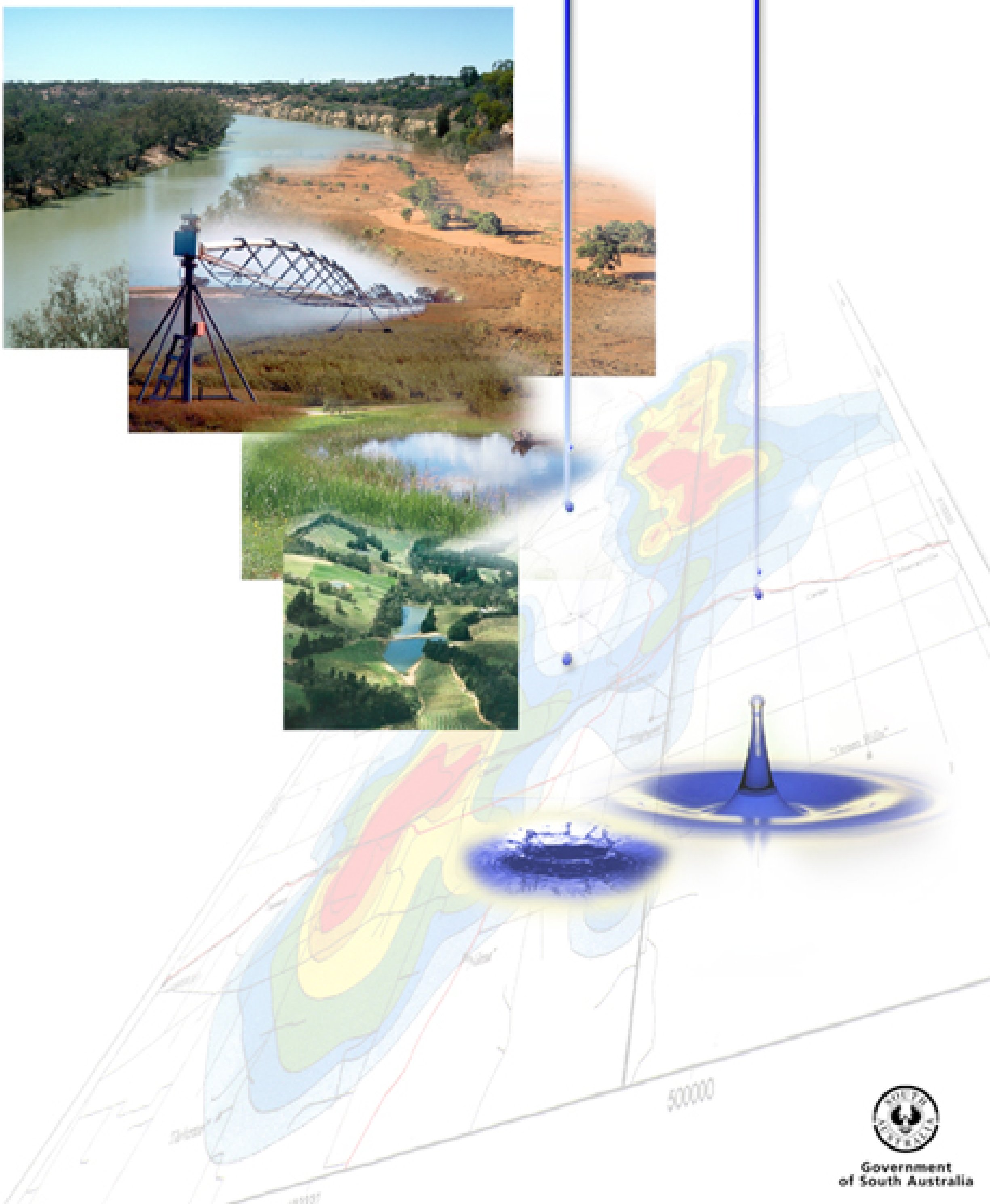
Department for
Water Resources

Marne River Catchment Groundwater Assessment

Report DWR 2001/009



Government
of South Australia

Marne River Catchment Groundwater Assessment

Steve R. Barnett, Dragana Zulfic and Wei Yan

Groundwater Assessment
Resource Assessment Division

September 2001

Report DWR 2001/009

Department for
Water Resources

SOUTH AUSTRALIA
Government
of South Australia

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FOREWORD

South Australia's water resources are fundamental to the economic and social wellbeing of the State. Water resources are an integral part of our natural resources. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between rainfall, vegetation and other physical parameters. Development of surface and groundwater resources changes the natural balance and causes degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of a resource to continue to meet the needs of users and the environment. Degradation may also be very gradual and take some years to become apparent, imparting a false sense of security.

Management of water resources requires a sound understanding of key factors such as physical extent (quantity), quality, availability, and constraints to development. The role of the Resource Assessment Division of the Department for Water Resources is to maintain an effective knowledge base on the State's water resources, including environmental and other factors likely to influence sustainable use and development, and to provide timely and relevant management advice.

Bryan Harris
Director, Resource Assessment Division
Department for Water Resources

ABBREVIATIONS

General

AHD	Australian height datum
GDEs	groundwater dependent ecosystems
k	hydraulic conductivity
PAV	permissible annual volume
SWL	standing water level
T	transmissivity
t	time
TDS	total dissolved solids
y	year

Measurement

Units of measurement used in this volume are those of the International System of Units (SI) as well as units outside the SI which have been authorised for use within Australia's metric system.

d	day (time interval; 86.4 x 10^3 s)
ha	hectares (area 10^4 m^2)
h	hour (time interval; 3.6 x 10^3 s)
min	minute (time interval; 60 s)

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Department for Water Resources

Report DWR 2001/009

Marne River Catchment groundwater assessment

Steve Barnett, Wei Yan and Dragana Zulfic

ABSTRACT

The Marne River is a main tributary catchment for the River Murray which generates ephemeral flows in wet years. Concerns have been expressed at the construction of large dams in the headwaters of the catchment, and their impacts on streamflow, and consequently recharge to aquifers.

The catchment can be divided into two distinct groundwater regions: the Hills Zone and the Plains Zone. The Hills Zone comprises the consolidated basement rocks of the Mount Lofty Ranges, which form fractured rock aquifers. Borehole yields are generally low and salinities vary. The 1999 land use survey found groundwater pumping for limited irrigation of vineyards to total about 1000 ML/y. A catchment water balance calculated that extractions are currently well below the estimated recharge and no sustainability issues are apparent.

The Plains Zone is underlaid by unconsolidated sediments of the Murray Basin. The main aquifer is the Murray Group Limestone, which is developed for the irrigation of lucerne, olives and turf, and is recharged mainly by infiltration of streamflow. Groundwater level trends have shown a close correlation with streamflow, and hence rainfall in the Mount Lofty Ranges. After three years of virtually no recharge from streamflow, groundwater levels dropped by up to 3 m (or 10% of the aquifer thickness) to the lowest levels recorded since monitoring began in 1980.

A well-calibrated groundwater computer model was constructed and has been used to quantify components of the water budget and predict the impacts of various streamflow scenarios and pumping regimes on groundwater levels.

A surprise finding was the significant amount of groundwater used by large red gums growing along the river valley. The prediction results show that continued use at current extraction levels over the next 20 years with the same streamflow conditions will have no impact. Authorised use over the same 20 year period will only add an extra 2.5 m drawdown in the unconfined Kongolia area. Drawdowns increased by 5–8 m for authorised use in the confined area near the hills, which will have an impact on other users. There was very little difference to drawdowns if unauthorised extractions were included in these scenarios.

If streamflow or recharge does not occur over the next 20 years with continual extractions, the aquifer in the Kongolia area would be unusable after only 10 years due to low groundwater levels. In order to raise levels, caused by lack of

recharge or streamflow, to the long term average, about three average years worth of streamflow and a flood event would be required.

The modelled long term average inflows to the aquifer of about 5000 ML/y compare favourably with the authorised extractions of about 2800 ML/y. However, before analysts use the figures as a basis for determining a permissible annual volume for extraction, the water requirements for groundwater dependent ecosystems (GDEs) should be determined. These GDEs include the red gum vegetation and wetlands downstream of Black Hill which are dependent on regional groundwater levels and local recharge from rainfall.

INTRODUCTION

The Marne River is a main tributary catchment for the River Murray which rises in the eastern Mount Lofty Ranges and flows eastward down onto the Murray Plains near Cambrai before eventually reaching the River Murray at Wongulla (Fig. 1). It is an ephemeral stream which intermittently flows to the Murray in wet years and is subject to occasional flooding as a result of heavy downpours on the hills.

Over recent years, there has been strong concerns expressed at the construction of large dams for the irrigation of vineyards in the headwaters of the catchment, and the impacts they may have by reducing streamflow. This reduction in streamflow may consequently reduce recharge to the aquifers developed on the plains, and may also adversely affect wetlands in the lower reaches.

The River Murray Catchment Water Management Board commissioned a study by BC Tonkin & Associates, with the assistance of Water Search groundwater consultants, to investigate the impacts of water use within the Marne catchment on the available water resources (both surface water and groundwater).

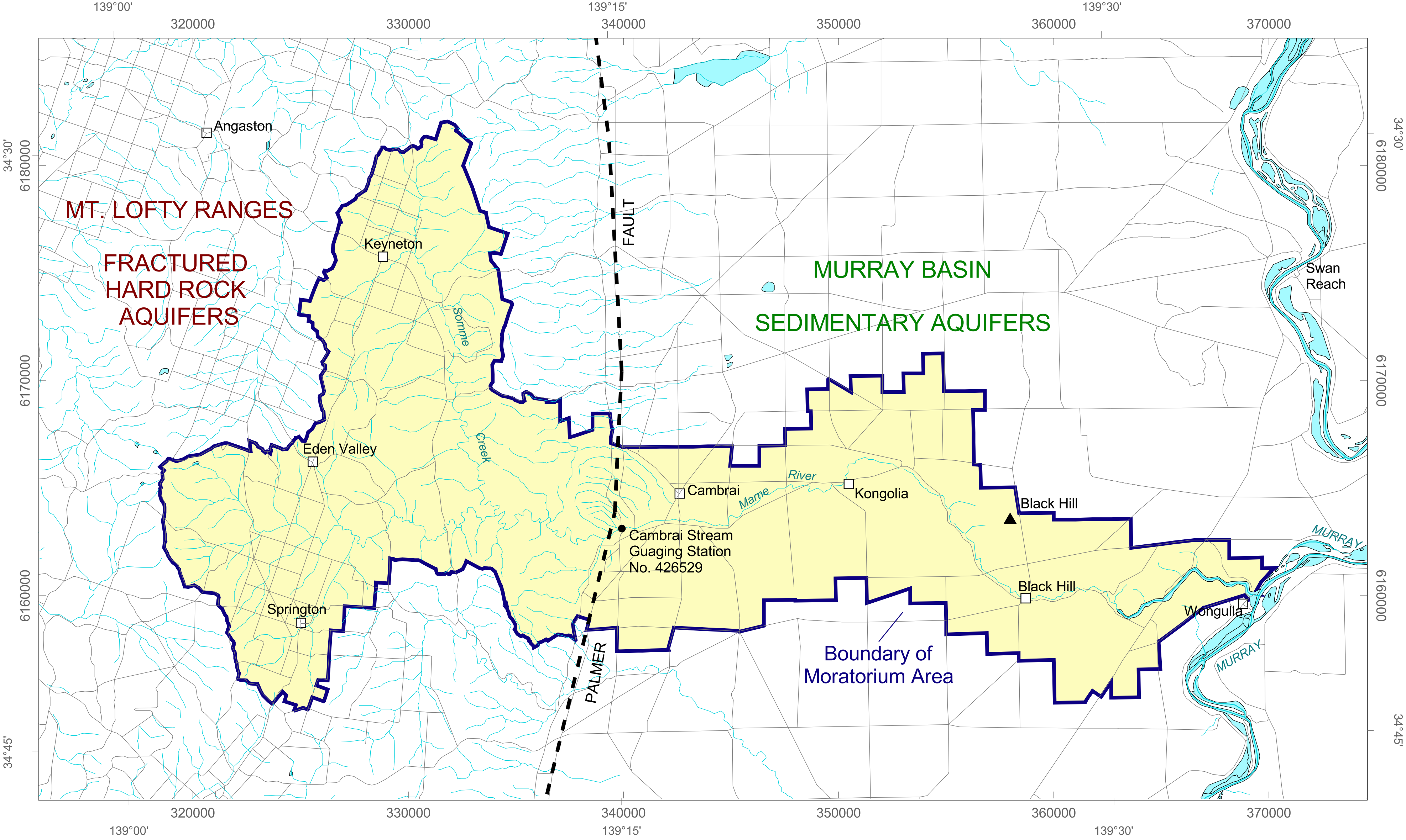
The final report (BC Tonkin & Associates, 1998) concluded that although the current water usage appears to be sustainable, there is likely to be increased demand in the future.

In response, the Minister for Environment and Heritage invoked a Notice of Restriction (under the *Water Resources Act 1997*) on the taking of groundwater and surface water from the Marne River Catchment for one year, commencing on 6 May 1999.

The Department for Water Resources (DWR) has been requested to assess the sustainability of surface water and groundwater resources to meet existing and future demands. This report details the assessment of the groundwater resources.

HYDROGEOLOGY

The Marne catchment can be divided into two distinct regions with different geology and consequently, different groundwater systems: the Hills Zone and Plains Zone, which are separated by the Palmer Fault scarp (Fig. 1).



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MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

Locality plan

Figure 1

HILLS ZONE

This zone comprises the consolidated basement rocks of the Mount Lofty Ranges. Groundwater is stored and moves through joints and fractures in these rocks in fractured rock aquifers. While most of the rainfall runs off straight to the streams or is used by plants, recharge to the underground fractured rock aquifers occurs directly from the portions of rainfall which percolates through the soil profile.

Groundwater moves from the higher points in the landscape to the lowest where discharge occurs to the streams. Consequently, the streams generally act as drains for the fractured rock aquifer systems (Fig. 2). This discharge constitutes the baseflow of the streams which can dominate flow for most of the year, particularly over the summer and between rainfall events.

In the Marne catchment, the basement rocks consist of micaceous and feldspathic sandstones and siltstones of the Kanmantoo Group (of Cambrian age). These rocks have been metamorphosed by heat and pressure, and are generally tight and impermeable, with few open systems of fractures and joints in which groundwater can be stored and transmitted. Consequently, borehole yields are low (generally below 2 L/s), apart from isolated occurrences south of Springton and near Eden Valley (Fig. 3).

Clayey weathering products from the metamorphosed rocks tend to infill any joints and fractures present and soluble products can be dissolved. These factors tend to reduce recharge and raise the salinity of the groundwater.

There is also a marked decrease in rainfall across the catchment reflecting a strong rain-shadow effect. Annual rainfall ranges from 810 mm in the higher western parts of the catchment, to only 350 mm on the eastern margin. Figure 4 shows a corresponding broad trend of increasing salinity across the catchment from west to east in response to the decreasing recharge. Groundwater salinity is dependent on the rock type and rainfall recharge, and varies from 500–7000 mg/L. Groundwater is mainly used to provide stock and domestic supplies, and some minor irrigation in the western portion of the catchment where the better quality water drawn.

A land use survey carried out in August 1999, found irrigation of vineyards to be the main water use in the Hills Zone, with minimal application rates being used (about 1.5 ML/ha). Only 16 irrigation bores are used, with a further 33 bores augmenting dam supplies. The quantities extracted from groundwater are estimated to be generally small (about 1070 ML/y). A coarse water balance for the Hills Zone was calculated using dam and streamflow volumes (Savadamuthu, 2001) and estimates of evapotranspiration (Appendix 1).

If it is assumed that there is a 10–15% reduction in water use from annual pasture (due to the shallow stony soils over much of the catchment), a good balance can be obtained. It shows that the extractions are well below the estimated recharge, which averages 3000–3500 ML/y, and no sustainability issues are apparent. Localised drawdown problems may occur if pumping is concentrated in small areas.

PLAINS ZONE

After flowing out of the hills onto the plains, the Marne River loses water as it recharges the underlying aquifers which are used for stock, domestic and irrigation purposes (Fig. 2).

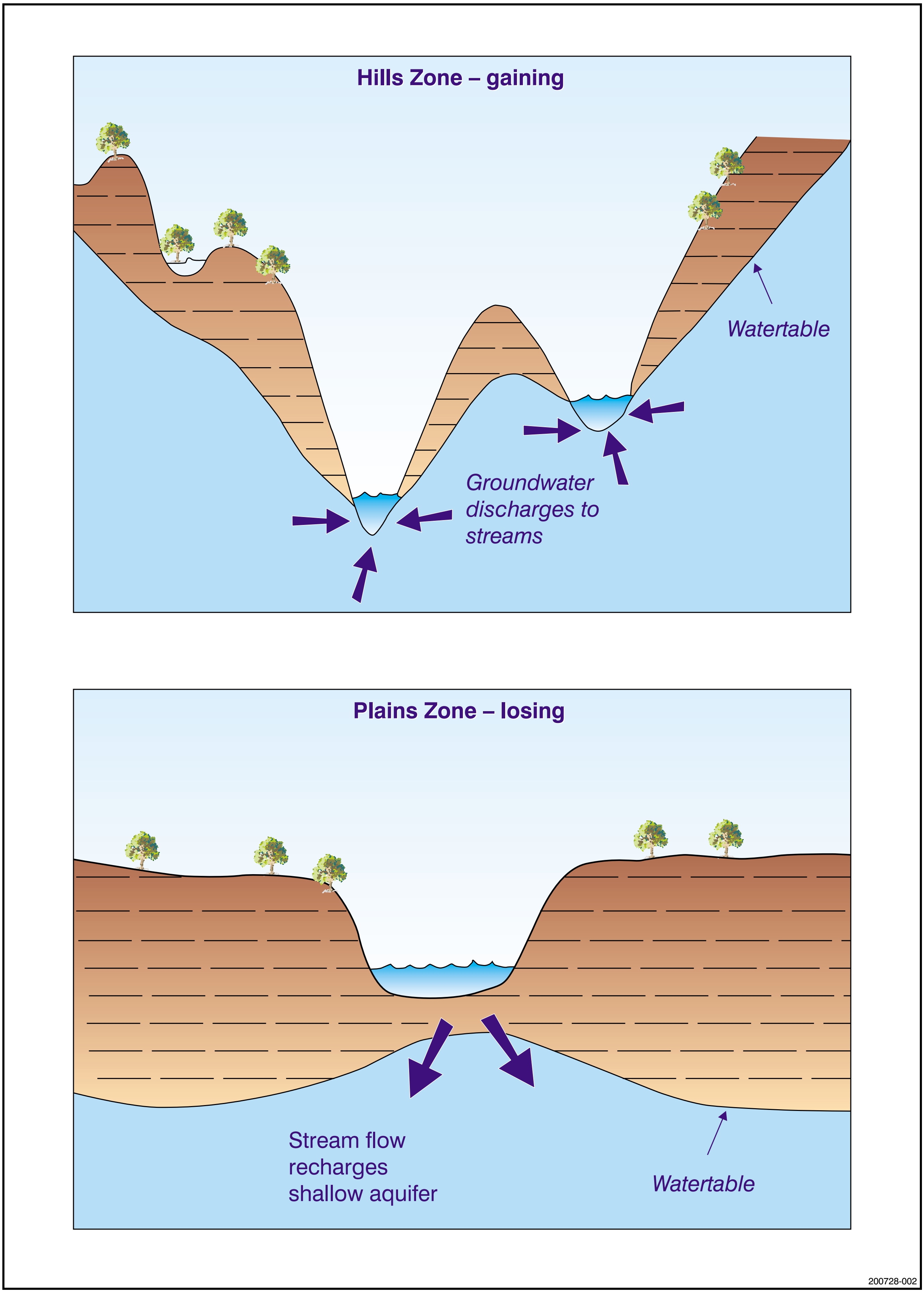
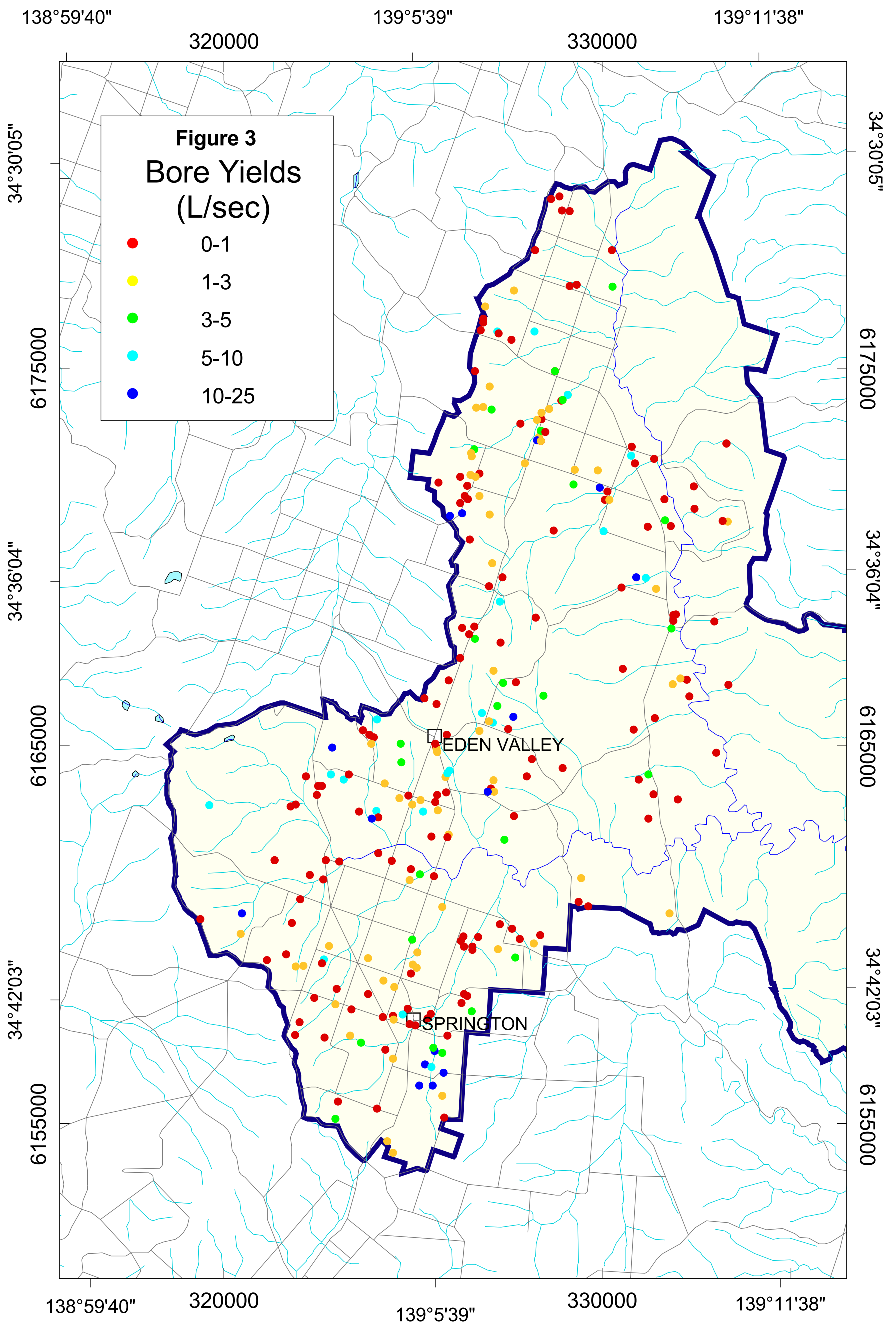
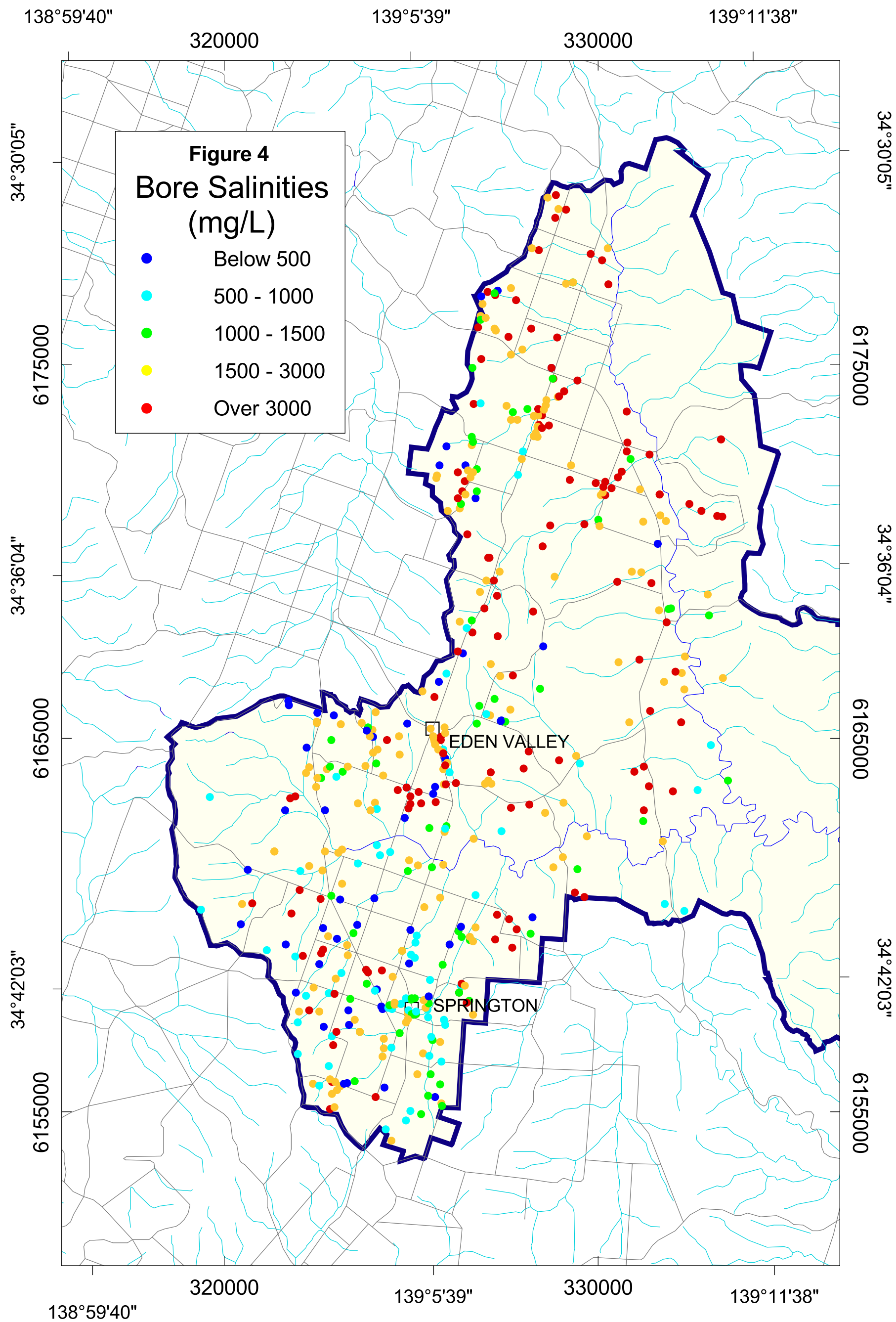


Figure 2 Groundwater – surface water interaction





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MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

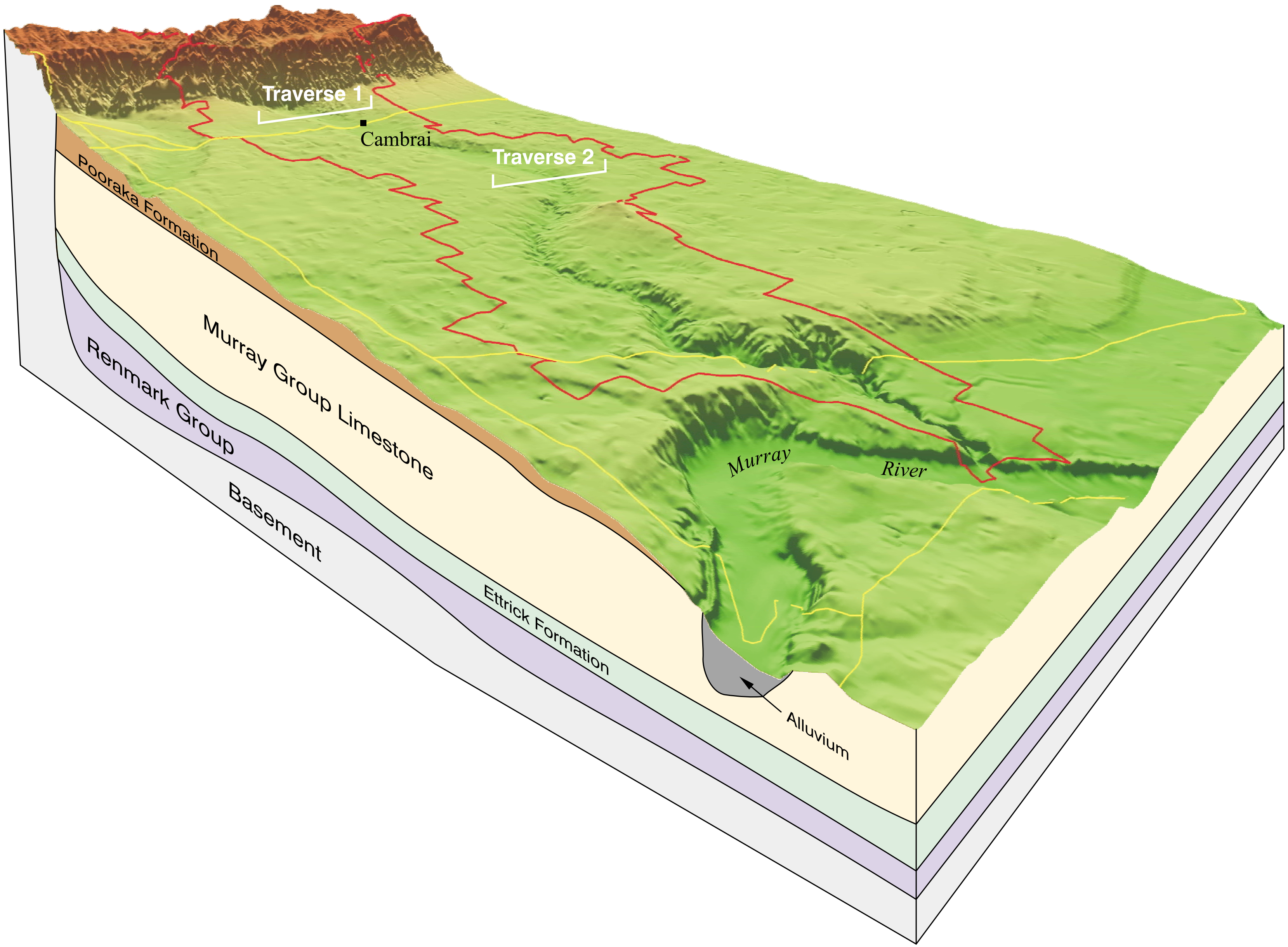
Hills Zone

0 2 4 6 Kilometers

Datum: GDA94
Projection: MGA Z54

GDA

Figures 3 and 4



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200728-005

MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

Geological cross-section (E–W) of the Plains Zone showing Topography

Figure 5

From the western boundary of the Plains Zone at the Palmer Fault scarp, the Marne River falls about 100 m to the level of the River Murray, over a distance of 30 km. The landscape is undulating to flat with elevations from 40–50 m AHD near the River Murray to about 180 m AHD at the western boundary (Fig. 5). The only significant relief is represented by Black Hill which rises to an elevation of 153 m AHD.

Unconsolidated sediments of the Murray Basin underlie the Plains Zone. They consist of layers of limestones, sands and clays up to 80 m thick, which overlie basement rocks that are exposed in the Hills Zone to the west. Groundwater flows through pore spaces in the sand and limestone beds towards the River Murray, where it eventually discharges.

There are four main layers of Murray Basin sediments in the Marne Catchment as shown in the geological sections (Figs 5 and 6). The groundwater characteristics of each will be discussed in order of increasing depth below ground level, namely:

- Quaternary sediments
- Murray Group Limestone
- Ettrick Formation
- Renmark Group.

Quaternary sediments

There are a variety of these younger sediments which were deposited in different environments, ranging from the pale-yellow wind-blown sands found on the higher ground, to the alluvial silts, sands, clays and gravels of the modern drainage channels.

The Marne River has developed a broad floodplain with a maximum width of about 2 km to the east of Cambrai and at Kongolia, which decreases to a few hundred metres width further downstream. While the river channel is often only several metres in width, the valley is often 1–2 km wide, so that the Marne can be described as an underfit stream. This suggests the floodplain was formed when flows were much higher during a wetter period 6000–8000 years ago.

The alluvial sediments average about 10 m in thickness and consist mainly of interbedded clay, sands and gravels which increase in thickness toward the hills. Small supplies of up to 0.5 L/s have been obtained from about 20 shallow bores, completed in the alluvium, with salinities mostly in the range 1500–2200 mg/L.

The colluvial outwash of the Pooraka Formation forms a wedge-shaped deposit of red-brown clays and minor gravels up to 60 m thick adjacent to the Palmer Fault scarp, which decreases in thickness to only a few metres toward the east away from the hills (Figs 5 and 6). The Marne floodplain has been eroded down into these clays.

Murray Group Limestone

This limestone is yellow-brown to grey, highly fossiliferous and sandy, with solution cavities present in some areas. The groundwater from this aquifer is the main source of irrigation, domestic and stock supplies for the Marne Valley area.

The limestone aquifer is unconfined over most of the Marne Valley but in the western part of the area, upstream of Cambrai, the aquifer is locally confined, being overlain by the thick sequence of clays and clayey sands of the Pooraka Formation (Fig. 6).

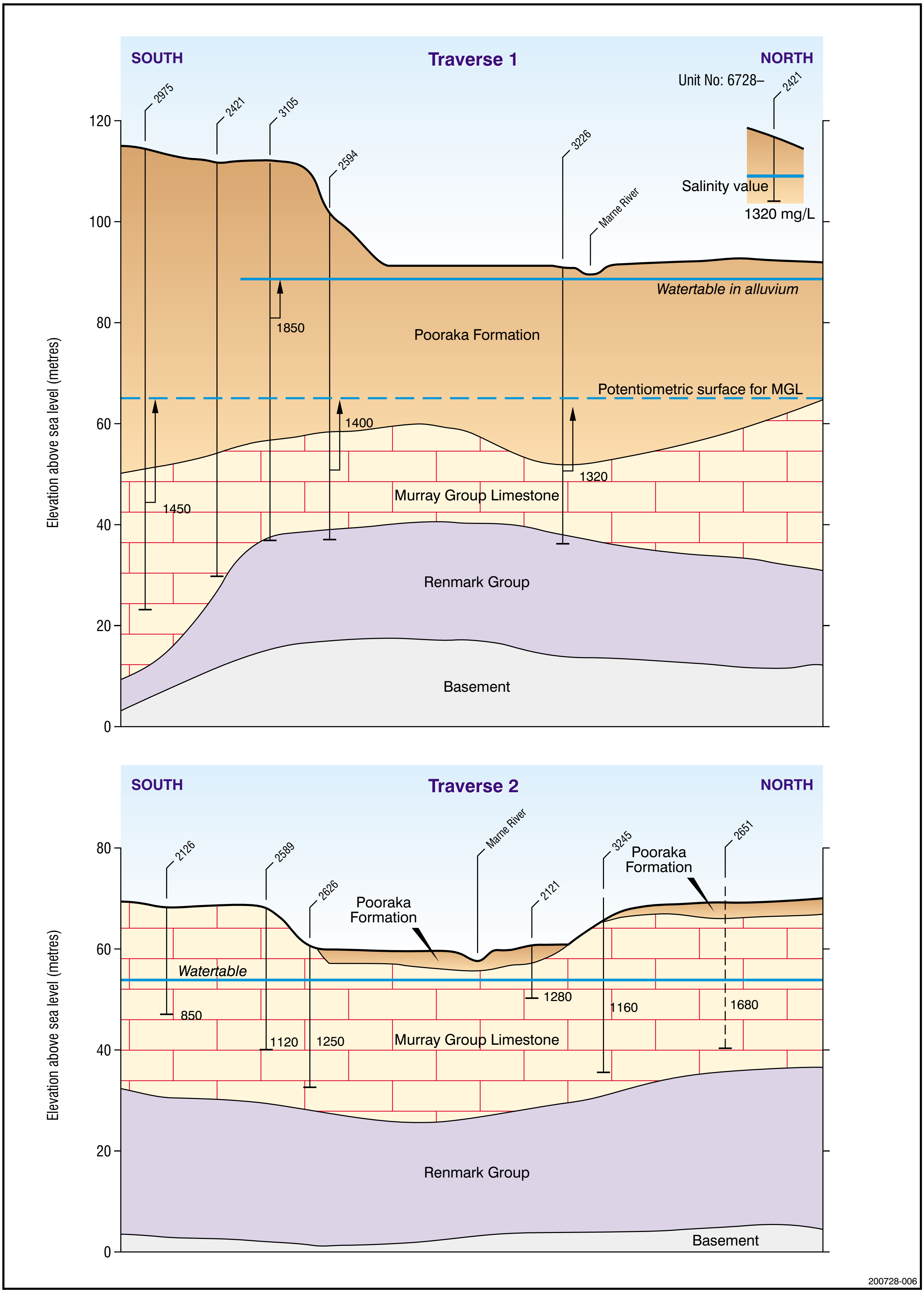
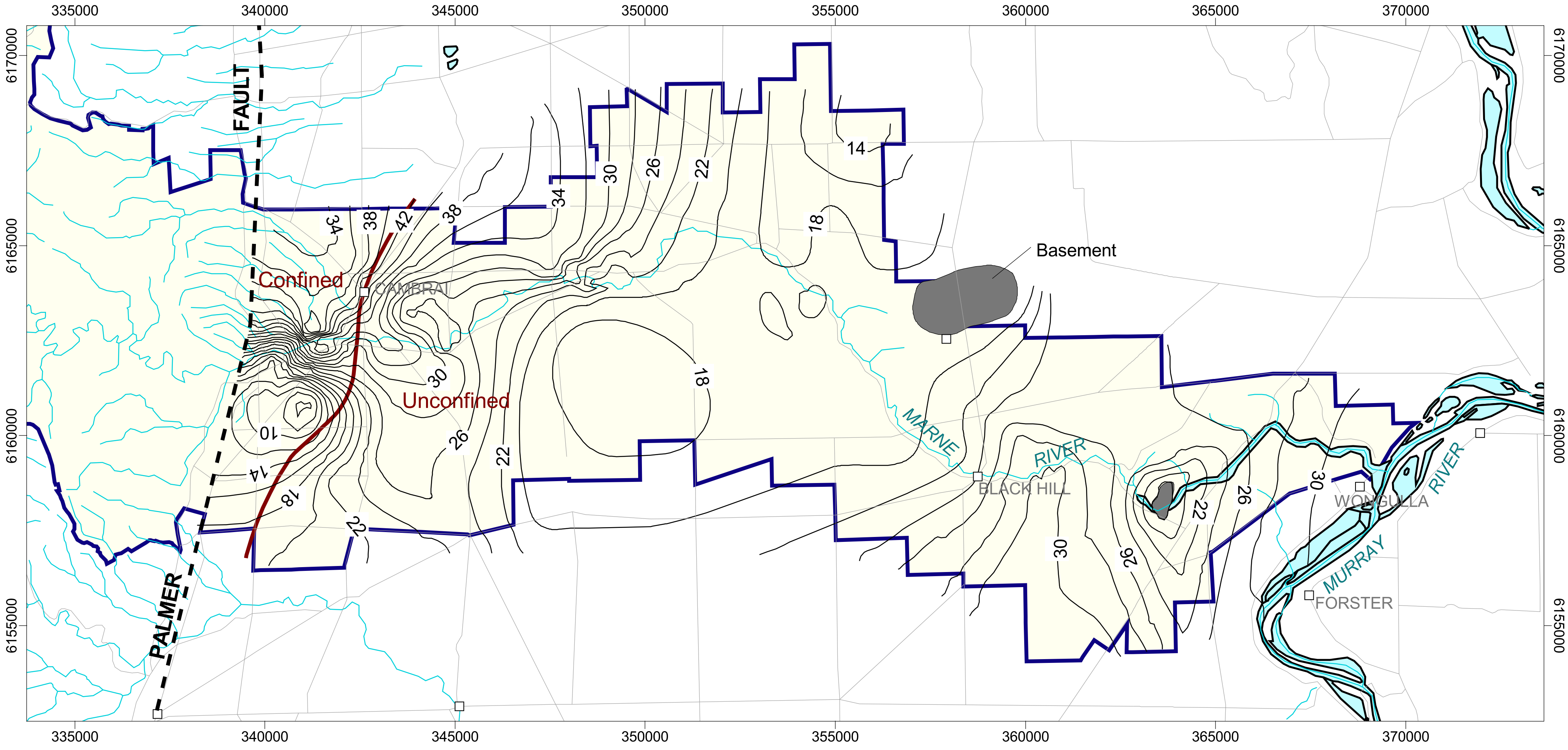


Figure 6 Geological cross-section (N–S) of the Plains Zone



MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

0 2000 4000 6000 Meters

Datum: GDA94
Projection: MGA94 Zone 54

AV: 200728_007

Thickness of the limestone aquifer

Figure 7

The thickness of the Murray Group Limestone is well defined from the numerous bore records, especially along the river valley (Fig. 7). It is variable, from only a few metres in the western portion of the study area, where the sediments are thinning out towards the contact with the basement rocks, to about 50 m on the eastern margins of the area. In the part of the valley where usage is intensive, the average aquifer thickness is 20–25 m.

The groundwater flow direction is generally from the ranges in the west toward the east, where the aquifer discharges in the River Murray valley which is the lowest point in the area. The watertable gradient is very steep and falls about 30–35 m over the 20 km distance (Fig. 8).

The salinity ranges from 1000–3000 mg/L, with the majority of wells in the 1000–2000 mg/L range. The lowest values are just below 1000 mg/L in the Kongolia area (Fig. 9).

Yields of up to 25 L/s are recorded in individual wells, with the majority falling in the 5–15 L/s range. There has been evidence of solution features in the limestone aquifer from aquifer tests, which are probably the result of infiltrating surface waters.

Ettrick Formation

This is a low permeability unit consisting of grey-green sandy marls of variable thickness, which help confine the underlying Renmark Group aquifer. It is absent over most of the study area.

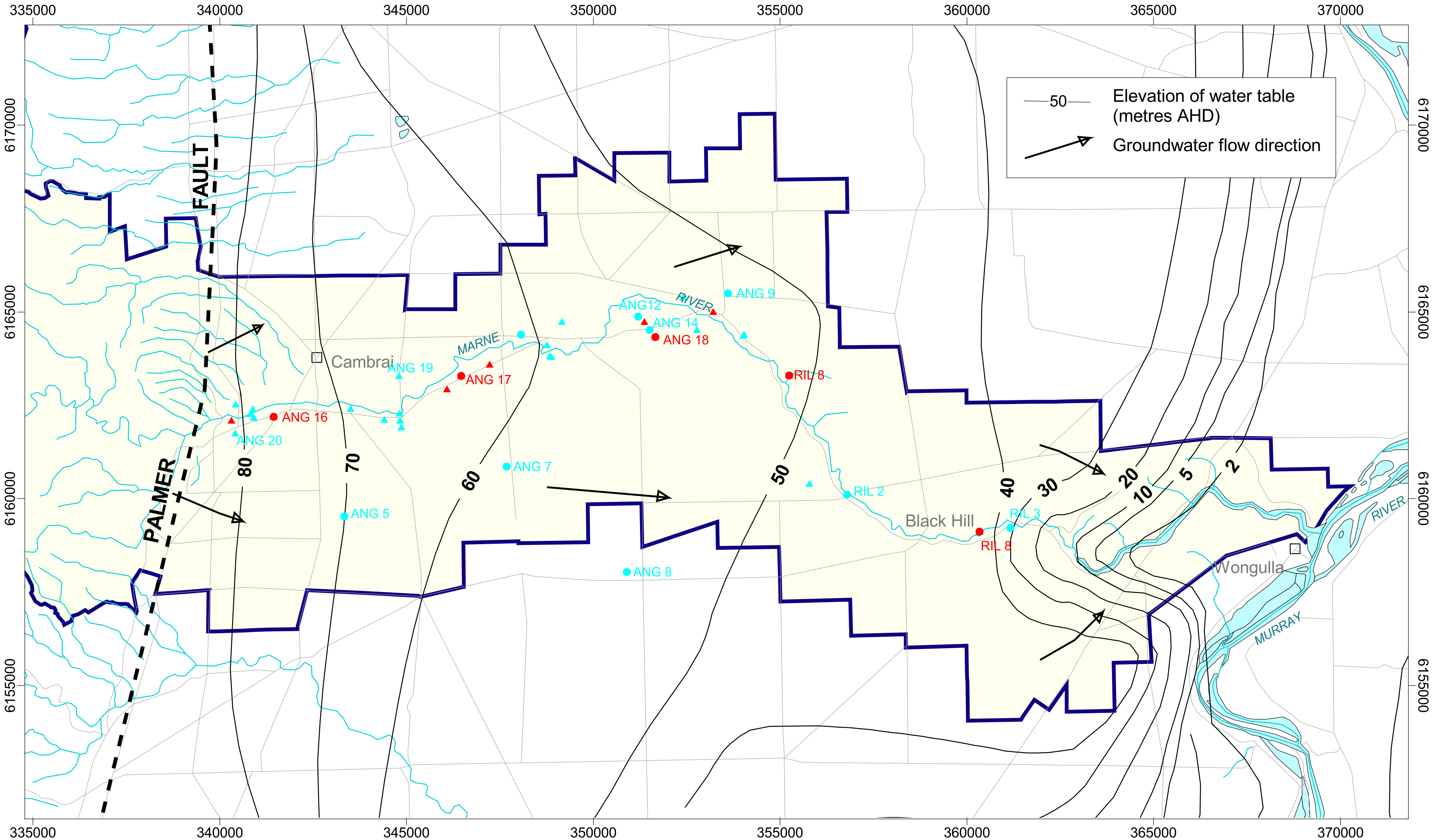
Renmark Group

This confined aquifer consists of dark-brown, fine- to medium-grained sands and bands of carbonaceous clays and lignites. These sediments are discontinuous because their distribution is restricted by the undulating nature of the basement topography. It is confined by carbonaceous clays and lignites and the overlying marls, where they occur.

Very few bores penetrate and develop this aquifer because the overlying limestone aquifer provides groundwater of better quality and more reliable yields. According to the scarce lithological data, the Renmark Group sediments have been encountered at depths varying from about 20 m (near Kongolia and Black Hill) to over 70 m (near the Mount Lofty Ranges). Several bores that fully penetrate these sediments show that the thickness varies from 10 m to over 50 m.

Salinities range from 2000–3000 mg/L. Recharge is most likely to occur from the basement rocks of the Mount Lofty Ranges along the western margins of the basin, with the regional groundwater flow similar to the overlying limestone aquifer (i.e., from the basin margins eastward towards the River Murray).

Since the limestone aquifer is the main aquifer developed for irrigation, the following sections refer to this aquifer only.

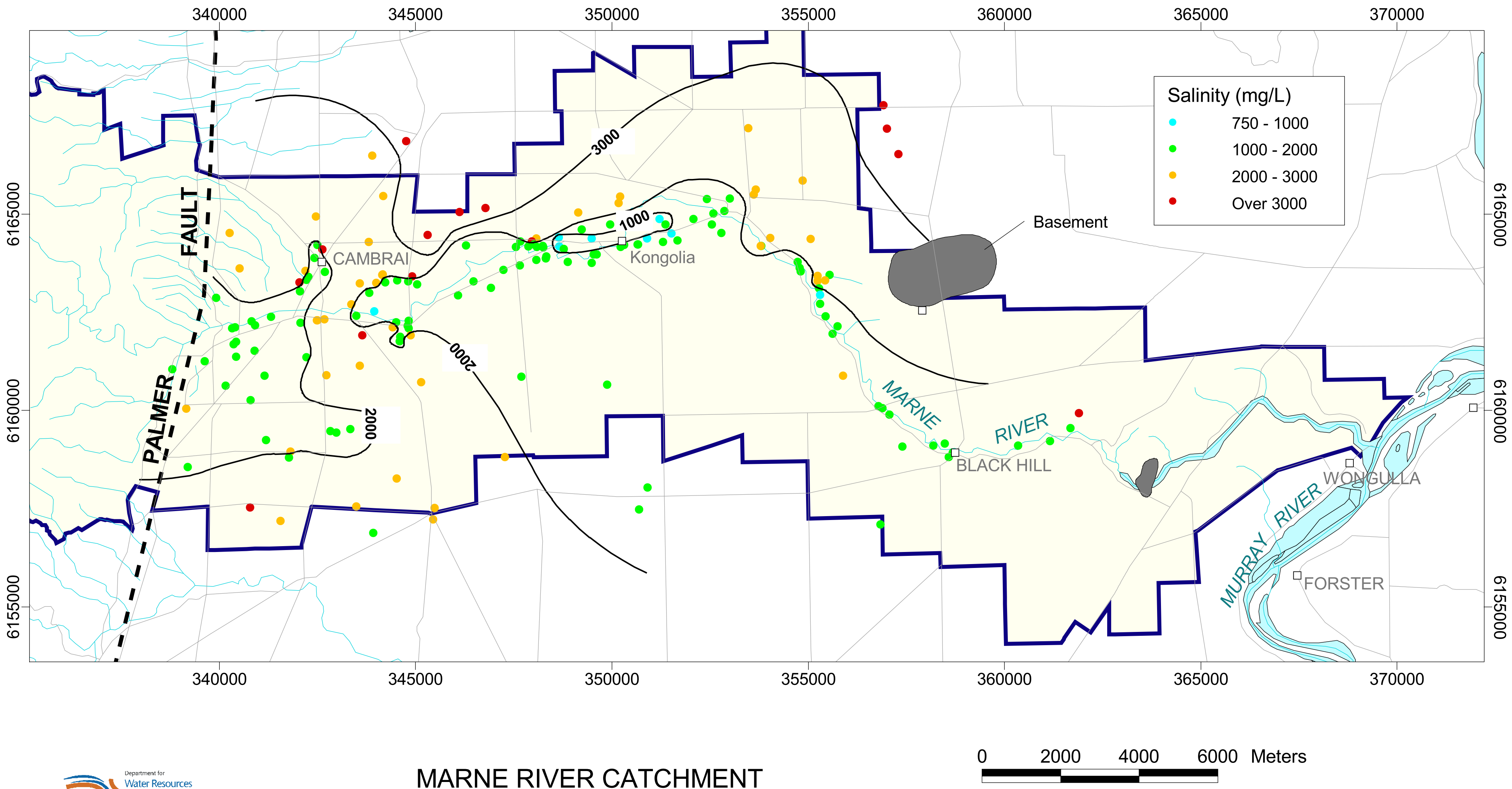


MARNE RIVE CATCHMENT
GROUNDWATER ASSESSMENT

Watertable elevation contours

AV: 200728_008

Figure 8



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MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

Salinity of limestone aquifer

AV: 200728_009

Figure 9

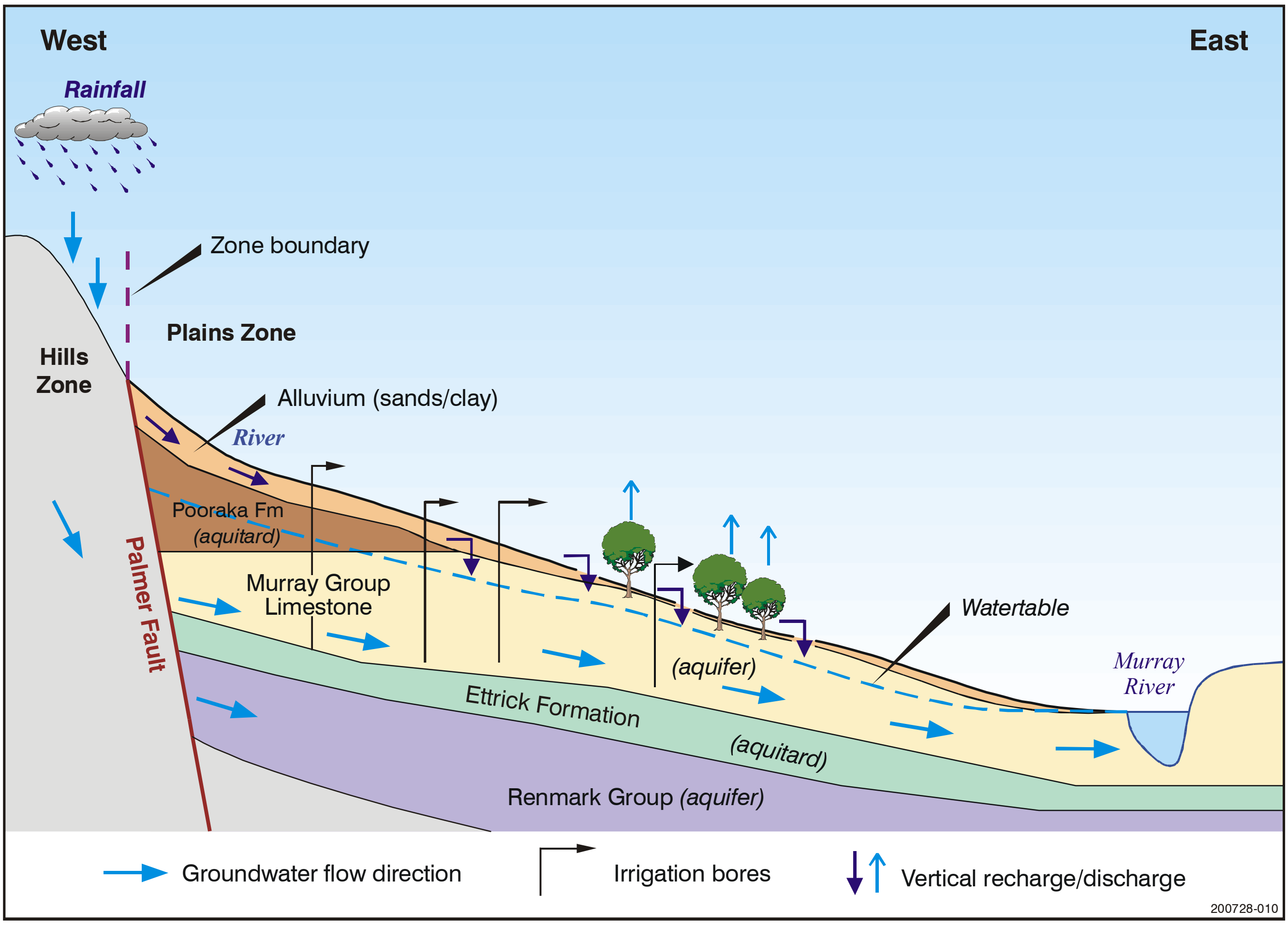


Figure 10 Recharge and discharge mechanisms for the limestone aquifer

RECHARGE

Recharge to the limestone aquifer can occur by three processes (Fig. 10):

1. from surface water flowing in the Marne River down through underlying permeable alluvial sediments (where the aquifer is unconfined)
2. by groundwater subflow from the Hills Zone fractured rock aquifers across the Palmer Fault zone (where the aquifer is confined)
3. by vertical recharge from rainfall.

The observed salinity pattern in the limestone aquifer (Fig. 9) gives an indication of where the various recharge processes are occurring. Adjacent to the hills, salinities below 2000 mg/L represent recharge by lateral subflow from the fractured rock aquifers. In this area, vertical recharge is prevented by the thick clayey Pooraka Formation. The levels of salinity increase further away from the hills until a sudden decrease in salinity below 2000 mg/L occurs 2 km downstream of Cambrai. At this point, the Pooraka Formation has thinned sufficiently to allow the commencement of vertical recharge by the infiltration of streamflow.

Further downstream, there are lower salinity zones where recharge occurs, with the lowest salinities (below 1000 mg/L) associated with areas where floodwaters pond for some time.

There is a gradual trend of increasing salinity downstream, because surface water flows also decrease downstream due to infiltration losses, resulting in less recharge to the aquifer.
Recharge from rainfall is insignificant outside the Marne Valley due to the thickness of the clayey Pooraka Formation and the low rainfall, which decreases from only 350 mm/y near the ranges, to 275 mm/y at the River Murray. Observation bores ANG 5 and BAG 16 show no response to seasonal rainfall with the exception of a heavy localised rainfall event in late 1989.

In years of little or no streamflow, the watertable within the Marne Valley shows a continuous decline through the winter months. The recharge from rainfall is consequently thought to be small, and in wetter years, would be difficult to distinguish from the much larger contribution from streamflow.

DRILLING HISTORY

An analysis of the State drillhole database SA_GEODATA for the Notice of Restriction area has provided data on the history of well drilling. In 1976, the passing of the Water Resources Act required a permit to be obtained for each new well drilled, and the submission of well construction details to the appropriate agency. However, in order to obtain information on wells drilled before 1976, a well location survey was carried out in the Hundreds of Angas and Ridley in 1980.

The oldest bore was drilled in 1909 for a stock water supply and from then until 1976, about 190 bores were established in the area. Since 1976, another 129 bores have been drilled, 81 of which were for irrigation (Fig. 11). While some of the bores are likely to be replacements for older, less efficient or collapsed irrigation bores, it is still a significant increase, especially since 1995 when 46 out of the 81 were drilled (Table 1). Almost all have been drilled within 1 km of the Marne River.

Table 1 History of groundwater development

Purpose	**Number of wells drilled**		
	<1976	*1976–95*	*>1995*
Irrigation	~ 45	35	46
Domestic	~ 55	16	5
Stock	~ 90	20	7
Total	**~190**	**71**	**58**

TRENDS IN GROUNDWATER USAGE

The main land use activity in the area is livestock grazing and cereal cropping. Lucerne irrigation has been established in the Marne Valley for some time, with recent developments of turf farms and irrigated olive orchards.

The first groundwater use survey was carried out over the 1986–87 irrigation season, when the 15 irrigators kept a record of the number of hours they irrigated during the season. This was multiplied by the pumping rate of the bores to give an estimate of the total extraction for the area. The results are presented in Table 2.

After the Notice of Restriction was declared in May 1999, a land use survey was carried out to determine current water use in the area. This was done by measuring the irrigated land area and multiplying it by an estimated application rate, as well as more detailed pumping information when available.

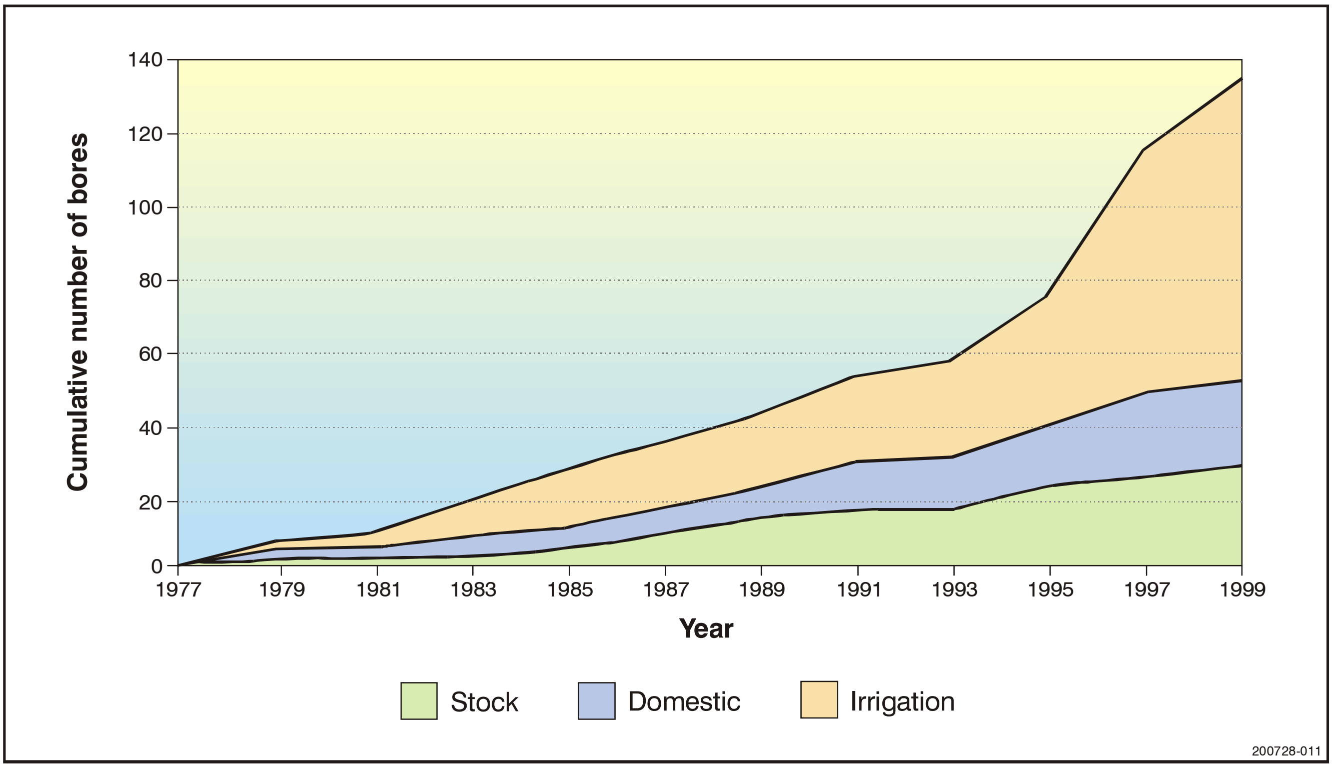


Figure 11 Drilling history

Table 2 Water use survey results

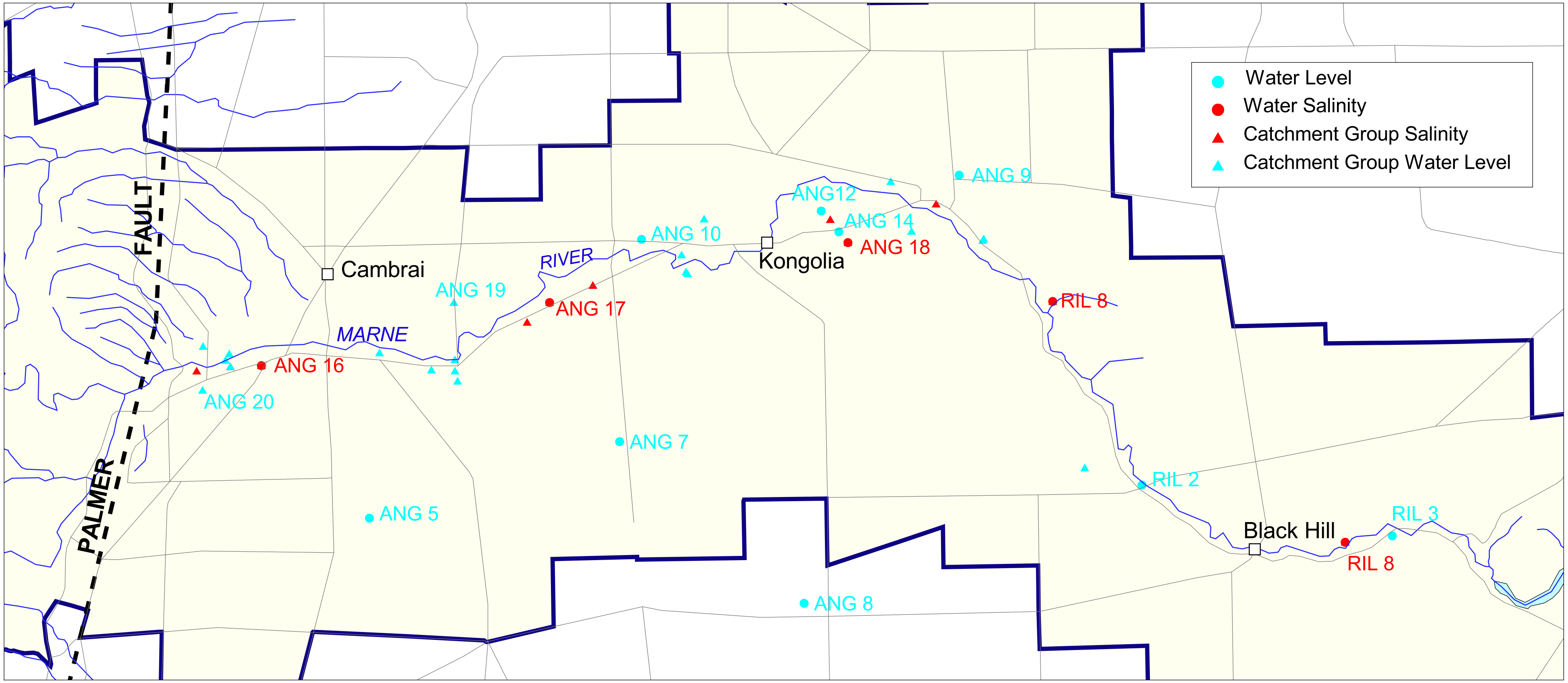
Year	No of bores	Area irrigated (ha)	Application rate (ML/ha)	Total extraction (ML)	Method
1986–87	25	–	10–20	1100	pump hours
1998–99	53	250	10–15	1650	crop area

GROUNDWATER MONITORING

Monitoring in the Marne area has been carried out since 1980, when a network of 16 observation bores were established for groundwater level monitoring (ANG 1–11 and RIL 1–5). Several bores have since become unusable, with another three being added to the network in 1987, including one monitoring the confined Renmark Group aquifer. Currently, 18 bores are being monitored at two monthly intervals by a DWR contractor (Fig. 12).

The formation of the Marne–Somme Catchment Group has enabled the monitoring of another 16 bores since 1995 at two to three monthly intervals using local volunteers. These bores are aligned in traverses across the Marne Valley, which allows a much better appreciation of the lateral spread of recharge to the aquifer from flood events.

Salinity monitoring by DWR began in 1990 using four irrigation wells (ANG 16–18 and RIL 7). This has been augmented by another six irrigation bores monitored by the Catchment Group since 1995 (Fig. 11b).



MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

0 1 2 3 4 5 Kilometers

Datum: GDA94
Projection: MGA94 Zone 54

AV: 200728_012

**Plains Zone observation networks-
groundwater level and salinity**

Figure 12

MONITORING TRENDS

GROUNDWATER LEVELS

The strong relationship between groundwater levels and streamflow is very evident when the hydrographs are examined. The amount of recharge from streamflow decreases with distance downstream and also with distance laterally away from the Marne River. This is illustrated by Figure 13, which shows the response for ANG 10 (3 km downstream from where recharge commences), ANG 14 (7.5 km) and RIL 1 (15 km). Similarly, Figure 12b shows the response in ANG 10 (0.3 km laterally from river), ANG 11 (1 km) and ANG 5 (3 km).

The timing and quantity of streamflow is controlled by the rainfall in the upper catchment in the Hills Zone, and consequently, so are the groundwater levels in the Plains Zone. Figure 14 shows the very close correlation between these levels and the winter rainfall at Mount Pleasant. The green line shows the difference between the actual measured winter rainfall (May to August) at Mount Pleasant, and the long term winter average. An upward trend in this line shows above average winter rainfall, while a downward trend shows below average winter rainfall. Figure 14 also shows the close relationship with annual streamflow.

Of critical interest are the last four years. The winter rainfall at Mount Pleasant is 350 mm below average over the three year period of 1997–99. This extended dry period reduced streamflow and recharge to such an extent that groundwater levels fell to their lowest recorded level since monitoring began in 1980. These falls averaged about 3 m at ANG 10 but decreased downstream to less than 0.5 m near Black Hill (Fig. 15). This however, represents only about 10% of the aquifer thickness.

Where the aquifer is confined close to the ranges, changes in the pressure level have been measured which are due to irrigation pumping and not recharge from streamflow. Since these drawdowns are a pressure response, they occur more rapidly and at a larger magnitude than unconfined drawdowns, which are a response to slow groundwater movement through the pore spaces of the aquifer.

Since 1996, drops in pressure level of about 2–3 m were observed, perhaps reflecting decreased lateral subflow from the ranges, or more likely changes in groundwater pumping.

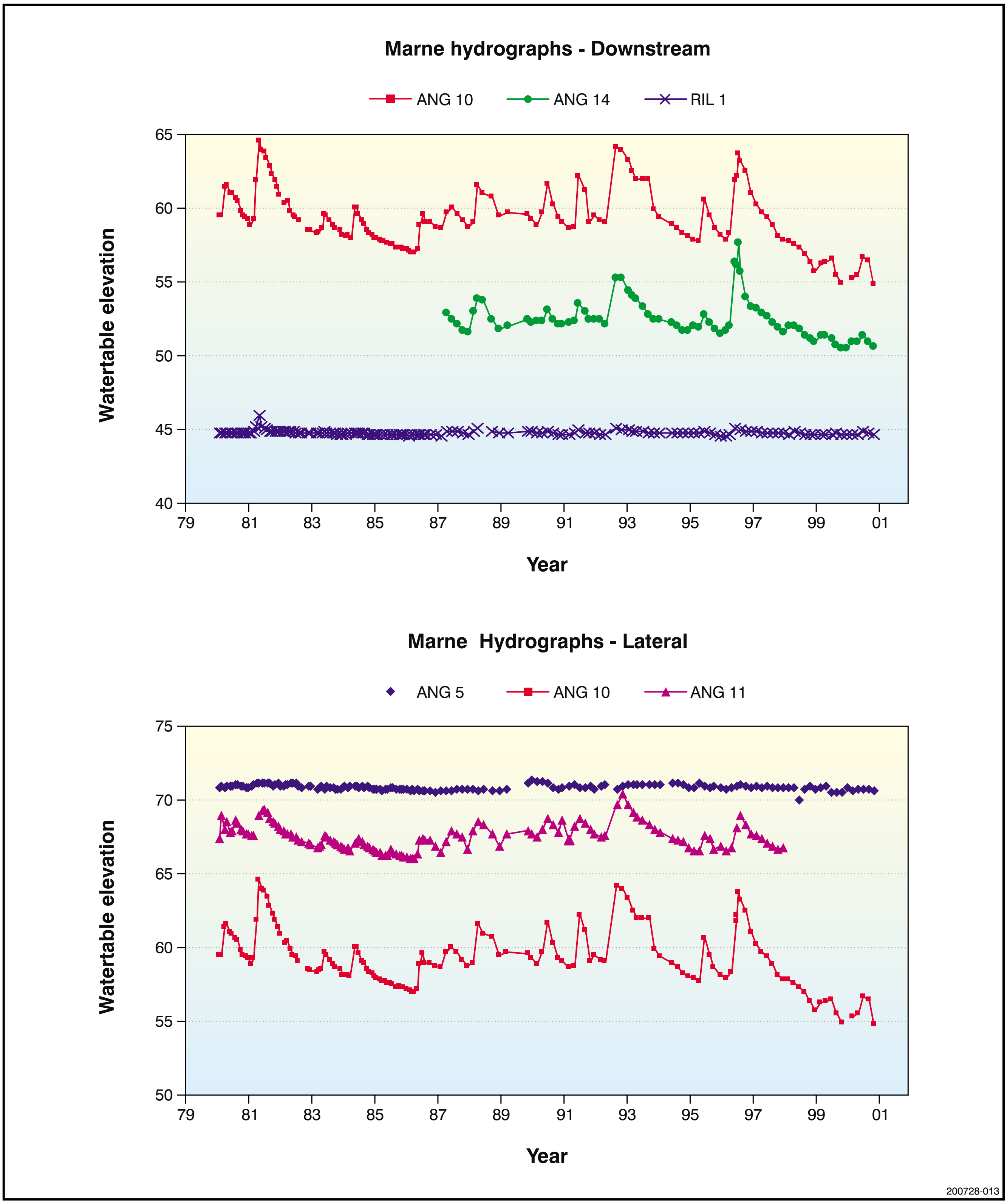


Figure 13 Groundwater level trends for the Plains Zone

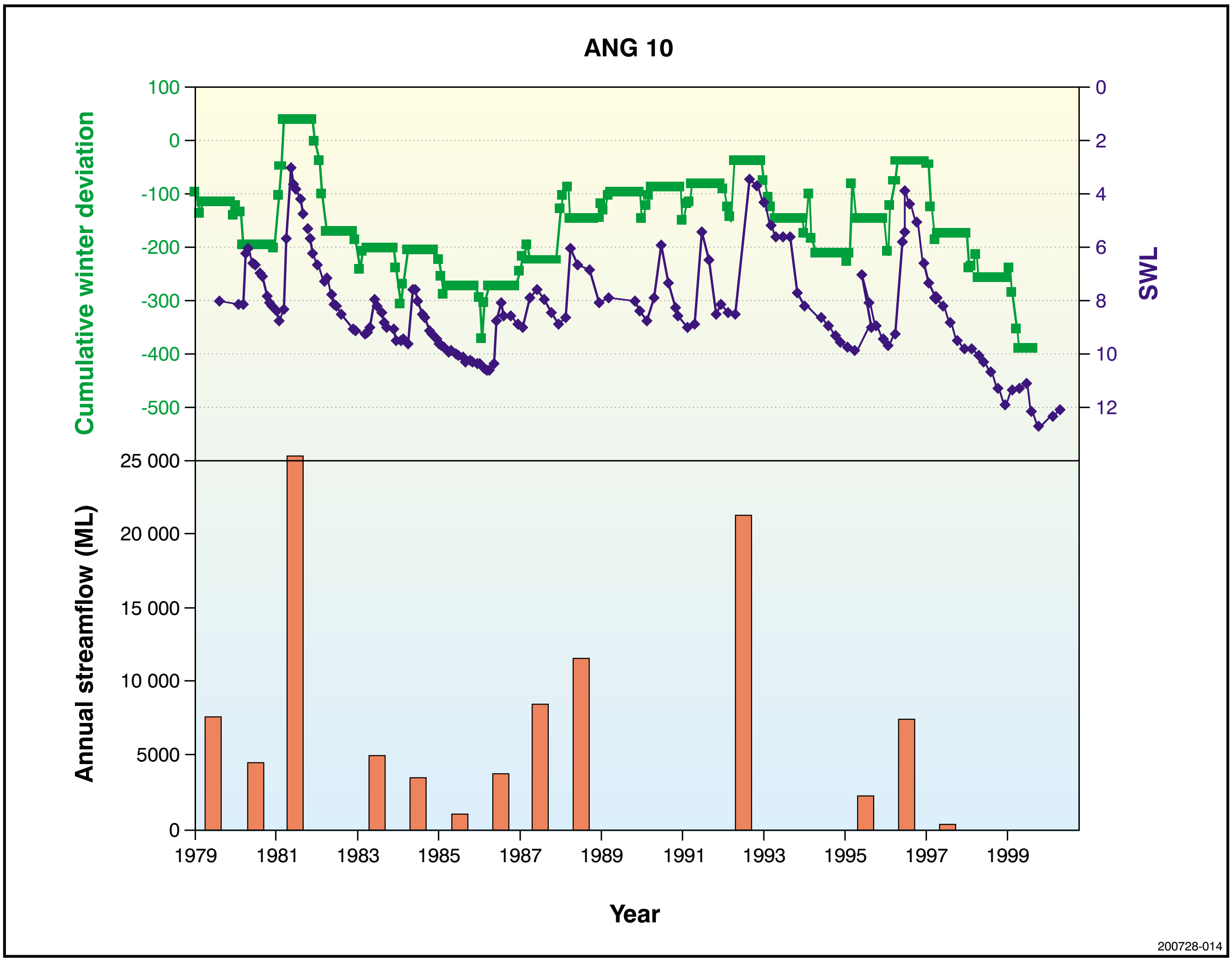
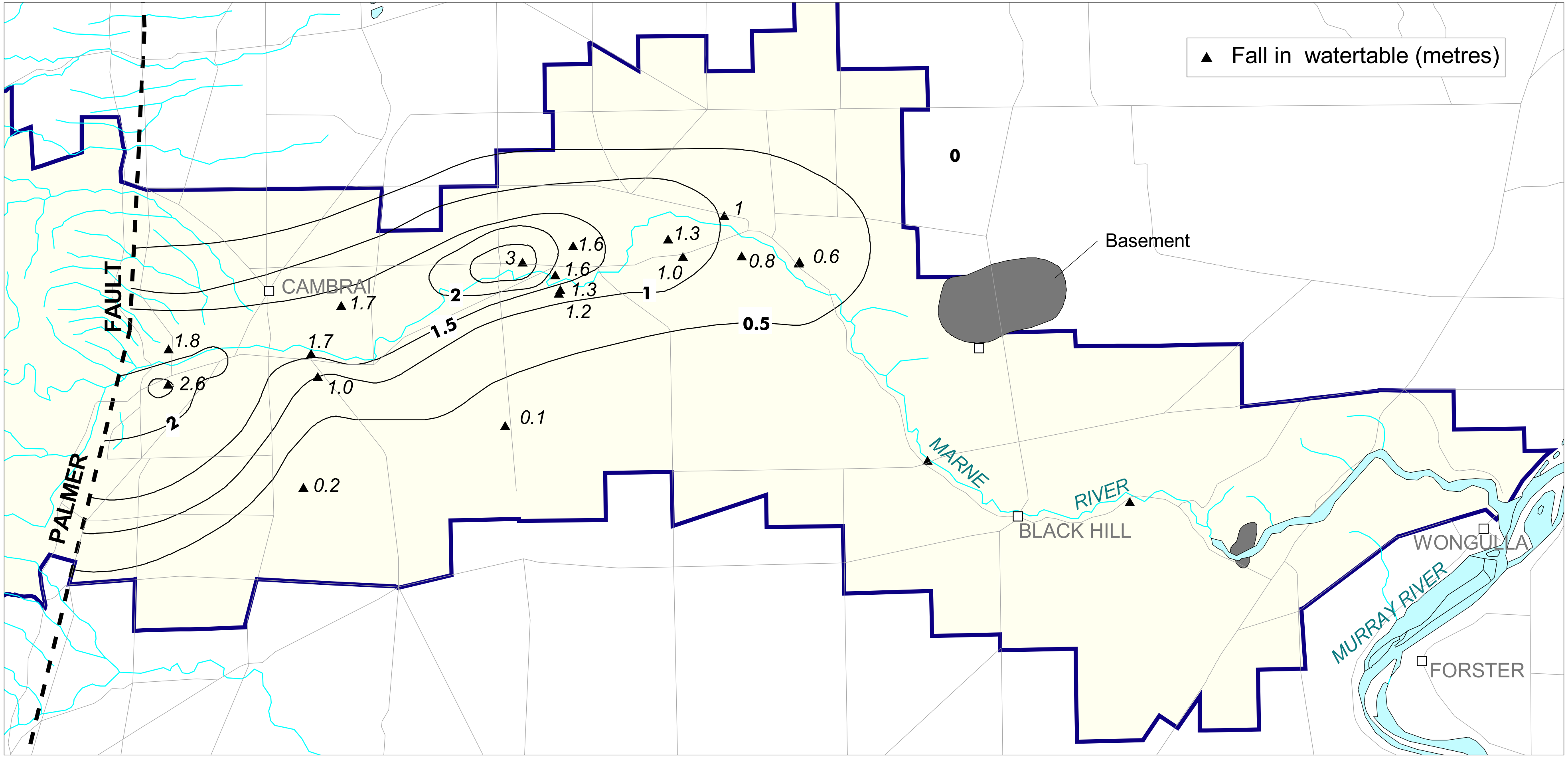


Figure 14 Relationship between rainfall, streamflow and groundwater level, ANG 10



MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

0 2000 4000 6000 Meters

Datum: GDA94
Projection: MGA94 Zone 54

Department for Water Resources

AV: 200728_015

Fall in watertable since 1996

GDA

Figure 15

GROUNDWATER SALINITY

The salinity readings recorded in the Plains Zone are variable, with two trends emerging — rising and stable (Fig. 16). The main influence on salinity levels seems to be flood events, especially large events which inundate significant areas of the floodplain.

Rising trend

The most obvious trend is from ANG 18 which is rising at about 60 mg/L/y. This bore is situated in a large area of lucerne irrigation on the floodplain with a depth to the watertable of about 10 m. This rise could be attributed to the recycling of irrigation water.

This process occurs as irrigation water is drawn up through the root system, with most of the dissolved salt accumulating in the root zone and not being taken up by the plant. This salt then percolates back down into the aquifer during subsequent irrigation applications or from rainfall recharge, resulting in a continuous cycle of increasing groundwater salinity.

ANG 16 also shows a rising trend of about 15 mg/L/y. This bore is completed in the shallow Quaternary aquifer which has highly variable salinities. The rise is probably due to lateral movement of more saline water which is separate from the underlying limestone aquifer.

Bore 2122 shows a recent increase which may be related to a change in irrigated crop close to the bore from sprinkler irrigation of lucerne to flood irrigation of watermelons, which would increase the drainage volumes and flushing of salt.

Stable trend

Most of the observation bores fall into this category over a long term, although there are some short term fluctuations.

Effects of flood events

Figure 16 shows that most bores experienced a marked salinity decrease immediately after the 1996 flood event, with an equally sudden rise afterwards followed by a gradual decline in salinity up to the present time.

It is understood that this occurred due to the rapid recharge of low salinity river water, causing a simultaneous rise in the watertable and a reduction in groundwater salinity. As the watertable falls, it flushes down salt from the unsaturated zone, where salt has accumulated because lucerne and trees use water but not the salt which is dissolved in it. This could also cause the rise in groundwater salinity after the flood. As the watertable gradually declines, lower salinity groundwater from further away is drawn in toward the irrigation bores.

If no further recharge were to occur, the salinity would increase as the more saline regional groundwater moves in to replace the lower salinity recharged water as it is pumped out.

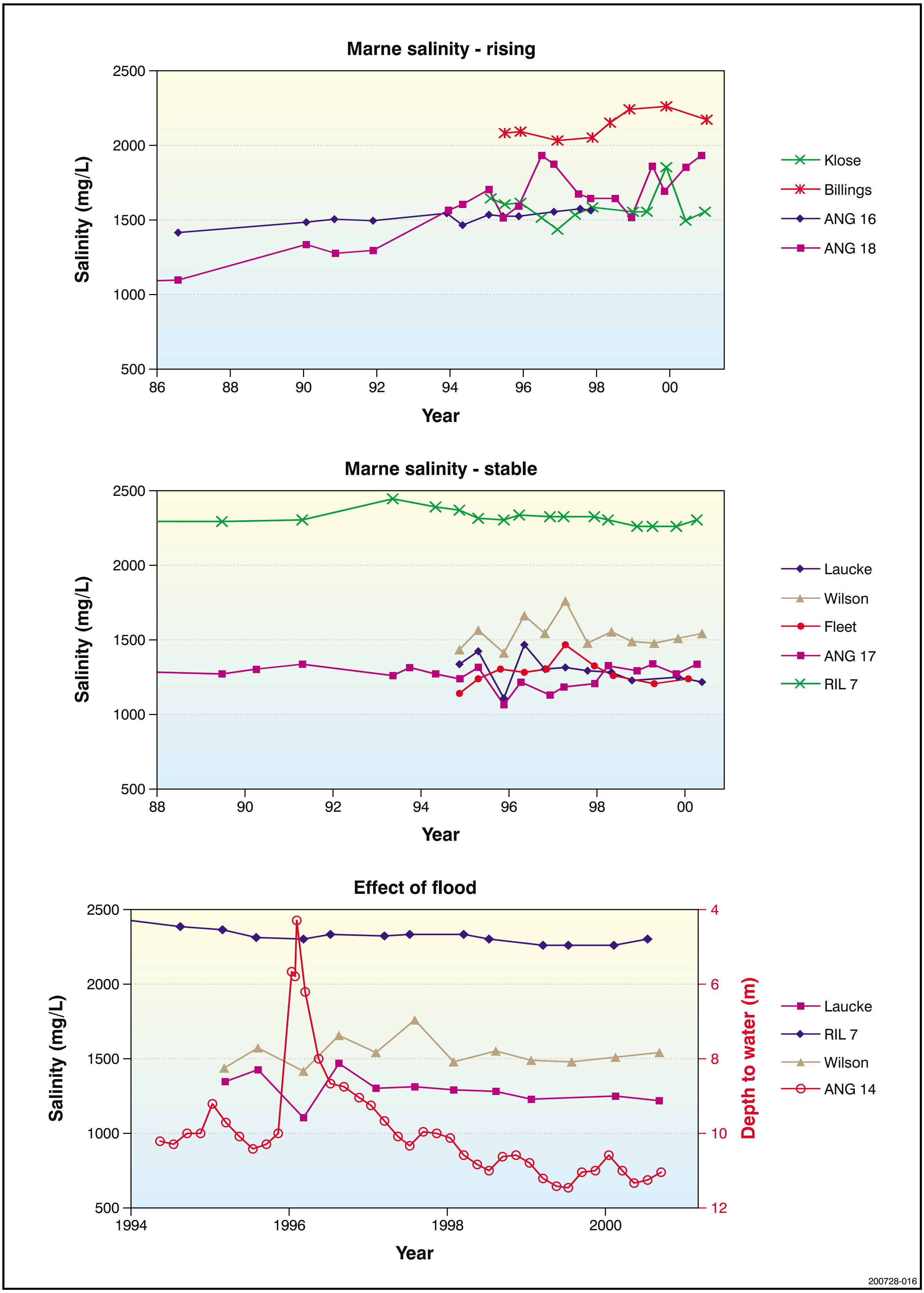


Figure 16 Groundwater salinity trends for the Plains Zone

AQUIFER TESTS

Four aquifer tests on the limestone aquifer were conducted between March 1995 and November 1996, and provided valuable information for the construction of a groundwater model.

A 24 hour continuous discharge test was conducted southwest of Cambrai in October 1996, where the limestone aquifer is confined. Several observation bores were used. The values obtained for the transmissivity (T) were 56–87 m^2/d and for the hydraulic conductivity (k) 1.5–2 m/d.

Unusually high values were obtained in the two tests conducted on the bores near Black Hill. Analysis of a 48 hour pumping test (March 1995) indicates the presence of solution cavities in the limestone, with very high T values in the range 1600–1900 m^2/d, with k in the range 90–110 m/d.

The most recent eight hour test (November 1996) provides values of 300 m^2/d for T, and 17.5 m/d for k.

GROUNDWATER MODELLING

A one-layer groundwater flow model was developed for the Plains Zone (Barnett and Yan, 2001) as a management tool to:

- better understand the processes of interaction between surface water and groundwater
- estimate recharge and discharge volumes in different streamflow conditions
- predict the changes in regional groundwater levels due to various streamflow conditions and extraction scenarios.

Calibration was achieved using observation bore data, streamflow measurements at the Marne River gauging station and estimates of groundwater extractions. However during this process, it was noticed that the estimated pumping volumes alone did not provide enough discharge from the model to enable calibration. It was then decided to assess the water use of the red gum vegetation occurring along the floodplain.

Two methods were used to estimate the water use, assuming 2 t/d and 200–300 mm/d. Both methods gave the same order of magnitude estimate of just under 3000 ML/y. When the estimates were applied to the model, the result gave an excellent calibration result (Fig. 17). Obviously, further investigations are needed to better estimate this component of the catchment water balance, which has not been considered before.

This process highlights the value of computer modelling in defining hydrologic processes that are not immediately apparent or considered important.

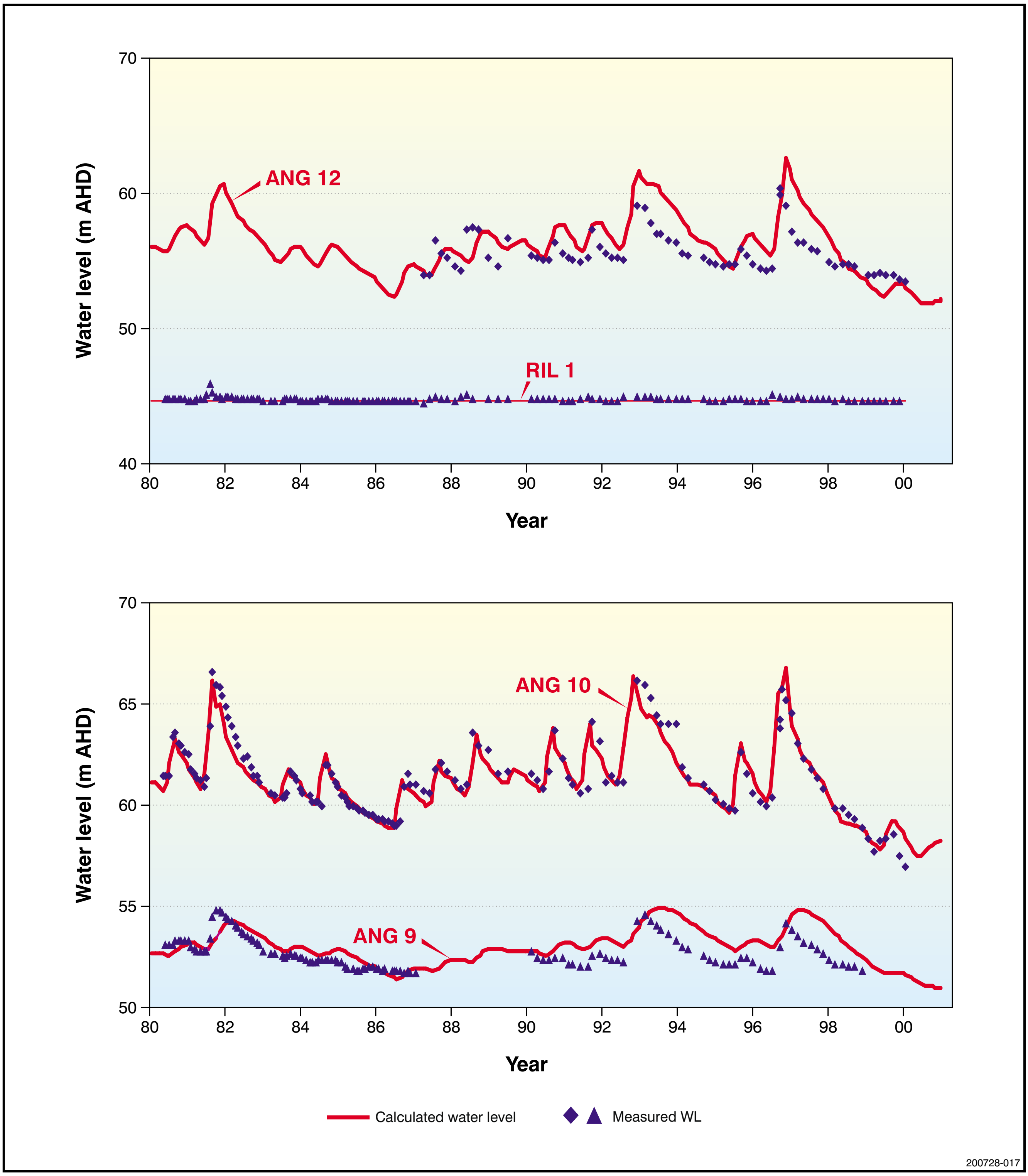


Figure 17 Comparison of modelled and observed groundwater levels

SCENARIOS

The calibrated model was used to predict the future impact on groundwater levels for the next 20 years of three different streamflow scenarios:

1. assuming streamflow conditions over the next 20 years will be a repeat of the previous 20 years
2. no streamflow at all over the next 20 years
3. what streamflow is required to regain long term average groundwater levels in the Kongolia area

For each of these scenarios, three groundwater extraction regimes were run:

- usage for 1999–2000 (1646 ML/y)
- authorised usage (2740 ML/y)
- authorised plus unauthorised (2908 ML/y).

The usage for 1999–2000 was estimated from land use survey data and crop application rates.

The authorised usage is the estimated extractions of the authorisations granted as a result of submissions made to DWR for irrigated areas during the Notice of Restriction. It is unlikely that full authorised usage will ever be attained since these submissions tend to be optimistic and ambit in nature, however it represents the maximum possible usage.

Several submissions were refused since inadequate evidence of intent to irrigate was provided to meet the criteria for granting an authorisation. These estimated extractions were added to see if there was any additional discernible impact on the resource.

RESULTS

The results are displayed as hydrographs for existing observation bores in the confined portion of the aquifer (ANG 20), unconfined close to river (ANG 9–10 and RIL 1 further downstream) and unconfined further from the river (ANG 7).

Scenario 1: Repeat of last 20 years streamflow

Figure 18 shows the results for Scenario 1 which indicates very little change at ANG 7 and RIL 1. The confined ANG 20 shows similar ranges of fluctuations to current levels at current usage rates. Drawdowns increased by 5–8 m for authorised use, however no areas of the model became dry.

At the unconfined ANG 10, a similar pattern of drawdown emerged with the water level finishing 2 m lower than present. This is because the simulation started at the lowest level since 1980. If the simulation had started in 1996, there would have been no resultant drawdown. Authorised use adds another 2.5 m to the current use drawdown in the Kongolia area after 20 years. There was no observable difference when the unauthorised applications were included.

Scenario 2: No streamflow for 20 years

This represents the worst possible case scenario of no streamflow or recharge to the unconfined portion of the aquifer for the next 20 years with continuing extractions (Fig. 19).

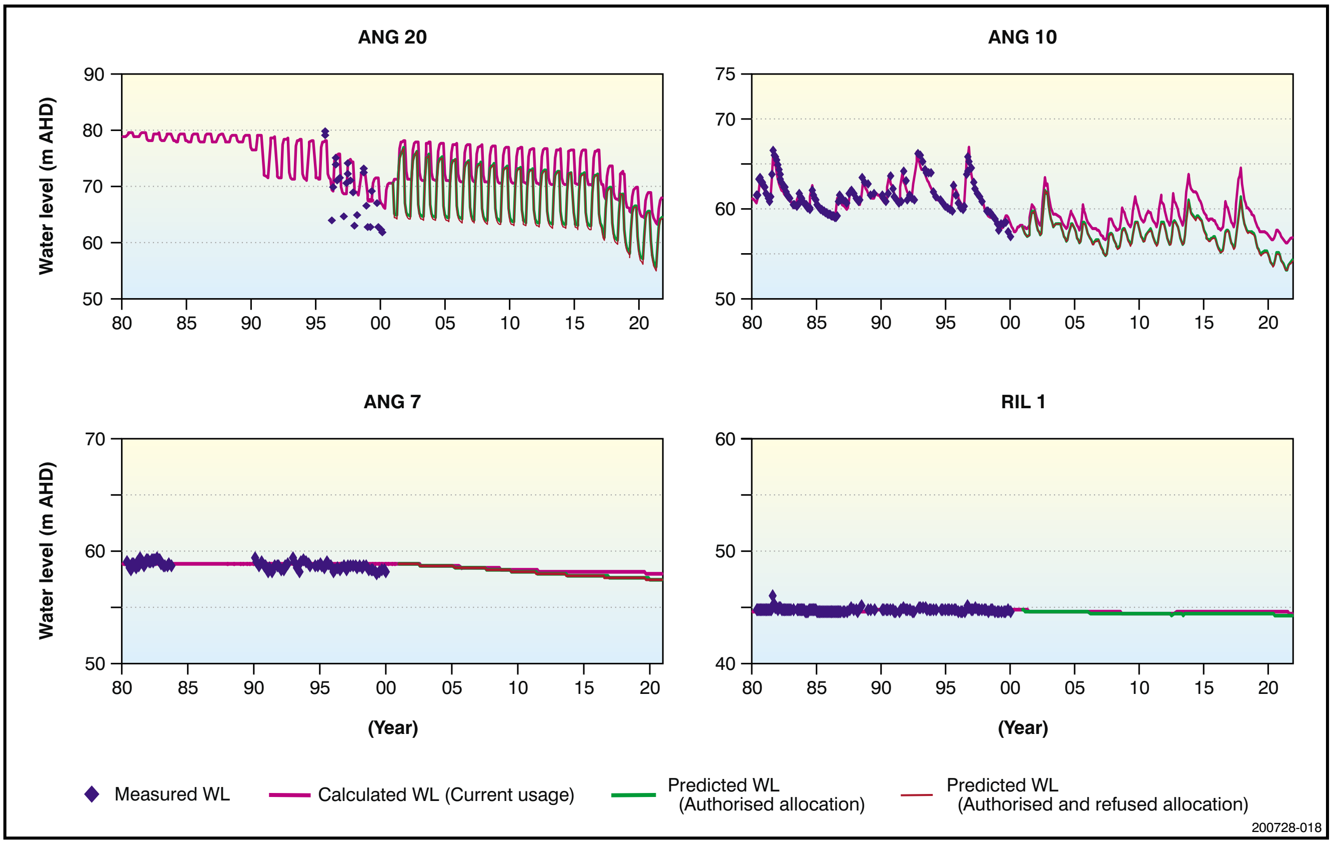


Figure 18 Model results for Scenario 1 (repeat of last 20 years streamflow)

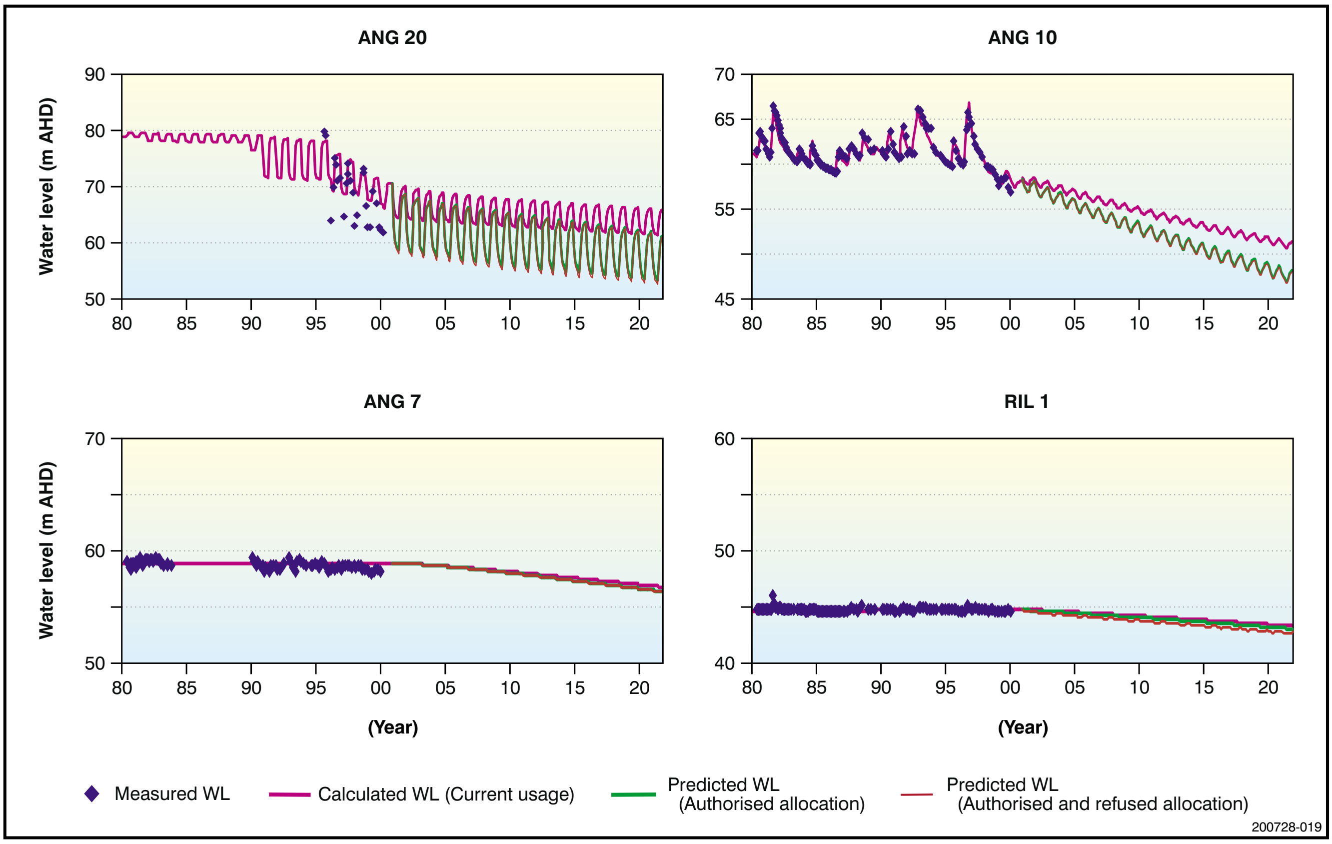
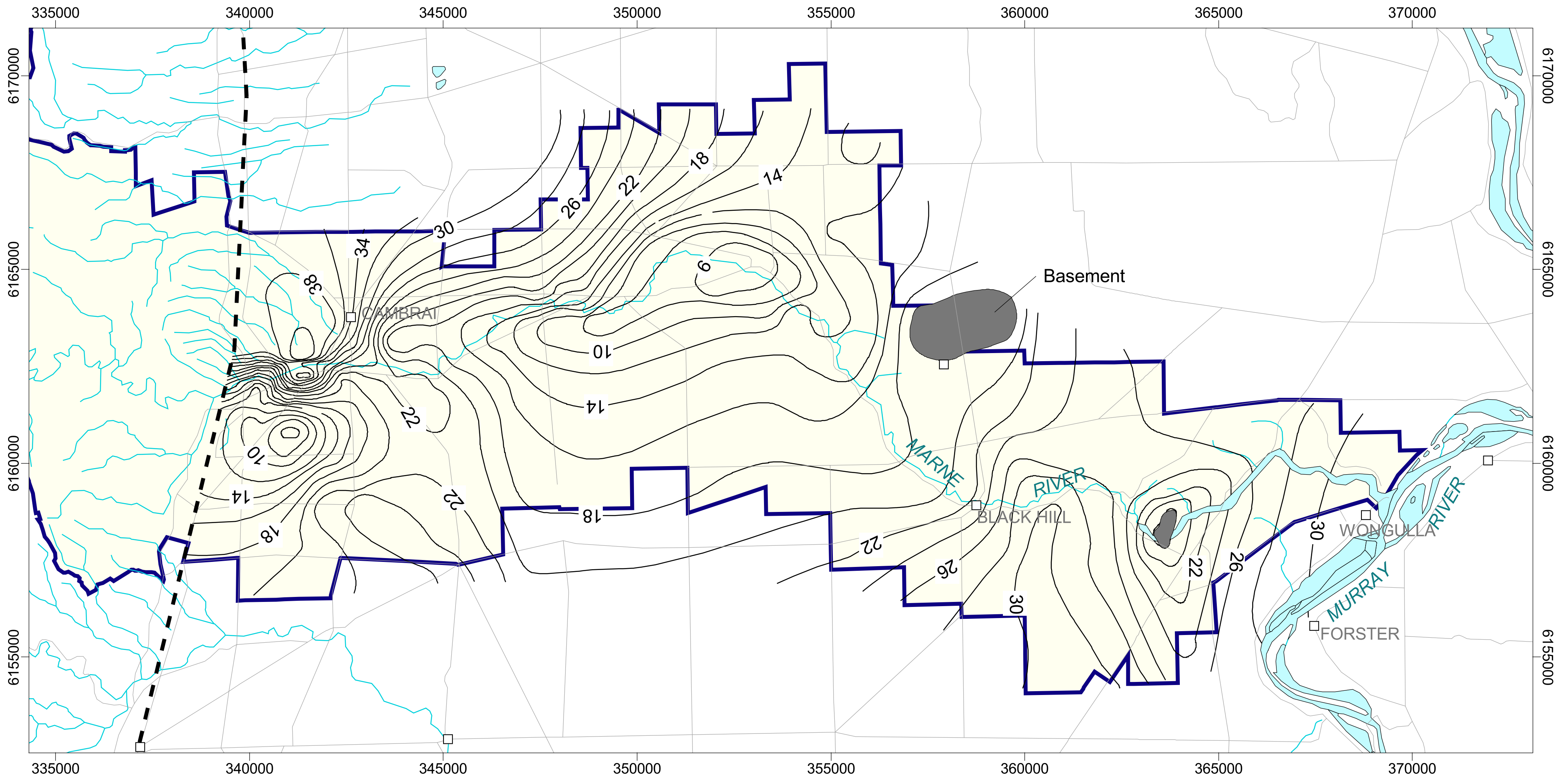


Figure 19 Model results for Scenario 2 (no streamflow for 20 years)



Department for Water Resources

MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT

Scenario 2- aquifer thickness after no stream flow for 20 years

0 2000 4000 6000 Meters

Datum: GDA94
Projection: MGA94 Zone 54

AV: 200728_020

Figure 20

Even ANG 7 and RIL 1 show drawdowns of up to 3 m in this scenario, with very little difference between any of the pumping regimes. The confined ANG 20 shows increasing drawdowns of up to about 5 m greater than present for current use, with an extra 2 m for authorised use.

The most dramatic impact is shown at ANG 10, where the drawdown for authorised use would reach 15 m below current levels after 20 years. This would dewater the aquifer significantly as shown by the contours of aquifer thickness (Fig. 20). In practice, the aquifer would be unusable in the Kongolia area after about 10 years because a certain thickness of aquifer is required for boreholes to operate efficiently. Again, there is little observable difference if the unauthorised applications were included.

Scenario 3: Regain average groundwater levels

This scenario was run to determine what recharge from streamflow would be required to raise the watertable in the unconfined portion back to approximate long term average levels. Figure 21 shows the impact at ANG 10.

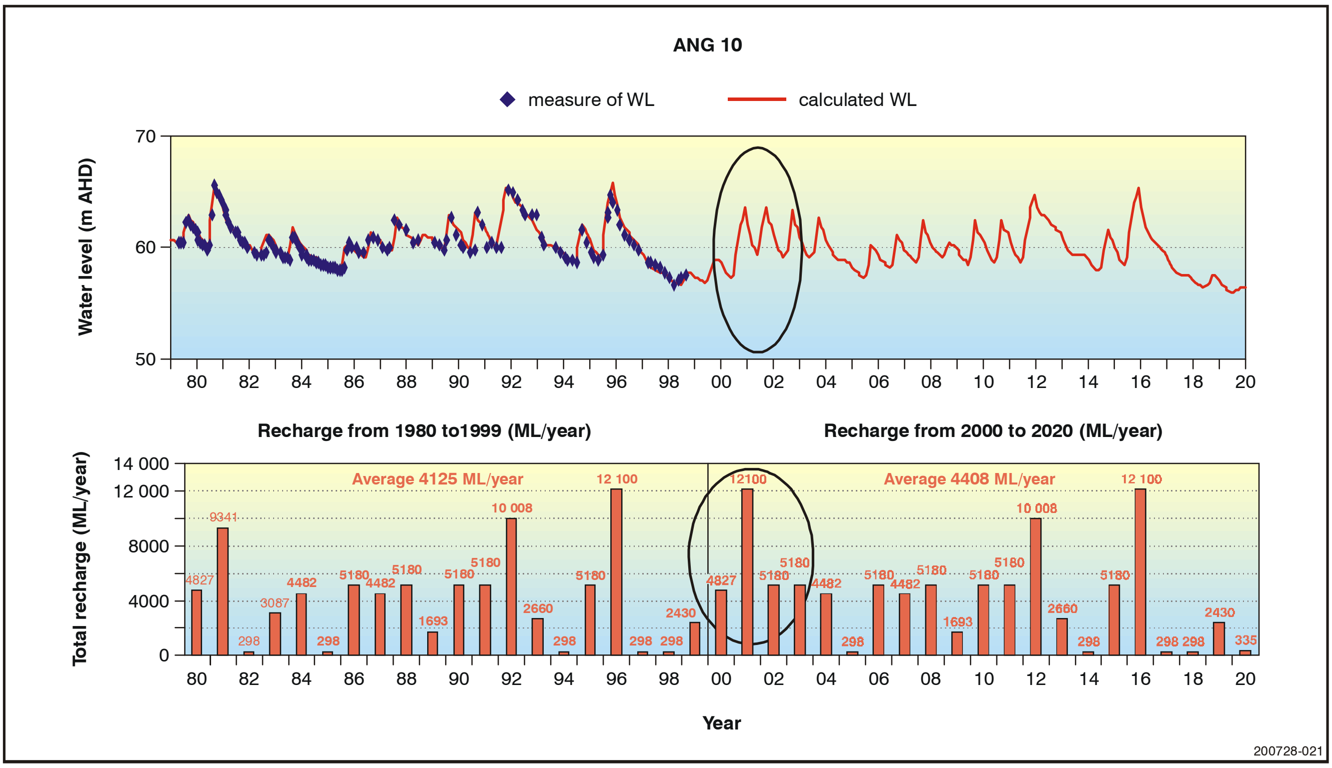


Figure 21 Model results for Scenario 3 (average streamflow for 3 years)

SUSTAINABLE YIELD

DEFINITION

The *State Water Plan 2000* accepts the definition of sustainable yield proposed by the National Groundwater Committee of 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 State Water Plan also states that the time frame must take into account delayed ecological impacts and that the sustainable yield may not necessarily be a fixed annual volume. A precautionary approach must be taken with lower sustainable yields in areas with little information and in areas of high use.

The higher value uses may be agriculture, ecosystems, infrastructure, industry or other activities, which 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).

It should be noted that recharge is not mentioned in the definition of sustainable yield since, depending on the aquifer characteristics, other factors are more important.

SUSTAINABILITY ISSUES

GROUNDWATER RESOURCES

Hills Zone

As mentioned previously, there are no significant sustainability issues for the fractured rock aquifers of the Hills Zone at current levels of extraction.

Plains Zone

It is difficult to assign a fixed value for the sustainable yield of the groundwater resource independent of streamflow. The two are related and very dependent on annual rainfall in the Mount Lofty Ranges.

The sustainability of the limestone aquifer is wholly dependent on recharge from average flows or higher from the ranges (>5000 ML/y) every 2–3 years. If flows are below average, or average flows occur less frequently, groundwater levels will decline and salinities will gradually increase.

To enable calibration with observed groundwater levels in the unconfined area downstream of Cambrai, the model required an average annual recharge from streamflow of just over 4000 ML over the last 20 years. In the confined area close to the ranges, lateral subflow from the fractured rock aquifers averaged 1000 ML/y.

These inflows of about 5000 ML/y compare favourably with the authorised use of about 2800 ML/y. However, before these figures can be used as a basis for determining a PAV, the water requirements for GDEs should be determined.

GROUNDWATER DEPENDENT ECOSYSTEMS

In the Plains Zone, there are some significant ecosystems clearly dependent on groundwater. The extensive red gum vegetation along the Marne River floodplain is tapping into the shallow good quality groundwater. Any long term reduction in streamflow would result in a lowering of the watertable and stress on these trees. In order for this stress to become apparent, the critical water level is not known. The quantity used by the trees is also not known with certainty, and should be investigated.

In the lower reaches of the Marne River downstream of Black Hill, wetlands occur where the river channel has cut down to the regional watertable. Some of the semi-permanent pools are fed by a spring on Hundred, Ridley, Section 324, which has recently stopped flowing for the first time in decades.

Irrigation extractions would normally have no effect on these wetlands (unless there was no recharge for more than 10 years) for several reasons. The nearest significant irrigation is 6 km to the northwest, where the watertable is 10 m higher in elevation. Between the irrigation and the wetlands is observation bore RIL 1 which has shown no significant variation since 1980 (Fig. 13). The large basement outcrop of Black Hill also lies between the two.

It is this basement outcrop that is the most likely source for the spring on Section 324 (Fig. 22). Rainfall percolates down through the veneer of sand and shallow limestone until it reaches the impermeable basement. It then flows off the southern side of Black Hill and collects at one point where it emerges as the spring. There is a dry valley directly to the north of the spring which could be the surface expression of this subsurface flow.

The catchment area is approximately 9 km^2, and if a recharge rate of 50 mm/y (about 15% of rainfall) is assumed for the shallow, sandy soils, the average flow would be 14 L/s, which approximates the normal spring flow. The three dry years would have resulted in virtually no recharge, with the spring flow then completely draining the elevated catchment.

In this case, the local rainfall is the main control of the spring flow and not streamflow. However, further downstream, the wetlands are dependent on regional groundwater levels, which are controlled by local recharge and drawdowns from local extractions.

FURTHER INVESTIGATIONS

The present good understanding of the groundwater system and future management of the resource will be enhanced by the following works and investigations.

1. Upgrading the existing stream gauging station (No. 426529) and constructing at least one more station in the vicinity of Black Hill in order to quantify stream losses and hence recharge to the limestone aquifer.
2. Investigating the water use of red gums by sap flow measurements and monitoring hourly groundwater level fluctuations in order to help define the requirements of GDEs.
3. Determining the relationship between the spring fed pools on Section 324 and the regional watertable.

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AV: 200728_022

MARNE RIVER CATCHMENT
GROUNDWATER ASSESSMENT
Catchment area for spring on Section 324

Figure 22

SUMMARY AND CONCLUSIONS

The Marne River catchment is divided into two distinct groundwater regions: the Hills Zone and the Plains Zone. The Hills Zone comprises the consolidated basement rocks of the Mount Lofty Ranges which form fractured rock aquifers. Borehole yields are generally low and salinities variable. The 1999 land use survey found groundwater pumping for limited irrigation of vineyards to total about 1000 ML/y. A catchment water balance calculated that extractions are well below the estimated recharge, and no sustainability issues are apparent.

The Plains Zone is underlain by unconsolidated sediments of the Murray Basin. The main aquifer is the Murray Group Limestone which is developed for the irrigation of lucerne, olives and turf, and is recharged mainly by infiltration of streamflow. Analysis of groundwater level trends has shown a close correlation with streamflow and hence rainfall in the Mount Lofty Ranges. After three years of virtually no recharge from streamflow, groundwater levels dropped by up to 3 m (or 10% of the aquifer thickness) to the lowest levels recorded since monitoring began in 1980.

The well-calibrated groundwater computer model used in the report found that there was significant groundwater used by large red gums growing along the river valley. The prediction results show that continued use at current extraction levels over the next 20 years with the same streamflow conditions will have no impact. Authorised use over the same 20 year period will only add an extra 2.5 m drawdown in the unconfined Kongolia area. Drawdowns increased by 5–8 m for authorised use in the confined area near the hills, which will have an impact on other users. There would be very little difference to drawdowns if unauthorised extractions were included in these scenarios.

If streamflow or recharge does not occur over the next 20 years with continual extractions, the aquifer in the Kongolia area would be unusable after only 10 years due to low groundwater levels. In order to raise levels, caused by lack of recharge or streamflow, to the long term average, about three average years worth of streamflow and a flood event would be required.

The modelled long term average inflows to the aquifer of about 5000 ML/y compare favourably with the authorised extractions of about 2800 ML/y. However, before analysts use the figures as a basis for determining a permissible annual volume for extraction, the water requirements for groundwater dependent ecosystems (GDEs) should be determined. These GDEs include the red gum vegetation and wetlands downstream of Black Hill which are dependent on regional groundwater levels and local recharge from rainfall.

APPENDIX

1 MARNE CATCHMENT WATER BALANCE, HILLS ZONE

CATCHMENT WATER BALANCE *MARNE (HILLS)*

Irrigation/extraction

Crop type/use	Area (ha)	Water need (mm)	Water use (ML)
Vineyards	255	175	450
Lucerne	60	1000	600
Stock and domestic			20
		Total	**1070**

Evapotranspiration

Land use	Area (ha)	Water use (mm)	Water loss (ML)
Pasture	22 290	380	85 100
Vineyards	770	400	3080
Forestry	80	500	400
Lucerne	60	440	260
		Total	**88 840**

Streamflow

Runoff (ML)	6420
Baseflow (ML)	1280
Total	**7700**

Recharge

Method	Comments	Estimate (ML)
Deduction	Rainfall -(ET + runoff + damvol)	4550
Deduction	Groundwater extraction + baseflow	2350
Chloride	Comparison rainfall and groundwater	450
	Adopted value	**3000 – 3500**

Dam storage

Total	**2433**

⇒ **Total outflow** **102 250 ML**

Rainfall (Effective) **440 mm** **X** Area **232.82 km²** ⇒ **102 250 ML**

Total inflow

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