DWLBC REPORT

Southern Fleurieu Groundwater Assessment

2006/24

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Southern Fleurieu Groundwater Assessment

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Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

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Report DWLBC 2006/24

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

The Southern Fleurieu Peninsula is one of the wettest areas of the State with an annual rainfall of about 850 mm. It is underlain by a variety of basement rocks and unconsolidated sediments that have exerted a strong control over not only how the current landscape evolved over millions of years, but also the occurrence of groundwater resources and how they interact with groundwater dependent ecosystems.

There are two different types of aquifers in the Southern Fleurieu. Fractured rock aquifers occur where groundwater is stored and moves through joints and fractures in the basement rocks. Sedimentary aquifers occur in the valleys where groundwater flows through the pore spaces within the sediments.

The fractured rock aquifers comprise the Barossa Complex gneisses, Kanmantoo Group metasediments such as schists and greywackes, and the Adelaidean sandstones and siltstones. These aquifers are not widely used and will not sustain extensive irrigation developments due to low yields (generally below 3 L/sec) and relatively high salinities, which average over 1500 mg/L.

The sedimentary aquifers are much more productive. The most intensive groundwater use occurs in the Myponga and Hindmarsh Tiers Catchments where restricted occurrences of the Tertiary Limestone are developed for the irrigation of dairy pasture using wells with yields over 20 L/sec. The Permian Sands aquifer displays a wide variation in characteristics in the region, with further development of this aquifer for irrigation most likely to occur in the Myponga Catchment.

Groundwater dependent ecosystems (GDEs) are an important consideration for management of groundwater resources. Wetlands, permanent pools and baseflow have been characterised according to their hydrogeological setting which controls the water source and availability for these ecosystems.

In the Southern Fleurieu project area, the groundwater sustainable yield was determined on a catchment basis, using recharge estimates derived from catchment water balances. It is recognised that these estimates of sustainable yield may have a large error margin and consequently, an adaptive management approach is recommended whereby the sustainable yield can be refined over time based on monitoring the actual response of the aquifers to the extraction regimes. Although there is no evidence of any current overdevelopment of groundwater resources, significant reductions in recharge due to land use change could lead to over-allocation of the resource during the water allocation planning process. Management options to minimise impacts of future development on both existing groundwater users and (GDEs) have been formulated.

The existing groundwater monitoring networks are concentrated in areas of intensive development, and are considered adequate. Additional monitoring is recommended in both the Myponga and Hindmarsh Tiers Catchments to cover new areas of irrigation and forestry on the Permian Sands aquifer. A broad reconnaissance water level network should be established in other catchments where the Permian Sands aquifer is currently undeveloped. Annual salinity monitoring of strategic irrigation wells should be carried out, with landholder notification of the results.

It is imperative that the impacts of forestry on groundwater resources be quantified, in order for the industry to be an accountable and responsible water user.

1. INTRODUCTION

The Southern Fleurieu Peninsula is one of the wettest areas of the State with an annual rainfall of about 850 mm. The area is dominated by plateaux averaging 350 m above sea level, which are separated by broad valleys. Grazing is the predominant land use, with dairying and forestry also important.

Concerns about the sustainability of the water resources in the region were first raised in 2000 after several dry years. It was thought that the lack of a catchment management body had resulted in overdevelopment of the resource. More recently, the impacts of forestry on ecosystems has also been raised as an important issue.

Following the inclusion of the region into the Adelaide and Mt Lofty Ranges NRM Region, a project was initiated to increase the level of knowledge regarding the state of water resources in the Fleurieu Peninsula to help formulate a management plan for water resources, environmental water requirements and urban water demand. This report carries out an assessment of groundwater resources of the Southern Fleurieu catchments and their potential for further development, reviews current monitoring networks, and describes the hydrogeological settings of groundwater dependent ecosystems. More importantly, this report also recommends management strategies for the protection of these ecosystems, and for sustainable development of groundwater resources.

Figure 1 shows the boundary of the study area, and the major catchments discussed in the report.

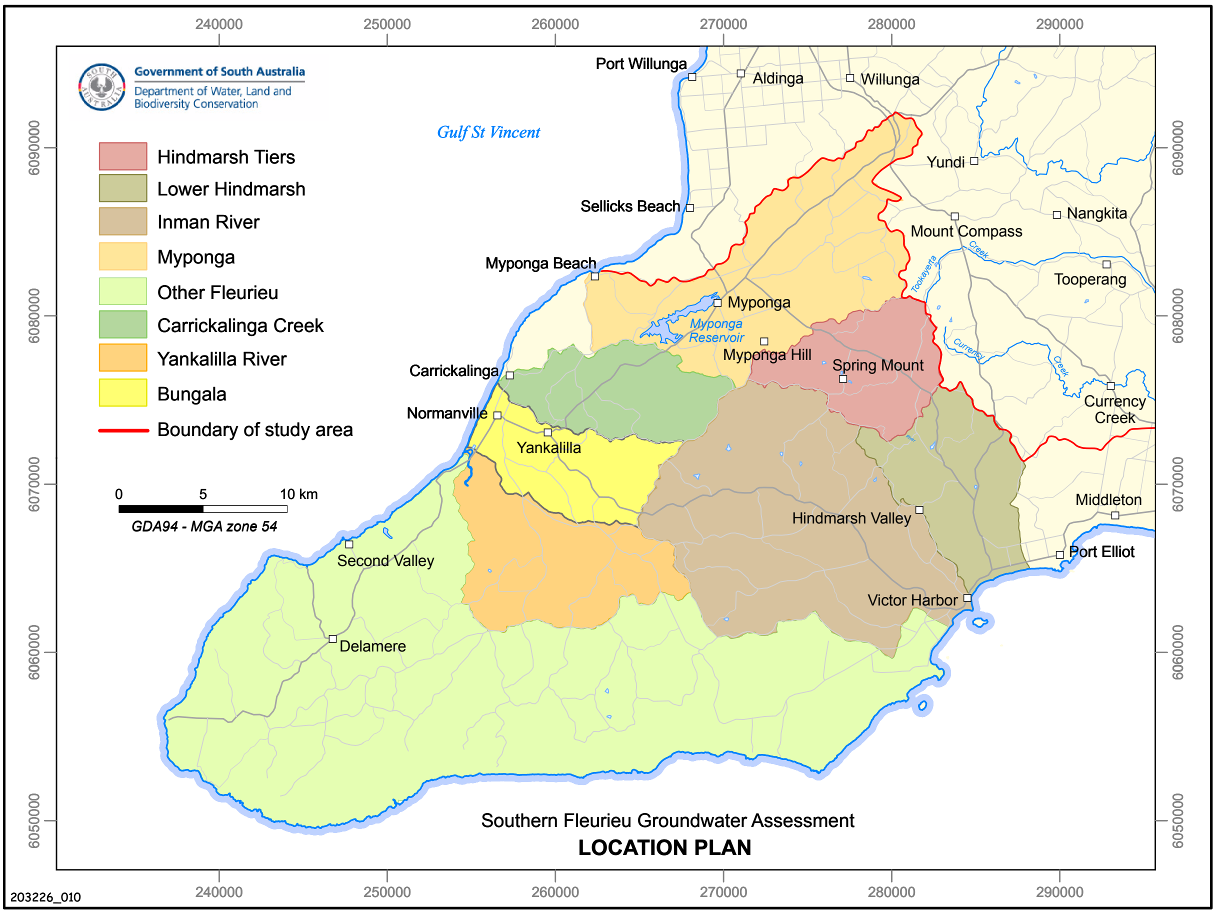

Figure 1. Southern Fleurieu Catchments location plan

2. HYDROGEOLOGY

2.1 GEOLOGY

The study area is underlain by a variety of consolidated basement rocks and unconsolidated sediments that have exerted a strong control over how the current landscape was formed (Fig. 2).

The **Barossa Complex** consists of gneisses, schists and pegmatites which were metamorphosed at high temperature and pressure deep in the Earth's crust and are thought to be 1600 million years old. They are the oldest rocks in the Mt Lofty Ranges and have been exposed by erosion to form the central core of the Southern Fleurieu, forming the highest topography reaching up to 440 m above sea level. The Barossa Complex is surrounded by younger Adelaidean sedimentary rocks.

Adelaidean sedimentary rocks, although strongly folded, have been relatively unaffected by heat and pressure and therefore provide a record of depositional and climatic conditions that occurred about 1000 million years ago. These rock units consist mainly of siltstone, shale, and slate with minor interbeds of sandstone and quartzite. They underlie the northern part of the study area.

The southern two thirds of the area is underlain by the **Kanmantoo Group**. A large trough was formed by rapid subsidence in a broad arc around the eastern side of the present Mt Lofty Ranges during the Cambrian period about 500 million years ago. The feldspathic sandstone that infilled this trough was later metamorphosed by heat and pressure into greywacke, schist and gneiss with a thickness of about 21 km.

About 280 million years ago in the **Permian** era, large continental ice sheets moving from the southeast to the northwest, carved out several large U-shaped valleys from the older basement rocks (Myponga, Hindmarsh and Inman Valleys), which were later filled by glacial deposits (Fig. 2). These sediments consist of unconsolidated sands, silts and clays with occasional gravel beds with a maximum recorded thickness of 300 m, and are known as the Cape Jervis Formation. Because the sediments are easily eroded, the Permian Sands form low rounded hills in contrast to the steeper and more rugged basement rocks.

Tertiary marine limestones were deposited about 50 million years ago in the St. Vincent Basin, which is divided into three important sub-basins: the Willunga, Noarlunga and Adelaide Plains Embayments. Because the Permian sediments are unconsolidated and more easily eroded than the older basement rocks, the marine transgression extended up into some of the glacial valleys (Myponga and Hindmarsh Tiers) and deposited the limestone which is probably correlated with the Port Willunga Beds of the Willunga Basin (Furness et al, 1981).

During the Late Tertiary period, major faulting occurred and tectonic movements elevated the Mt Lofty Ranges to their present height, and also raised the marine sediments at least 200 m above the level at which they were originally deposited.

At the lowest points in the catchments adjacent to the drainage lines, **Quaternary alluvium** has been deposited, and usually consists of dark grey silts and clays and some reworked Permian sand. Significant thicknesses of peat occur in some places.

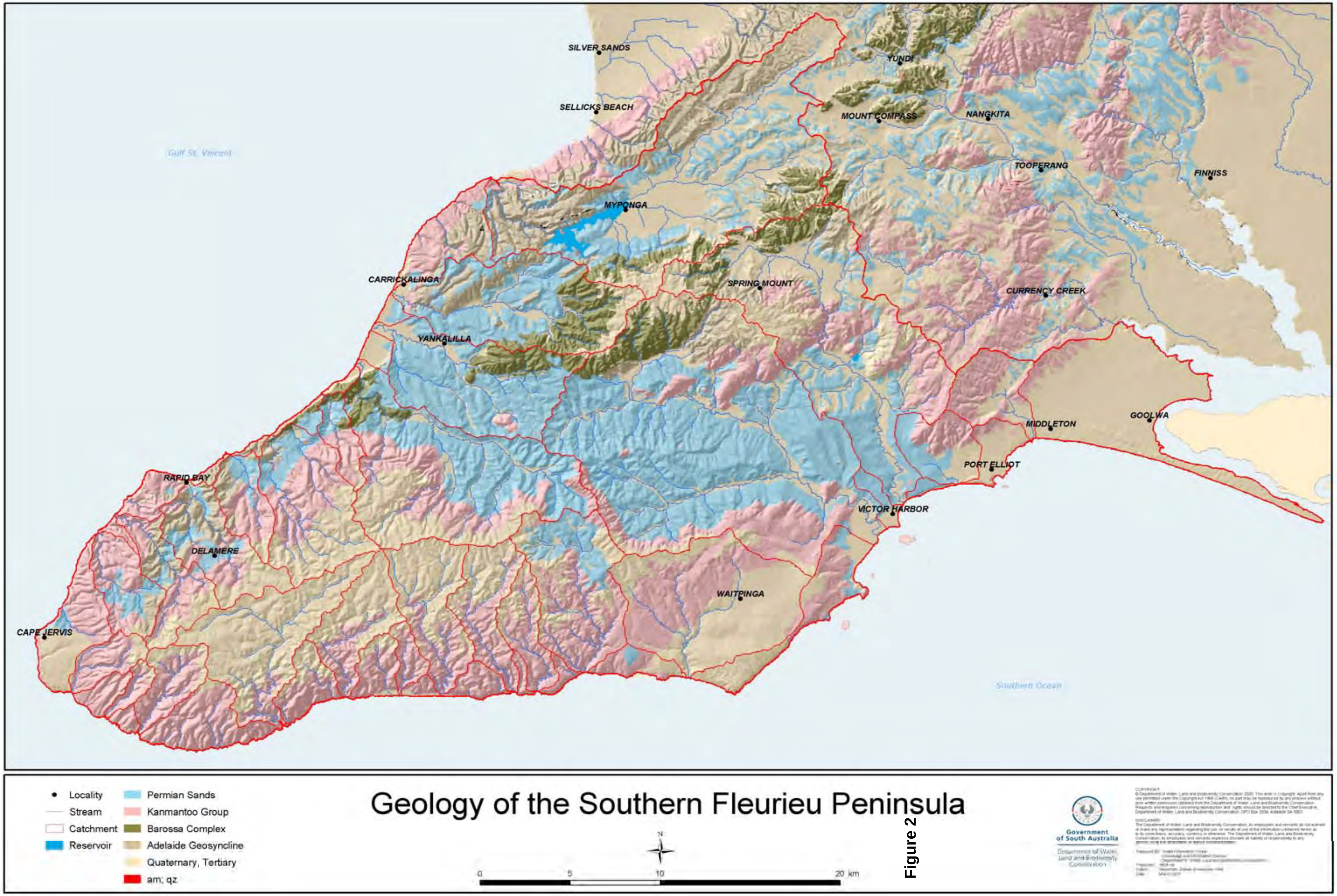
Geology of the Southern Fleurieu Peninsula
SILVER SANDS
SELLICKS BEACH
YUNDI
MOUNT COMPASS
NANGKITA
Gulf St. Vincent
TOOPERANG
FINNISS
MYPONGA
CARRICKALINGA
SPRING MOUNT
CURRENCY CREEK
YANKALILLA
MIDDLETON
GOOLWA
PORT ELLIOT
RAPID BAY
VICTOR HARBOR
DELAMERE
WAITPINGA
CAPE JERVIS
Southern Ocean
Locality
Stream
Catchment
Reservoir
Permian Sands
Kanmantoo Group
Barossa Complex
Adelaide Geosyncline
Quaternary, Tertiary
am; qz
N
0
5
10
20 km
Figure 2
Government of South Australia
Department of Water, Land and Biodiversity Conservation

Figure 2

In the Southern Fleurieu Catchments, there are two different types of aquifers. Fractured rock aquifers occur where groundwater is stored and moves through joints and fractures in the basement rocks. Sedimentary aquifers occur in the valleys where groundwater flows through the pore spaces within the sediments.

Groundwater moves from the higher points in the landscape (which are usually basement rocks around the catchment boundaries), towards the lowest areas where discharge normally occurs through the sedimentary aquifers in the valleys to the streams. This discharge constitutes the baseflow of the streams that dominates flow for most of the year, particularly over the summer and between rainfall events.

Recharge to both these aquifers occurs directly from that portion of rainfall that percolates down to the watertable through the soil profile (most of the rainfall runs off straight to the streams or is used by vegetation).

2.2 FRACTURED ROCK AQUIFERS

2.2.1 BAROSSA COMPLEX

The Barossa Complex is generally considered to be a poor aquifer from which irrigation supplies are usually not obtained. These basement rocks are, in general, tight and impermeable with few open systems of fractures and joints in which groundwater is stored and transmitted. Clayey weathered materials have infilled joints and fractures and soluble components of these materials can dissolve and raise the salinity of the groundwater. The clays can also restrict the infiltration of rainwater.

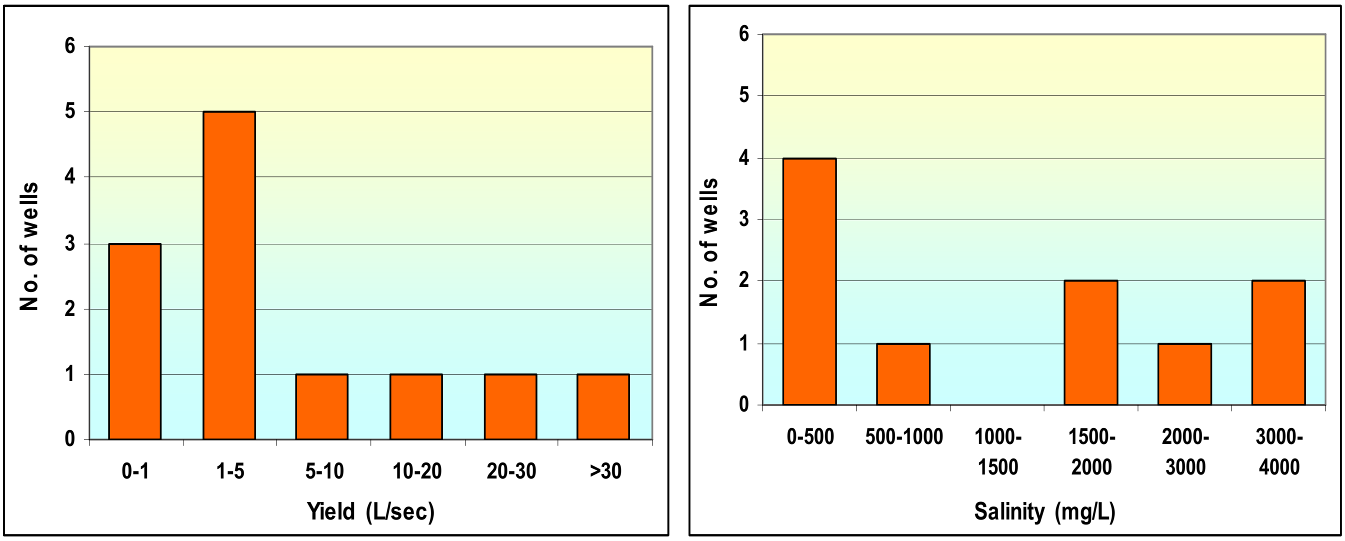

Figure 3. Barossa Complex – yield and salinity characteristics

Figure 3 shows a wide range of yields and salinities from the few bores completed in this Formation. As expected, yields are mostly below 5 L/sec. Because of this, and the generally steep terrain, the groundwater development potential for this aquifer is considered low.

2.2.2 KANMANTOO GROUP

For similar reasons to those outlined above, the Kanmantoo Group is also generally considered to be a poor aquifer, with higher salinities in the range 1500–3000 mg/L also evident (Fig. 4) due to the lower rainfall to the east resulting in reduced flushing and recharge to this aquifer. However, isolated instances of low salinity still occur. Yields are also low, mostly below 5 L/sec. Groundwater development potential for this aquifer is also considered low.

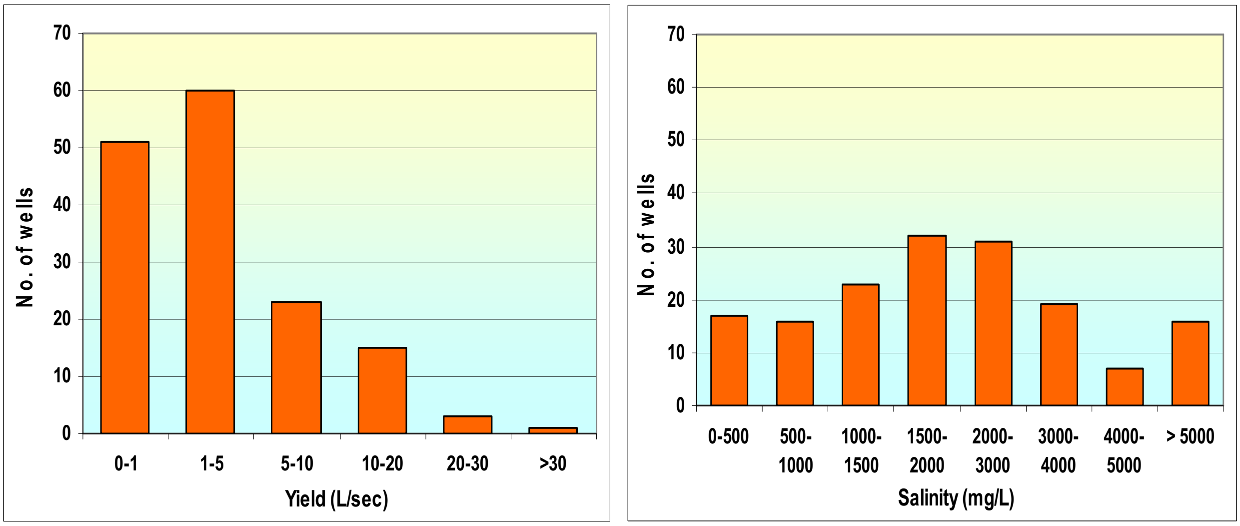

Figure 4. Kanmantoo Group – yield and salinity characteristics

2.2.3 ADELAIDEAN SEDIMENTARY ROCKS

Because the Adelaidean sedimentary rocks have not been subject to the heat and pressure of metamorphism, they are considered reasonably good aquifers because the joints and fractures are open and permeable resulting in relatively high yields. In addition, these sediments occur to the west of the region where the rainfall is higher, resulting in higher recharge and low salinities (Fig. 5).

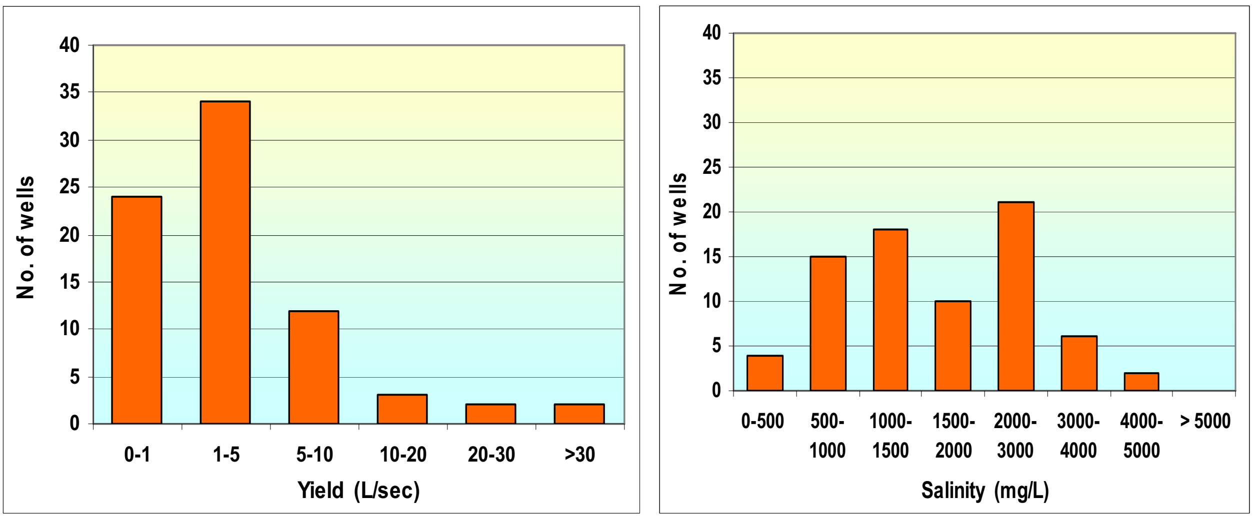

Figure 5. Adelaidean sedimentary rocks – yield and salinity characteristics

2.3 SEDIMENTARY AQUIFERS

2.3.1 PERMIAN SAND

The Permian Sand aquifer is generally not highly productive in the study area, except in the northern Myponga Basin (Table 1). This is possibly due to low permeability sediments reducing recharge. Although yields are generally low (Fig. 6), the quality is very good, mostly below 500 mg/L.

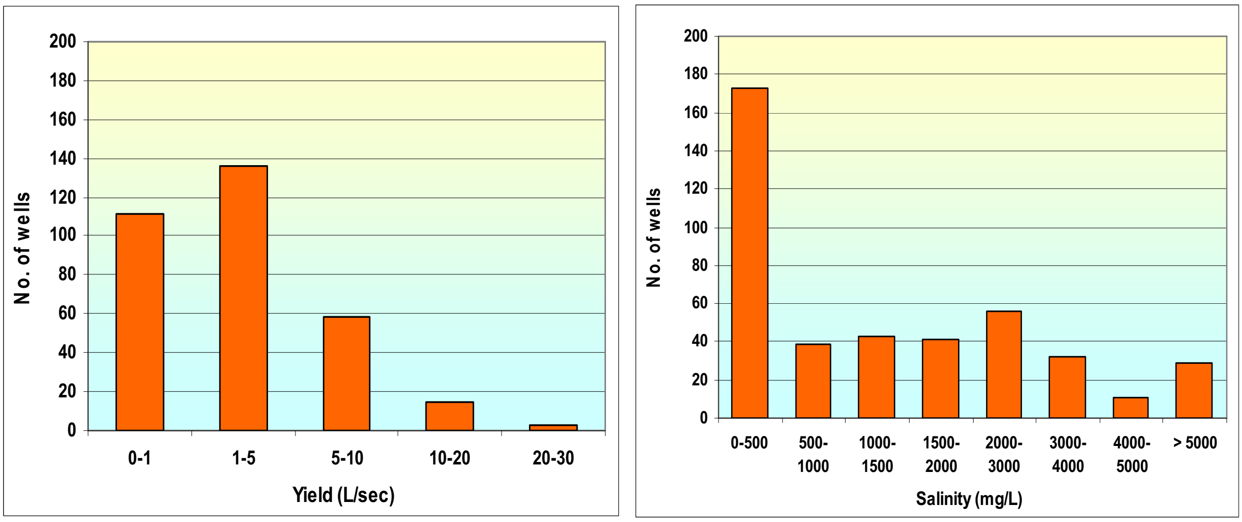

Figure 6. Permian Sands – yield and salinity characteristics

2.3.2 TERTIARY LIMESTONE

The Tertiary Limestone is by far the most productive aquifer with high yields over 10 L/sec and salinities generally below 1000 mg/L. This aquifer is widely developed for irrigation of mostly dairy pasture in the Myponga Basin and Hindmarsh Tiers.

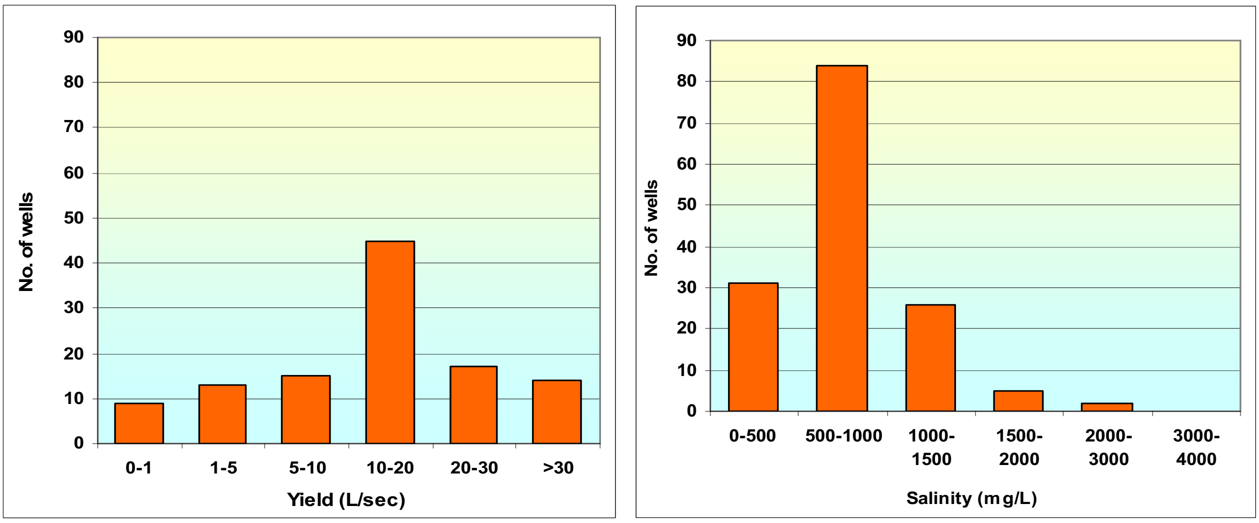

Figure 7. Tertiary Limestone – yield and salinity characteristics

2.4 SUMMARY

Table 1 summarises the aquifer characteristics in the Southern Fleurieu catchments in decreasing order of productivity. As expected, the Tertiary Limestone is the most productive, and is likely to be subject to future increases in demand for irrigation in the Hindmarsh Tiers and Myponga catchments.

Table 1. Aquifer characteristics

Aquifer	Median Yield (L/sec)	Median Salinity (mg/L)
Tertiary Limestone	14.0	750
Adelaidean Sedimentary Rocks	2.5	1540
Barossa Complex	2.5	1715
Kanmantoo Group	1.8	1795
Permian Sands	1.8	1000
Lower Hindmarsh	1.0	2380
Inman Valley	1.0	2280
Yankalilla	1.0	1800
Myponga	3.2	260
Tookayerta	2.5	180

The fractured rock aquifers will not sustain extensive irrigation developments due to low yields and relatively high salinities.

The Permian Sands aquifer displays a wide variation in characteristics in the various catchments (Table 1), probably due to lateral changes in the glacial depositional environments resulting in higher clay contents in the Lower Hindmarsh, Yankalilla and Inman Valley catchments. The interbedded sands and clays are probably not as laterally continuous as in the Myponga catchment, and the neighbouring Tookayerta catchment to the north (Barnett and Zulfic, 1999). Further expansion of development of this aquifer will most likely be restricted to the Myponga catchment.

3. CURRENT STATUS OF GROUNDWATER RESOURCES

3.1 MYPONGA CATCHMENT

The Myponga Catchment covers an area of about 12 320 ha and is located about 50 km south of Adelaide (Fig. 1). The main land use is dairying with significant areas of pasture irrigated during summer from groundwater. Small areas of vegetables and vineyards are also irrigated. The valley lies at about 220 m elevation. Rainfall is winter dominant, with an annual average of 760 mm.

The substantial groundwater resource found in the Myponga Basin is stored in both the Tertiary Limestone and Permian Sands. The Tertiary Limestone is the most widely used aquifer for irrigation and is confined by Quaternary alluvium over most of the area. The Permian Sands are used for irrigation purposes where the limestone is absent around the basin margin and to the northeast toward Pages Flat (Furness et al, 1981).

Over most of the basin, salinities are below 1000 mg/L (Fig. 8). The geological cross-section (Fig. 9) shows the Tertiary Limestone aquifer reaching thicknesses of 200 m and being contained within the Permian Sands (which are up to 300 m thick).

Yields of up to 60 L/sec have been obtained from the limestone, with aquifer tests suggesting a hydraulic conductivity range from 3–12 m/day (Edwards, 1977). Groundwater movement is from the Permian sand recharge areas in the southern and eastern parts of the catchment where the salinities are lowest (below 500 mg/L), toward the Myponga Reservoir in the northwest part of the catchment.

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Southern Fleurieu Groundwater Assessment
GEOLOGY AND GROUNDWATER SALINITY OF MYPONGA CATCHMENT

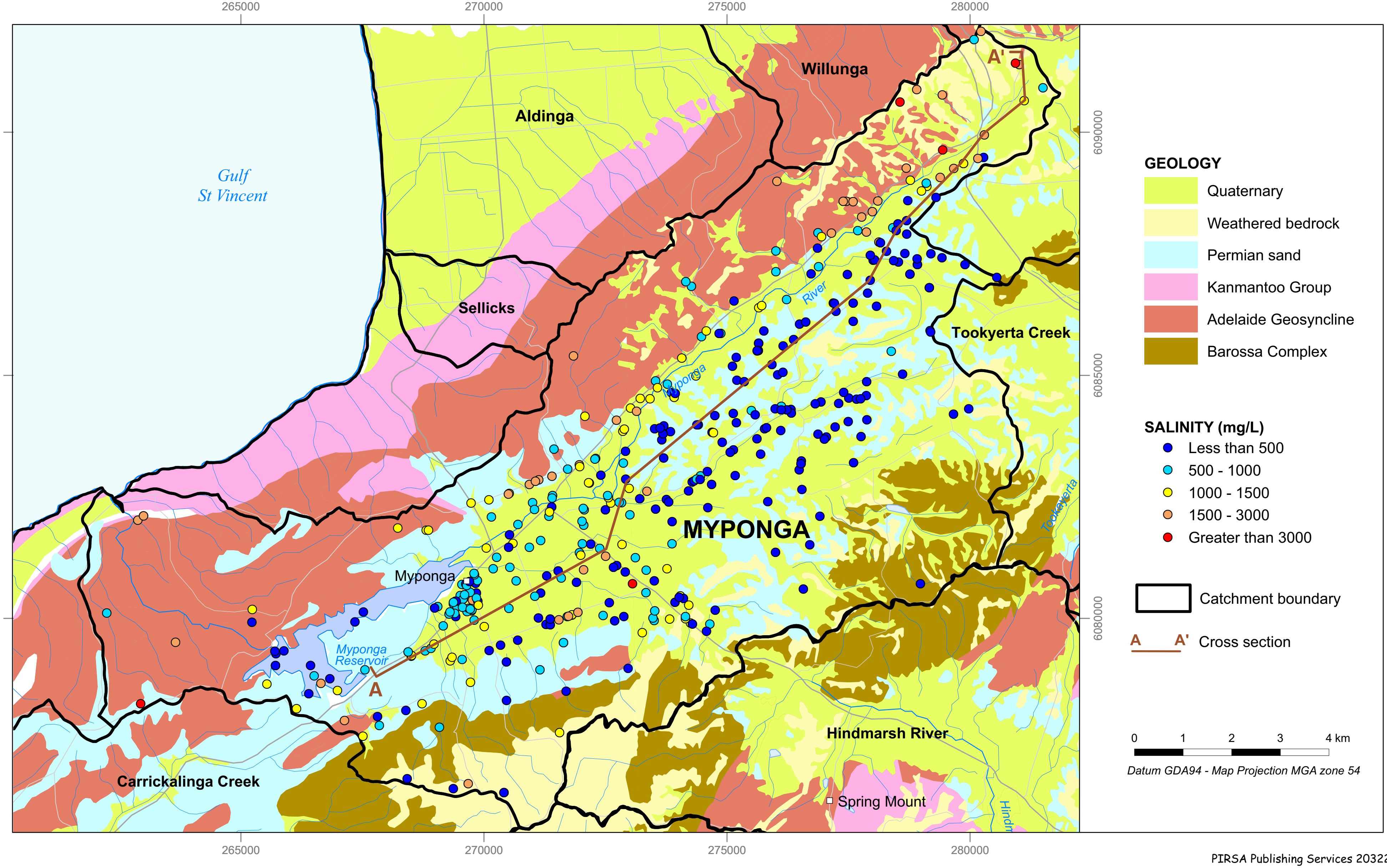

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Figure 8

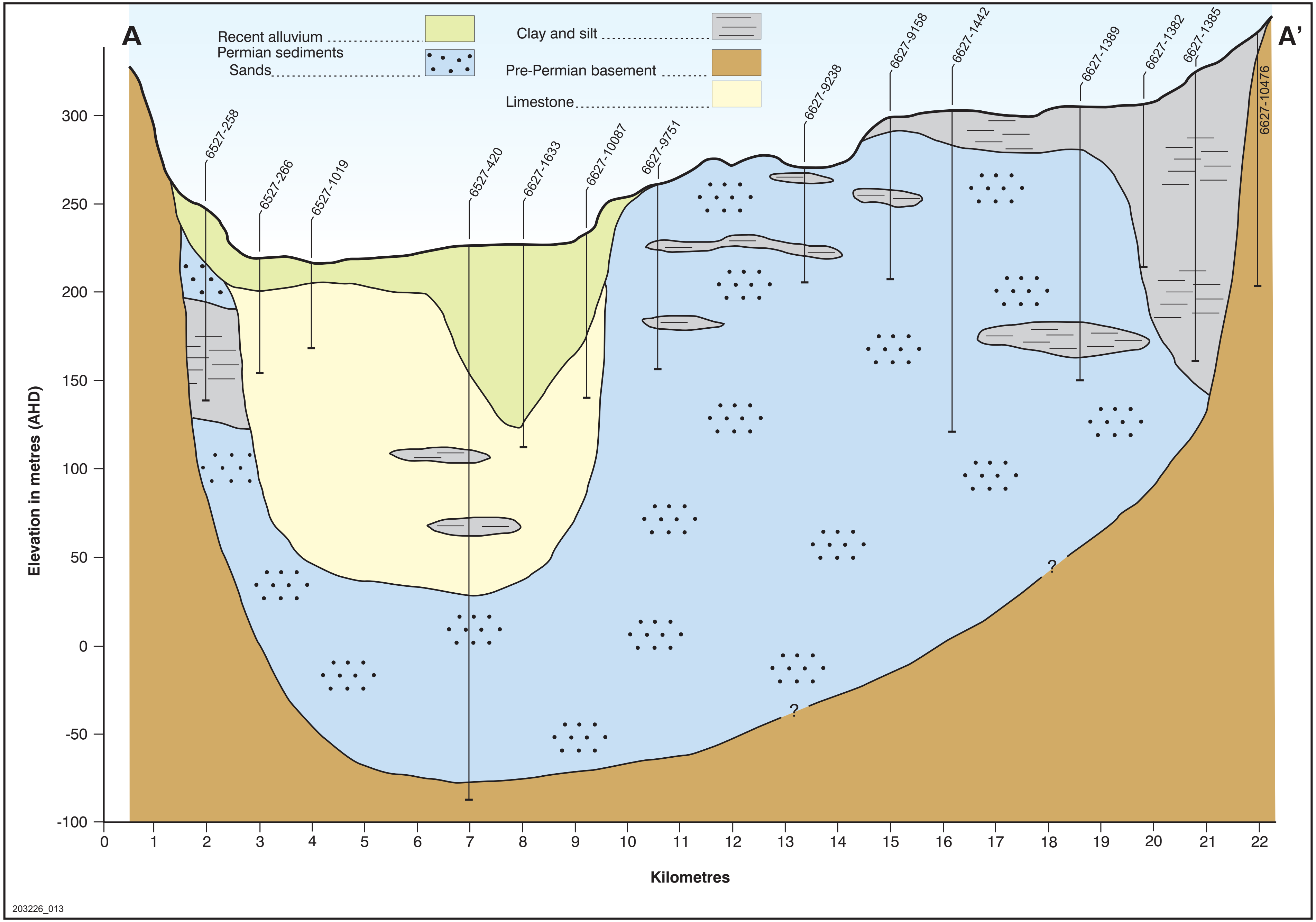


Figure 9 Geological cross-section of Myponga Catchment.

3.2 HINDMARSH TIERS CATCHMENT

The Hindmarsh Tiers Basin covers about 700 ha in total area, although the total area of the surface water catchment used in this study is 5580 ha. The valley floor lies at about 230 m elevation, and like Myponga, the main land use is dairying which uses groundwater to irrigate pasture. Rainfall is winter dominant, with an annual average of 866 mm.

Figure 10 shows a cross-section across the basin that depicts the Tertiary limestone attaining a thickness of over 100 m and being confined by Quaternary alluvium. There are bores completed into the Permian sands in this area as well which are used for irrigation purposes. Groundwater salinities are also low in this basin, being mostly below 1000 mg/L (Fig. 11).

Yields of up to 55 L/sec can be obtained from wells completed into the Tertiary limestone aquifer, with drawdowns of only a few metres despite the confined nature of the aquifer. Groundwater flows from the Permian Sand recharge areas in the west of the catchment, toward the east where it discharges from the aquifer system by evapotranspiration and baseflow into the Hindmarsh River. Groundwater underflow out of the area through the basement fractured rock aquifers is likely to be small due to their low permeability.

Aquifer tests performed on the Tertiary limestone aquifer found high values of hydraulic conductivity ranging from 85–125 m/day, which suggests that flow through the aquifer in the Hindmarsh Tiers may be controlled by solution cavities (Furness et al, 1981).

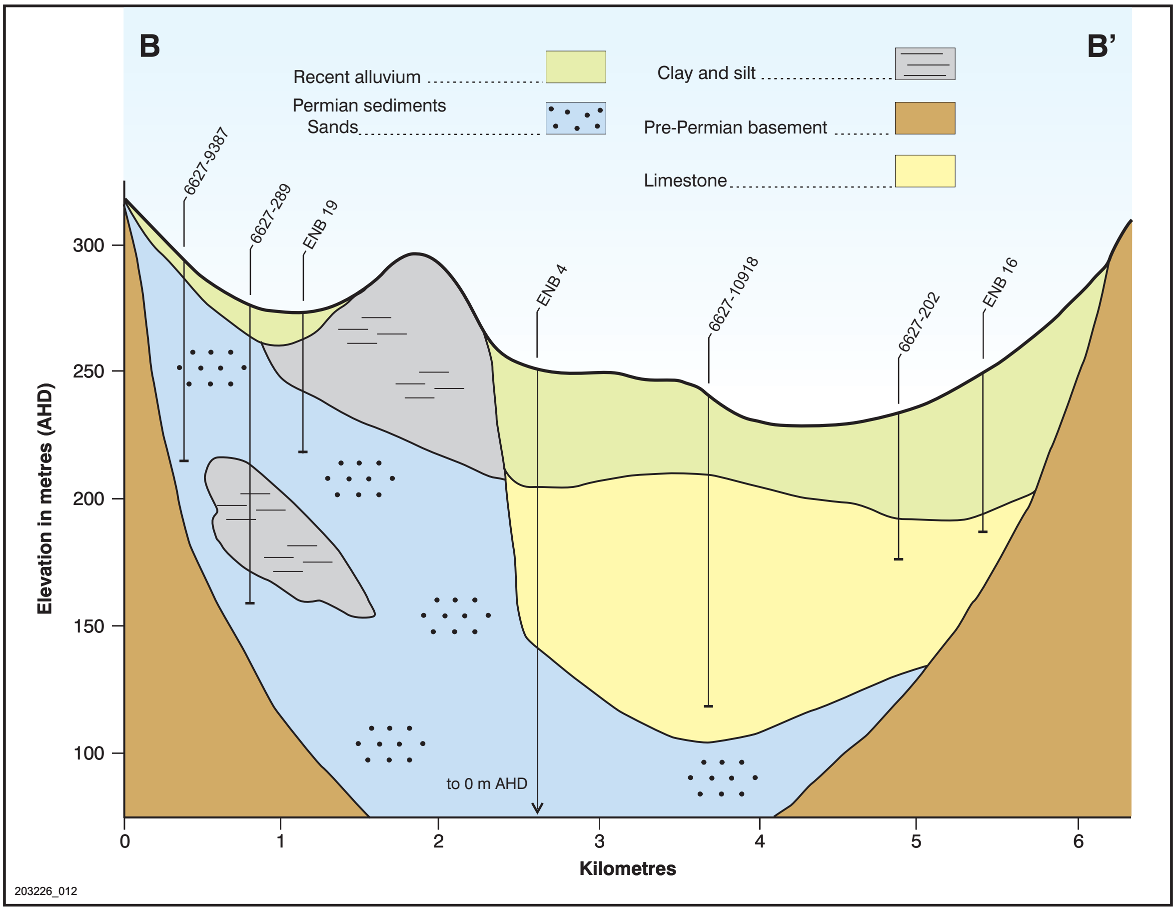
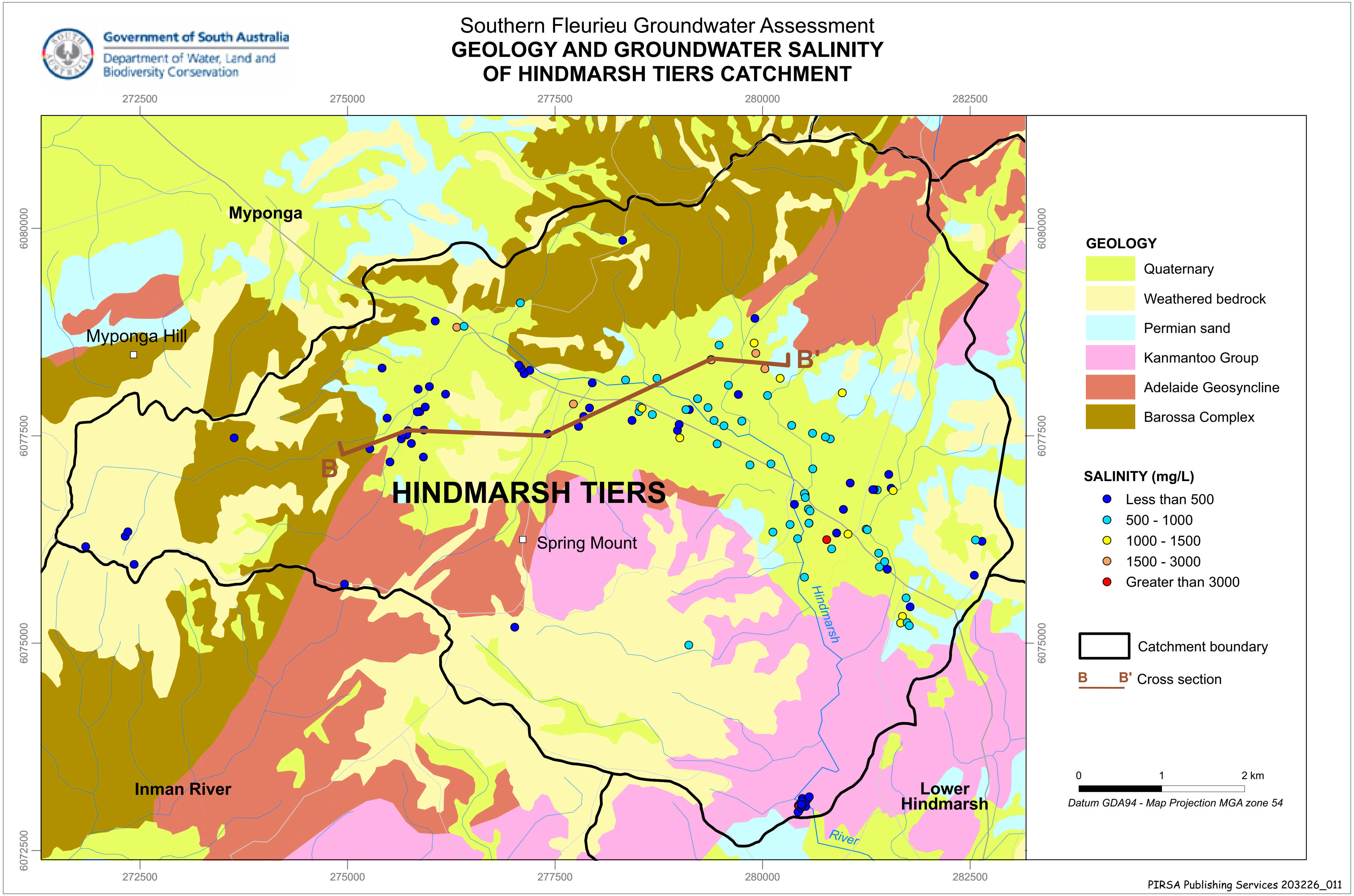


Figure 10. Geological cross-section of Hindmarsh Tiers Catchment



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GEOLOGY AND GROUNDWATER SALINITY
OF HINDMARSH TIERS CATCHMENT
272500
275000
277500
280000
282500
6080000
6077500
6075000
6072500
Myponga
Myponga Hill
HINDMARSH TIERS
Spring Mount
Hindmarsh
River
Inman River
Lower Hindmarsh
B
B'
GEOLOGY
Quaternary
Weathered bedrock
Permian sand
Kanmantoo Group
Adelaide Geosyncline
Barossa Complex
SALINITY (mg/L)
Less than 500
500 - 1000
1000 - 1500
1500 - 3000
Greater than 3000
Catchment boundary
B B' Cross section
0 1 2 km
Datum GDA94 - Map Projection MGA zone 54
PIRSA Publishing Services 203226_011

Figure 11

3.3 LOWER HINDMARSH CATCHMENT

The lower Hindmarsh Catchment is a narrow valley flanked by low rolling hills on either side, which ends at Victor Harbour on the coast (Fig. 12). It is separated from the Hindmarsh Tiers Basin by an east-west escarpment of resistant hills of Kanmantoo Group basement rocks. The topography falls about 180 m across this escarpment. Figure 13 shows a geological cross section for the central part of the catchment. The rainfall also decreases markedly to the southeast as shown by the annual average of 536 mm at Victor Harbour compared to 866 mm in the Hindmarsh Tiers.

The valley is underlain by Permian Sands that are a mixture of sand and clay layers up to about 250 m thick. One bore encountered a small artesian supply at a depth of 200 m at the northern end of the catchment. Bore yields are typically low with salinity values ranging from 2000–4000 mg/L, probably in response to lower recharge (Fig. 12).

Groundwater usage is therefore low and there is little likelihood of large increases in development of this resource.

3.4 INMAN RIVER CATCHMENT

The Inman River catchment runs in an easterly direction from Bald Hills through to Victor Harbour and covers an area of 19 500 ha. Many watercourses in the catchment were originally marshy wetlands with no defined channel (Burston and Good, 1995). The hills that enclose the catchment are mostly resistant metamorphic rocks of the Kanmantoo Group. Again, rainfall is winter dominant, with an annual average of 706 mm.

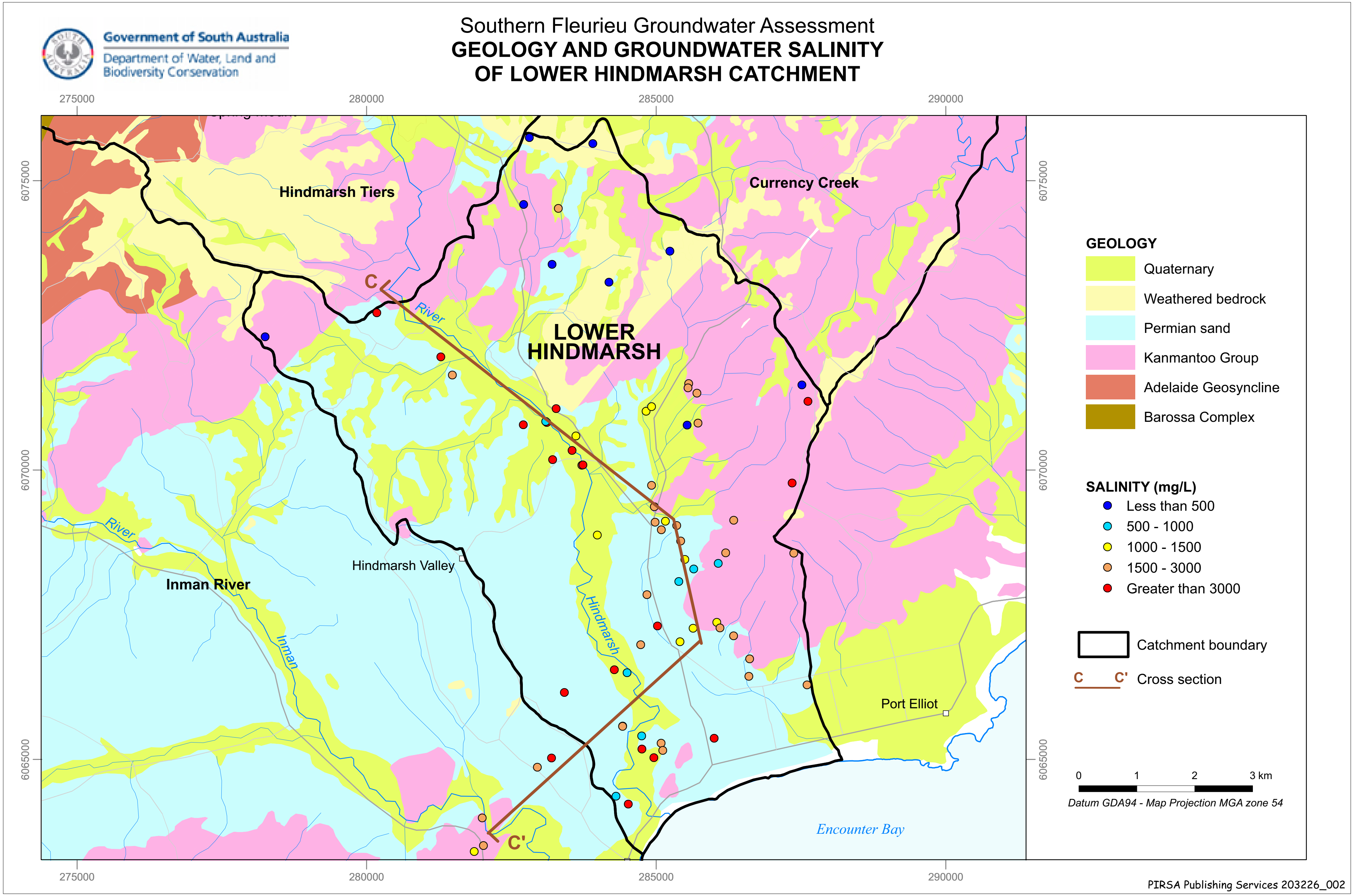
The Permian glaciation deepened the ancient valleys but left considerable depths of glacial and glacio-fluvial deposits. Bores drilled along Back Valley Creek have passed through nearly 300 m of glacial sediments before striking basement rock. Figure 15 depicts the geological cross-section from west to east, which shows a high proportion of low permeability clays and sandy clays.

Because of the predominance of clayey sediments, bore yields are generally quite low (mostly below 2 L/sec), with only two over 10 L/sec. These sediments also restrict recharge from rainfall resulting in highly variable salinities from below 1000 mg/L to over 5000 mg/L (Fig. 14). Several bores obtained over 10 L/sec from the surrounding fractured rock aquifers but salinities are moderate to high.

As for the adjacent lower Hindmarsh Catchment, groundwater usage is low and there is little likelihood of further development.

3.5 CARRICKALINGA CREEK CATCHMENT

This catchment can be subdivided into three areas. The eastern portion is comprised of the Barossa Complex granites and gneisses, which form a high steep-sided plateau with an elevation of 350 m. There is virtually no groundwater development in this area due to low yields. To the west, Adelaidean sedimentary rocks form steep hills up to 250 m in elevation, again with little groundwater development due to variable yields and salinities.



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GEOLOGY AND GROUNDWATER SALINITY OF LOWER HINDMARSH CATCHMENT
275000
280000
285000
290000
6075000
6070000
6065000
Hindmarsh Tiers
Currency Creek
LOWER HINDMARSH
C
C'
River
Hindmarsh Valley
Inman River
Inman
Hindmarsh
Port Elliot
Encounter Bay
GEOLOGY
Quaternary
Weathered bedrock
Permian sand
Kanmantoo Group
Adelaide Geosyncline
Barossa Complex
SALINITY (mg/L)
Less than 500
500 - 1000
1000 - 1500
1500 - 3000
Greater than 3000
Catchment boundary
Cross section
0
1
2
3 km
Datum GDA94 - Map Projection MGA zone 54
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Figure 12

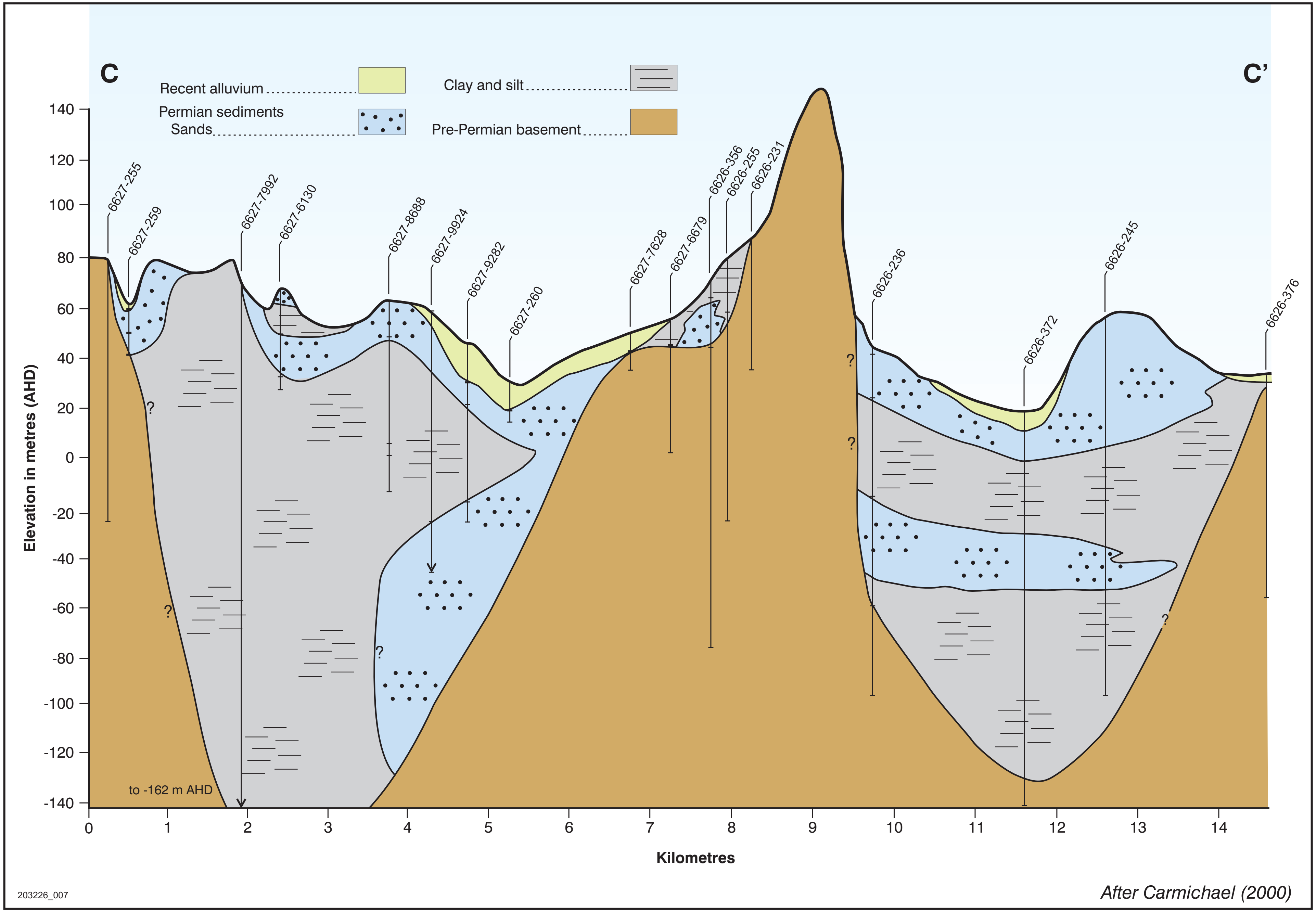
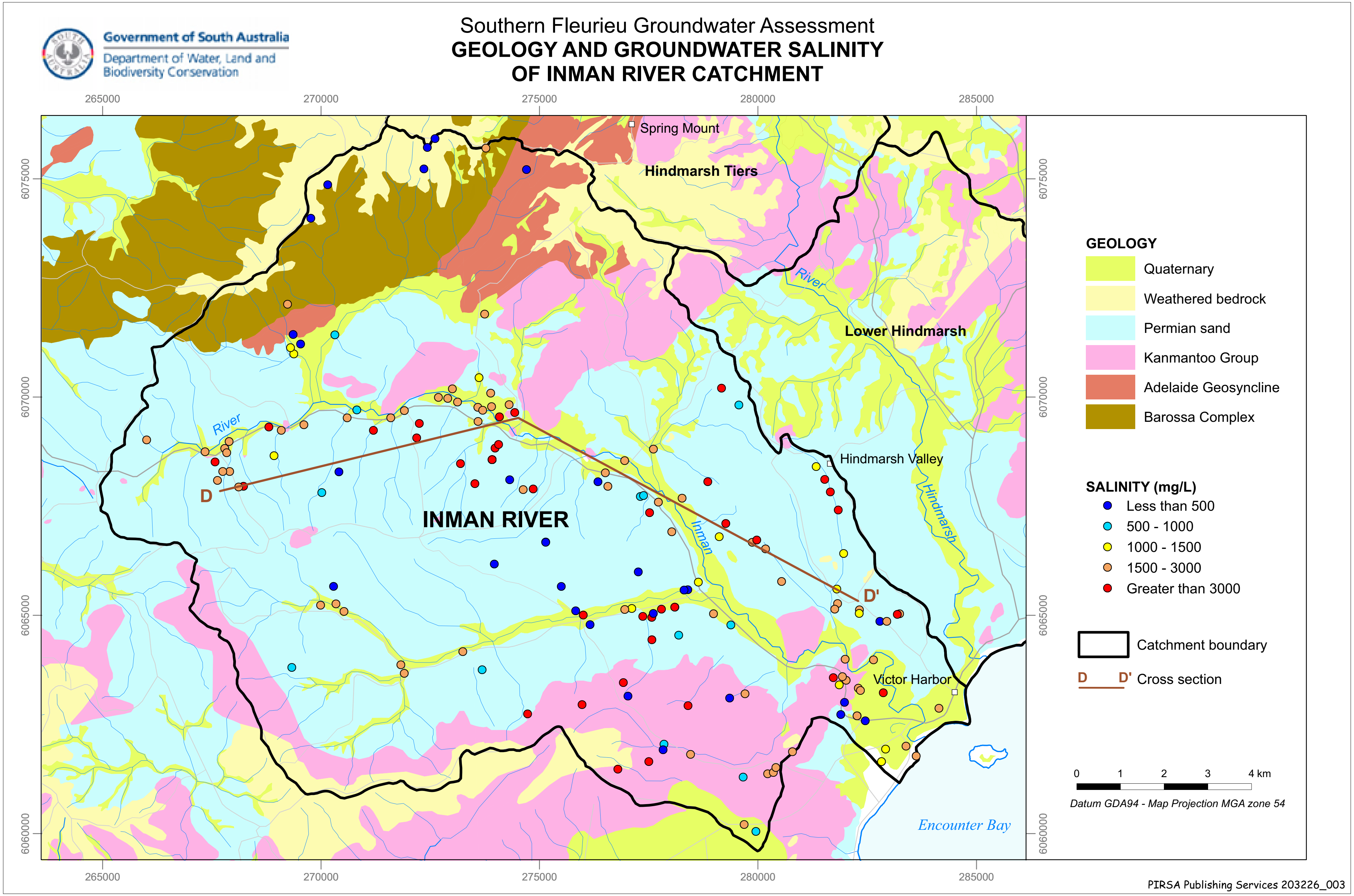


Figure 13 Geological cross-section of Lower Hindmarsh Catchment.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Southern Fleurieu Groundwater Assessment
GEOLOGY AND GROUNDWATER SALINITY OF INMAN RIVER CATCHMENT
265000
270000
275000
280000
285000
6075000
6070000
6065000
6060000
Spring Mount
Hindmarsh Tiers
Lower Hindmarsh
Hindmarsh Valley
Hindmarsh
River
Inman
INMAN RIVER
Victor Harbor
Encounter Bay
D
D'
GEOLOGY
Quaternary
Weathered bedrock
Permian sand
Kanmantoo Group
Adelaide Geosyncline
Barossa Complex
SALINITY (mg/L)
Less than 500
500 - 1000
1000 - 1500
1500 - 3000
Greater than 3000
Catchment boundary
D D' Cross section
0 1 2 3 4 km
Datum GDA94 - Map Projection MGA zone 54
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Figure 14

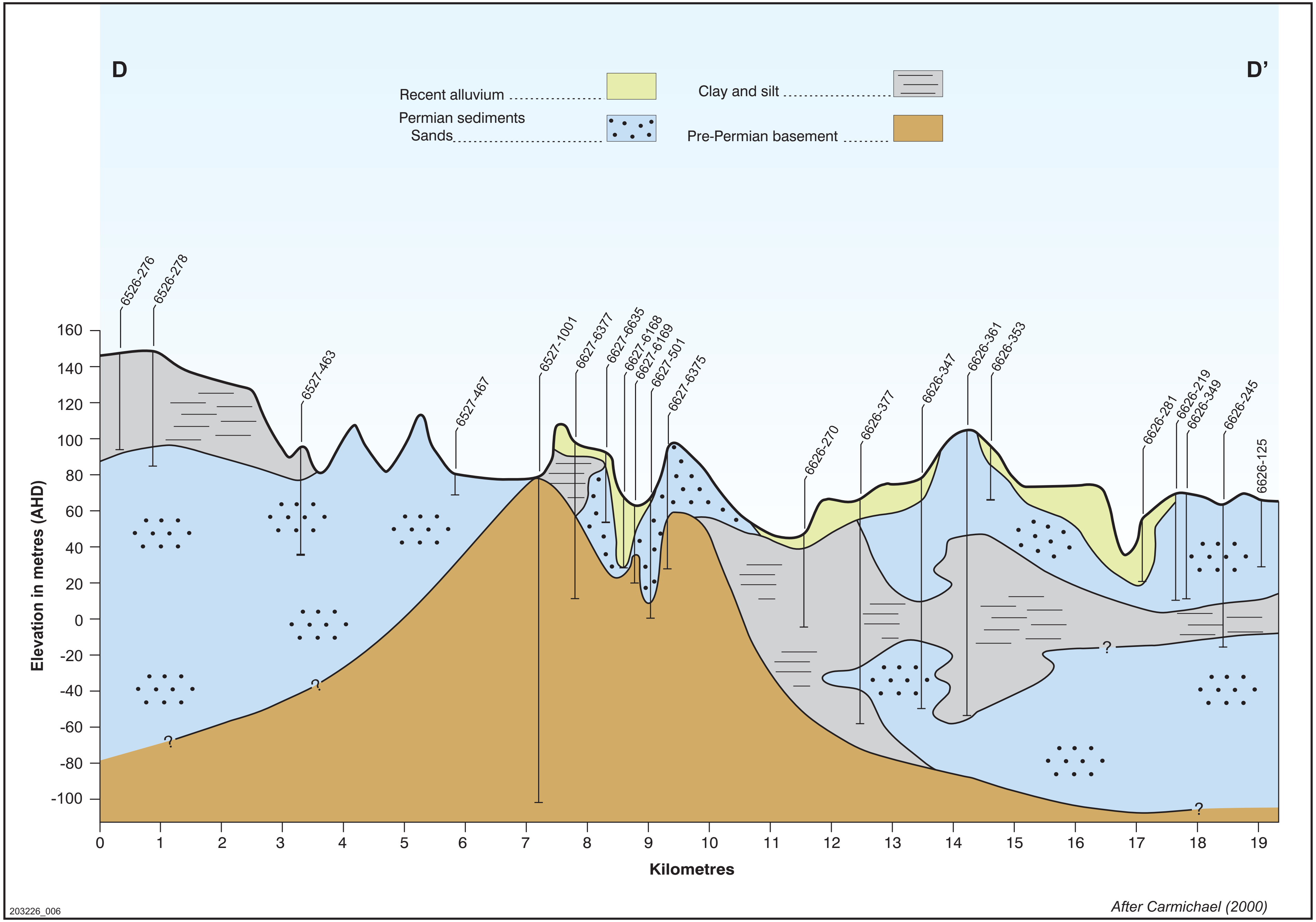


Figure 15 Geological cross-section of Inman Catchment.

The centre of the catchment is dominated by a broad glacial valley, which is infilled with Permian Sands and is an extension of the Myponga Basin to the northeast. The maximum thickness of these sediments is unknown, but exceeds 150 m (Fig. 17). Annual rainfall varies from 500 mm at the coast, to about 750 mm on the eastern plateau.

Most groundwater use occurs from the Permian Sands aquifer, with salinities varying from just under 200 mg/L, to over 4000 mg/L (Fig. 16). Yields are also highly variable (ranging up to 25 L/sec), reflecting the low permeability of the aquifer in some areas. Paradoxically, there are also a considerable number of dams in the area underlain by Permian Sands because of the low permeability.

Irrigation development is limited to about 150 ha of pasture, vines and orchards, with water sourced from both dams and irrigation wells.

3.6 BUNGALA/YANKALILLA RIVER CATCHMENTS

These catchments are combined in this report because they are mostly underlain by the Permian Sands aquifer where groundwater flow is probably independent of the surface topography and the catchment divide separating them. They are bounded to the south by a steep escarpment of Kanmantoo Group fractured rocks, and the Barossa Complex to the west and northeast. There is very little groundwater development in these fractured rocks due to their low yields, although there are some isolated occurrences of high yields. Several wells yield over 20 L/sec from well fractured quartzites for pasture irrigation just to the southeast of Yankalilla township.

There is probably hydraulic connection within the Permian Sands aquifer with the Carrickalinga Creek catchment to the north, and Inman River catchment to the east. Groundwater flow is toward the coast in a northwesterly direction. Yields from this aquifer are generally less than 3 L/sec, with highly variable salinities from less than 500 mg/L to over 3000 mg/L (Fig. 16). Not surprisingly, groundwater development is very limited.

Southern Fleurieu Groundwater Assessment

GEOLOGY AND GROUNDWATER SALINITY OF CARRICKALINGA, BUNGALA and YANKALILLA CATCHMENTS

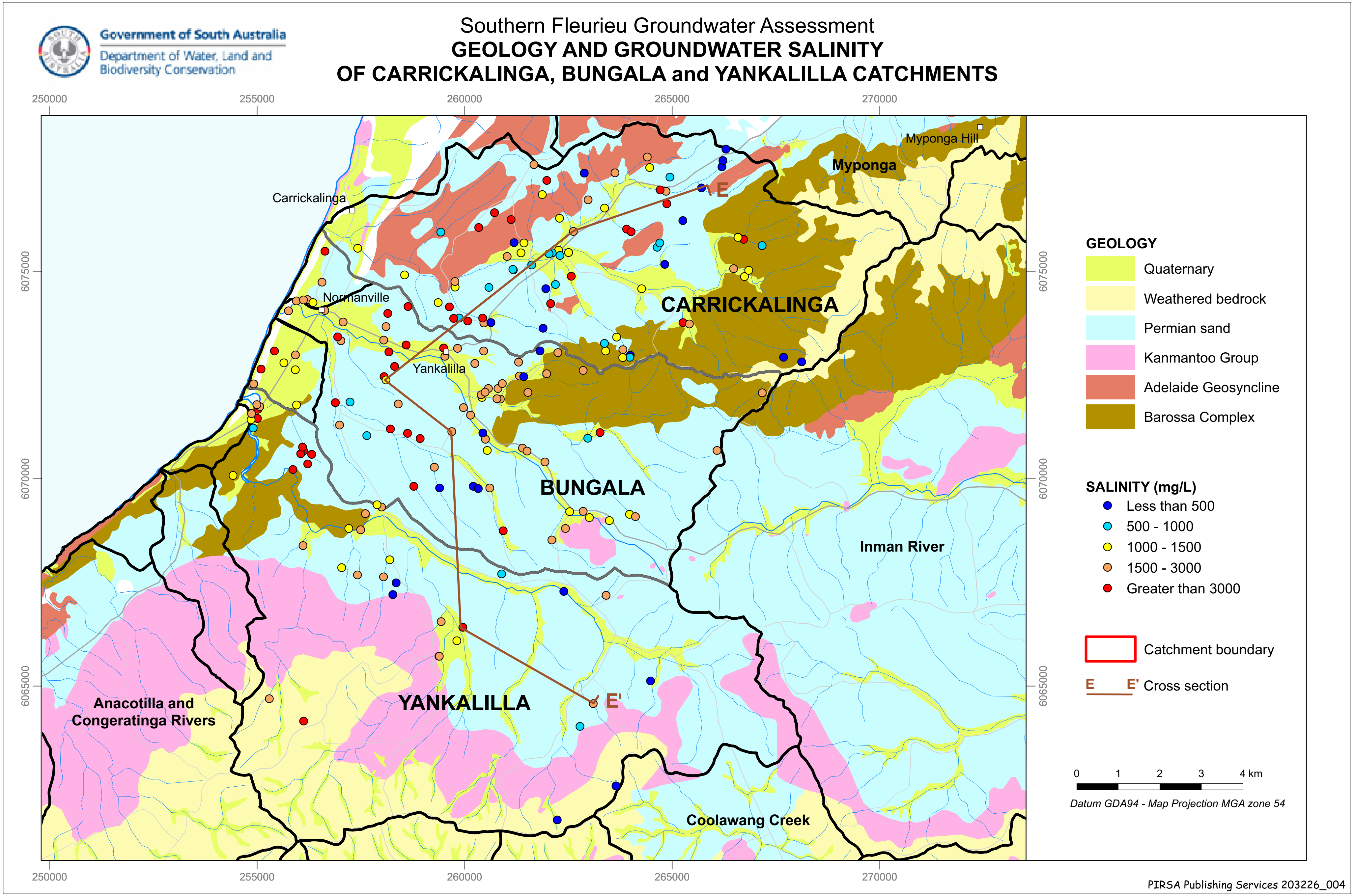


Figure 16

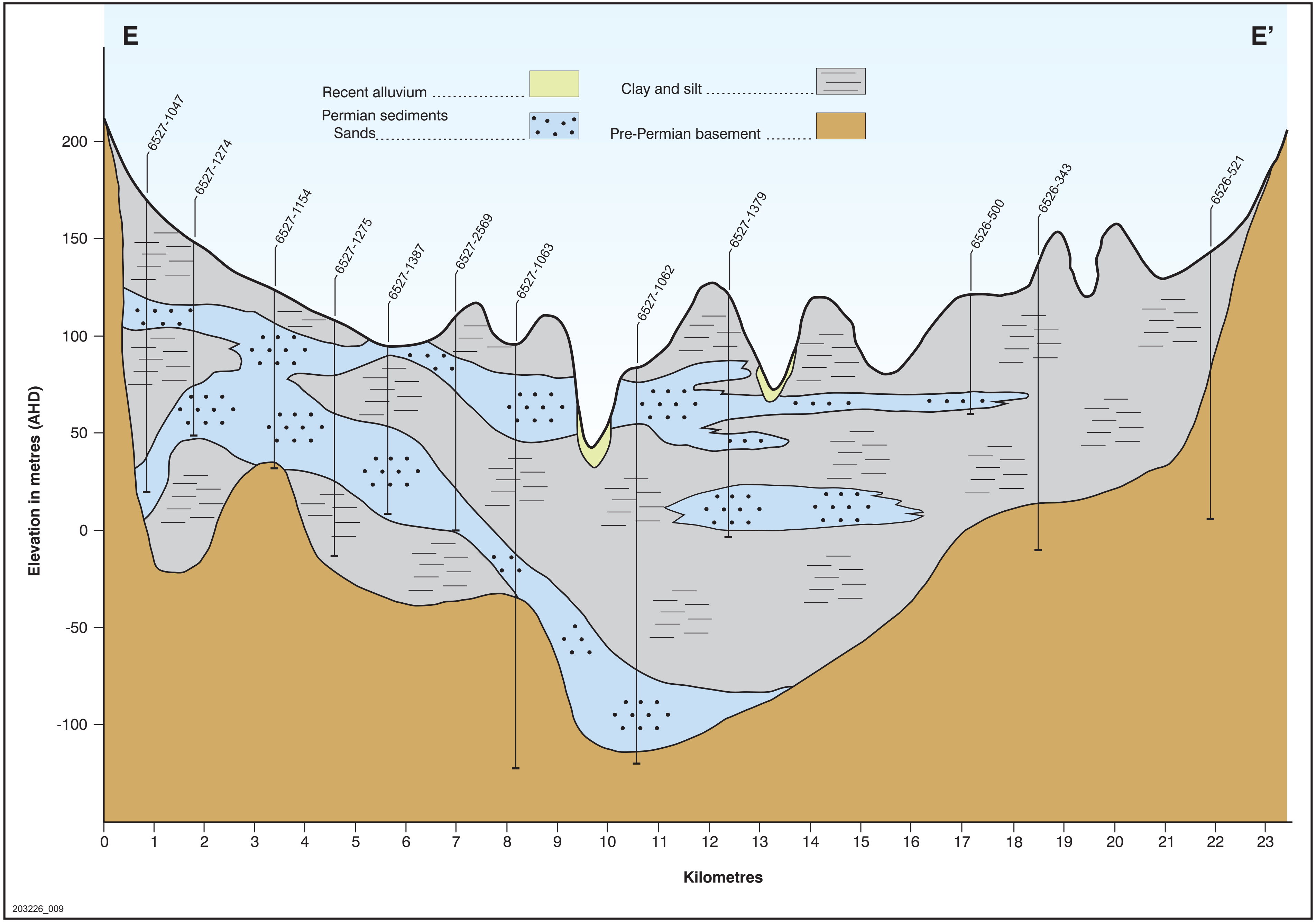


Figure 17 Geological cross-section of Carrickalinga, Bungala and Yankalilla Catchments.

3.7 OTHER FLEURIEU CATCHMENTS

The remaining catchments in the Southern Fleurieu are underlain by generally poor fractured rock aquifers of the Kanmantoo Group, which are deeply weathered at the surface especially to the south on the Parawa plateau. These clays restrict recharge and promote runoff, especially in the steep coastal catchments. Groundwater salinities vary greatly from below 500 to over 5000 mg/L (Fig. 19), which is considered to be above the upper limit for many irrigated crops. Well yields are mostly below 3 L/sec.

An exception to this general rule is provided by limestone units of the Normanville Group, which were previously mined at Rapid Bay (shown in green in Fig. 18). They can contain solution features and cavities, which has resulted in higher well yields (up to 20 L/sec), and lower salinities through enhanced recharge (a process which also enhances the risk of contamination from inappropriate land use). The presence of the solution features is unpredictable, which will impede extensive development of the aquifer.

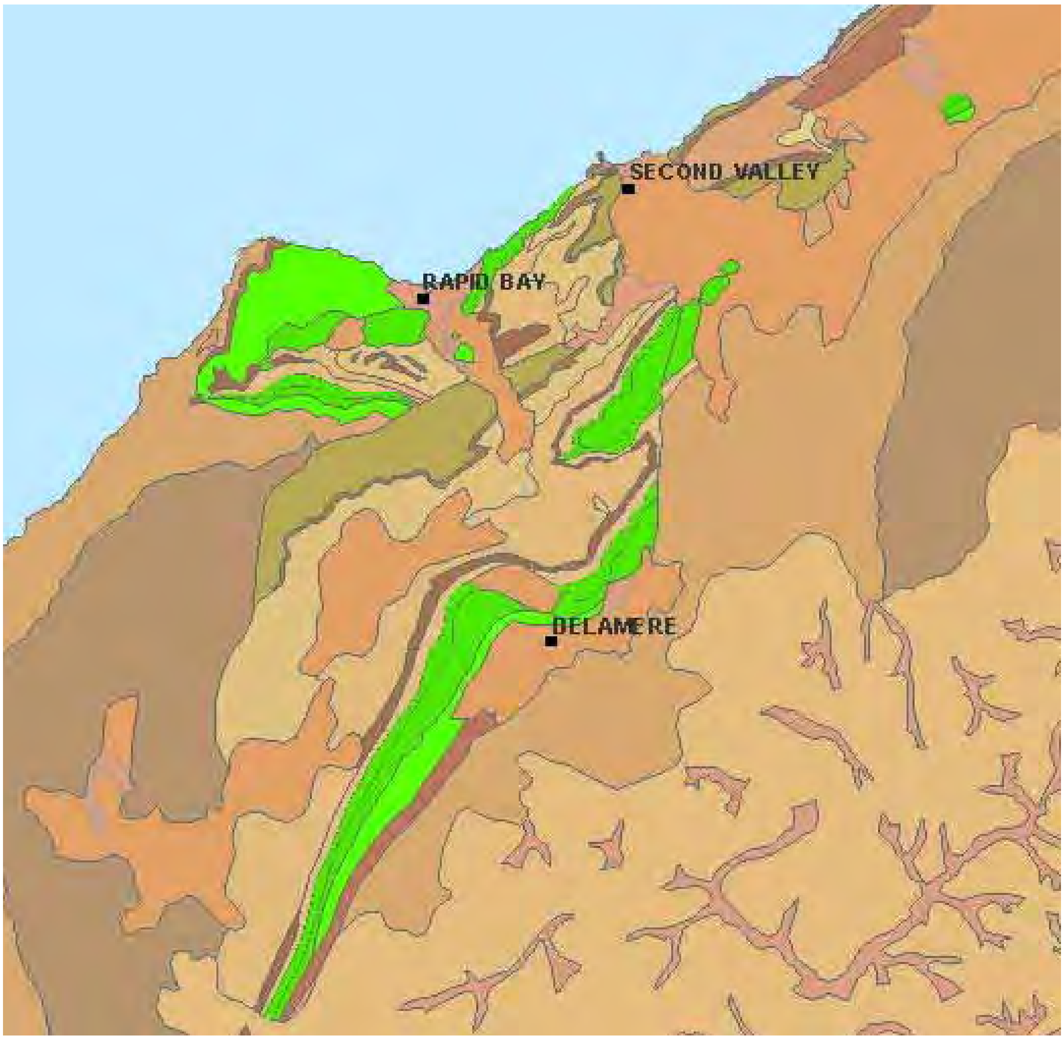


Figure 18. Extent of Normanville Group limestone units

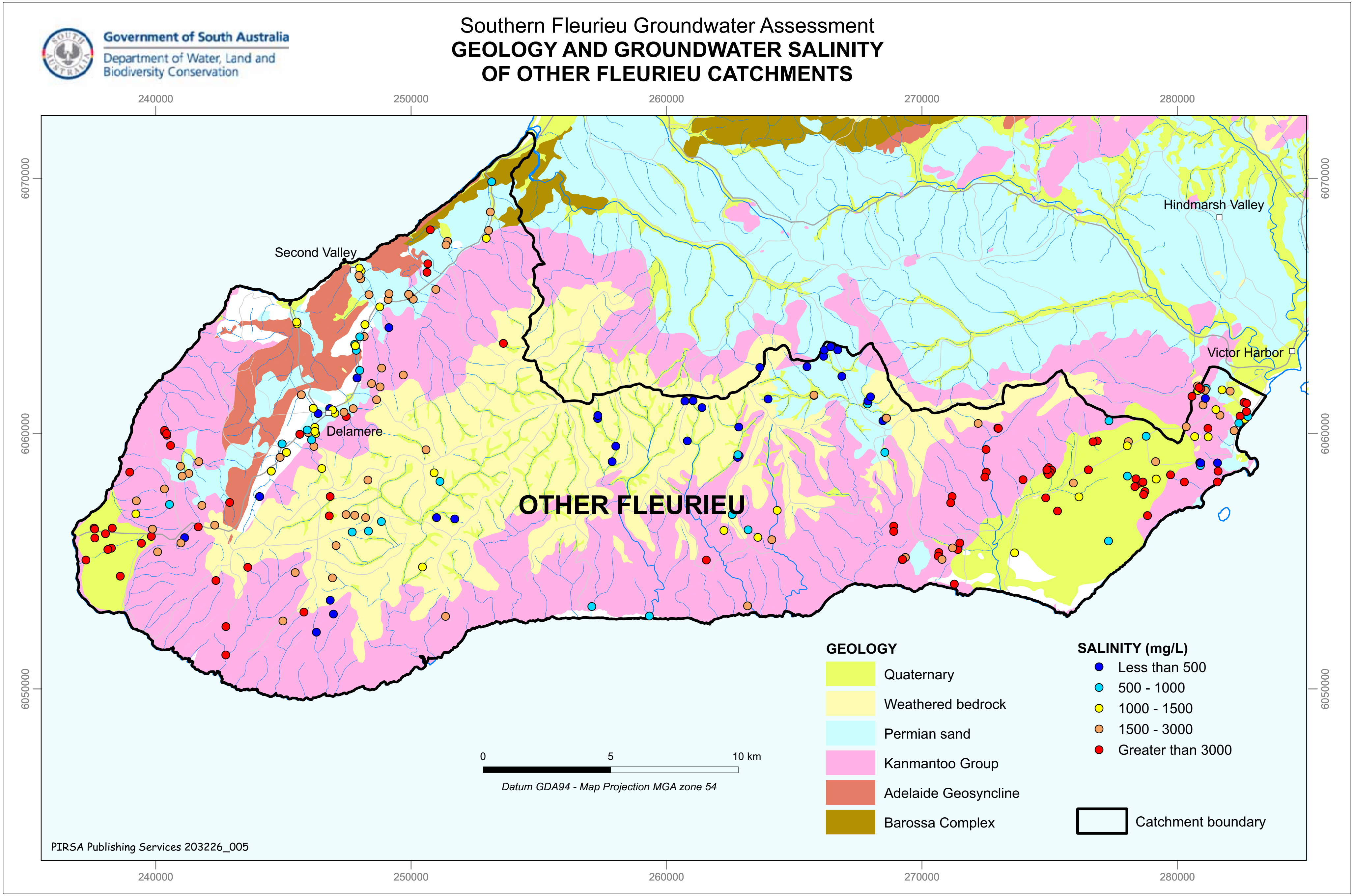

Government of South Australia
Department of Water, Land and Biodiversity Conservation
Southern Fleurieu Groundwater Assessment
GEOLOGY AND GROUNDWATER SALINITY
OF OTHER FLEURIEU CATCHMENTS
240000
250000
260000
270000
280000
6070000
6060000
6050000
Second Valley
Delamere
Hindmarsh Valley
Victor Harbor
OTHER FLEURIEU
GEOLOGY
Quaternary
Weathered bedrock
Permian sand
Kanmantoo Group
Adelaide Geosyncline
Barossa Complex
SALINITY (mg/L)
Less than 500
500 - 1000
1000 - 1500
1500 - 3000
Greater than 3000
Catchment boundary
0
5
10 km
Datum GDA94 - Map Projection MGA zone 54
PIRSA Publishing Services 203226_005

Figure 19

4. GROUNWATER DEPENDENT ECOSYSTEMS

4.1 SOUTHERN FLEURIEU WETLANDS

The Southern Fleurieu wetlands are listed as a Critically Endangered Ecological Community under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999, because not only are the flora and fauna unique, some species are considered to be declining, and the wetlands are subject to land use changes that threaten their viability.

The wetlands support dense native vegetation and occur on waterlogged soils with moisture available all year round. This moisture availability is controlled by geology and is limited to two main environments - in drainage lines and in broad depressions in valley floors.

In order to determine the main sources of water supplying the wetlands, and to assist in formulating management approaches (discussed later in this report), the wetlands have been broadly categorised on the basis of their position in the landscape and their underlying geology. These categories are described below.

4.1.1 PERCHED WETLANDS

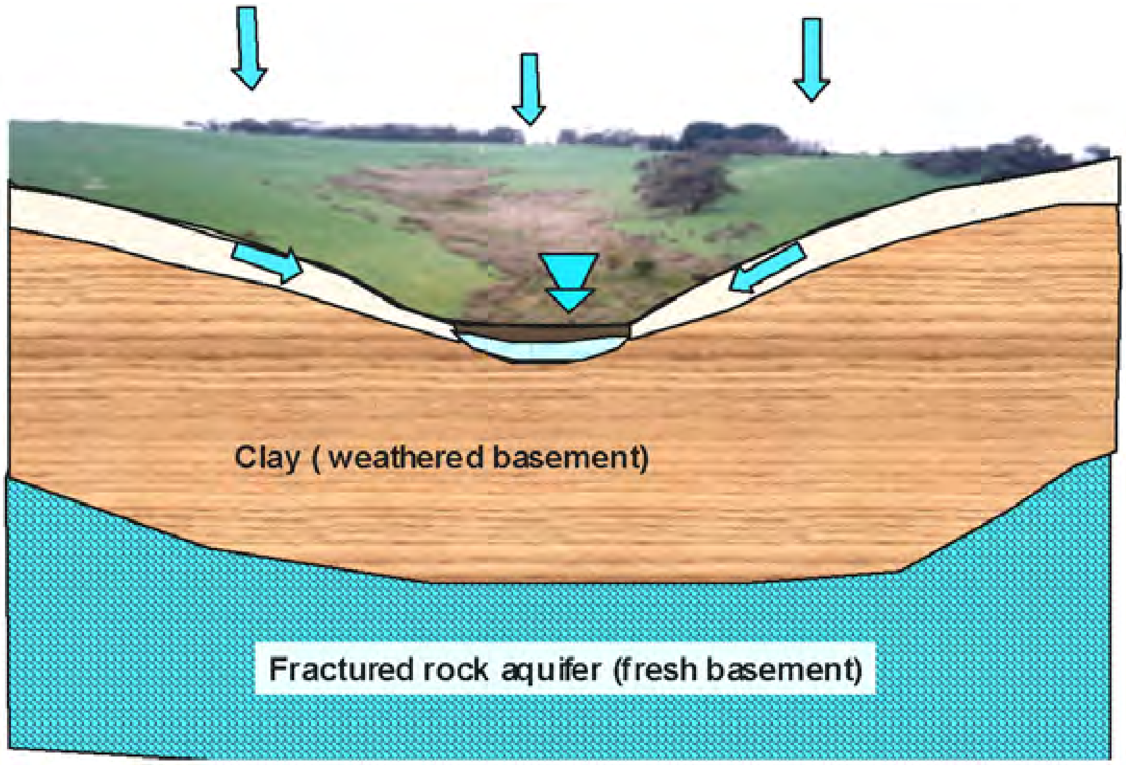
Wetlands are considered perched when they occur in drainage lines over clayey weathered basement, which can attain a thickness of up to 30 m. As a result, there are no losses from the drainage line by vertical infiltration, and no effective connection between the wetlands at the surface and the fractured rock aquifer found beneath the clay. Because there is no contribution from the deeper regional groundwater in the fractured rock aquifer, the wetlands are dependent on rainfall runoff or lateral subflow from the soil profile above the clay (Fig. 20). Water also flows slowly down the catchment within the wetland sediments.

Perched wetlands are generally found near the top of catchments (in first or second order streams with steep gradients) where deep weathering of basement rocks occurred during the Tertiary period. Most are located to the south on the Parawa plateau over weathered Kanmantoo Group metasediments, with some also found on the high plateau south of Myponga over weathered Barossa Complex granites. In the study area, there are 478 of these wetlands, which constitutes 77% of the total number.

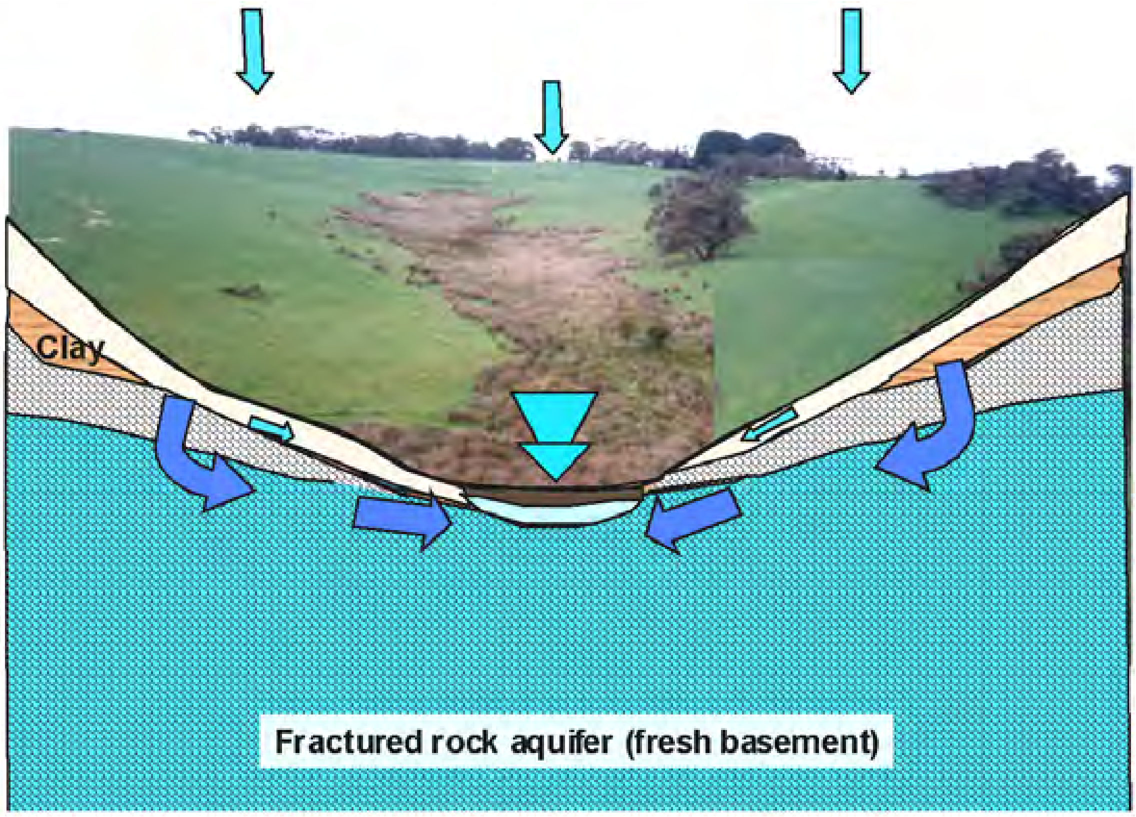
4.1.2 FRACTURED ROCK WETLANDS

Toward the bottom of the catchments, the weathered basement has been mostly eroded away and wetlands may be in direct contact with the regional fractured rock aquifer (Fig. 20). In addition to runoff and minor subflow, groundwater discharge may make a significant contribution to wetland water requirements, particularly during the summer months.

These wetlands are found on the lower flanks of high plateaux and toward the south coast in mostly fourth order streams where stream gradients are relatively low. Exposures of fresh bedrock would be commonly visible. There are estimated to be 12 of this type of wetland (about 2% of the total).



PERCHED



FRACTURED ROCK

Figure 20. Wetland categories – Perched and fractured rock

4.1.3 TRANSITIONAL WETLANDS

There will be a gradual transition between the perched wetlands near the top of the catchment, and the fractured rock wetlands near the bottom of the catchment toward the coast. The predominant source of water for a wetland may change as the ground elevation decreases down the catchment, with the boundaries between areas where particular sources of water predominate, difficult to determine.

4.1.4 PERMIAN SANDS WETLANDS

Wetlands underlain by Permian Sands usually occur in the lowest parts of the landscape in valleys and depressions where they are in direct contact with the regional watertable aquifer (Fig. 21). Because of the sandy soils, there is very little surface runoff and groundwater provides almost all of the wetland water requirements. Provided the watertable is not too low for plant uptake, there are no constraints on the amount of water available for transpiration. A total of 117 Permian Sand wetlands have been identified (19% of total).

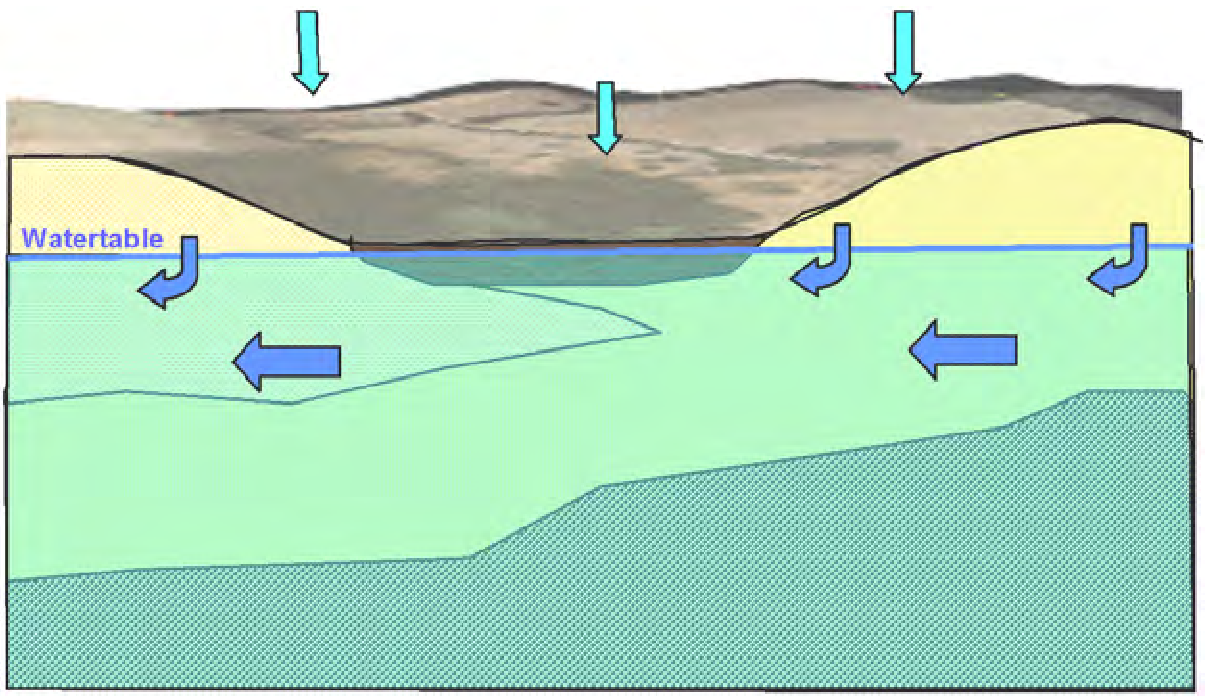


Figure 21. Wetland categories – Permian Sand

4.1.5 HYDROGEOLOGICAL INVESTIGATIONS

To determine the relative dependence of wetlands on surface water and groundwater resources, a network of shallow watertable monitoring wells was drilled in selected wetlands. Selection of monitoring well sites was based on a range of criteria including wetland condition, geology, position in topography, surrounding land uses, and site access. A total of 23 monitoring wells were constructed at 15 wetland sites.

The impact of surrounding land use is a key focus for the assessment. Monitoring sites were located to determine the impacts of clearing and grazing, the draining of wetlands, upstream dams, and forestry (blue gum and pine plantations). One site was selected in a native vegetated catchment to observe the naturally occurring trends.

Details of well construction methods and representative geological logs are presented in Appendix A. Table 2 lists the shallow monitoring wells and their respective wetlands.

4.2 PERMANENT POOLS

Permanent pools are very important ecological refuge areas for aquatic life during dry periods. They also support a wide range of vegetation, which add to the diversity of habitats available for aquatic fauna to utilise. These pools are usually deep enough to intersect the watertable, which can supply water all year round.

Whilst it would be impracticable to determine the degree of connection with the watertable for each pool, and the volumes supplied by groundwater, it is intended to develop a management regime that will minimise the impacts from further groundwater development. The main impact would be a lowering of the watertable by pumping which could lead to a drying out of the pools. This regime would include the formulation of buffer zones around the permanent pools, with the width determined by aquifer characteristics, similar to the buffers around wetlands.

4.3 BASEFLOW

Permanent baseflow is provided by groundwater discharge and is that part of the flow regime of a stream that is constantly flowing, often at very low flow rates. Baseflow maintains extended areas of wetted habitat suitable for a range of fauna and flora, and also maintains water quality in permanent pools and connection between permanent pool habitats during dry periods.

A decrease in groundwater levels due to inappropriate groundwater development could reduce discharge to the streams, or in a worst case scenario, induce flow out of the stream. Again, a buffer approach is recommended to prevent the radius of influence of new extractions from intersecting the streams.

Table 2. Wetland monitoring wells

Wetland No.	Wetland Name	Wetland Category	Obswell No.	Depth (m)	Salinity (mg/L)
S2586a	Lawless Lane / Myponga Swamps	Permian Sands	MYP 29	1.5	
S2586b	Lawless Lane / Myponga Swamps	Permian Sands	MYP 30	2.5	129
S2920a	Lawless Lane Swamps	Permian Sands	MYP 31	5.7	182
S2920b	Lawless Lane Swamps	Permian Sands	MYP 32	1.6	167
S2566a	Glenshera Swamp	Permian Sands	MYP 33	1.8	128
S2873a	Burnfoot Wetlands	Perched	ENB 23	1.5	278
S2866a	Wadnama Wetlands	Perched	ENB24	1.3	210
S2321a	Maylands Swamp	Perched	WAP 1	4.5	224
S2321b	Maylands Swamp	Perched	WAP 2	1.0	1692
S2354a	Willow Creek Swamps	Perched	WAP 13	5.0	227
S2883a	Willow Creek Swamps	Perched	WAP 3	5.0	191
S2883b	Willow Creek Swamps	Perched	WAP 4	1.3	2121
S2351a	Upper Coolawang Creek Wetlands	Perched	WAP 5	2.3	639
S2174a	Illawong Swamp (Martins Block)	Perched	WAP 6	1.8	215
S2177a	Upper Tunkalilla Creek Swamps	Perched	WAP 7	1.3	715
S2177b	Upper Tunkalilla Creek Swamps	Perched	WAP 8	1.5	183
S2184a	Upper Deep Creek Wetlands	Perched	WAP 9	2.5	662
S2155a	Upper Deep Creek Wetlands	Perched	WAP 10	2.5	
S2217a	Gold Diggings Swamp (NW branch)	Perched	WAP 11	2.0	210
S2217b	Gold Diggings Swamp (NW branch)	Perched	WAP 12	0.8	183
S2289a	Anacotilla Creek Swamp	Perched	YAK 2	1.8	4751
SFBalq1	Balquidder Plantation	Perched	WAP 18	1.5	1850
SFBalq2	Balquidder Plantation	Perched	WAP 19	1.4	1311

5. MONITORING

In the past, groundwater monitoring in the Southern Fleurieu has been restricted to only areas of concentrated extraction. Recently however, monitoring of groundwater levels in wetlands has commenced to help understand their water requirements in order minimise impacts from further development.

5.1 MYPONGA AND HINDMARSH TIERS CATCHMENTS

Observation networks in the study area exist only where groundwater extractions are concentrated in the Myponga Basin (17 bores located in Fig. 22) and the Hindmarsh Tiers Basin (16 bores located in Fig. 23). Readings began in 1976 and continued until 1994 when funding and staff reductions resulted in a cessation of monitoring. Monitoring resumed again in 1999. In 2000, the Myponga network was extended to the northeast to monitor extractions from the Permian Sands aquifer in the Pages Flat area. The circular or rectangular green areas in Figures 22 and 23 are areas of irrigated pasture.

Because the limestone aquifers are confined by the overlying Quaternary clays, the drawdowns show in typical hydrographs from the observation bores (Figs 24–25) are variations in confined aquifer pressure. These seasonal variations of 5–6 m due to pumping for irrigation each summer, occur more quickly and are greater than drawdowns in the unconfined Permian Sands aquifer (eg MYP 7, ENB 19).

In addition to these drawdowns, there are long term variations caused by changes in annual rainfall. In drier years, not only is there less recharge from rainfall, but there is also a greater demand for irrigation pumping to compensate for the lower rainfall.

Also plotted in Figures 24 and 25 is the cumulative deviation of the mean annual rainfall. This graph measures the difference between the actual measured rainfall and the average rainfall on a monthly basis. An upward trend in this line indicates above average rainfall, and conversely, a downward trend indicates below average rainfall.

There has been little change in the highest pre-irrigation groundwater levels in the Myponga area, with variations of 1–2 m in the lowest summer level, which show a close correlation with the rainfall deviation. In the Hindmarsh Tiers, there have been 2–3 m variations over the years due to these changes in annual rainfall with again, a close correlation with the rainfall deviation. The apparent decline in ENB 10 in recent years is most likely due to spring readings since 2000 being taken in September before full recovery occurs (which in previous years was in November).

The three year interval 1997–99 has experienced dry winters, which has led to declining groundwater levels but not to an alarming extent. When examining these hydrographs, it must be remembered that they represent pressure levels and that the limestone aquifer (which is 100–200 m thick) is full at all times. Only in some areas near the basin margins does the seasonal decline in groundwater level actually represent a slight dewatering of the aquifer.

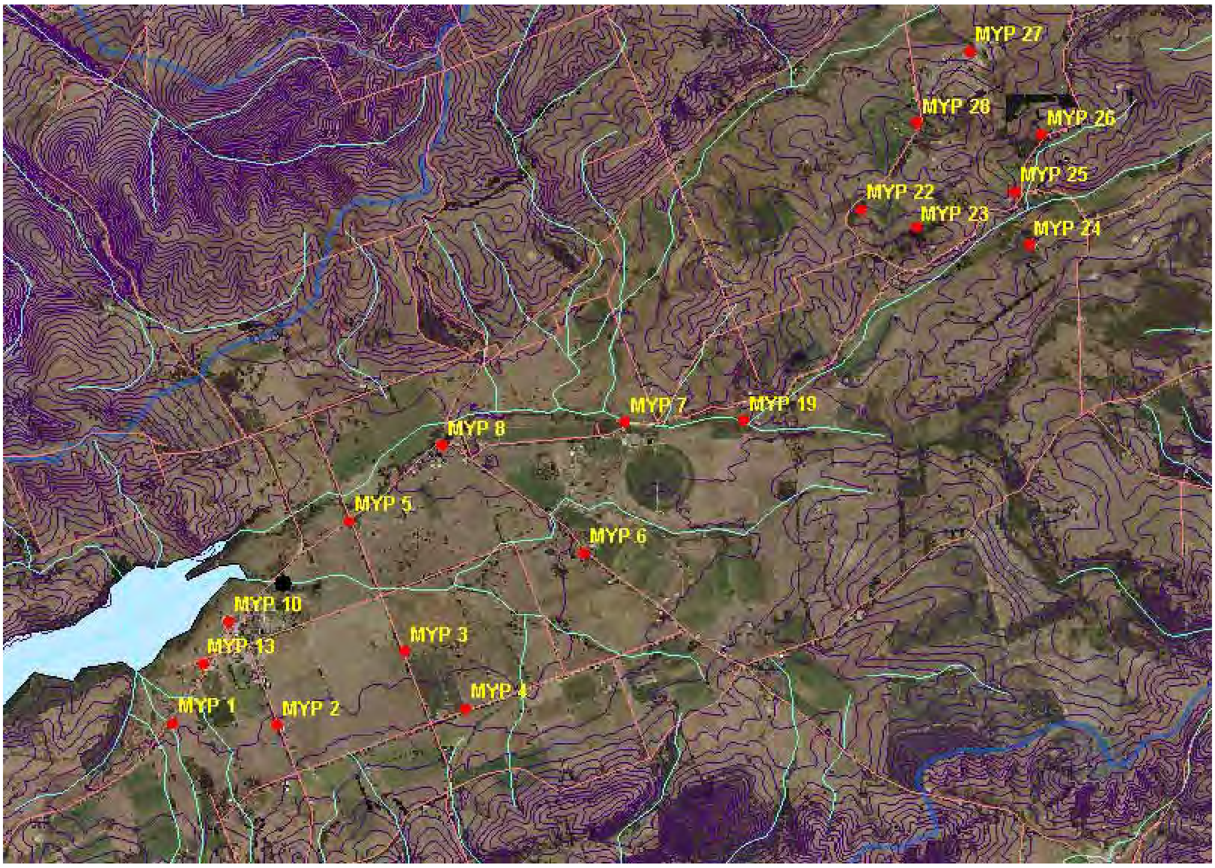


Figure 22. Myponga observation network

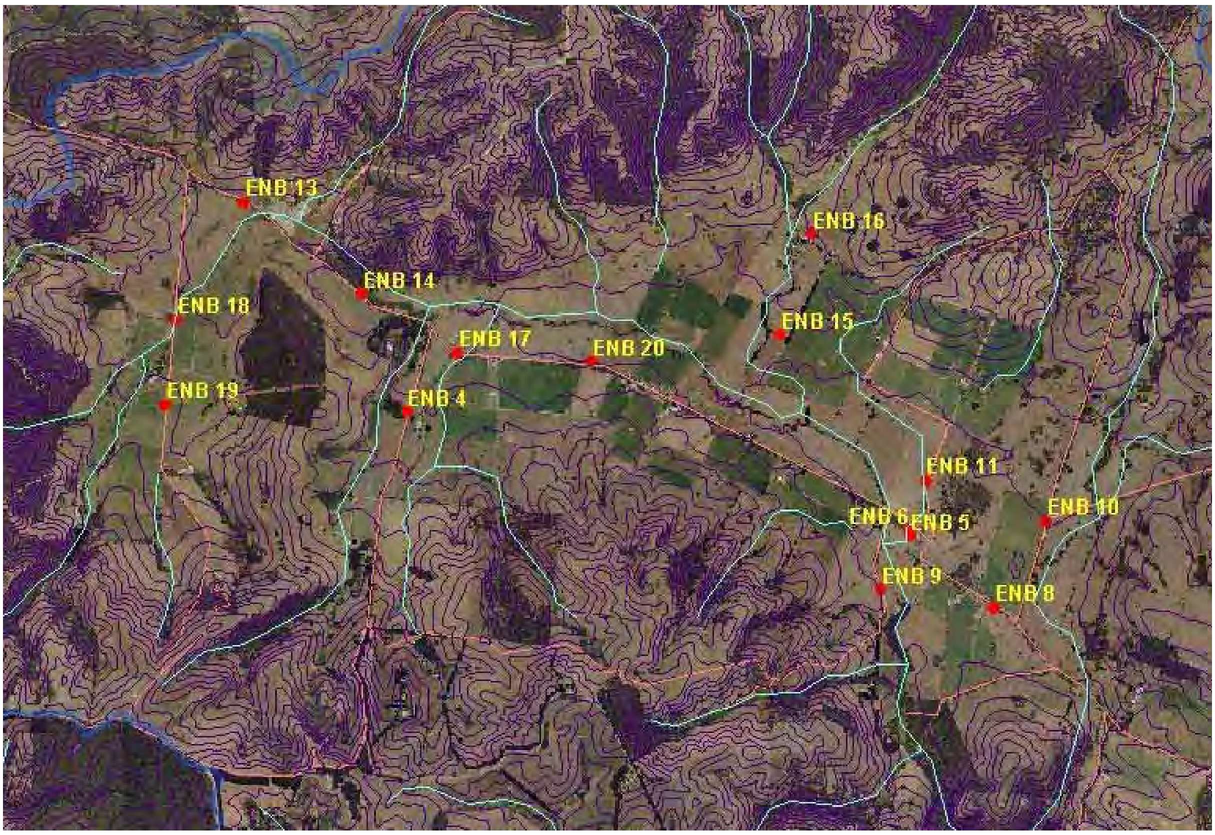


Figure 23. Hindmarsh Tiers observation network

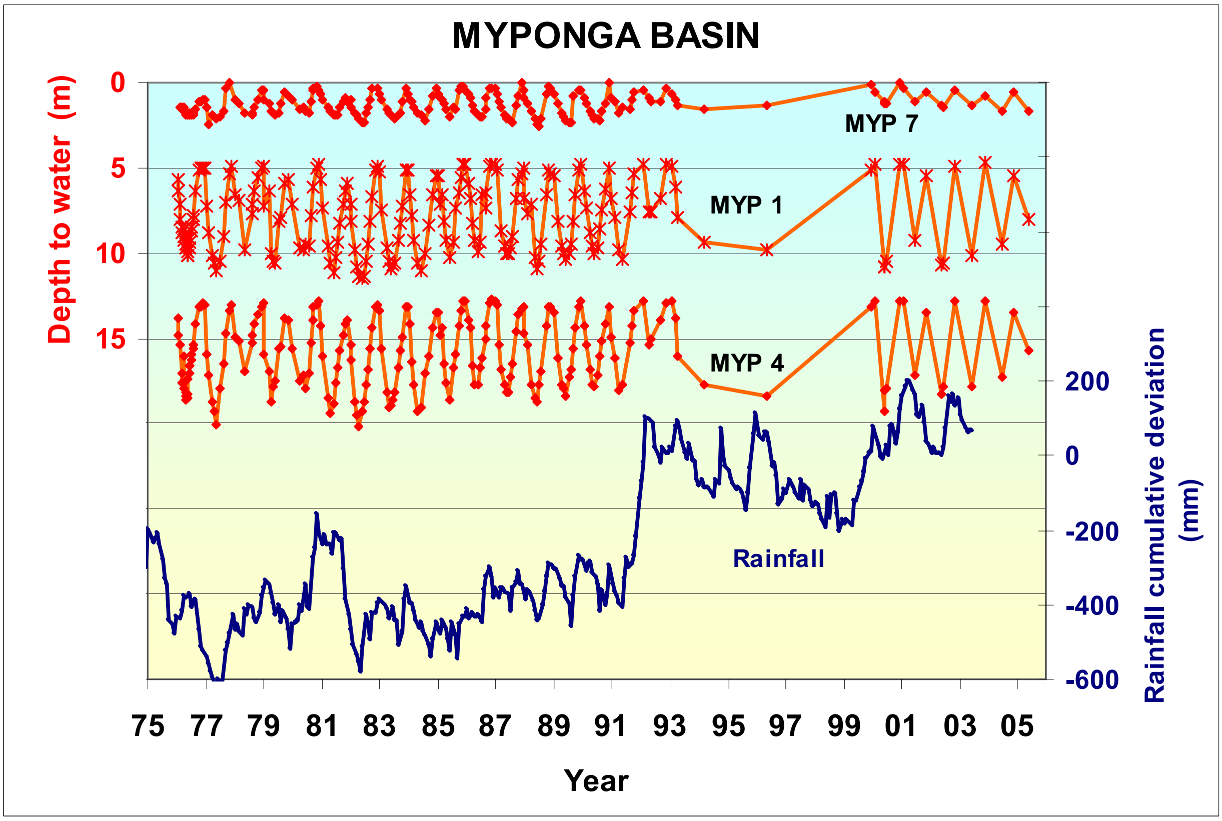


Figure 24. Myponga Basin representative hydrographs

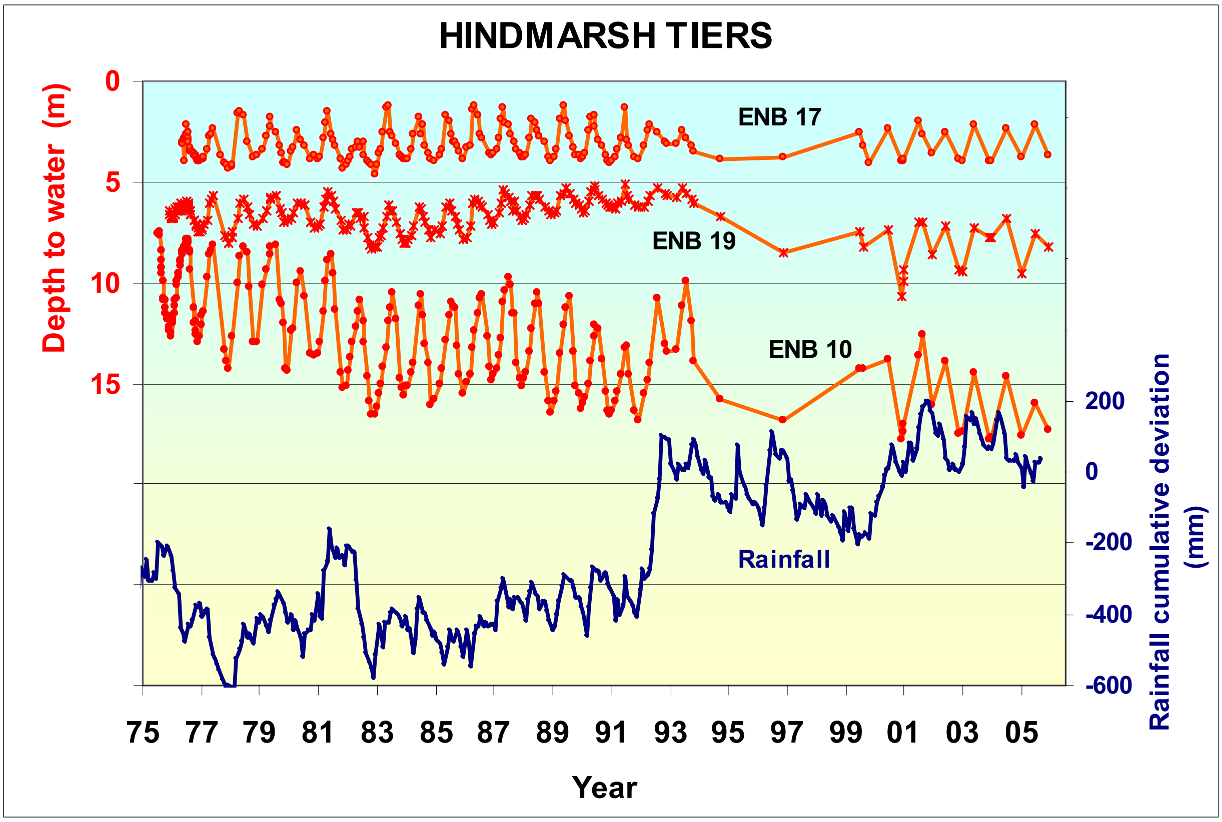


Figure 25. Hindmarsh Tiers representative hydrographs

5.2 SOUTHERN FLEURIEU WETLANDS

The 23 shallow monitoring wells listed in Table 2 have been monitored at regular intervals since June 2005, along with nine existing supply wells that are located close to wetlands but are intersecting deeper regional aquifers. The wells can be roughly subdivided into the north and south network as shown in Figure 27.

Although it is too early for long term trends to be detected, some information about hydrologic processes can be obtained. Figure 26 shows the water level fluctuations (shown in blue) in observation well MYP 29 completed in the Permian Sands aquifer, and is part of the northern network (Fig. 27). Here, the watertable responds quickly to rainfall events due to the permeable nature of the sandy soils.

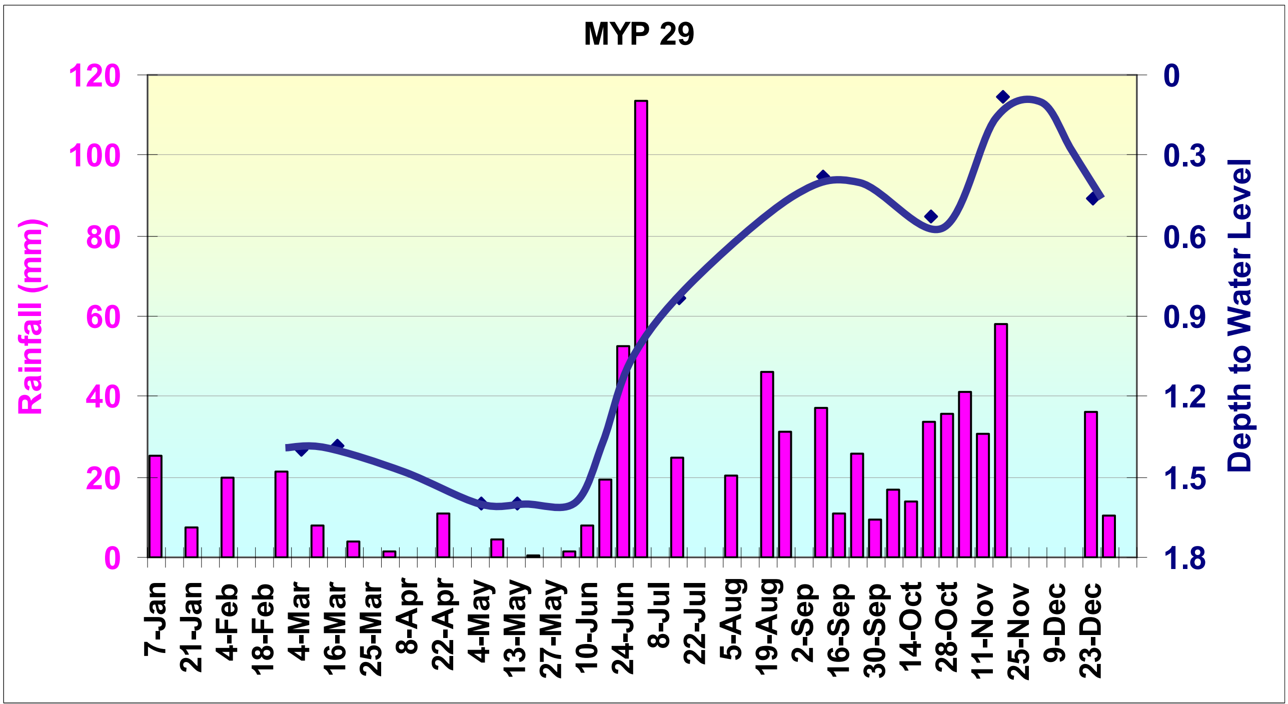
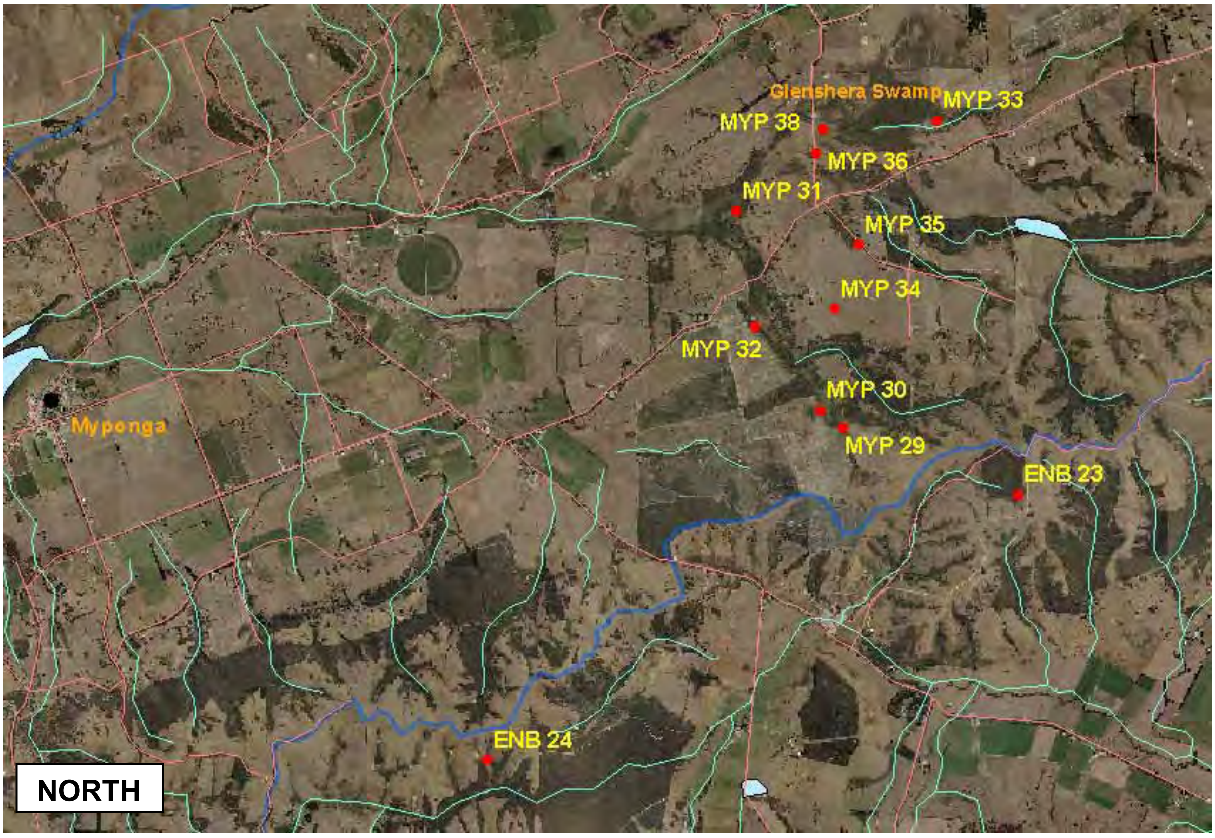


Figure 26. Southern Fleurieu wetlands observation network (north and south)

Ongoing monitoring will hopefully detect any impacts from changes in landuse (eg forestry, irrigation) surrounding the wetlands. Any additional wells drilled during further investigations, or as a requirement for monitoring land use changes, should be included in the network.

The low-yielding nature of the wetland sediments necessitate that observation wells should only be used for water level monitoring, because volumes extracted for water quality sampling may not only be inadequate, but may also affect water levels for some considerable time.



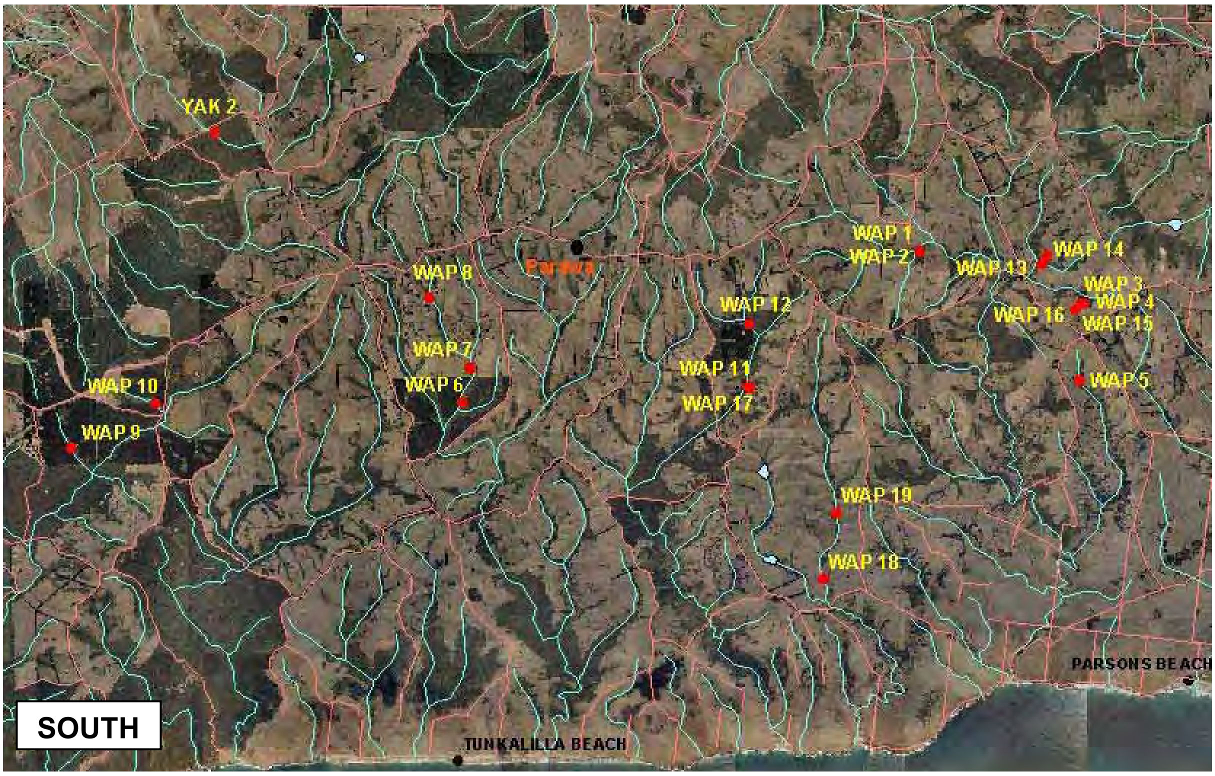


Figure 27. Southern Fleurieu wetlands observation network (north and south)

5.3 ELSEWHERE IN STUDY AREA

Because of the lack of groundwater development in other parts of study area, there has been no systematic monitoring of groundwater levels or salinity.

5.4 ACCESSING MONITORING DATA

All observation well data for the networks mentioned above can be obtained free of charge from the OBSWELL database via the web at this address ;

http://applications01.pirsa.sa.gov.au:102/new/obsWell/SearchGroup/startSearch - here

The following network names should be used to peruse or download observation well data;

- MYPONGA for the Myponga network,
- HINDMRSH for the Hindmarsh Tiers network, and
- STHNFLEU for the Southern Fleurieu wetlands network.

5.5 RECOMMENDATIONS

The existing networks are generally adequate for water level monitoring. The Myponga network in the vicinity of Pages Flat could be rationalised and extended further to the northeast to cover new areas of irrigation and forestry on the Permian Sands aquifer. The Hindmarsh Tiers network could also be extended further to the east in new areas of irrigation, also from the Permian Sands aquifer. Also within the Hindmarsh Tiers network, wells ENB 5, 6 and 12 should be cleaned out, and spring readings should be carried out in November to ensure monitoring of the maximum recovery level.

A broad reconnaissance water level network should be established in other catchments with Permian Sands which are as yet, undeveloped. These include the Lower Hindmarsh, Inman, Carrickalinga, Bungala and Yankalilla Catchments.

To date, there has been no regular salinity monitoring in any area, probably as a result of the very good quality of groundwater used for irrigation. Regular annual monitoring of strategic irrigation wells should be carried out, with landholder notification of the results.

Strategic permanent pools should be selected for water level and salinity monitoring, together with watertable levels in nearby existing wells in order to increase understanding of the connectivity between them.

6. ASSESSMENT OF CAPACITY OF RESOURCE TO MEET DEMANDS

Water balances have been carried out for major catchments in the study area (Barnett and Zulfic, 2002), which involved the estimation of recharge, groundwater extraction and sustainable yield. A summary of the water balances for each catchment is discussed below, together with the assessment of the groundwater resources to meet demands. The detailed water balances and explanation of the method are presented in Appendix B.

Because of the lack of metering of irrigation extractions in the study area, the estimates of groundwater pumping are based on the observed irrigated area and the theoretical crop irrigation requirement. The assumptions made when calculating the theoretical crop requirement generally result in an overestimate of about 25% from the actual applied irrigation.

6.1 MYPONGA CATCHMENT

Most of the extractions in this catchment are from the confined limestone aquifer for the irrigation of dairy pasture. Table 3 shows the changes in groundwater pumping over time.

Table 3. Historic land and water use – Myponga Basin

	Area (ha)				
	1976	**1985**	**1995**	**2000**	**2005**
Pasture	440	477	542	544	501
Vegetables		20	25.5	25.5	21.4
Vineyards			6.5	6.5	76
Horticulture					61
Water use (ML)	**3212**	**3535**	**4038**	**4053**	**4330**

These figures show that a 14% expansion in irrigated areas took place during the period 1985–95, with a further 7% increase from 2000–05.

Barnett and Zulfic (2002) estimated recharge to be 15 000 ML/yr, which is well in excess of the estimated extraction. Examination of the hydrographs (Fig. 24), show no adverse impacts from either the confined limestone aquifer or the unconfined Permian Sands aquifer. Consequently, it is considered that the aquifers have therefore no difficulty in meeting current and reasonable future demands, provided there is no dramatic change to the recharge regime.

6.2 HINDMARSH TIERS CATCHMENT

Like Myponga, most of the extractions in this catchment are from the confined limestone aquifer for the irrigation of dairy pasture. Barnett and Zulfic (2002) estimated recharge to be 8000 ML/yr, which is well in excess of the estimated extraction (Table 4). Currently, there is no evidence of adverse impacts and it is considered that the aquifers will meet current and reasonable future demands, provided there is no dramatic change to the recharge regime.

Table 4. Historic land and water use – Hindmarsh Tiers

	Area (ha)				
	1976	**1985**	**1995**	**2000**	**2005**
Pasture	175	250	308	313	423
Water use (ML)	**1278**	**1825**	**2248**	**2285**	**3088**

Extractions in this area have shown a steady increase of 23% during the period 1985–95, with a further 35% increase from 2000–05.

6.3 INMAN AND LOWER HINDMARSH CATCHMENTS

The predominantly low yields and high salinities in these catchments result in small demand, mainly for stock and domestic purposes. The Inman Catchment has an estimated extraction of 60 ML/yr, less than 1% of the recharge estimated by Barnett and Zulfic (2002). Extractions in the Lower Hindmarsh have not been quantified, but are thought to be less than the Inman. Consequently, the groundwater resources can easily meet current demands, with little potential for future development.

6.4 CARRICKALINGA, YANKALILLA, BUNGALA AND OTHER FLEURIEU CATCHMENTS

At present, there is insufficient information available to carry out catchment water balances in order to estimate recharge. Land and water use surveys have yet to be carried out for this area, but recent aerial photography indicates very little irrigation development. There is no monitoring information at the moment to verify, or otherwise, any adverse impacts from this development. In the absence of any complaints or anecdotal evidence from the community, it can only be assumed that the resource is meeting the current small demand, with little potential for future development.

7. POTENTIAL IMPACTS OF WATER USE

The potential detrimental impacts that the use of groundwater from the Southern Fleurieu aquifers may have on the quantity or quality of water of another resource need to be considered.

The boundary of the region is based on surface water catchments, and consequently is mostly defined by topographic highs comprised of basement rocks. They contain fractured rock aquifers of limited permeability, and create steep terrain that is unsuitable for irrigation. These factors result in a lack of extraction that could impact on the groundwater resources in an adjacent catchment. Similarly, it is highly unlikely that development in an adjacent catchment will impact on Southern Fleurieu groundwater.

An exception is the boundary with the Finniss and Tookayerta Catchments (to the west of Mt Compass township), which occurs over the Permian Sands aquifer. Groundwater flow is currently in a southwesterly direction, into the Southern Fleurieu area. Any intensive extractions within 500 m of the boundary may have drawdown impacts in the other catchment, but they are not expected to have detrimental impacts on the resource.

A similar situation occurs to the east of Hindmarsh Tiers with the boundary between the Hindmarsh River Catchment (within the study area) and Currency Creek Catchment overlying the Permian Sands aquifer. Groundwater flow is northward, parallel to the boundary. Because of the limited thickness of the aquifer in the Hindmarsh Catchment and generally low yields in the area, is expected that there will be no impacts from water use in either catchment.

It is recognised that groundwater extractions may have an impact on surface water resources, particularly if wells are located very close to streams or wetlands. A decrease in groundwater levels due to inappropriate groundwater development could reduce discharge to the streams, or in a worst case scenario, induce flow out of the stream. Management options to minimise this impact will be discussed later in this report.

8. GROUNDWATER MANAGEMENT

The sustainable development of groundwater needs to consider the long-term effects of groundwater development on surface water availability, on natural ecosystems, and on the availability of water resources for future generations. Usually, sustainable yields for groundwater resources are often based on estimates of recharge, which often have a large uncertainty of at least +/- 30%. Unfortunately, these estimates of sustainable yields then become "magic numbers" for water resource managers who proceed to manage the resources within +/- 5% of the yield estimate, despite the uncertainty.

The State Water Plan 2000 accepts the definition of sustainable yield as proposed by the National Groundwater Committee of Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), namely that the sustainable yield is:

> *The groundwater extraction regime, measured over a specified planning timeframe, that allows acceptable levels of stress and protects the higher value uses associated with the total resource.*

The higher value uses may be agriculture, ecosystems, infrastructure, industry or other activities that are to some extent dependent on groundwater, and which the community reasonably expects will be maintained or developed for a defined period. The task of determining and ranking the value of potential uses or demands for any aquifer is likely to be a subjective process that will require a combination of community input and expert opinion (Evans et al., 1998).

One of the fundamental principals of the National Water Initiative is to return overallocated and/or overused groundwater systems to sustainable limits. Obviously, every effort should be made to ensure that the initial estimates of the sustainable yield available for allocation are precautionary, and are not undermined by significant and unaccounted changes to the water budget. The Initiative also seeks to “protect the integrity of water access entitlements from unregulated growth in interception (eg farm dams and forestry) through land-use change”.

As mentioned previously, the initial theoretical estimates of sustainable yield may have a large error margin, and consequently, an aquifer response or adaptive management approach is recommended whereby the sustainable yield can be refined over time based on monitoring the actual performance of the aquifers under pumping stress observed over several years.

In the Southern Fleurieu project area, the determination of the groundwater sustainable yield will be discussed on a catchment basis, together with management options to minimise impacts of future development on both existing groundwater users and groundwater dependent ecosystems (GDEs). Because the volumetric water requirements have yet to be determined for most GDEs, a precautionary approach has been applied in recommending a Permissible Annual Volume (PAV) available for allocation.

In addition, the establishment of buffer zones around existing groundwater users (irrigation, stock and domestic) and GDEs is proposed to protect them from the impacts of future groundwater development. This will prevent concentrations of pumping which could lead to excessive drawdowns and salinity increases. Implementation of buffer zones may prevent the full development of the PAV in some cases. The proposed buffer widths are conservative and may be refined with further investigation.

A summary of PAVs and buffer requirements is presented in Table 5.

8.1 MYPONGA CATCHMENT

As discussed in the previous section, the current use of approximately 4330 ML/yr is well below the estimated recharge of 15 000 ML/yr. Although much of the extraction is from the confined limestone aquifer, which would have little direct connection with permanent pools or wetlands, a precautionary PAV of 11 000 ML/yr (75% of annual recharge) is recommended in view of close connection with GDEs in the area of Permian Sands to the northeast of the catchment, and the potential impacts of forestry in this area.

In the western part of the catchment, most of the current extractions are from the confined limestone aquifer and consequently, the drawdown response in the aquifer to pumping is larger, both horizontally and vertically, than would be experienced in the Permian Sands unconfined aquifer to the east. A buffer of 500 m is recommended between the location of new irrigation wells in the confined limestone aquifer (with a yield greater than 10 L/sec), and the existing irrigation wells. Because this aquifer is confined, there is no direct hydraulic connection with GDEs, and a specific buffer for their protection is not required. In any case, the combined well buffer around all existing irrigation wells may cover most of the GDEs in this area.

In the Permian Sands aquifer, a buffer width of 250 m is recommended between the location of new irrigation wells (assuming a yield greater than 5 L/sec) and existing wells. This is taking into consideration the fact that most irrigation wells are screened in coarse sands that occur about 80 m below ground. For GDEs, a buffer width of 400 m is recommended. This distance is greater than the well buffer because wells may still operate effectively with several metres additional drawdown, whereas this same drawdown could have significant impacts on GDEs.

8.2 HINDMARSH TIERS CATCHMENT

The current use in this catchment is also well below the estimated recharge of 8000 ML/yr. A precautionary approach would result in a PAV of 6000 ML/yr (75 % of annual recharge). Most of the extractions are from the confined limestone aquifer with no direct connection with GDEs expected. Similar buffer widths to the Myponga Catchment are recommended, and are presented in Table 5.

8.3 INMAN AND LOWER HINDMARSH CATCHMENTS

Given the small amount of current development and limited potential for future expansion, conservative PAVs of 5000 and 2500 ML/yr are recommended for the Inman and lower Hindmarsh Catchments respectively, with a buffer of 250 m between the location of new and existing irrigation wells (assuming a yield greater than 5 L/sec), and 400 m between the location of new irrigation wells and GDEs.

8.4 CARRICKALINGA, YANKALILLA AND BUNGALA CATCHMENTS

Because of the lack of information and small amount of current development in these catchments, it is proposed to extrapolate the recharge rate of 87 mm/yr from the adjoining Inman Catchment, which has a similar geology. If groundwater development increases, further work can be carried out to refine the recharge estimates. Table 5 shows the derived PAVs based on a conservative 80 mm/yr recharge rate. Buffer widths similar to other Permian Sand catchments are recommended.

8.5 FRACTURED ROCK CATCHMENTS

Whilst there have been no specific recharge investigations for fractured rock aquifers, the low demand means that extrapolations from nearby catchments where water balances were carried out will be sufficient for the initial estimates of sustainable yield. In catchments with a high proportion of sedimentary aquifers (Myponga, Hindmarsh Tiers, Tookayerta and Inman), the recharge estimates were from 10–15% of annual rainfall (Barnett and Zulfic, 2002). In the Currency Creek catchment, about 75% of the area is underlain by Kanmantoo Group fractured rocks, and the recharge estimate reduced to 8% of annual rainfall.

Given the thick weathered zone overlying fresh bedrock, and the steep slopes that would encourage runoff rather than recharge, a recharge rate of 5% of rainfall is proposed for fractured rock aquifers, which equates to 35 mm/yr. A summary of all catchments and their resultant PAV is presented in Table 6. No further work is warranted to refine the PAVs at this stage.

A buffer of 250 m is recommended between new extraction wells (assuming a yield greater than 5 L/sec), and 400 m for GDEs. The exceptions to this requirement are perched wetlands which have no direct connection with the fractured rock aquifer. The buffer is reduced to 30 m for wells deeper than 30 m that penetrate below the thick weathered zone.

Table 5. Permissible Annual Volumes for Southern Fleurieu Catchments

Catchment	**PAV** (ML/yr)	Buffer for irrigation wells	Buffer for GDEs
Myponga River	11 000		
Limestone		500	N/A
Permian Sands		250	400
Hindmarsh Tiers	6000		
Limestone		500	N/A
Permian Sands		250	400
Inman River	5000	250	400
Lower Hindmarsh River	2500	250	400
Carrickalinga Creek	4500	250	400
Bungala River	4000	250	400
Yankalilla River	6500	250	400
Fractured rock	Table 6	250	400 (30)

Table 6. Permissible Annual Volumes for fractured rock catchments

Catchment	PAV (ML/yr)
Carrickalinga Head	580
Lady Bay	45
Little Gorge	275
Wirrina Cove	85
Anacotilla and Congeratinga Rivers	1340
Boat Habour Hill	30
Parananacooka River	450
Rapid Bay	40
Rapid Head	200
Yattagolinga River	870
Yohoe Creek	640
Starfish Hill	45
Coolawang Creek	1430
Salt Creek	550
Cape Jervis	600
Waitpinga Creek	2100
Newland Head - The Bluff	670
Tunkalilla Creek	900
Callawonga Creek	680
Boat Harbor Creek	700
The Deep Creek	1450
Ballaparudda Creek	440
First Creek	170
Fishery Creek	300
Tunkalilla Beach	260
Tapanappa	325
Blowhole Creek	425
Parsons Beach	210
Balquhidder	50
Cooalinga Creek	125
Bare Rock	65
Tunk Head	160
Talisker	150
Aaron and Tent Rock	580
Victoria Wreck	60
Naiko Inlet	65

8.6 FORESTRY

Forest plantations can potentially impact on water resources in three ways. They can reduce surface water runoff, they can significantly reduce groundwater recharge, and they can directly extract water from shallow groundwater resources within about 7 m of the ground surface. These impacts could significantly alter the water balance of a catchment.

Barnett and Zulfic (1999) calculated how the water loss by evapotranspiration in the Tookayerta Catchment has varied over time as shown in Table 7.

Table 7. Historical land cover and evapotranspiration in the Tookayerta Catchment

Vegetation cover	**Area** (ha)			
	1949	**1979**	**1989**	**1992**
Native vegetation	1668	582	564	654
Pines		108	180	216
Eucalypt plantation				
Loss by ET (ML/yr)	**8874**	**3726**	**4048**	**4736**

The above figures show the decrease in evapotranspiration as clearing of the catchment progressed. This would have led to increasing recharge to the groundwater system and subsequently, increasing streamflow. However, this trend is being reversed by the increasing area of native vegetation (replantings and regrowth) and pine plantations.

DWLBC are undertaking extensive investigations to better estimate stream flow and groundwater recharge, understand the impacts of water use on environmental water requirements and set sustainable limits for use, diversion and extraction of both surface and groundwater resources. Large scale plantings could significantly increase water use into the future and undermine sustainable yield estimates, leading to over-allocation of the water resource.

If forestry is to become a sustainable industry, its impact on water resources should be accountable so that it can be considered a legitimate water user in the Water Allocation Plan management framework. This is especially the case where there maybe competition for high value water resources. For example, portions of the Tookayerta, Myponga and Finniss Catchments are underlain by low salinity groundwater (less than 1000 mg/L) in the Permian Sands aquifer. This area should be considered a prohibited area for forestry, until the water requirements for plantations are known, and the WAP has determined the volume of water available for additional use.

8.7 SALINITY

The Southern Fleurieu Peninsula Salinity Management Plan (Liddicoat and Hermann, 2002) identified only 500 ha of land (~0.5% of the area) affected by dryland salinity caused by rising watertables following clearing. Rising stream salinities were thought to be a greater hazard. The Plan outlines a range of management options involving a combination of recharge reduction, engineering and living with salt options.

APPENDICES

A. WETLAND INVESTIGATIONS

MONITORING WELL INSTALLATION

To determine the relative dependence of wetlands on surface water and groundwater resources, a network of shallow water table monitoring wells was drilled across the Southern Fleurieu. Monitoring the water level trends in these shallow wells compared to rainfall data can indicate whether there is a direct or indirect relationship to ground and surface water. The drilling process itself also provides essential information on the geology underlying the wetland, which can also indicate the dependence on either water source.

The drill sites were selected based on a range of conditions including wetland condition, geology, position in topography, surrounding land uses, any changing dynamics of wetland observed, and site access. Information regarding wetland ‘significance’ and condition was determined by surveys and assessments conducted by the Department of Environment and Heritage (Harding, 2005).

The impact of surrounding land use is a key focus for the assessment. Drill sites were located where the impacts of clearing, grazing, draining of wetlands, location of upstream dams, and forestry (blue gum and pine plantations) could be monitored. One drill site was selected in a native vegetated catchment to observe the naturally occurring trends.

Based on the above information, 15 swamps were selected for the location of 23 monitoring wells across the Southern Fleurieu.

Methods and Construction

Monitoring wells were drilled using three methods. A small mobile drilling rig mounted on a 4WD Landcruiser traytop was used for ten sites where access was possible (Fig. 28). Sites not accessible with the rig were drilled with either a petrol powered two-person auger (Fig. 29) or a hand-held posthole auger. Eight sites were drilled with the petrol-powered auger, which drilled to a maximum depth of 1.8 m. Any additional depth required was completed with the posthole auger. Five sites were drilled solely using the posthole auger.

Wells were lined with 50 mm diameter Class 9 or 12 PVC casing with slots in the water bearing zones. The bottom of the casing was sealed with an end-cap. The slotted sections of the wells were covered with a ‘filter sock’ to limit silt and sands from entering and blocking the casing. Some were completed with a gravel pack and a bentonite plug at the surface. All wells were cemented at the surface to stabilise the casing and seal the hole from surface water. Some wells were completed with a galvanised steel standpipe cover to prevent damage to the PVC casing by stock. Details on the construction of wells and geology encountered during drilling are presented at the end of this Appendix for representative sites in two of the predominant wetland categories.

Figure 28. 4WD mounted drilling rig

Figure 29. Two-person petrol powered auger

AQUIFER TESTS

Aquifer tests were conducted in two different geological settings to establish if any connection exists between the shallow groundwater in wetlands and regional aquifers already developed for groundwater supplies. Existing supply wells close to wetlands were pumped and monitoring wells in the wetlands were observed for any impact.

Perched

The first tests were conducted in the Coolawang Creek Catchment adjacent Willow Creek Swamp (S2883). Two shallow monitoring wells have been constructed adjacent this swamp – WAP 3 is 5 m deep and WAP 4 is 1.3 m deep (Fig. 30). There are two supply wells located near the swamp. The first well (6526-506) is located upslope and 160 m from the wetland. It is 103 m deep and intersects the Kanmantoo Group fractured rock aquifer, which occurs below 15 m of clay. The second well (6526-36) is reportedly 13 m deep and is located on the edge of the wetland. It sources its water from the shallow water table through clays and sands deposited in the valley.

The first well was pumped for 24 hours on 5th Sept 2005 at an approximate flow rate of 1.1 L/sec. Despite the fact that the water level in the pumped well gradually dropped from an original 10.4 m (bgl) to beyond 64.0 m (indicating a very poor aquifer), there was no change in water levels in the two shallow monitoring wells. The water level in the shallow pumping well (6526-36) had dropped by 0.02 m.

Following completion of the first test, the shallow pumping well was started on 6th September 2005. The water level in this well dropped from an original 0.02 m (bgl) to a stable 5.44 m (bgl) after the 24-hour period. Water levels in the adjacent shallow monitoring wells did not alter at all throughout the pumping test. The estimated pumping rate for this well is 0.5 L/sec, which also suggests this well is a intersecting a very low yielding aquifer.

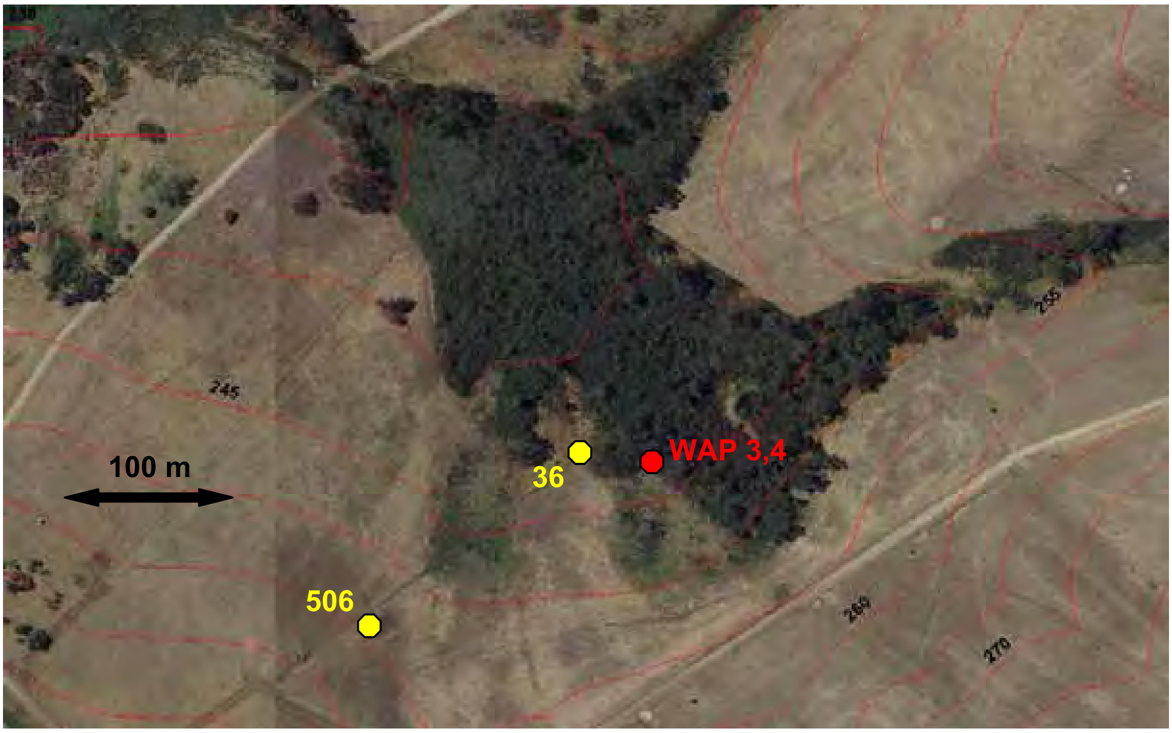


Figure 30. Aquifer test site at Willow Creek

Permian Sand

The second test site was located adjacent the Glenshera Swamp (S2566) in the Myponga River Catchment. The pumping well (6627-172) is reportedly 106 m deep, which is typical for supply wells in the area due to the low permeability sediments at shallower depths. Its pumped rate was ~1.0 L/sec. Observations were made in two former stock and domestic supply wells located adjacent to each other, slightly downslope and ~60 m from the pumping well (Fig. 31). One of the wells (6627-173) is of circular concrete construction and was 4.6 m deep, with the second well (6627-171) equipped with 152 mm steel casing and 6.3 m deep.

Pumping began on 21st December 2005 and continued for 24 hours. After this time, the water level in the pumped well dropped 32 m, from an original 2.68 m (bgl) to 34.95 m (bgl). However, there was no real change in water levels in the two shallow wells. The water level in the concrete well (6627-173) dropped from 0.7–0.725 m, and the steel casing well (6627-171) dropped from 0.16–0.19 m. These very small drops in water level are difficult to distinguish from natural variations.

Figure 31. Aquifer test site at Glenshera Swamp

GROUNDWATER PROGRAM

WATER WELL LOG

PROJECT: Southern Fleurieu EWR

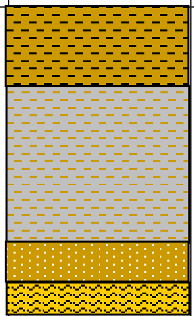
OBS No. WAP 11

UNIT No. 6526-540

Hundred: Waitpinga **Sec:** 345

Coordinates: E 252582 N 6058880 El. Surface(m) El. Ref. Point(m) Datum: AHD

AQUIFER SUMMARY	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	L/sec	Test length	Method	mg/L	Analysis No.
	1.8	1.36 (BGL)	1.0	2.0	NA	NA	NA	715	697932

DEPTH (m)		GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	Depth Core Sample	CASING		
From	To						Dia (mm)	From (m)	To (m)
0	0.5		SILTY CLAY	Light brown			50 PVC	-0.5	2.0
0.5	1.8		SILTY CLAY	Brown and grey with orange mottling					
1.8	1.9		CLAYEY SAND	Light brown/orange, some quartz gravels, moist					
1.9	2.0		SANDY CLAY	Orange, some quartz gravels, becoming drier					

REMARKS:

Nelson's Obswell, S2217a

DRILL TYPE: Auger	COMPLETED: 4/5/2005
DRILL FLUID: NA	LOGGED BY: Adrian Costa / Renata Rix
DATE: 4/5/2005	SHEET: 1 OF 1

The Department of Water, Land and Biodiversity Conservation

GROUNDWATER PROGRAM
WATER WELL LOG

PROJECT: Southern Fleurieu EWR

Observationm No. MYP 30

Unit No. 6627-11118

Hundred: Myponga **Sec:** A 48

Coordinates: E 276572 N 6080609 El. Surface(m) El. Ref. Point(m) Datum: AHD

AQUIFER SUMMARY	DEPTH TO WATER CUT (m)	DEPTH TO STANDING WATER (m)	INTERVAL (m)		SUPPLY			TOTAL DISSOLVED SOLIDS	
			From	To	L/sec	Test length	Method	mg/L	Analysis No.
	1.2	0.88 (BGL)	0.7	1.7	NA	NA	NA	129	683722

DEPTH (m) From	DEPTH (m) To	GRAPHIC LOG	ROCK/SEDIMENT NAME	GEOLOGICAL DESCRIPTION	FORMATION/AGE	Depth Core Sample	CASING Dia (mm)	CASING From (m)	CASING To (m)
0	0.8		SANDY SILT	Dark brown, organic matter			50 PVC	-0.5	2.5
0.8	1.2		SAND	Grey, coarse grained, wet					
1.2	2.0		CLAYEY SAND	Grey, coarse grained sand					
2.0	2.5			Red/orange, clay content increasing with depth					

REMARKS:

ABG New Trees Obswell, S2586b PERMIAN SAND WETLAND

DRILL TYPE: Auger	COMPLETED: 13/4/2005
DRILL FLUID: NA	LOGGED BY: Adrian Costa / Renata Rix
DATE: 13/4/2005	SHEET: 1 OF 1

B. CATCHMENT WATER BALANCES

One of the best ways to determine the health of a business is to examine its balance sheet - the same applies for a catchment. If spending (water outflow) is greater than income (water inflow), problems can be expected. Determining the water balance of a catchment is a fundamental step in establishing the sustainable groundwater yield for development.

The water balance methodology is applied to the four catchments where each of the following components of the water balance (Fig. 32) can be measured or estimated to a reasonable degree of accuracy.

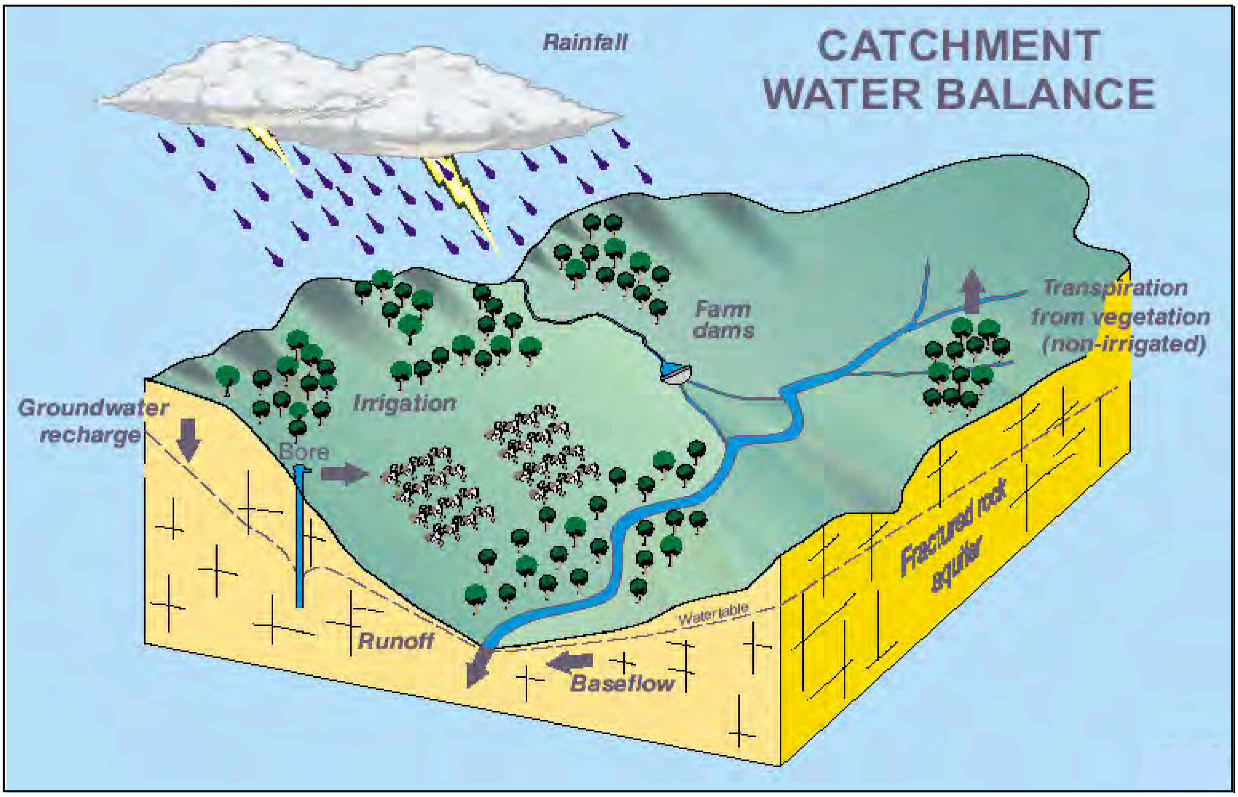


Figure 32. Catchment water balance components

RAINFALL

Rainfall is the main driving force of the hydrologic cycle and is the major water input to catchments. Rainfall in this region is winter dominant as discussed earlier. By combining a rainfall isohyet map with the areal coverage of a catchment, the total average annual volume of rainfall falling on the catchment can be calculated. Because most of the summer rainfall is lost by evaporation before it has a chance to percolate down to the plant root zone or the watertable, only winter rainfall (April–October) is considered to be effective in contributing to the water balance. Table 8 lists the rainfall in the selected catchments.

Table 8. Catchment rainfall volumes

Catchment	Annual rainfall (ML)	Effective Rainfall (ML)
Myponga	95 150	77 190
Hindmarsh Tiers	47 880	38 650
Inman	142 730	114 400

EVAPOTRANSPIRATION

After rain has fallen, water is absorbed by plants and trees through their roots. It is also evaporated from the topsoil and even from wet leaves in the tree canopy. Following recent research, reasonable estimates of plant water use by transpiration for various crops can be made. Surprisingly, this is often the largest water use component in the catchment.

A GIS coverage of land use in the MLR was constructed in 1993 and more recently in 1999 using current aerial photographs and ground truthing. This coverage can provide areas of native vegetation, pasture, vineyards etc and hence, the volume of water transpired (from non-irrigated areas) can be calculated. This coverage can be updated using more recent aerial photography.

Carmichael (2000) explains how the total volumes of evapotranspiration presented in the tables at the end of this appendix were derived. It must be stressed that these estimates of plant water use are accurate only to +/-10–15% and consequently, the estimates of evapotranspiration can at best, only have a similar accuracy.

STREAMFLOW

There is a network of about 70 continuous recording gauging stations throughout the MLR. Most of the data is stored at DWLBC on HYDSIS. Runoff and baseflow components can be separated from these records. Baseflow is the contribution to streamflow provided by groundwater discharge. Carmichael (2000) explains in more detail how the following estimates in Table 9 were obtained.

Table 9. Catchment streamflow volumes

Catchment	**Runoff** (ML)	**Baseflow** (ML)
Myponga	5300	3240
Hindmarsh Tiers	4032	2128
Inman	13 040	9005

SURFACE STORAGES

Some of the runoff is captured in farm dams. A recent study by DEHAA has calculated the volume of all farm dams in the MLR using infra-red aerial photography and a carefully derived formula. This coverage is also available on GIS. It is assumed that the dams are full at the end of winter/spring, and receive no more inflows during summer. Table 10 shows the volumes calculated.

Table 10. Catchment dam storage volumes

Catchment	**Dam Volume** (ML)
Myponga	613
Hindmarsh Tiers	175
Inman	896

GROUNDWATER PUMPING

The main component of groundwater pumping in the study area is for irrigation purposes. Unfortunately, very few of these bores have meters installed to measure their discharge. However, if a reasonably accurate estimate of the area and crop type irrigated can be obtained, estimates of the various crop water application requirements for irrigation during summer can then allow an approximate calculation of the total volume extracted.

Previous water balance studies used the 1999 land use survey coverage on GIS to provide irrigated areas and crop types. This method works well in the smaller catchments where properties are also small and are dominated by one land use. Unfortunately in the Southern Fleurieu, property sizes are larger and irrigation of dairy pasture or vegetables is carried out on only part of the property. Regrettably, the 1999 land use survey did not specifically delineate these irrigated areas and instead classified the whole property as dairy or vegetables which would give misleading results when calculating water use.

To overcome this shortcoming, recent aerial photography and field inspections were used to estimate irrigation water use. In some catchments, surface water from dams supplied up to 80% of the irrigation water. For the estimates of irrigation water use detailed in the following tables, an attempt was made to differentiate between surface and groundwater sources, with only the groundwater contribution being listed. The GIS landuse coverages were not used in these determinations.

It must be pointed out that these estimates are accurate only to +/-10–20%, but are nonetheless the best available. Metering of irrigation and industrial users is strongly recommended to obtain more accurate estimates of groundwater use. The estimates for pumping from private wells for domestic use is based on the number of domestic wells on SA-GEODATA and the average domestic consumption from SA Water reticulation in the area. It is probably an overestimate. There may be combined well and dam water supplies and some field verification of actual use may be required.

GROUNDWATER RECHARGE

This is perhaps the most important component and the most difficult to estimate. It can generally only be measured indirectly, and is variable over any given catchment because of its dependence on other variable factors such as soil type and vegetation cover. There are several methods available to estimate recharge.

a) water balance

Essentially this means calculating all other components of the water balance with the outstanding quantity attributed to recharge. This method averages the recharge over the whole catchment. Examination of hydrographs has shown very little change in storage in average rainfall years and consequently, recharge can be calculated by:-

Recharge = Rainfall - (Evapotranspiration + runoff + dam storage)

Another possible method of calculation is to look at only the groundwater component of the water balance:-

Recharge = Groundwater pumping + baseflow

Data from the Myponga Catchment is used here as an example.

Recharge = Rainfall - (Evapotranspiration + runoff + dam storage)

= 77 190 - (49 850 + 5300 + 613)

= 21 425 ML/yr or 173 mm/yr (24% annual rainfall)

By using the groundwater balance only,

Recharge = Groundwater extraction + baseflow

= 5155 + 3240

= 8395 ML/yr or 68 mm/yr (9%)

b) chloride balance

The chloride ion can be used to estimate recharge provided that it is not dissolved from rocks and minerals. After rain falls, evapotranspiration processes remove water from the soil. The conservative chloride ion remains and is consequently concentrated in the reduced amount of water that eventually percolates down to recharge the groundwater. Recharge can be calculated by:-

$$\textbf{Recharge} = \textbf{(annual rainfall - runoff)} \times \frac{\mathbf{Cl_{rf}}}{\mathbf{Cl_{gw}}}$$

where Cl_{rf} = chloride in rainfall (mg/L)

and Cl_{gw} = chloride in groundwater (mg/L)

Care must be taken when using this method for several reasons. Pumped samples from private holes may obtain water from deep within the aquifer rather than just below the watertable, which is the preferred location. In areas of intensive agriculture, chloride may be added by the recirculation of irrigation water and also by the application of fertilizers.

The chloride content of rainfall decreases with distance from the coast and several equations have been derived to quantify this relationship.

Hutton, 1976

$$\mathbf{Cl = \frac{0.99}{4\sqrt{d}} - 0.23}$$

where d = distance from coast in km
Cl = chloride concentration in milliequivalents/litre

Kayaalp, 1998

$\mathbf{Cl = 1.1 + 2.98\, e^{-d/111}}$ WET (in rainfall)

where d = distance from coast in km
Cl = chloride concentration in milliequivalents/litre

$\mathbf{Cl = 60 + 1043\, e^{-d/2.7}}$ DRY (aerosol dust)

where d = distance from coast in km
Cl = chloride loading in kg/km^2/month

The total chloride accession which consists of the sum of wet and dry chloride can then be included in the recharge formula above. The chloride content of groundwater can be obtained from the Water Chemistry module of SA_GEODATA.

Table 11. Chloride recharge estimates

Catchment	Cl_{gw} (mg/L)	Cl_{rf} (mg/L)	Recharge mm/yr	Recharge % of rainfall	Recharge ML
Hutton (1976)					
Myponga	280	12.7	37	5	4535
Hindmarsh Tiers	248	9.1	29	3.5	1610
Inman	1480	9.7	4	0.6	850
Kayaalp (1998)					
Myponga	280	5.7	18	2	2275
Hindmarsh Tiers	248	4.5	14	2	795
Inman	1480	4.7	2	0.2	416

From Table 11, the Hutton values were used in the calculations for the catchment recharge because the values determined by the Kayaalp method appear to be an underestimate, especially when considered as a percentage of annual rainfall. This trend is also evident in other catchment water balances.

c) Watertable rise

This technique measures the direct effect of recharge during the winter season, which leads to an increase in water stored in the aquifer. This is a reasonably straightforward method, however uncertainties are introduced because the measured watertable rise must be multiplied by the specific yield to obtain the volume of recharge that has entered the aquifer. Specific yield values are difficult to measure and are highly variable, even within the same aquifer.

In the Southern Fleurieu, the only regular water level monitoring has been carried out in Myponga and Hindmarsh Tiers. Because the annual fluctuations in water level in these areas are mainly caused by pumping and not natural discharge, the watertable rise method is not applicable.

d) Discussion

The two different methods of estimating recharge obtained different ranges of values in each catchment, although they were generally of the same order of magnitude, as shown in Table 12.

Table 12. Comparison of recharge estimates

Catchment	Water balance (ML)	Chloride (ML)
Myponga	8500–21 500	4535
Hindmarsh Tiers	4000–12 000	1610
Inman	9000–24 000	850

As stated earlier, in other water balance studies, the values calculated by the chloride method also appear to be low when compared to the other methods of calculating recharge. This probably indicates that a new chloride equilibrium has not been reached since land clearing and that the values obtained could reflect pre-clearing recharge rates.

Another complication may be the fact that the Southern Fleurieu is surrounded by the ocean on three sides (from the northwest through to the southeast), which could affect chloride levels in a manner inconsistent with the assumptions used in the theory of this method of determining recharge rates.

The water balance estimates could also be considered conservative because of the assumption that the November-March rainfall does not contribute to the water balance. The estimates of groundwater pumping and baseflow are at best approximate to within +/- 25–30%. The detailed catchment water balances are presented in the following tables. Essentially, the aim of a catchment water balance is to balance the inflow by rainfall (shown in pale blue in the following tables), with the sum of the outflows (shown in pink).

After consideration of the recharge values derived by all methods shown in the recharge section of the catchment water balances, it is proposed to accept the following values for these catchments (Table 13).

Table 13. Accepted recharge values

Catchment	ML	mm/yr	% of rainfall
Myponga	15 000	122	16
Hindmarsh Tiers	8 000	143	17
Inman	17 000	87	12

CATCHMENT WATER BALANCE

MYPONGA

Irrigation/extraction

Crop type/use	Area (ha)	Water use (mm)	Water loss (ML)
Pasture	501	730	3657
Vegetables	21.5	266	57
Vineyard	76	196	149
Horticulture	61	693	423
Stock and domestic			150
		Total	**4436**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Pasture	10 590	383	40 575
Native vegetation	1690	538	9090
Vegetables	21.5	600	129
Vineyard	76	475	361
Horticulture	61	200	122
		Total	**50 277**

Streamflow

Runoff (ML)	5300
Baseflow (ML)	3240
Total	**8540**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall -(ET + runoff + damvol)	21 000
Deduction	Groundwater extraction + baseflow	7676
Chloride	Comparison rainfall and groundwater	4535
	Adopted value	**15 000**

Dam Storage

			Total outflow
Total dam volume (ML)	**613**	⇒	**77 190 ML**

Rainfall

Rainfall	**626 mm**	**X** Area	**123.2 km^2**	⇒	**77 190 ML**
(Effective)					**Total inflow**

CATCHMENT WATER BALANCE

HINDMARSH TIERS

Irrigation/extraction

Crop type/use	Area (ha)	Water use (mm)	Water loss (ML)
Pasture	423	730	3088
Stock and domestic			75
		Total	**3163**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Native vegetation	795	538	4280
Pasture	4786	380	18 250
		Total	**22 530**

Streamflow

Runoff (ML)	4132
Baseflow (ML)	2128
Total	**6160**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall -(ET + runoff + damvol)	11 915
Deduction	Groundwater extraction + baseflow	5290
Chloride	Comparison rainfall and groundwater	1610
	Adopted value	**8 000**

Dam Storage

Total outflow

Total dam volume (ML)	**175**	⇒	**38 650 ML**

Rainfall

Rainfall	**693 mm**	**X** Area	**55.8 km²**	⇒	**38 650 ML**
(Effective)					**Total inflow**

CATCHMENT WATER BALANCE

INMAN

Irrigation/extraction

Crop type/use	Area (ha)	Water use (mm)	Water loss (ML)
Orchard	13		20
Stock and Domestic			40
		Total	**60**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Pasture	17 000	377	64 094
Native vegetation	1950	511	9962
Plantation forest	306	586	1796
Orchard	13	200	26
		Total	**75 878**

Streamflow

Runoff (ML)	13 040
Baseflow (ML)	9045
Total	**22 045**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall -(ET + runoff + damvol)	24 856
Deduction	Groundwater extraction + baseflow	9045
Chloride	Comparison rainfall and groundwater	850
	Adopted value	**17 000**

Dam Storage

			Total outflow
Total dam volume (ML)	**896**	⇒	**114 400 ML**

Rainfall

Rainfall	**586 mm**	**X** Area	**195 km²**	⇒	**114 400 ML**
(Effective)					**Total inflow**

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
milligram	mg	10^{-3} g	mass
millimetre	mm	10^{-3} m	length
second	sec	base unit	time interval
tonne	t	1000 kg	mass
year	yr	356 or 366 days	time interval

δD	hydrogen isotope composition
$\delta^{18}O$	oxygen isotope composition
^{14}C	carbon-14 isotope (percent modern carbon)
CFC	chlorofluorocarbon (parts per trillion volume)
EC	electrical conductivity (µS/cm)
pH	acidity
ppm	parts per million
ppb	parts per billion
TDS	total dissolved solids (mg/L)

GLOSSARY

Act (the). In this document, refers to The *Natural Resources Management Act* (South Australia) 2004.

Adaptive management. A management approach, often used in natural resource management, where there is little information and/or a lot of complexity and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

Aquifer, confined. Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

Aquifer test. A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

Aquifer, unconfined. Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Aquitard. A layer in the geological profile that separates two aquifers and restricts the flow between them.

Artesian. Under pressure such that when wells penetrate the aquifer water will rise to the ground surface without the need for pumping.

Baseflow. The water in a stream that results from groundwater discharge to the stream. (This discharge often maintains flows during seasonal dry periods and has important ecological functions.)

Bore. *See well.*

Buffer zone. A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (e.g. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses).

Catchment. A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Cone of depression. An inverted cone-shaped space within an aquifer caused by a rate of groundwater extraction which exceeds the rate of recharge. Continuing extraction of water can extend the area and may affect the viability of adjacent wells, due to declining water levels or water quality.

Domestic purpose. The taking of water for ordinary household purposes and includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares.

DWLBC. Department of Water, Land and Biodiversity Conservation. Government of South Australia.

Ecosystem. Any system in which there is an interdependence upon and interaction between living organisms and their immediate physical, chemical and biological environment.

Environmental water requirements. The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

Evapotranspiration. The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

Groundwater. *See underground water.*

Habitat. The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

Irrigation. Watering land by any means for the purpose of growing plants.

Irrigation season. The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May.

Land capability. The ability of the land to accept a type and intensity of use without sustaining long-term damage.

Megalitre (ML). One million litres (1 000 000).

ML. *See megalitre.*

MLR. Mount Lofty Ranges.

Natural recharge. The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) *(See recharge area, artificial recharge.)*

Potentiometric head. The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer.

Precautionary principle. Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

PWA. Prescribed Wells Area.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer.

State water plan. The plan prepared by the Minister under Part 7, Division 1, s. 90 of the Act.

Stock Use. The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act).

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Water allocation plan (WAP). A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

Water-dependent ecosystems. Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

Wetlands. Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.

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