DWLBC Technical Report

Bushfire and Salinity
Lower Eyre Peninsula Case Study

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

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Bushfire and Salinity

Lower Eyre Peninsula Case Study

**Trevor Dooley, Chris Henschke, Stuart Wright
and Dr Anna Dutkiewicz**

**Land and Biodiversity Conservation Division
Department of Water, Land and Biodiversity Conservation**

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Knowledge and Information Division

Department of Water, Land and Biodiversity Conservation

25 Grenfell Street, Adelaide

GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

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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.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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Terry Evans (Rural Solutions SA, Lenswood) provided details of EM (electromagnetic) surveys that were undertaken on the lower Eyre Peninsula.

This report was prepared for DWLBC by consultants from Rural Solutions SA: Trevor Dooley, Chris Henschke and Stuart Wright. Dr Anna Dutkiewicz and other DWLBC scientific personnel provided valuable feedback and comments.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

Bushfires can destroy perennial vegetation, which leads to a reduction in vegetation transpiration and an associated increase in recharge to the groundwater systems. Increased recharge and subsequent rises in groundwater can trigger the onset of salinity outbreaks. For burnt vegetation however, the reduction in transpiration is often temporary after a fire as vigorous regrowth can occur, resulting in periods of high water use and the establishment of a new water equilibrium.

In January 2005, the opportunity arose to investigate the impact of bushfires on groundwater levels and salinity, following an extreme bushfire event on lower Eyre Peninsula. The bushfire burnt out approximately 14,000 ha of remnant vegetation across 83,000 ha of land, including the salt-affected southern half of the Cummins-Wanilla Basin.

The investigation relied on time series data from groundwater monitoring networks established across the basin, along with interpretation of climatic trends, salinity expression and vegetation health following the bushfire. Some results presented in this report are tentative, given the complexity of the processes at work, and a lack of site-specific data in critical areas. However, several conclusions have been drawn.

For the majority of lower Eyre Peninsula, there was no discernible impact of the bushfire on depth to groundwater levels. Bores outside the bushfire zone reacted in a similar manner to those within the zone, with many showing record high levels in response to the wet winter and spring of 2005. These high recharge events corresponded to seasonal fluctuations within a longer-term falling trend in depth to groundwater, a trend which commenced in the early 1990s and correlated with a corresponding declining trend in average rainfall.

The 2005 rise in groundwater was short term in areas where significant regeneration of the burnt native vegetation occurred within the basin. In these areas, the extent of salt-affected land has remained virtually unchanged. However, where the existing vegetation was totally destroyed by the bushfire, some new outbreaks of salinity have been recorded. It is likely that the bushfire clearing has induced a change in the water balance in these salt prone areas resulting in a more permanent rise in groundwater.

Groundwater level data for the Cummins-Wanilla Basin has been collected over an extended period of time and this has facilitated the meaningful interpretation of the impact of bushfire on groundwater and salinity extent.

It is recommended that:

- The regular long-term monitoring of groundwater be maintained on the lower Eyre Peninsula and across the dryland agricultural districts of the state. Long-term monitoring will allow for the identification of salinity risk, and bushfire occurrence needs to be considered as a factor in salinity risk.
- Further enhancement of the lower Eyre Peninsula salinity monitoring focus site is required, through site-specific piezometer installation, and the undertaking of repeat EM surveys.

1. INTRODUCTION

On January 11th 2005, an extreme bushfire event swept across the lower Eyre Peninsula. The fire burnt across 83,000 ha of land, including the southern half of the Cummins-Wanilla Basin and the Koppio Hills (Figure 1). Along with agricultural land, significant areas of native vegetation, forestry and conservation parks were burnt.

The Cummins-Wanilla Basin is a high-risk dryland salinity catchment, which has been the subject of numerous investigations and project work over the years. The site is part of a network of focus areas that are monitored by Department of Water Land and Biodiversity Conservation (DWLBC) across dryland agricultural regions of the State (DWLBC, 2007). The focus areas are selected catchments that are representative of major regional and local groundwater flow systems in each NRM region. Monitoring focus areas aims to quantify changes over time of two key nationally recognised land salinity indicators:

(i) depth to groundwater

(ii) location, size and intensity of salt affected areas

The two focus areas for the monitoring of dryland salinity are situated within the Cummins-Wanilla Basin, therefore a substantial number of monitoring bores (piezometers) were located in the bushfire zone. Several unprotected PVC piezometer tubes that melted at ground level during the bushfire were repaired to enable continued monitoring.

Using monitoring data from bores inside and outside the bushfire zone, groundwater trends were analysed and compared to investigate any impact of the bushfire on depth to groundwater. This was undertaken within the context of knowledge gained from previous salinity studies, combined with more recent inspection of saline sites and vegetation health. As illustrated in Figures 2 and 3, significant regeneration of the vegetation burnt in 2005 had occurred by 2007.

The aims and objectives of this investigation were largely opportunistic in response to the bushfire event. This report presents findings of the investigation into the impact of the Eyre Peninsula bushfire on salinity extent in the area (and other related issues). The impact of bushfires on salinity is of growing interest given that climate change may potentially increase the intensity and frequency of bushfires in southern Australia (Hennessy et al 2005).

This case study also presented an opportunity to review the significant groundwater dataset that has been collected from the Cummins-Wanilla Basin over time (Figure 1), and determine the degree to which existing groundwater monitoring can define the spatial and temporal changes in groundwater levels following episodic events such as bushfires.

Figure 1. Extent of the 2005 bushfire on lower Eyre Peninsula (outlined in red)

Figure 2. Wanilla Conservation Park (located within the Wanilla focus catchment) following the fire, April 2005

Figure 3. Regeneration of Wanilla Conservation Park, September 2007

2. BACKGROUND

2.1 SITE DESCRIPTION

The region traversed by the bushfire, the lower Eyre Peninsula, is described in detail in the lower Eyre Peninsula District Soil Conservation Board Plan (LEPDSCB, 2003).

The lower Eyre Peninsula experiences a Mediterranean climate with cool moist winters and warm to hot dry summers. Rainfall ranges from 432 mm at Cummins to 598 mm at the Wanilla Fountain Forest Reserve, although there has been a falling trend in rainfall since the mid 1990s resulting in below average annual rainfall in most years.

Original native vegetation in the area included low open forests of sugar gum and sheoak, open scrub supporting mallee and broombush, open tea tree heath, and chenopod shrubland. By the early 1950s, much of this vegetation had been cleared for agricultural development, with the remainder being fragmented across conservation blocks, on small patches of non-arable farmland, and as dispersed occurrences along drainage lines, roads, fences, and railway lines. It has been estimated that between 7% and 15% of the native vegetation remains in the lower Eyre Peninsula region (ERDC, 2005).

Cropping is the principal agricultural land use, with wheat, barley, oats and pulses grown in rotation. Grazing of sheep and cattle occurs on annual and perennial pastures.

The Cummins-Wanilla Basin, bounded by the Lincoln Uplands to the east and the Marble Range to the west, is a broad flat valley with sluggish ill-defined drainage trending north to south. The Tod River and Little Swamp catchments drain the eastern portion of lower Eyre Peninsula.

2.2 SALINITY AND GROUNDWATER

Of interest to this study are the three catchments traversed by the fire: 1) the greater Cummins-Wanilla Basin; 2) the Wanilla focus catchment (part of the Cummins-Wanilla Basin); and 3) the Tod River catchment (Figure 1).

The Cummins-Wanilla Basin

In this extensive basin, tertiary sands form the principal aquifer of around 85,000 ha. Groundwater flows in a westerly direction from the Lincoln Uplands to discharge in basin flats and drainage lines (Herraman, 1980; Henschke et al. 2001). In the southern part of the basin, Quaternary limestone (Bridgewater Formation) overlies the sands and clays. Much of the basin is classified as an intermediate to regional groundwater flow system.

Extensive discharge areas occur along the sluggish drainage lines and adjacent to terminal lagoons and saline wetlands. There is evidence of primary salinity occurrence, with saline swamps being documented in early explorer surveys. Salinity problems within the basin are exacerbated by inflows of surface brackish water from uplands to the east, and the poorly drained flat topography that is underlain by 20 m of impervious clay.

Over 7% of land within the Cummins-Wanilla Basin has been lost to agricultural production due to rising saline groundwater, and previously healthy wetlands have degenerated into saline swamps (Doudle et al. 1993). Groundwater modelling undertaken by Stauffacher et al. (2000) indicated that if no preventative action was taken, the area of salt-affected land could in time increase to 12% of the catchment area.

In the 1990s, groundwater monitoring commenced in the basin, utilising a series of exploratory bores drilled by a mining company (Pugh, 1992). On lower Eyre Peninsula, there are three main bore networks recorded in DWLBC state groundwater database (Obswell) that are regularly monitored for determining salinity trends; CUMMINS and WANILLA (Wanilla focus catchment), both located in the Cummins-Wanilla Basin, and TODRIVER (Toolillie Gully) in the adjacent Tod River catchment. There are 70 bores listed in Obswell for the CUMMINS network, with 26 of these bores having been monitored on a regular basis. Background information for many of these bores (drilling logs, bore construction details, results of groundwater sampling) is provided in reports by Pugh (1992, 1997).

Several unprotected bores (PVC risers with no outer standpipe) were damaged in the 2005 bushfire (Figure 4). Melted tubes were repaired in November 2005 (Appendix A). Sites protected by an outer steel casing were not damaged.

Figure 4. Piezometer tube in the Cummins-Wanilla Basin, melted by the bushfire (bottom of the photograph, taken in August 2005)

The Wanilla focus catchment

The Wanilla focus catchment is situated on the eastern slopes of the Cummins-Wanilla Basin near the town of Wanilla. It extends over 1000 ha, with 3% of the area being affected by dryland salinity. The catchment's underlying groundwater system is classified as a local/intermediate system (in variably weathered granitic rocks). The catchment was instrumented in the early 1990s for groundwater and surface water monitoring (Richardson et al. 1994).

Approximately 70% of the catchment has been cleared for agricultural development. The largest area of remaining vegetation occurs in the Wanilla Conservation Park (approximately 280 ha), which was completely burnt in the January 2005 bushfire.

Ground-based EM (electromagnetic) surveys were undertaken within the focus catchment in October 1992 and in April 2005, a few months following the bushfire, to determine the extent and severity of salinity (DWLBC, 2007). The WANILLA network consists of 55 bores located within Wanilla focus catchment. Of these, 31 bores have been monitored regularly since the early 1990s. Background information to the catchment, including details of hydro-geological investigations and catchment water and salt balances, is available in a report by Richardson et al. (1994).

The Tod River catchment

In the Tod River catchment, groundwater flow occurs in a local fractured rock system. It is strongly influenced by bedrock topography and there is significant segmentation of groundwater across the catchment (S Evans, DWLBC, pers. comm. 1994).

Around 2% of land (500 ha) within the catchment is salt-affected (Dooley and Henschke, 2000). Jolly et al. (2000) reported mean stream salinity levels ranging from 6000 mg/L to 9000 mg/L, with a salt load of 19 tonnes per day estimated at the main diversion weir for potable water storage in the Tod Reservoir.

Shallow bores were installed by local community groups in the 1990s and much deeper monitoring bores established by the (then) Department of Mines (Pugh, 1996). The positive heads (water levels above ground level) observed in some bores indicate that semi-confined or confined aquifers operate within the fractured rock system (Dooley and Henschke, 2000).

There are 13 bores listed in Obswell for the TODRIVER network, with drilling logs and groundwater chemical analysis results provided in a report by Pugh (1996). This network was severely damaged in the 2005 bushfire, and several melted bores under artesian pressure consequently leaked groundwater at the soil surface.

2.3 THE JANUARY 2005 BUSHFIRE

On Tuesday 11th January, a devastating bushfire (known as the Wangary fire, and the day as Black Tuesday) burnt across 83,000 ha of land on lower Eyre Peninsula, resulting in the tragic loss of life, homes, properties and stock.

The Environment Resources and Development Committee (ERDC) reported that extreme weather conditions on Black Tuesday, consisting of high temperatures, low humidity and very strong winds, combined to exacerbate the fire (ERDC 2005). Strong north to north-westerly winds fanned the fire and drove it from near Wangary to the coast at North Shields in three hours (refer to Figure 1).

Significant areas of grassland, scrub and stubble paddock were burnt (Figure 5). Flammable fuel loads for agricultural lands, at the time of the fire, were estimated at between 0.5 to 3.0 t/ha, while that of roadside vegetation was estimated at 5.0 to 7.0 t/ha (ERDC, 2005). This high intensity summer fire resulted in 14,000 ha of remnant woodland vegetation being burnt (DEH, 2007), along with smaller areas of planted vegetation.

The ERDC reported that vegetation on or close to the ground appeared to have been totally burnt, along with shrubs and trees to a height of 2-3 m. However, taller mature trees had their trunks burnt, but their canopies only singed (Figure 6).

Figure 5. Burnt agricultural land and scrubland (February 2005)

2.4 NATIVE VEGETATION

Detailed monitoring of vegetation recovery was undertaken following the bushfire. Monitoring results for three species (DEH, 2007) are described below, to highlight the varying mechanisms and degree of recovery recorded after the fire.

The sugar gum (*Eucalyptus cladocalyx)* is an important component of open woodlands across lower Eyre Peninsula, and around 50% of these woodlands were burnt. However, there were high rates of canopy recovery following the fire, mass seedling recruitment and high seedling survival. The highest mortality rate recorded for mature trees was 15%.

In the agricultural areas of lower Eyre Peninsula, *Acacia pinguifolia* commonly occurs in narrow remnants stands within road reserves and railway easements. In the burnt areas, fire caused the mortality of most mature plants. However after the fire, seedlings effectively germinated and, after two years, most seedlings had successfully established to become new mature recruits to the population.

Melaleuca brevifolia species is an important component of open shrubland on lower Eyre Peninsula, often re-sprouting from lignotubers following fire. Where the 2005 bushfire was intense, mortality rates for the species were high (up to 50%) and seedling recruitment was lower due to released seeds being consumed by the fire. The onset of dry conditions in 2006 is thought to have reduced the recovery of this species after the fire.

3. METHODOLOGY

3.1 DEPTH TO GROUNDWATER TRENDS

The three main Obswell networks in the area affected by bushfire are CUMMINS (bores labelled CUM and MKT), WANILLA (bores labelled WNL) and TODRIVER (bores labelled KPP). A field audit of these networks identified suitable sites for more intensive groundwater monitoring following the bushfire (Figure 6). A subset of 52 bores were selected (Figure 7). Appendix A lists their specifications, along with a list of bores repaired after the fire.

Figure 6. Monitoring bores located in the WANILLA network, April 2005

The subset of bores included seven sites outside the bushfire zone (north of Edillilie) which were used as control sites. For each bore, depth to groundwater (watertable levels) were plotted over time (a hydrograph), and simple linear trends were then determined by applying the "fit a linear trend line" function available in Obswell.

These trends, calculated over a 17 year period commencing in the early 1990s, were categorised into one of four classes (Appendix B):

- Seasonal – watertable responds to seasonal conditions and shows an annual cycle of rise and fall, but with no overall trend over the measurement period
- Falling – the watertable has an overall falling trend over the time
- Episodic – the watertable responds to major rainfall events or wet years and shows a significant steep rise, followed by a recession that may not necessarily drop back to the level preceding the event
- Rising – the watertable responds seasonally with winter peaks and summer troughs with an overall rising trend over the time.

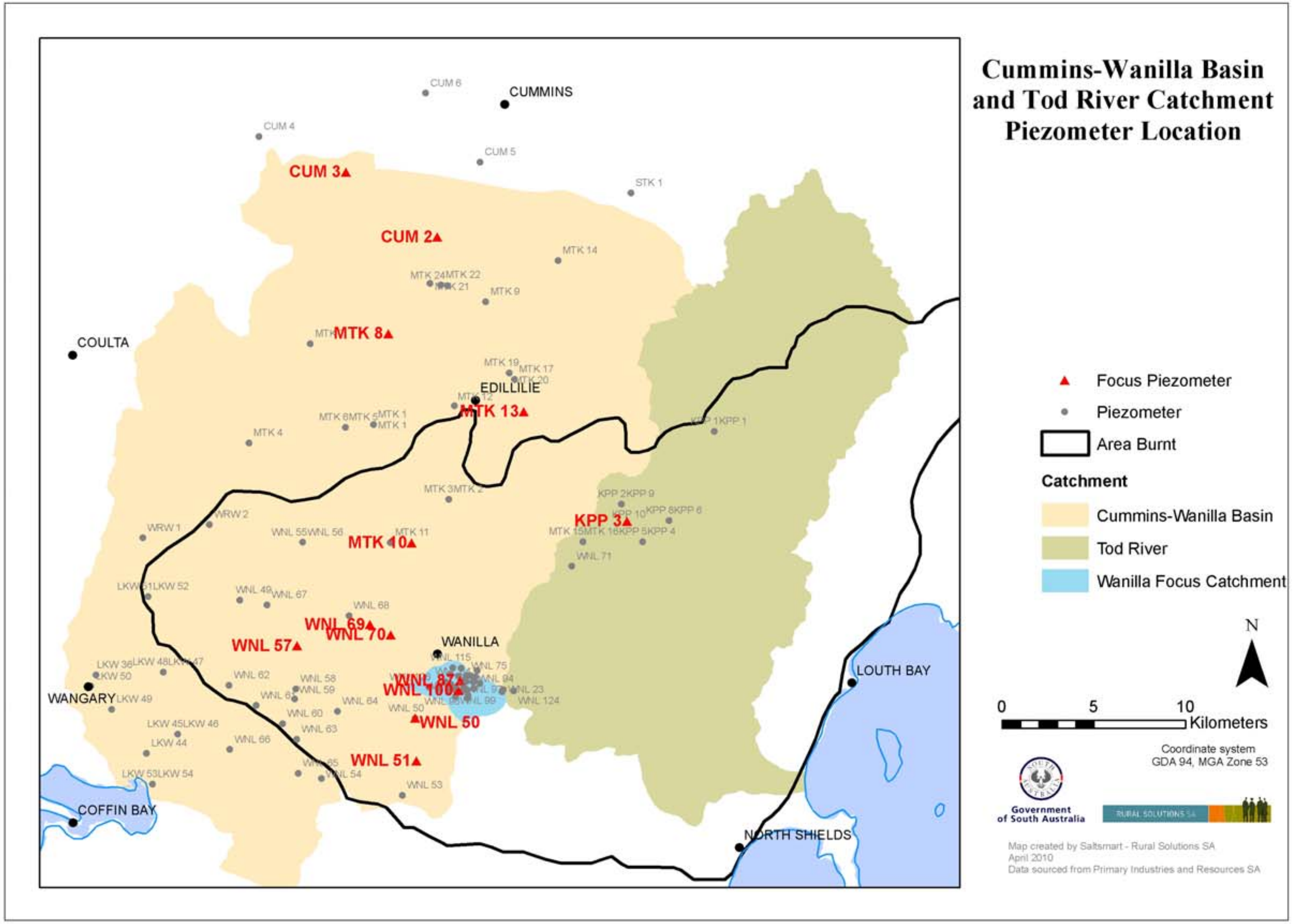


Figure 7. Map showing the piezometer networks across lower Eyre Peninsula and the location of the Wanilla focus catchment.

Hydrographs for nine sites within the bushfire zone, and four control sites outside the bushfire zone, are presented in Appendix C. The trends determined from these thirteen sites (highlighted as focus piezometers in Figure 7) were representative of the 52 sites examined.

Cumulative residual rainfall curves were included in the hydrographs, to help determine the impact of long term rainfall trends on depth to groundwater. The cumulative residual rainfall curve (blue line in Figure 8) represents the running total of the difference between actual rainfall and average rainfall calculated from the first rainfall date to the latest reading. Rainfall data for the surrounding rainfall stations was obtained from Silo Data Drill (available from the Bureau of Meteorology). The data was interpolated to estimate rainfall at each site.

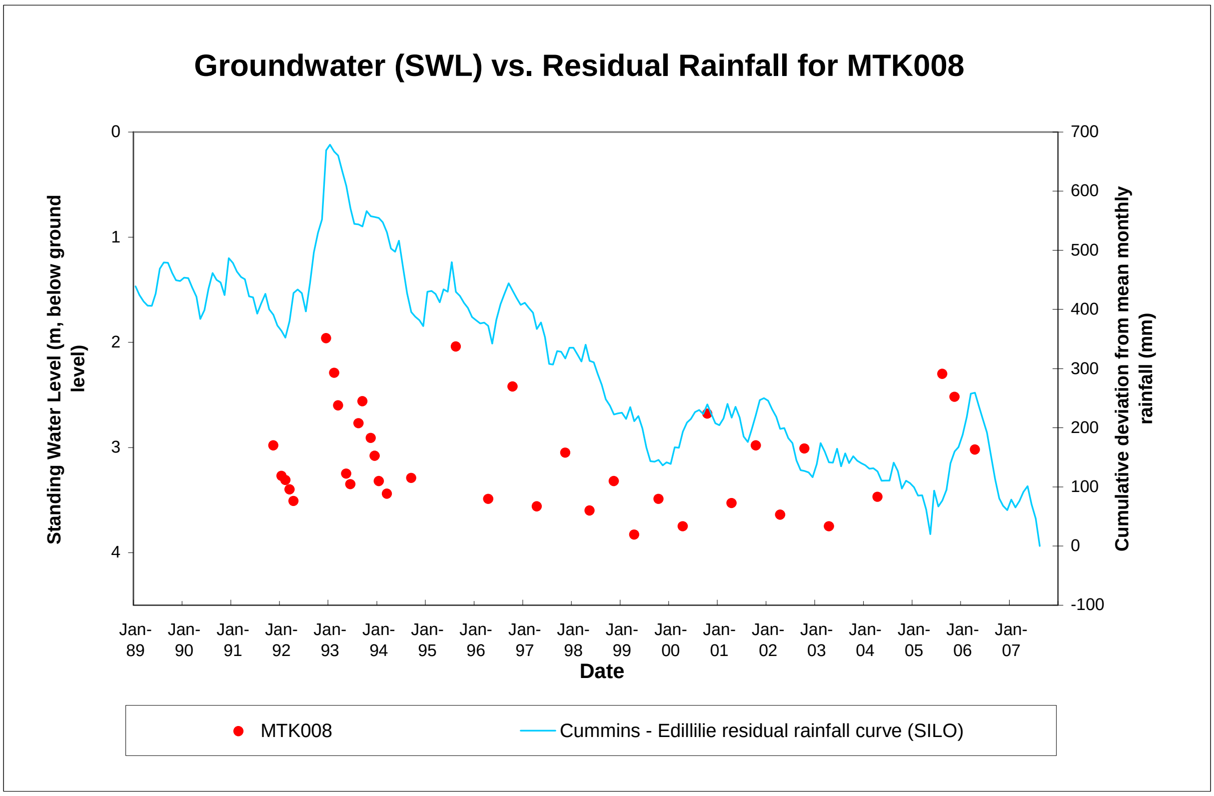


Figure 8. Hydrograph comparing groundwater levels with cumulative residual rainfall (blue line)

In addition to comparing long-term trends between control bores and bores within the bushfire zone, an analysis was also undertaken of the highest groundwater levels on record (Appendix B). This analysis determined the occurrence of peak levels following the bushfire, and whether such peak levels occurred both inside and outside the bushfire zone. As an example, site MTK008, a control bore outside the bushfire zone, recorded its third highest depth to groundwater level in August 2005 following the bushfire (Figure 8).

Average monthly rainfall during 2005 was also examined (Appendix D). Above average rainfall was experienced in the winter and spring of 2005 following the bushfire (shown as a peak in the residual rainfall curve in Figure 8).

3.2 SALINITY EXPRESSION

Following the bushfire, field inspections were conducted within and outside the bushfire zone to observe 1) whether any differences in salinity extent and/or severity were apparent and 2) the amount of vegetation burnt and the degree of regrowth that occurred after two years. Several saline seeps were examined in detail, with two seeps being mapped using an electromagnetic (EM) induction survey. An EM survey was undertaken in 2006 on the John Chesher property (refer to Figure 11), which was severely burnt in the bushfire. EM survey was also undertaken in 2005 (Figure 9) at a site 7 km north of Chesher's property, as part of the ongoing focus catchment monitoring. This area had been previously surveyed in 1992. Details of these surveys are reported in a separate DWLBC report (Evans et al, In prep.)

An EM meter measures the bulk apparent electrical conductivity (ECa) of the soil profile to a depth determined by the type of instrument (EM31 or EM38) and the orientation of the instrument coils. The EM meter is responsive to variations in soil moisture, soil salinity and clay content of the soil and regolith. Following calibration with soil samples, the intensity of salt affected land may be assessed using the criteria shown in Table 1.

Table 1. Interpretation of ECa readings in EM surveys (after NLWRA 2007)

Intensity of salt affected land	ECa (dS/m)	Description
Non-saline	<0.5	Land not affected by soil salinity
Slightly saline	0.5 – 1.0	Ground seasonally damp, reduced vegetation diversity
Moderate saline	1.0 – 1.5	Salt-tolerant plant species dominate
Severely saline	>1.5	Bare salt crusts and samphire

Figure 9. EM quad-bike survey in the Wanilla focus catchment, April 2005

4. RESULTS

4.1 GROUNDWATER TRENDS

Appendix B contains the minimum, maximum and 2007 watertable levels [standing water levels (SWL)] for each of the 52 Obswell sites analysed, including 7 control sites outside but adjacent to the bushfire zone. Of the 52 sites analysed, ten sites within the TODRIVER network had such limited data that no trends could be generated. For the remaining 42 sites, trends in depth to groundwater were classified as follows:

- 23 sites showed seasonal trends (3 were outside the bushfire zone)
- 14 sites showed falling trends (2 were outside the bushfire zone)
- 5 sites showed episodic trends (2 were outside the bushfire zone)
- no sites showed rising trends.

Six of the 23 sites exhibiting seasonal groundwater trends recorded their highest water level on record during 2005 after the fire (Table 2). Five of these sites were within the bushfire zone, with the sixth site (MTK013) being a control bore situated near the northern boundary of the bushfire zone.

Table 2. Bores recording their highest levels following the bushfire

Site	Highest SWL (m)	Date of highest SWL
WNL051	-0.31*	Nov 2005
WNL065	0.75	Aug 2005
WNL087	-0.70	Nov 2005
LKW054	0.71	Aug 2005
MTK013	2.20	Nov 2005
KPP003	0.15	Aug 2005

*A negative sign indicates that the water level is above ground level

Sites WNL052 and MTK010, both inside the bushfire zone, recorded their second highest peaks on record in November 2005, indicating that groundwater levels rose during the wet season following the fire. Two control bores (CUM002 and MTK008) outside the bushfire zone recorded their second and third highest peaks respectively (Appendix C).

4.2 SALINITY EXPRESSION

Following reports of new salinity outbreaks on burnt land east of the Wanilla Forest, a field inspection of two properties (landholders Greg Myers and John Chesher) was undertaken. Located on the leeward side of the Wanilla Forest (Figure 11), the vegetation on these properties were all but destroyed in the bushfire, the intensity of which was likely exacerbated by a firestorm generated within the forest. The Wanilla Forest (Figure 1) comprised tall eucalypts in the northern half, with pines in the southern half. While the eucalypts in the forest have since regenerated (Figure 10), the pines were destroyed in the fire.

Figure 10. Regeneration of eucalypts on the north-eastern edge of the Wanilla Forest

The proximity of the Wanilla Forest pines to the Chesher property is shown in Figure 11. The map also shows the location of an EM survey undertaken over the salinity outbreak area in March 2006. Figure 12 shows the remnant vegetation patches that surround the EM survey area. An explosive fireball, most likely generated within the pines, destroyed the significant areas of remnant vegetation on the property. As the native trees and their root systems were cooked in the intense heat, little regeneration has occurred since.

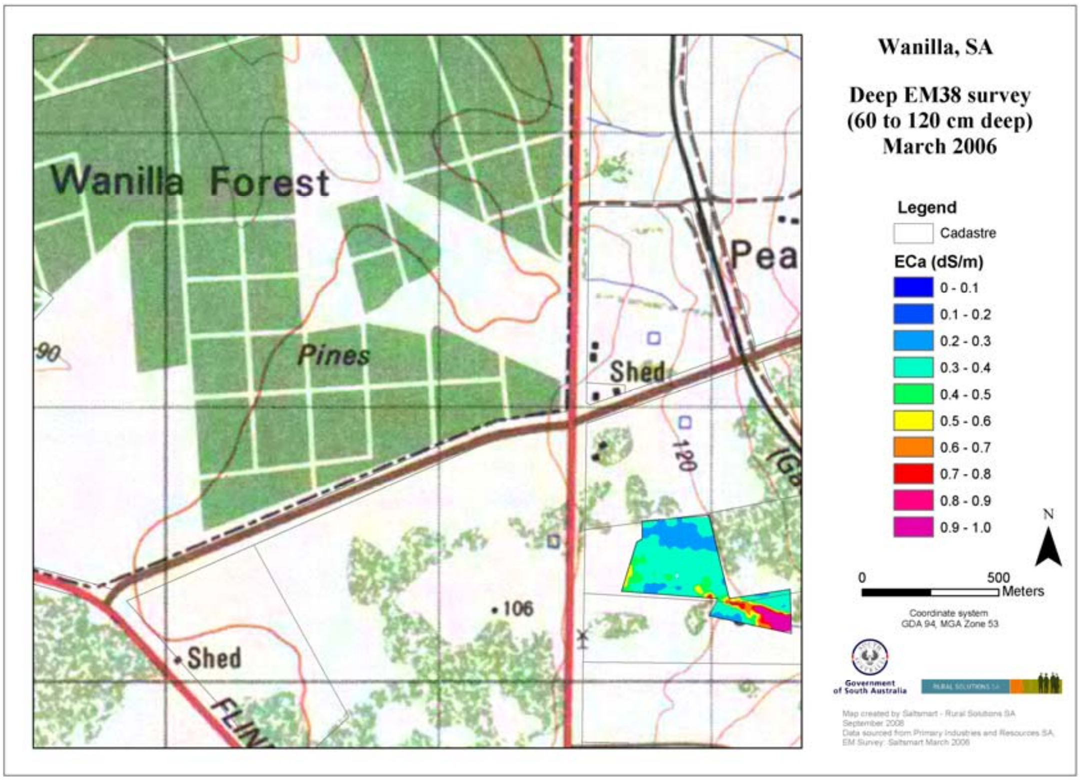


Figure 11. Location of EM mapping on the Chesher property, adjacent to the Wanilla Forest

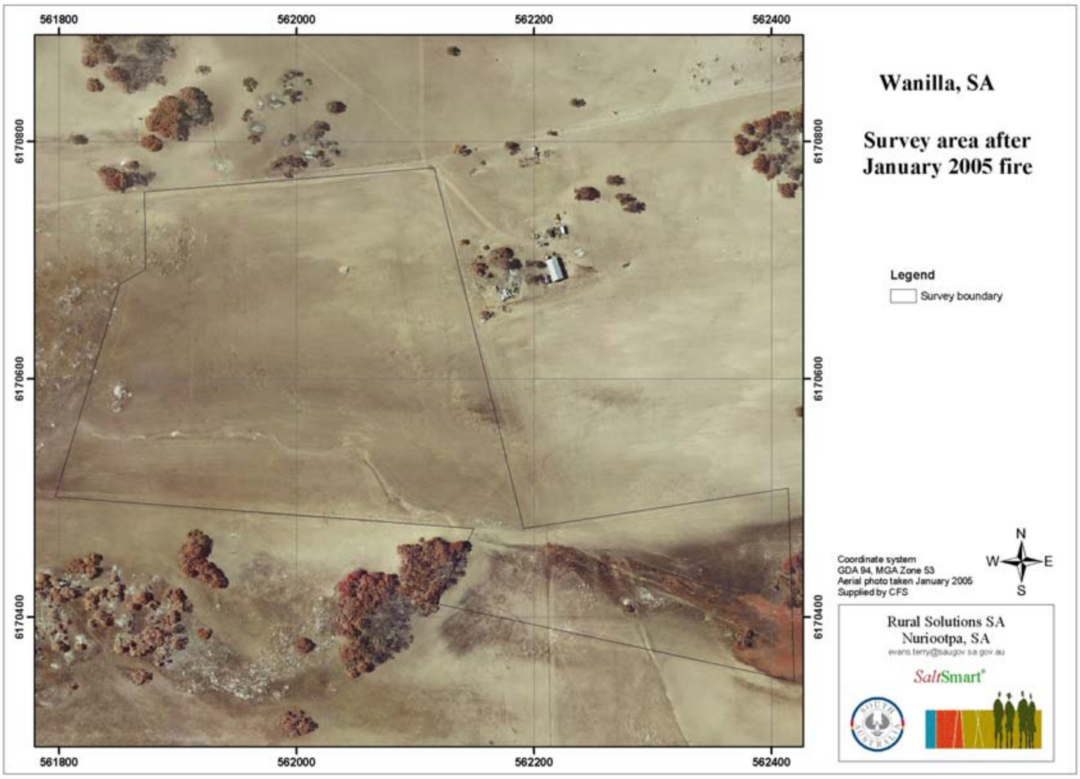


Figure 12. Post fire aerial photograph (infrared image where green vegetation is seen as red shades) showing the "cooked vegetation" and salinity outbreak on the Chesher property (patchy areas in bottom of photo)

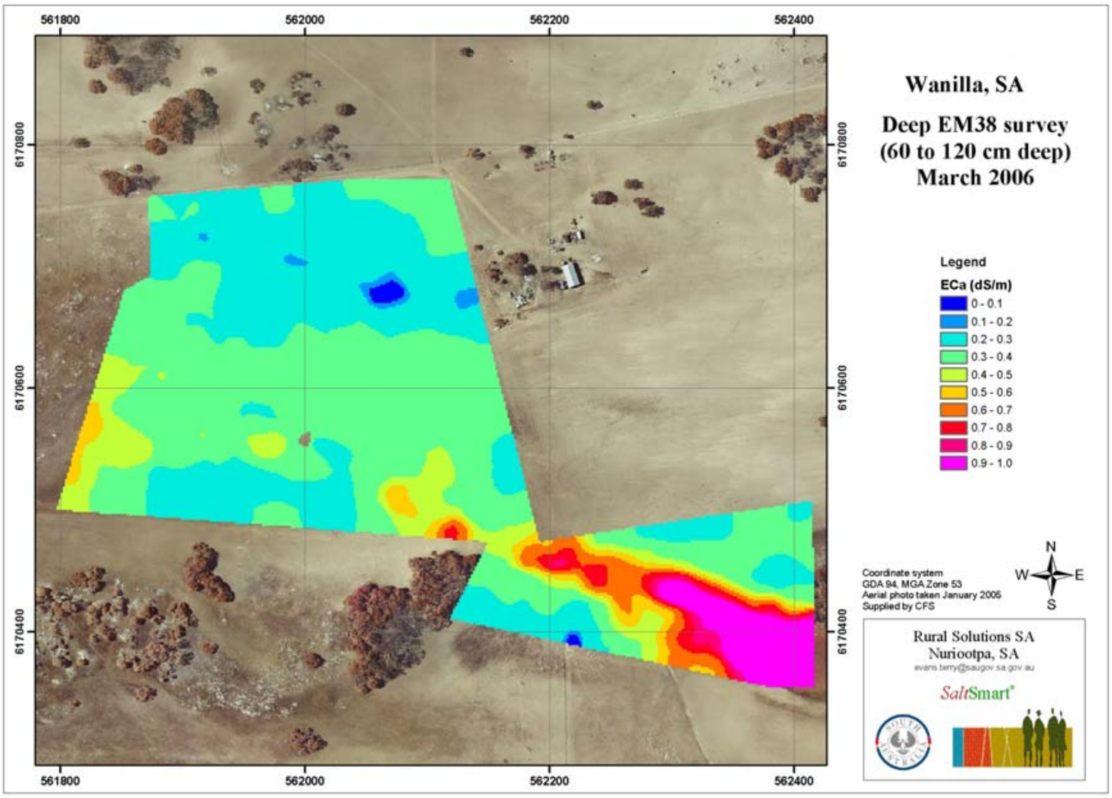


Figure 13. EM map showing the saline drainage line (linear red feature) on Chesher's property

Figure 13 illustrates the results from the March 2006 EM survey on the Chesher property. Salinity increases in severity along the main drainage line (red indicates saline areas where ECa > 0.7 dS/m). The saline area was visibly seeping, and actively encroaching up a drainage line when inspected in September 2007 (Figure 14). Also evident in Figure 14 is an area of burnt remnant vegetation, which showed only limited and patchy signs of regrowth in 2007.

Figure 14. Salinity (patchy bare ground) encroaching up a drainage line on the Chesher property, September 2007

Similarly, on the Myers property north-east of the Wanilla Forest, native vegetation burnt in the 2005 bushfire has shown no signs of regeneration. The remnant vegetation was situated on hill slopes and in broad flat gullies. New saline discharge areas have occurred along the break in slope (Figure 15) where the local groundwater flow systems is changing to a more regional system. Saline areas have also spread along the valley since the bushfire (G Myers, pers. comm. September 2007).

The active saline seepage on the Chesher and Myers properties are in stark contrast to that observed and measured in the Wanilla focus catchment, also located within burnt areas. Comparisons between EM surveys conducted in 2005 and 1992, has determined that saltland area has decreased at an average rate of 2% to 3% per year over the period (DWLBC, 2007). This marked retraction in saltland over 13 years has occurred in response to falling groundwater levels resulting from below average rainfall seasons. Visual inspection of this catchment in September 2007 also suggested that there had been no increase in size or intensity of saltland since the bushfire. As illustrated in Figures 2 and 3, substantial regeneration of burnt vegetation had occurred within this sub-catchment over the two years following the bushfire.

Figure 15. Salinity spreading on the Myers property, September 2007

The nearest groundwater monitoring bores to the Myers and Chesher properties (WNL050 and WNL051) are 2 to 3 km away (refer to Figure 7). The long-term groundwater trend at both sites is classified as seasonal (Appendix C), being -0.02 and +0.02 m/yr respectively. Groundwater level in both bores is shallow (0-2 m), with WNL051 recording its highest level on record in November 2005 (0.31 m above the ground surface). In the 2005 to 2007 period, groundwater levels in WNL050 was at its highest level since 1992.

Much of the apparent change in the expression of salinity following the 2005 bushfire was confined to an area east of the Wanilla Forest which is associated with the Myers and Chesher properties. However, reports of a temporary apparent worsening in salinity following the bushfire were also received from areas west of Wanilla, towards the centre of the Cummins-Wanilla Basin (Doug Pope, pers. comm. March 2009).

5. DISCUSSION

An analysis of hydrographs has shown that groundwater levels on lower Eyre Peninsula peaked in 2005 (Table 2); at some sites water levels were at an all time high after 16 years of records. Given that these recharge peaks occurred in bores both inside and outside the bushfire zone, it appears that the bushfire had little discernible influence on depth to groundwater. The response was due to the wetter than average winter and spring conditions experienced in the second half of 2005.

Various authors have reported significant hydrologic change following bushfire. Benyon et al. (2007) noted that where bushfire effectively converted old growth native vegetation to more vigorous regrowth, the resultant increase in transpiration could dramatically reduce water yield in affected catchments. Similarly DSE (2004), in discussing the pattern of water use in burnt Victorian bushland, described an initial reduced water usage period (resulting from less transpiring vegetation) followed by much higher water use as vigorous regeneration occurred.

The magnitude of any hydrologic response to bushfire will depend on the area of perennial vegetation burnt relative to the area of the catchment; the reports by Benyon et al. (2007) and DSE (2004) pertained to large, densely vegetated areas (e.g. 1,000,000 ha). As well, the percentage area effectively and permanently cleared by bushfire will influence the magnitude of the hydrologic response. Johnson et al. (2007) observed differences in peak watertable levels beneath partially (25%) to fully (100%) harvested forests, with groundwater levels being highest under the clear felled areas.

Intensity of bushfire will determine in part whether clearing of perennial vegetation is temporary or permanent in nature. Chafer (2007) described wildfire as being spatially heterogeneous in terms of both patchiness and severity, and noted that recovery of NSW native vegetation to pre-fire conditions could occur within three years where fire intensity was low to moderate, but could take up to ten years where fire intensity was high to extreme.

The lower Eyre Peninsula bushfire zone contained around 14,000 ha of extremely fragmented remnant woodland vegetation (DEH, 2007), along with a few larger vegetated areas such as the Wanilla Conservation Park (280 ha), and the mixed eucalypts and pines of the Wanilla Forest. The total area of perennial vegetation burnt represented around 15% of the bushfire zone. Stirzaker et al. (2002) discussed water use of perennial vegetation as a key component of catchment hydrology, and therefore a key factor in both the cause and potential mitigation of salinity. These authors emphasised the relationship between the area of a catchment cleared/revegetated and the magnitude of the resultant hydrologic response.

Much vigorous regrowth followed the 2005 bushfire, assisted by the above average winter and spring rainfall of 2005 although, as noted by (DEH, 2007), the onset of dry conditions in 2006 hampered the re-establishment of some species. The local intense heat generated in certain areas (such as adjacent to the Wanilla Forest) was sufficient to completely destroy vegetation, with little regeneration evident four years after the bushfire. A Victorian government report on the impact of bushfires in the state discussed how fire frequency, intensity, and seasonal conditions, impact on the different survival features of plant species and the potential for severe fires to effectively remove all vegetation.

The pine plantation in the Wanilla Forest was totally destroyed by the fire. Rustomji and Hairsine (2006) discussed the destruction of pine plantations by the 2003 ACT bushfire, noting that the immediate reduction in live vegetation would result in a short term (3 to 7 year) increase in catchment water yield until replacement vegetation was established. Stadter (1992) reported rises in groundwater levels of between 1.0 m and 4.5 m beneath mature pine forests in the South East of SA destroyed in the 1983 Ash Wednesday bushfire.

Within a regional context, there was little measurable impact of the 2005 bushfire on lower Eyre Peninsula groundwater levels, due to the relatively small and fragmented areas of perennial vegetation burnt, the swift regeneration that was observed, and the overriding influence of long term climatic trends. The high water levels recorded within and outside the bushfire zone following the wet winter/spring period of 2005 represented a seasonal fluctuation within a long term declining trend in depth to groundwater across the Eyre Peninsula (Figure 16).

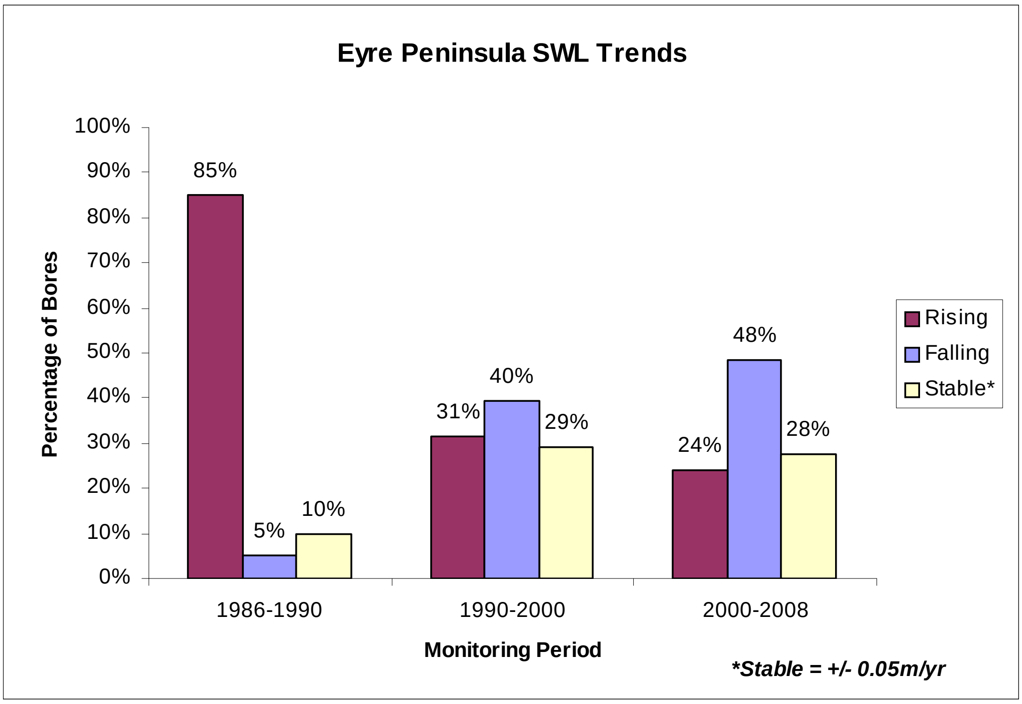


Figure 16. Standing Water Level (SWL) trends for the majority of bores across Eyre Peninsula

As Figure 16 illustrates, general watertable levels on Eyre Peninsula have fallen over the past two decades (Dooley et al, in prep.), corresponding to a similar decline in the average rainfall received. The return of drier conditions in 2006 continued the declining rainfall trend evident on Eyre Peninsula since the early 1990s (DWLBC, 2007). However, a proportion of bores are still rising (Figure 16), signifying the site-specific nature of groundwater and salinity processes, as influenced by local climatic factors, land use change, and groundwater flow systems.

Within this context of a declining depth to groundwater trend, new salinity outbreaks were observed following the 2005 bushfire, suggesting a potential cause and effect from site-specific factors. The characteristics common to new salinity outbreak sites included:

- General proximity to the Wanilla Forest, where a mix of pines and eucalypts burnt in the bushfire exacerbated the severe intensity of firestorms that subsequently destroyed vegetation on leeward properties. The pines were totally destroyed.

- Destruction of remnant vegetation on the affected properties by the intense firestorm, with little current regeneration evident.
- Location in a hydrologically sensitive area of the Cummins-Wanilla Basin where:
    - more local, break of slope groundwater flow systems operated,
    - relatively shallow groundwater existed, and
    - incipient salinity (salinity of the lower soil horizons, but with few visible salinity signs on the soil surface) was likely to be present

These characteristics suggest that new salinity outbreaks on the Chesher and Myers properties were most likely caused by a local rise in groundwater following the wet winter and spring of 2005. The rise was sustained by increased recharge resulting from the permanent loss of remnant vegetation due to bushfire intensity, with additional contribution from the loss of pines in the Wanilla Forest. Increased evaporation from incipient salinity areas that were bared by the fire would also have exacerbated the salinity process.

Examples of secondary clearance causing new outbreaks of salinity have previously been reported. Rust PPK (1994) described the impact of aphid infestation in the 1970s on lucerne stands in SA's Bundaleer Valley. The destruction of perennial dryland lucerne stands, combined with a series of wet years, was sufficient to alter the water balance and cause outbreaks of salinity in an area that traditionally exhibited relatively shallow groundwater.

Where native vegetation on lower Eyre Peninsula vigorously regenerated following the bushfire, as in the central areas of the Cummins-Wanilla Basin and in the Wanilla focus catchment, no sustained increase in salinity extent and severity was observed. In the case of the Wanilla focus catchment, an existing decreasing trend in salinity extent and severity may have been maintained.

Chafer (2007) examined water yield from Sydney water supply catchments following extensive bushfire damage in 2001. These catchments exhibited trends somewhat similar to the lower Eyre Peninsula, in that long term annual rainfall patterns showed a constant declining trend over fifteen years, with a related declining trend in annual water yield. Analysis of post-fire water yield suggested a pattern of initial increase in yield, followed by a sustained depression in yield as regeneration of vegetation occurred. The observations by Chafer (2007) indirectly support the notion that salinity extent and severity may revert back to its pre-fire condition following a temporary increase, or it may even decrease in extent in response to increased transpiration.

As there were no bores directly situated on the Myers or Chesher properties, or within the pines of the Wanilla Forest, uncertainty exists as to how groundwater reacted in these locations following the 2005 bushfire. While the regional monitoring network provided information relevant at the regional scale, more detailed site-specific groundwater information was lacking, and hindered interpretation of local processes.

On balance however, it is thought that the 2005 bushfire has contributed to new outbreaks of salinity on lower Eyre Peninsula. Destruction of perennial vegetation led to reduced transpiration, increased recharge and sustained rising groundwater such that saline seeps developed on the land surface in areas that were already prone to salinity.

Given the potential for increased frequency of intense bushfires in southern Australia (Bushfire CRC, 2008), further consideration of their impact on salinity and related natural resource management issues is warranted.

6. CONCLUSIONS AND RECOMMENDATIONS

Groundwater levels at several locations on lower Eyre Peninsula reached record highs in the second half of 2005. Comparison of groundwater levels in bores within and outside the January 2005 bushfire zone has determined there was no discernible impact of the bushfire on depth to groundwater. Rather, the wetter than average 2005 winter and spring conditions contributed to the observed recharge peaks in the hydrographs analysed.

These recharge peaks represented seasonal fluctuation within a long term declining trend in depth to groundwater, a trend correlated to declining rainfall trend since 1992 and one continued by the onset of drier conditions in 2006. While at record levels in some locations, the temporary rise in groundwater levels in 2005 resulted in no sustained change in the expression of dryland salinity for most of lower Eyre Peninsula.

However, for land east of the Wanilla Forest, the 2005 rise in groundwater appears to have been sustained, resulting in new outbreaks of salinity. Here, intense local firestorms destroyed perennial vegetation such that no significant regeneration was evident four years after the fire. This is in stark contrast to other portions of the Cummins-Wanilla Basin where vigorous regeneration of burnt native vegetation followed the wet June of 2005.

For affected properties such as Myers and Chesher, it is likely that the pre-fire groundwater conditions had already induced a degree of subsoil (incipient) salinity. The permanent clearance of vegetation by the January bushfire, although not large in area, reduced transpiration and increased recharge enough to sustain a local rise in groundwater following the wet winter and spring. As a result, salinity developed on the surface, and has been spreading since 2005.

This case study investigation was opportunistic, relying on time series data from groundwater monitoring networks established across the Cummins-Wanilla Basin, along with interpretation of climatic trends, salinity expression and vegetation health following the bushfire. This case study has reinforced the value of long-term groundwater monitoring data. It has also highlighted the local nature of salinity processes, and the need for site-specific information if a comprehensive interpretation is to be made. Installing piezometers and implementing a repeat EM survey on the Chesher property would add value to any future review of this case study.

It is recommended that regular and sustained monitoring of groundwater networks on Eyre Peninsula and across the dryland agricultural areas of the state be an on-going component of the process to monitor the condition of SA’s natural resources. Furthermore, with the predicted increased frequency and intensity of bushfires under climate change scenarios, bushfire occurrence needs to be a factor considered in the determination of salinity risk.

APPENDICES

A. BORE SPECIFICATIONS

Network: CUMMINS

Project: Cummins Basin groundwater monitoring network

Reference: Pugh (1992, 1997)

Obs No	Unit No	Field No	Date Drilled	Construct Depth (m)	Ground Elevation (m)	Reference Elevation (m)
WNL050	01788	11	Nov 91	5.00	74.49	75.15
WNL051	01784	-	Dec 91	26.00	98.12	98.79
WNL052	01785	-	Dec 91	26.00	98.12	98.79
WNL054	01787	-	Dec 91	12.00	66.00	65.96
WNL057	01716	SH 106	Jun 90	14.50	N/R	52.00
WNL059	01717	SH 119	Jun 90	45.00	N/R	35.00
WNL061	01719	SH 128	Jun 90	30.00	N/R	32.00
WNL063	01722	SH 133	Jun 90	24.00	N/R	30.00
WNL065	01724	SH 151	Jun 80	24.00	N/R	40.00
WNL067	01726	SH 162	Jun 90	30.00	N/R	31.00
WNL069	01728	SH 173	Jun 90	30.00	N/R	48.00
WNL070	01729	SH 181	Jun 90	36.00	N/R	60.00
WRW002	00927	-	May 91	4.20	N/R	39.66

Obs No	Unit No	Field No	Date Drilled	Construct Depth (m)	Ground Elevation (m)	Reference Elevation (m)
LKW045	01790	3 (A)	Oct 91	20.00	13.47	14.34
LKW046	01791	3 (B)	Oct 91	20.00	13.47	14.34
LKW047	01774	-	Oct 91	11.00	21.67	22.22
LKW048	01775	-	Oct 91	11.00	21.78	22.22
LKW050	00322	-	Oct 91	10.00	N/R	20.67
LKW051	01776	-	Oct 91	20.00	18.42	19.16
LKW052	01777	-	Oct 91	16.00	18.42	18.98
LKW053	01778	-	Oct 91	12.00	3.06	3.66
LKW054	01779	-	Oct 91	4.00	3.10	3.66
MTK007	00926	-	Jun 91	8.00	N/R	72.44
MTK008	01017	-	Jun 91	10.00	N/R	55.09
MTK010	00859	SH 185	Jun 90	7.50	N/R	50.00
MTK011	00860	SH 189	Jun 90	24.00	N/R	55.00
MTK012	00858	SH 190	Jun 90	19.00	N/R	70.00
MTK013	00861	SH 198	Jun 90	15.00	N/R	79.00
CUM002	01021	-	Jun 91	15.00	N/R	64.78
CUM003	01022	-	Jun 91	18.00	58.91	59.73
CUM005	01024	-	Jul 91	20.00	N/R	65.23

Notes:

Unit No – will have a prefix of 6028- for WNL and LKW bores

will have a prefix of 6029- for WRW, MTK and CUM bores

Construct depth = Constructed depth which is the depth of base of the bore below ground level (may not necessarily be the same as the original drilled depth)

Reference Elevation = Reference elevation from top of PVC casing (TOC)

N/R = Not Recorded in Obswell

Repairs carried out on fire damaged piezometers in the Cummins Basin network

Site	Old Tube Height (m)	New Tube Height (m)
WNL057	0.37	0.60
WNL059	0.32	0.53
WNL061	0.35	1.01
WNL067	0.45	1.13
WNL069	0.58	1.06
WNL070	0.50	0.55
MTK010	0.32	1.04
MTK011	0.37	0.56

Network: WANILLA

Project: Investigation and management of dryland salinity at Wanilla on lower Eyre Peninsula

Reference: Richardson et al. (1994)

Obs No	Unit No	Field No	Date Drilled	Construct Depth (m)	Ground Elevation (m)	Reference Elevation (m)
WNL074	01730	W 1 C	Apr 90	22.78	166.62	167.17
WNL076	01731	W 2 C	Apr 90	31.08	147.76	148.24
WNL081	01733	W 4 C	Apr 90	12.10	135.11	135.64
WNL087	02032	W 6 B	Apr 90	2.30	108.53	109.32
WNL091	02029	W 7 C	Apr 90	31.36	97.11	97.61
WNL095	01737	W 8 C	Apr 90	10.09	145.75	146.26
WNL098	01738	W 9 C	Apr 90	28.00	148.63	149.14
WNL100	01739	W 10 C	Apr 90	24.46	121.17	121.67
WNL109	02021	W 17 C	May 91	12.26	109.97	110.57
WNL113	02020	W 21 C	May 91	28.39	123.65	124.28
WNL115	01756	W 22 C	May 91	7.58	111.18	111.71
WNL123	02063	W 27 C	Jun 91	52.59	225.32	225.78

Unit No – will have a prefix of 6028- for WNL bores

Construct depth = Constructed depth is the depth of base of the bore below ground level

Grnd Elev = Ground elevation

Ref Elev = Reference elevation, top of PVC casing (TOC)

Network: TODRIVER

Project: Toolillie Gully dryland salinity investigation

Reference: Pugh (1996)

Obs No	Unit No	Field No	Date Drilled	Construct Depth (m)	Ground Elevation (m)	Reference Elevation (m)
MTK015	01007	PARSON	May 91	24.00	180.41	180.756
MTK016	01008	PARSON	May 91	42.00	180.41	180.76
KPP003	01006	DOCKING (2a)	May 91	31.00	N/R	152.41
KPP011	01016	DOCKING (2b)	May 91	22.00	N/R	152.57
KPP004	01009	SCOTTS	May 91	43.00	N/R	166.06
KPP005	01010	SCOTTS	May 91	30.00	N/R	166.06
KPP006	01011	WEIR	Jun 91	43.00	N/R	135.45
KPP007	01012	WEIR	Jun 91	24.00	N/R	135.45
KPP008	01013	WEIR	Jun 91	15.00	N/R	135.45

Unit No – will have a prefix of 6029- for all bores

Construct depth = Constructed depth which is the depth of base of the bore below ground level

Grnd Elev = Ground elevation

Ref Elev = Reference elevation, top of PVC casing (TOC)

N/R = Not Recorded

B. WATER LEVEL DATA

(1) *Cummins-Wanilla Basin*

Obs No	Lowest SWL (m)	Highest SWL (m)	Current SWL (m)	Current RSWL (m)	Trend (m/yr)	Trend Description
WNL050	1.54	-0.30	0.54	73.95	-0.02	seasonal
WNL051	1.84	-0.31	0.48	97.64	+0.02	seasonal
WNL052	1.91	-0.32	0.54	97.58	+0.01	seasonal
WNL054	9.48	6.77	8.49	57.51	-0.02	episodic
WNL057	6.67	4.35	7.11	44.89	0.00	episodic
WNL059	3.41	1.45	3.21	31.79	-0.01	seasonal
WNL061	5.26	1.94	5.26	26.74	-0.04	seasonal
WNL063	4.07	2.03	3.63	26.37	0.00	seasonal
WNL065	3.22	0.75	2.66	37.34	-0.01	seasonal
WNL067	4.64	2.30	4.64	26.36	-0.03	seasonal
WNL069	2.02	0.50	2.02	45.98	-0.02	seasonal
WNL070	9.17	5.46	9.00	51.00	-0.10	falling
WRW002	5.91	3.15	5.79	33.87	-0.03	seasonal
LKW045	5.33	3.75	5.33	8.14	-0.06	falling
LKW046	5.33	3.75	5.33	8.14	-0.06	falling
LKW047	2.43	0.97	2.19	19.48	+0.01	seasonal

Obs No	Lowest SWL (m)	Highest SWL (m)	Current SWL (m)	Current RSWL (m)	Trend (m/yr)	Trend Description
LKW048	2.44	0.51	2.19	19.59	+0.01	seasonal
LKW050	8.45	6.65	8.32	12.35	-0.07	falling
LKW051	2.96	1.41	2.23	16.19	+0.02	seasonal
LKW052	3.03	1.45	1.49	16.93	-	Limited data
LKW053	1.49	0.68	1.23	1.83	+0.01	seasonal
LKW054	1.54	0.71	1.24	1.86	+0.02	seasonal
MTK007	1.01	0.20	0.64	71.80	-0.02	seasonal
MTK008	3.83	1.96	3.02	52.07	-0.01	seasonal
MTK010	2.39	0.72	2.39	47.61	+0.01	seasonal
MTK011	7.24	5.10	7.24	47.76	-0.02	seasonal
MTK012	11.75	10.30	11.46	58.54	-0.03	falling
MTK013	4.03	2.18	3.23	75.77	-0.01	seasonal
CUM002	3.87	2.16	3.45	61.33	0.00	episodic
CUM003	8.05	6.85	7.72	51.19	-0.05	falling
CUM005	12.85	12.01	12.16	53.07	+0.02	episodic

SWL = Standing Water Level

RSWL = Reduced Standing Water Level, which relates water levels to a common reference point, usually measured in metres above mean sea level

Current SWL and RSWL are taken from the last recorded water levels in Obswell which was in May 2007.

(2) *Wanilla focus catchment (Pope's sub-catchment)*

Obs No	Lowest SWL (m)	Highest SWL (m)	Current SWL (m)	Current RSWL (m)	Trend (m/yr)	Trend Description
WNL074	18.24	16.93	18.01	148.61	-0.06	falling
WNL076	17.33	15.92	17.06	130.70	-0.04	falling
WNL081	3.94	1.17	2.23	132.88	0.00	seasonal
WNL087	0.05	-0.70	-0.59	109.12	+0.01	seasonal
WNL091	1.12	-0.64	0.84	96.27	-0.04	falling
WNL095	3.57	-0.19	1.76	143.99	-0.02	seasonal
WNL098	19.25	15.38	18.75	129.88	-0.20	falling
WNL100	11.10	7.96	10.65	110.52	-0.17	falling
WNL109	4.34	0.50	3.79	106.18	-0.15	falling
WNL113	20.92	17.98	20.80	102.85	-0.17	falling
WNL115	6.61	2.40	6.49	104.69	-0.11	falling
WNL123	6.35	0.37	4.15	221.17	+0.02	episodic

SWL = Standing Water Level

RSWL = Reduced Standing Water Level, which relates water levels to a common reference point, usually measured in metres above mean sea level

Current SWL and RSWL are from the last recorded water levels in Obswell which was in September 2007.

(3) *Toolillie Gully*

Obs No	Lowest SWL (m)	Highest SWL (m)	Current SWL (m)	Current RSWL (m)	Trend (m/yr)	Trend Description
MTK015	-1.82	-2.30	-2.30	182.72	-	Limited data
MTK016	-1.70	-2.15	-2.15	182.57	-	Limited data
KPP003	1.22	0.15	0.15	152.26	-	Limited data
KPP011	1.05	0.77	0.62	151.95	-	Limited data
KPP004	18.41	17.06	18.30	147.76	-	Limited data
KPP005	19.10	18.06	18.34	147.72	-	Limited data
KPP006	1.96	-0.11	1.03	134.42	-	Limited data
KPP007	1.77	-0.11	0.80	134.15	-	Limited data
KPP008	2.42	-0.27	2.42	133.03	-	Limited data

Current SWL and RSWL are for 07/10/2000 when monitoring ceased in the catchment. The exception is KPP003 which is the only bore that is still being monitored after the bushfire and was last monitored in September 2007.

Explanation of Trend Description:

Seasonal = displays winter peaks and summer troughs

Episodic = shows significant sharp rises after major rainfall events / wet seasons followed by a steady recession until the next major wet year

Falling = watertable has an overall falling trend

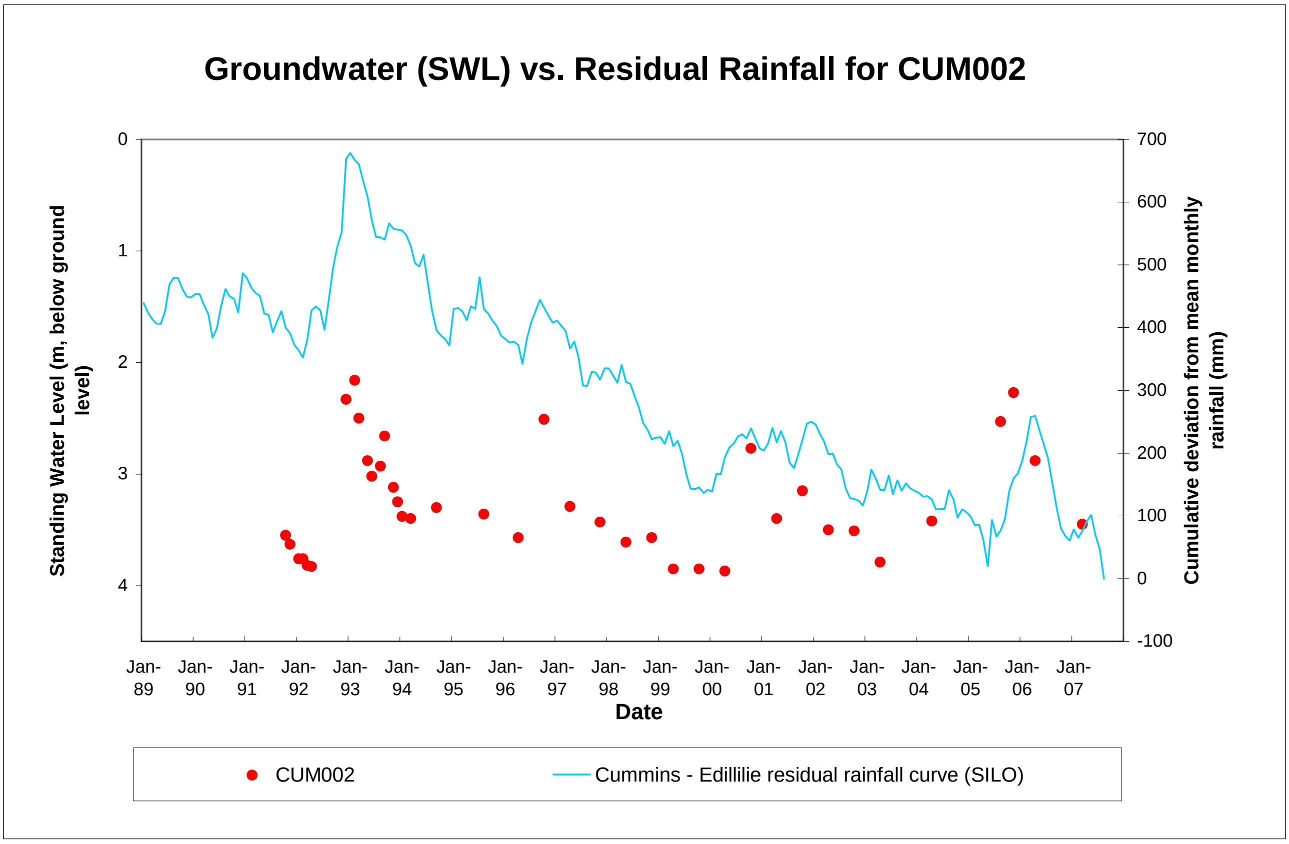
Limited data = not enough data to establish a meaningful trend

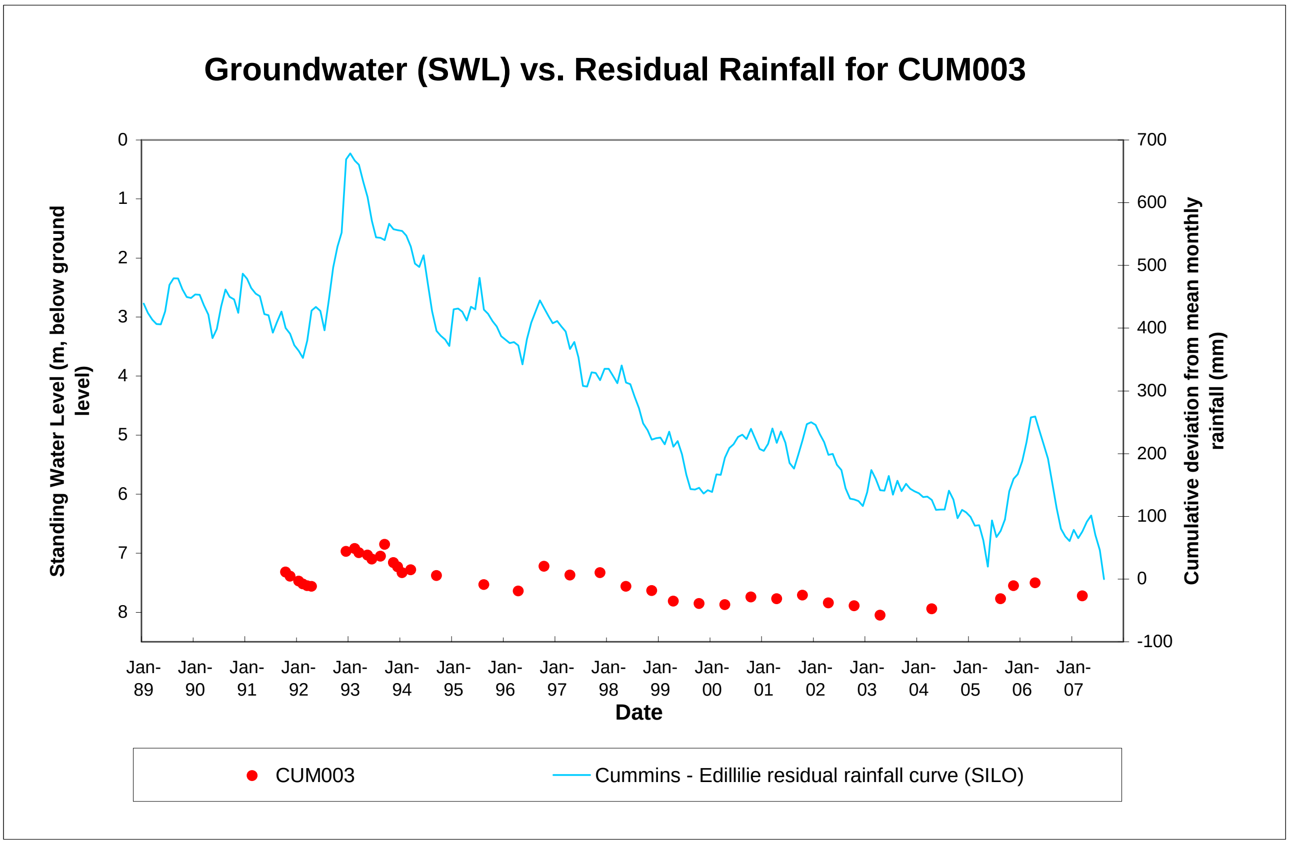
C. HYDROGRAPHS

The following graphs are plots of standing water level (SWL) for groundwater vs. cumulative residual rainfall.

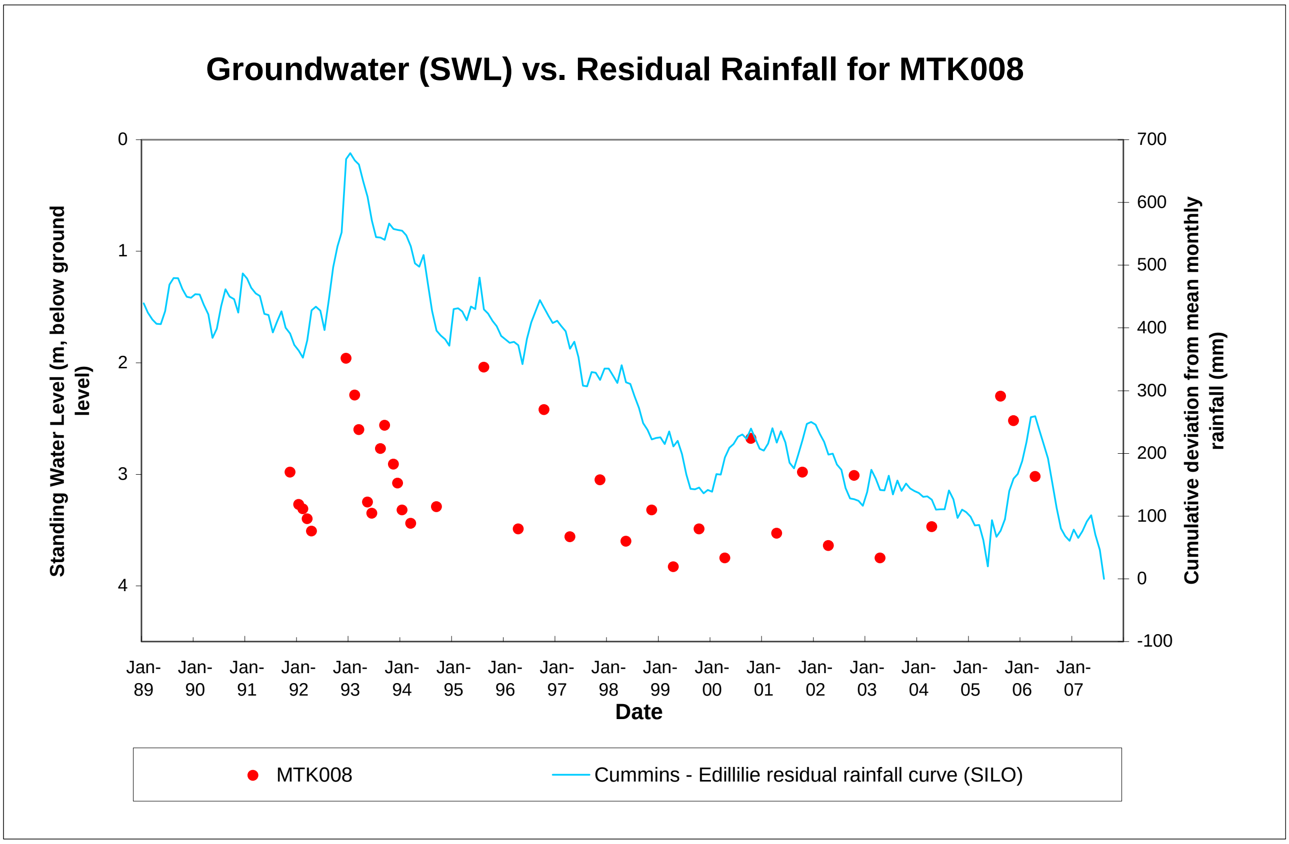
Hydrographs of four control bores located north of the bushfire zone are presented, followed by sites that were all located within the bushfire zone.

Control bores located outside of the bushfire zone

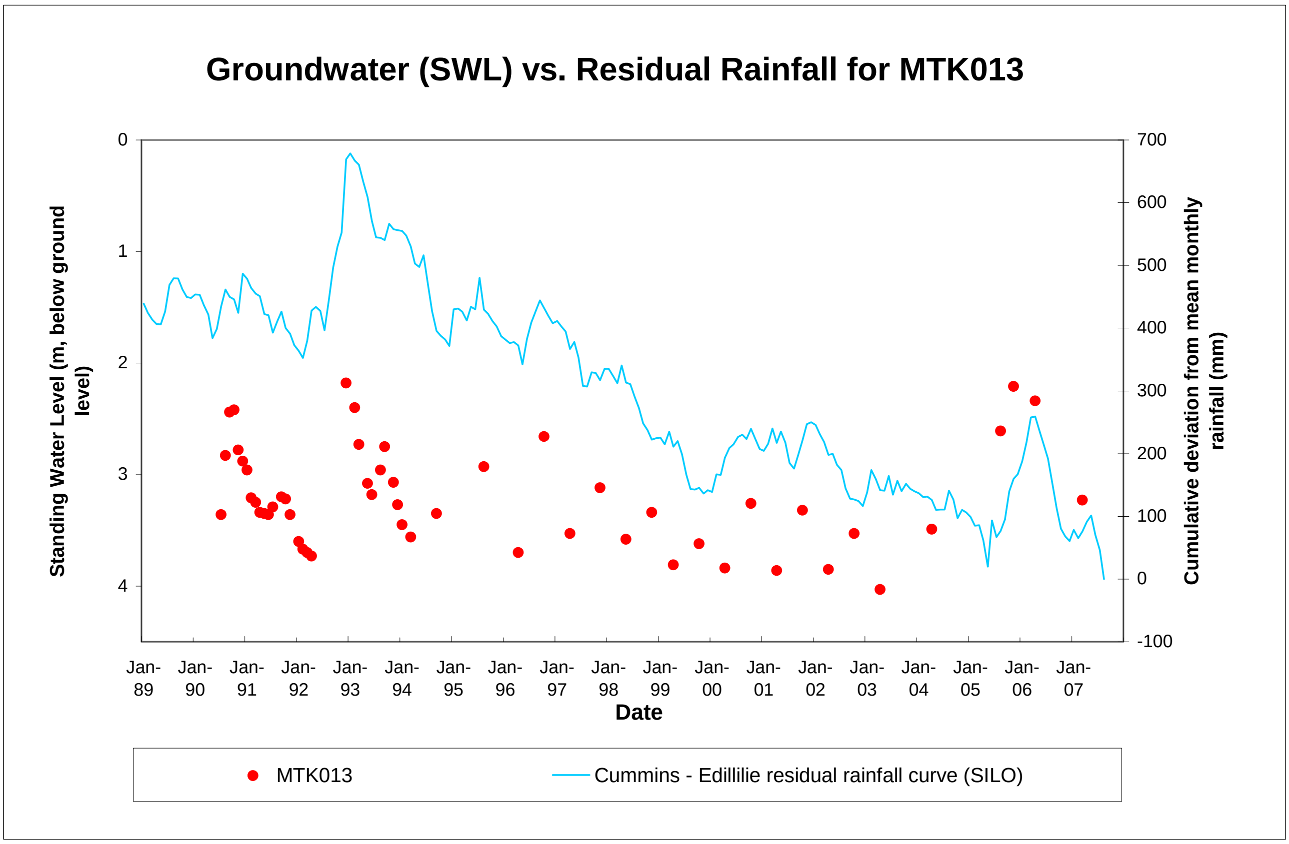




Groundwater (SWL) vs. Residual Rainfall for CUM003
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
1
2
3
4
5
6
7
8
700
600
500
400
300
200
100
0
-100
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
CUM003
Cummins - Edillilie residual rainfall curve (SILO)



Groundwater (SWL) vs. Residual Rainfall for MTK008
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
1
2
3
4
700
600
500
400
300
200
100
0
-100
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
MTK008
Cummins - Edillilie residual rainfall curve (SILO)



Notes:

Sites CUM 2, 3 and MTK 8 are located west of the highway between Edillilie and Cummins and were not impacted by the bushfire. Site MTK 13 is situated near the northern boundary of the bushfire zone.

CUM002

Seasonal peaks and troughs in water level tend to mirror cumulative residual rainfall, but while residual rainfall has shown an overall falling trend since the early 1990s, the overall water level trend has been static. The second highest water level occurred in November 2005 (2.27 m) with the highest peak (2.16 m) occurring in February 1993.

CUM003

Both water level (-0.05 m/yr) and rainfall show an overall decreasing trend since 1993. The significant peak in the rainfall in late 2005 / 2006 is also reflected in the water levels.

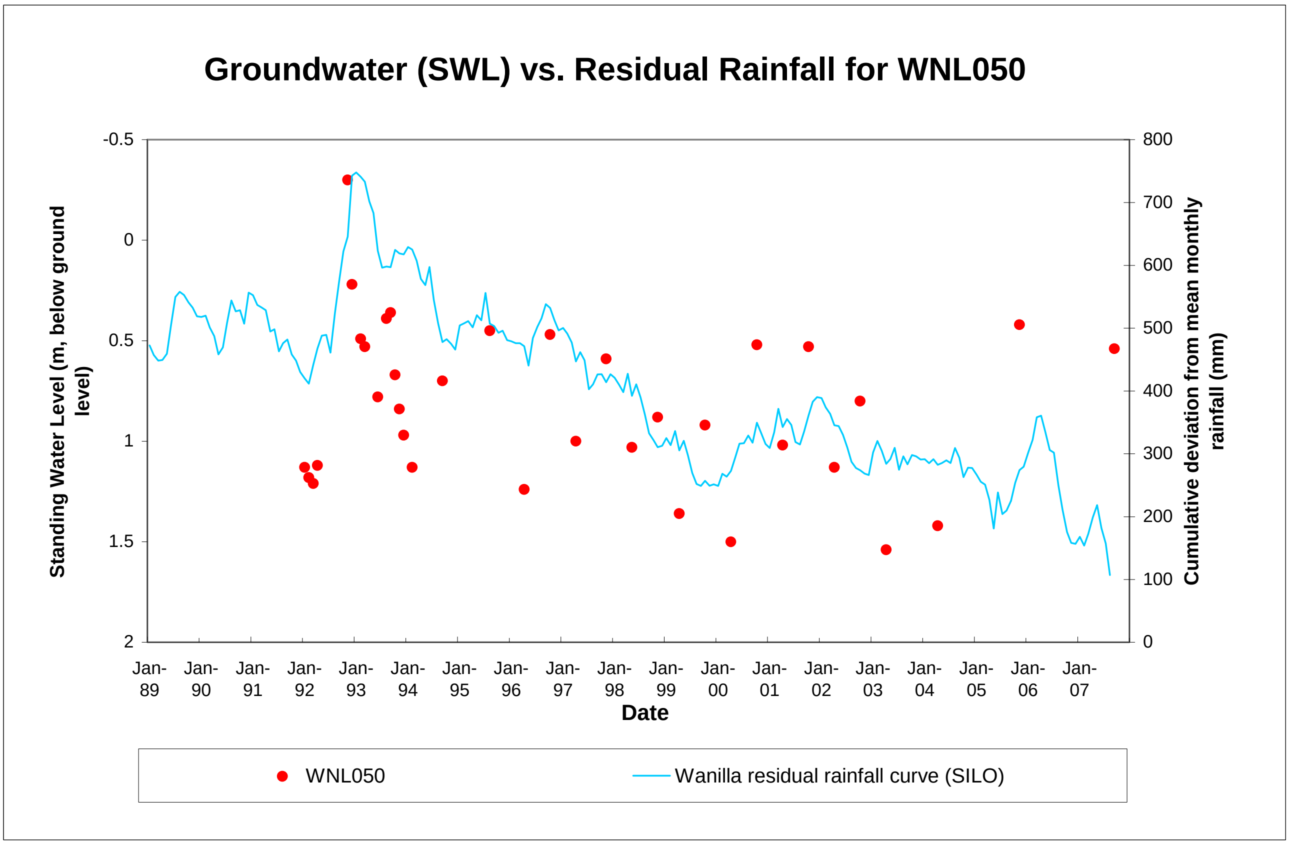
MTK008

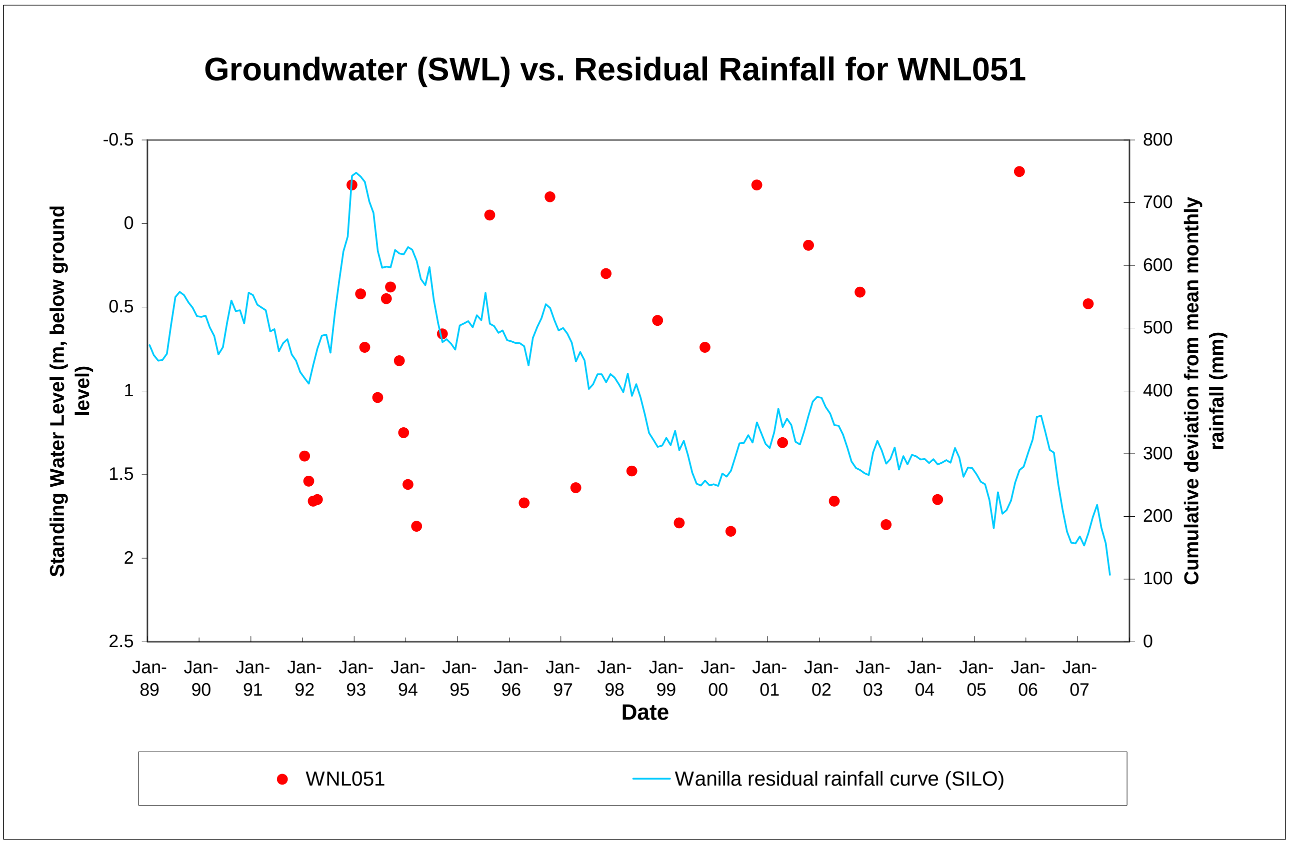
The water level peak in August 2005 (2.30 m) was the third highest on record. The highest water levels occurred in December 1992 (1.96 m) and in August 1995 (2.04 m). The overall water level trend has been essentially static despite a falling rainfall trend.

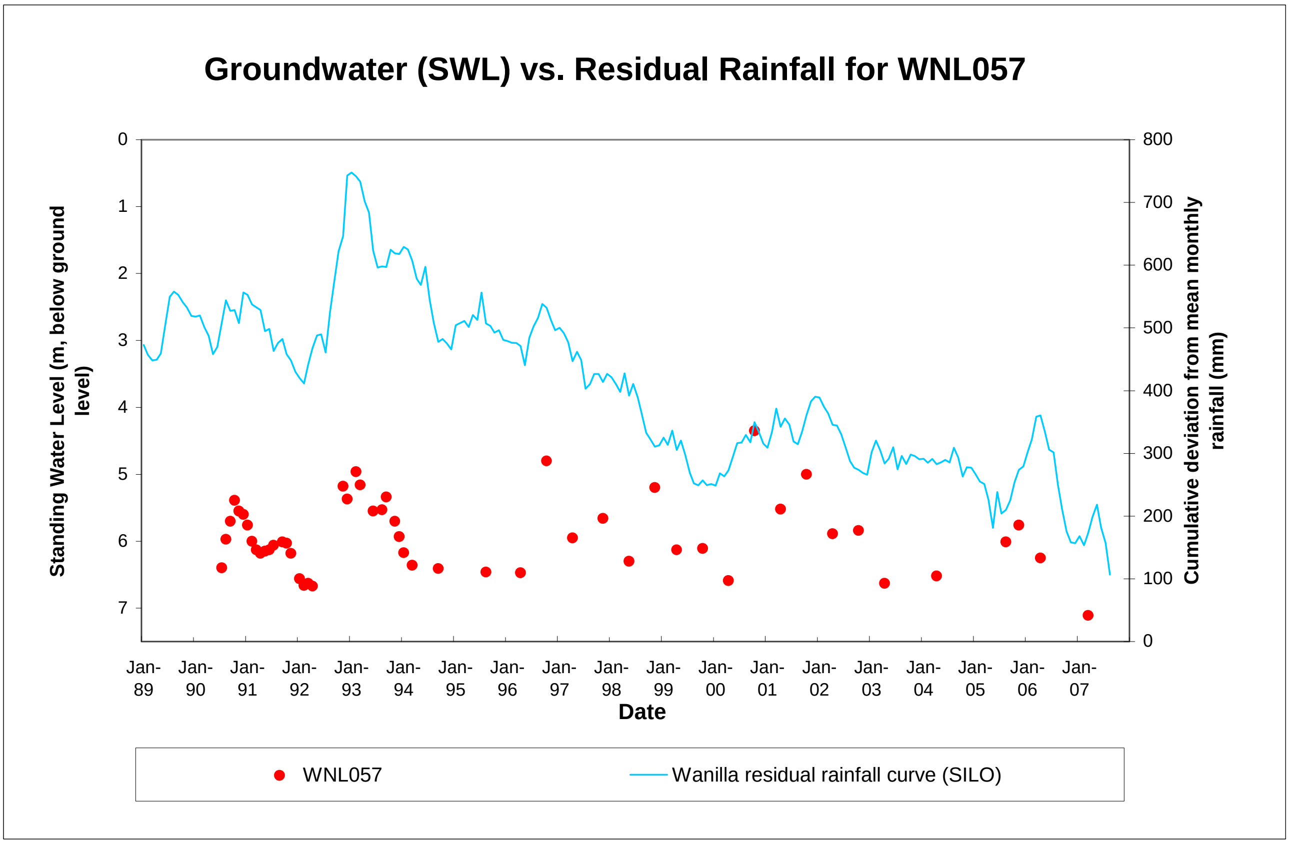
MTK013

Site MTK 13 is located a couple of km east of Edillilie and was near the northern boundary of the bushfire zone. The highest water level peak (2.2 m) occurred in November 2005 matching that of December 1992. The overall water level trend has been static with seasonal peaks and troughs.

Sites located within the bushfire zone




Groundwater (SWL) vs. Residual Rainfall for WNL051
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
-0.5
0
0.5
1
1.5
2
2.5
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
WNL051
Wanilla residual rainfall curve (SILO)


Groundwater (SWL) vs. Residual Rainfall for WNL057
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
1
2
3
4
5
6
7
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
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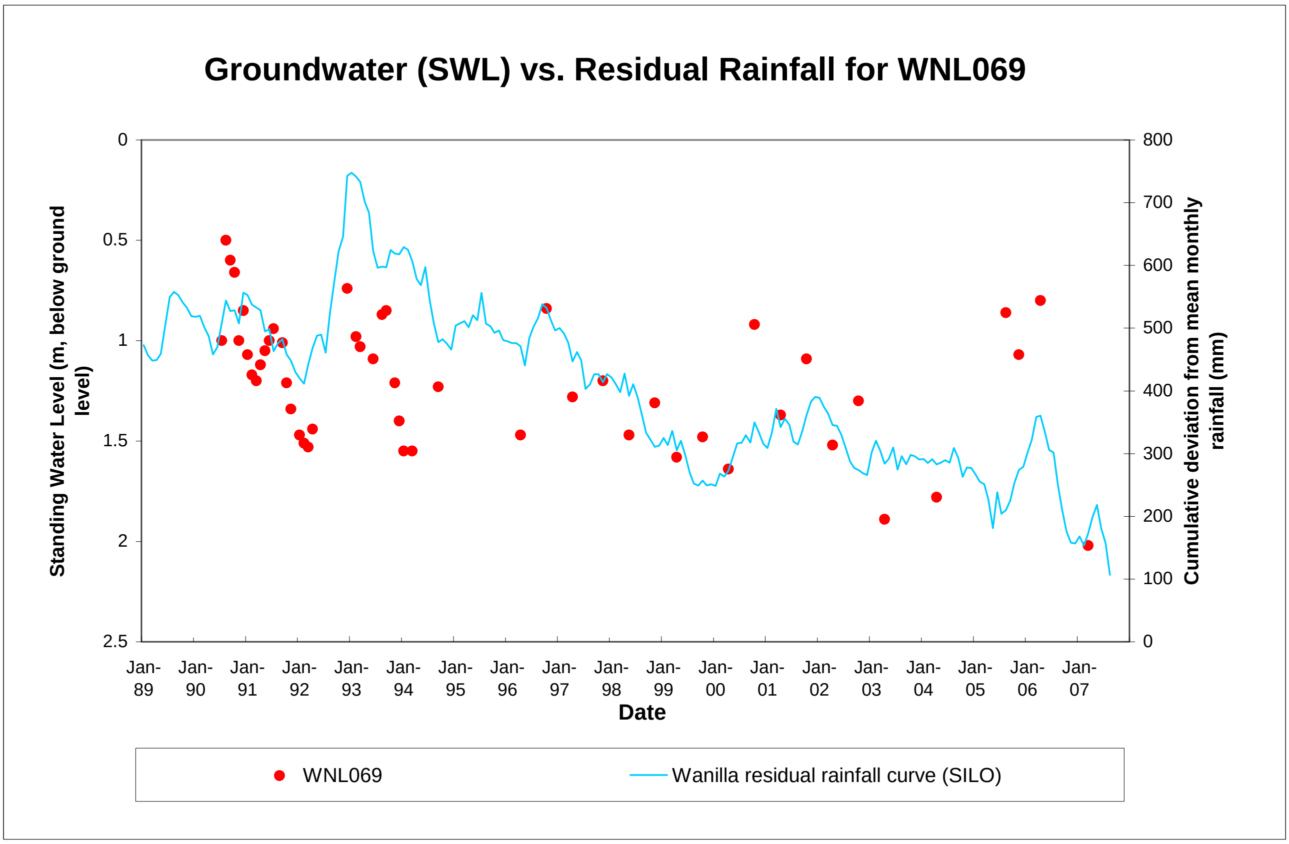
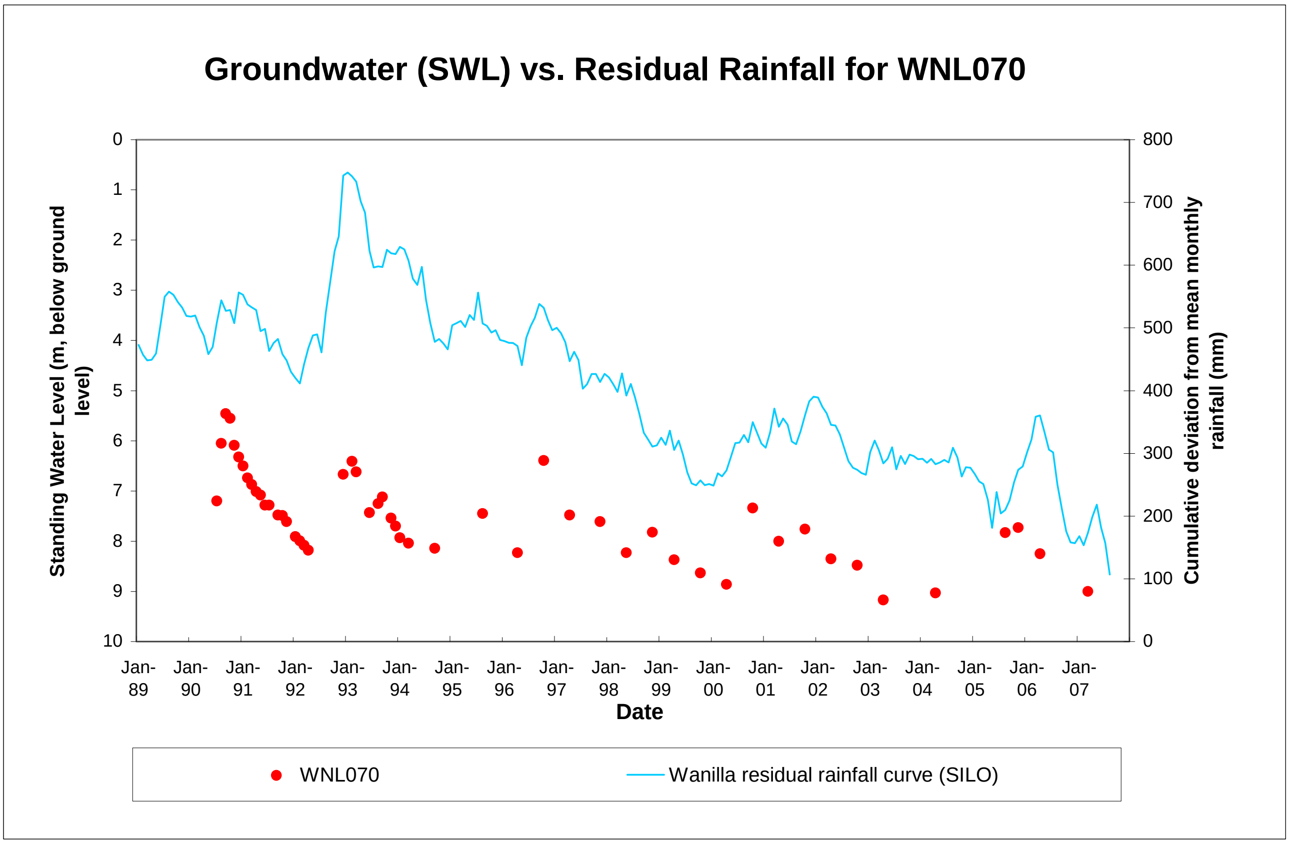
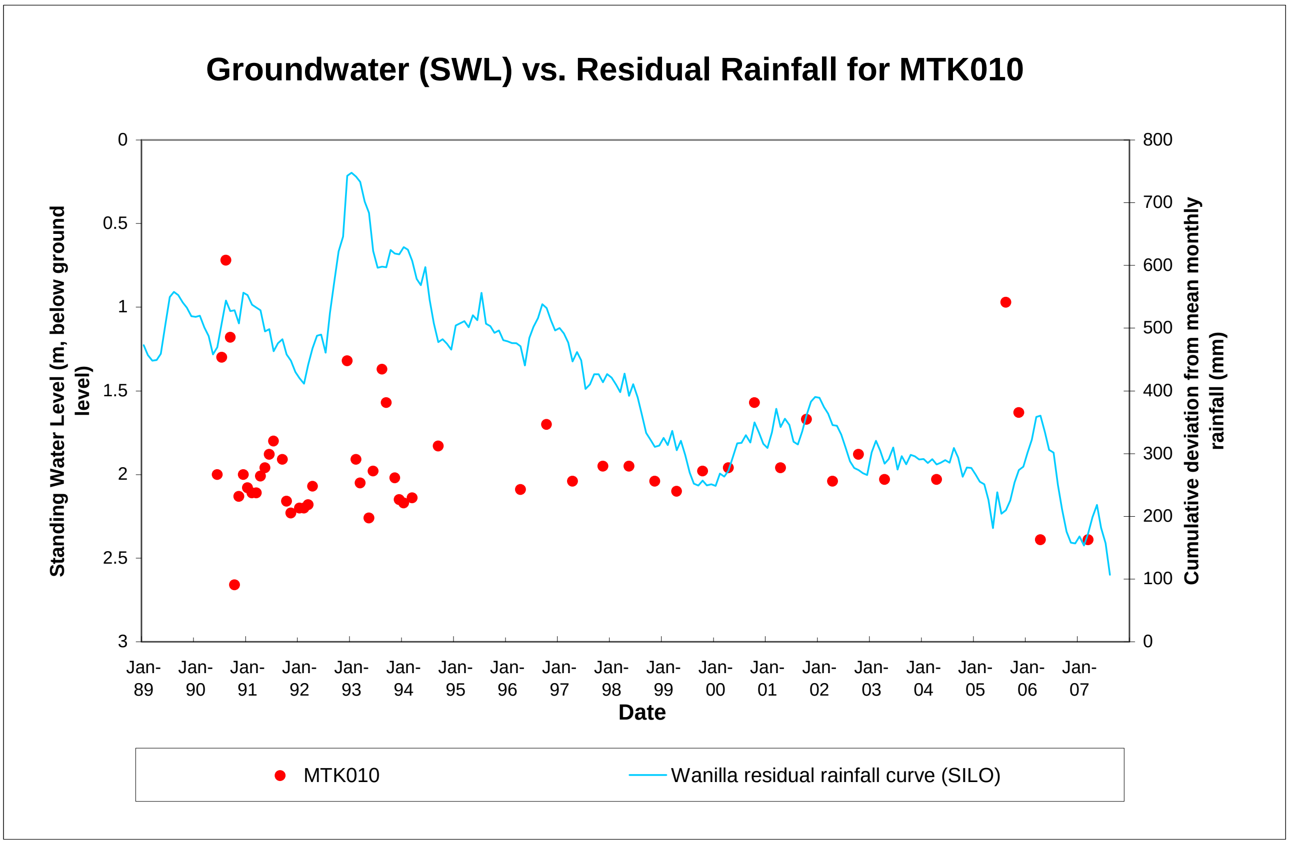
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
WNL057
Wanilla residual rainfall curve (SILO)

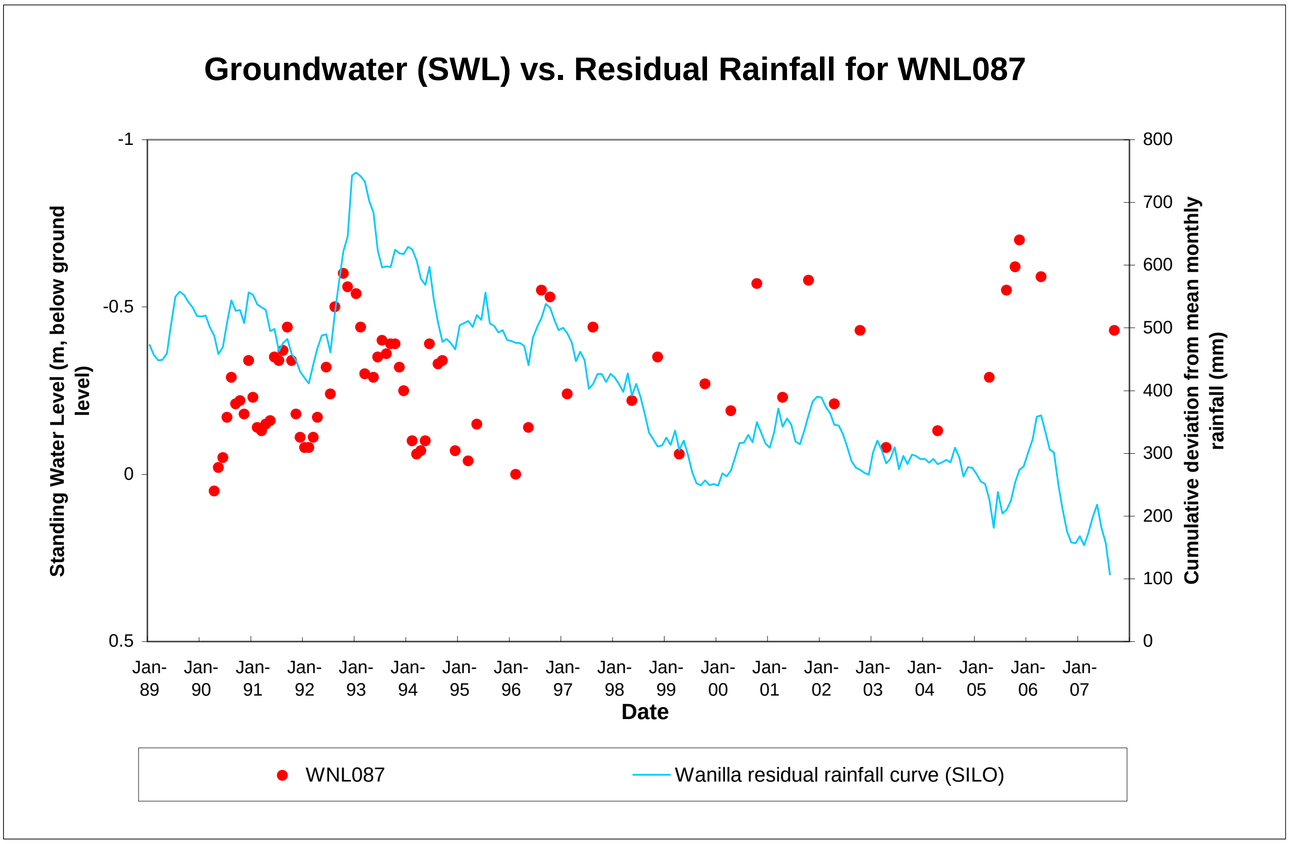


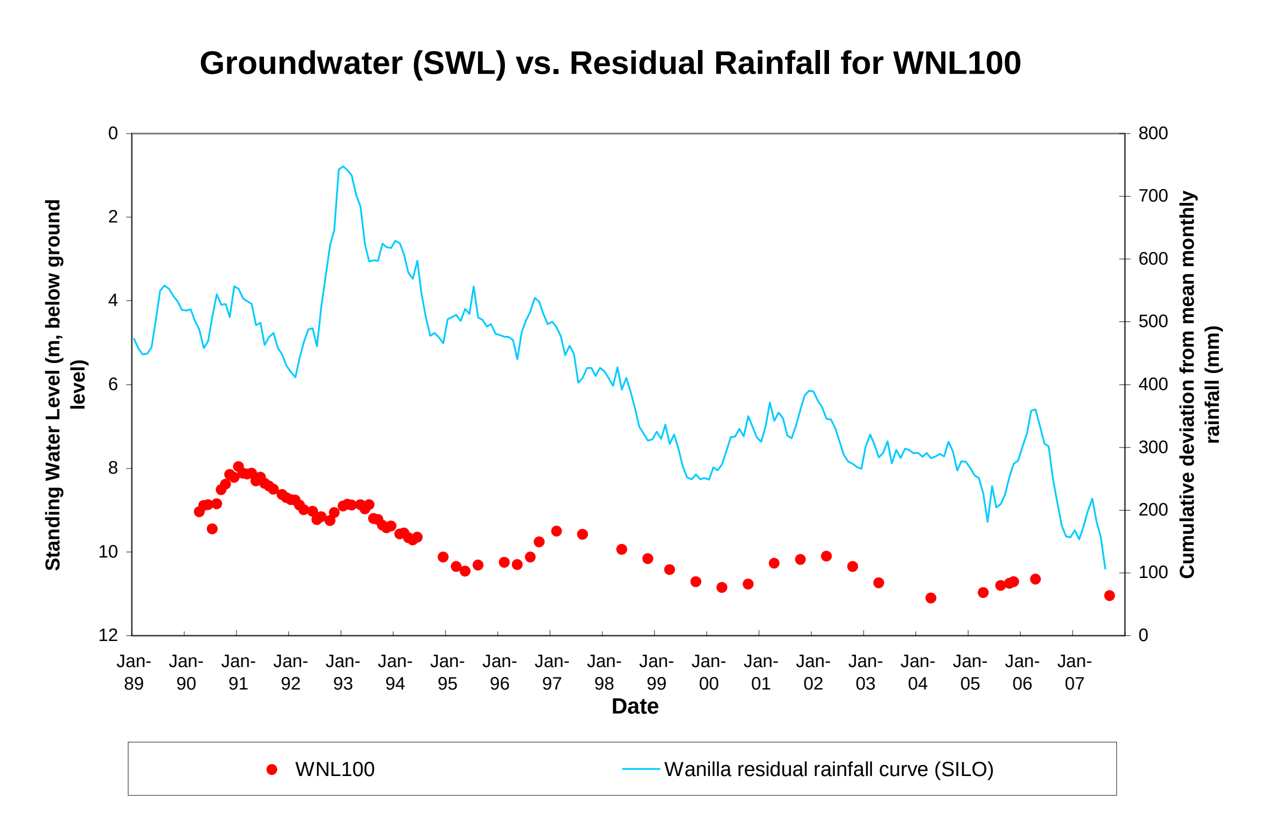
Groundwater (SWL) vs. Residual Rainfall for WNL069
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
0.5
1
1.5
2
2.5
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
WNL069
Wanilla residual rainfall curve (SILO)

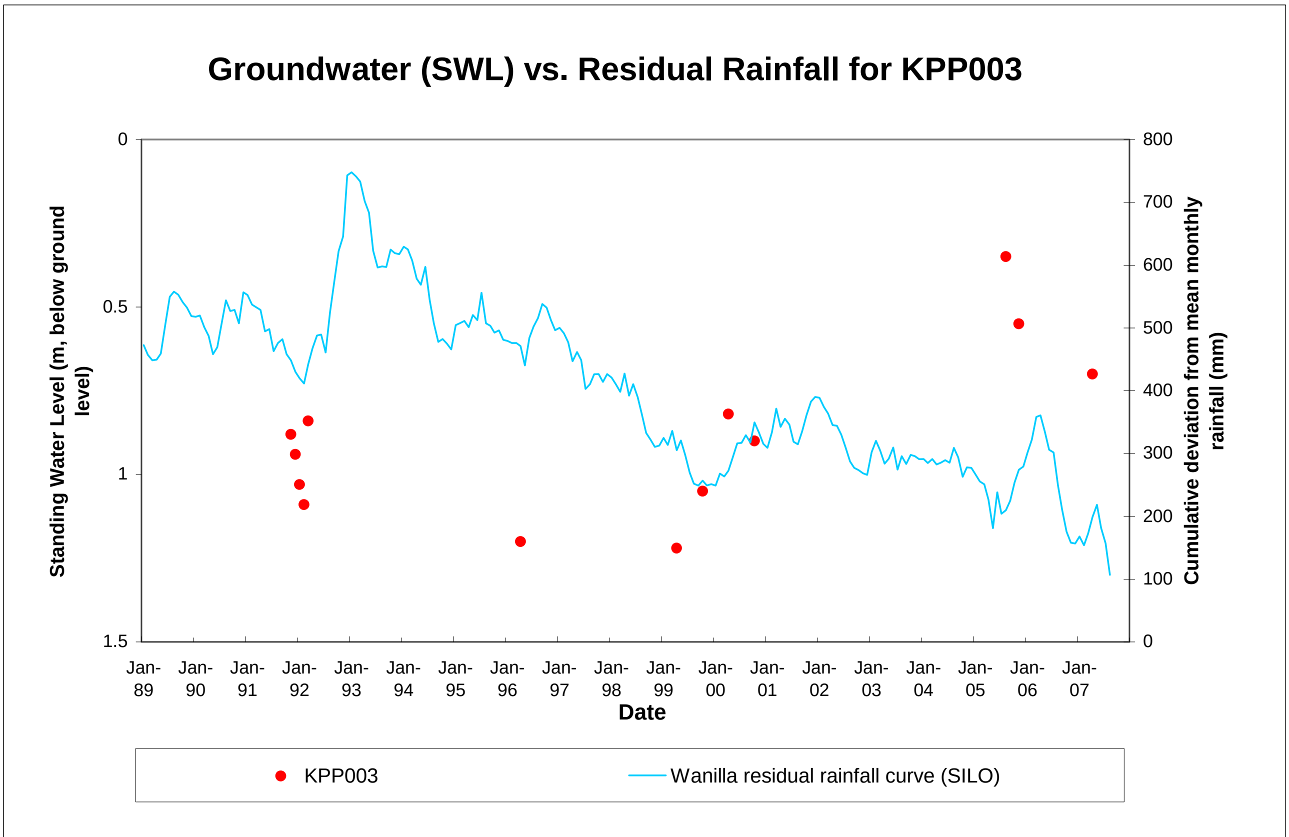


Groundwater (SWL) vs. Residual Rainfall for WNL070
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
1
2
3
4
5
6
7
8
9
10
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
WNL070
Wanilla residual rainfall curve (SILO)


Groundwater (SWL) vs. Residual Rainfall for MTK010
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
0.5
1
1.5
2
2.5
3
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
MTK010
Wanilla residual rainfall curve (SILO)


Groundwater (SWL) vs. Residual Rainfall for WNL087
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
-1
-0.5
0
0.5
800
700
600
500
400
300
200
100
0
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Date
WNL087
Wanilla residual rainfall curve (SILO)


Groundwater (SWL) vs. Residual Rainfall for WNL100
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
2
4
6
8
10
12
800
700
600
500
400
300
200
100
0
Jan-89 Jan-90 Jan-91 Jan-92 Jan-93 Jan-94 Jan-95 Jan-96 Jan-97 Jan-98 Jan-99 Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07
Date
WNL100
Wanilla residual rainfall curve (SILO)


Groundwater (SWL) vs. Residual Rainfall for KPP003
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
0
0.5
1
1.5
800
700
600
500
400
300
200
100
0
Jan-89 Jan-90 Jan-91 Jan-92 Jan-93 Jan-94 Jan-95 Jan-96 Jan-97 Jan-98 Jan-99 Jan-00 Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07
Date
KPP003
Wanilla residual rainfall curve (SILO)

Notes:

The bushfire impacted sites are located in the south eastern part of the Cummins Wanilla Basin, mainly west and south of the town of Wanilla. Site KPP 3 is located in the Tod River catchment.

WNL050

This site is located on the northern entrance track to the Myer farm where salt outbreaks are being observed following destruction of all of the surrounding remnant native vegetation. Groundwater is very shallow (0 - 1.5 m). The overall water level trend has been falling at 0.02 m/yr which reflects the falling rainfall trend. The highest water level peak occurred in November 1992 (-0.30 m above the ground surface).

WNL051

This site is located on the north eastern boundary of the Wanilla Forest which was burnt out. Salinity outbreaks occurred 3 km south east of this site on the Chesher farm. Groundwater is very shallow (0 – 2 m) and shows significant peaks and troughs. The highest peak occurred in November 2005 (-0.31 m above the ground surface). The overall water level trend shows a very slight rise over time (+0.02 m/yr).

WNL057

This bore is located on the NE corner of a large area of scrub that was burnt out. Seasonal peaks and troughs in water level correspond with rainfall, with the highest peak occurring in October 2000 (4.35 m). The overall groundwater trend is static.

WNL069

Groundwater is very shallow at this gully site. Water levels had the highest peak (0.50 m) in August 1990. The overall water level trend has been falling (at -0.02 m/yr) reflecting the rainfall trend.

WNL070

Water level trends closely follow the cumulative residual rainfall with water levels showing an overall falling trend since 1990 (-0.10 m/yr). Water levels peaked at 7.26 m in November 2005, but that is a significantly lower than the peak of 5.46 m in September 1990.

MTK010

There is a static groundwater level trend at this site. The second highest peak in water levels (0.97 m) occurred in August 2005 with the highest being 0.72 m in August 1990. The water level peaked rapidly at this site in response to the very wet June.

WNL087

This site (W6B) is located in a swampy gully in the Wanilla focus catchment. The aquifer is under artesian pressure and groundwater is above the surface. A very slight rising trend (+0.01 m/yr) is observed and water levels reached their highest peak in November 2005 (-0.70 m above the ground surface).

WNL100

This site (W10B) is located on a mid-slope position in the Wanilla focus catchment. Water levels have shown a falling trend (-0.17 m/yr) with seasonal peaks and troughs that closely resemble cumulative residual rainfall.

KPP003

This site is located in the Toolillie Gully and groundwater is very shallow in this area. Unfortunately records are sparse at this site, but indicate that water levels peaked in 2005.

D. MONTHLY RAINFALL FOR 2005

Monthly rainfall data for 2005 is presented for the towns of Edillilie and Wanilla. The bushfire occurred in January and well above average rainfall was experienced across the basin in winter and spring of that year.

Month	Rainfall (mm)	
	Edillilie	Wanilla
January	3.8	1.1
February	0.7	4.0
March	17.7	14.5
April	4.4	8.5
May	10.3	13.56
June	145.0	140.6
July	51.2	54.2
August	76.7	78.3
September	65.2	66.2
October	78.4	64.5
November	41.7	43.6
December	26.0	25.0
Totals	521.1	514.1

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

Shortened forms

~	approximately equal to
bgs	below ground surface
EC	electrical conductivity (µS/cm)
K	hydraulic conductivity (m/d)
pH	acidity
ppm	parts per million

GLOSSARY

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

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

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

Dryland salinity — The process whereby salts stored below the surface of the ground are brought close to the surface by the rising watertable. The accumulation of salt degrades the upper soil profile, with impacts on agriculture, infrastructure and the environment.

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of SA)

EC — Electrical conductivity; 1 EC unit = 1 micro-Siemens 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

ECa — Apparent Electrical Conductivity of bulk soil

EM — Electro-magnetic induction equipment used to measure the soils electrical conductivity

EP — Eyre Peninsula

GFS — Groundwater Flow System

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a bore for storage underground; see also 'underground water'

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

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

Observation bore (or well) — A narrow bore or piezometer whose sole function is to permit water level measurements

Obswell — Observation Well Network is the state repository of groundwater information in SA

Piezometer — A narrow tube, pipe or bore; used for measuring moisture in soil, water levels in an aquifer, or pressure head in a tank, pipeline, etc

PIRSA — Primary Industries and Resources South Australia (Government of South Australia)

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

RSSA — Rural Solutions South Australia (Government of South Australia)

RSWL — Reduced Standing Water Level relates standing water levels to a common reference point, usually measured in metres above mean sea level

Sub-catchment — The area of land determined by topographical features within which rainfall will contribute to run-off at a particular point

SWL —Standing Water Level as recorded in a piezometer or observation bore

TDS — Total dissolved solids, measured in milligrams per litre (mg/L); a measure of water salinity

Tributary — A river or creek that flows into a larger river

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