Chapter 6 – Groundwater in the Great Artesian Basin

6.1. LOCATION AND EXTENT

The Great Artesian Basin (GAB) is Australia's largest artesian groundwater basin (Figure 6.1). Underlying an area of approximately 1.7 million km^2, the GAB extends beneath much of the arid and semi-arid interior of Queensland, New South Wales, South Australia and the Northern Territory, extending to sub-surface depths of up to 3,000 metres (Figure 6.2). The GAB consists of a multi-layered, confined aquifer system developed in continental quartzose sandstone formations deposited during the Mesozoic era (225–65 million years ago) (Habermehl, 1980).

The GAB comprises the Eromanga, Surat and Carpentaria sedimentary basins and parts of the Bowen and Galilee Basins (Figure 6.2). The hydrostratigraphic units, i.e., aquifers and confining beds, generally correlate across the basin and are mostly identical to the lithostratigraphic (rock) units. Sandstone units that form the GAB aquifers commonly contain minor inter-bedded siltstone and mudstone facies that are relatively impermeable and have a variable distribution (Radke et al., 2000). Some aquifers in the GAB are up to 400 m thick, although average thicknesses are ~150–200 m for the main aquifers.

Located in the southern-most part of the Eromanga sedimentary basin, the Project study area encompasses about 8,000 km^2 of the GAB, within the Lake Frome Embayment. In this area the sedimentary formations of the GAB overlie basement rocks of the Early Palaeozoic Kanmantoo Fold Belt (Hawke and Cramsie, 1984). The basement rocks outcrop to the north of the study area and form part of a regional structural feature known as the Tibooburra Ridge.

6.2. AQUIFERS

The Eromanga Sedimentary Basin consists of a conformable, almost horizontal bedded sequence of Early Jurassic to Late Cretaceous sedimentary rocks. The sequence comprises continental quartz-rich sandstone, siltstone and mudstone units formed within a shallow marine setting during the Early Cretaceous. These rocks conformably overlie sandstone-dominated formations deposited in lacustrine and fluvial environments of the Late Cretaceous (Habermehl, 1980). The Eromanga Basin sequence thins towards the southern boundary of the GAB, commonly wedging-out against relatively shallow basement rocks associated with major structural zones such as the Tibooburra Ridge.

The most significant groundwater systems in the GAB occur in the Late Jurassic to Early Cretaceous aquifer sequence, collectively termed the Cadna-owie–Hooray Aquifer. The Cadna-owie–Hooray Aquifer extends across the entire GAB, although its thickness and hydraulic properties may vary. This important groundwater-bearing unit is a composite of several aquifers that hydraulically interconnect over basement highs, and merge in the western Eromanga Basin (Radke et al., 2000). Equivalent aquifers to the Cadna-owie Formation and Hooray Sandstone include the Algebuckina Sandstone in the western Eromanga Basin, the Gilbert River Formation in the Carpentaria Basin and the Mooga, Gubberamunda and Pilliga Sandstones in the Surat Basin (Figure 6.1).

The GAB also comprises several relatively shallow aquifer systems within the Winton and Mackunda Formations. These aquifers are mainly sub-artesian and contain groundwater resources of variable quality and quantity, with brackish to saline water most abundant and suitable only for stock watering (Senior et al., 1978). Approximately 30,000 bores tap the aquifers of the Winton–Mackunda Formation, reaching depths of up to several hundred metres (Habermehl and Lau, 1997).

In many parts of the GAB the Mesozoic units are concealed by Cenozoic continental sediments and sedimentary rocks, varying in thickness from tens of meters up to 150 meters. Aeolian sediments dominate in western parts of the Eromanga Basin, forming the extensive dune fields of the Simpson Desert.

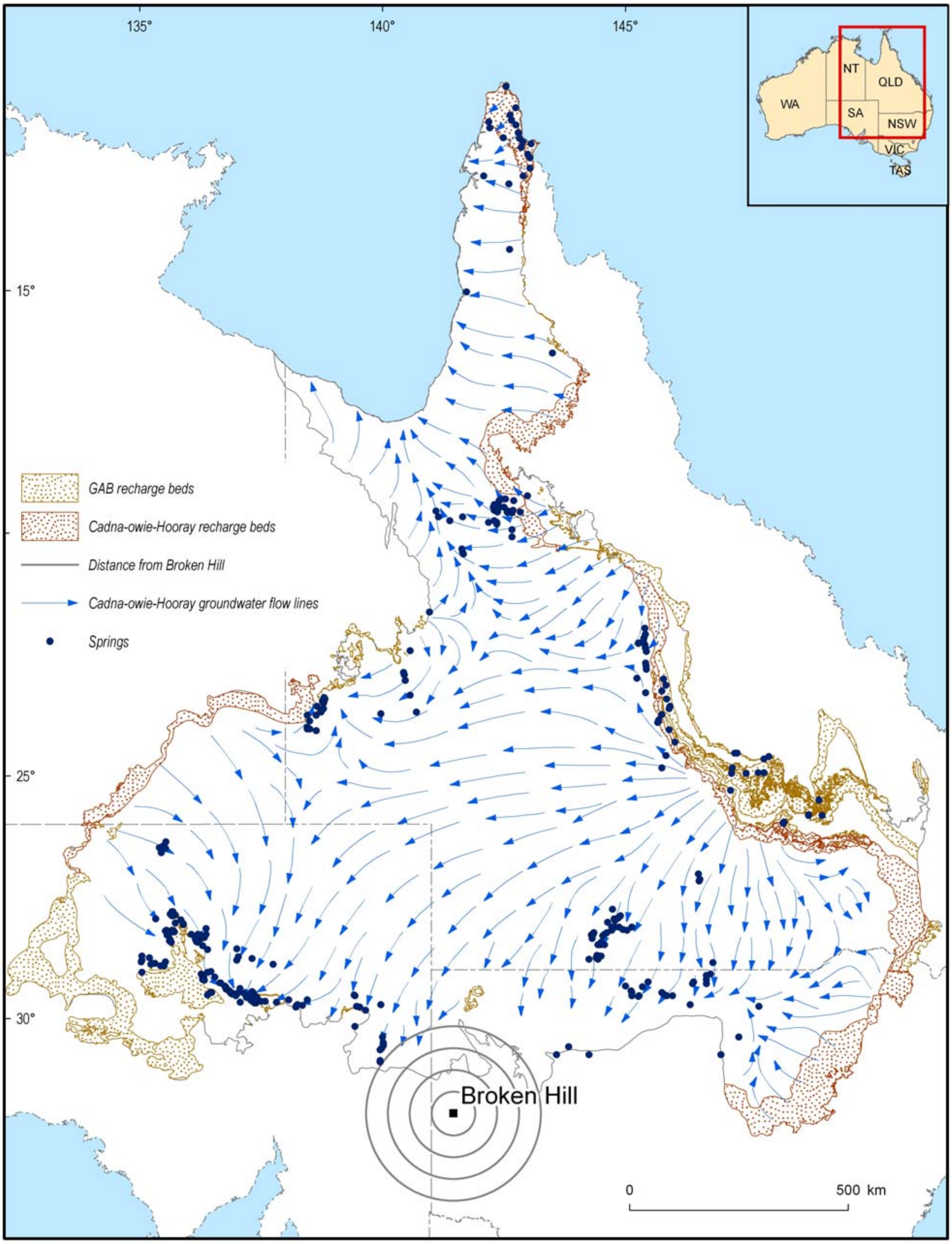

Figure 6.1: *Map of the Great Artesian Basin (GAB), showing the distribution of recharge beds at the basin margins, and the general direction of groundwater flow in different areas. The southern-most extent of the GAB is just over 100 km to the north of Broken Hill, and well away from any recharge areas (after Radke et al., 2000).*

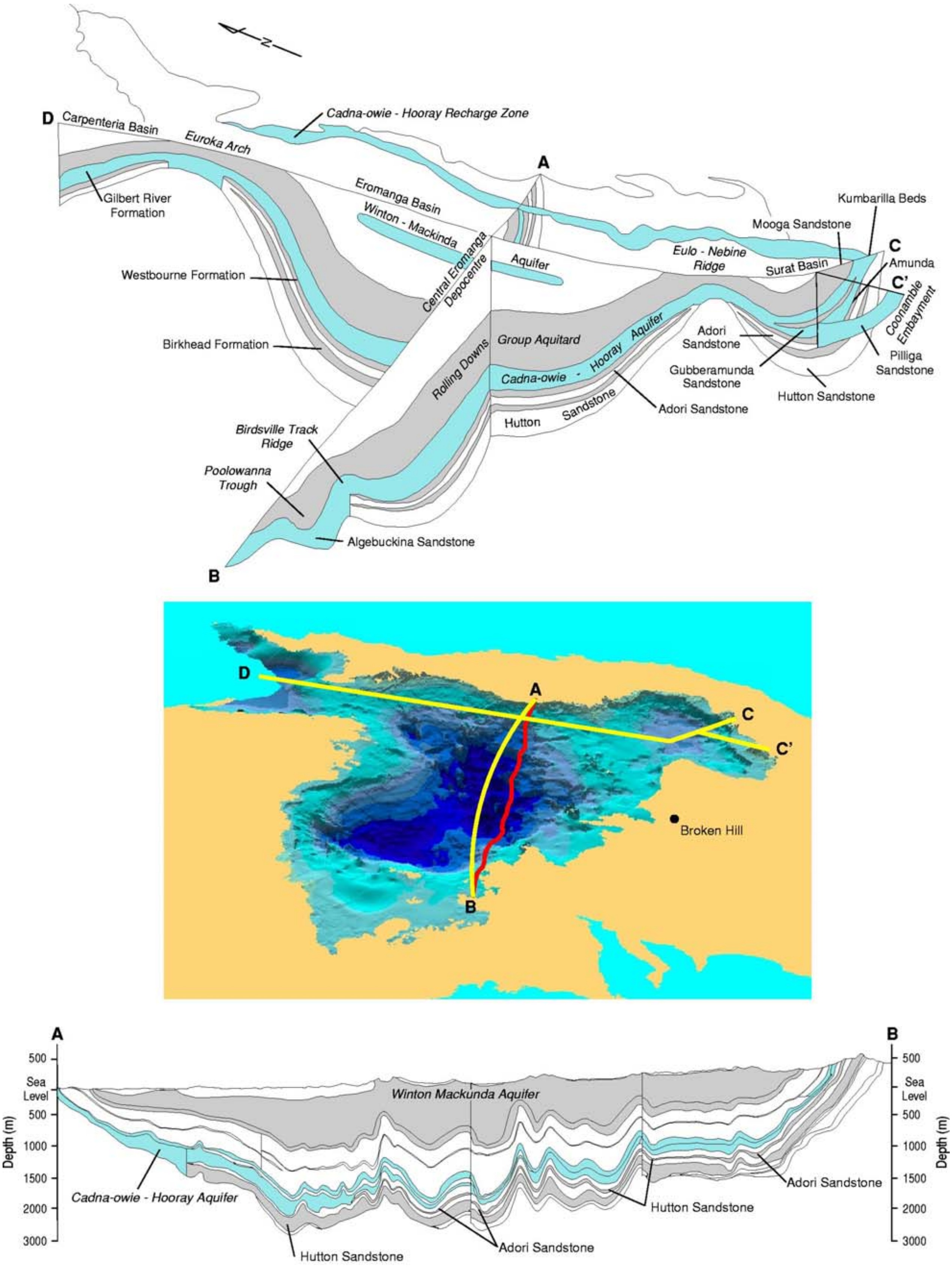

Figure 6.2: *Composite schematic map and cross-sections of the Great Artesian Basin (GAB), showing the distribution of the basin and variations in thickness of the sedimentary rocks. The main aquifer system is shown in the upper and lower sections as a continuous blue-green layer across the basin. The pale blue-green areas on the central map depict relatively thin sedimentary sequences, whereas the dark blue area is the thickest part of the basin (after Radke et al., 2000).*

6.3. GEOLOGICAL CONTEXT

Although there is little direct evidence (e.g., from drilling records) on the nature of the GAB stratigraphic profile in the study area, the thickness of the Cadna-owie–Hooray Aquifer across the Basin was estimated by Welsh (2006) for a transient groundwater model (Figure 6.3). The isopach map produced by Welsh (2006) indicates aquifer thicknesses of about 40–50 m at the 150 km boundary from Broken Hill, thinning significantly towards the southern boundary of the GAB (~100 km from Broken Hill).

Limited stratigraphic information about the GAB sequence in the study area is available from a petroleum exploration well, Bancannia North-1, which drilled the southern extension of the Lake Frome Embayment over the Bancannia Trough (Figure 6.3). At a depth of 123 metres, Bancannia North-1 intersected about 280 metres of sedimentary rock interpreted as part of the Early Cretaceous GAB sedimentary package. Overlying these rocks was a sequence of unconsolidated Cenozoic sediments consisting of unconsolidated sand, silt and clay.

The Early Cretaceous rocks in Bancannia North-1 were interpreted as two main units:

1. The upper sequence (first intersected at 123 metres depth); consisting of siltstone grading to mudstone, and minor inter-bedded sandstone and limestone horizons; totalling about 220 metres; and
2. The lower sequence (intersected at 343 m); consisting of grey, mostly medium- to coarse-grained sandstone interbedded with shale and minor limestone and coal lenses; totalling about 57 metres.

Interpretations of the lower sequence based on the lithological data suggests that this package of sedimentary rocks may represent the Early Cretaceous Cadna-owie–Hooray aquifer. Directly underlying the Early Cretaceous rocks are Upper Devonian to Carboniferous sedimentary formations which commonly form the basement to the GAB. This indicates that the Early Jurassic and Triassic part of the lower GAB sequence may be absent from the study area.

The drilled thickness of the interpreted Early Cretaceous sequence in Bancannia North-1 unit is slightly greater than that estimated by Welsh (2006). This discrepancy may indicate that aquifer thickness was underestimated by Welsh (2006) across the study area, or that localised aquifer thickness variations occur in some parts of the Bancannia Trough. Either way, both sources of evidence indicate that the main GAB aquifers thin towards the basin margins within the study area, although they are relatively thick when compared with other aquifer systems investigated as part of this assessment.

6.4. GROUNDWATER PROCESSES

6.4.1. Groundwater Recharge

Groundwater recharge occurs mainly along the eastern margins of the GAB where the main sandstone aquifers outcrop in upland areas which experience high rates of precipitation. Recharge occurs via direct infiltration of rainfall into the sedimentary package, with additional contributions by leakage through surficial sediments overlying the aquifers, leakage from intersecting rivers and alluvial groundwater systems and, in some areas, infiltration through overlying aquitards. The eastern recharge area follows the course of the Great Dividing Range, extending from Dubbo in the south to Cape York in the North (Figure 6.1).

Recharge also occurs along parts of the arid north-western and western boundary of the basin. Recharge events here are more episodic and involve considerably lower volumes than the eastern recharge area, reflecting the lower rainfall and climatic variability

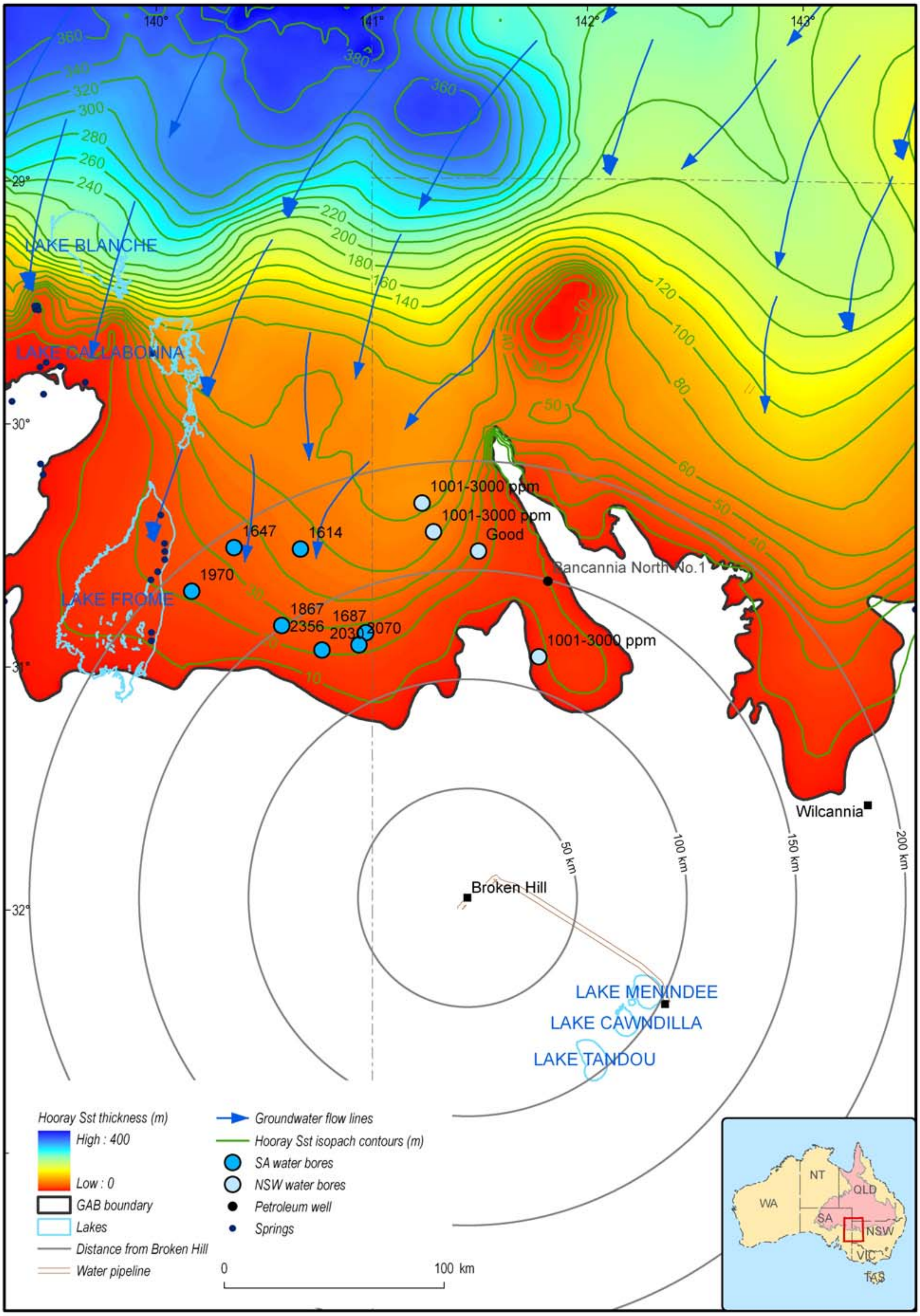

Figure 6.3: *Estimated thickness variations of the Cadna-owie–Hooray Aquifer in the Broken Hill Region, showing groundwater salinity levels (qualitative in NSW and quantitative in SA) from deep bores within 200 km of Broken Hill (after Welsh, 2006)..*

6.4.2. Groundwater Flow

The regional groundwater flow direction in the Cadna-owie–Hooray Aquifer may be inferred from hydraulic gradients derived from the basin-wide potentiometric surface of Radke et al., 2000 (Figure 6.1). Groundwater flow is generally directed towards the west–south-west from the eastern recharge area, and towards the east –south-east from the western recharge area (and in some cases to the north). Flow velocities vary from 1–5 m/yr between the eastern and western margins of the basin (Habermehl and Lau, 1997).

Using the interpretation of Radke et al. (2000), the Broken Hill study area coincides with a stagnant zone of very low groundwater flow in the GAB, estimated at < 0.3 m/yr. Groundwater flow in this region is towards the south-west (Figure 6.3). The rate and trend of the regional groundwater flow pattern suggests that groundwater in the study area is moving very slowly towards an ultimate discharge zone in the vicinity of Lake Frome.

6.4.3. Groundwater Discharge

Natural discharge occurs within the GAB as outflow from springs, diffuse vertical discharge through confining beds to the regional watertable and sub-surface discharge to neighbouring sedimentary basins. Outflow from springs is commonly associated with geo-structural features such as faults and shear zones, which allow upward flow of groundwater, and the abutment of aquifers against impervious basement rocks. Most springs in the south-western region of the Eromanga Basin occur at the intersection of basement faults.

Habermehl (1980) identified 12 major spring groups in the Basin, one of which – the Lake Frome Group – is located approximately 180 km to the north-west of Broken Hill. Spring discharge rates are generally low and range from 1 L/s to approximately 150 L/s at Dalhousie Springs in South Australia (Cox and Barron, 1998). The natural springs of the GAB are groundwater-dependent ecosystems and important environmental assets protected under the Australian Government's Environmental Protection and Biodiversity Conservation Act (1999). The long-term survival of the GAB springs depends on sound management of the overall groundwater resource, such that any new major groundwater extraction plan would need to carefully consider potential impacts on affected springs.

6.5. GROUNDWATER QUALITY

The study area is part of a very low flow area typified by groundwater which predominantly contains Na-Cl-SO_4 and Na-Ca-Cl-SO_4 ions. This contrasts with the Na-HCO_3-Cl type groundwater discharging from the eastern Eromanga Basin. These groundwater compositions are superimposed on a general trend where salinity increases away from the recharge area, along the potentiometric gradient.

The salinity of groundwater resources tapped by existing artesian bores within the study area ranges from 1,000–10,000 mg/L, although most are <3,000 mg/L (total dissolved solids or TDS) (Table 6.1). Salinity levels increase toward the boundaries of the GAB, consistent with the basin-wide salinity trend.

6.6. AQUIFER CHARACTERISTICS

Pressure testing of bores in the main aquifers of the western Eromanga Basin showed that aquifer transmissivity is generally low, mostly <30 m^2/day[5]. Aquifer transmissivity is lowest around basement highs, where the Hooray Sandstone is relatively thin (or absent) and the Cadna-owie Formation is the main source of groundwater (Hawke and Cramsie, 1984). Transmissivity within the study area is thus likely to be <30 m^2/day, decreasing towards the GAB's southern boundary due to the thinning aquifer sequence (towards the southern boundary of the GAB).

Hillier and Foster (2002) estimated the total volume of water stored across the GAB in the main Jurassic aquifers at 64,900 million megalitres. In addition, a substantial volume of groundwater (unquantified) also occurs within the Cretaceous sequences and the deeper Triassic sandstone units. However, the

[5] Based on sparse information collected by the New South Wales Geological Survey during the mid-1970's.

available volume of groundwater in the Broken Hill study area is interpreted to be low due to the relatively thin sedimentary sequence and the low aquifer transmissivity.

6.7. STATISTICAL ANALYSIS OF GAB BORES IN THE BROKEN HILL REGION

6.7.1. Deep Bores

Within the Broken Hill study area four deep groundwater bores are interpreted to tap the more productive (lower) portion of the Early Cretaceous GAB aquifer system. Three of these bores occur in South Australia (one of which has been abandoned), and one within New South Wales (Table 6.1). These artesian bores have variable (although low) yields and brackish quality water (<3,000 mg/L).

Table 6.1: Summary data for GAB groundwater bores in the Broken Hill region.

BORE ID	BORE NAME	LOCATION	TOTAL DEPTH (M)	SALINITY (TDS - MG/L)	YIELD L/SEC	SWL (M)
7036-150	Kidman 1A	SA	238	1,687	1.5	-1.38
7036-8	Kidman's Bore No. 1 (Abandoned)	SA	258	2,070	not recorded	not recorded
7036-7	Kidman's Bore No. 2	SA	177	2,030	0.0062	-1
GW003829	Sandy Creek Bore	NSW	207	1,000 – 3,000 (qualitative)	not recorded	not recorded

6.7.2. Shallow Bores

In the GAB portion of the study area there are about 40 shallow groundwater bores (<150 m deep). Most of these bores are interpreted to tap the less productive (upper) portion of the Early Cretaceous aquifers, or parts of the overlying Cenozoic sequence. Four deeper bores in NSW (>150 m) are close to the southern boundary of the GAB and most likely have drilled through and into the underlying basement rocks.

Qualitative salinity data indicates that most bores are saline and only suitable for stock use. For example, shallow groundwater from a South Australian bore had measured TDS of 5,455 mg/L, significantly higher than the adjacent and deeper bores into the GAB (Table 6.1).

6.8. GROUNDWATER USE AND MANAGEMENT

The GAB was first used as a groundwater resource in the late 1880's, and since that time about 4,700 flowing artesian bores have been drilled across the basin. Most bores tap the Early Cretaceous to Late Jurassic aquifers, as they generally represent the shallowest and highest quality flowing artesian water resource. The reduction in groundwater pressure over time has resulted in almost 1,400 bores ceasing flow. Additionally, some areas of the GAB have a regional pressure drawdown in excess of 100 m.

Management of groundwater resources in the GAB is controlled by multiple legislative arrangements specific to each of the GAB states. In the context of this study, the following policies are relevant:

6.8.1. NSW GAB Water Allocation Policy

Under the terms of the NSW GAB Water Sharing Plan 30 % of water saved under the bore 'Cap-and-Pipe' program is available for reallocation to new users. Since 1990 the total amount of water saved across the NSW GAB has averaged 50,000 ML/yr; thus, a volume of 10,000–15,000 ML/yr is potentially available for the NSW portion of the GAB.

6.8.2. SA GAB Water Allocation Policy

Management of GAB resources in South Australia is based on groundwater pressure, i.e., allocation of water resources depends on the impact that extraction has on the potentiometric surface of the Cadna-owie–Algebuckina Aquifer at the boundary of the South-west Springs Zone. The relevant sections of the South Australian draft Water Allocation Plan which relates to allocations from the GAB ‘Central Zone’ (Section 6.2) (and are thus applicable to groundwater extraction from the study area) states:

“20. Water shall not be allocated where the taking and use of water shall cause, or be likely to cause, a cumulative drawdown in excess of 1 m on the potentiometric surface of the Cadna-owie–Algebuckina Aquifer at the boundary with the South-west Springs Zone.”

“21. Despite principle 20, where the taking of water from a proposed new well(s) results in a predicted cumulative drawdown greater than 1 m on the potentiometric surface of the Cadna-owie–Algebuckina Aquifer, at the boundary with the Southwest Springs Zone, water may be allocated and used from that well if an Environmental Impact Report has been prepared demonstrating, to the satisfaction of the Minister, that this activity shall not have an unacceptable impact on the ecology of springs that may be located within the underground water zone of influence around that well. Such water allocated shall only be used in accordance with specific conditions relevant to the findings of that assessment.”

Large-scale groundwater extractions as part of any new urban supply scheme from Broken Hill (if sourced from the GAB) would thus need to satisfy the legislative requirements of the relevant South Australian and New South Wales water management plans.

6.8.3. Australian Government Environmental Protection and Biodiversity Conservation Act

Ecological communities that depend on groundwater discharge from GAB springs are protected under the Environment Protection and Biodiversity Conservation Act 1999, and are listed as Threatened Ecological Communities. Any proposal for a new, large-scale groundwater extraction operation in the vicinity of GAB springs would require approval from the Australian Government Minister of the Environment, Water, Heritage and the Arts. In particular, there are potential negative impacts on existing groundwater-dependent springs in the Lake Frome region associated with any new GAB groundwater extractions for Broken Hill.