Water resource assessment for the Western Eromanga region

Summary of a report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment

Smerdon BD, Welsh WD, Marston FM and Ransley TR

21 December 2012
About the project

Since 2007, CSIRO has been undertaking groundbreaking scientific assessments of current and future water availability in major water systems across Australia through its Sustainable Yields projects. To date, rigorous assessments of the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources have been completed for the Murray-Darling Basin, northern Australia, south Australia and Western Australia and Tasmania.

The underlying aim has been to provide consistent water resource assessments to guide water policy and water resources planning.

Determinations of sustainable water resource development and allocations require choices by governments and communities about the balance of outcomes (environmental, economic and social) sought from water resource management and use. These choices are best made on the basis of sound scientific information, particularly a robust description of the extent, variability and nature of the water resource. Consistent with the previous Sustainable Yields projects, the Great Artesian Basin Water Resource Assessment (the Assessment) provides an analytical framework to assist water managers in the Great Artesian Basin (GAB) to meet National Water Initiative commitments.

> Salt encrusted Lake Eyre spring, South Australia (CSIRO)
Assessing groundwater resources in the Great Artesian Basin

Overview

The Great Artesian Basin (GAB) is Australia’s largest groundwater basin. It underlies and semi-arid regions and extends across one-fifth of Australia, across parts of Queensland, New South Wales, South Australia and the Northern Territory. The Great Artesian Basin Water Resource Assessment (the Assessment) outlines the current status of groundwater resources in the GAB and the potential impacts of climate change and resource development on those water resources. It focuses only on aquifers of the Jurassic and Cretaceous periods, which are present across the entire GAB. For reporting purposes, individual regions – generally aligned with geological basins – were defined: the Surat, Central Eromanga, Western Eromanga and Carpentaria regions. This report summarises the findings of the Assessment for the Western Eromanga region – detailed analysis is presented in the companion region report. Further reporting of the Assessment is covered by a range of products including four region reports that focus on the four reporting regions. In addition, there is a whole-of-GAB report. The region reports are summarised in 16-page summary reports for a general audience. Similarly, the whole-of-GAB report is summarised as a synthesis for a general audience. Four technical reports provide additional scientific detail underpinning the region reports. Other scientific outputs include a computer-coded groundwater flow model, data used and produced in the Assessment (housed at Geoscience Australia), and a three-dimensional (3D) visualisation of the GAB.

> Figure 1. Geographic extent of the Great Artesian Basin, selected overlying surface water drainage divisions and reporting regions of the Assessment
The Great Artesian Basin

The GAB is a complex groundwater entity that is difficult to visualise and challenging to describe. To help describe the GAB and improve knowledge of groundwater resources, this summary report uses technical terms that may be unfamiliar to many readers – definitions of these terms are provided on the back page.

The GAB is a groundwater basin made of rock layers that form aquifers (the permeable layers that readily transmit water) and aquitards (the confining layers that restrict groundwater flow). Because the GAB is defined as a groundwater basin, it encompasses several geological basins that were deposited at different times in Earth’s history, from 200 to 65 million years ago, in the Jurassic and Cretaceous periods. These geological basins sit atop deeper, older geological basins and, in turn, have newer surface drainage divisions situated on top of them (e.g. the Lake Eyre and Murray-Darling river basins). In this context – as a groundwater basin – the GAB is a vast groundwater entity stretching across one-fifth of Australia (Figure 1).

Groundwater resources in the GAB support environmentally significant springs and many economic activities including pastoral, agricultural, mining and extractive industries and inland population centres – and the demand for groundwater is growing. Properly managing these groundwater resources, for often competing interests, requires a better understanding of how the groundwater basin works. In addition to groundwater flow occurring in the aquifers and aquitards of the GAB, there are connections with geological formations underneath, on top of, and beside the GAB (Figure 2).

The Assessment investigated the latest geological and hydrogeological information and developed a comprehensive description of the GAB aquifers, including the geological history, structure of the rock layers, and three-dimensional (3D) visualisation of aquifers and aquitards. Groundwater flow models were used to assess the effects of future climate and groundwater development on water levels in the Cadna-owie – Hooray Aquifer, which is the main aquifer in the GAB, and potential impacts to groundwater-dependent ecosystems such as the GAB springs south-west of Lake Eyre.

> Figure 2. Three-dimensional illustration of a slice through geological basins, including the Eromanga Basin that hosts the Great Artesian Basin (GAB). This diagram shows aquifer layers of the GAB and underlying geological basins. Because the GAB is a groundwater entity, some of the GAB aquifers may be in contact with groundwater in underlying basins.
The Western Eromanga region

> Figure 3. The Western Eromanga region showing selected rivers, lakes and springs

- The climate of the region is arid, with highly intermittent rainfall.
- Groundwater in the region is only replenished by percolation from episodic flow events in the Finke and Plenty Rivers.

## Region facts and figures

### Geology

The extent of the Western Eromanga region aligns with the western margin of the Great Artesian Basin, the ridgeline of the Birdsville Track Ridge in the east (which extends approximately southward from Birdsville) and is limited in the south by the exposed (outcropping) older Proterozoic basement rocks of the Flinders and Willoran ranges. The basement rocks of the Denison and Davenport ranges (about 60 km west of Lake Eyre) puncture the Jurassic and Cretaceous formations. The region is very flat with the surface water drainage systems terminating in salt pans or salt lakes. The rivers and creeks originate in the elevated GAB margin.

### Climate

The climate of the Western Eromanga region is generally arid and it is often described as a ‘desert’ with average maximum temperatures of 36 to 39 °C in summer and 18 to 24 °C in winter. Rainfall tends to be associated with weak winter cold fronts and intermittent summer monsoons making for variable average annual measures across the region: ~160 mm/year although actual amounts may vary significantly both spatially and temporally.

### Groundwater use

Groundwater in the region supports environmentally significant springs and is primarily used for stock purposes; pastoralism is the main agricultural activity. Groundwater resources are managed by three jurisdictions (Northern Territory, Queensland, and South Australia), each having different legislation. Groundwater is extracted from GAB aquifers within the region to support copper and uranium mining that occurs at Olympic Dam – itself outside both the region and the GAB.

### History

Natural springs and wetlands of the GAB have played an important role in providing habitat for a range of species in the region. The springs have also been valued by Aboriginal people for thousands of years, as a water source of strong cultural and spiritual value. Early European explorers, including Edward John Eyre (in 1839) and John McDouall Stuart (in 1859), marvelled at springs and relied on these water supplies to journey into the interior of Australia. The first artesian bores tapped the GAB in the late 1870s and by 1910 there were over 850 artesian bores in the GAB.
Discharge springs

Discharge springs are points of natural discharge of groundwater at the ground surface that originate from the **artesian aquifers**. They vary from small vents to large mounds and can be surrounded by wetlands.

Clusters of springs tend to share similar water chemistry and be related to common geological features.

The way that discharge springs form is classified into four processes, which are shown in Figure 4. Water is forced upwards by artesian pressure. A permeable fault zone can provide a pathway to the ground surface, as can the permeable contact area where an aquifer abuts impermeable basement rocks. Where an artesian aquifer is close to the ground surface water can seep through over a broad area, or a river can erode surface sediments exposing the aquifer along a channel.

Most springs in the Western Eromanga region **discharge** water from GAB aquifers. However, recent research has shown that some springs in the region are discharging water through the GAB from deeper aquifers below the GAB and some springs in the Lake Eyre supergroup are **recharged** from the local **watertable**.

- **Springs provide a permanent source of water and so have great cultural and ecological significance.**
- **The persistence of springs over many thousands of years has allowed the development of distinct species, with some aquatic plants and animals confined to only one or a few springs.**
- **The springs hosting species that are not found elsewhere have a high ecological value.**
Figure 4. Conceptualisation of the structural linkage processes that form springs in the Great Artesian Basin ((a) to (c) developed by Queensland Department of Environment and Resource Management (DERM) in 2011; (d) adapted from DERM). Updated conceptual models are available online at <http://wetlandinfo.derm.qld.gov.au/wetlands/ScienceAndResearch/ConceptualModels.html>

(a) Geological structure type, where water flows upward through a fault

(b) Abutment type, where aquifers abut against an impermeable outcrop

(c) Thin confining type, where groundwater breaks through to the surface

(d) Surface depression type, where a creek line comes into contact with Great Artesian Basin aquifers
Modelling groundwater levels from 2010 to 2070

An existing large-scale groundwater model was used to estimate the impact of climate and development on groundwater levels in the GAB by 2070. The model – originally developed for the Great Artesian Basin Sustainability Initiative (GABSI) in 2006 – simulates groundwater levels in the Cadna-owie – Hooray Aquifer as a single layer spanning the GAB and does not include any of the geological complexities discovered by the Assessment. It is the only model to consider the main aquifers across the GAB and shown to represent the change in groundwater levels at such a large scale.

The modelling considered scenarios with different combinations of climate conditions and levels of groundwater development.

The modelling considered current (circa 2010) climate as well as three possibilities for future climate: a wet extreme, median and dry extreme future climate. In these three future possibilities, the rainfall and evaporation vary, which would result in different groundwater recharge rates in 2070. The groundwater recharge rates span between 66 percent lower than existing rates for the dry extreme future climate and 32 percent higher for the wet extreme future climate.

The modelling considered both current (circa 2010) and future levels of groundwater development, as represented by changing rates in groundwater extraction. In the Western Eromanga region, these future changes include a reduction in extraction due to bore rehabilitation under GABSI and continued development from the Olympic Dam borefield at the current rate. Future groundwater development from conventional petroleum wells and other extractive industries is assumed to be negligible.

Figure 5 shows the change in groundwater levels from 2010 to 2070 under the scenario with median future climate and current groundwater development. Under the future climate and current groundwater development, groundwater development from bores is 60 GL/year. Groundwater levels decrease across the majority of the region under all future climate scenarios. These results suggest that groundwater is extracted at a faster rate than it is replenished.

Figure 6 shows the change in groundwater levels from 2010 to 2070 under the median future climate and future groundwater development scenario. Under the future climate and future groundwater development scenario, groundwater development from bores is 59 GL/year. Under all scenarios of future climate and future groundwater development, groundwater levels decrease across the majority of the region. Assuming GABSI continues to completion, recovery of groundwater levels is minimal because only a small numbers of bores require rehabilitation.

The modelled estimates of groundwater levels are sensitive to rates of groundwater recharge and groundwater extraction.

As a result of intensive field research in South Australia, a new understanding of the hydrogeology has emerged recently for the Western Eromanga region. The results of the existing large-scale groundwater model used in the Assessment – shown on Figures 5 and 6 – do not incorporate this new information. These modelling results should be used for qualitative purposes only and for an estimation of potential trends in the future. Based on the new understanding and observations of recent groundwater levels, it is possible that changes in groundwater levels as predicted by the large-scale model may not eventuate across some parts of the Western Eromanga region.

> Figure 5. Change in groundwater levels from 2010 to 2070 under median future climate and the continuation of current development, where GABSI groundwater savings are concluded in 2010 level. The conservation rankings for spring complexes within each supergroup are used to establish risk to springs in the Great Artesian Basin. For example, spring complexes with a high ranking in an area of groundwater decline could be at greater risk.
Risks to Great Artesian Basin springs

Many ecosystems depend on groundwater from the GAB aquifers. These groundwater-dependent ecosystems (GDEs) range in size from small vents to large mounds and may be surrounded by wetlands. Spring complexes that are located in major regional clusters are referred to as supergroups, with thirteen supergroups found in the GAB and three in the Western Eromanga region.

The Assessment determined the likely risk and opportunity to springs in the GAB based on the modelled change in groundwater levels from 2010 to 2070 and the conservation value of the spring complexes. High risk means that loss of spring ecological values is highly likely due to a high likelihood that a spring complex would cease to flow. Low risk means loss of ecological values is unlikely. Assessment of impact considers both the likelihood of decline in groundwater level and likelihood of recovery of flow to a spring complex.

Under future climate and the current level of groundwater development (Figure 5), groundwater levels at nearly all of the spring complexes are likely to decline, particularly where high conservation value springs exist in the Dalhousie and Lake Eyre supergroups, with little likelihood of any spring complex recovery.

Under future climate and future groundwater development (Figure 6), groundwater levels at nearly all of the spring complexes in the south-west of the region are likely to decline, particularly where high conservation value springs exist in the Dalhousie and Lake Eyre supergroups, with little likelihood of any spring complex recovery. However, in the north-east, groundwater levels may possibly rise and springs in the Mulligan River supergroup may have opportunity for recovery.

• Within an aquifer, groundwater moves from areas where groundwater levels are higher to areas where groundwater levels are lower. Changes in climate – the amount of rainfall – lead to changes in groundwater level. Similarly, changes in groundwater extraction will lead to a change in groundwater level.

• Management of GAB groundwater relies on groundwater levels. The assessment of future conditions was made by considering different scenarios of the climate in 2070 and estimates of future groundwater extraction.

• Groundwater modelling provides an estimate of the future groundwater levels in the GAB, from which the risks to groundwater-dependent ecosystems were determined.

• The springs in the Mulligan River supergroup may have opportunity for recovery.

> Figure 6. Change in groundwater levels from 2010 to 2070 under median future climate and future levels of groundwater development. Under future development the GABSI program is run to full completion whereby all eligible uncontrolled artesian bores are controlled. Under future development the impact of the development of petroleum resources or coal seam gas is not considered. The conservation rankings for spring complexes within each supergroup are used to establish risk to springs in the Great Artesian Basin. For example, spring complexes with a high ranking in an area of groundwater decline could be at greater risk.
The Great Artesian Basin and deeper, older geological basins: critical connections

The sequence of Jurassic to Middle Cretaceous age sediments in the Western Eromanga region were deposited on top of older geological basins. It is these underlying basins that cause the GAB to have its structure and general shape.

The Triassic Simpson Basin is below the deepest part of the Eromanga Basin in the Western Eromanga region (Figure 7). Because the GAB is situated on top of these deeper geological basins, there are some locations where GAB aquifers are potentially connected to aquifers in the deeper basins. The potential for hydraulic connection is greatest in the south-west of the Western Eromanga region (Figure 8).

> Figure 7. Depth of rock layers in the Great Artesian Basin and outline of deeper, older geological basins
• There exists the potential for hydraulic connectivity at the boundary of aquifers at the base of the GAB and the underlying aquifers, partial aquifers and leaky aquitards that form the upper sequences of the deeper, older geological basins.

• In the areas where aquifers at the base of the GAB are connected, there may be groundwater moving from one basin to another.

Figure 8. Potential areas of hydraulic connection between the base of the Great Artesian Basin and underlying basement sequences in the Western Eromanga region

Note: map does not imply connection above formations at the base of the GAB
Measuring groundwater levels: the change since 1900

Groundwater levels have been measured in the GAB since the early 1900s. Now, for the first time, groundwater levels at 20-year intervals have been mapped for the Cadna-owie – Hooray Aquifer for the period 1900 to 2010. These maps show changes in the measured groundwater levels from early development (circa 1900) (Figure 9) to the present day (circa 2010) (Figure 10).

Creating maps of groundwater levels relies on the spatial distribution of water bores and the number of water bores measured. Most water bores in the Western Eromanga region are located in the south and south-west of the region, and there are very few bores in the north and north-eastern parts of the region.

Groundwater levels in the Western Eromanga region are highest on the western margin of the region south of the border between the Northern Territory and South Australia, where the aquifers are exposed near the intake beds. Groundwater levels diminish towards Lake Eyre and are lowest south of Lake Eyre.

The presence of faults may create barriers for flowing groundwater, which can influence maps of groundwater levels.

> Figure 9. Map of groundwater levels for early development (circa 1900 to 1920). Values are expressed as an elevation (mAHD). Note: the faults shown in this figure have been re-mapped by the South Australian Department of Environment, Water and Natural Resources. However, the updated fault map was not available when groundwater levels were mapped.

> Figure 10. Map of groundwater levels for present day (circa 2000 to 2010). Values are expressed as an elevation (mAHD). Note: the faults shown in this figure have been re-mapped by the South Australian Department of Environment, Water and Natural Resources. However, the updated fault map was not available when groundwater levels were mapped.
The differences between groundwater levels measured at specific bores provide an opportunity to plot a map of change (Figure 11). From 1900 to 2010, groundwater levels are fairly stable, with only a slight decline in the east.

Groundwater levels are fairly stable across the region since the early 1900s. Geological faulting causes breaks in maps of the groundwater level. Groundwater level recovery can be seen in some water bores.

> Lake Eyre South Australia (CSIRO)

> Figure 11. Difference in groundwater levels between 1900 and 2010. The graphs illustrate groundwater level measured at a bore in an area of declining levels and an area with consistent levels. Values are expressed as an elevation (mAHD)
Groundwater and rivers

Water moves between rivers and groundwater in both directions. Some rivers rely on groundwater as a water source, which is referred to as baseflow. This occurs where the watertable is higher than the river, so the groundwater moves from the ground into the river.

In other rivers the opposite occurs: the watertable is lower than the river, so the river water moves into the ground.

Interactions between groundwater and rivers in the Western Eromanga region are generally limited to the intake beds.

Figure 12 shows the approximate watertable elevation for the Western Eromanga region. The shape of the watertable contours is similar to a topographic map. Groundwater will flow from higher watertable elevations toward lower watertable elevations. Mapping the watertable elevation in the vicinity of river channels reveals how the groundwater interacts with river water, which is shown for the Finke River Figure 12.

> Figure 12. Map of the approximate watertable elevation, defined as the shallowest groundwater in the uppermost geological formations. A watertable mound stretching from the GAB margin along the Finke River and which seems to be contributing to the groundwater discharging at Dalhousie Springs, is also detailed. Values are expressed as an elevation (mAHĐ).

Note: to show greater detail, the area of interest uses a different range in the scale of the water table elevation.
A water budget describes the amount of groundwater inflow and outflow. For a complex groundwater system – such as the GAB – there could be several different components for inflow and outflow. There is a degree of uncertainty about each component of the water budget. This can lead to a range of values – that have either been determined from a single method (having a range of uncertainty) or from using the findings from different studies. In addition to these recharge processes, the Cadna-owie – Hooray Aquifer and equivalents of the Western Eromanga region are also replenished by groundwater inflow from the neighbouring Central Eromanga region. The known water budget components for the Cadna-owie – Hooray Aquifer, which is the main aquifer in the GAB, are shown in the table below. Although not all values are known for certain, the water budget components indicate outflows are greater than inflows for the region.

### Groundwater Recharge
- Occurs through the intake beds located on the western slopes of the Great Dividing Range.
- Inflow rates are estimated by a method called the chloride-mass-balance using groundwater data or from the results of groundwater modelling.
- Estimates vary from 7 GL/year (previous studies) to 40 GL/year (this Assessment – the large-scale groundwater model described on page 6).

### Spring Discharge
- Naturally occurring groundwater discharge at the ground surface.
- Measured rates of spring flow are known for some individual springs that have been studied, but not all springs in the region.
- Estimates vary from 9 GL/year to 24 GL/year based on previous studies undertaken during the 1980s.

### Bore Extraction
- The combination of free or controlled artesian flow and pumped extraction from water bores drilled into the aquifers.
- Measured rates of bore extraction are not known for all bores in the region.
- Estimated to vary from 60 GL/year (this Assessment – the large-scale groundwater model described on page 6) to 83 GL/year (previous study).

### Diffuse Discharge
- Slow vertical leakage from the aquifers upwards to the regional watertable. In some locations, leakage may be enhanced by the presence of preferential pathways – such as faults.
- Estimated by a method using Darcy’s Law assuming that preferential pathways cover a varying amount of the region.
- Estimated to be 37 GL/year assuming that 5 percent of the region has preferential pathways, 72 GL/year assuming that 10 percent of the region has preferential pathways, and 109 GL/year assuming that 15 percent of the region has preferential pathways. The exact amount of preferential pathways is unknown.

### So what does it all mean?

**The Assessment modelling shows that future climate conditions are more likely to affect groundwater levels than future groundwater development.**

- Groundwater extraction in the south-eastern part of the region is likely to exceed recharge, which could lead to decreased groundwater levels and a diminishing water resource.
- Under all future scenarios of climate and development, springs in the Dalhousie and Lake Eyre supergroups are at risk of decreased flows with little likelihood of recovery. However, although all springs in the Mulligan River supergroup will decline under current (circa 2010) levels of development, groundwater levels may possibly rise under future development and some springs in the Mulligan River supergroup may recover.

**Rates of groundwater recharge are very low.**

- Groundwater is recharged by water from ephemeral rivers seeping through the river beds to the intake beds. The rivers are fed by rainfall, but annual rainfall is low and river flow events are highly episodic.
- Recharge rates are low and are much less than in the past. Water stored in aquifers in the western margin of the region is a legacy from higher recharge rates during wetter periods in the geological past.

**The GAB is vast and detailed information is very sparse, clustered in only a few areas.**

- Groundwater level data are not currently measured at regular intervals or available for sufficiently long terms to accurately monitor groundwater conditions.
- Ecological and hydrological (including water quality) data are not uniformly available for GAB springs. Accurate location and elevation measurements are needed to assess the potential impacts from changes in groundwater level.
Understanding groundwater

Basic terms and concepts

Aquifer: a permeable geological material that can transmit significant quantities of water to a bore, spring, or surface water body. Generally, ‘significant’ is defined based on human need, rather than on an absolute standard.

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For further information:

Water for a Healthy Country Flagship:
Brian Smerdon
Phone: (08) 8303 8720
Email: Brian.Smerdon@csiro.au

Contact Us
Phone: 1300 363 400
+61 3 9545 2176
Email: enquiries@csiro.au
Web: www.csiro.au/flagships

CSIRO and the Flagships program

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