DWLBC REPORT

Hydrogeological Review of the Tintinara - Coonalpyn PWA Water Allocation Plan

2008/09

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

Hydrogeological Review of the Tintinara–Coonalpyn PWA Water Allocation Plan

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Government of South Australia
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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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SUMMARY

As part of a review of the Water Allocation Plan for the Tintinara – Coonalpyn Prescribed Wells Area, an assessment of the current condition of the groundwater resources of both confined and unconfined aquifers was carried out. Despite recent increases in pumping due to drought and the expansion of some irrigation enterprises, extractions from the unconfined aquifer (43 500 ML) and confined aquifer (9500 ML) are still well below the allocation limits.

Since 2000, watertable levels in the **Tintinara MA** have steadily declined by 1.5 m in response to below average rainfall and irrigation extraction. This represents about 5% of the unconfined aquifer storage volume. Very little, if any recharge occurred during the 2006 drought, leading to the lowest groundwater levels on record. Average winter rains during 2007 resulted in a strong recovery close to pre-drought levels. Previously observed salinity rises have stabilised over the last few years, possibly in response to increased irrigation efficiency and ongoing below average rainfall.

In order to reduce the gap between extraction and allocation, it is recommended that a reduction in the total allocation of 12–14 000 ML/y be made in the Tintinara MA. When this reduction has been made, removal of the area limitation on licences should be considered. No changes to trigger levels are recommended.

Within the unconfined **Sherwood MA** and **Coonalpyn MA**, monitoring has so far shown virtually no impact on the resource from the current level of extractions. Given the predicted long term decline in the resource due to vegetation clearance, it is considered that development of groundwater use up to the VLA is well within the capacity of the resource. No changes to the management approach or trigger levels are warranted at this stage.

It is recommended the boundary of the **Boothby MA** be varied to include the Tintinara township to allow possible use of the unconfined aquifer for aquifer storage and recovery of stormwater for the irrigation of recreational grounds.

Confined aquifer drawdowns in the **Tolmer MA** have increased due to a combination of hydrostatic loading, drought and expansion of irrigation. No adverse impacts on the resource have been observed, with salinity levels stable or decreasing. In order to reduce the gap between extraction and allocation, it is recommended that a reduction in the total allocation of 2500–3000 ML/y be made. It is also recommended that the stipulation that peak and residual triggers be measured at the township should be removed, together with the 4 km radius trigger for both peak and residual drawdown.

In the **Tauragat MA**, irrigation of large olive plantations from the two deepest confined 'sub-aquifers' in this zone have lead to significant drawdowns. A lack of monitoring wells in these 'sub-aquifers' prevents the areal extent of drawdown being accurately delineated, but also indicates that very few users will be impacted by the extractions. Groundwater modelling suggests projected withdrawals are within the capacity of the resource, with impacts from flow reversal not expected to be significant.

The number of water level monitoring wells in the network is considered adequate for the Tintinara–Coonalpyn PWA. Five new observation wells have been added in areas of concentrated pumping in the unconfined Tintinara MA to determine if flow reversal occurs during the irrigation season. Similarly, additional observation wells have been selected for the confined aquifer in the Tolmer MA to monitor impacts of expanded irrigation to the south-west of Tintinara township.

1. INTRODUCTION

The Tintinara–Coonalpyn Prescribed Wells Area (TCPWA) covers an area of approximately 3423 km^2 and includes the Hundreds of Archibald, Carcuma, Conybeer, Coombe, Lewis, Livingston, Makin, McCallum, and Richards (Fig. 1). Both major towns, Coonalpyn and Tintinara, lie on the main Adelaide-Melbourne highway that runs through the western part of the TCPWA in a southeast direction.

Apart from stock and domestic supplies from the Tailem Bend to Keith pipeline, there are no extensive supplies of good quality surface water in the TCPWA, and therefore groundwater provides the only water resource for irrigation in the region. Groundwater flows through two major aquifer systems: a regional unconfined limestone aquifer and an underlying confined aquifer with sand and bryozoal limestone (coral) layers. The upper, unconfined limestone aquifer is the most extensively used of the two aquifers, mainly for the irrigation of lucerne. However, poor groundwater quality in this aquifer in some areas has resulted in development of the underlying confined aquifer as a water resource, with olives and lucerne the predominant irrigated crops. A detailed description of the regional hydrogeology of the TCPWA can be found in Barnett (2002).

In 1998, the Tintinara–Coonalpyn area was placed under a Notice of Restriction pursuant to the Water Resources Act 1976. This was considered necessary because of concerns from the community that the rapid expansion of irrigation activity in parts of the area could have a detrimental impact on the water resource. It was later prescribed on 2 November, 2000. Subsequently, after an assessment of the resource capacity and extensive community consultation, the Water Allocation Plan for the TCPWA was prepared by the former South East Catchment Water Management Board (SECWMB) and released by the Minister of Environment and Conservation in May 2003.

Under the *Natural Resource Management Act 2005*, each Water Allocation Plan must be reviewed every five years. To assist the South East Natural Resources Management Board (SENRMB) in this process, this report will review, for both the unconfined and confined aquifers :

- the current condition of the groundwater resources of both aquifers, taking into consideration available groundwater monitoring data and the capacity of both aquifers to meet the demands on a continuing basis.
- the management approach adopted for the sustainable use of the resource and the volume available for licenced allocation (VLA) for each management area.
- the current use and allocation in each of the management areas within the PWA.
- the likely future demand for groundwater from this resource in the PWA.
- whether the taking or use from either aquifer has had a detrimental effect on the quantity or quality of water that is available from any other water resource, both within and outside of the PWA.
- the adequacy of the current groundwater monitoring network in the PWA for monitoring the capacity of the resource to meet demands, including recommendations for any additional monitoring requirements and changes to trigger levels.

This report does not review any impacts on groundwater dependent ecosystems.

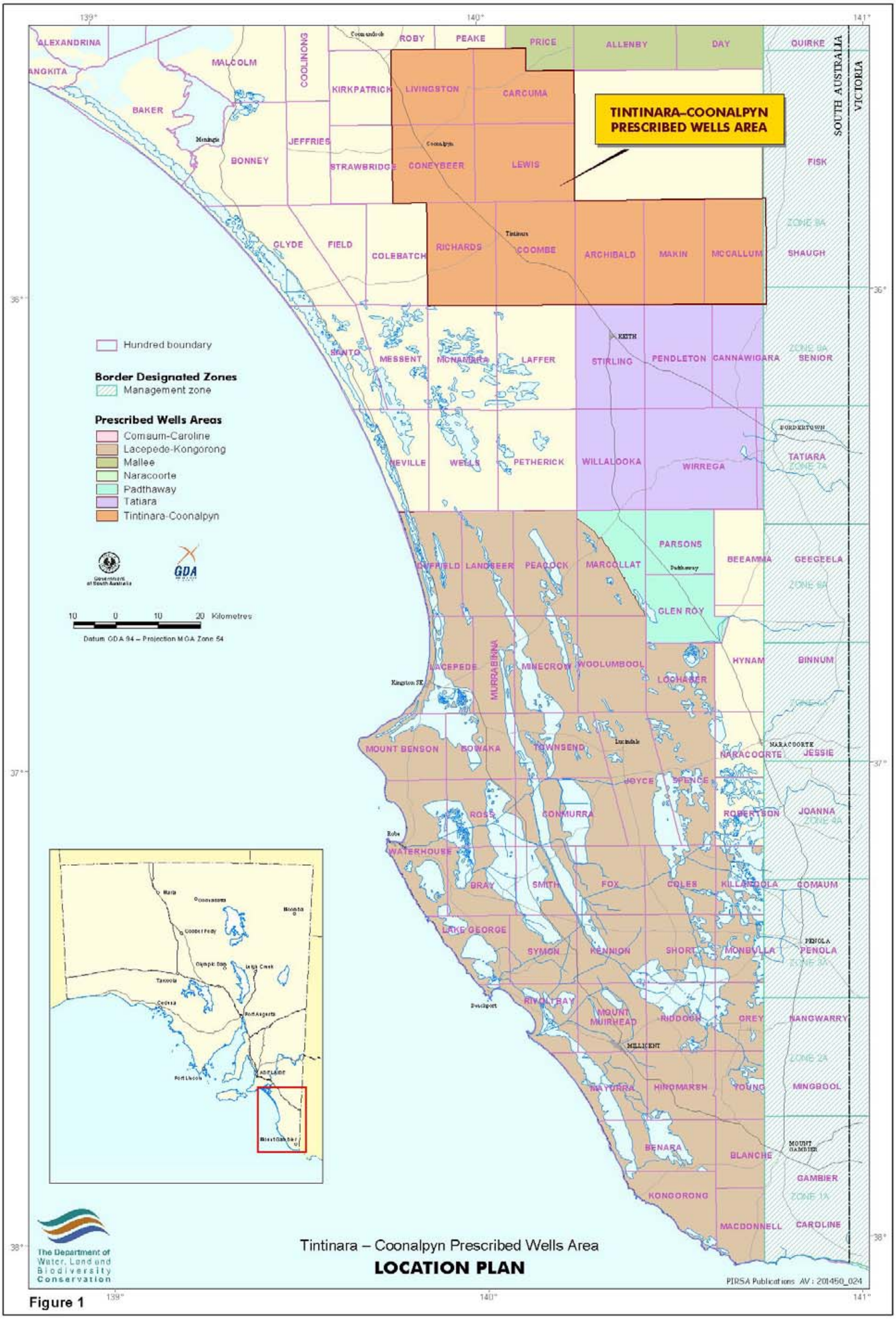
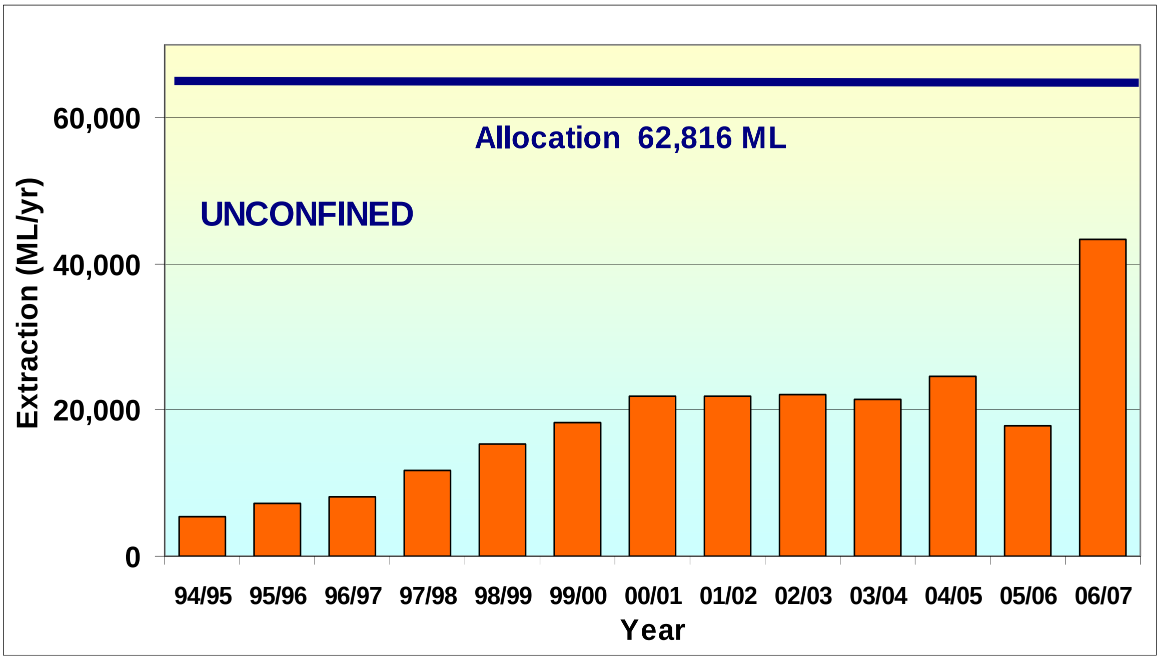


Figure 1. Tintinara – Coonalpyn PWA location plan

2. ALLOCATION AND GROUNDWATER USE

Before describing the current status and trends for both the unconfined and confined aquifers in the TCPWA, it is useful to examine the overall trends in extraction and compare them to the volume available for licenced allocation (VLA). The extraction and allocation volumes for each management area will be discussed further in this report.

Figure 2 shows that extraction from the unconfined aquifer had stabilised at just over 20 000 ML/y, until the drought-induced increase to almost 43 500 ML in 2006–07, well below the allocation limit. Similarly, confined extractions have steadily increased to 9500 ML/y (due mainly to olive irrigation in the Tauragat MA), and is well below the allocation limit.



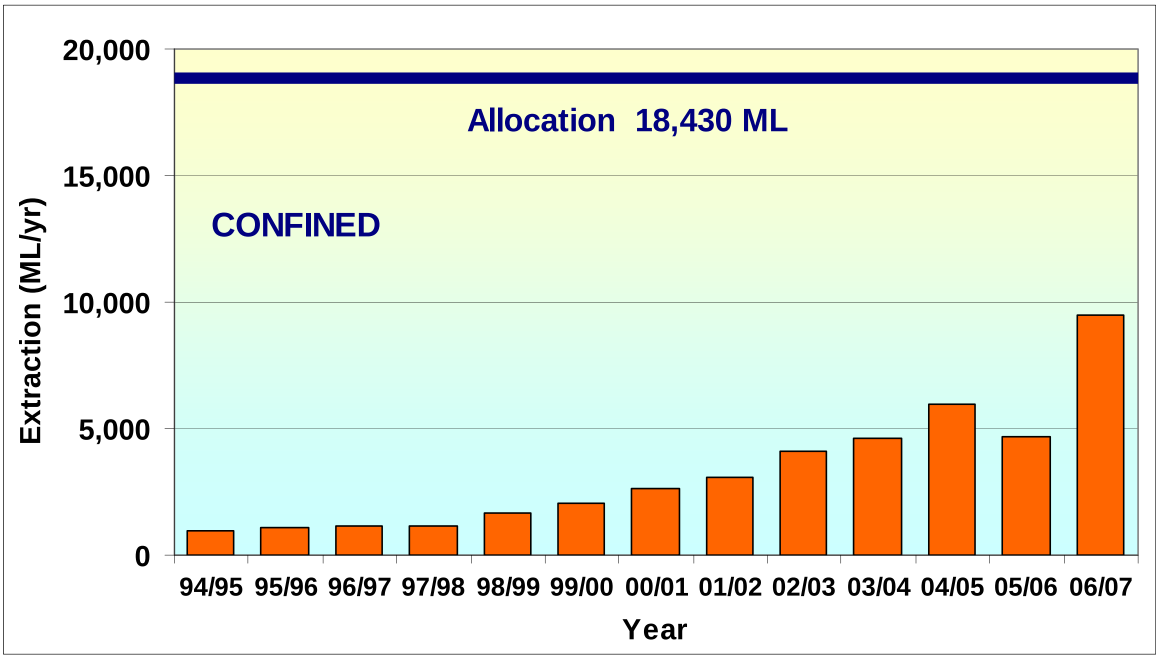


Figure 2. Comparison of extraction and VLA for unconfined and confined aquifers

3. UNCONFINED MANAGEMENT AREAS

The current status of the groundwater resources will be discussed for each management area (Fig. 3) with examination of water level and salinity trends, together with a comparison of extractions and the allocation volumes (VLA).

Metering was introduced in 2003 but prior to that year, extraction volumes were estimates based on irrigated areas. The hydrographs will depict the cumulative deviation from mean rainfall (in blue) which measures the difference between the actual measured rainfall and the long term 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.

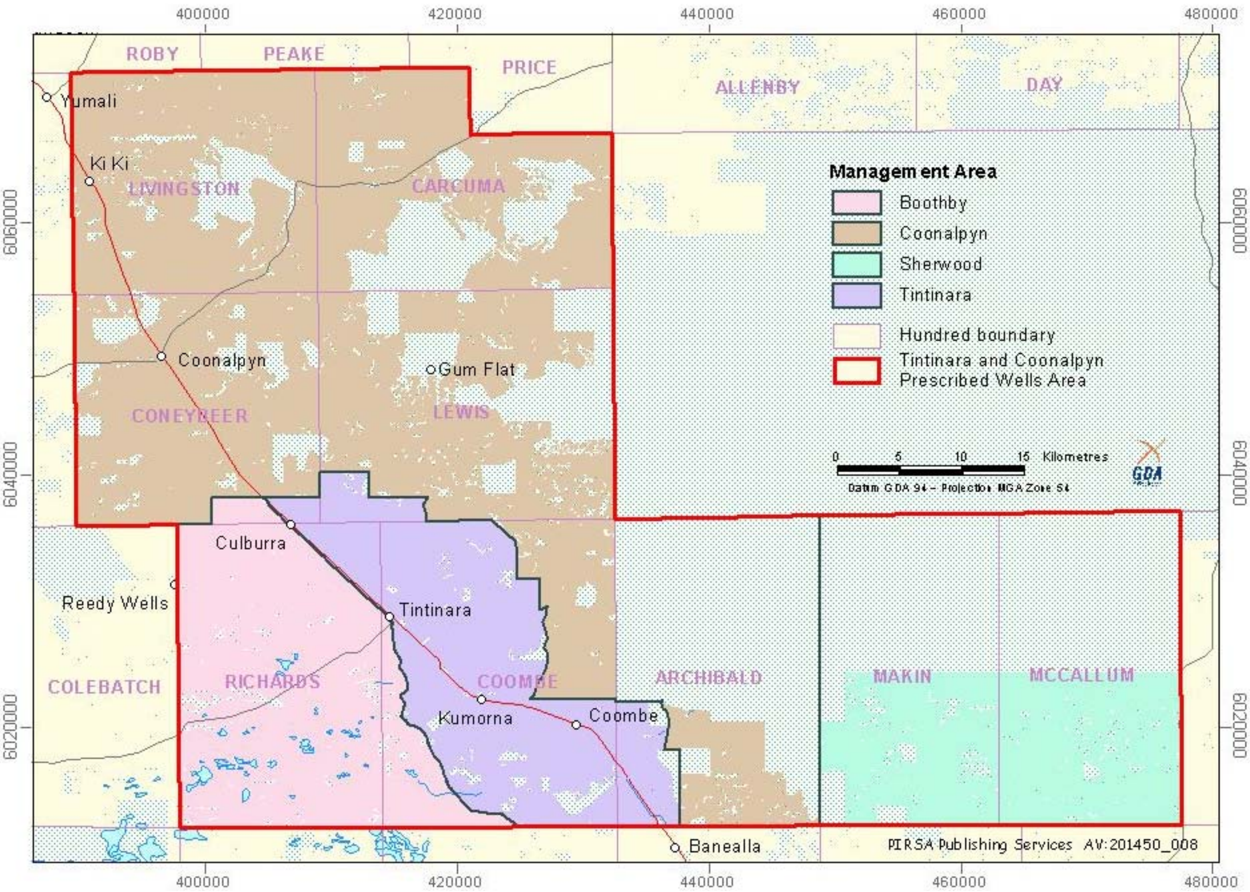


Figure 3. Unconfined aquifer management areas

3.1 TINTINARA MA – COASTAL PLAIN

3.1.1 CURRENT STATUS

This zone comprises most of the Hd of Coombe and the western part of Hd Archibald, and has the highest extraction in the TCPWA for centre pivot and flood irrigation of lucerne. The Quaternary limestone aquifer lies at a depth ranging from 15 m below ground surface, to less than a metre in areas of salinisation. Groundwater salinities are mostly below 8000 mg/L. Management issues of concern in this management area include salinity increases due to recycling of irrigation water, and the eastward expansion of dryland salinity due to the rising watertable.

Figure 4 shows groundwater extractions have generally stabilised from 2000–05 at about 15 000 ML/y after previous steady increases. A significant decrease to just over 10 000 ML occurred in 2005–06 due to the very wet spring delaying commencement of irrigation. The 2006 drought resulted in a significant increase to 26 100 ML in the 2006–07 season compared to previous years.

Over the last five years, water level monitoring has shown a consistent declining trend in the Tintinara MA (Fig. 4) in response to below average rainfall and irrigation extraction. The cumulative deviation from mean rainfall (in blue) measures the difference between the actual measured rainfall and the long term 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. Very little, if any recharge occurred during the 2006 drought, leading to the lowest groundwater levels on record. Average winter rains during 2007 resulted in a marked recovery in groundwater levels close to pre-drought levels.

Salinity trends from sampling irrigation wells are quite variable as shown in Fig. 4. Decreasing trends have been observed on the eastern margins of the irrigated area because drawdowns have increased the inflow of lower salinity groundwater from the east (6926-586). Other wells that have been exhibiting a rising trend in the past, have now stabilised (ARC 8) while some are maintaining a slow rising trend (6926-586, 6926-503).

The seasonal drawdown during the 2006–07 irrigation season is shown in Figure 5. Areas with greater than 1.0 m drawdown are associated with irrigation concentration. Because of the drought, the maximum drawdown of about 1.5 m is greater than the 1.0 m maximum observed during the 2005–06 season. The regional seasonal drawdown unaffected by irrigation averages 0.5 m.

The groundwater flow direction during the period of maximum drawdown for the 2006–07 irrigation season is displayed in Figure 6. The hydraulic gradient is fairly low due to the high permeability of the aquifer. Throughflow is maintained through virtually all of the management area, however the addition of up to five new observation wells in areas of concentrated pumping is needed to confirm this. In the Coombe area, the readings suggest a small area of flow reversal, however although it is probably caused by heavier drought pumping, the readings were taken at different times during the irrigation season and flow reversal may not have actually occurred.

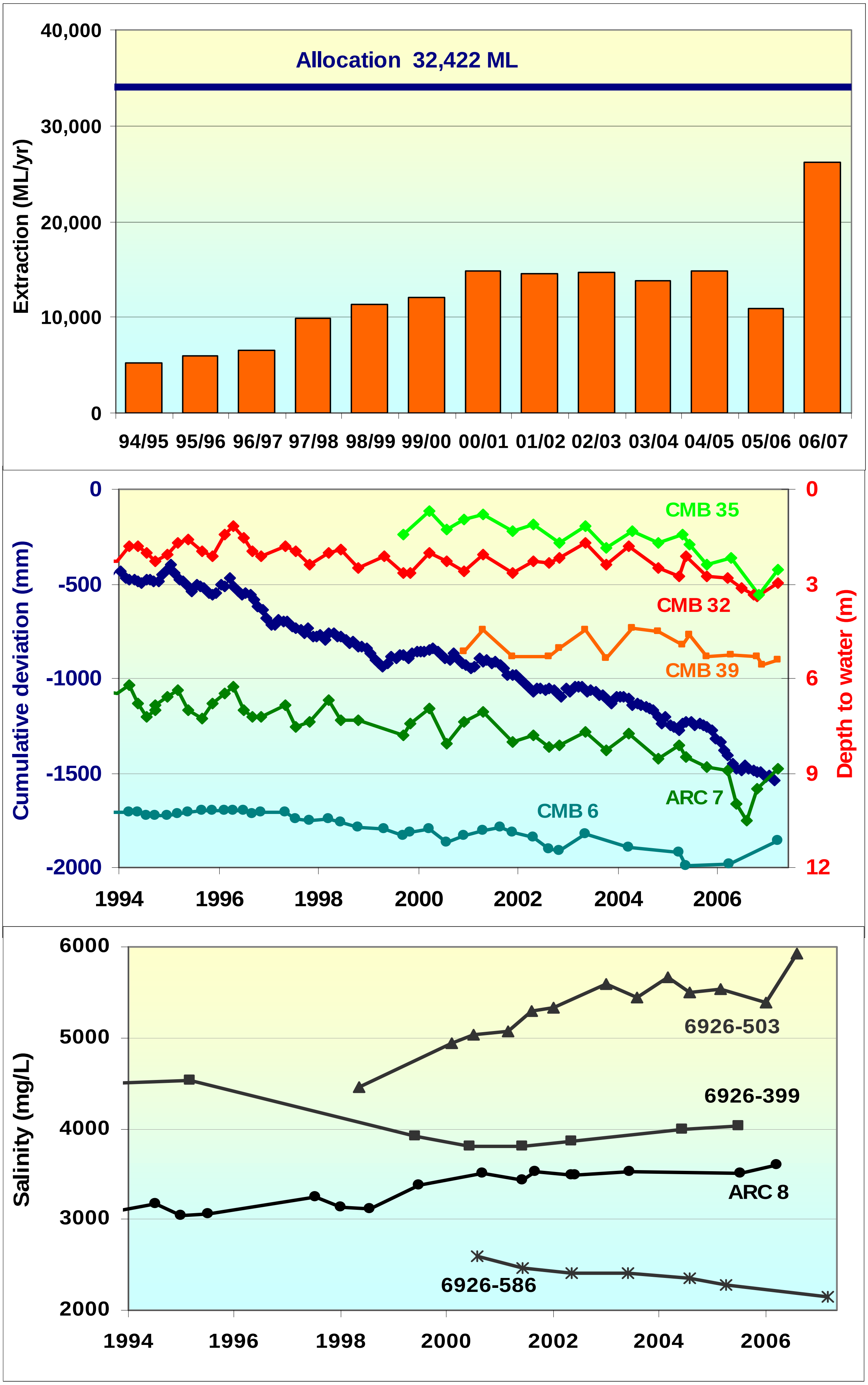


Figure 4. **Extraction, water level and salinity trends in Tintinara MA**

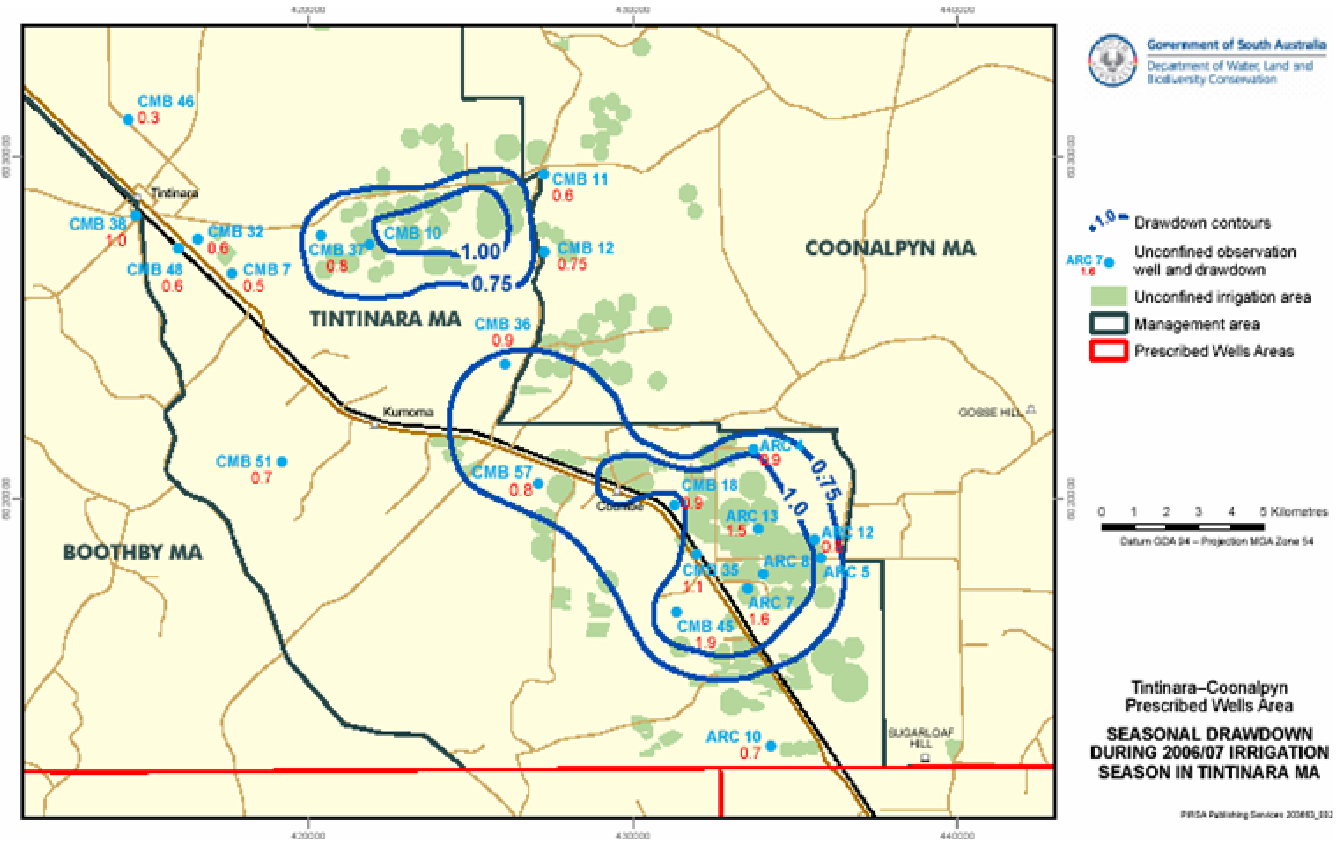


Figure 5. Seasonal drawdown during 2006–07 irrigation season in Tintinara MA

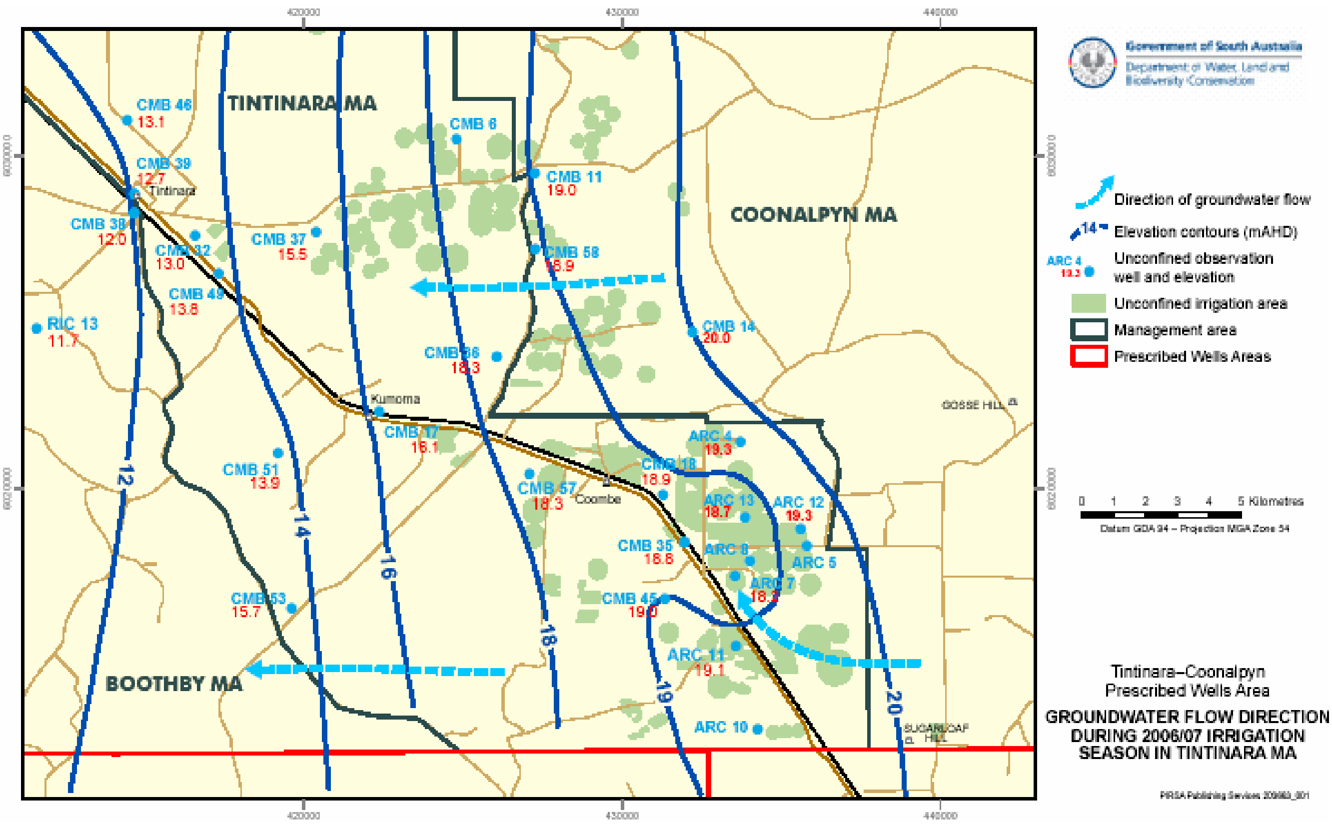


Figure 6. Groundwater flow direction during 2006–07 irrigation season in Tintinara MA

3.1.2 MANAGEMENT APPROACH

Management issues of concern in the Tintinara MA include salinity increases due to recycling of irrigation drainage water, and the eastward expansion of dryland salinity due to the rising watertable. The existing Water Allocation Plan provides trigger levels for drawdown and salinity trends in order to provide early warning of adverse trends.

The water level resource condition trigger of a net change of 0.1 m/y (measured over the preceding 5 years to 2007), was exceeded by all of the total of 18 observation wells as shown in Figure 7. The average rate of water level decline for the ten observation wells in irrigated areas (red dots) was 0.22 m/y. In the eight observation wells drilled under a National Action Plan vegetation health project, which are located away from irrigated areas, the rate of water level decline for was 0.25 m/y (blue dots). This indicates the very significant climatic contribution to the water level decline, and possibly also some groundwater uptake by vegetation.

The salinity resource condition trigger of a mean arithmetic increase of 2% per year (measured over the preceding 5 years), was exceeded by only four of the 26 irrigation wells with regular sampling, with the overall average indicating a 0.75% increase.

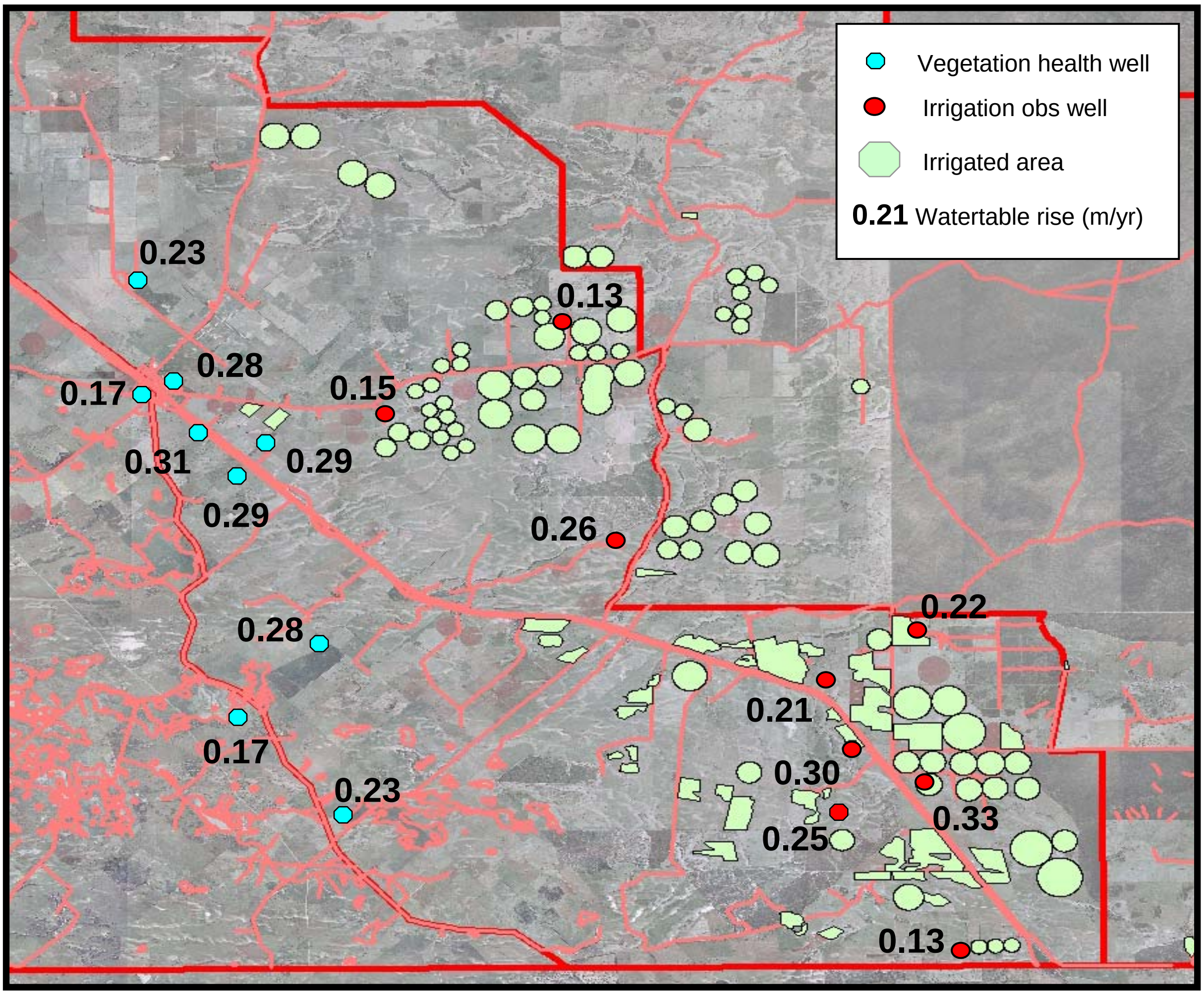


Figure 7. Water level trends in Tintinara MA

3.1.3 CAPACITY TO MEET DEMAND

Groundwater monitoring has indicated that at current extraction levels, the resource in the Tintinara MA can meet demand. Water levels have declined in response to dry years as well as irrigation extraction. The overall decline of up to 1.5 m since 2000 represents a 5% loss of storage from the unconfined aquifer, which averages 45 m in thickness.

In general, the fairly widespread rising salinity trends reported previously (Barnett, 2002) do not appear to be continuing. This could be due to several factors. Increased irrigation efficiency would have reduced drainage and the resultant flushing of recycled salt to the aquifer. The ongoing below average rainfall would have also reduced flushing of salt.

However, extractions are constrained by the irrigated area limitation placed on water licences. If this limitation were to be removed, extractions would increase significantly. If this increase were to coincide with continuing below average rainfall and more frequent drought periods in the future, the capacity of the diminishing resource to meet increasing demand would be doubtful.

3.1.4 MANAGEMENT RECOMMENDATIONS

Current extractions total only about half of the allocation limit for this Management Area, which is due mostly to the generous theoretical irrigation crop requirements adopted. This gap will make future management responses more difficult and ineffective. For example, a reduction in allocations to alleviate falling groundwater levels and salinity impacts due to climate change, will have little or no impact on actual levels of extraction.

It is recommended that a reduction in the total allocation of the order of 12–14 000 ML/y be made over time in the Tintinara MA, based on the usage trends before the 2006 drought. When this reduction has been made, removal of the area limitation on licences should be considered. This adjustment will ensure that if further reductions in allocations are required in the future, actual reductions in extractions will occur.

Although climate-driven lowering of watertable levels breached trigger levels in addition to irrigation impacts, no changes to trigger levels are recommended.

3.2 *SHERWOOD MA – EASTERN MALLEE HIGHLANDS*

3.2.1 CURRENT STATUS

This zone comprises the Hds of McCallum, Makin and the eastern part of Archibald. The Murray Group limestone aquifer is utilised for the centre pivot irrigation of lucerne and vegetables, with minor flood irrigation and drip irrigation of olives. The watertable lies 25–50 m below ground surface. The main sustainability issue is the flushing of unsaturated zone salt down to the aquifer, which contains low salinity groundwater.

A comparison of extractions compared to the maximum allocation (Fig. 7) shows that usage has been relatively stable at about 4–5000 ML/y, until a significant increase in 2006–07 to 7500 ML due to the drought. Usage is well below the VLA of just over 13 000 ML/y.

In the 15 years prior to 2000, the watertable rose steadily by about one metre due to the increased recharge following clearance of native vegetation (MKN 1, 8). Since then, water levels have been relatively stable away from the impacts of irrigation, as shown by the red/orange hydrographs in Figure 7, despite several years of below average rainfall. Where closer to irrigation extractions, observation wells (green hydrographs) in Figure 7 show gradual water level declines averaging 0.05 m/y since 2000.

The salinity trends for the Sherwood MA are also shown in Figure 7. Whilst a slow rising trend may be discernable in all four observation wells since 2000, examination of the longer records indicate that in the long term, salinity trends are mainly stable. MCA 7 is showing anomalous rises, but its salinity is still below that of the surrounding irrigation wells. Because the observation wells are not located within irrigated areas, any changes in their salinity would probably be caused by lateral movement of groundwater, rather than the vertical flushing of unsaturated zone salt.

MCA 7 has highlighted a small salinity stratification within the limestone aquifer. The stock and domestic wells are 50–60 m deep (about 10 m below the watertable) and exhibit salinities 100–150 mg/L lower than nearby irrigation wells that average 100 m in depth.

Although regular sampling of irrigation wells has been sporadic and too few samples have been taken so far to establish clear trends, two older wells indicate a small rising trend. To the west of the Management Area where the depth to the watertable is about 25 m, a rising trend of 10 mg/L/y has been observed over the last 25 years. Further east where the watertable depth is deeper at 35 m, the trend is 5 mg/L/y. These trends indicate that flushing of unsaturated zone salt beneath older irrigated areas (>20 years), may have commenced reaching the aquifer. It should be stated that in both situations, the rising trend is based on only two samples taken 25 years apart.

Irrigation wells at the eastern boundary of the Management Area, where the watertable depth is 50 m, are showing a reduction in salinity in response to the lateral flow of lower salinity groundwater from the east.

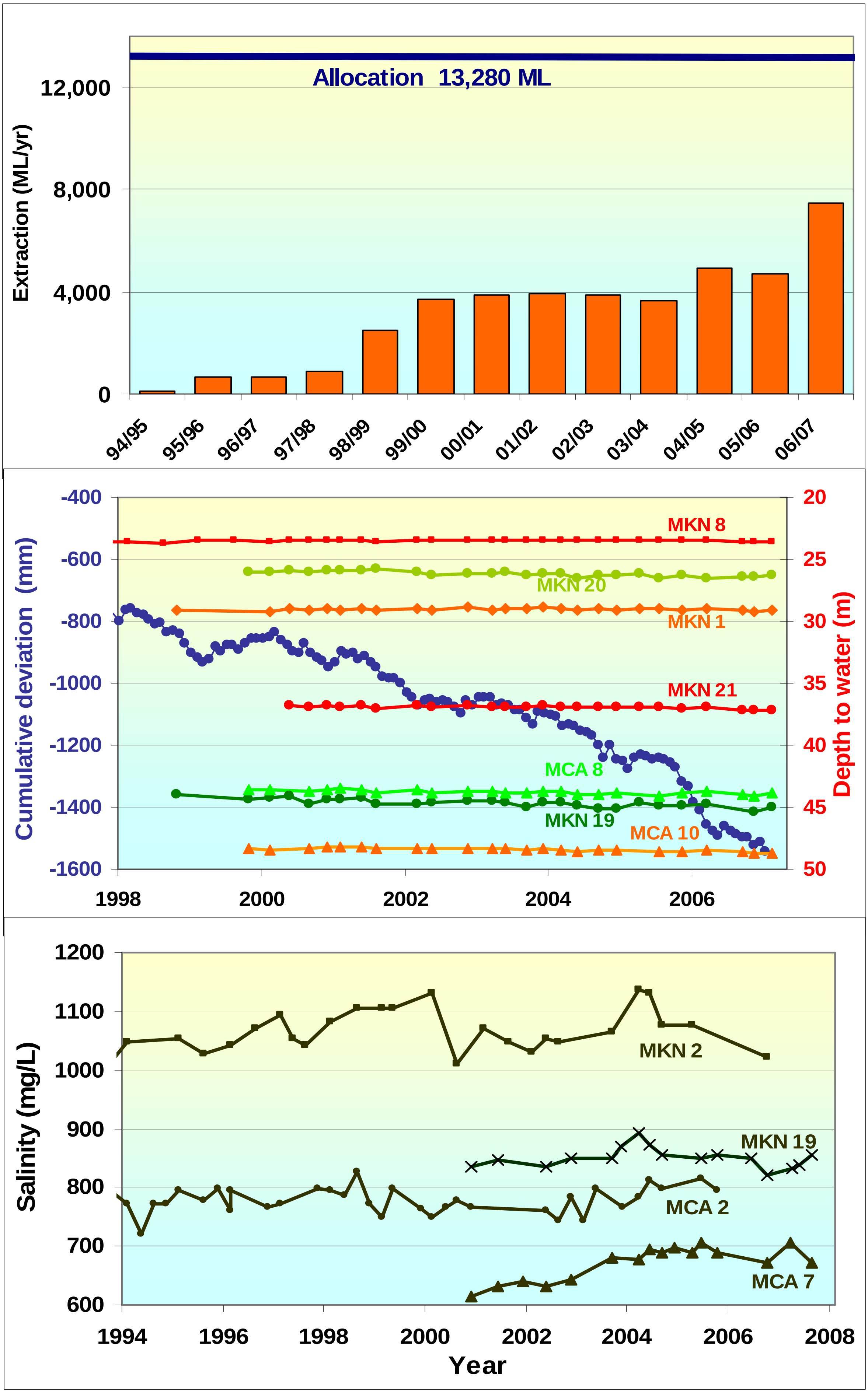


Figure 7. **Extraction, water level and salinity trends in Sherwood MA**

3.2.2 MANAGEMENT APPROACH

The current management regime in the Sherwood MA is based on a 2 km buffer zone around the existing areas of irrigation in order to mitigate the impacts of flushing unsaturated zone salt into the aquifer by irrigation drainage. Although water level monitoring has so far shown little or no impact on the resource from the current level of extraction, some salinity increases of up to 10 mg/L/y beneath lucerne established for more than 25 years have been observed.

A salinity modelling exercise (Osei-Bonsu et al, 2004) predicted increases of 185 mg/L/y beneath annual irrigation with a drainage rate of 200 mm/y, and increases of 23 mg/L/y for rotational irrigation (1 in 4 years) with a drainage rate of 135 mm/y. These results are not entirely inconsistent with the observed rises, given the sporadic nature of the irrigation, and reduced drainage rates causes by applications lower than that required for maximum lucerne production. Beneath dryland areas, salinity increases are not expected for about 50 years.

The salinity resource condition trigger of a mean arithmetic increase of 1% per year (measured over the preceding 5 years), was exceeded by two of the five observation wells - MCA 7 which was discussed earlier, and MCA 2 whose trend over 23 years shows a slight decrease. None of these trends have adverse resource implications. More regular sampling of irrigation wells over the next five years will enable a better interpretation of salinity trends.

The water level resource condition trigger of a net change of 0.1 m per year (measured over the preceding 5 years), was not exceeded by any of the 12 observation wells.

No changes to the management approach or trigger levels are warranted at this stage.

3.2.3 CAPACITY TO MEET DEMAND

Monitoring has so far shown virtually no impact on the resource from the current level of extractions. If current licences are close to full development, transfers to new developments are subject to spacing criteria, which will minimise impacts on exiting users. Given the predicted long term decline in the salinity of the resource, it is considered that development up to the VLA is well within the capacity of the resource.

3.3 COONALPYN MA – NORTHERN MALLEE HIGHLANDS

3.3.1 CURRENT STATUS

This zone comprises the Hds of Carcuma, Conybeer, Lewis and the northeastern part of Coombe. Well dispersed centre pivot irrigation of lucerne occurs from the Murray Group limestone aquifer which lies 15–60 m below ground surface. Figure 8 shows that previous extractions were just under 5000 ML/y until the 2006 drought resulted in a doubling of extractions to 9800 ML/y. These extractions are well below the VLA of 17 114 ML/y.

Away from the influence of irrigation to the west of the Management Area, the regional watertable has risen about 1.5 m since monitoring began in 1987, with the rising trend stabilising (LVG 1, CNB 2) or falling slightly due to dry years and the 2006 drought, as presented in Figure 8. In the deep sandy soils north of Tintinara toward Carcuma, a rise of 3–4 m has been observed since 1983. However, observation wells close to irrigation are showing a gradual decline (CMB 11, 12, LEW 8). The lack of high recharge events since 1996 would also contribute to the decline.

Salinity monitoring is only carried out in the eastern half of the MA where groundwater is usable. Away from the impacts of irrigation, previously observed rising trends due to native vegetation clearance have stabilised or are decreasing due to reduced flushing from below average rainfall, as shown in Figure 8. Some irrigation wells where the depth to the watertable is 20 m or less, are showing rising trends of 30–70 mg/L/y (6926-395).

3.3.2 MANAGEMENT APPROACH

As in the Sherwood MA, the main sustainability issue in the Coonalpyn MA is the flushing of unsaturated zone salt down to the aquifer, which contains low salinity groundwater. The current management regime is also based on a 2 km buffer zone around the existing areas of irrigation, in order to mitigate the impacts of flushing unsaturated zone salt into the aquifer by irrigation drainage.

The salinity resource condition trigger of a mean arithmetic increase of 2% per year (measured over the preceding 5 years), was not exceeded by any of the five observation wells unaffected by irrigation. The trigger was however, exceeded by two of the six irrigation wells sampled. More regular sampling of irrigation wells over the next five years will enable a better interpretation of salinity trends.

The water level resource condition trigger of a net change of 0.1 m per year (measured over the preceding 5 years), was exceeded by two of the total of seven observation wells. These were CMB 11 and 12 that are located very close to the boundary with the Tintinara MA, and were affected by extractions from that Management Area.

No changes to the management approach or trigger levels are warranted at this stage.

3.3.3 CAPACITY TO MEET DEMAND

The predicted long term decline in the resource has already commenced in some areas. Water level monitoring has so far shown little impact on the resource from the current level of extractions. It is considered that foreseeable development is well within the capacity of the resource.

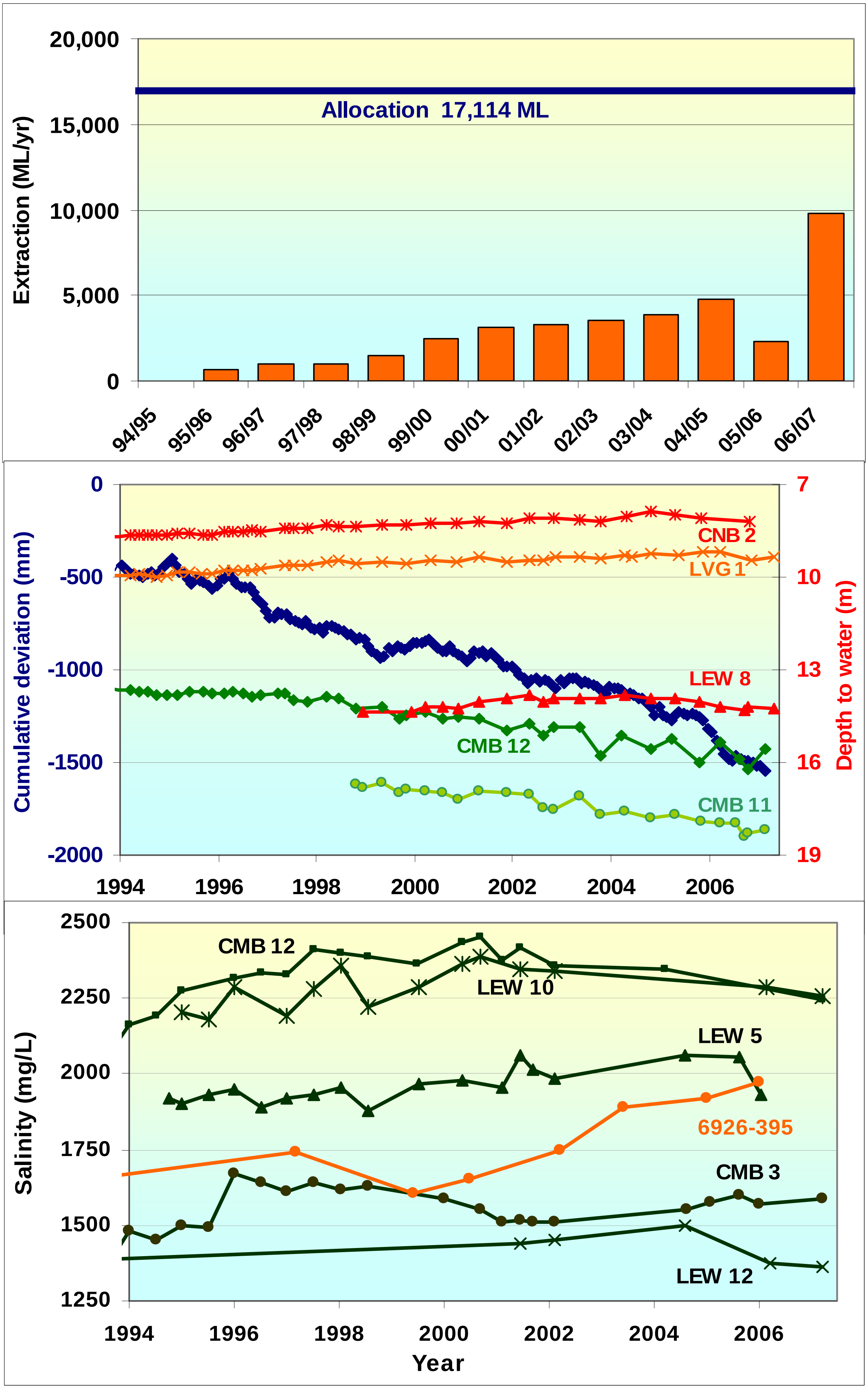


Figure 8. Extraction, water level and salinity trends in Coonalpyn MA

3.4 BOOTHBY MA – COASTAL PAIN

3.4.1 CURRENT STATUS

This zone comprises most of the Hd of Richards to the west of Tintinara. The Quaternary limestone aquifer, with the watertable at ground surface, or just below it, has salinities ranging from 8000 mg/L to well over 35 000 mg/L in areas of dryland salinisation. There is no current extraction in this Management Area.

There are only four observation wells in this Management Area monitoring the unconfined aquifer, with water levels following rainfall trends and showing a steady fall over the last three years (Fig. 9). These falls were observed immediately below areas irrigated from the confined aquifer (RIC 14) where drainage water might have caused a rise in the shallow watertable. There was very little recharge during the 2006 drought causing water levels to fall to record low levels during the following summer. Average winter rains in 2007 allowed a recovery of water levels to pre-drought levels.

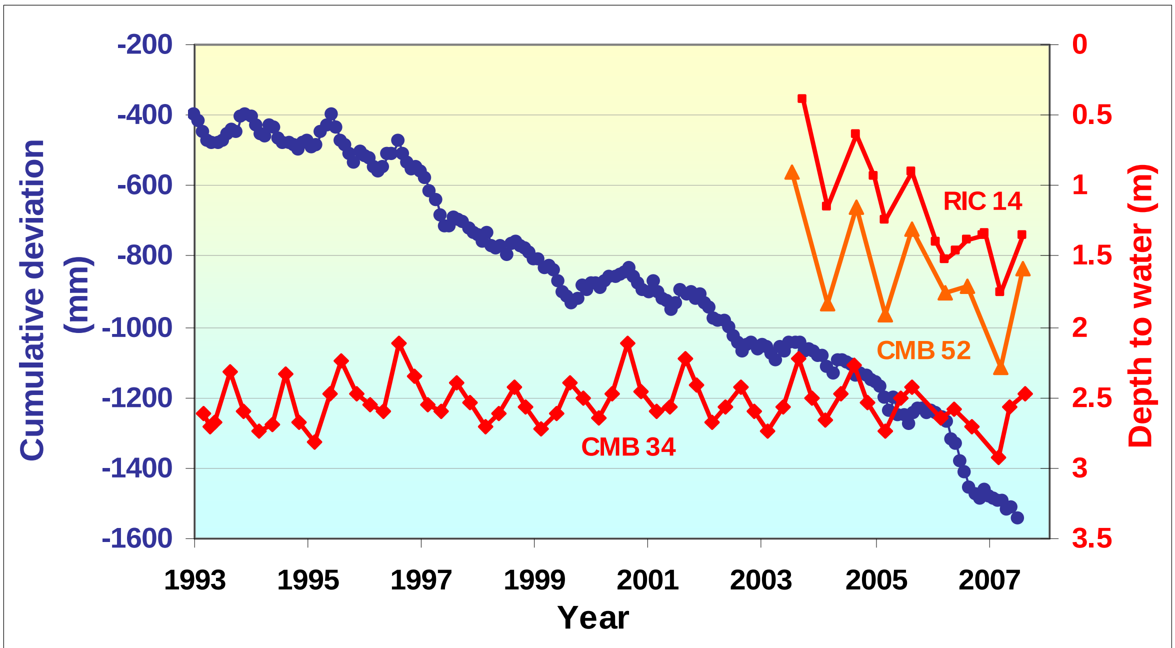


Figure 9. Water level trends in Boothby MA

The shallower watertable shows greater seasonal fluctuations than the deeper watertables due to the greater influence of evaporative discharge and quicker response to recharge from rainfall.

3.4.2 MANAGEMENT APPROACH

In order not to inhibit the development of saline groundwater over 8000 mg/L for innovative purposes in the future, (eg aquaculture, mineral production etc), the Boothby MA has a PAV nominally based on recharge of 20 000 ML with no buffer zone requirement. There has been little demand in this Management Area and no changes to the PAV are recommended.

However, it is recommended that the boundary be changed to include the Tintinara township as shown in Figure 10. This would allow use of the unconfined aquifer for aquifer storage and recovery of stormwater for the irrigation of recreational grounds. This innovative practice will reduce demand from the confined aquifer.

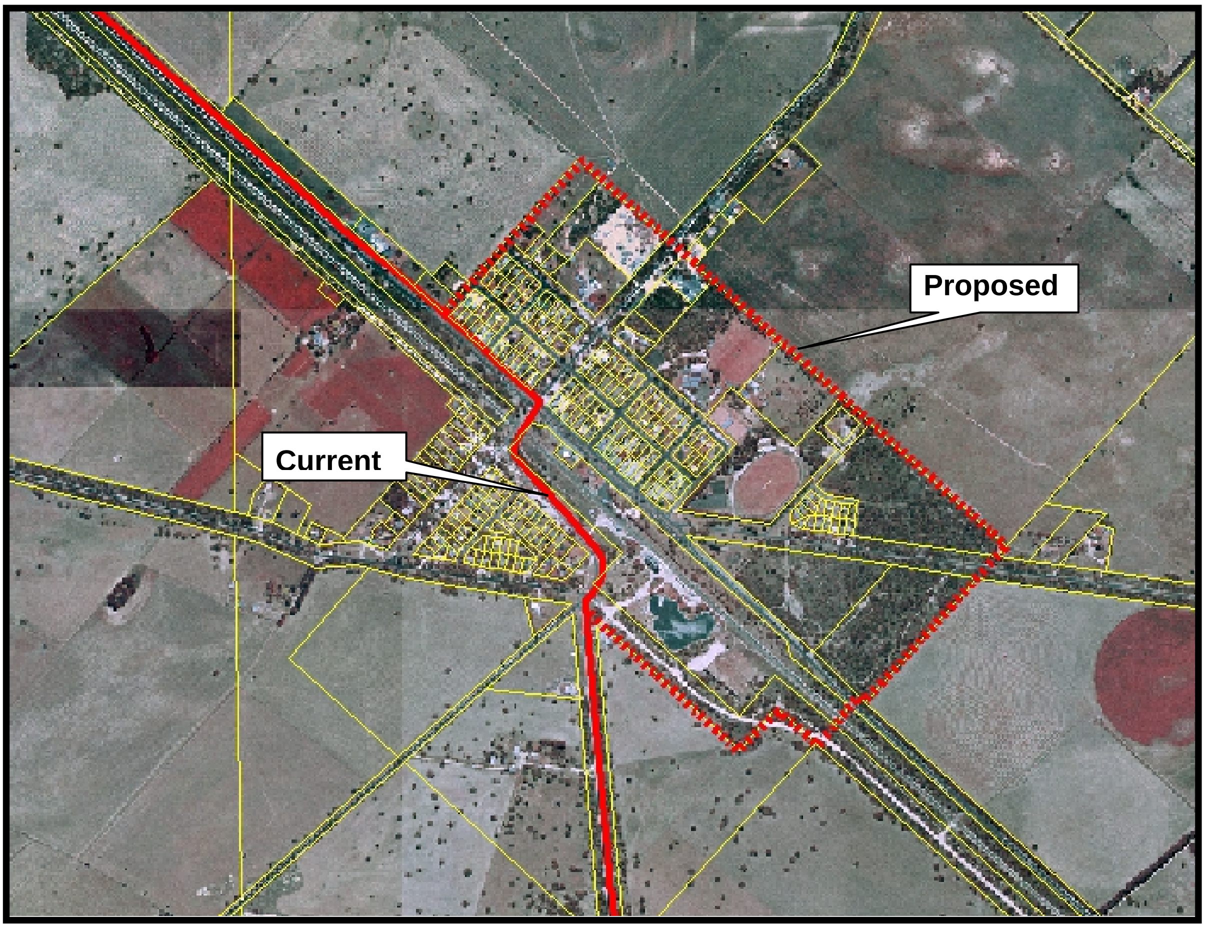


Figure 10. Proposed boundary change for the Boothby MA

4. CONFINED MANAGEMENT AREAS

The current status of the groundwater resources will be discussed for each management area (Fig. 11) with examination of water level and salinity trends, together with a comparison of extractions and the allocation volumes (PAV).

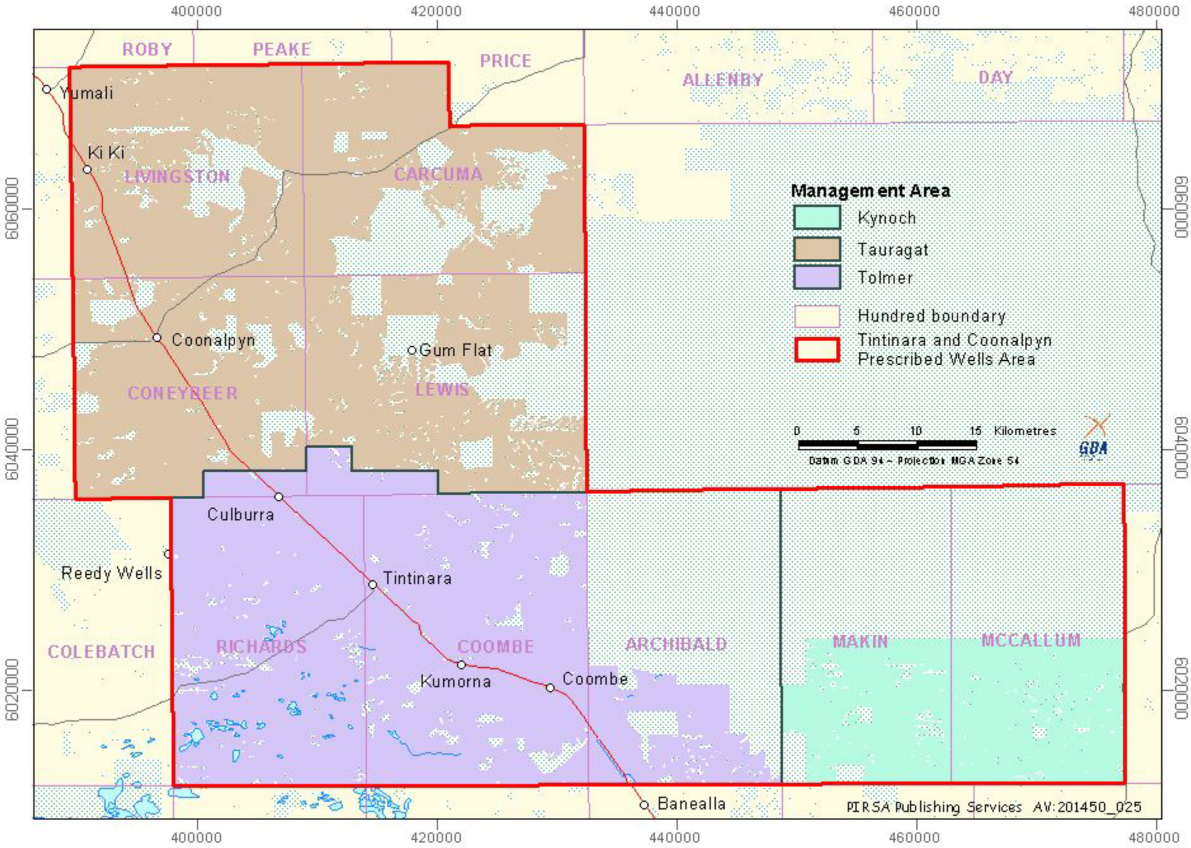


Figure 11. Confined aquifer management areas

4.1 TOLMER MA – COASTAL PAIN

4.1.1 CURRENT STATUS

The Buccleuch Formation confined aquifer lies at a depth of about 60 m below ground, and is the only groundwater supply to the west of Tintinara. Centre pivot irrigation of lucerne is being carried out over the shallow saline Quaternary limestone watertable.

There are two processes that are affecting pressure level trends in the confined aquifer. One is hydrostatic loading, which was discussed in Barnett (2002). In areas unaffected by pumping, the confined pressure levels closely match the trends in the overlying unconfined aquifer. For example, a rising watertable results in more water being stored in the unconfined aquifer and therefore more weight pressing down on the confining layer, which increases the hydrostatic pressure on the underlying confined aquifer.

This process has been observed elsewhere in the Murray Basin (Barnett, 1995), in the Liverpool Plains, NSW (Timms and Acworth, 2005), and overseas (van der Kamp and Moathius, 1991).

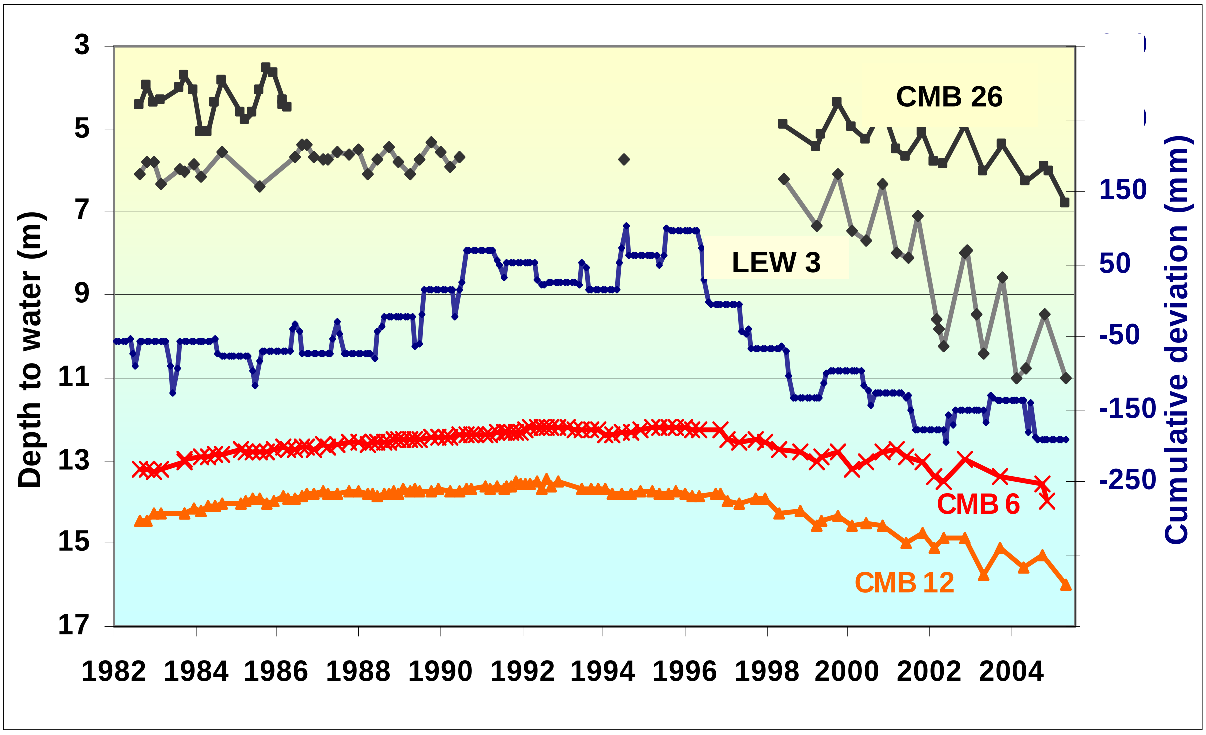


Figure 12. Parallel water level trends due to hydrostatic loading

Figure 12 shows the cumulative deviation of winter rainfall in blue and the corresponding trend in the unconfined aquifer to the east of Tintinara in red/orange. The confined aquifer observation wells in grey show a parallel trend to that in the unconfined, which is superimposed on the seasonal fluctuations due to pumping. The confined wells are located about 5 km from the nearest irrigation well.

Figure 13 shows that extractions have climbed steadily to 5400 ML/y during the drought year of 2006–07, which is about 70% of the PAV. As mentioned previously, extractions decreased in 2005–06 due to the wet spring.

Extractions have a major influence on pressure levels during the irrigation season. Despite the fact that extractions have increased in recent years, the seasonal drawdowns have stabilised, with a maximum of about 5 m, as shown in Figure 13. The regional downward trend due to hydrostatic loading is evident, even for observation wells showing little impact from irrigation (eg CMB 19 and 26).

The 2006 drought has affected water levels in two ways. Firstly, the dry winter prompted irrigation to commence earlier than normal, which has resulted in pressure levels not recovering to their normal level. Together with increased demand, this lead to higher than normal drawdowns during the 2006–07 irrigation season that are not expected to have an adverse impact on the resource.

Figure 13 also shows that salinity trends are stable throughout the Management Area, with a number of wells showing a slight decreasing trend which is probably due to drawdowns increasing the inflow of lower salinity water from the east.

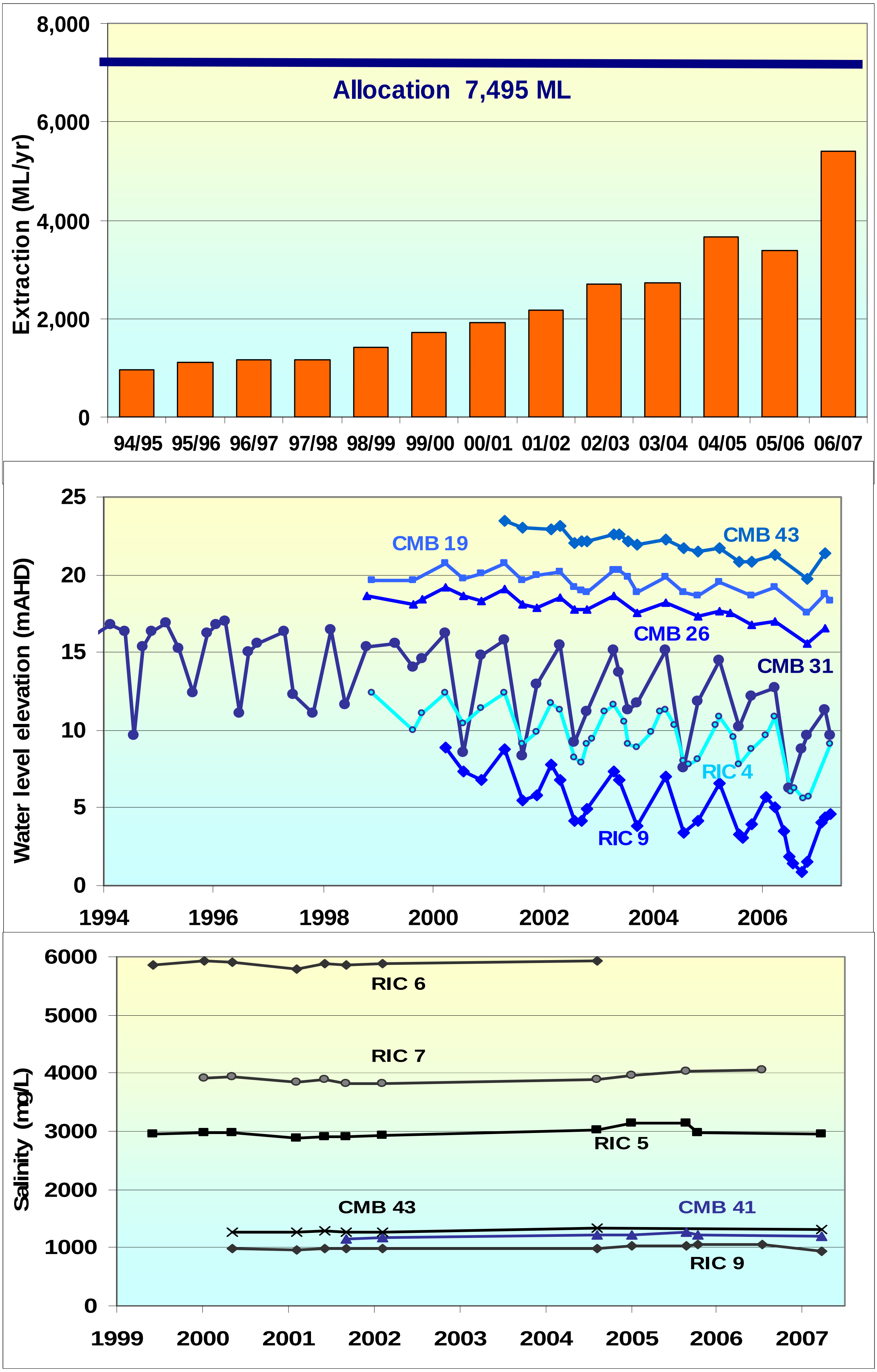


Figure 13. Extraction, water level and salinity trends in Tolmer MA

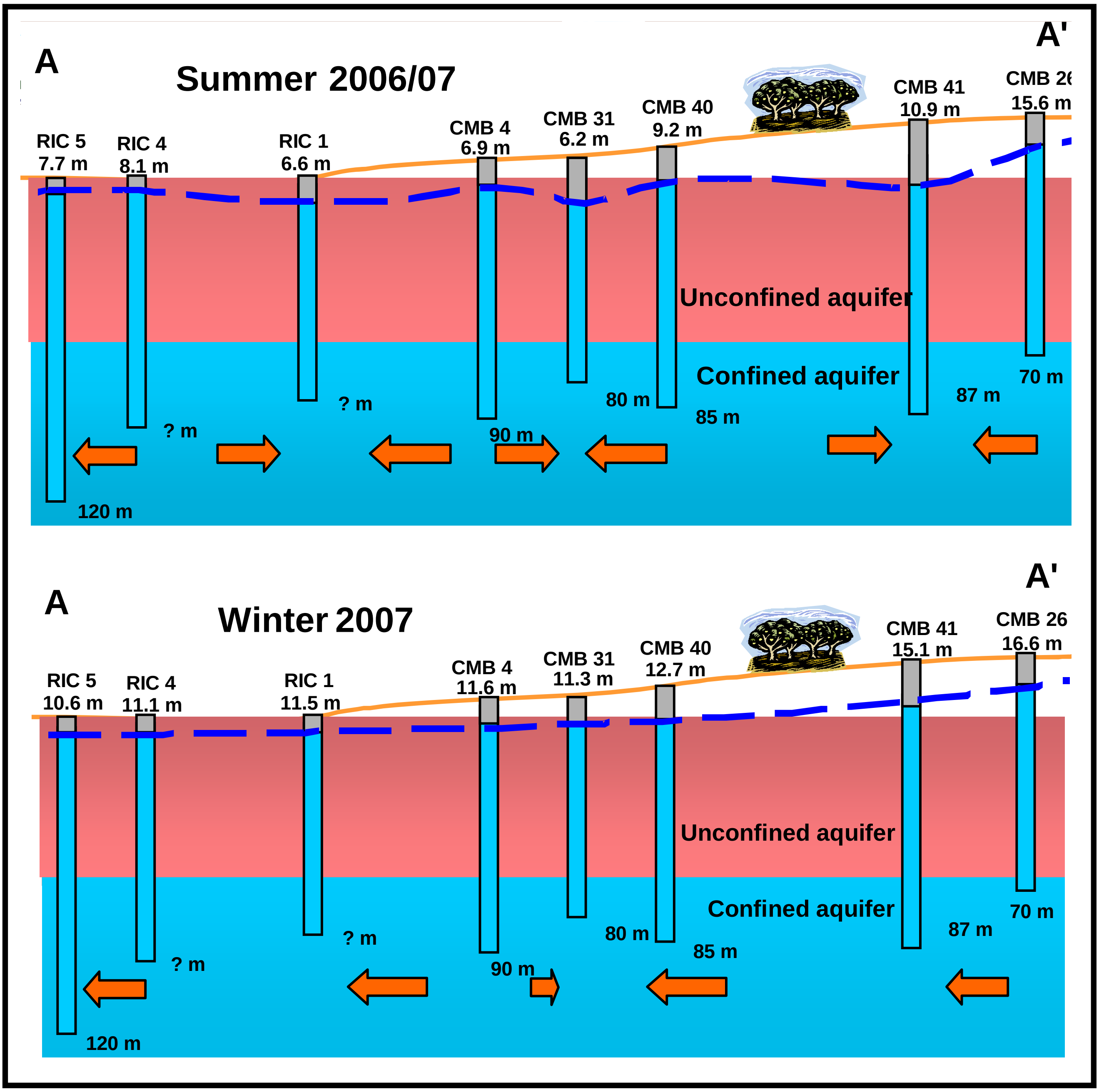


Figure 14. Cross-section through drawdown area in Tolmer MA

Cross-sections through the area of drawdown (Fig. 14) show the pressure level and depth of each observation well and the groundwater flow direction (the location of the section is presented in Fig. 15).

During the Summer 2006–07 irrigation season, areas of flow reversal developed near areas of concentrated pumping which later disappeared during Winter 2007 when throughflow was resumed, apart from a small area near the Tintinara township. Although this lack of recovery near the township was probably caused by heavier than normal drought pumping, the readings were taken at different times during the irrigation season and flow reversal may not have actually occurred.

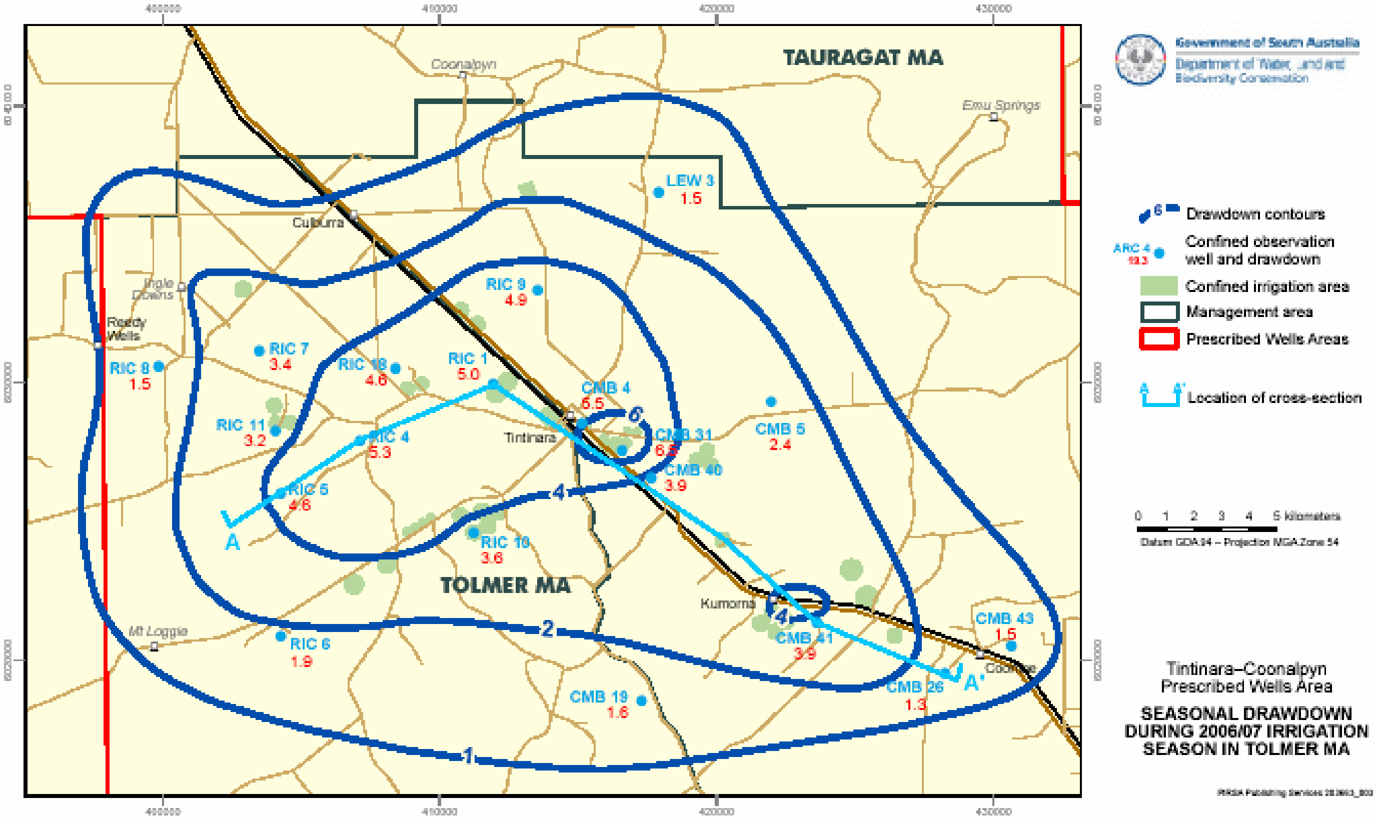


Figure 15. Seasonal drawdown during 2006–07 irrigation season in Tolmer MA

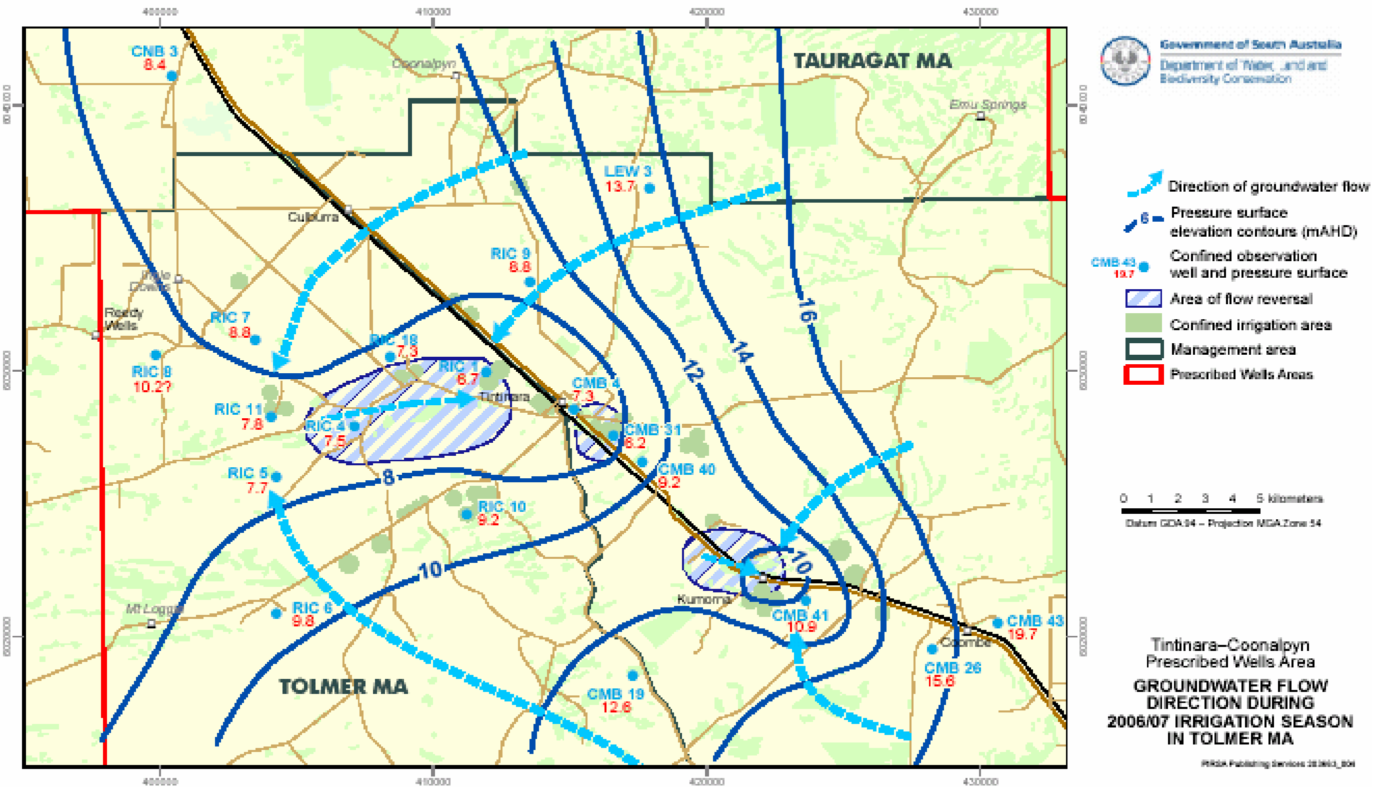


Figure 16. Groundwater flow direction during 2006–07 irrigation season in Tolmer MA

The shape of the drawdown contours presented in Figure 15 has changed since that shown in Barnett (2002), due to the addition of new observation wells to the network that has delineated a second cone of depression southeast of the Tintinara township with a similar drawdown. Because of the changing pumping regimes, the location and magnitude of the maximum drawdown contour will vary throughout the irrigation season. Consequently, Figure 15 represents a ‘snapshot’ at the time of monitoring.

Figure 16 depicts the flow direction during the period of maximum observed drawdown for the 2006–07 irrigation season. Because the confined pressure level not only varies spatially, but also increases with depth within the confined aquifer, and given that observation wells (privately owned stock and domestic wells) are completed at different depths (ranging from 75 to 120 m), there may be some small errors in this plan. As discussed previously, new observation points have resulted in a new understanding of the groundwater flow direction compared to 2002.

Confined groundwater flow during the 2006–07 irrigation season as depicted in Figure 16 is predominantly east to west, with a cone of depression to the west of the township focussing flow from the northeast and southeast. There are two predominant areas of flow reversal associated with concentrations of pumping. To the west of the township, the area is about 50% greater than in previous years due to heavier drought pumping, but is still restricted to an area with salinities below 3000 mg/L.

4.1.2 MANAGEMENT APPROACH

The main sustainability issue is the prevention of excessive drawdowns that could lead to groundwater flow reversal and inflows of more saline groundwater from the west. The impact of drawdowns on other users (eg dryland farmers) and their pumping infrastructure is a separate issue which is not related to the sustainability of the groundwater resource. The existing Water Allocation Plan provides trigger levels for drawdown and salinity trends in order to provide early warning of adverse trends.

Figure 17 shows the peak seasonal drawdown triggers for the Tolmer MA in pink. They are centred on the Tintinara township which was the centre of pumping when the existing Water Allocation Plan was formulated. The observed values for the 2006–07 season in red show that the peak drawdown trigger of 10 m at the township was not exceeded, but because points of extraction are now more dispersed, the 4 m drawdown trigger for 4 km from the township was exceeded by several wells.

The residual drawdown triggers and observed 2006 (in black) and 2007 (in red) values are displayed in Figure 18. Despite the drought which prompted irrigation to commence earlier in 2006 than normal (which resulted in pressure levels not recovering to their normal level), there were no breaches of the residual trigger in 2006. Only one well (RIC 10) exceeded the trigger levels in 2007 due to its close proximity to an irrigation well which is supplying an increased area of irrigation.

There were no breaches of the confined salinity trigger.

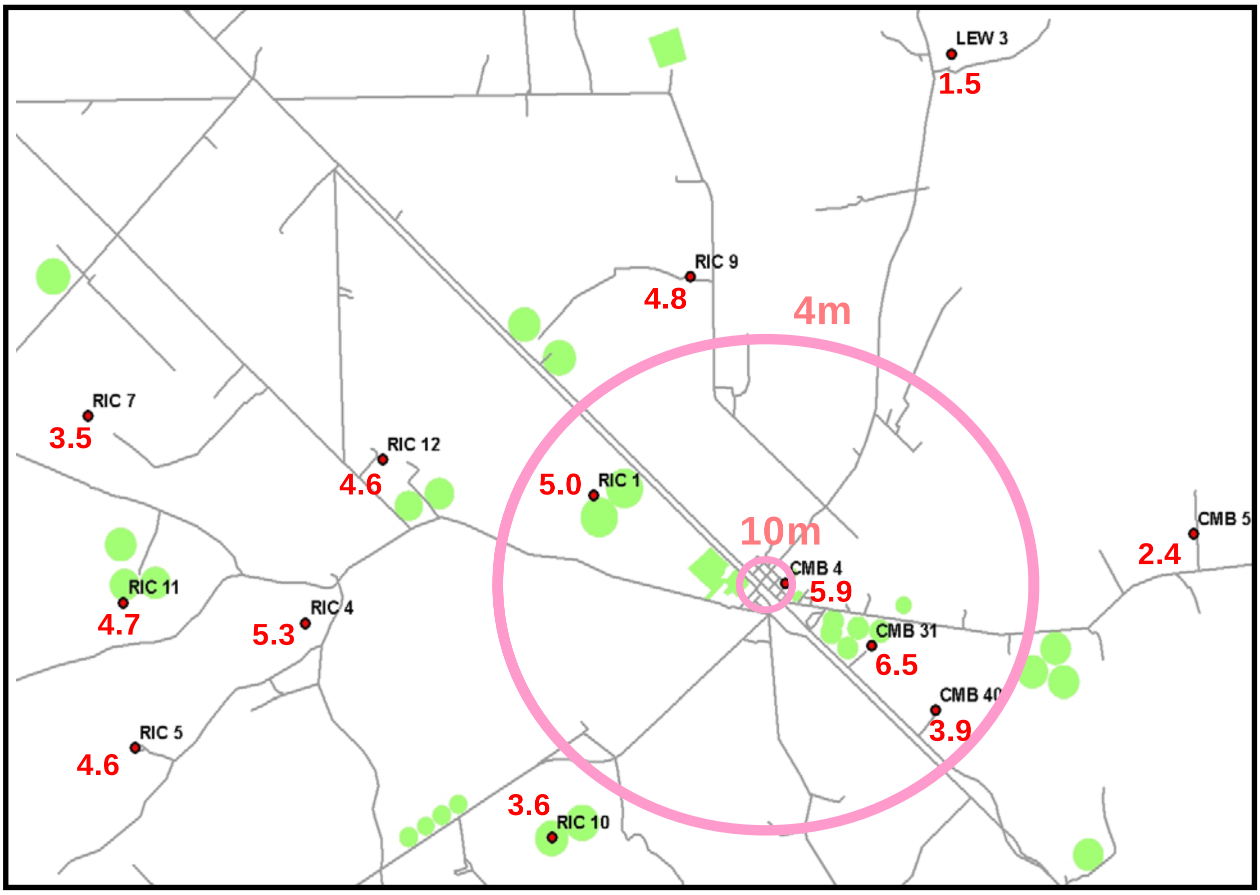


Figure 17. Observed 2006 peak drawdown compared to triggers

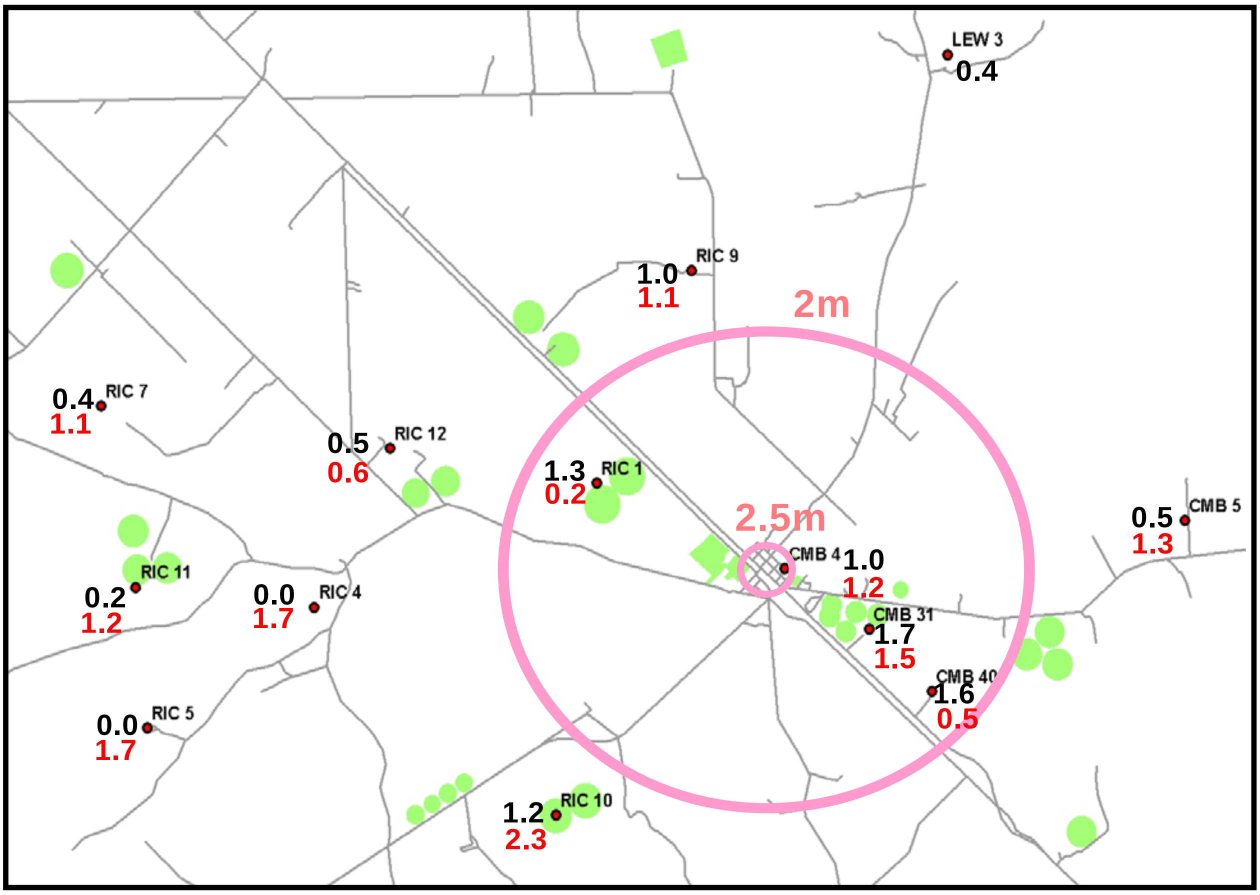


Figure 18. Observed 2006 and 2007 residual drawdown compared to triggers

4.1.3 CAPACITY TO MEET DEMAND

Confined aquifer drawdowns in the Tolmer MA have increased due to a combination of hydrostatic loading, drought and expansion of irrigation. The capacity of the confined aquifer resource to meet demand is dependent on whether any adverse impacts on the resource occur as a result of the increased drawdowns. As stated earlier, this is a separate consideration from adverse impacts on pumping infrastructure.

The most important adverse impact would be increases in salinity brought about by flow reversal from the west where salinities are higher. Current monitoring indicates that salinity levels are stable or showing a slight decreasing trend which is probably due to drawdowns increasing the inflow of lower salinity water from the east.

There is no evidence to suggest the resource cannot meet demand, and it is critical that salinity monitoring continue to enable ongoing review of any adverse impacts.

4.1.4 MANAGEMENT RECOMMENDATIONS

As is the case with the unconfined Tintinara MA, current extractions in the Tolmer MA total only about half of the allocation limit with an area limitation imposed on licences. It is recommended that a reduction in the total allocation of the order of 2500–3000 ML/y be made over time, based on the usage trends before the 2006 drought. When this reduction has been made, removal of the area limitation on licences should be considered. This adjustment will ensure that if further reductions in allocations are required in the future, actual reductions in extractions will occur.

It is also recommended that the peak drawdown trigger of 10 m be retained, but the stipulation that it be measured at the township should be removed. The 4 km radius trigger should also be removed. Similarly, it is recommended that the stipulation for the residual trigger be measured at the township, and the 4 km radius trigger, should be also be removed.

4.2 TAURAGAT MA – NORTHERN MALLEE HIGHLANDS

4.2.1 CURRENT STATUS

Extractions for large olive plantations dominate water extractions from the three confined ‘sub-aquifers’ in this zone. Figure 19 shows a simplified cross-section through the Tauragat MA. Almost all irrigation extractions occur from only the middle and lower confined aquifers, with virtually all stock and domestic use from the upper confined aquifer.

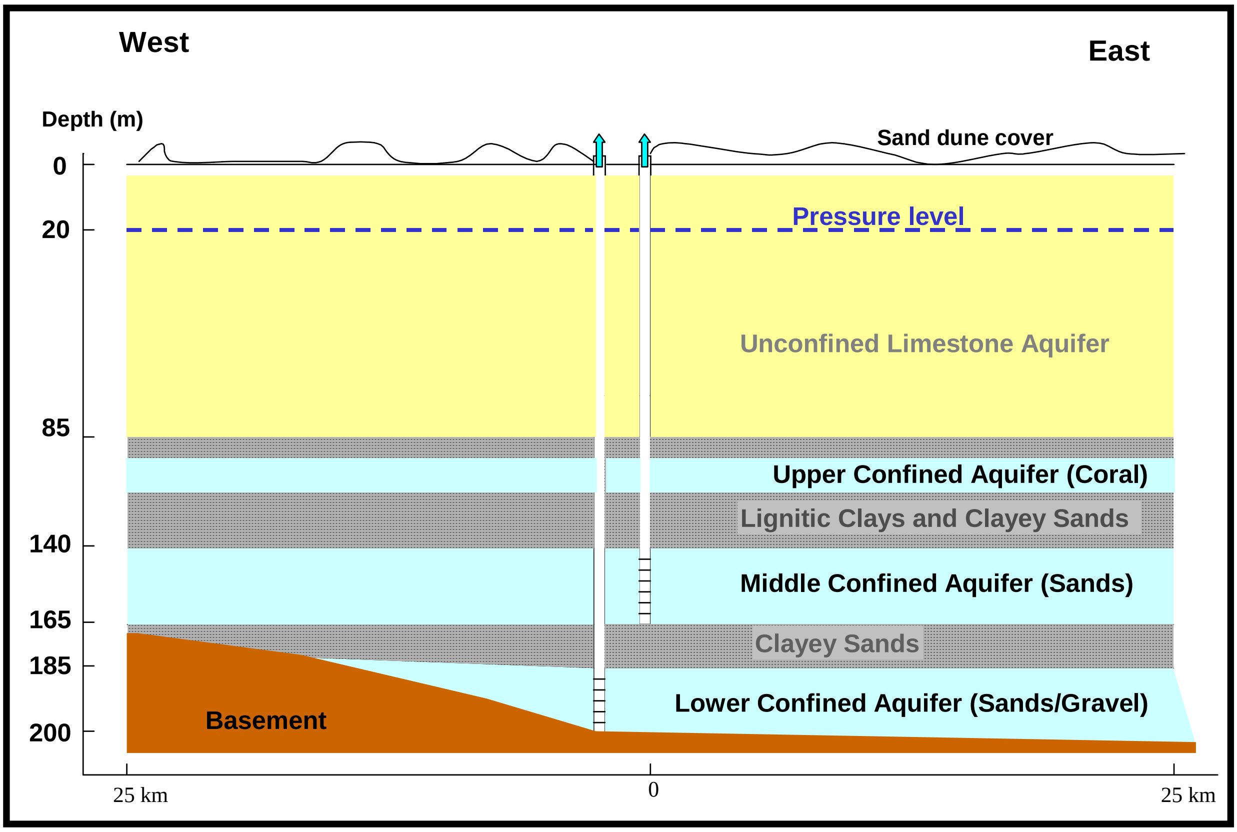


Figure 19. Cross section through the Tauragat MA

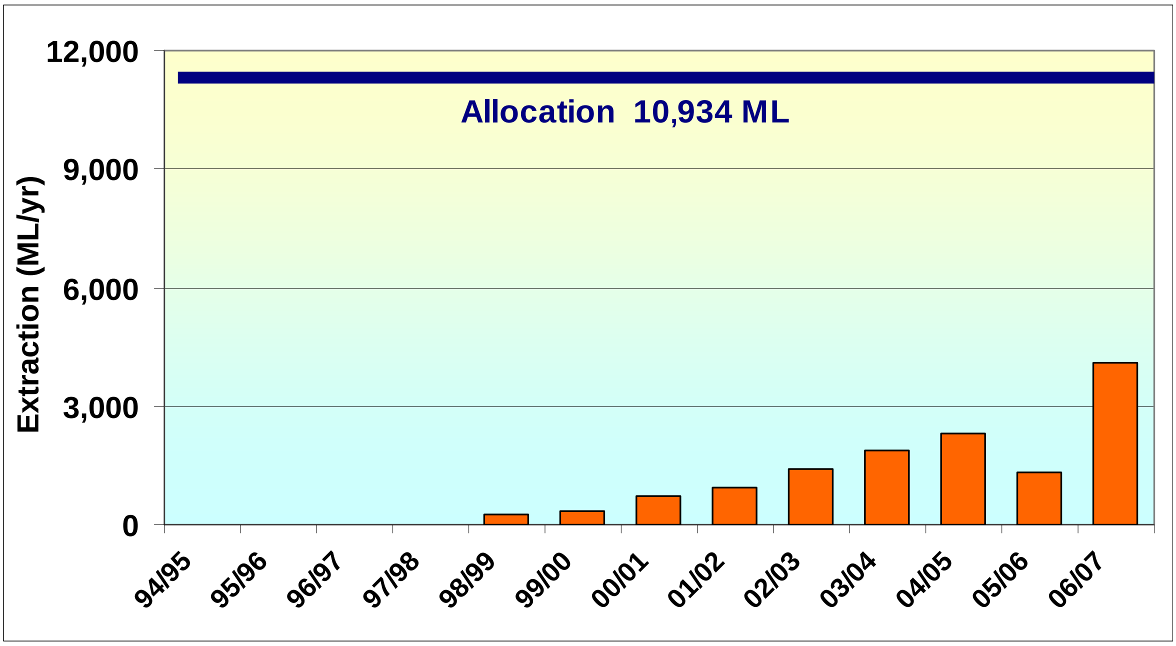
Figure 20 indicates extractions have been well below the allocation limit until the 2006–07 irrigation season, when a combination of the 2006 drought and the establishment of new olive plantings resulted in extractions increasing significantly to about 50% of the VLA.

Representative hydrographs from the three aquifers are also presented in Figure 20. Because of the greater depth to the watertable in this area, there is likely to be a lower response to changes in recharge than in the Tolmer MA, and consequently, hydrostatic loading is not likely to have a significant influence on pressure levels. Pressure levels in these wells are decreasing which corresponds with the increases in annual extraction resulting from the increasing demand of the growing olive trees.

LVG 4 is completed in the upper aquifer and is located 3 km west of the olive plantations. The pressure level has only fallen a metre since olive irrigation began, indicating low rates of leakage between the upper and lower aquifers. It also implies minimal (if any) impacts on other groundwater users reliant on this upper aquifer.

LEW 13 is thought to intersect the middle aquifer, and is located adjacent to another irrigation enterprise (7 km south of the olive plantations) where three wells develop the middle aquifer. A drawdown of 10 m has been observed since irrigation began. Apart from LEW 13, there are only two other stock and domestic wells completed in this aquifer (both are being monitored – CNB 1 and LVG 5).

Well 6926-535 is an unequipped irrigation well. Apart from equipped and unequipped irrigation wells such as this located within the two olive plantations, there are no other wells intersecting this aquifer. A seasonal drawdown of almost 10 m is apparent, with a downward trend due to increasing extractions.



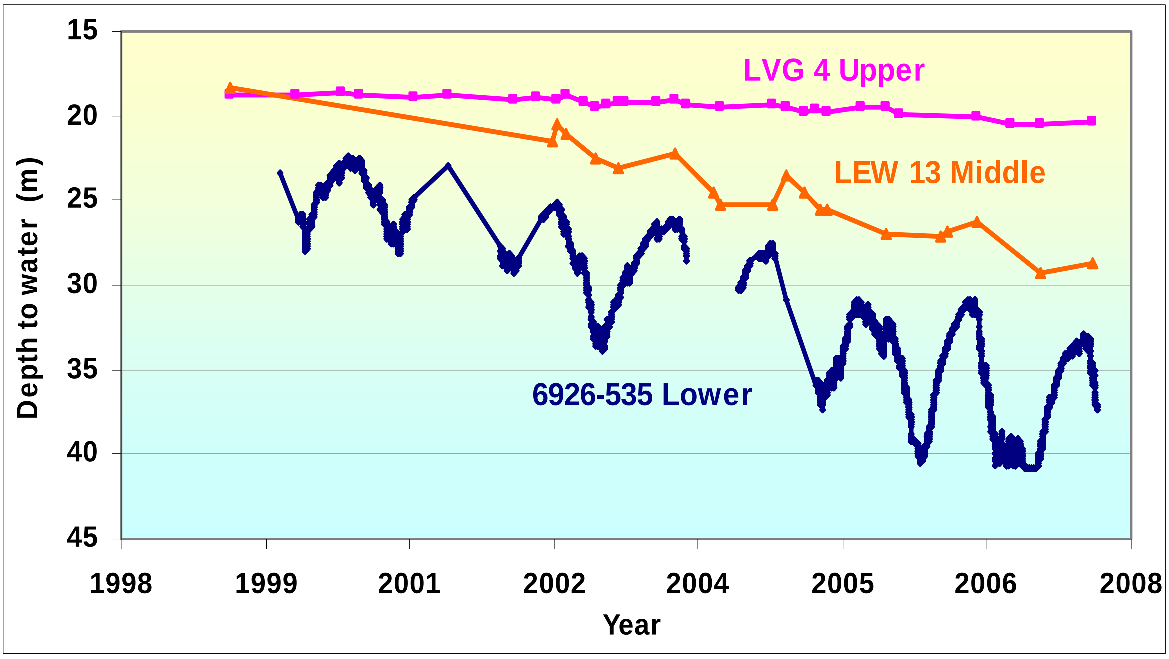


Figure 20. Extraction, and water level trends in Tauragat MA

4.2.2 MANAGEMENT APPROACH

As in other management areas, trigger levels have been established in this area as shown in Table 1. Due to the lack of observation wells in the confined aquifers, some of these trigger levels for pressure level drawdowns have been based on modelling results.

Table 1. Trigger levels for Tauragat MA

Aquifer	**Peak drawdown** (m)			**Residual drawdown** (m)		
	Centre of cone	**4 km radius**	**10 km radius**	**Centre of cone**	**4 km radius**	**10 km radius**
UPPER	4.5	3		2	1.5	
MIDDLE	45	25	10	9	7	3
LOWER	65	25		10	6	

Lower confined aquifer

Unequipped irrigation wells on the olive plantations are showing peak drawdowns of 9–10 m and residual drawdowns of 2 m, values well below the trigger levels.

Middle confined aquifer

Unequipped irrigation wells on the olive plantations are showing peak drawdowns of 8–9 m and residual drawdowns of 2–2.5 m, values well below the trigger levels.

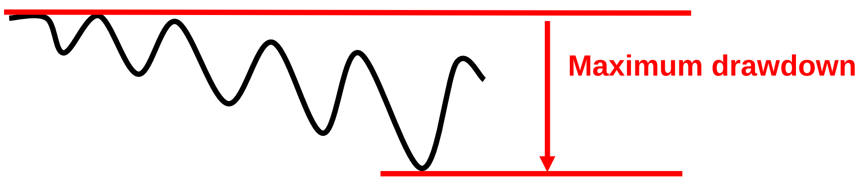
Upper confined aquifer

The only observation well available to assess this trigger is LVG 4, which experienced peak drawdowns of about 0.5 m and residual drawdowns of 0.2 m, values well below the trigger levels.

There is currently no salinity monitoring for the confined aquifer in the Tauragat MA due to the lack of wells in the middle and lower aquifers where drawdown is greatest. This lack of monitoring points also prevents the areal extent of drawdown being delineated, although groundwater model predictions of drawdown extent will be discussed below.

4.2.3 CAPACITY TO MEET DEMAND

Although current extractions are well within the resource capacity, expansion of one of the olive plantations has commenced, with a significant increase in water demand toward full allocation levels. The impacts of this increased extraction have been predicted using a groundwater flow model. The contours shown in the following plans are the maximum drawdowns during the irrigation season compared to the pre-irrigation levels (as depicted in the sketch below.



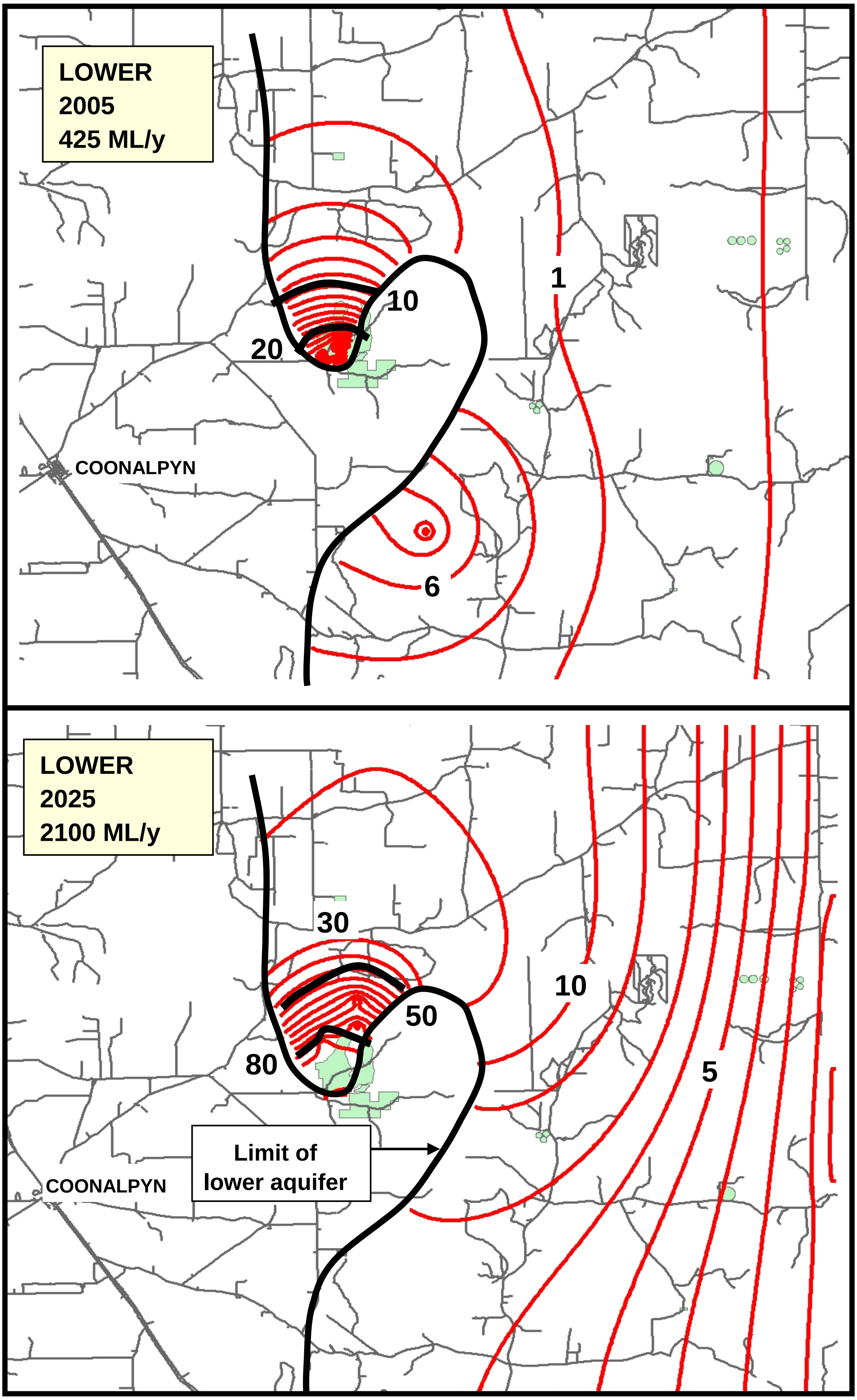


Figure 21. Predicted lower confined aquifer drawdowns in Tauragat MA

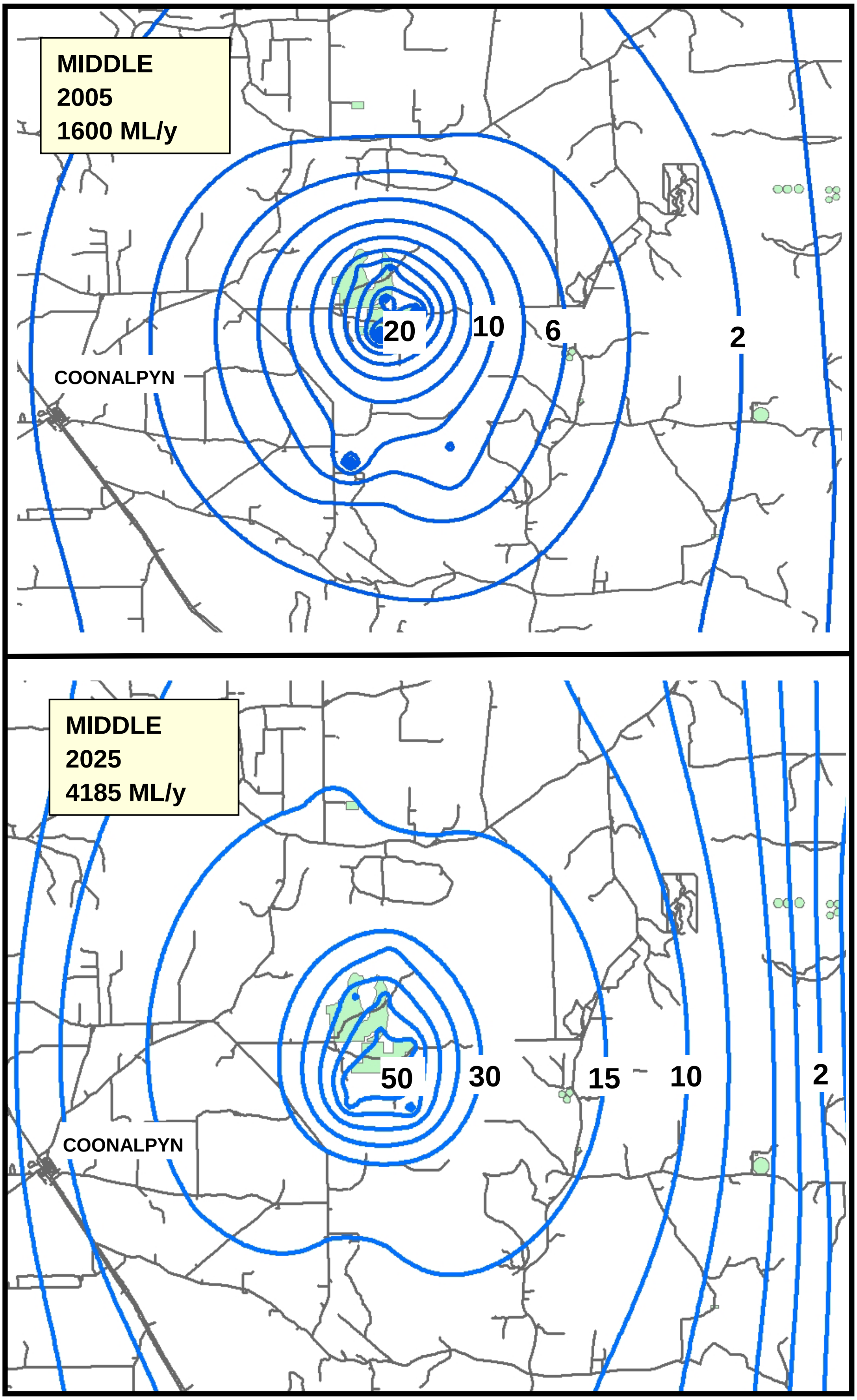


Figure 22. Predicted middle confined aquifer drawdowns in Tauragat MA

4.2.3.1 Lower confined aquifer

Figure 21 shows the lower confined aquifer is absent in the western half of the area. Groundwater flows toward the pumping wells from the east where the salinity is lower, consequently a rise in salinity due to extraction is unlikely. Apart from the northern olive licencee, there are no other users intersecting the lower confined aquifer that will be affected by drawdowns in pressure level.

The development of the full lower confined allocation of 4800 ML/y by the northern olive licencee is uncertain. A more likely figure of 2100 ML/y was chosen for the modelling exercise, which is still a considerable increase over the current extraction of 425 ML/y. At 2100 ML/y, the modelled peak drawdowns at 4 km would probably exceed the trigger after several years pumping.

4.2.3.2 Middle confined aquifer

This aquifer is thought to extend over the whole area, as depicted in Figure 22. The magnitude and extent of the modelled drawdown in pressure level is likely to be exaggerated due to the lack of observation wells to calibrate the model at some distance from the olive plantations, and the simplifying assumptions used in constructing the model. The model assumes the aquifers have uniform thickness and permeability, whereas in reality, the aquifers are highly variable.

The main sustainability issue with extractions from this aquifer is the reversal of the normal westerly groundwater flow, and the influx of more saline groundwater from the west. Figure 23 shows the permanent cone of depression in the full recovery pressure elevation level for 2025, and the resultant groundwater flow directions.

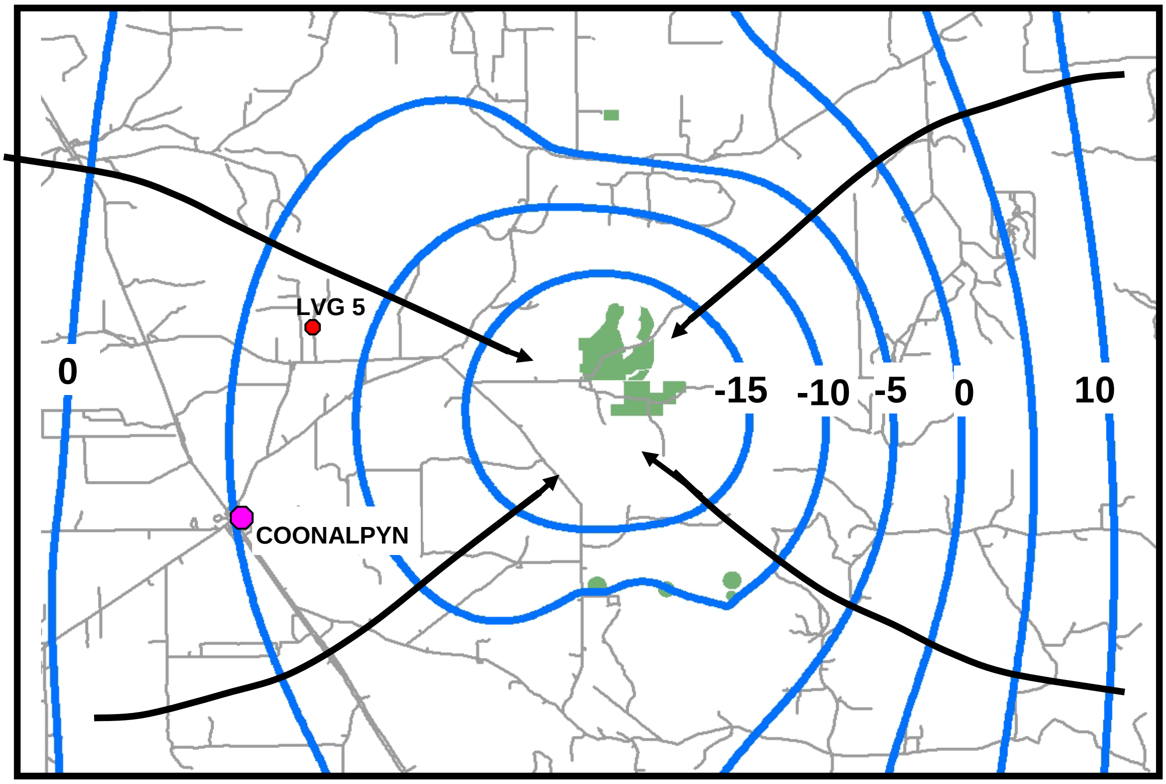


Figure 23. Predicted middle confined aquifer recovery elevation in 2025

Since irrigation began in 2000, the total distance of flow reversal from the west by 2025 calculated by the model would be 250 m at a point 7 km west of the plantations. Due to the lack of wells completed in this aquifer, the salinity implications of this flow reversal are not known with certainty, but are not expected to be significant. The modelled pressure drawdowns in the centre of the cone will not exceed trigger levels by 2025.

Figure 23 also shows the location of a newly completed stock well (LVG 5) completed in the middle aquifer which will provide very useful water level and salinity trends.

4.2.3.3 Upper confined aquifer

Although most stock and domestic wells intersect this aquifer, there are only a few irrigation and intensive farming supply wells. Figure 24 presents the 2005 drawdown contours which are based on monitoring and modelling, and shows three small centres of drawdown. The northernmost is caused by irrigation of a small olive plantation, with the central cone caused by downward leakage induced by pumping from the middle confined aquifer. The southern drawdown is similarly caused by pumping from the middle confined aquifer, which has a good hydraulic connection with the upper confined aquifer in this area due to poor or absent confining layers.

The predicted pressure drawdowns in 2025 (Fig. 24) at full allocation pumping are likely to be exaggerated for reasons explained earlier. No triggers have been exceeded in this aquifer. Flow reversal from the west and salinity impacts are expected to be minmal.

The original PAV for all three confined ‘sub-aquifers’ was based on the modelled impacts of extractions from the middle and lower confined aquifers only. Now that monitoring has given a better indication of the limited impacts of this extraction on the upper confined aquifer, further allocations could be made from this aquifer in the western part of the Tauragat MA some distance from the observed areas of drawdown.

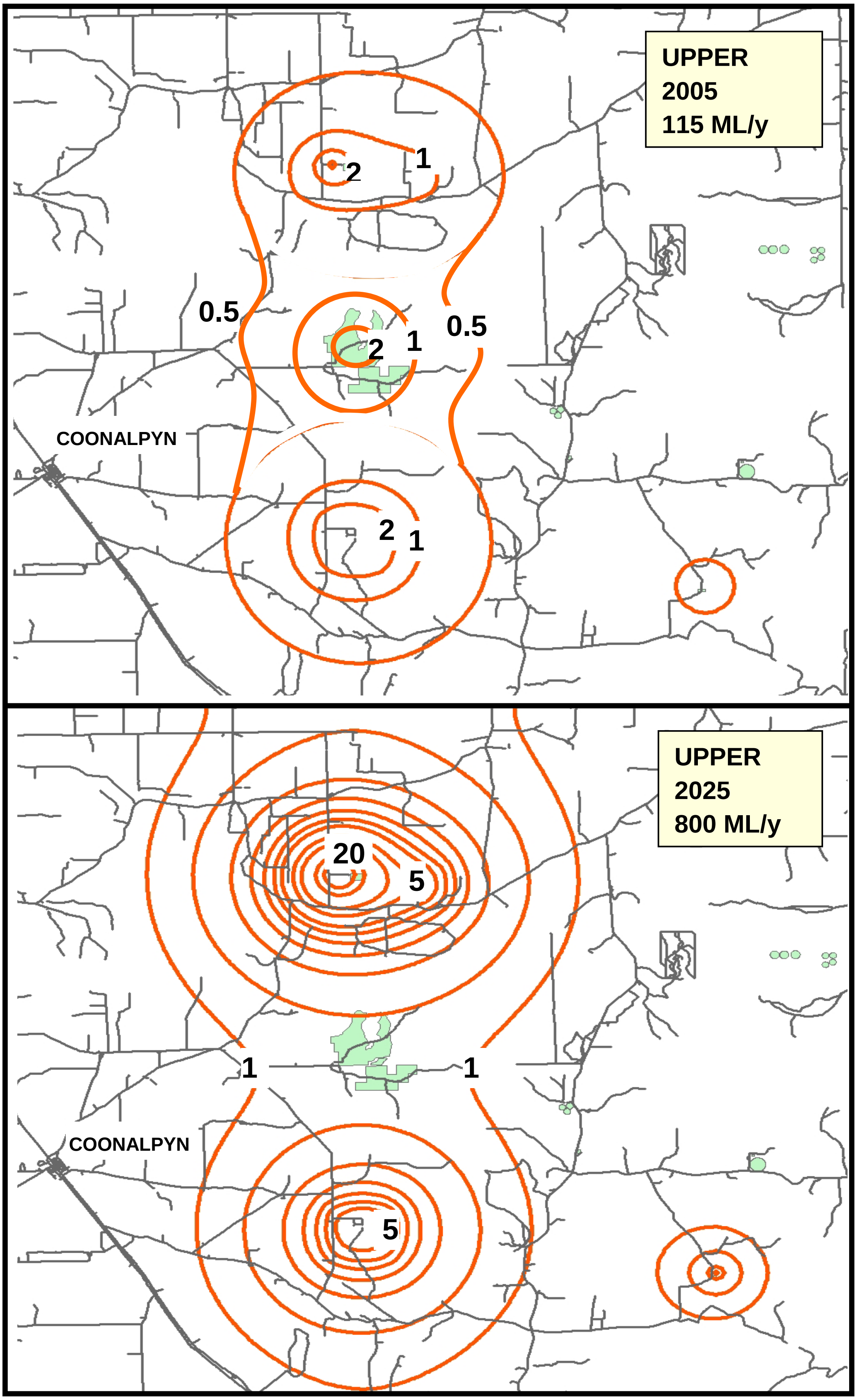


Figure 24. Predicted upper confined aquifer drawdowns in Tauragat MA

5. MONITORING NETWORKS

The DWLBC and its predecessors have been monitoring groundwater levels in the TCPWA since 1983 when concerns were first expressed about falling watertables. Salinity monitoring began in the Mallee Highlands area in 1987 to monitor the impacts of land clearing. Whilst this monitoring has so far been concentrated in areas of better quality groundwater where irrigation is occurring, the network has been expanded to include areas of saline groundwater where the relationship between vegetation health and groundwater depth and salinity will be investigated under the National Action Plan for Salinity and Water Quality.

All observation well data for the networks mentioned below can be obtained from the OBSWELL database via the web at this address:

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

The network names of TINTNARA and COONALPN should be entered to examine or download observation well data.

5.1 UNCONFINED AQUIFER

5.1.1 WATER LEVEL MONITORING NETWORK

The network has recently been upgraded and expanded to monitor the increase in irrigation development and also water levels beneath areas of significant native vegetation. There are currently 43 wells monitored for water level. These wells are measured approximately quarterly (March, June, September and December) or at appropriate times to monitor the beginning and end of the irrigation season. This monitoring is carried out by DWLBC and contractors.

The number of water level monitoring wells in the network is considered adequate for the TCPWA, with the recent addition of five new observation wells in areas of concentrated pumping in the Tintinara MA helping to confirm the presence or otherwise of flow reversal during the irrigation season. The network can be quickly expanded when necessary to monitor new areas of irrigation. Because the demand for lucerne irrigation is not continuous through the summer, it is recommended a data logger be installed in one of the observation wells in the Tintinara MA to observe any variations in drawdown over the irrigation season.

5.1.2 SALINITY MONITORING NETWORK

There are currently a total of twelve observation wells monitoring salinity in the TCPWA. Most of these were selected to monitor the salinity impacts of land clearing beneath the Mallee Highlands. Sampling is undertaken at a sampling frequency of six months.

In 2000, a program to sample all private irrigation wells on an annual basis began, initially on the Coastal Plain to determine any effects of groundwater recycling in the shallow unconfined aquifer. This has recently been extended to the Mallee Highlands to detect any salinity increases due to vegetation clearance. It is proposed that irrigators be required to supply at least one water sample a year at the end of the irrigation season (as is the case for the Barossa and Northern Adelaide Plains PWAs).

5.2 CONFINED AQUIFER

5.2.1 WATER LEVEL MONITORING NETWORK

There are currently 28 water level observation wells monitoring the confined aquifer in the Tolmer MA, one of which is equipped with a data logger for continuous readings. There are also 16 observation wells located in the Tauragat MA (Hundreds of Lewis, Livingston and Carcuma), to monitor drawdowns due the irrigation extractions for olive plantations (three have data loggers). All available wells intersecting the middle and lower confined aquifers are being monitored. The network can only be expanded by drilling new observation wells at considerable expense.

The only monitoring well in the Mallee Highlands to the east of Tintinara is SHG 6, which lies just outside the eastern boundary of the TCPWA.

The network can be quickly expanded when necessary to monitor new areas of irrigation.

5.2.2 SALINITY MONITORING NETWORK

There are 13 monitoring wells (including irrigation wells) currently used to monitor groundwater salinity in the confined aquifer in the Tolmer MA, where they will provide early warning for any increases in salinity due to reversal of groundwater flow caused by drawdown if it occurs.

There is currently no monitoring of salinity in the Tauragat MA, and the network should be expanded into this area, utilising both existing irrigation and stock wells.

6. IMPACTS OF USE

The potential detrimental impacts that taking, or using, water from the TCPWA may have on the quantity or quality of water of another resource and vice versa, were considered in the following situations:

- the impact of taking groundwater from both the unconfined and confined aquifers may have on each other
- the impact of taking groundwater from both the unconfined and confined aquifers may have on adjacent water resources, prescribed or not
- the impact of taking groundwater from adjacent water resources (prescribed or not), may have on the resources of the TCPWA.

6.1 IMPACT OF USING THE UNCONFINED AQUIFER

Because the aquitard that separates the unconfined and confined aquifers in the TCPWA is generally more than 20 m thick and has a very low vertical permeability, there is no evidence that any use from the unconfined aquifer has directly affected the confined aquifer. Similarly, there is no evidence of any impacts on adjacent unconfined aquifer resources due to extractions in the TCPWA.

6.2 IMPACT OF USING THE CONFINED AQUIFER

6.2.1 UNCONFINED AQUIFER

Again, because of the low permeability aquitard, there is no evidence of any impacts on the unconfined aquifer due to extraction from the confined aquifer. However, there is a possibility of an indirect impact on shallow watertables beneath areas irrigated from the confined aquifer to the west of Tintinara. To monitor any impacts of this irrigation drainage, observation wells were drilled in two irrigated areas. The results (Fig. 9) show that no watertable mounding occurred beneath these areas.

There is some evidence that irrigation in the Tauragat MA could be accelerating the flushing of the unsaturated zone salt down to the watertable, with the long term potential to increase the salinity of the unconfined aquifer. Over most of the area however, the unconfined aquifer is too saline for irrigation use.

6.2.2 ADJACENT WATER RESOURCES

There is no evidence of any drawdown impacts to the south in the Tatiara PWA, although olive irrigation in the Coonalpyn MA may cause small drawdowns to the north in the Hd Peake-Roby-Sherlock PWA.

6.3 IMPACT OF USING ADJACENT WATER RESOURCES

6.3.1 UNCONFINED AQUIFER

There may be drawdown impacts if extractions in the Tatiara PWA are concentrated close to TCPWA boundaries to the south and the east. Although water level monitoring has shown very little (if any) drawdown in Sherwood MA due to pumping, either from within the zone or from the adjacent Hd Shaugh (Tatiara PWA), a small decrease in lateral inflows from the east would be expected.

A similar situation applies to the east of the north-east boundary of the Hd Carcuma where several irrigation bores are located just to the south of the Mallee PWA. The drawdown impacts are not likely to be excessive.

6.3.2 CONFINED AQUIFER

The only area where extractions from the confined aquifer may impact on the TCPWA is in the Peake-Roby-Sherlock PWA. This area is outside the SENRMB area. Current extraction levels are unlikely to have any impact, although there may be further development due to legal uncertainties regarding the allocation process. A monitoring network has been established in the area to detect any impacts from such development.

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
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
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
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	365 or 366 days	time interval

GLOSSARY

Act (the) — In this document, refers to the *Natural Resources Management (SA) Act 2004,* which supercedes the *Water Resources (SA) Act 1997*

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 that holds water and allows water to percolate through

Aquifer, confined — Aquifer in which the upper surface is impervious (see 'confining layer') 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 resources 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

ASR — Aquifer Storage and Recovery; involves the process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal; also known as aquifer storage and retrieval

Artesian — An aquifer in which the water surface is bounded by an impervious rock formation; the water surface is at greater than atmospheric pressure, and hence rises in any well which penetrates the overlying confining aquifer

Artificial recharge — The process of artificially diverting water from the surface to an aquifer; artificial recharge can reduce evaporation losses and increase aquifer yield; see also 'natural recharge', 'aquifer'

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

Cone of depression — An inverted cone-shaped space within an aquifer caused by a rate of groundwater extraction that 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)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

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 water bodies

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes, and the properties of aquifers; see also '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

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

Permeability — A measure of the ease with which water flows through an aquifer or aquitard, measured in m^2/d

Potentiometric head — The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer, measured in metres (m); also known as piezometric surface

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

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

PWA — Prescribed Wells Area

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. See also artificial recharge, natural recharge

Transfer — A transfer of a licence (including its water allocation) to another person, or the whole or part of the water allocation of a licence to another licensee or the Minister under Part 5, Division 3, s. 38 of the Act, the transfer may be absolute or for a limited period

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

Volumetric allocation — An allocation of water expressed on a water licence as a volume (eg. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation)

Water allocation, area based — An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water–use year

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Water licence — A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area; this grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water; a water licence confers a property right on the holder of the licence and this right is separate from land title

Water-use year — The period between 1 July in any given calendar year and 30 June the following calendar year; also called a licensing year

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

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