

Deloitte Access Economics

# National Centre for Groundwater Research and Training

## Economic Value of Groundwater in Australia

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**Deloitte.**

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# Executive Summary

Increasing surface water scarcity in Australia in recent years has seen a growing reliance on groundwater use. This is a trend that is likely to continue into the future as competition for water resources grow further.

Despite the growing importance of groundwater use, there is a lack of understanding of its economic value. This report aggregates the disparate research on Australian groundwater uses and values into a centralised economic value description and estimate.

Current average annual groundwater use is approximately 3,500 GL. Groundwater is used across many industries of the Australian economy. Water used for agricultural irrigation is the largest single user group, comprising on average approximately 60% of Australia's annual groundwater use. Other user groups include mining (12%), manufacturing and other industries (17%), household water supply (5%), and as an input into potable water supply networks (9%). Groundwater is also used as drinking water for livestock; however there is no data available showing quantity of use for this purpose.

Groundwater also provides value that does not relate to its extractive use. Groundwater supports different environmental values and, by extension, industries that depend upon those environmental values such as tourism and forestry. Another important value of groundwater relates to the option to use it in the future, or its 'insurance' value, which can underpin investment decisions in agriculture and mining and provides value even when the groundwater is not used. Although these non-use values are not quantified in this report, under some circumstances they can be just important. Thus the economic values quantified in this report represent a partial value proposition.

## **Economic value of groundwater use estimate**

Understanding the economic value of extractive groundwater use requires consideration of how water use and productive activity would change if groundwater was not available. The difference in economic outcomes with and without groundwater is taken to be its "economic use" value.

On a value per mega litre (ML) basis, this economic use value varies greatly over time and space. The value of any particular use of groundwater depends upon numerous variables relating to: A) the attributes of the groundwater resource (such as scarcity, quality and reliability) B) the circumstances where it is used (especially whether there is another water substitute) and C) the type of use (such as irrigation, mining, manufacturing, domestic etc.)

The highest per ML value typically comes from groundwater use from households where no potable supply is available, with an upper bound \$6,400 per ML. In business use where the groundwater supports production, the highest value uses are in manufacturing and mining. By comparison, the value per ML in agricultural use is generally lower, especially where there are alternative agricultural water sources. However, because the volume of groundwater use in agriculture is so large, so too is the direct use value to agriculture overall.

In aggregate, the extractive use of approximately 3,500 GL of groundwater each year provides a direct use value of between \$1.8 to \$7.2 billion per year, with a midpoint estimate of \$4.1 billion per annum. Accounting for flow on effects to other industries, the economic contribution of groundwater use to Gross Domestic Product (GDP) across the Australian economy is estimated to be between \$3.0 – \$11.1 billion, with a midpoint

estimate of \$6.8 billion per annum. This midpoint \$6.8 billion represents the estimate of how much lower GDP would be in the absence of groundwater. Additional to this is \$419 million of use value to households. The values to each industry and to the economy overall are identified below.

**Table 1.1: Economic value of groundwater use to Australia**

Sector	Direct value range and central estimate (\$ per ML) <sup>1</sup>	Groundwater volumes (ML)	Direct value-add (\$m)	Ratio of direct to total value add	Total groundwater contribution to GDP (\$m)
Agriculture - irrigation	\$30-500 \$200	2,050,634	\$410	2.00	<b>\$820</b>
Agriculture - drinking water for livestock	– –	–	\$393	2.08	<b>\$818</b>
Mining	\$500 – 5,000 \$2,750	410,615	\$1,129	1.45	<b>\$1,637</b>
Urban water supply	\$1,000 – 3,000 \$2,000	303,230	\$606	1.89	<b>\$1,146</b>
Households	\$1,400 – 6,400 \$2,500	167,638	\$419	NA	<b>NA</b>
Manufacturing and other industries	\$1,000 – 3,000 \$2,000	588,726	\$1,177	2.00	<b>\$2,355</b>
<b>TOTAL</b>		<b>3,520,843</b>	<b>\$4,136</b>		<b>\$6,777</b>

Note: <sup>1</sup> Figures provided are broad estimates using data from a range of sources between the years of 2006 and 2012. A range is given, followed by a central midpoint. The central estimate is the midpoint of the range, except for agriculture where the central estimate is less than the midpoint of the range (reflecting the more common lower value groundwater uses in agriculture). Given the broad nature of estimates, we have not inflated the raw figures to present values. However we believe the range is representative of present values (i.e. 2013 dollars).

### Interpreting the dollar figures

A central estimate of \$4.1 billion of direct value-add and an overall economic value add of \$6.8 billion to GDP represents an important input into the Australian economy, and one which is larger in direct value-add terms than discrete sectors of the economy such as forestry and fishing. Furthermore, there are several other important considerations that add further to the actual and potential value of groundwater to the Australian economy.

Firstly, this quantified economic use value is only a partial value proposition. This is because the values quantified above only reflect the consumptive use values of groundwater. Other non-extractive and option values have not been quantified here. An example of a non-extractive groundwater value is the value of groundwater to forestry, whereby mature trees draw groundwater through root systems that reach below the water table. An example of an option value for groundwater is in agriculture, where a farmer may choose to plant a crop or invest in permanent horticulture (e.g. fruit trees) knowing that groundwater is available as a back-up water source should surface water become unavailable. In this way, groundwater acts as security and underpins investment, even in years where the groundwater is not used.

Furthermore, the dollar estimates here reflect the use value to the groundwater users, and to the economy. This is a different, and substantially lower, figure than the overall level of economic activity that groundwater *supports* or, in other words, the ‘total value of production’ that is dependent on groundwater. Table 1.2 shows that, in aggregate, we conservatively estimate that the total value of production where groundwater is a significant input into production is \$33.8 billion throughout Australia. Metal ore mining makes up 73% (or \$24.4 billion) of this total, which is not surprising given it is a large water dependant industry and a lot of activity occurs in arid areas that are close to 100% groundwater dependent. Irrigation in agriculture is the second major contributor with 11% (or \$3.7 billion), which is a significant contribution showing 29% of water sourced for agriculture is from groundwater. A further \$1 billion also occurs in agriculture, through the value of production from livestock in groundwater dependant areas.

It is important to note that these ‘value of production supported’ figures are much higher than the ‘economic value’ provided in Table 1.1, as there are many other inputs that support production (such as capital, labour, energy, fertiliser etc.). Therefore groundwater cannot be ascribed the full value of production it supports as its own unique contribution to value add in the economy.

**Table 1.2 Total value of production that is dependent on groundwater**

Sector	Proportion (%) of sector that is groundwater dependent	Total value of production (\$billion)	Total value of production dependent on groundwater (\$billion)
<b>Agriculture</b>			
Agriculture – Irrigation	29%	12.9	3.7
Agriculture – Drinking water for livestock	7%	13.8	1.0
<b>Mining</b>			
Metal ore mining	37.6%	65	24.4
Coal mining	0.1%	62	0.1
<b>Manufacturing</b>			
Food production	0.9%	68.8	0.6
Beverage production	1.6%	9.2	0.1
Petroleum and coal production	0.9%	28.6	0.2
Basic chemical and chemical production	1.2%	17.6	0.2
Primary metal and metal production	3.2%	99.2	3.2
Fabricated metal	1.8%	6.8	0.1

Sector	Proportion (%) of sector that is groundwater dependent	Total value of production (\$billion)	Total value of production dependent on groundwater (\$billion)
production			
<b>TOTAL</b>		<b>383.8</b>	<b>33.8</b>

A further consideration enhancing the value of groundwater is its great potential to grow over time. It is likely that both the use values and the value of production supported will increase substantially over time due to several factors, most notably:

- *There is available capacity* to increase the resource use, evidenced by the sustainable yield of groundwater being substantially higher than the current use volume.
- *Increasing future water demand* at a time of surface water resources already being scarce and, in some cases, over allocated
- Expected *increase in economic activity in areas where there are ample groundwater resources*, especially in northern Australia. Groundwater will be important to the future economic growth of such areas because of insufficient or unreliable surface water, itself a function of either low or seasonal rainfall and a lack of suitable dam sites.

A final consideration relevant to the future value of groundwater is that much of it is a renewable resource, so long as use remains below the sustainable yield. The exception to this is, of course, fossil water which takes many years to accumulate in aquifers and is therefore not quickly replenished. The renewable proportion of groundwater, however, can continue to add economic value on a perpetual basis, unlike many of the non-renewable natural resources that the economy also depends upon.

#### **Deloitte Access Economics**

# 1 Introduction and background

This report aggregates the disparate research on Australian groundwater uses and values into a centralised economic value description and estimate. This background chapter provides a high level overview of groundwater in Australia, including the scope and definition of the resource and its location and volumes throughout Australia.

## 1.1 Definition of groundwater

Groundwater is water that has infiltrated into the ground and become contained in aquifers. Aquifers are simply bodies of porous soil and rock. Groundwater can be extracted from aquifers through wells or bores and is replenished when rain seeps back into the water table, or when surface water from rivers or streams drain into the ground.<sup>1</sup>

Groundwater and surface water are inextricably related through the hydrologic (or water) cycle. Extracting groundwater can impact surface water resources and vice versa. Historically, groundwater and surface water have been treated as separate entities. However, in times of drought and water scarcity, understanding and managing the interconnection between groundwater and surface water has become more important.

## 1.2 Location of groundwater

Australia is the driest inhabited continent in the world and comprises extensive arid and semi-arid areas with limited surface water. Australia has many different types of groundwater sources and these vary in terms of quality, productivity and size.

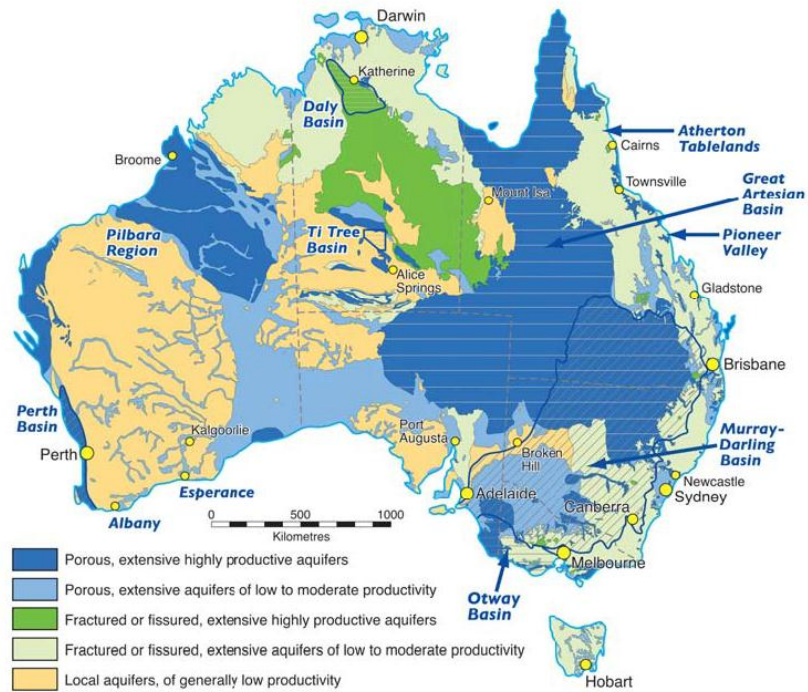
Figure 1.1 illustrates Australia's main groundwater resources and their classification. Darker blue regions represent aquifers that are the most extensive (covering a large area) and productive (i.e. those with a bore yield of more than 5 Litres per second), whereas yellow regions represent more localised (covering a small area) and less productive groundwater sources. Importantly, areas with highly productive aquifers are found in arid and semi-arid zones in Australia resulting in high groundwater dependence in these areas, as shown in Figure 1.2.

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<sup>1</sup> National Water Commission (NWC) 2012, *Groundwater Essentials*, p2

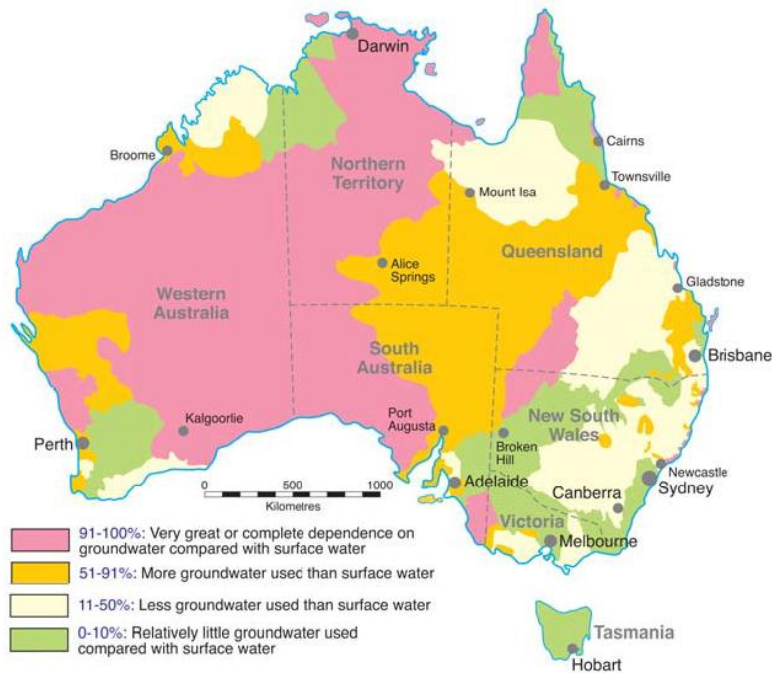


**Figure 1.1: Australia's groundwater resources**



Source: Jacobsen and Lau, *Hydrogeology of Australia*, 1987

**Figure 1.2: Australia's reliance on groundwater**



Source: National Centre for Groundwater Research and Training, 2013

## 1.3 Groundwater volumes and sectors

The following chapter discusses groundwater volumes in terms of yield, entitlement and actual usage and the sectors of the economy which use groundwater.

### 1.3.1 Volumes of yield, entitlement and use

Groundwater volumes in Australia can be expressed in several different ways:

- Total reserves – which is the total level of groundwater stocks in Australia. This volume is largely unknown due to the complexity and uncertainty over the nature and extent of many groundwater aquifers.
- Sustainable yield – which is, generally speaking, the ‘theoretical’ level of groundwater extraction that is needed to protect social, environmental and economic uses of groundwater, and therefore should not be exceeded. This is likely to be substantially less than total reserves.

The best estimate for sustainable yield for Australia as a whole is estimated at **29,173 GL**.<sup>2</sup> We note that there has been further work undertaken by CSIRO into sustainable yield of the Murray Darling Basin.

- Entitlements – This is the volume that groundwater users are ‘allowed’ to extract as specified on a relevant licence or equivalent. Entitlements are defined by the National Water Commission as “*a perpetual or ongoing entitlement to exclusive access to a share of water from a specified ‘consumptive pool’ as defined by a relevant water plan.*”<sup>3</sup> Entitlements are currently less than sustainable yield however, due to the uncertainty around estimates of sustainable yield, this does not necessarily mean groundwater is under-allocated particularly in certain areas.

The groundwater entitlements on issue are currently **6,544 GL** as shown in Figure 1.3. Entitlement volumes have generally increased over the last five years.

- Annual use – This is the volume that has been actually extracted from groundwater sources through bores or wells (or other means) and used by the various sectors of the economy. Due to the majority of groundwater bores and wells not being metered or groundwater levels consistently monitored, use figures are very uncertain. The various sources of use volumes over the last 20-30 years also use different methodologies and are therefore not directly comparable.

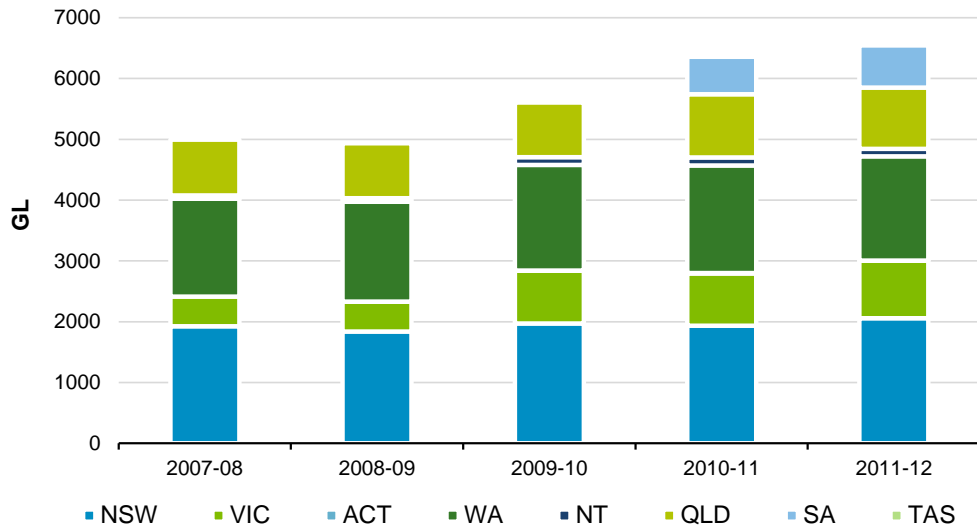
Figure 1.4 below shows a range of estimated usage for the last 30 years and shows that generally groundwater use ranges from between **2,600 ML** to **5,200 ML** per annum.

The latest ABS *Water Accounts 2010-11* provides three years of data on groundwater use for agriculture and water supply, and also self-extracted water from other industries. This has been used as the best available data for this report (as discussed in Section 4.2). The ABS figures, however, appear low in comparison to other estimates therefore there may be some groundwater use not counted. Consequently our estimate of total economic value of groundwater is likely to be conservative.

<sup>2</sup> National Land and Water Resources Assessment (NLWRA), 2001

<sup>3</sup> National Water Commission, *Australian Water Markets Report 2010-11*, p14

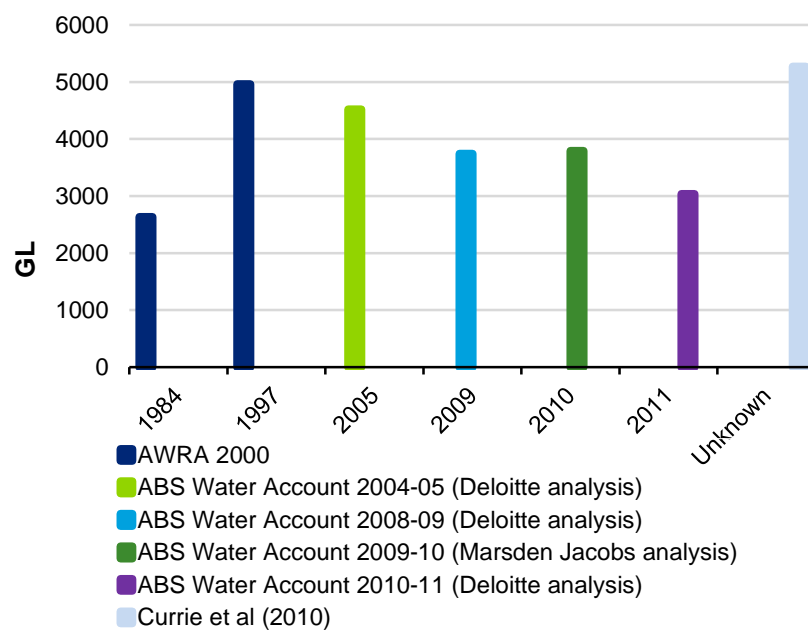
**Figure 1.3: Groundwater entitlements on issue GL (2007-08 to 2011-12)**



Source: National Water Commission 2012, *Australian Water Markets Report 2011-12*

Note: The total volume across the time series is not comparable due to South Australia groundwater entitlement data not being available from 2007-08 to 2009-10.

**Figure 1.4: Estimates of Australia’s total average annual groundwater use GL (1984 – 2012)**



Note: Deloitte and Marsden Jacobs analysis uses a methodology to determine groundwater use based on the ABS Water Account. This approach is outlined in Section 4.2.

### 1.3.2 End use sectors

Groundwater is used in a number of different contexts. Agriculture is a key user, accounting for approximately 60-70% of Australia's total groundwater use. The remaining 30-40% is used within industries such as mining and manufacturing, and also for urban consumption (for commercial, industrial, municipal and domestic end uses). In areas where reliable surface water is the main resource, groundwater will generally only be utilised when surface water is temporarily unavailable. However in some cases groundwater will be used to supplement surface water sources and can often be a cheaper source of supply. In arid and semi-arid Australia, groundwater serves as the only reliable source of freshwater.<sup>4</sup>

#### Irrigated agriculture

Irrigated agriculture includes crops (cotton, rice and sugarcane), vegetable growing, fruit and tree nut growing, livestock farming and other crops. It does not include agricultural support services, forestry or aquaculture.

Groundwater is generally used in agriculture to irrigate crops and pasture for livestock. In some areas (such as Shepparton in Victoria), groundwater is used as a cheaper supplement for surface water and in many cases is 'blended' to meet quality requirements (i.e. groundwater being of lesser quality in this circumstance is blended with surface water which is higher quality). In areas that would otherwise be too arid to cultivate, groundwater can enable agriculture to be feasible and in semi-arid areas (where another supply source might exist in limited volumes), groundwater can improve agricultural productivity by increasing available water.<sup>5</sup>

#### Drinking water for livestock

In arid areas in Australia (the pink shaded areas in Figure 1.2), groundwater essentially provides the only source of drinking water for livestock, without which livestock grazing could not occur. This use predominantly consists of cattle and sheep grazing, but also includes water for some other livestock species.

#### Mining

Mining includes coal, oil, gas, metal, minerals, quarries and exploration activities. Groundwater is an important resource for many mining activities. In Australia's arid zones, many large mining projects and much of the petroleum production industry are completely dependent on groundwater.<sup>6</sup> The mining industry uses water for the following operational activities:<sup>7</sup>

- Ore and waste transportation in slurries and suspension
- Separation of minerals through chemical processes
- Physical separation of material such as in centrifugal separation
- Dust suppression during mineral processing and around roads and conveyors

<sup>4</sup> NWC 2012, *Groundwater Essentials*, p20

<sup>5</sup> Qureshi, M. E., Reeson, A., Reinelt, P., Broxovic, N. & Whitten, S. 2012, Factors determining the economic value of groundwater, *Hydrogeology Journal*, vol 20, p825

<sup>6</sup> NWC 2012, *Groundwater Essentials*, p20

<sup>7</sup> Prosser, I., Wolf, L. & Littleboy, A. 2011, *Water in mining and industry*, In: Prosser, I. (ed.), *Water: Science and Solutions for Australia*, CSIRO, Australia, p138

- Washing equipment

While mining activities use groundwater as an input into production, in some circumstances groundwater is often extracted from mine dewatering activity and therefore is considered a cost on mining. Dewatering is where water is collected through the process of mining and mineral extraction, or rainfall, run-off and water infiltration.<sup>8</sup> For the purposes of this paper, we have only considered groundwater as an input into production.

In recent times, groundwater has been extracted to access coal seam gas (CSG) in Queensland and northern NSW, which is seen as an alternative to domestic coal consumption and also a high potential energy export for Australia.<sup>9</sup> CSG is found in the coal seam bed and is kept bound to the coal by the groundwater pressure and overlying geological formations.<sup>10</sup> To release the gas from the coal, the water pressure must be lowered by extracting large amounts of groundwater from the coal seam to the surface. Currently, however, there are concerns about how this water is disposed of, and how depressurisation may affect water usage in surrounding aquifers.<sup>11</sup>

### **Manufacturing and other industries**

Manufacturing includes manufacturing of food, wood and paper, petrochemicals and metals.

Manufacturing businesses often have access to a reticulated water supply, however will often use groundwater from private bores if available. This groundwater may offer a cheaper source of water and reduce business' dependence on the reticulated water supply.

Water is used in the process of manufacturing including boiling for steam, separation of materials, cooling, cleaning of raw materials and washing equipment.

Other industries include construction, wholesale/retail trade, transport, services and public administration. Other industries often have access to a reticulated water supply, however will often use groundwater from private bores if available. This groundwater may offer a cheaper source of water and reduce business' dependence on the reticulated water supply. Water is used for watering lawns and gardens, cleaning and in construction.

### **Water supply**

Some urban and rural water providers use groundwater as a key water supply source for providing to urban and rural end uses, for example Portland and surrounding towns in Western Victoria are supplied almost entirely by groundwater.

In an urban setting, groundwater is first extracted then treated via treatment plants before being delivered to households, industry, municipal and other commercial uses. In a rural setting, groundwater will supplement water for irrigation purposes. For a water supplier (particularly rural where open channels are used), water is lost in the process of delivery of water. For an urban provider, water is also used in the process of water and sewage treatment.

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<sup>8</sup> ABS, *Water Account Australia 2004-05*, p80

<sup>9</sup> Prosser et al, 2011, p141

<sup>10</sup> Department of Primary Industries (DPI), NSW 2013, Water and coal seam gas, viewed 13 June, 2013, <http://www.water.nsw.gov.au/Water-management/Groundwater/Water-and-coal-seam-gas/Water-and-coal-seam-gas>

<sup>11</sup> Prosser et al, 2011, p141

Water suppliers for some regional towns, have groundwater on standby for when surface water storages become depleted, providing important water security for these towns. Groundwater became an important supply source in the 2006 to 2009 drought in eastern Australia.

### **Households**

While water providers supply groundwater through reticulated systems to households, there are some households that directly source their own groundwater from a private bore/well. These households may or may not be connected to a reticulated system.

Regional towns don't yet have a reticulated water supply but will source groundwater for non-drinking purposes (such as garden watering and toilet flushing) and have a rainwater tank for drinking purposes. Households that do have a reticulated water supply can often use groundwater for outdoor use and reticulated supplies for indoor use and drinking water.

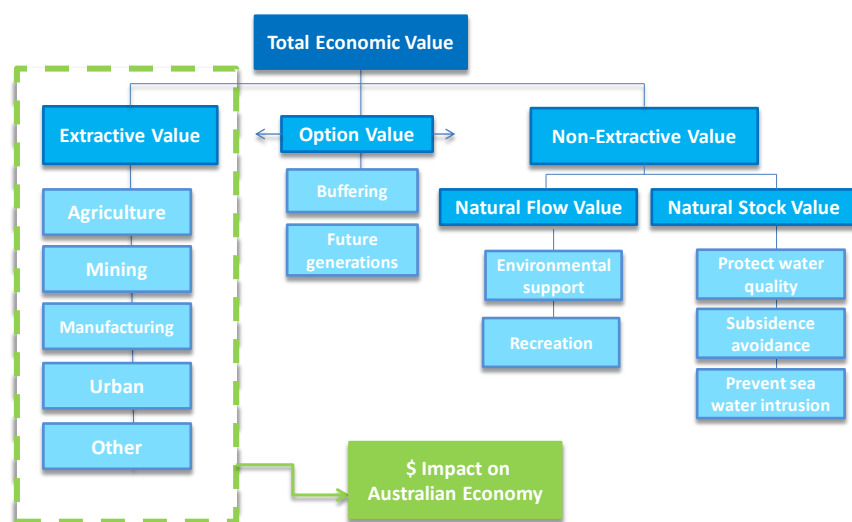
## 2 Types and drivers of economic value

This chapter provides information on the types of groundwater values and also what drives those values. This understanding is important in interpreting the final economic estimates.

### 2.1 Types of value

The economic value of groundwater is made up of several components. Figure 2.1 divides these components into three main categories being extractive, non-extractive and option values. For the purposes of this study, the scope of the economic value is limited to extractive use value.

Figure 2.1: Economic value of groundwater – types of values



Source: Adapted from Qureshi 2012

#### 2.1.2 Extractive values

Extractive value measures the value associated from the actual, intended or potential use of the extracted groundwater by the various sectors of the economy. It therefore includes the value relating to actual consumption of drinking water as well as the value attributable to using groundwater to produce end-products. The extractive value of groundwater will vary significantly, depending on how it is used, the availability of alternative substitutes, and the value of the end product.

#### 2.1.3 Non-Extractive values

Groundwater also provides important non-extractive values. It supports the natural water flows that are vital for ecosystems and wetlands, as well as providing 'base flow' into surface water resources and supporting recreational activities at discharge sites. Groundwater stocks also have significant value as they can prevent land subsidence and act as a barrier against seawater intrusion into aquifers. In addition, as over extraction can

degrade the quality of groundwater, there is significant value in ensuring that the stock of groundwater within a given aquifer is not depleted by extraction at unsustainable levels.<sup>12</sup>

#### 2.1.4 Option values

Option values relates to the value individuals derive from maintaining or preserving the groundwater for their own future benefit, or for future generations. When surface water is temporarily limited, users can derive significant value from having the 'option' to access a buffer water supply. This alternative source can be particularly important for farmers seeking to mitigate against the risk of droughts, as it serves to decrease the income variability associated with fluctuations in surface water resources. This insurance value exists even in years where water is not used.

## 2.2 Drivers of value

There are four key drivers of the value of groundwater being scarcity, cost of alternative water sources, quality and reliability.

### 2.2.1 Scarcity

The price for water generally reflects the physical costs to supply the water (such as piping infrastructure and treatment plants) and not the actual value of the water itself. These prices are often independently regulated to ensure they reflect the efficient costs of supplying water. In a water trading environment, however, the price indicates the true value for water. The value of water in a water market therefore generally diminishes as supply increases. When water is scarce, people will tend to value it more highly. In areas where groundwater serves as a close substitute for surface water, the value users attribute to groundwater will tend to be higher when surface water is scarce.

Factors that will drive scarcity include:

- Droughts – the prolonged drought experienced across southern Australia from 1997-2009 significantly increased water scarcity, particularly for surface water. In some places, runoff was less than half the long term average and resulted in depleted storages and consequent low yearly allocations for lower security water.<sup>13</sup> This has the effect of increasing the value for water generally as was evidenced by the high water trading prices paid in some of the worst drought years. For example, in Victoria surface water trading prices in the Goulburn area averaged \$702 per ML in 2007-08 (a very dry year where allocations were low), and more recently averaged around \$30 per ML in 2010-11 (a wet year where allocations were close to 100%).
- Policy and regulatory changes – such as changes to allocated surface and groundwater in catchments, through buy backs for the environment or through changes to water allocation/sharing plans. Regulation can also inadvertently drive increasing groundwater use, for example a cap on the river diversions in 1997 saw large increases in groundwater use in the Murray-Darling Basin.

<sup>12</sup> Qureshi et al, 2012, p823

<sup>13</sup> Chiew F., & Prosser, I., 2011, *Water and Climate*. In: Prosser, I. (ed)., *Water: Science and Solutions for Australia*, CSIRO, Australia, p138



- Climate change – Most climate projections indicate lower levels of precipitation for Australia in central and southern Australia and overall increases in temperature and rainfall variability.<sup>14</sup> This is likely to impact river flow, groundwater levels and the connectivity between rivers and shallow aquifers, as well as increase demand for water.

### 2.2.2 Cost and availability of alternatives

The value of groundwater will be significantly influenced by the availability of alternative water sources and associated costs. This availability depends principally on location of use. In coastal areas, alternative options include desalination from seawater, recycled water from urban areas, rainwater collection and stormwater reuse. Inland areas are more limited in the available options as transporting desalinated sea water is likely to be cost-prohibitive and there is less recycled water available due to smaller urban areas (although some recycling of irrigation drainage water may be possible).

In coastal areas around major cities, accessing the reticulated water supply system provides a security of supply. Most Australian cities now have well established 'alternative' sources of water, for example Brisbane, Sydney, Melbourne, Adelaide and Perth have a desalination plant and many recycled water options. Assuming access to the reticulated water supply, groundwater in a coastal area near a major city (therefore an adequate volume supply for the city's needs), will have less value compared to groundwater in a regional area near a major town (which has less alternatives available).

### 2.2.3 Quality

The value of groundwater will also depend on its quality, especially in terms of salinity levels and pollutant concentration. Different users will place different values on groundwater quality. For example, where groundwater is used for drinking water, low quality groundwater will only be valuable if it can be treated appropriately, and this may come at significant costs. In contrast, mining and some industrial processes do not require high quality groundwater.

As poor quality groundwater has been shown to reduce crop yield, farmers may place a higher value on higher quality groundwater. However, farmers are sometimes able to blend low-quality groundwater with surface water to augment irrigation prospects.<sup>15</sup> Poor quality groundwater may also cause environmental damage, if extracted and not disposed of appropriately.<sup>16</sup> Rising saline groundwater can result from excess irrigation water seeping through fields or unlined canals, in addition to naturally saline groundwater.

### 2.2.4 Reliability

In comparison to surface water, which is generally dependent on short term rainfall, groundwater is less influenced by short term climatic variability than surface water systems and consequently provides a useful 'buffer' in times of reduced surface water allocations.<sup>17</sup> As a reliable, on-demand supply groundwater provides substantial value within agricultural

<sup>14</sup> Barron, O., et al. 2010, *The impact of climate change on groundwater resources: the climate sensitivity of groundwater recharge in Australia*, CSIRO, pxi

<sup>15</sup> Qureshi et al, 2012, p823

<sup>16</sup> NWC 2012, *Groundwater Essentials*, p28

<sup>17</sup> ABARE 2007, *Groundwater management, efficiency and sustainability*, p8

contexts. This is particularly important for perennial crops such as vineyards or orchards, where periods of low rainfall can potentially threaten many years of investment,<sup>18</sup> if reliable groundwater supplies are not present.

However, extracting groundwater at levels beyond sustainable yields can reduce 'base flow' to rivers and streams and cause damage to environmental assets and groundwater quality.<sup>19</sup> Additionally, groundwater resources are replenished much slower than surface water, in some cases water in aquifers has been stored for thousands of years.<sup>20</sup>

## 2.3 Common methods for assessing value

There are many available approaches to estimating the economic value of a resource such as groundwater, using both 'revealed' preference and 'stated' preference techniques. Revealed preference means that the value of a product or service is revealed through the consumer's purchase (i.e. market prices). Stated preference means that the value of a product or service is determined by what the consumer says (or states) that they are willing to pay (e.g. through a survey). Stated preference techniques are generally used in the absence of markets, such as for environmental values which don't usually have a market price.

The most appropriate valuation methodology will vary, depending on the circumstances, data availability and what value (extractive, non-extractive and option value) is being assessed.

### 2.3.1 Extractive value

A number of approaches have been used to estimate the value of groundwater in given areas. The most commonly used in case studies concerning the economic value of groundwater are the deprival value, residual value, market prices and proxy market prices. Other methods such as hedonic pricing, benefit transfer and replacement cost or avoidance have not been found in published groundwater case studies, however are still used in the consideration of groundwater value.

#### **Deprival value method**

The deprival value represents the cost users would incur to replace groundwater with the next least costly alternative source. This methodology is based on the assumption that if groundwater users were deprived of groundwater, they would be willing to pay up to the value of the next best alternative water source, less groundwater's associated ongoing costs.<sup>21</sup>

#### **Residual value method**

The residual value represents the value of the product that is generated from the use of groundwater. It is calculated by determining the profit (revenue less costs incurred)

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<sup>18</sup> Qureshi et al, 2012, p825

<sup>19</sup> Australian Water Resources Assessment (AWRA) 2000, *National land and water resources audit*

<sup>20</sup> Howe, I. 2012, Protecting our valuable groundwater resources, *Australian Drilling*, September/October, p42

<sup>21</sup> Marsden Jacob Associates (MJA) 2012, *NWC Waterlines, Assessing the value of groundwater*, p9

associated with using groundwater to produce the given product.<sup>22</sup> This methodology is generally assumed to be appropriate when it is not possible or prohibitively costly to replace groundwater with an alternative source.

#### **Market price method**

The market price is revealed by the prices paid for groundwater entitlements and allocations in water markets throughout Australia. In some cases where groundwater is used in an area where surface water trading occurs, the price paid for surface water is used as a proxy for groundwater value.

#### **Proxy market price method**

The proxy market price is revealed not through the market price paid for the resource itself, but through other costs to access (or protect) the resource. Examples might include the costs that groundwater users are willing to incur to access groundwater resources, such as drilling, pumps, pipes and storage or, alternatively, the scale of past investments that have been made to protect the resource.

#### **Productivity method**

This is the marginal value-add made possible by groundwater use in industries that utilise groundwater as an input to production. In efficient markets this should, in theory, reveal the same value as the market price method.

#### **Benefit transfer**

The benefit transfer method is where revealed preferences transfer from one area to another area (adjusted for other variables as needed).

#### **Hedonic pricing**

Hedonic pricing reflects the contribution of groundwater rights to higher land values, in situations where groundwater access entitlements have not been unbundled from land. This requires that groundwater availability be isolated as the sole source of difference in property prices which, in reality, is not always a practical approach.

#### **Replacement or damage cost avoidance**

This is the cost that is avoided through groundwater availability eliminating the need to develop an alternative, more expensive source of water, or through avoiding the need to undertake environmental remediation or protection.

### **2.3.2 Non-extractive and option values**

Groundwater also provides value that does not relate to its extractive use. Groundwater supports different environmental values and, by extension, industries that depend upon those environmental values such as tourism and forestry.

Another important value of groundwater relates to the option to use it in the future, or its 'insurance' value, which can underpin investment decisions in agriculture and mining and provides value even when the groundwater is not used.

These environmental and option values of groundwater have not been valued here. However, under some circumstances they are arguably be just as important as extractive

<sup>22</sup> RM Consulting Group (RMCG) 2008, *Groundwater economics study*, p3

use values. As such, the economic values quantified in this report capture only some of the total value of groundwater in Australia.

## 3 Previous studies

This chapter summarises our literature scan on studies relating to the economic value of groundwater which include; Australian or state-wide estimates, region-specific (case study) estimates, and more general water trading data.

These previous studies are important in providing both inputs to our estimate of the economic value of groundwater and as useful benchmarks to compare our estimate against. An interesting observation in relation to the regional estimates is that groundwater value is highly dependent and sensitive to location and end use. Some of the regional estimates using the deprival method, are well above our direct value ranges per ML for each of the sectors. This shows that our estimates may be conservative.

All estimates refer to the direct use value (i.e. the direct value to the user) of groundwater. There are no publicly available documents outlining the economic value of groundwater for the economy as a whole (i.e. effect on downstream industries and/or overall Gross Domestic Product).

### 3.1 National and state estimates

There have only been two key attempts at estimating the direct use value of groundwater at a national or state level.

The only publicly available estimate for direct use value for Australia as a whole was by Marsden Jacobs & Associates (MJA) in September 2012.<sup>23</sup> The MJA study used the deprival method (i.e. the cost of the next best alternative water source if groundwater was not available) for five key sectors and also supplemented this with a number of case studies using various methods and approaches (discussed further in Section 3.2).

A study by Resource Management Consultant's Group (RMCG) in 2008<sup>24</sup> estimated the economic use value of groundwater for Victoria, using the deprival value for all sectors except irrigation which used a residual value. The residual value, in this case, uses the gross margin from irrigation products generated from groundwater use. The method was used as it was assumed that the next best water source alternative would be cost-prohibitive therefore irrigation production would cease. The forgone production gross margin therefore represents the economic value of groundwater for the irrigation sector.

The findings of these two studies are summarised in the table below.

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<sup>23</sup> Marsden Jacobs and Associates 2012, *National Water Commission Waterlines series no. 89, Assessing the value of groundwater September 2012*

<sup>24</sup> RM Consulting Group 2008, *Groundwater economics study*

**Table 3.1 Summary of results from MJA and RMCG studies on the economic use value of groundwater**

Study	Results – \$ per ML	Results – totals
MJA 2012	Agriculture \$50-200	<b>\$2.3 – 7 billion (Australia)</b>
	Mining \$500-5000	Agriculture \$0.1-\$0.5bn
	Water supply \$2000-4000	Mining \$0.2-2.1bn
	Household \$1000-5000	Water supply \$0.6-1.3bn
	Industry \$2000-4000	Household \$0.2-1bn Industry \$1.2-2.2bn
RMCG 2008	Irrigation \$110-590	<b>\$340 million (Victoria)</b>
	Industrial \$2500-4000	Irrigation \$102m
	Urban \$1200-6000	Industrial \$123m
	Stock & Domestic \$1132	Urban \$62m Stock & Domestic \$52m

## 3.2 Regional estimates

There are a number of case studies representing the economic value of groundwater for particular regions. The range of numbers in the case studies demonstrates that groundwater value is highly dependent on the end-use and drivers of value such as scarcity, cost and availability of alternatives, quality and reliability.

The MJA report included five case studies including; Gngangara, Shepparton, Daly River, Lockyer and Northern Tasmania. These values included both extractive and non-extractive value estimates, and each differed in relation to the method used.

There are also some other publicly available case studies where the economic value of groundwater has been estimated. Some of these case studies did not seek to identify the value to the region per se, but rather investigated the economic impact of a policy change in groundwater, such as the imposition of a new trading rule or a reallocation of groundwater through a water resource/sharing plan. Therefore they are not directly comparable to a deprival value, but rather represent value at the margins (e.g. a marginal decrease of 10% in groundwater translates into an entirely different value per ML than a 100% deprival value).

The case study results are summarised in the table below and show that there is a wide range of values for each of the sectors. For example:

- Household use values range from \$100 to 1,800 per ML
- Irrigated agriculture values range from \$100 to \$1,875 per ML
- Industry values range from \$452 to \$10,000 per ML
- Public water supply values range from \$1,800 to \$2,600 per ML

Further detail on methodologies used for these case studies are included in Appendix A.

**Table 3.2 Summary of results from previous case studies on the economic value of groundwater**

Area and source	Scope	Results – \$ per ML
Gnangara, Western Australia (MJA, 2012)	Gnangara groundwater system contains the Superficial, Mirrabooka, Leederville and Yarragadee aquifers. It covers 220,000km <sup>2</sup> and underlies Perth's northern suburbs.  Gnangara groundwater system supplies 35-50 per cent of Perth's drinking water	<ul style="list-style-type: none"> <li>Public water supply: \$1800/ML</li> <li>Horticulture and agriculture \$900-1870/ML</li> <li>Domestic bores \$100-1800/ML</li> <li>Parks and gardens \$100-1800/ML</li> <li>Industry \$1800-10,000/ML</li> </ul>
Shepparton, Victoria (MJA, 2012)	Shepparton Irrigation Region is located in the Murray Darling Basin. The region includes the Murray Valley, Shepparton, Central Goulburn and Rochester irrigation areas and some adjacent dryland areas  The region represents the largest irrigated agricultural area by volume in Victoria	<ul style="list-style-type: none"> <li>Dairy: ceiling value of \$100/ML (beyond which farmers assumed to purchase stockfeed)</li> </ul> Horticulture and cropping activities: <ul style="list-style-type: none"> <li>Upper traded value of \$750/ML in 2007 droughts</li> <li>Lower traded value of \$25/ML in 2011 floods.</li> <li>Long run average over 2007-2011 approximately \$290/ML</li> </ul>
Daly River, Northern Territory (MJA, 2012)	Daly River is a perennial river system and represents one of the most important ecosystems in the Northern Territory as it continues to flow throughout the dry season due to groundwater baseflows.  Groundwater represents 90% of the NT's freshwater use	<ul style="list-style-type: none"> <li>Public water supply \$2600/ML</li> <li>Agriculture: \$452/ML</li> <li>Industrial uses: \$452/ML</li> <li>Stock and domestic \$4665/ML</li> </ul>
Lockyer Valley , South East Queensland (MJA, 2012)	Circular basin covering 2800km <sup>2</sup> that produces 30% of the Queensland's vegetables by value.  The Lockyer Valley's main groundwater resources supply approximately 80 per cent of irrigation water to the resident agricultural sector	<ul style="list-style-type: none"> <li>Agriculture: \$600/ML</li> </ul>
Northern Tasmania (MJA, 2012)	Focuses on agriculture in Tasmania's three most northern catchments: <ul style="list-style-type: none"> <li>The Arthur Inglis-Cam region (16GL average annual extraction)</li> <li>The Mersey-Forth region (17 GL average annual extraction)</li> <li>The Piper-Ringarooma region (1 GL average annual extraction)</li> </ul>	Agriculture: <ul style="list-style-type: none"> <li>Vegetables: \$1000/ML</li> <li>Other crops including poppies, pyrethrum and berries :\$1900/ML</li> <li>Dairy : \$600/ML</li> </ul>

Area and source	Scope	Results – \$ per ML
Perth Metropolitan area, Western Australia  (CSIRO, 2007)	Assesses the economic value of groundwater from the Superficial Aquifer for irrigating lawns and gardens in the Perth metropolitan area	Avoided costs of having to use scheme water to irrigate green space:  Value to decision maker <ul style="list-style-type: none"> <li>• Councils: \$500/ML</li> <li>• Other institutions: \$500/ML</li> <li>• Households: \$328.57/ML</li> </ul> Value to society <ul style="list-style-type: none"> <li>• Councils: \$900 /ML</li> <li>• Other institutions \$904.76/ML</li> <li>• Households: \$628.57/ML</li> </ul>
Goonoo Goonoo Creek, Tamworth, New South Wales  NSW Office of Water (2010)	Assesses the economic impacts associated with changing groundwater access rules to impose a daily constraint for Peel Valley	<ul style="list-style-type: none"> <li>• Irrigated agriculture (Lucerne production): \$402/ML</li> </ul>

### 3.3 Groundwater trading data

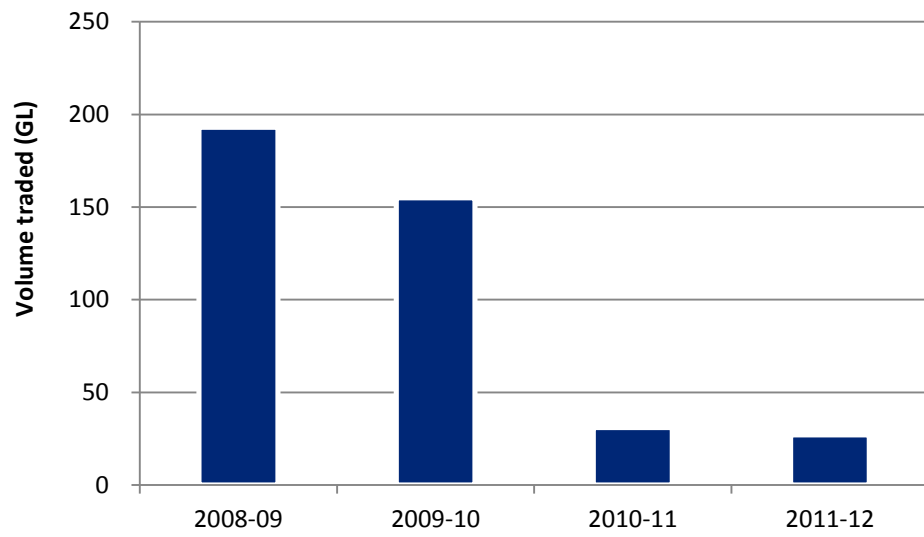
Market prices can provide an indication of what users are willing to pay for groundwater. However, Australia has relatively few well-functioning groundwater markets. The National Water Commission's *Water Market Trends and Drivers 2011* (p68) report notes that groundwater entitlement trading is limited in most jurisdictions due to the following reasons:

- *Aquifers often have limited hydrogeological connections, and with limited physical infrastructure linking groundwater areas that lack connectivity restricts trade to within individual aquifers.*
- *In many areas, groundwater entitlements are yet to be fully unbundled from land*
- *While all states have legislation that enables groundwater trading, in some areas, the provisions relating to groundwater licencing and trading are relatively recent and the market has not yet had time to fully develop*
- *There is uncertainty about the definition of individual groundwater management units. For a market to be established, it is important to be able to physically define the relevant water system. In many areas work to better define aquifer system boundaries is still ongoing. Without certainty about boundaries, jurisdictions have been reluctant to allow unfettered trade.*
- *Around 49% by number and 21% by volume of entitlements on issue in Australia are groundwater entitlements.*
- *In many cases trade may be prevented by regulatory or other constraints, such as arbitrary caps on trade between zones and catchments*

Of the available data for groundwater trading data, NSW has the highest volume traded. As shown in the figure below, the volume traded varies according to surface water availability, being relatively low in the dry years of 2008-09 and 2009-10 and relatively high in the wet years of 2010-11 and 2011-12.



**Table 3.3 Groundwater allocation trade volumes in NSW (2008-09 to 2011-12)**



Source: National Water Commission, *Australian National Water Markets Report 2011-12*, p215

## 4 Methodology and interim calculations

This section describes our methodology and outlines our interim calculations for determining the economy wide impacts of groundwater (presented in Chapter 5).

We have estimated the economic value of groundwater and contribution to Gross Domestic Product (GDP) using a four step process:

1. Assessment and determination of direct (use) values (\$ per ML) for the various categories of groundwater users (agriculture, mining, urban water supply, households and manufacturing and other industries), based on the studies identified in Chapter 3 and further research on unit costs of alternative water supplies outlined in Appendix B
2. Extrapolation of the direct use values to the total groundwater volumes in Australia for each category of groundwater user, based on the last three years of ABS data in the *Water Accounts 2010-11*
3. Application of economic multipliers specific to each category of groundwater user, to determine wider economic benefits of groundwater value to the rest of Australia's economy (i.e. contribution to GDP) based on the input-output framework using ABS input output tables
4. A separate consideration of the value of production that groundwater supports, which is a different economic indicator than the value-add captured by contribution to GDP.

### 4.1 Direct value

The first stage involved determining appropriate direct use values (i.e. direct value to the user of groundwater) on a per ML basis, versus the next best alternatives. As groundwater value is dependent and sensitive to the various factors described in 2.2, and therefore values can vary significantly between sites, a range of values is provided.

To determine direct use values, we had regard to previous studies that have assessed the direct value of groundwater (as outlined in Section 3). As discussed, the only publicly available estimates of direct use values for Australia or the states are the MJA 2012 report and the RMCG 2008 report. We have therefore used these studies as a starting point for our estimates, supplemented by publicly available unit costs per ML for various alternative water sources, surface water trading data and case study data.

#### Sectors

The MJA 2012 report used the use categories of agriculture, mining, water supply, households and industry. This was derived from ABS categories in the Water Account Australia report.<sup>25</sup> The RMCG analysis used the categories of irrigation, industrial, urban and domestic and stock.

For our analysis, we have used sectors derived from ABS which include:

- Agriculture – irrigation
- Agriculture – drinking water for livestock
- Mining

<sup>25</sup> Australian Bureau of Statistics 2011, *Water Account Australia 2009-10*

- Urban water supply
- Households
- Manufacturing and other industries

We used the ABS data as we consider it is the best available consolidated data for Australia with respect to a breakdown in sectors. We have defined these categories in Section 1.3.2.

#### Direct use value (\$/ML)

Our direct use values differ from MJA estimates in some of the sectors, reflecting a different viewpoint or more recent data. In some cases, our judgement is the same as the estimates in the MJA report and, in these cases, we have adopted the MJA use value. The table below shows our estimates and assumptions to derive the direct use value range for each sector in the consistent metric of \$ per ML.

Due to the unavailability of water use data for ‘agriculture – drinking water for livestock’ it was not possible to derive a \$ per ML direct use value. Therefore we have adopted a different methodology and derived a *total* direct use value for this sector, which is explained in the table below.

**Table 4.1 Direct use value estimates and assumptions**

Use	Direct value range (\$ per ML) <sup>1</sup>	Comment on assumption used
Agriculture – Irrigation	\$30 – 500 (\$200)	<p>It is assumed that if deprived of groundwater, most agricultural enterprises would access surface water as an alternative. Therefore, we have used the average monthly price ranges of surface water allocation trades in the Murray Darling Basin for the last four years 2008-09 and 2011-12,<sup>26</sup> as a proxy for the cost of the next best alternative for groundwater which is between \$30 and \$500. Note, if the enterprise used surface water if deprived of groundwater, they save on any extraction costs of groundwater but incurs any delivery costs of using surface water instead. These different delivery costs haven’t been factored in here.</p> <p>However, we note that water markets have not been in operation for a long time and the last four years (48 months) represent some extreme conditions. For example, for only 2 out the last 48 months did the average monthly price exceed \$400 (in August and September of 2009 with prices at \$500 p/ML), therefore we have adopted \$400 as the top end of the range to calculate the mid-point of \$200 to remove the effect of these outliers.</p>
Agriculture – Drinking water for livestock		<p>In some cases agricultural enterprises may not have access to surface water in a freely functioning trading market, particularly those which use water for livestock drinking purposes in arid and semi-arid zones in Australia that are totally dependent on groundwater. These entities, if faced with groundwater deprival, are unlikely to source the next best alternative (which is likely to be piping water long distances) due to this option being cost-prohibitive. In these cases the economic value of groundwater, therefore, is the gross margins from lost production.</p>

<sup>26</sup> National Water Commission, *Australian Water Markets Report 2011-12*

Use	Direct value range (\$ per ML) <sup>1</sup>	Comment on assumption used
		<p>The RMCG 2008 report estimated the gross margin for intensive livestock at \$590 per ML, however this was for intensive livestock (not drinking water for livestock) and only for Victoria. Therefore without total water use figures RMCG's estimate cannot be extrapolated to the rest of Australia.</p> <p>In the absence of a publicly available figure for this drinking water for livestock use, we adopted an approach using GIS mapping and ABS statistics to estimate the proportion of the livestock industry that occurs within groundwater dependent areas. This was done through the following steps:</p> <ol style="list-style-type: none"> <li>1. Using the map in Figure 1.2 we digitally mapped the area which was 90-100% dependent on groundwater into GIS</li> <li>2. We then determined the gross value of livestock production<sup>27</sup> occurring in these groundwater dependent areas, which was 7% of the national total. Because there are no consistent alternative water sources, it is assumed that this livestock grazing activity from these arid areas could not occur without groundwater for the stock.</li> <li>3. To determine the 'value add' of this sector we determined the ratio of 'value add' to 'total production' for the wider sector 'sheep, grains, beef and dairy cattle'<sup>28</sup> from ABS Input Output tables (which was 41%)</li> <li>4. We then applied this 41% (value add to total production proportion) to the 7% gross value livestock production, to arrive at \$393m of direct value add to groundwater dependent livestock production</li> </ol>
Mining	\$500 – 5,000 (\$2,750)	<p>The MJA 2012 range estimate is considered reasonable for mining and therefore used as the basis of our estimate. The MJA estimate is based on the range of piping water from short (\$500 per ML) and long (\$5,000 per ML) distances if deprived of groundwater. The upper bound is based on the price paid by mining companies in Kalgoorlie Boulder to access water from Perth.</p> <p>Other quoted costs of alternatives include \$3,680 per ML which was the price quoted for desalination at Esperance and pipeline to Kalgoorlie.<sup>29</sup> Other large pipeline costs from northern to southern Australia have been quoted as being in the order of \$5,000 to 6,000 per ML.<sup>30,31</sup></p> <p>Therefore the \$5,000 upper bound estimate appeared reasonable and unlikely to be exceeded for mine sites.</p>
Urban water	\$1,000 – 3,000 (\$2,000)	The range of \$1,000 to \$3,000 is based on publicly available figures

<sup>27</sup> Use of Gross value for 2012 of 'Livestock slaughterings and other disposals' from Australian Bureau of Statistics, *Value of Agricultural Commodities Produced, Australia, 2011-12*

<sup>28</sup> Australian Bureau of Statistics, *5209.0.55.001 Australian National Accounts: Input-Output Tables - 2008-09*

<sup>29</sup> Economic Regulation Authority, 2005, *Inquiry on the cost of supplying bulk potable water to Kalgoorlie Boulder*

<sup>30</sup> Department of Premier and Cabinet WA, 2006, *Options for bringing water to Perth from the Kimberly*

<sup>31</sup> Australian Water Association, 2007, *Water in Australia Facts and Figures, Myths and Ideas*

Use	Direct value range (\$ per ML) <sup>1</sup>	Comment on assumption used
supply		<p>regarding the most likely alternatives for urban water supply. In most capital cities, desalination is considered to be the upper bound benchmark for alternative water source options available to water providers (i.e. alternatives that cost more are generally not considered). Now that desalination is established in most capital cities, the marginal cost is typically below \$2,000 per ML. For example, in Sydney it is around \$700 per ML.</p> <p>Large regional areas, however, do not have access to desalinated seawater and are therefore faced with other alternatives such as demand management measures, purchase of temporary water from irrigators, recycled water and/or a pipeline from the nearest available source. While there may be some small towns that have high cost of alternative supplies, the vast majority of the regional population is in large regional centres with access to temporary water trading and/or recycling. If a pipeline were required, most towns would require a short distance pipeline (in the order of 100-200km), rather than the long distance pipeline which characterise the high end estimates for pipelines. Most short distance pipelines are in the order of \$1,000 to \$3,000 per ML.</p> <p>The MJA 2012 range was based on the cost of alternative options such as desalination, recycling or long distance pipelines typically costing in the order of \$2,000 - \$4,000 per ML. We believe the upper bound estimate is likely to be high.</p> <p>Appendix B provides a table summarising the cost of alternative water sources that were considered.</p>
Households	\$1,000 – 6,400 (\$2,500)	<p>This estimate range is based on the cost of the next best alternative water supply being either mains supply (i.e. \$1,000 being the lower end of urban water supply) or the cost of a rainwater tank for households without a mains supply alternative (i.e. \$6,400 being the upper bound for a rainwater tank). We have used costs associated with a rainwater tank for outdoor use where a pump is not required based on MJA 2007 estimates.<sup>32</sup> This is consistent with groundwater being used typically by households for non-drinking and outdoor purposes, and therefore not requiring a pump.</p> <p>In recognition of the fact that the majority of households will have access to an urban water supply (and therefore will increase use of it if deprived of groundwater), the mid-point value has been lowered to \$2,500.</p> <p>The MJA 2012 range was \$1,000 to \$5,000 based on the assumption that if deprived of groundwater households would demand 50% less and would source the remaining 50% from a rainwater tank at a cost of \$10,000 per ML. However this estimate does not capture the 'cost' of conservation and the upper bound \$10,000 per ML is based on rainwater tanks where a pump is required.</p>
Manufacturing and other	\$1,000 – 3,000 (\$2,000)	<p>This range was considered to be the same value range for urban water supply, as it is assumed that most (if not all) major manufacturing businesses would be located in areas where there is a water supply</p>

<sup>32</sup> Marsden Jacobs and Associates 2007, *NWC Waterlines, the cost effectiveness of rainwater tanks in urban Australia*, pES.xi

Use	Direct value range (\$ per ML) <sup>1</sup>	Comment on assumption used
industries		available.

Note: <sup>1</sup> Figures provided are broad estimates using data from a range of sources between the years of 2005 and 2012. Given the broad nature of estimates, we have not inflated the raw figures to present values. However we believe the range is representative of 2013 economic conditions.

## 4.2 Groundwater use volumes

The direct use value of groundwater on a \$ per ML basis for each sector can be extrapolated into the total direct use value for Australia by multiplying it by groundwater use volumes for each sector. These volumes have been derived from the ABS *Water Account Australia 2010-11*, which has water use statistics for three financial years (2008-09 to 2010-11). The ABS Water Account is considered the best consolidated data available on water use volumes for end-use categories.

For each use category, we have used the average groundwater use volumes of the last three years (2010-11, 2009-10 and 2008-09) as the basis of extrapolation to Australia. These three years provide a sample of use volumes that represents both drought and flood years. In the areas where the majority of groundwater is used (i.e. 67% of total groundwater is used in Queensland, NSW and Victoria), 2010-11 was a wet year, 2009-10 a normal year and 2008-09 a dry year.

The ABS Water Accounts 2010-11 provide actual groundwater volumes used for categories of 'agriculture' and for 'distributed water supply'. However, some analysis was required to adjust distributed water supply (due to potential double counting of agriculture) and other use categories of mining, households and manufacturing and other industries. These assumptions are summarised below and in Table 4.2.

### Water supply

The ABS provides total groundwater use numbers for 'distributed water supply' which includes provision of water to both urban and agricultural uses. However, the ABS also provides a total groundwater volume figure for agriculture which includes groundwater from both 'self-extracted' and 'distributed water supply' sources. Therefore we have made an adjustment to 'distributed water supply' to ensure no double counting. This adjustment uses the proportion of total 'distributed groundwater' to 'total distributed use' and multiplies it by total 'agricultural distributed' use. For example, in 2010-11, total 'distributed groundwater' (453 GL) represented 6% of 'total distributed use' (7,106 GL). Therefore 6% of 'agricultural distributed water' (2,562 GL) was 164 GL. This 164 GL was then subtracted off the 453 GL, resulting in an urban water supply figure of 290 GL. This calculation was done for each of the three years and the average was taken (303 GL shown in Table 4.2).

### Other sectors

The approach for all four remaining sectors was to take total sector consumption and subtract distributed (or mains water) and reuse water.<sup>33</sup> This therefore equals the consumption component of 'self-extracted' water, as it takes out any 'in-stream' use which

<sup>33</sup> This was the same approach adopted by MJA 2012

is mainly surface water. We consider this to be a coarse assumption and is likely to overestimate groundwater volumes, as 'self-extracted' water does include other sources (such as rainwater tanks or surface water). However, in recognition of the fact that there is much groundwater use that is not monitored or recorded, it is likely to result in an overall conservative estimate of groundwater use in Australia.

**Table 4.2 Groundwater use volumes and assumptions**

Use category	Average volumes from 2008-09 to 2010-11		Assumption
	Total volume (ML)	Groundwater volume (ML)	
Agriculture	7,079,934	2,050,634	Actual volumes provided by ABS Water Account
Mining	511,879	410,615	Derived by taking total sector consumption and subtracting distributed (mains water) and reuse water. Therefore we have only included groundwater used as an input into production and not from mine dewatering.
Urban water supply	5,010,271	303,230	Actual volumes provided by ABS Water Account, minus agricultural water (assumed to be 4%, 8% and 6% of total agriculture water supply in 2008-09, 2009-10 and 2010-11 respectively)
Households	1,787,279	167,638	Derived by taking total sector consumption and subtracting distributed (mains water) and reuse water
Manufacturing and other industries	1,820,230	588,726	Derived by taking total sector consumption and subtracting distributed (mains water) and reuse water
<b>TOTAL</b>		<b>3,520,844</b>	

### 4.3 Contribution to GDP

Section 4.1 highlights the value of groundwater use to the users, grouped by the industries where the use occurs. These are the direct use values of groundwater.

These direct use values have flow on effects to other industries within the Australian economy. These flow on (or indirect) effects can be estimated through the use of economic multipliers. Multipliers measure the impact that a change in the level of economic activity in one industry has on other industries in the economy. The multipliers reflect that, when activity in one industry changes, so too does the demand for inputs from other industries. As such, those other industries are also affected. The extent of the relationship is estimated by the size of the multiplier.

Estimation of the multipliers here has been undertaken in an input-output (IO) framework using Australian Bureau of Statistics input-output tables, which report the inputs and outputs of specific sectors of the economy.<sup>34</sup>

Input-output tables quantify the intermediate flows between sectors – what each sector buys and sells to other sectors in production. These IO tables measure the direct economic activity of every sector in the economy at the national level. Importantly, they allow intermediate inputs to be further broken down by source. These detailed intermediate flows can be used to derive the total change in economic activity associated with a given direct change in activity for a given sector.

The multipliers used for each sector are provided in Table 4.3. The multipliers are ratio figures which represent the ratio between the total increase in the direct value across the economy as a function of the original increase in direct value in one industry. For example, a multiplier of 2 means that for every dollar of direct value, there is an additional dollar of value-add stimulated elsewhere in the economy, meaning that the total increase in value-add is \$2.

The overall change in value-add in the economy is measured through Gross Domestic Product (GDP), which is the commonly used measure of the ‘size of the economy’, and change in GDP the commonly used measure of economic growth.

**Table 4.3 Ratio applied to direct total value add for each sector**

Sector	Ratio of direct to total value add
Agriculture – All	2.00
Agriculture – Livestock only	2.08
Mining	1.45
Urban water supply	1.89
Households	NA
Manufacturing and other industries	2.00

## 4.4 Total value of production

The estimate of the ‘economic value’ of groundwater considers the next lowest cost alternative facing groundwater using industries if they were deprived of groundwater, and then determining the value add to the downstream economy of these sectors by applying

<sup>34</sup> Australian Bureau of Statistics, 5209.0.55.001 *Australian National Accounts: Input-Output Tables - 2008-09*

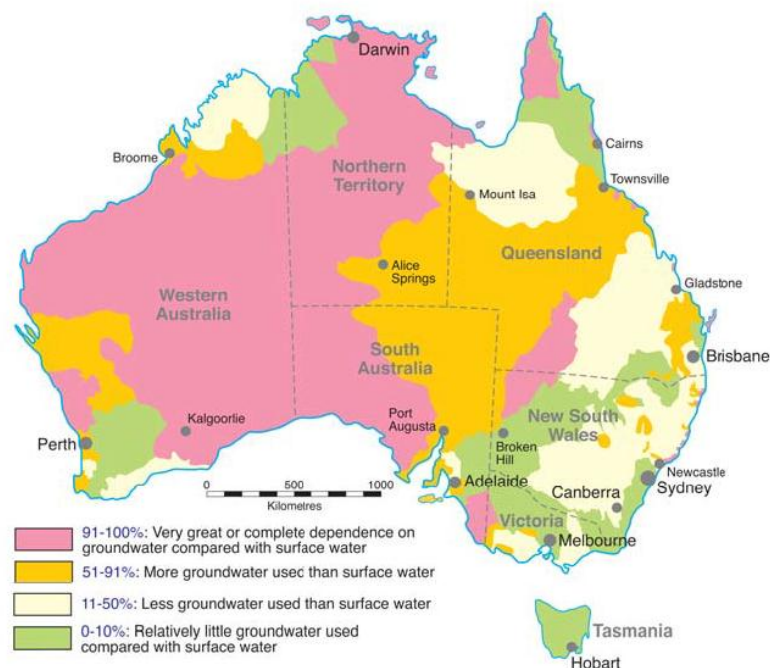


an economic multiplier. This recognises that the value-add of an input into production is not the same thing as the total value of that production<sup>35</sup>.

However, this concept of the 'total value of production' that groundwater supports is another useful economic metric to consider. To estimate this, we have focussed on those industries that appear to use groundwater as a significant input into production, where the production could not occur without groundwater. In defining the production of such industries, there were two considerations, as follows:

- The industry must use water as a significant input into production. Although all industries use water to some extent, we have focussed where the water is a key input into production, without which production is not likely to occur.
- The production from that industry must occur in areas where groundwater is the only water source. To calculate this, we have focussed on the economic activity that occurs within in the pink shaded area in Figure 4.1.

**Figure 4.1: Australia's reliance on groundwater**



Source: National Centre for Groundwater Research and Training, 2013

<sup>35</sup> In using this estimate of total value of production, however, the economic value cannot be fully ascribed to groundwater for several reasons, such as

- There are many other inputs that support production (such as capital, labour, energy, fertiliser etc.). All of these inputs into production 'support' production, which is why any one of the inputs (such as groundwater) cannot be ascribed the full value of production as its own unique contribution to an economic metric such as GDP, or GDP would be many times higher than what is actually is.
- The loss of any one input into production does not necessarily mean that all production ceases, because there are substitutes in production. Applied to groundwater, this means that an absence of groundwater in mining or agriculture doesn't mean that all mining or agriculture ceases. Some production at the margin may indeed cease, but in other cases other (more expensive) water sources may be used or water is substituted by some other input into production, or the production itself may relocate. The economic loss in these situations is the difference between the value of production with and without groundwater, not the total production that groundwater supports.

The production that occurs in the key water using industries and in the areas where groundwater is generally the only water source defines the production we consider to be 'dependant on groundwater'. This GIS based approach was used in all key groundwater using industries, except agricultural irrigation, where there is more reliable data to determine the value of production supported by groundwater (see below).

In short, our approach to determining the value of production that is groundwater-dependent included three steps:

1. Selecting the relevant industry sectors where water is an important input into production
2. Determining the relative proportion of these sectors (except irrigation) that fall within groundwater dependent areas of Australia using GIS mapping techniques
3. Using the sector proportions derived in step 2 to calculate the value of production that is groundwater-dependent.

These three steps are expanded further below.

#### **Selection of relevant industry sectors**

Our major consideration for selection of industry sectors was whether water was an important input into production. We therefore excluded sectors where water was for incidental use only (i.e. for common use purposes such as drinking, toilet flushing, showering, garden watering for aesthetic purposes etc.). Our assessment was informed by a combination of data sources such as the use volumes in the ABS *National Water Account*, water expenditure in the ABS *Australian National Accounts: Input-Output Tables* and further research. Our selected sectors are as follows:

- Agriculture – irrigation
- Agriculture – drinking water for stock use
- Mining, which includes only the sub-sectors of:

- Metal ore mining

This is the mining sector with the highest water usage. Water is used in transport of ore and waste in slurries and suspension, mineral separation, dust control/suppression, mine dewatering and truck washing<sup>36</sup>

- Coal mining

There is a material amount of water used per tonne of coal produced.<sup>37</sup> Water is used for dust control/suppression, mine dewatering, truck washing and coal processing.

- Manufacturing, which includes only the sub-sectors of:

- Food production
- Beverage production
- Petroleum and coal production
- Basic chemical and chemical production

<sup>36</sup> Prosser, I., Wolf, L. & Littleboy, A. 2011, *Water in mining and industry*, In: Prosser, I. (ed.), *Water: Science and Solutions for Australia*, CSIRO, Australia, p138

<sup>37</sup> For example, in 2012, Rio Tinto Australia used the following amounts of freshwater in their Queensland coal mines: Clermont Mine 108 litres per tonne; Hail Creek Mine 1031 litres per tonne; Kestrel Mine 402 litres per tonne.

- Primary metal and metal production
- Fabricated metal production

These manufacturing sectors were chosen because their production processes involved significant water usage as identified in the ABS *National Water Account* and ABS *National Accounts: Input-Output Tables*.

### Sector proportions dependent on groundwater

Using GIS software, we defined the pink shaded areas of the map in Figure 4.1 (to show which areas of Australia were 90-100% dependent on groundwater). The Statistical Local Areas level 2 (SA2s) from this pink shaded area were then calculated.

For each SA2 in the pink shaded area, the value of production for each selected commodity sector (outlined above) was estimated. In the case of agricultural livestock, there were direct regional production values that could be used. For the other sectors, we calculated the proportion of all employment in the industry that occurs in the pink areas, and then assumed that the same proportion holds for value of production as well. By aggregating up production estimates for all the SA2s in the groundwater dependant regions, the proportion of all national production that occurs in such regions could be calculated.

As noted previously, this GIS based mapping process was undertaken for all sectors except agricultural irrigation. In that case, it was not required to map production values, as aggregated data is available which shows the proportion of agricultural water coming from groundwater sources (29%).

### Value of production underpinned by groundwater

Using these sector proportions (i.e. % of the sector that is dependent on groundwater), we then determined the value of production for each sector in these groundwater dependent areas using the best available data sources for 'total value of production'. The proportions for each sector and associated data sources are provided in the table below.

Key inputs to economy wide results and data sources		
Sector	Proportion (%) of sector that is groundwater dependent	Total value of production
<b>Agriculture</b>		
Agriculture – Irrigation	<b>29%</b> (Derived from ABS <i>National Water Account 2010-11</i> . See also Table 4.2)	<b>\$12.9 billion</b> (ABS <i>National Water Account 2010-11</i> )
Agriculture – Drinking water for livestock	<b>7%</b> (Derived from GIS mapping for the <i>Livestock slaughtering and other disposals</i> sector)	<b>\$13.8 billion</b> (Gross value of 'Livestock slaughtering and other disposals' from ABS <i>Value of Agricultural Commodities Produced 2011-12</i> )
<b>Mining</b>		
Metal ore mining	<b>37.6%</b> (Derived from GIS mapping)	<b>\$65 billion</b> (ABS <i>Australian National Accounts: Input-Output Tables - 2008-09</i> )
Coal mining	<b>0.1%</b> (Derived from GIS mapping)	<b>\$62 billion</b> (ABS <i>Australian National Accounts:</i>

Key inputs to economy wide results and data sources		
Sector	Proportion (%) of sector that is groundwater dependent	Total value of production
		<i>Input-Output Tables - 2008-09</i>
<b>Manufacturing</b>		
Food production	<b>0.9%</b> <i>(Derived from GIS mapping)</i>	<b>\$68.8 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>
Beverage production	<b>1.6%</b> <i>(Derived from GIS mapping)</i>	<b>\$9.2 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>
Petroleum and coal production	<b>0.9%</b> <i>(Derived from GIS mapping)</i>	<b>\$28.6 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>
Basic chemical and chemical production	<b>1.2%</b> <i>(Derived from GIS mapping)</i>	<b>\$17.6 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>
Primary metal and metal production	<b>3.2%</b> <i>(Derived from GIS mapping)</i>	<b>\$99.2 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>
Fabricated metal production	<b>1.8%</b> <i>(Derived from GIS mapping)</i>	<b>\$6.8 billion</b> <i>(ABS Australian National Accounts: Input-Output Tables - 2008-09)</i>

## 5 Economy wide results

### 5.1 Economic use value of groundwater

Table 5.1 shows that, in aggregate, the use of approximately 3,500 GL of groundwater each year provides a direct value-add value of \$4.1 billion per annum. The direct value-add of these sectors also contribute to flow on effects to other industries. Accounting for this, the total economic contribution to GDP across the Australian economy is \$6.8 billion per annum.

The 'direct value-add value' and the 'economic contribution to GDP' are calculated from the central estimate of the direct value range, reflecting average long run historical figures. Therefore it is likely that in any given year (largely depending on surface water availability) the direct value add of groundwater would range, in aggregate, from \$1.8 – \$7.2 billion, while the total economic contribution of groundwater to GDP would range from \$3.0 – \$11.1 billion.

**Table 5.1 Total economic value of groundwater value to Australia**

Sector	Direct value range and central estimate (\$ per ML) <sup>1</sup>	Groundwater volumes (ML)	Direct value-add (\$m)	Ratio of direct to total value add	Total groundwater contribution to GDP (\$m)
Agriculture - irrigation	\$30-500 \$200	2,050,634	\$410	2.00	<b>\$820</b>
Agriculture - drinking water for livestock	– –	–	\$393	2.08	<b>\$818</b>
Mining	\$500 – 5,000 \$2,750	410,615	\$1,129	1.45	<b>\$1,637</b>
Urban water supply	\$1,000 – 3,000 \$2,000	303,230	\$606	1.89	<b>\$1,146</b>
Households	\$1,400 – 6,400 \$2,500	167,638	\$419	NA	<b>NA</b>
Manufacturing and other industries	\$1,000 – 3,000 \$2,000	588,726	\$1,177	2	<b>\$2,355</b>
<b>TOTAL</b>		<b>3,520,843</b>	<b>\$4,136</b>		<b>\$6,777</b>

Note: <sup>1</sup> Figures provided are broad estimates using data from a range of sources between the years of 2006 and 2012. Given the broad nature of estimates, we have not inflated the raw figures to present values. However we believe the range is representative of 2013 economic conditions.

### 5.2 Interpreting the economic use value

A central estimate of \$4.1 billion of direct value-add and an overall economic value add of \$6.8 billion to GDP represents an important input into the Australian economy, larger in direct value-add terms than discrete sectors of the economy such as, for example, forestry,

fishing, poultry, motion pictures, gambling and heritage, creative and performing arts.<sup>38</sup> Even so, this economic use value is only a partial value proposition, and there are several important considerations also relevant to the overall value proposition for groundwater.

### **A partial estimate of economic value**

The estimate in Table 5.1 represents a 'partial' (not a total) estimate of groundwater value in Australia. This is due to quantification of only groundwater that is physically extracted and consumptively used (through a bore or other means), and therefore does not capture the numerous 'non-extractive' or 'option' values. These are values that do not depend upon the groundwater being used. As noted earlier, the inability to quantify these values here means that the groundwater use values quantified here represents only a partial value proposition for groundwater overall.

An example of a 'non-extractive' groundwater use is forestry, because the water is not extracted by a bore or other means, but is used as mature trees draw groundwater through root systems that reach below the water table. Therefore without groundwater, this industry would be severely compromised. As an example of the potential value of groundwater for forestry, the expected profit for forestry and related sectors is \$0.74 billion for 2012-13.<sup>39</sup> Other key non-extractive uses include tourism, where groundwater supports natural environments which are tourist attractions or provide base flow to rivers which support recreation such as boating or fishing.

An example of an 'option' value for groundwater is in agriculture where farmers choose to plant a crop or invest in permanent horticulture (e.g. fruit trees) knowing that groundwater is available as a back-up water source should surface water become unavailable. In this way, groundwater acts as security and underpins investment in the same way as insurance can, even where the groundwater is not necessarily used.

### **Likelihood and potential for growth in groundwater value**

It is our view that the 'economic value' figures quoted in Table 5.1 are likely to grow substantially in the future for a number of reasons.

Firstly, as outlined in Chapter 1.3, there appears to be significant available capacity to increase the use of groundwater resources in an overall sense.<sup>40</sup> This is illustrated by the gap between the entitlements on issue at 6,544 GL and potential sustainable yield 29,173 GL.<sup>41</sup>

Secondly, there is projected to be an increase in economic activity in areas where there is ample groundwater resources, especially in northern Australia, which relates to increasing demand for food and other resources from Asia.<sup>42</sup> Northern Australia has limited surface water either due to low rainfall (inland areas), or because there are insufficient sites to

<sup>38</sup> Based on industry gross value added, 5209.0.55.001 Australian National Accounts: Input-Output Tables - 2008-09

<sup>39</sup> Aggregate profit figures collated from IBISWorld Industry Reports for *Forestry A0301* (February 2013); *Logging A0302* (March 2013); *Forestry support services A0510* (February 2013); and *Log Sawmilling C1411* (May 2013)

<sup>40</sup> There are obviously some areas that are using groundwater at full capacity

<sup>41</sup> National Land and Water Resources Assessment (NLWRA), 2001

<sup>42</sup> Commonwealth Government 2012, *Australia in the Asian Century White Paper*, October 2012

economically store (i.e. in dams) the highly seasonal surface water resources (i.e. pronounced wet and dry seasons). This means that groundwater will be an important, and in some cases the only, source of water.

Thirdly, surface water resources, in many areas, are either at capacity or over allocated, meaning any increased water demand will need to be sourced from alternative supplies. Groundwater is an obvious and reliable alternative supply.

A final consideration relevant to the future value of groundwater is that it is a renewable resource, so long as use remains below the sustainable yield. This means groundwater can continue to add economic value on a perpetual basis, unlike many of the non-renewable natural resources that the economy also depends upon, such as coal and old-growth forests.

### 5.3 Total value of production that is dependent on groundwater

Another way to look at the value of groundwater is the ‘total value of production’ that groundwater supports. Table 5.2 shows that, in aggregate, the total value of production of sectors in groundwater dependent areas of Australia is \$33.8 billion. Metal ore mining makes up 73% (or \$24.4 billion) of this total, which is not surprising given it is a large water user and is often undertaken in arid areas that are close to 100% groundwater dependent. Metal manufacturing is also a relatively large contributor with 10% (or \$3.2 billion) of the total, most likely reflecting manufacturing locations that are close to the metal mining source. Agriculture – irrigation is also a major contributor with 11% (or \$3.7 billion), which is a significant contribution showing 29% of water sourced for agriculture is from groundwater. Other manufacturing sectors contribute relatively small amounts to this total, reflecting that most locations are in urban areas which have a variety of water sources.

It is important to note that these figures are much higher than the ‘economic value’ provided in Table 5.1 as there are many other inputs that support production (such as capital, labour, energy, fertiliser etc.). Therefore groundwater cannot be ascribed the full value of production as its own unique contribution to the economy. In addition, the loss of any one input into production does not necessarily mean that all production ceases, but instead there may be production decreases at the margin, or other (more expensive) water sources may be used, or water is substituted by some other input into production, or the production itself may relocate. The economic loss in these situations is the difference between the value of production with and without groundwater, not the total production that groundwater supports.

**Table 5.2 Total value of production that is dependent on groundwater**

Sector	Proportion (%) of sector that is groundwater dependent	Total value of production (\$billion)	Total value of production dependent on groundwater (\$billion)
<b>Agriculture</b>			
Agriculture – Irrigation	29%	12.9	3.7

Sector	Proportion (%) of sector that is groundwater dependent	Total value of production (\$billion)	Total value of production dependent on groundwater (\$billion)
Agriculture – Drinking water for livestock	7%	13.8	1.0
<b>Mining</b>			
Metal ore mining	37.6%	65	24.4
Coal mining	0.1%	62	0.1
<b>Manufacturing</b>			
Food production	0.9%	68.8	0.6
Beverage production	1.6%	9.2	0.1
Petroleum and coal production	0.9%	28.6	0.2
Basic chemical and chemical production	1.2%	17.6	0.2
Primary metal and metal production	3.2%	99.2	3.2
Fabricated metal production	1.8%	6.8	0.1
<b>TOTAL</b>		<b>383.8</b>	<b>33.8</b>



# Appendix A – Summary of case studies

Paper	Scope/Description	Methodology	Results – per ML	Results – totals
<b>National and state estimates</b>				
Marsden Jacob Associates (MJA), 2012 <i>Assessing the value of Groundwater</i>	Assessment of economic value of GW for consumptive purposes, non-consumptive purposes and determining principles and guidelines for assessing the appropriate level and type of groundwater management resources	<p><b>Deprival method</b> applied to agriculture, mining, water supply, household and industry</p> <ul style="list-style-type: none"> <li>Mining next best alternative is pipeline ranging from \$500 - 5000/ML</li> <li>Agriculture historical value \$50-200/ML</li> <li>Water supply combination of next best inc. desalination, recycled water and pipelines, ranging from \$2000 – 4000/ML</li> <li>Households similar to water supply but higher range given next best alternative may be to conserve water (therefore a lower end of range) or pay water tanks or tankering (therefore higher end of range) \$1000 – 5000/ML</li> </ul> <p>Extrapolation to rest of Australia used volumes based on ABS national water accounts 2009-10</p> <p>Supported by 5 key case studies and referenced RMCG work (see below)</p>	<p>Agriculture \$50-200</p> <p>Mining \$500-5000</p> <p>Water supply \$2000-4000</p> <p>Household \$1000-5000</p> <p>Industry \$2000-4000</p>	<p><b>\$2.3 – 7 billion (Australia)</b></p> <p>Agriculture \$0.1-\$0.5bn</p> <p>Mining \$0.2-2.1bn</p> <p>Water supply \$0.6-1.3bn</p> <p>Household \$0.2-1bn</p> <p>Industry \$1.2-2.2bn</p>
RM Consulting Group (RMCG), 2008 <i>Groundwater economics study</i>	<p>Assessment of economic value of GW for consumptive purposes in Victoria within defined Groundwater Management Units (GMUs).</p> <p>Did not include non-consumptive use or 'unincorporated areas' or unused entitlements (in the total figure, although sleeper entitlements have been</p>	<p><b>Deprival method</b> applied to urban, industrial and stock and domestic (S&amp;D)</p> <ul style="list-style-type: none"> <li>Urban and industrial next best alternative was determined from Water Business' Water Plans 2008</li> <li>S&amp;D next best alternative was mobile desalination plants</li> </ul> <p><b>Residual value method</b> applied to irrigated agriculture (subtracting all costs associated with GW from revenue generated). Data sourced from gross margin publications.</p> <p>Extrapolation to the rest of GMU's and Victoria was based on usage volumes. These were collected from variety of sources including water businesses (urban), estimates (2ML per day registered bores for S&amp;D), State Water report (agriculture )</p> <p>Sensitivity analysis indicated that the total value (\$340 million) <b>could easily be</b></p>	<p>Irrigation \$110-590/ML/yr (res value)</p> <p>(Dep value)</p> <p>Industrial \$2500-4000</p> <p>Urban \$1200-6000</p> <p>Stock &amp; Domestic \$1132</p>	<p><b>\$340 million (Victoria)</b></p> <p>Irrigation \$102 million</p> <p>Industrial \$123 million</p> <p>Urban \$62 million</p> <p>Stock &amp; Domestic \$52 million</p>

Paper	Scope/Description	Methodology	Results – per ML	Results – totals
		<i>doubled</i> if different assumptions had been used in setting the unit economic values		
<b>Regional estimates</b>				
Case study: Gngangara (MJA, 2012)	<p>Gngangara groundwater system contains the Superficial, Mirrabooka, Leederville and Yarragadee aquifers. It stretches 220,000km<sup>2</sup> and underlies Perth's northern suburbs.</p> <p>Gngangara groundwater system supplies 35-50 per cent of Perth's drinking water</p>	<p>Two scenarios:</p> <ol style="list-style-type: none"> <li>Present value of extra 10-30 GL/year</li> <li>Present value of 100% reduction in groundwater</li> </ol> <p><b>Public water supply:</b> represents the LRMC of developing new sources to replace groundwater in today's dollars</p> <p><b>Industry</b> (defined as any productive use of groundwater by business outside of the agricultural sector):</p> <ul style="list-style-type: none"> <li>50% would source water from the IWSS (what's this) at \$1.80/kL</li> <li>25% of industry would introduce more water efficient practices or technology at \$3.00/kL</li> <li>25% would tanker water at \$10.00/kL</li> </ul> <p><b>Agriculture:</b></p> <ul style="list-style-type: none"> <li>Current average value of water traded is \$0.129/kL and gross margins estimated as:</li> <li>High value produce (eg. grapes) \$1.87/kL</li> <li>Medium value produce (eg. other fruit) \$0.88/kL</li> <li>Low value produce (vegetables) \$0.09/kL</li> </ul> <p><b>Domestic Bores:</b> \$1.80/kL to source usage from IWSS</p> <p><b>Parks and gardens:</b> \$1.80/kL (highest upper limit)</p>	<p>Public water supply: \$1800/ML</p> <p>Horticulture and agriculture \$900-1870/ML</p> <p>Domestic bores \$100-1800/ML</p> <p>Parks and gardens \$100-1800/ML</p> <p>Industry \$1800-10,000/ML</p>	<p>For Present value of 100% reduction</p> <p>Public water supply: \$4080 million</p> <p>Horticulture and agriculture \$378 million</p> <p>Domestic bores \$581 million</p> <p>Parks and gardens \$475 million</p> <p>Industry \$1038 million</p> <p>*Value of resource into perpetuity based on a 6% discount rate.</p>
Case study: Shepparton (MJA, 2012)	Shepparton Irrigation Region is located in the Murray Darling Basin. The region includes the Murray Valley, Shepparton, Central Goulburn and Rochester	<p><b>Deprival method</b> applied to dairy, horticulture and cropping activities</p> <p><b>Dairy</b> farmers assumed to pay for additional surface water supplies up to the value of \$100/ML. Beyond this value, they would purchase stockfeed</p> <p>Volume weighted average trade prices in greater Goulburn system used to inform industry's willingness to pay for water</p>	<p>Dairy: ceiling value of \$100/ML</p> <p>Horticulture and cropping activities: upper traded value of</p>	MJA suggest a lower limit of \$3 million per year and upper limit of \$11 million per year, based on average yearly consumption volumes

Paper	Scope/Description	Methodology	Results – per ML	Results – totals
	<p>irrigation areas and some adjacent dryland areas</p> <p>The region represents the largest irrigated agricultural area by volume in Victoria</p>		<p>\$750/ML in 2007 droughts</p> <p>lower traded value of \$25/ML in 2011 floods.</p> <p>Long run average over 2007-2011 approx \$290/ML</p>	and average long run trading price
<p>Case study: Daly River (NT)</p> <p>(MJA, 2012)</p>	<p>Daly River is a perennial river system and represents one of the most important ecosystems in the Northern Territory as it continues to flow throughout the dry season due to groundwater baseflows.</p> <p>Groundwater represents 90% of the NT's freshwater use</p>	<p><b>Deprival method</b> applied to water supply, agriculture, industry and stock and domestic</p> <p><b>Public water supply:</b> alternative to groundwater is to upgrade the Katherine water treatment plant</p> <p><b>Agriculture:</b> Use gross margins across agricultural produce (mangoes, cucurbits and field and fodder crops) because water trading markets are too thin to be informative</p> <p><b>Industrial water uses:</b> Assumed to be similar to agriculture</p> <p><b>Stock and domestic use:</b> Assume that without groundwater, 20% of users could access alternative water supplies at similar cost, whereas other users would use combination of rainwater tanks, water tanker deliveries and reduced water usage</p>	<p>Public water supply \$2600/ML</p> <p>Agriculture: \$452/ML</p> <p>Industrial uses: \$452/ML</p> <p>Stock and domestic \$4665/ML</p>	Total annual value estimated at \$22.1 million
<p>Case study: Lockyer Valley (S.E QLD)</p> <p>(MJA, 2012)</p>	<p>Circular basin stretching 2800km<sup>2</sup> that produces 30% of the Queensland's vegetables by value.</p> <p>The Lockyer Valley's main groundwater resources</p>	<p><b>Deprival method</b> applied to agriculture (Veggies, pastures, cereals, fruits and other crops)</p> <p>Assumed that if deprived of groundwater, irrigated area would be used for dryland farming of lucerne and cereals instead.</p> <p>Value of groundwater estimated as the difference between returns to irrigators</p>	<p>Annual value of irrigation using sustainable yield of 14 GL = \$10.9 million</p> <p>Annual value of dryland agriculture is \$2.5 million</p>	Net groundwater deprival value is \$8.4 million per year

Paper	Scope/Description	Methodology	Results – per ML	Results – totals
	supply approximately 80 per cent of irrigation water to the resident agricultural sector	achievable with groundwater irrigation and those achievable from the same land under dryland farming	Net groundwater deprival value is \$8.4 million/14000 ML = \$600/ML	
Case study: Northern Tasmania (MJA, 2012)	Focuses on agriculture in Tasmania’s three most northern catchments: <ul style="list-style-type: none"> <li>The Arthur Inglis-Cam region (16GL average annual extraction)</li> <li>The Mersey-Forth region (17 GL average annual extraction)</li> <li>The Piper-Ringarooma region (1 GL average annual extraction)</li> </ul>	<b>Deprival method</b> applied to agriculture (veggies, pasture (for dairy production), fruit, other,) and stock and domestic use  Assumed that in the absence of groundwater, most irrigated areas would convert to dryland farming	For vegetables: \$1000/ML  For other crops including poppies, pyrethrum and berries :\$1900/ML  Dairy – proposed average of \$600/ML	Total across all three catchments: \$20-68 million per year
Case study: Goonoo Goonoo Creek, Tamworth  NSW Office of Water (2010)	Assesses the economic value of groundwater from the Superficial Aquifer for irrigating lawns and gardens in the Perth metropolitan area	Examined change in the gross value of irrigated agriculture (Lucerne production) as a result of the groundwater access rules  Looked at an additional regional flow-on impact of a change in gross value of irrigated culture	Irrigated agriculture (Lucerne production): \$402/ML	\$1800 average annual decrease in the gross value of irrigated agriculture and additional regional flow on loss of \$3600
Case study: (CSIRO, 2007)	Assesses the economic value of groundwater from the Superficial Aquifer for	Calculated the annual benefit of bore water use, measured as saving in costs of having to use scheme water to irrigate green space	Value to decision maker  • Councils: \$500/ML	Value to decision maker  • Councils: \$20 million

Paper	Scope/Description	Methodology	Results – per ML	Results – totals
	irrigating lawns and gardens in the Perth metropolitan area		<ul style="list-style-type: none"> <li>• Other institutions: \$500/ML</li> <li>• Households: \$328.57/ML</li> </ul> Value to society <ul style="list-style-type: none"> <li>• Councils: \$900 /ML</li> <li>• Other institutions \$904.76/ML</li> <li>• Households: \$628.57/ML</li> </ul>	<ul style="list-style-type: none"> <li>• Other institutions: \$21 million</li> <li>• Households: \$23 million</li> </ul> Value to society <ul style="list-style-type: none"> <li>• Councils: \$36 million</li> <li>• Other institutions \$38 million</li> <li>• Households: \$44 million</li> </ul>

## Appendix B – Unit cost of alternative water sources

Source	\$ per kL (nominal \$)			
	Desalination	Recycling	Pipelines	Rainwater tanks
Hoang, M., et al 2009, <i>Desalination in Australia, CSIRO</i>	1.25 - 2.00			
Australian Water Association, 2007, <i>Water in Australia Facts and Figures, Myths and Ideas</i>	1.00 - 2.00	1.00-2.00	5.00 - 6.00	
Department of Water (WA) 2009, <i>Water efficiency, recycling and alternative supplies</i>	2.00 - 3.00	1.00-2.00		2.90-8.00
Economic Regulation Authority (WA) 2005, <i>Inquiry on the cost of supplying bulk potable water to Kalgoorlie-Boulder</i>	2.05 - 2.20		3.68	
Marsden Jacob Associates (MJA) 2012, <i>NWC Waterlines, Assessing the value of groundwater</i>	1.15 - 3.00	0.08-6.00	1.30 - 9.30	2.15 - 12.30
Deloitte analysis 2012	1.85			
Institute of Public Affairs 2008, <i>Water supply options for Melbourne, An examination of costs and availabilities of new water supply sources for Melbourne and other urban areas in Victoria</i>	3.01			2.00 - 6.00
Department of Natural Resources and Water 2007, <i>Direct connection pipeline – Burdekin to South East Queensland</i>	2.50 - 3.00			
Snowy Mountain Engineering Corporation 2007, <i>Integrated water supply options for North East New South Wales and South East Queensland</i>			0.81 - 6.78	
Department of Premier and Cabinet 2006, <i>Options for bringing water to Perth from the Kimberley, An independent Review</i>			5.1	
Department of Sustainability Environment Water Population and Communities 2010, <i>Water for the Future, Moving water long distances: Grand schemes or pipe dreams?</i>			5.00 - 6.00	
Mainstream Economics and Policy 2012, <i>Domestic rainwater tanks in Queensland: cost effectiveness and impacts on housing costs</i>	1.80 - 2.20	1.70 - 8.20		
<b>Range</b>	<b>1.00 - 3.01</b>	<b>0.08 - 8.20</b>	<b>0.81 - 9.30</b>	<b>2.00 - 12.30</b>

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