basin, and have been involved in numerous projects in individual catchments and important aquifer areas. PB have been contracted by DERM to complete this project.

Why are they ringing me?

Parsons Brinckerhoff is planning to contact approximately 375 people across South-West Queensland who own land on which a stock and/or domestic bore has been recorded as being drilled. The bores have been randomly selected to provide a good geographic spread across the region.

How do I know which bore they are talking about?

The Parsons Brinckerhoff staff member will have access to details of the bore in question. The information should include the local aquifer name, depth, date drilled and the Lot on Plan description.

What if I am not using the bore?

A bore that is not being used may still provide some data. If the bore has been replaced by another bore, then use from the new bore may be more relevant.

Is my bore supposed to be licensed?

No. This project is focussing on stock and/or domestic bores in non GAB aquifers in South-West Queensland. Bores used for these purposes in these aquifers do not require a licence under current legislation.

Will I be charged for the water I use?

No. There is no government charge for water used for stock and/or domestic purposes from your own private bore/s.

Will I be required to fit a meter on my bore?

No. There is no requirement to fit a meter on a bore that is used solely for stock and/or domestic purposes. This does not prevent you from fitting a meter for your own records.

Am I using too much or too little?

There is no upper or lower limit of water use applicable to bores used for stock and/or domestic purposes.

What is meant by stock and/or domestic purposes?

Generally, water for **stock and/or domestic purposes** includes water used in a domestic residence or outbuildings (eg dishwasher, washing machine, evaporative airconditioning, cistern, sinks) and around a domestic residence in gardens, swimming pools, fish or other ponds, bird baths etc. It also includes water used for cleaning (eg household, machinery, buildings, equipment), spraying (chemical dilution), some on-property construction activities and includes supply to water tanks or troughs for grazing livestock.

A definitive description can be found in the *Water Act 2000*. Try the following link; www.legislation.qld.gov.au/LEGSLTN/CURRENT/W/WaterA)).pdf
Page 661 for domestic and page 678 for stock.

What will the data collected be used for?

The water use data will be used by PB to inform their assessment of water use for stock and/or domestic purposes from groundwater sources in South-West Queensland. Individual property information will not be able to be identified in the final aggregated data set. The assessment should result in a more accountable method for determining stock and/or domestic use without metering or licensing information. Addresses and phone numbers will not be retained and will not be passed on to any other party.

How do I get more information or who can I talk to about any of the matters raised in this document?

General information is available on the departmental web site: www.derm.qld.gov.au or, if you wish to speak to someone, you can contact the department at Toowoomba on (07) 4688 1299.

Alternatively, you can contact Chiara Callipari from Parsons Brinckerhoff, on 0429 058 842 or by email on CCallipari@pb.com.au

PARSONS BRINCKERHOFF