Decadal analysis of trends in depth to groundwater for dryland salinity areas of SA

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Department of Environment and Natural Resources

Government of South Australia

Executive Summary

Analysis of records held within the Obswell groundwater database has determined a general falling trend in depth to groundwater for a majority of bores in dryland agricultural areas of South Australia (SA). Over the time period from the mid-1990s to 2008, there has been a noticeable:

- decrease in the number of bores exhibiting a rising trend in depth to groundwater
- increase in the number of bores exhibiting a falling trend in depth to groundwater.

This changing pattern in depth to groundwater is strongly linked to rainfall. Over the last two decades, prolonged periods of below-average rainfall have resulted in less recharge and the subsequent increase in falling or stabilising groundwater levels across SA.

The risk that salinity poses to valuable assets in the State has therefore decreased in recent years.

Recommendations for the future management of salinity in SA include:

- more specific analysis of the potential impacts of reduced rainfall and increased variability (climate change) on the extent and severity of salinity
- a refinement of salinity risk analysis for priority assets in SA
- exercising caution when evaluating salinity management initiatives; change in depth to groundwater must be assessed within the context of rainfall trends
- the continued monitoring of nationally consistent salinity indicators, especially depth to groundwater, at identified focus sites.

Acknowledgements

This report has been prepared by Rural Solutions SA. for the South Australian Department of Environment and Natural Resources (DENR), (formerly the Department of Water Land and Biodiversity Conservation).

Thanks to Dr. Anna Dutkiewicz of DENR who initiated this report, and provided valuable input and comment.

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Introduction

Nationally, depth to groundwater is used as a key indicator in land salinity monitoring, and for determining the level of salinity risk threatening valuable natural resources and man-made assets (DAFF 2008).

In South Australia, depth to groundwater measurements have been collected for several decades, with data stored in the state's Obswell database managed by the Department for Water (formerly Department of Water Land and Biodiversity Conservation or DWLBC).

Obswell data relevant to saline areas in the major dryland agricultural regions of SA has been analysed to determine apparent long term trends in depth to groundwater. Where available, reliable groundwater data spanning three decades, from the mid 1980s to the present, has been used.

For selected bores within each of the regions, the relationship between depth to groundwater trends and rainfall trends has also been examined.

Knowledge of trends in depth to groundwater, and their relationship with rainfall trends, helps in the interpretation of past and current expression of dryland salinity, as well as providing a basis for future projections of salinity risk.

This assists in setting future directions for the management and monitoring of dryland salinity in South Australia.

Aims

The specific purpose of this report is to determine, for the major regions of South Australia, the following:

- trends in depth to groundwater from the mid-1980s to the present
- rainfall trends over a corresponding time period
- relationship between depth to groundwater trends and rainfall trends
- resultant implications for management and monitoring of dryland salinity

Methodology

Analysis of depth to groundwater

In South Australia, depth to groundwater data are stored in Obswell, the state's groundwater database. Obswell is maintained by Department for Water (DFW), and is accessible through the Obswell website (https://obswell.pir.sa.gov.au/new/obsWell/MainMenu/menu).

Groundwater readings in Obswell include those obtained from focus sites dedicated to the monitoring of land salinity (salinity in dryland agricultural areas). DWLBC (2008a, 2008b, 2008c, 2009a and 2009b) has previously reported on the SA salinity focus site network, and detailed salinity/depth to groundwater trend results for each site.

Similarly, Obswell data has been used for several specific analyses of groundwater trends in SA, including in the Upper South East (DWLBC, 2006), within the Northern Adelaide Plains (Henschke and Wright, 2007), and in the SA MDB region (Barnett, 2008). Trend information from these studies has been incorporated into this report.

The detailed trend analysis used in the recent SA reports, was adopted for this study. The analysis method aimed to provide a fit-for-purpose regional approach, that incorporated some methods utilised by George et al (2008) in WA, and Reid et al (2008) in Victoria.

An analysis of depth to groundwater trends was undertaken for six natural resource management (NRM) regions of South Australia; Eyre Peninsula (EP), Northern and Yorke (N&Y), Kangaroo Island (KI), Adelaide and Mt Lofty Ranges (AMLR), SA Murray Darling Basin (SAMDB) and the Upper South East (SE). For ease of presentation, the SE and SAMDB regions have been combined.

Groundwater monitoring records from over 600 wells were chosen for analysis on the basis of 1) length and frequency of record 2) geographical spread of the wells over the six regions, and 3) their relevance to dryland salinity monitoring (wells directly influenced by irrigation pumping/application were discarded).

Trends in depth to groundwater for the 600 wells were calculated using a linear trend function (line of best fit) over three separate decades (pre 1990, 1990-2000, and post 2000). A similar decadal analysis approach was applied by George et al (2008) in Western Australia. For SA, it was considered that a decadal analysis largely corresponded with known major recharge events in the state, and would provide robust trend data when interpreted within the context of the previous more detailed studies.

Trends within each decadal period were then categorised as rising, falling or stable. For the stable category, a sensitivity analysis was undertaken, with +/- 0.05 m deemed to adequately encapsulate known stable bores and align with the recommended accuracy level (+/-0.05 m) for monitoring depth to groundwater (CA, 2008).

For each region, the total number of bores with rising, falling or stable trends were compared on a decade by decade basis, and the percentage of bores in each trend category was then compared across decades. Comparisons across regions helped to determine the existence, or otherwise, of a state-wide pattern of variation in depth to groundwater over time.

Thirty hydrographs were selected to represent the rising, falling and stable trends in depth to groundwater evident in each region, and they are attached in Appendix A. These hydrographs also contain a residual rainfall curve, used to help determine the influence of rainfall trends on depth to groundwater trends (discussed in Section 2.2).

Appendix B contains a listing of the Obswell networks within each region, including the number of wells contained in each network. While Obswell contains groundwater records for over 10,000 wells, the vast majority were established for the purpose of monitoring irrigation and water resource areas, with only a small proportion dedicated to the monitoring of dryland salinity.

Detailed analysis of groundwater trends in the Upper South East (USE) Dryland Salinity and Flood Management Program area has already occurred (DWLBC, 2006). Similarly, a recent detailed review of shallow watertable trends in the Northern Adelaide Plains area has been undertaken (Henschke and Wright, 2007). Therefore, monitoring bore results from these sub-regions were not included in the current analysis, but the trend information relevant to dryland salinity has been incorporated into the discussion in this report.

Analysis of rainfall

For each monitoring bore selected for analysis, a residual rainfall curve was plotted for the time period corresponding to the depth to groundwater records. Rainfall data was taken from SILO Data Drill, accessible from the Bureau of Meteorology website (www.bom.gov.au). This rainfall is not observed data, but is obtained by linear interpolation from surrounding rainfall stations.

The residual rainfall curve (cumulative deviation from mean monthly rainfall) captures the running total of the difference between actual rainfall and average rainfall from the first to the last rainfall reading over the study period. A generally rising curve represents periods of above-average rainfall, with a falling curve representing periods receiving below-average rainfall.

By plotting the residual rainfall curve on hydrographs, comparison of depth to groundwater (standing water level or SWL) and rainfall trends were undertaken for the selected bores. For example, in Figure 1, the depth to groundwater trend is classified as stable (at -0.02 m/yr) over the decade of the 1990s. Rainfall over this period has been average to above average, with a very wet period early in the decade (signified by the steep sustained rise in the residual rainfall curve). Corresponding with this wet period is a recharge peak in the depth to groundwater plot.

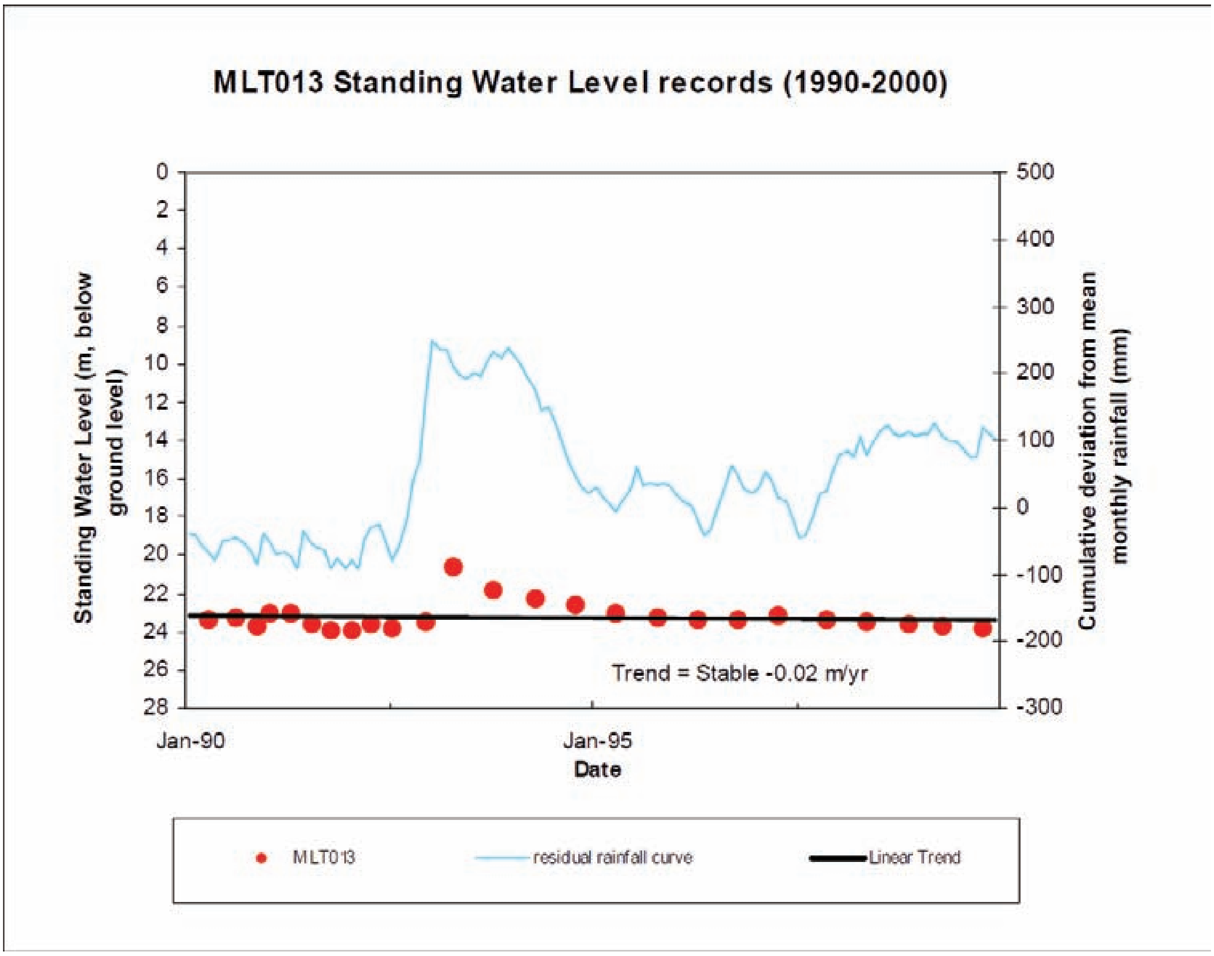


Figure 1. **Hydrograph (with residual rainfall curve) where the depth to groundwater (SWL) trend of -0.02 m/yr is classified as stable**

The analysis of the impact of rainfall patterns on depth to groundwater trends also considered contextual factors such as depth of bores and depth to groundwater, bore position in the landscape, the type of groundwater flow system (local, intermediate or regional), and surrounding land use/land management change over time.

Groundwater flow systems (GFS) and other background information associated with land salinity monitoring within each of the regions are described in a series of saltland snapshot factsheets (DWLBC 2008a, 2008b, 2008c, 2009a and 2009b).

Results

Eyre Peninsula NRM Region

Obswell contains data from sixteen groundwater monitoring networks on Eyre Peninsula (Appendix B). Several networks were established predominately for the monitoring of dryland salinity; Cowell and Darke Peak in the north east, and Cummins, Tod River and Wanilla in the south. Bores with reliable monitoring records were identified, and their trends in depth to groundwater were calculated on a decadal basis (Table 1 and Figure 2).

Table 1: Summary of groundwater trends on EP

Monitoring period	Total number of bores analysed	Percentage of bores (no of bores)		
		Rising	Falling	Stable
1986 - 1990	**20**	**85 (17)**	**5 (1)**	**10 (2)**
1990 - 2000	**124**	**31 (39)**	**40 (49)**	**29 (36)**
2000 - 2008	**116**	**24 (28)**	**48 (56)**	**28 (32)**

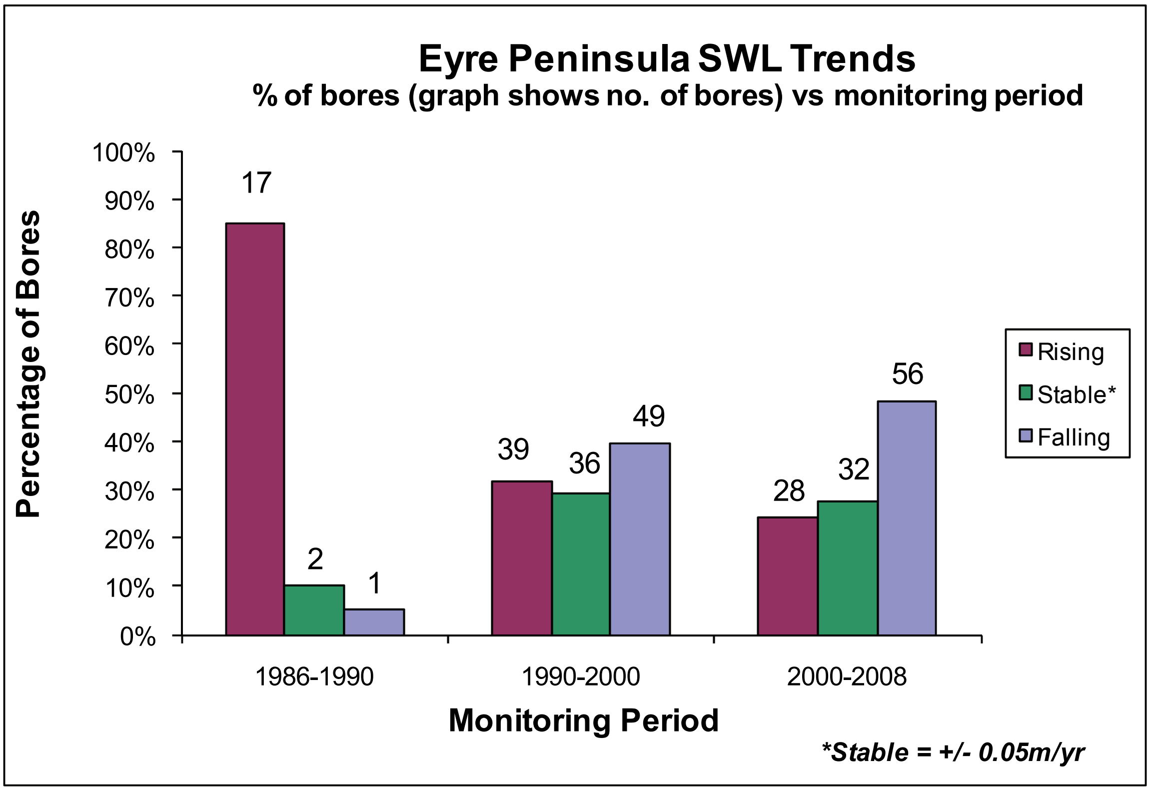


Figure 2. Groundwater trends on EP

Figure 3 shows the location of the selected bores, and illustrates the change observed from 1986 to 2008. There has been a decrease in the number of bores showing a rising trend (red up arrows) in depth to groundwater, and an increase in the number of bores with stable (green) or falling trends (blue down arrows). Example hydrographs for rising, falling and stable trends in bores on EP are attached in Appendix A.

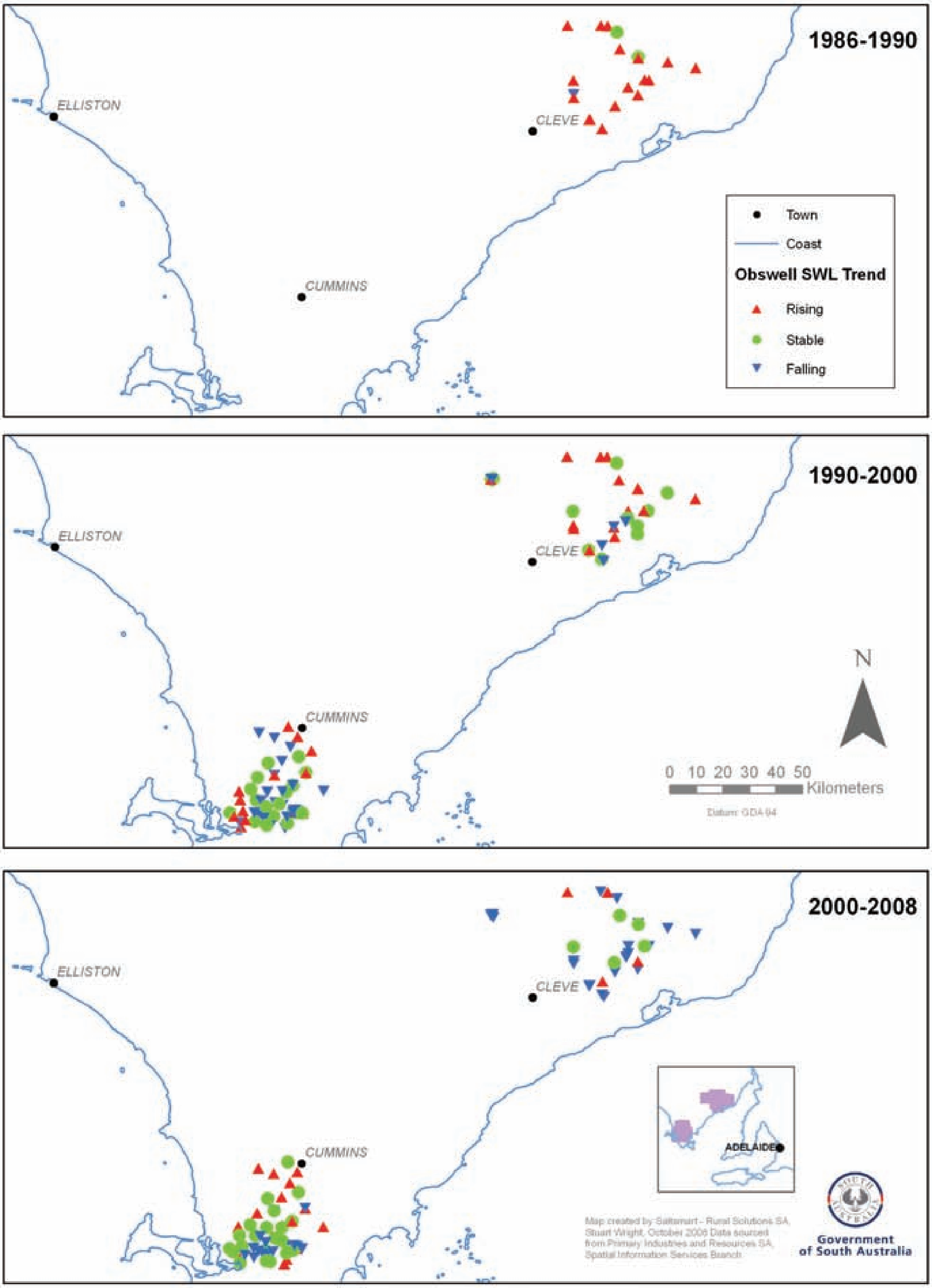


Figure 3. **Comparison of EP groundwater trends over 3 decades (note that no monitoring networks existed in the Cummins area in 1986-1990)**

Northern and Yorke NRM Region

For the Northern and Yorke region, there are 16 groundwater monitoring networks represented in Obswell (Appendix B). Over 200 bores with reliable and consistent monitoring records were selected and analysed for depth to groundwater trends (Table 2 and Figure 4). In 1986-1990 the only monitoring networks were in the Clare area.

Table 2: Summary of groundwater trends in the N&Y region

Monitoring period	Total number of bores analysed	Percentage of bores (no. of bores)		
		Rising	Falling	Stable
1986 - 1990	29	48 (14)	45 (13)	7 (2)
1990 - 2000	215	15 (31)	65 (150)	20 (43)
2000 - 2008	226	8 (18)	87 (197)	5 (11)

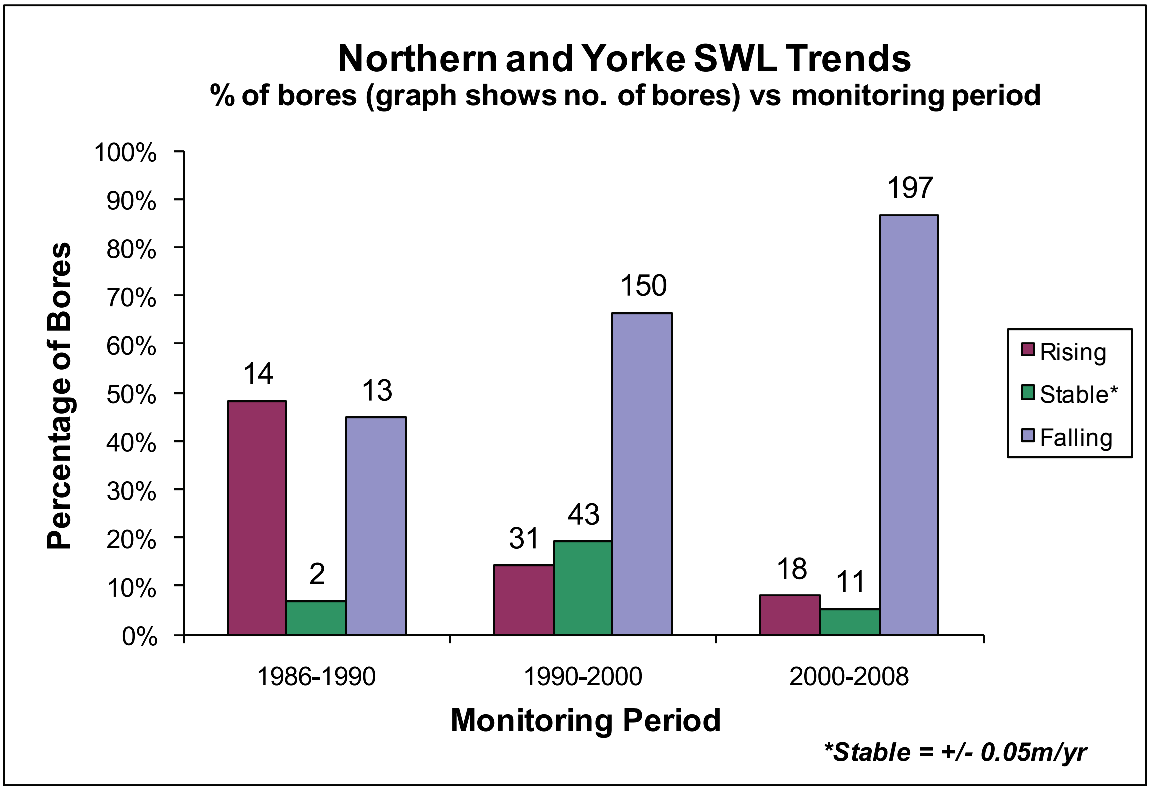


Figure 4. Groundwater trends in the N&Y region

Figure 5 shows the location of selected bores, and illustrates the change observed from 1986 to 2008. Since the 1990s, there has been a decrease in the number of bores showing a rising trend in depth to groundwater, and an increase in the number of bores with falling trends, especially in the dryland bores clustered around the Clare district. Example hydrographs for rising, falling and stable trends in bores in the N&Y region are attached in Appendix A.

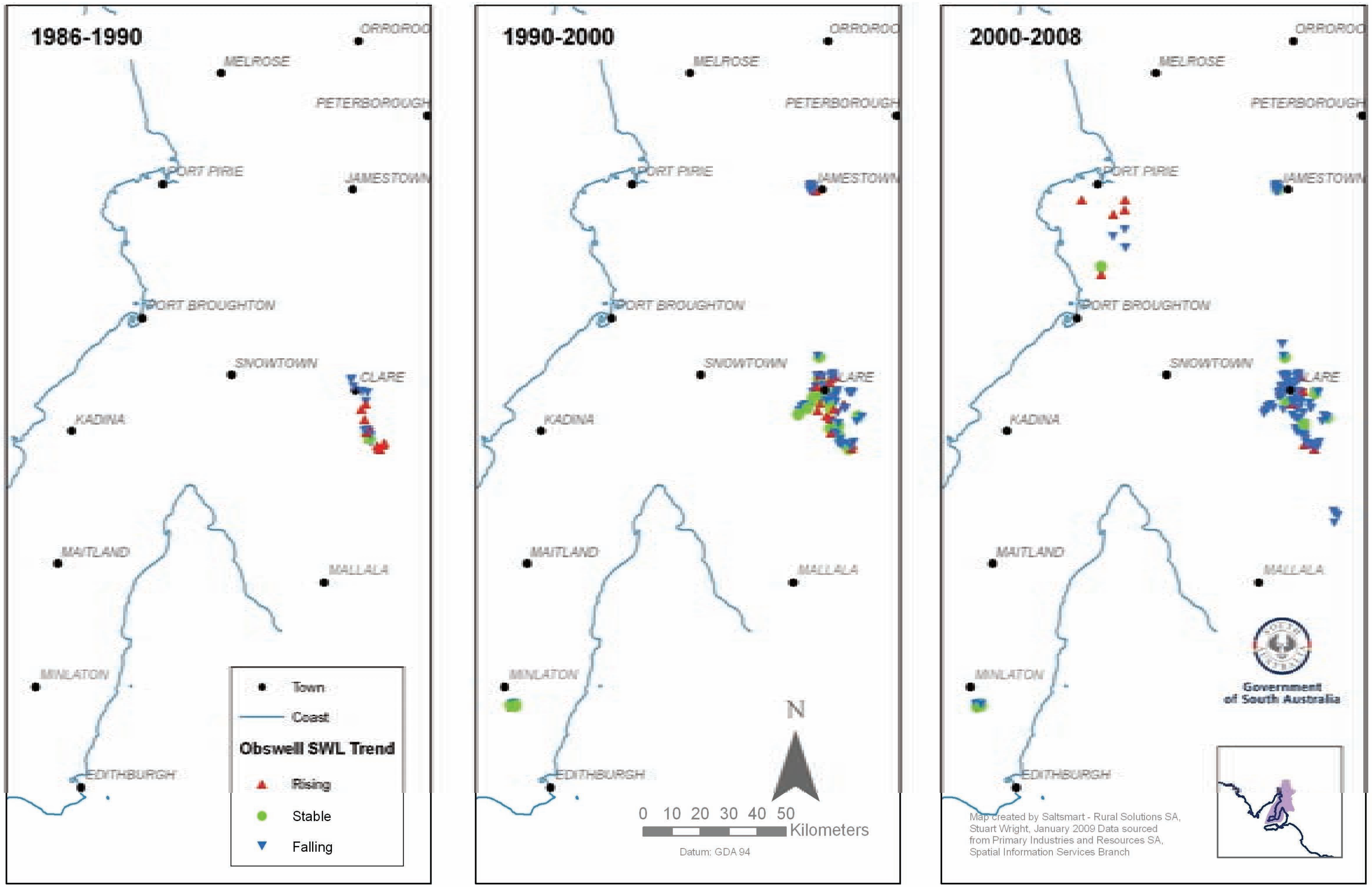


Figure 5. **Comparison of N&Y groundwater trends over 3 decades**

Kangaroo Island NRM Region

For Kangaroo Island, there are 7 groundwater monitoring networks in Obswell, with depth to groundwater data (Appendix B). There were no bores with reliable and consistent records pre-dating 1990, but around 100 bores were suitable for trend analysis for the decades of the 1990s and 2000s. Results of the trend analysis are shown in Table 3 and Figure 6.

Table 3: Summary of groundwater trends on KI

Monitoring period	Total number of bores analysed	Percentage of bores (no. of bores)		
		Rising	Falling	Stable
1980 - 1990	0	-	-	-
1990 - 2000	87	22 (19)	41 (36)	37 (32)
2000 - 2008	120	10 (12)	75 (90)	15 (18)

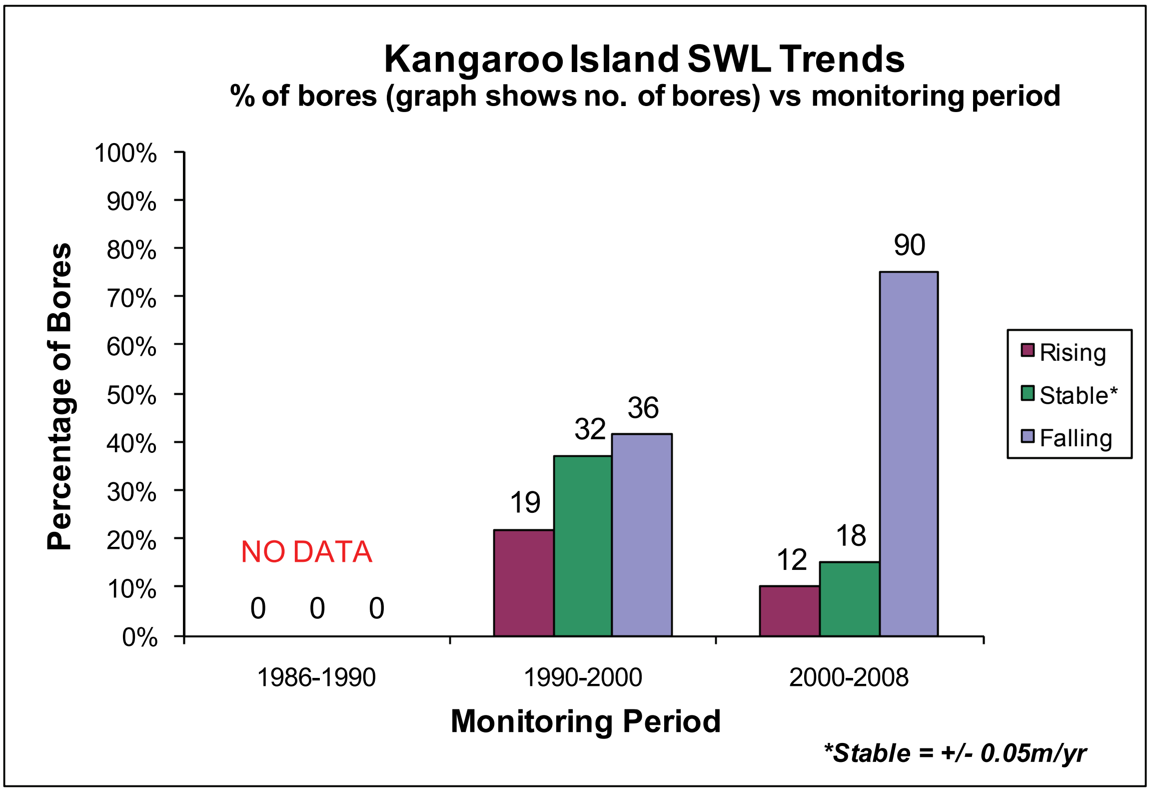


Figure 6. Groundwater trends on KI

Trend results for KI were similar to those from the EP and N&Y regions, with a decrease in the number of bores showing a rising trend in depth to groundwater, and an increase in the number of bores with falling trends. Figure 7 spatially represents the change in groundwater trends evident on KI from 1990 to 2008. Example hydrographs for rising, falling and stable trends on KI are attached in Appendix A.

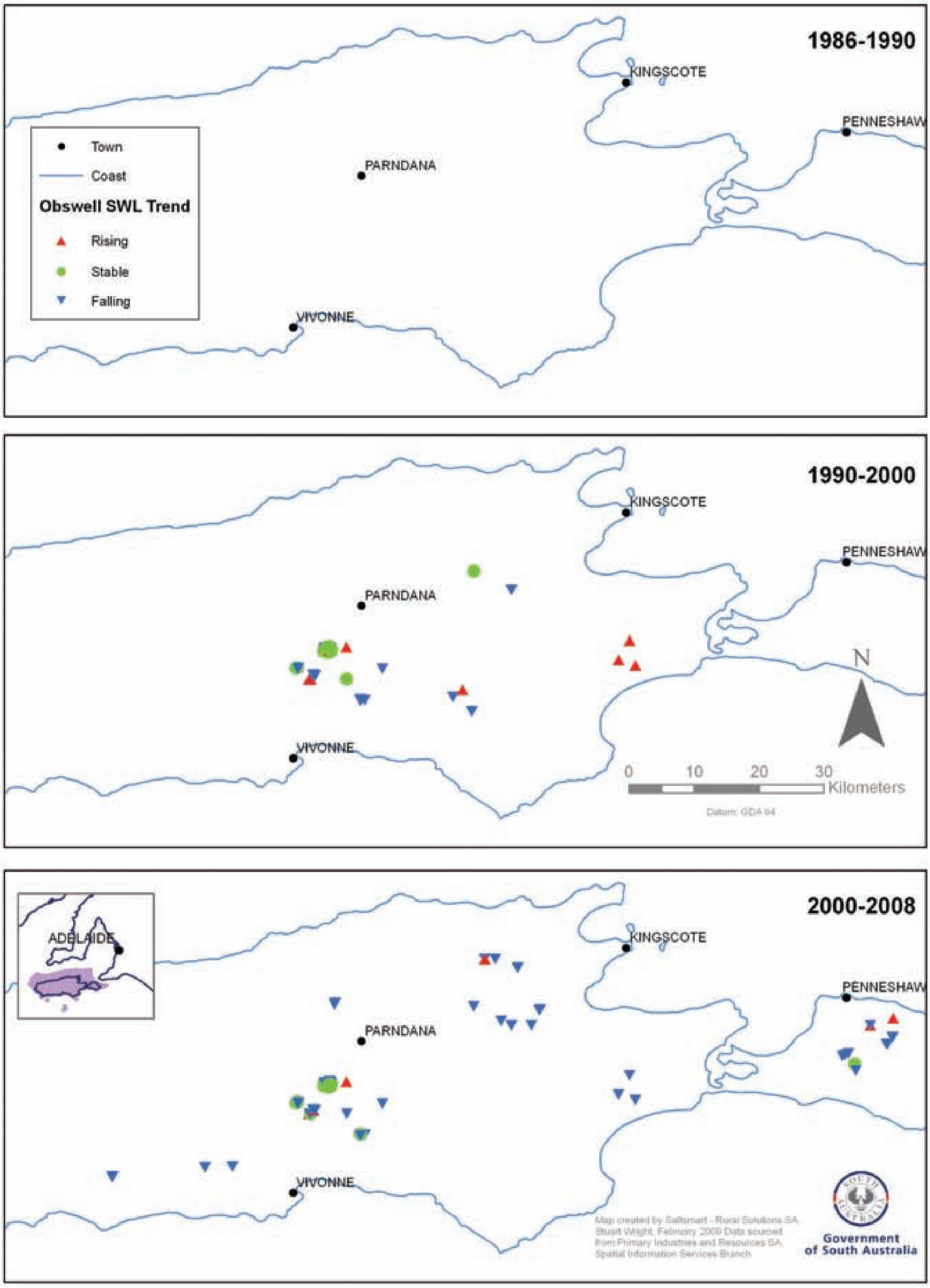


Figure 7. **Comparison of KI groundwater trends over 2 decades (no data pre-1990)**

Adelaide and Mt Lofty Ranges NRM Region

For the AMLR region, there are 26 groundwater monitoring networks in the Obswell database (Appendix B). Bores with reliable long term records were selected for dryland areas where some risk of salinity existed. Results from the analysis of depth to groundwater trends for the region are given in Table 4 and Figure 8.

Table 4: Summary of groundwater trends in the AMLR region

Monitoring period	Total number of bores analysed	Percentage of bores (number of bores)		
		Rising	Falling	Stable
1980 - 1990	23	52 (12)	39 (9)	9 (2)
1990 - 2000	76	16 (12)	59 (45)	25 (19)
2000 - 2008	114	14 (16)	54 (61)	32 (36)

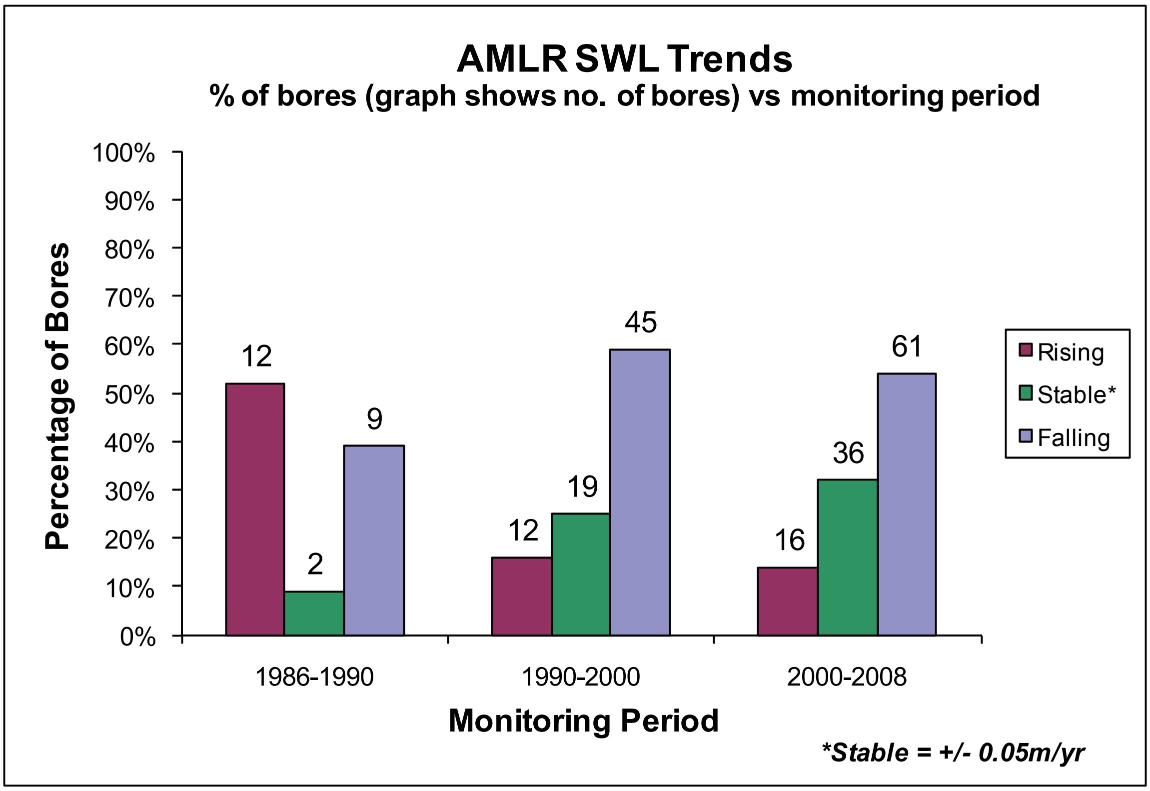


Figure 8. Groundwater trends in the AMLR region

Since the 1990s, depth to groundwater analysis results show a decrease over time in the number of bores with a rising trend, with an increase in the number of bores with falling/stable trends. The location of bores used in the analysis is shown in Figure 9, along with a spatial representation of the changing trends over time. Example hydrographs for rising, falling and stable trends in the AMLR region are attached in Appendix A.

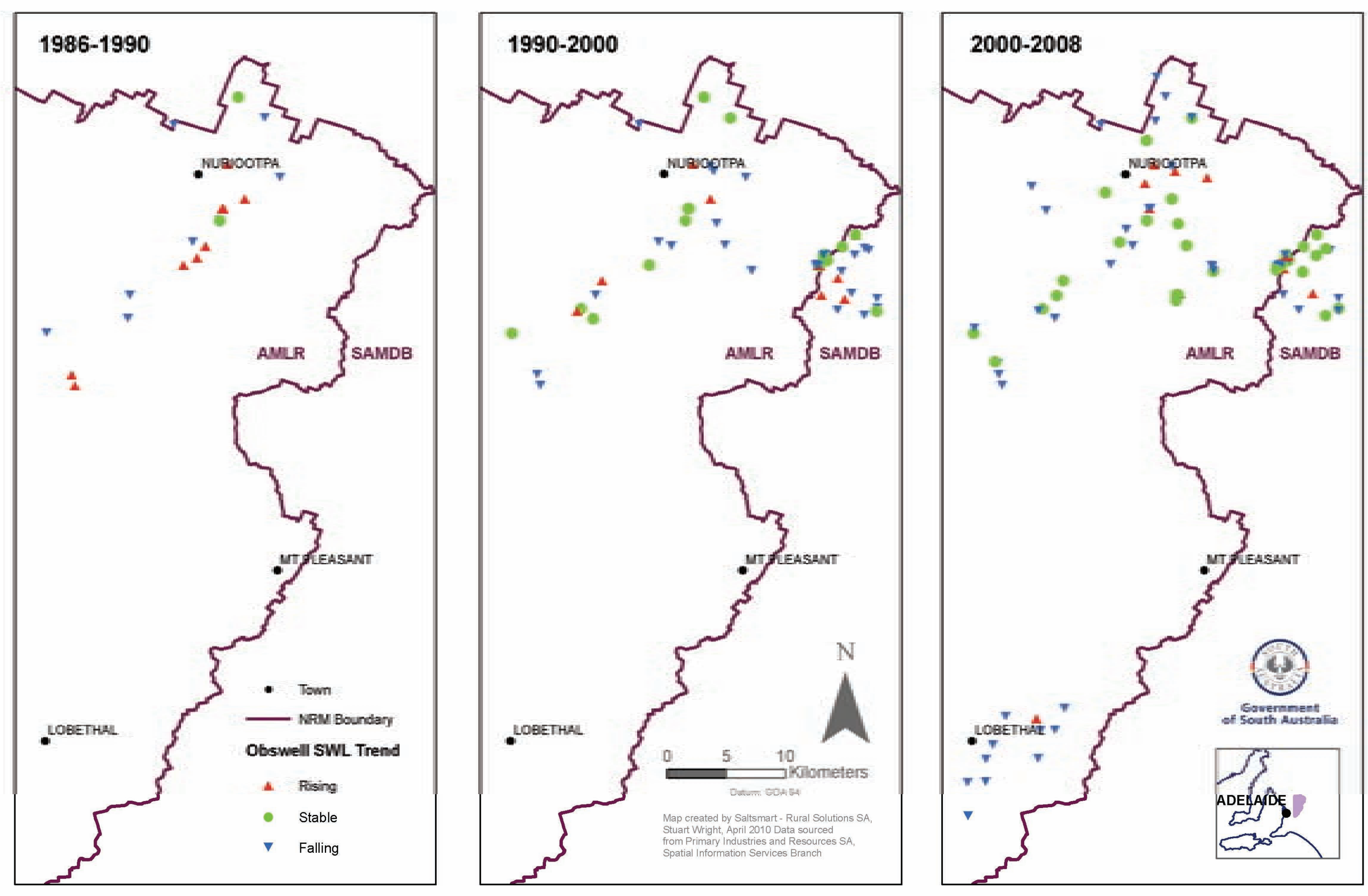


Figure 9. **Comparison of AMLR groundwater trends over 3 decades**

SA Murray Darling Basin and South East NRM Regions

Obswell contains 55 groundwater monitoring networks for the SAMDB region, and 25 networks for the SE region (Appendix B). Many bores in the SAMDB region are located within River Murray irrigation areas, while the SE region contains a dedicated monitoring network for the Upper South East Dryland Salinity and Flood Management Program. Bores that were influenced by irrigation were not included in the analysis. Results from analysis of depth to groundwater trends for selected bores in the combined regions are given in Table 5 and Figure 10.

Table 5: Summary of groundwater trends for the combined SAMDB & SE regions

Monitoring period	Total number of bores analysed	Percentage of bores (number of bores)		
		Rising	Falling	Stable
1986 - 1990	14	50 (7)	0 (0)	50 (7)
1990 - 2000	55	20 (11)	18 (10)	62 (34)
2000 - 2008	82	9 (7)	60 (49)	32 (26)

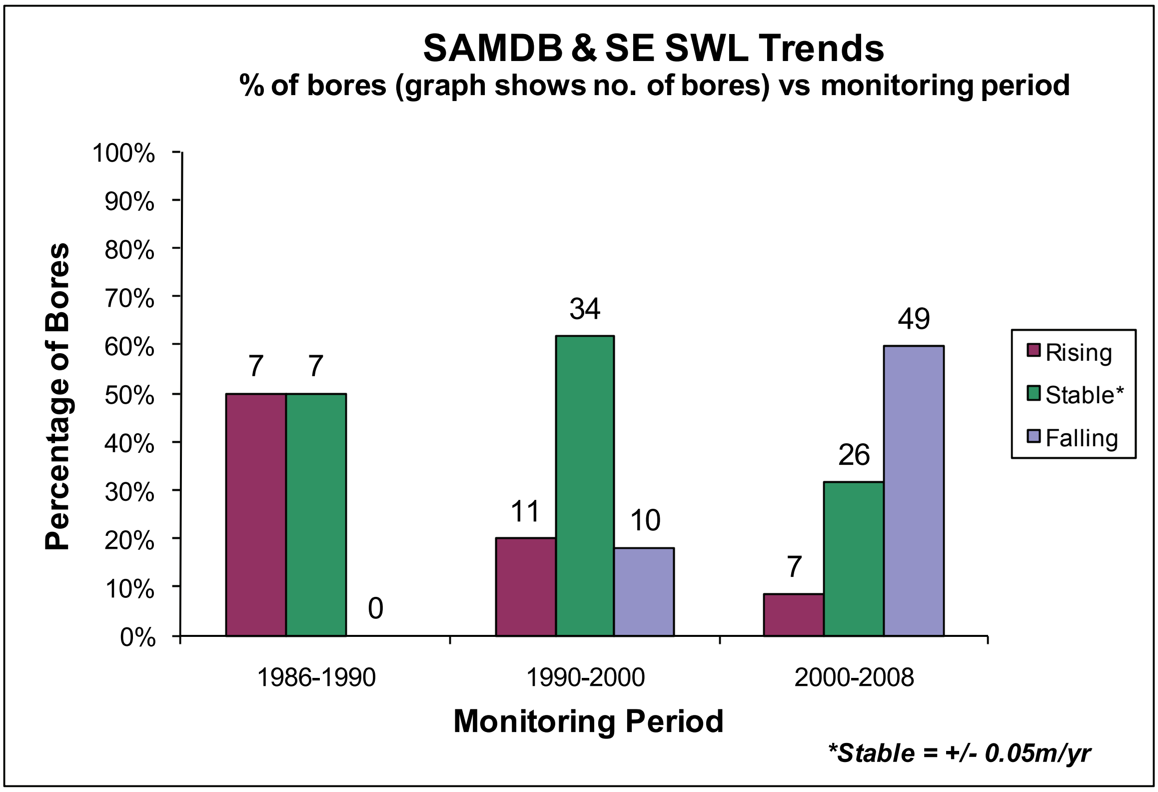


Figure 10. Groundwater trends in the combined SAMDB & SE regions

A steady decrease over time in the in the number of bores with a rising trend is evident. Example hydrographs for rising, falling and stable trends in the combined SAMDB and SE regions are attached in Appendix A.

The location of bores used in the trend analysis for the SAMDB and SE regions is shown in Figure 11, along with a spatial representation of the changing trends over time.

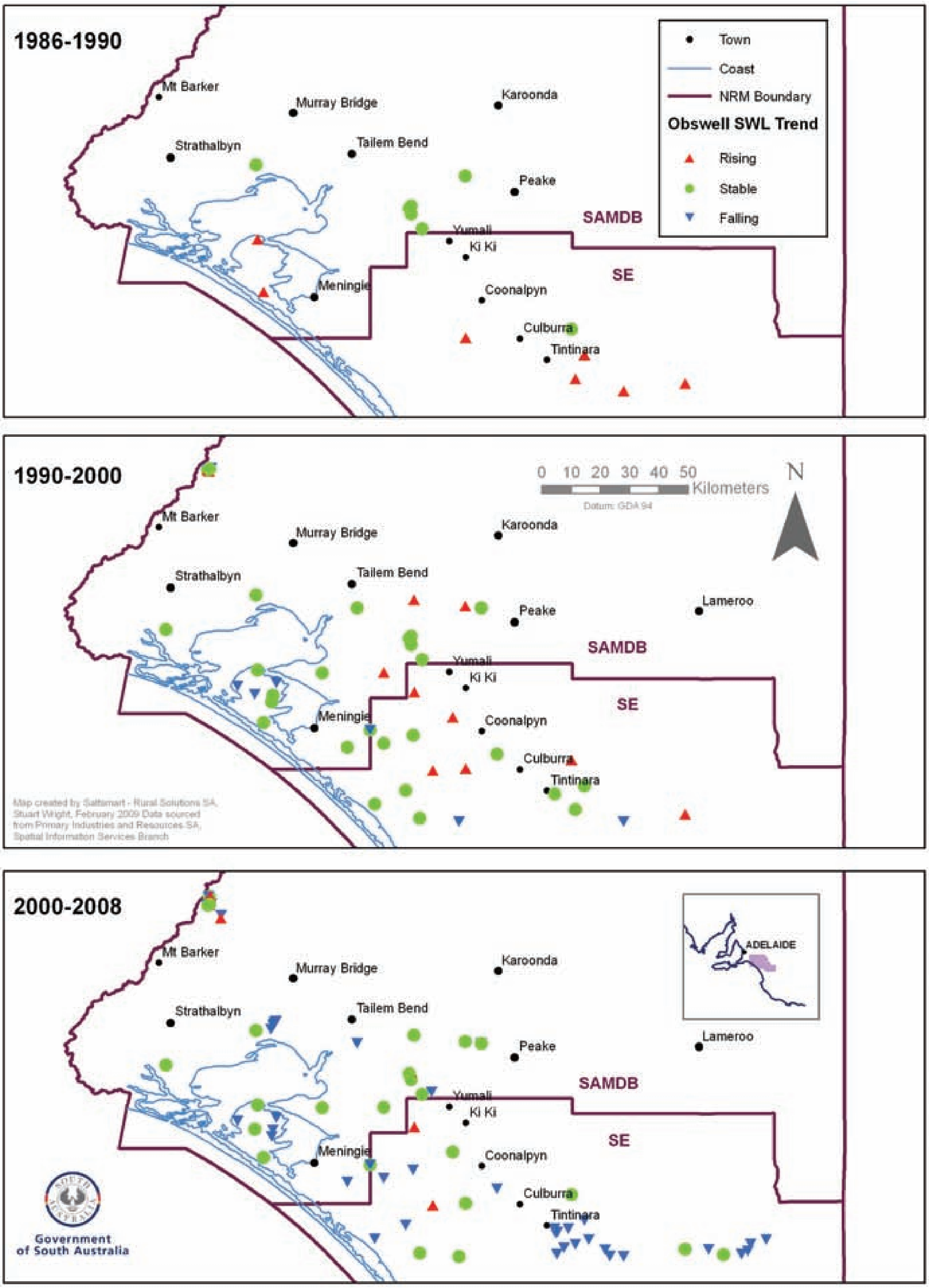


Figure 11. **Comparison of combined SAMDB & SE groundwater trends over 3 decades**

Discussion

The analysis of Obswell groundwater data from more than 600 bores in dryland agricultural areas of SA has determined a general pattern in depth to groundwater trends across all regions, for the period ranging from the mid-1980s to 2008. This pattern is best illustrated by summing the percentage change across the region to attain a state-wide picture (Table 6).

Table 6: Summary of groundwater trends for over 600 bores across agricultural regions

Monitoring period	Total number of bores across all regions	Percentage of bores (number of bores)		
		Rising	Falling	Stable
1986 - 1990	85	60 (51)	20 (17)	20 (17)
1990 - 2000	565	20 (113)	45 (254)	35 (198)
2000 - 2008	630	10 (63)	65 (410)	25 (156)

As results in Table 6 affirm, over time there has been a noticeable:

- decrease in the number of bores exhibiting a rising trend in depth to groundwater
- increase in the number of bores exhibiting a falling trend in depth to groundwater.

The change in depth to groundwater trends is strongly linked to rainfall, where prolonged periods of below-average rainfall since the mid 1990s have resulted in less recharge and falling groundwater levels. Henschke and Wright (2007) reported a falling trend in groundwater levels over the last decade for dryland bores on the Northern Adelaide Plains (Gawler/Salisbury), noting that the trend closely reflected a similar decline in cumulative residual rainfall.

Barnett (2008), in commenting on dryland salinity in the SA MDB region, noted that previously rising groundwater levels have slowed due to recent dry years, and falls in levels are now becoming apparent in most areas. DWLBC (2006) discussed dryland salinity in the Upper South East and stated that the rising trend seen in most bores during the 1980s has reverted to a falling trend over the past decade, following a similar pattern in rainfall trends.

Interstate reports reinforce the strong influence that rainfall trends can exert on trends in depth to groundwater. Reid et al (2008) reported on groundwater trends in Victoria. The authors suggested that a drying climate has been the main driver behind the change from rising trends in the 1980s and 1990s to general groundwater declines since 1996. For Western Australia, George et al (2008) reported that the number of bores with a previously rising trend decreased significantly in four out of five regions post 2000, due in large part to reductions in rainfall and recharge.

For South Australia, the general change in rainfall pattern is illustrated by the residual rainfall graph for Nuriootpa in the AMLR region as shown in Figure 12. Following a wet period which climaxed in the early to mid 1990s, there have been significant periods of drier than average rainfall, shown by the overall downward sloping trend of the residual rainfall curve.

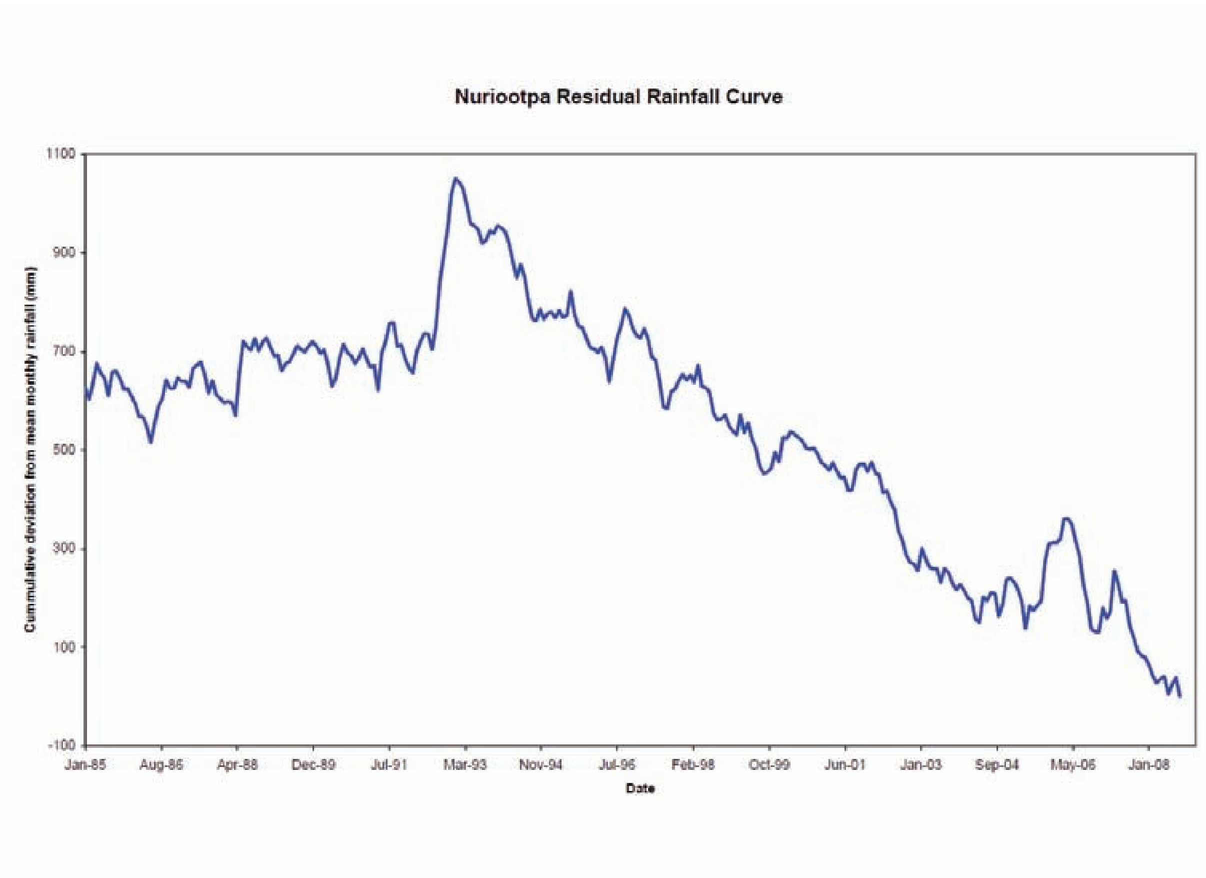


Figure 12. Decreasing trend in rainfall since the early 1990s

An example of the relationship between such a drying climate pattern and depth to groundwater is given in Figure 13. The hydrograph for a representative bore in the AMLR region shows depth to groundwater levels during the 1990s, overlain with the corresponding residual rainfall curve.

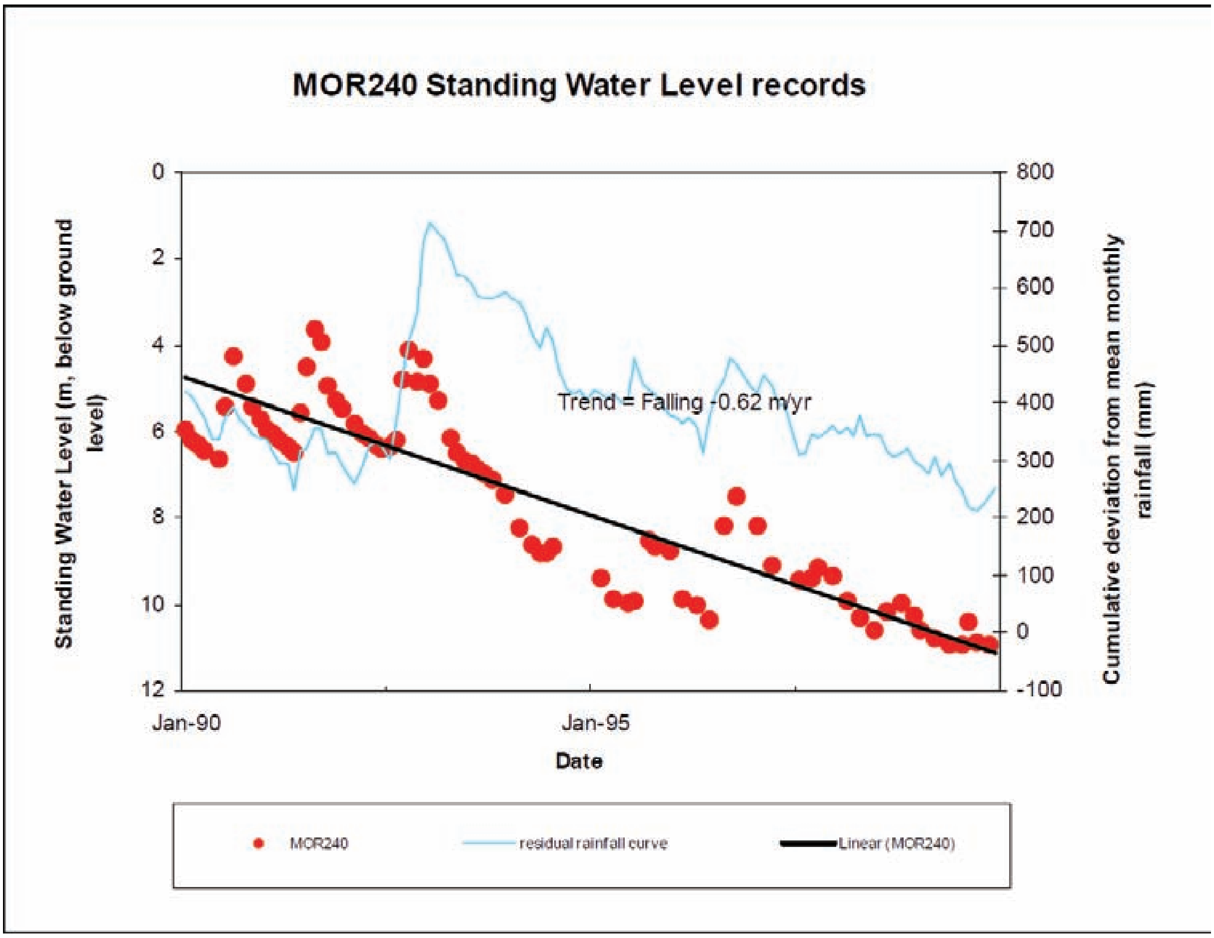


Figure 13. Overall trend in depth to groundwater (- 0.62 m/yr) related to rainfall trend

In Figure 13, the recharge peaks in the groundwater plot align with peaks (wetter periods) in the residual rainfall curve, reflecting a strong correlation between rainfall and groundwater standing water levels (SWL). Overall, a strong falling trend (-0.62 m/yr) in depth to groundwater is evident, corresponding with the decline in average rainfall following a very wet year early in the decade of the 1990s. This pattern best represents the response of many catchments in local groundwater flow systems in SA.

However, the response of groundwater levels to a drying climate can be delayed in large regional groundwater flow systems, given their inbuilt hydrologic inertia. Figure 14 shows that, under a drying climate, a continuous rise in depth to groundwater (0.06 m/yr) has been maintained throughout the 1990s for a monitoring bore in the SAMDB region where more regional groundwater flow systems are operating. It is only within the current decade that the trend has reached a plateau and declined.

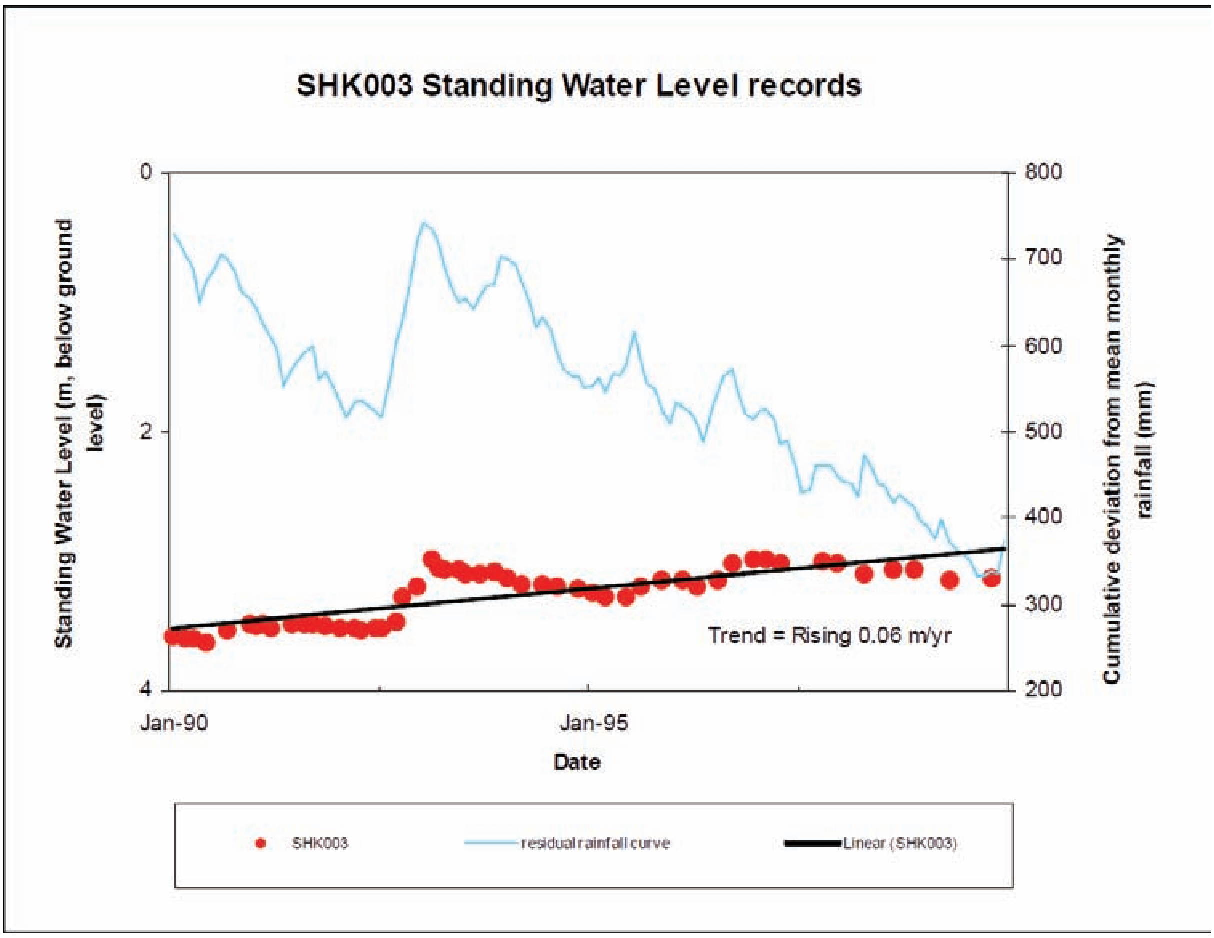


Figure 14. A rising trend in groundwater, while average rainfall is declining

The data presented in Table 6 shows that the number of bores with a rising trend from 20% in the 1990s to 10% in the 2000s. Dooley et al (2008) noted that while an overall linear falling trend in depth to groundwater was evident from the early 1990s to the present, some 5% to 30% of bores in any one region in SA exhibited a linear rising trend over the same period.

Besides rainfall trends, the influence of other factors on trends in depth to groundwater, such as the type of groundwater flow system, equilibrium state, and land use and land management change, is well recognised (Dooley et al, 2008; Reid et al, 2008; George et al, 2008; Henschke et al, 2010). However, as the latter authors note, once saline catchments reached water equilibrium, climate impacts will become the dominant controller of groundwater trends.

Rainfall trends of themselves are not uniformly experienced. A hydrograph from a monitoring bore on KI (Figure 15) illustrates an increasing trend (0.15 m/yr) in depth to groundwater recorded during the 1990s, aligning with receipt of average to above average rainfall over that time. This contrasts with the general rainfall trend experienced elsewhere during this period (Figure 12).

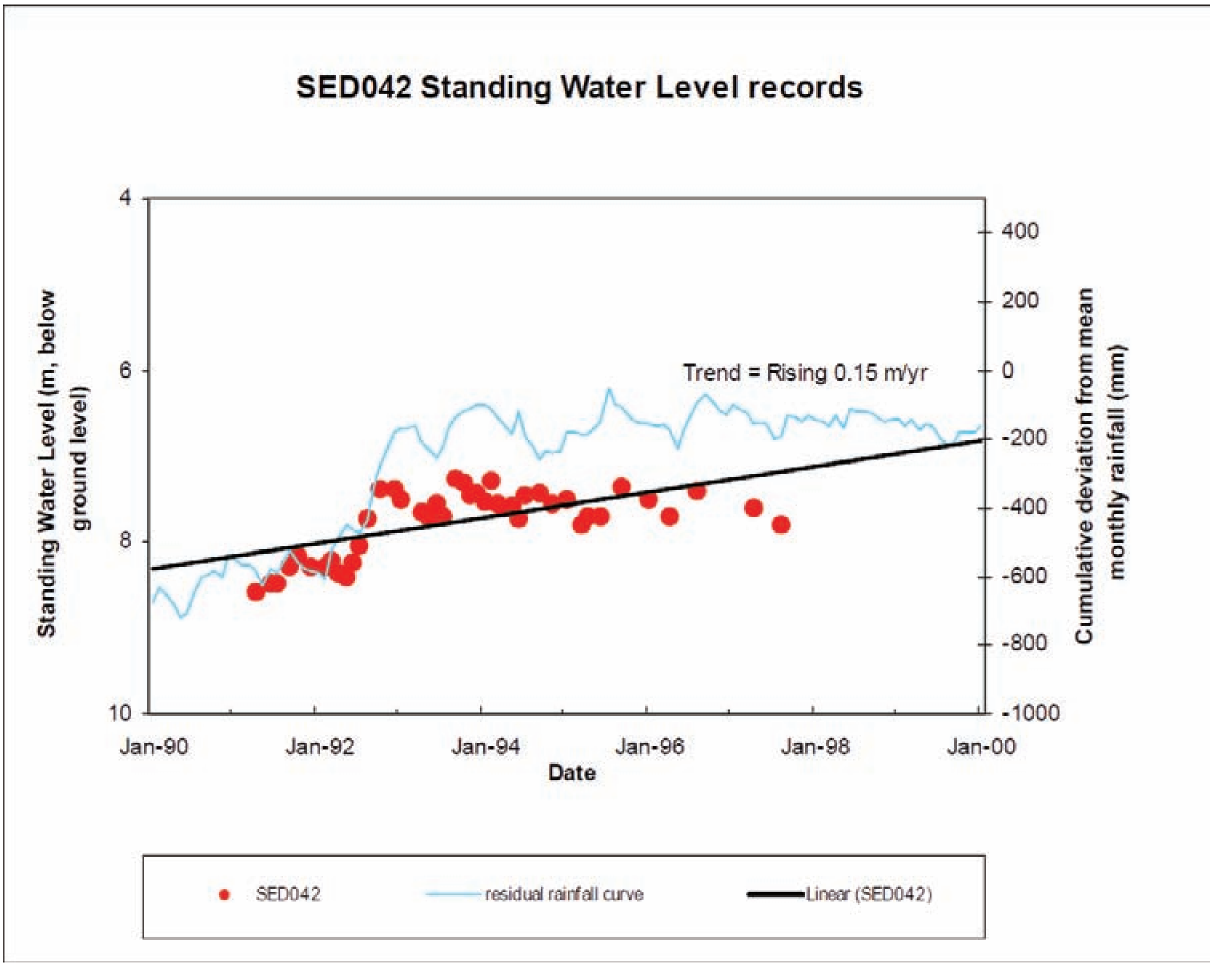


Figure 15. A rising groundwater trend on KI, aligned with a rising rainfall trend

The change in rainfall pattern and depth to groundwater trends from the mid 1980s to the present is captured in the example hydrographs in Appendix A. For the South East region, a DWLBC report (2006) highlighted the impact of episodic recharge events, such as very wet years and flooding, on salinity extent and severity. The authors also discuss longer term wetter and drier cycles over the past century as potential indicators of future rainfall and salinity patterns, while acknowledging the uncertain impact of climate change. Similarly, Dooley et al (2010) discuss the impact of extreme bushfire on salinity expression on Eyre Peninsula.

Salinity is a complex process often ruled by site-specific factors. While analysis undertaken for this report has determined a strong link between rainfall trends and trends in depth to groundwater, exceptions do exist, and they are primarily linked to other contextual factors such as groundwater flow system and land use change. However, it is considered that the risk that salinity poses to valuable assets in SA has decreased, given the significant stabilisation and decline since the mid 1990s of previously rising groundwater levels.

Incorporating a more rigorous statistical analysis encompassing wet and dry periods will help refine future determinations of depth to groundwater trends in SA.

Conclusions and Recommendations

The analysis of Obswell groundwater data from more than 600 bores in dryland agricultural areas of SA has determined a similar pattern in depth to groundwater trends across all regions, for the period ranging from the mid-1980s to 2008. Over time, there has been a noticeable:

- decrease in the number of bores exhibiting a rising trend in depth to groundwater
- increase in the number of bores exhibiting a falling trend in depth to groundwater.

This changing pattern in depth to groundwater is strongly linked to rainfall, where prolonged periods of below-average rainfall have resulted in less recharge and falling groundwater levels. The risk that salinity poses to valuable assets in SA has therefore decreased, given the significant stabilisation and decline over the past two decades of previously rising groundwater levels.

The implications of this for the future management of salinity include the need for:

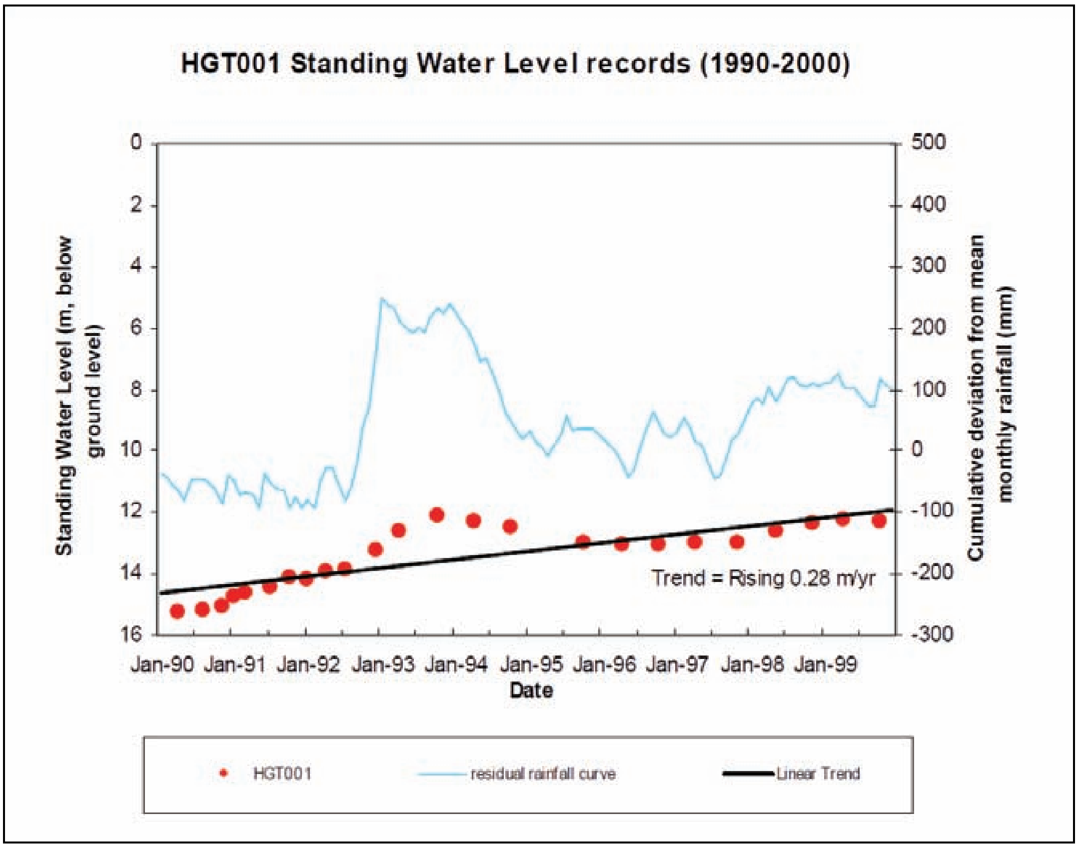
- analysis of the potential impacts of climate change on salinity extent and severity
- a refinement of salinity risk classification, incorporating risk analysis pertaining to priority assets in SA
- caution when interpreting groundwater trends; any change attributed to management intervention must be assessed within the context of rainfall
- continued monitoring of salinity indicators, especially depth to groundwater, at identified focus areas.

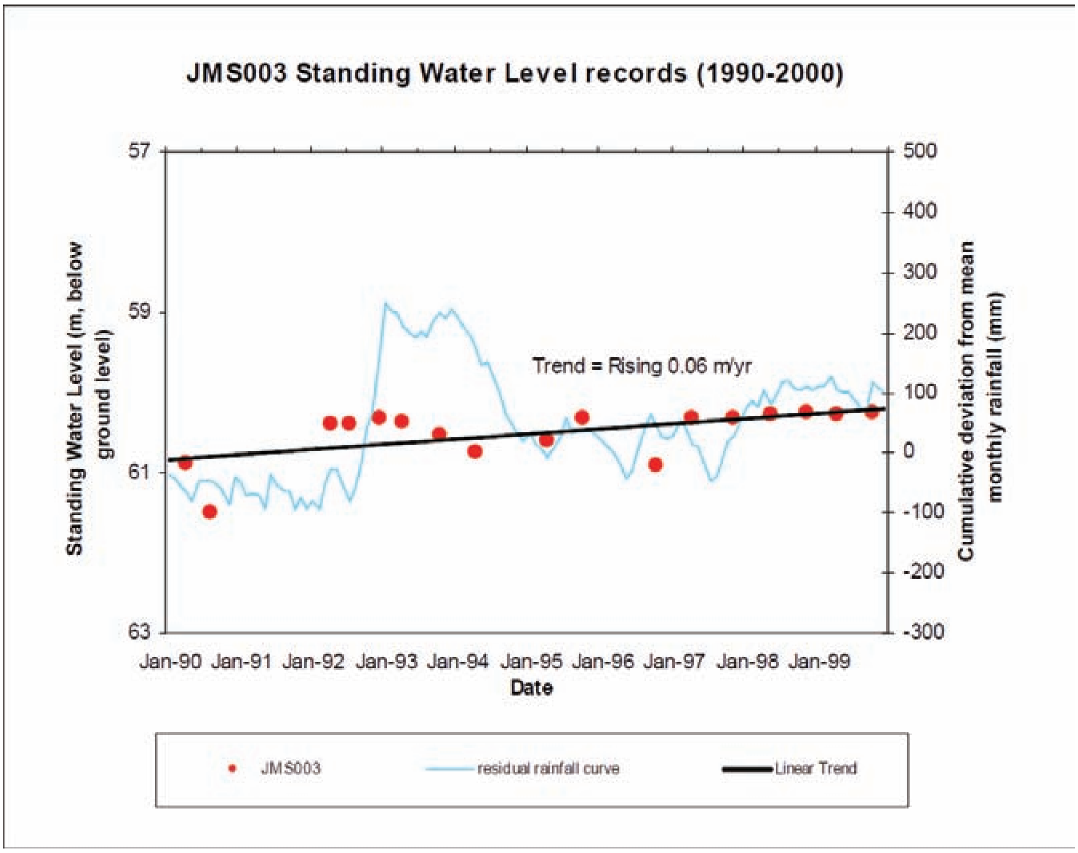
The dot points above summarise major recommendations arising from this report. Of immediate interest in terms of further investigation and future monitoring is the 10% of bores state-wide that are currently exhibiting a continually rising trend in depth to groundwater. For the future determination of depth to groundwater trends across SA, alternative methodologies incorporating more sophisticated statistical analysis of Obswell data should be assessed in terms of their value-adding potential.

Appendices

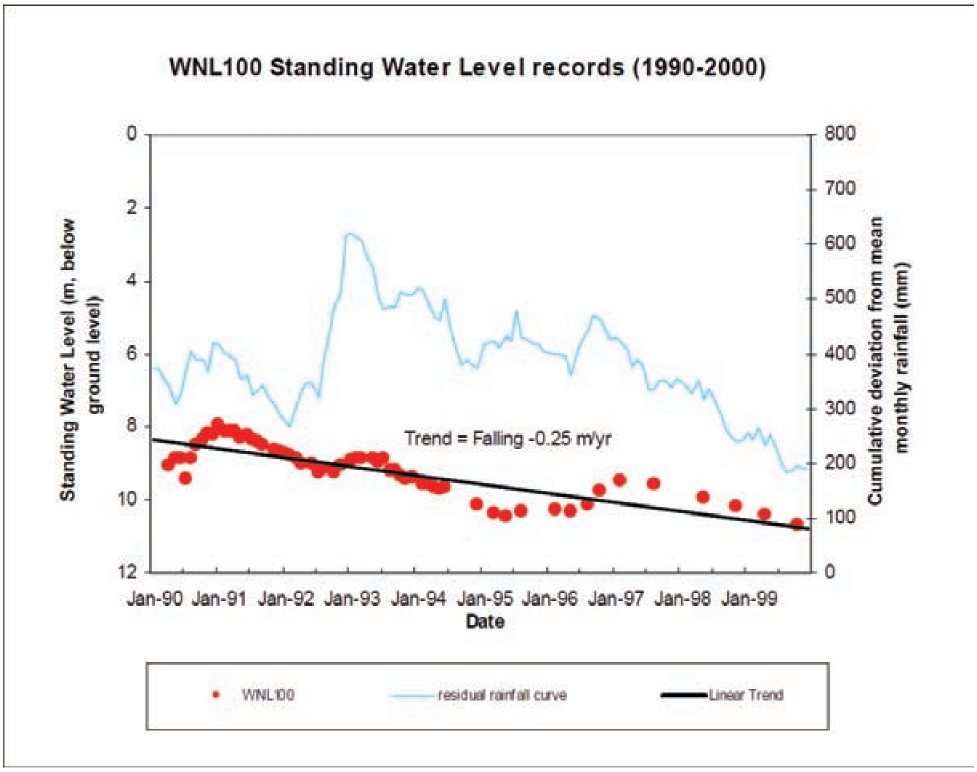
Appendix A. Example Hydrographs

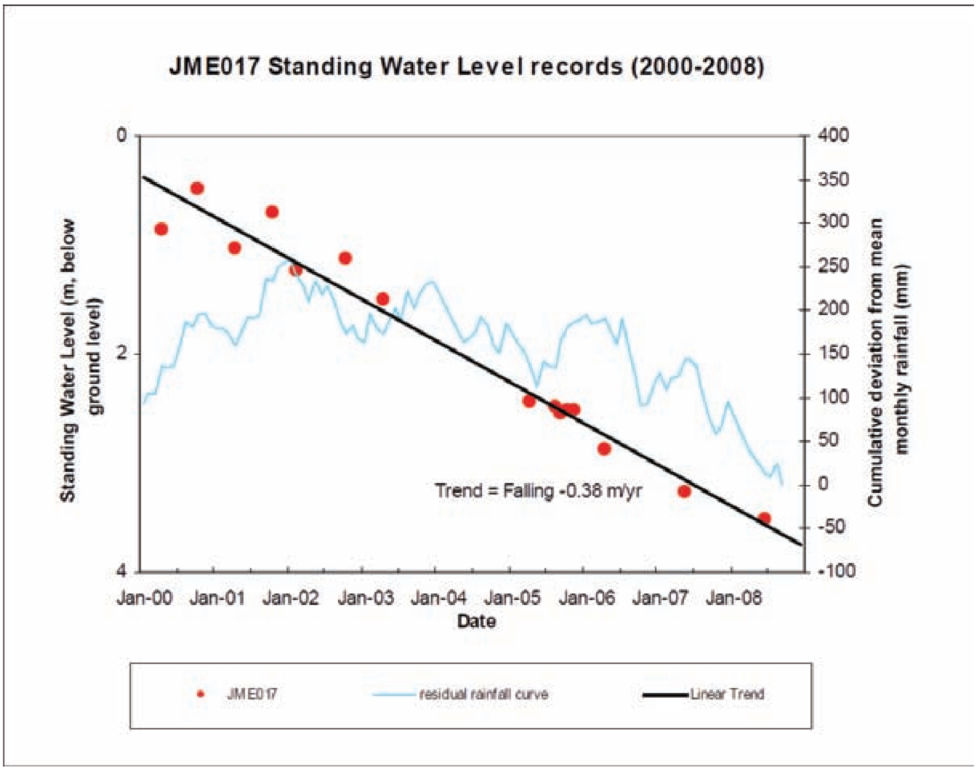
EP Region – rising trend examples (sites HGT001, JMS003)



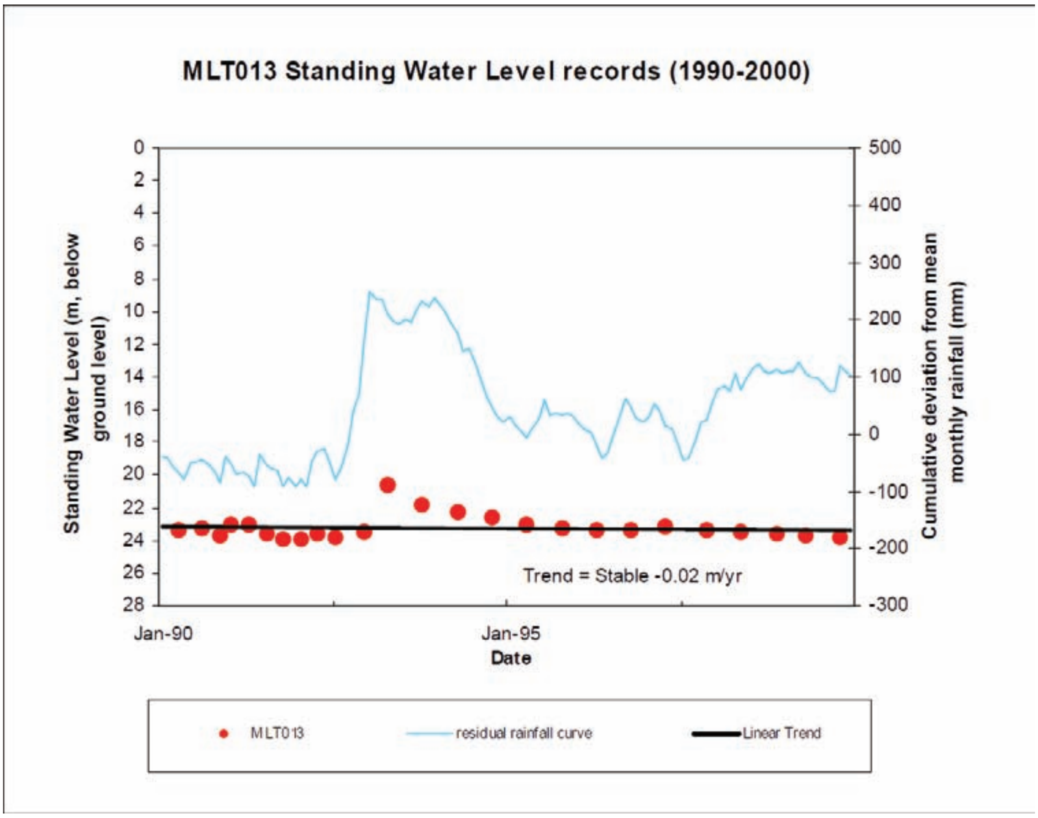


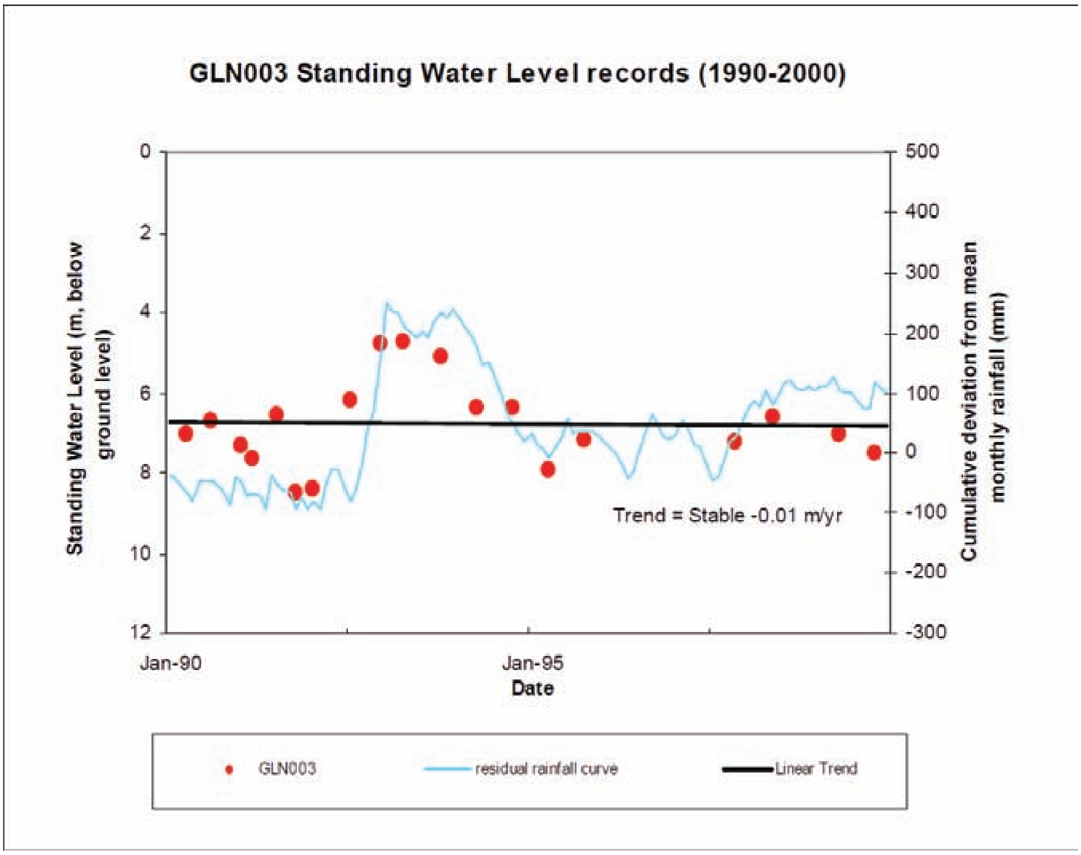
EP region - falling trend examples (Sites WNL100, JME017)



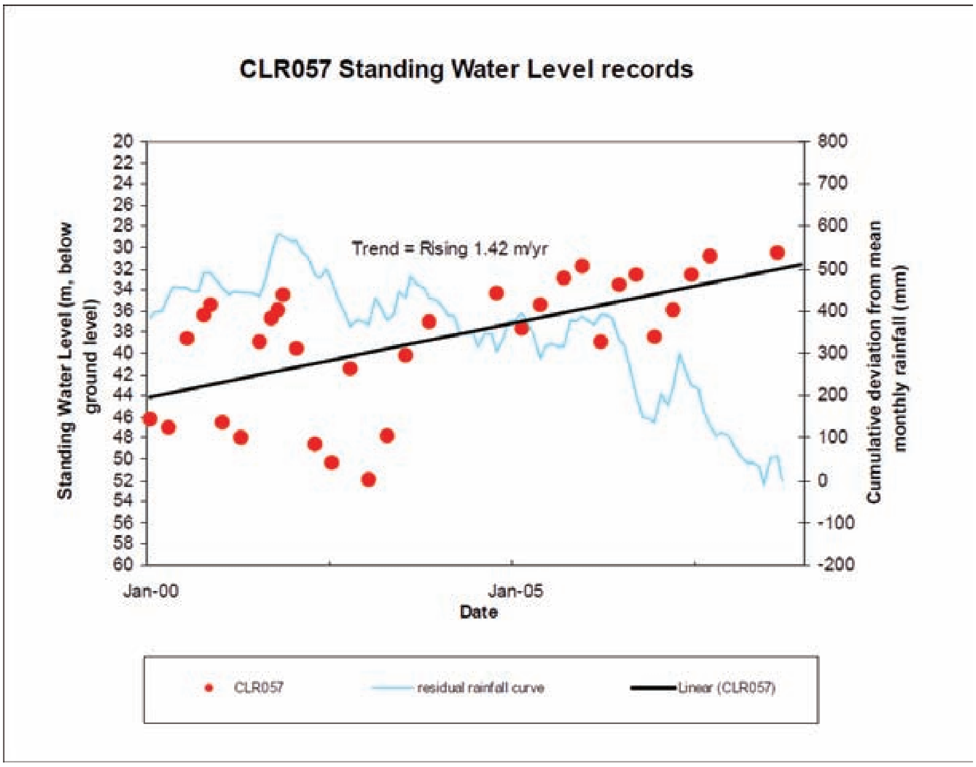


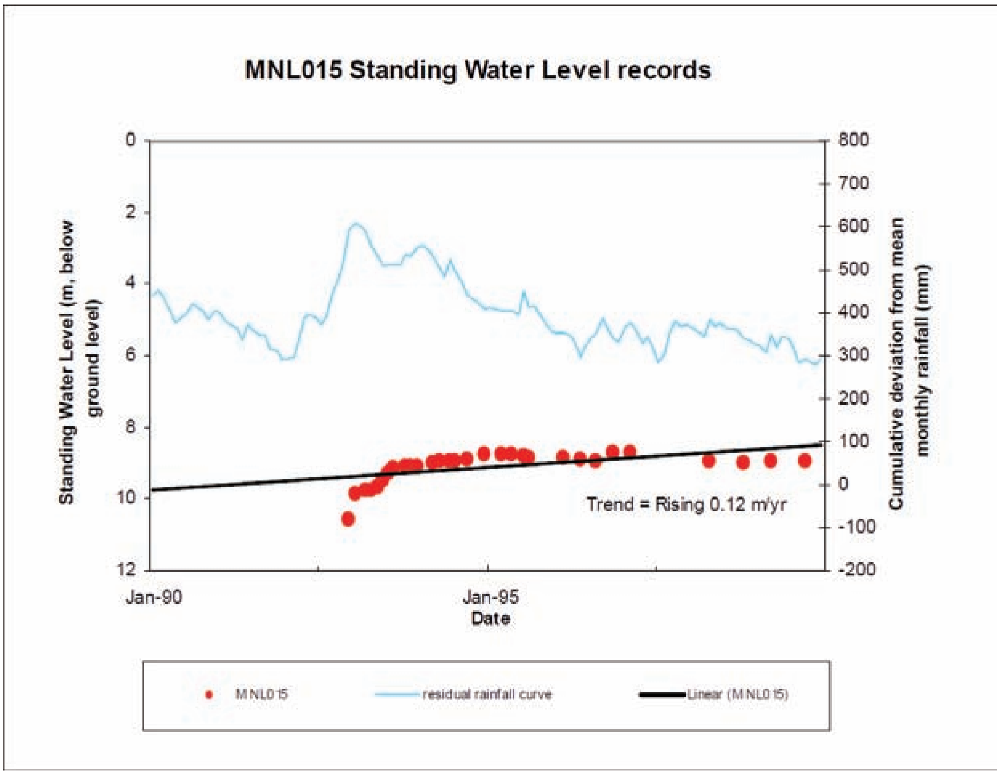
EP Region - stable trend examples (Sites MLT013, GLN003)



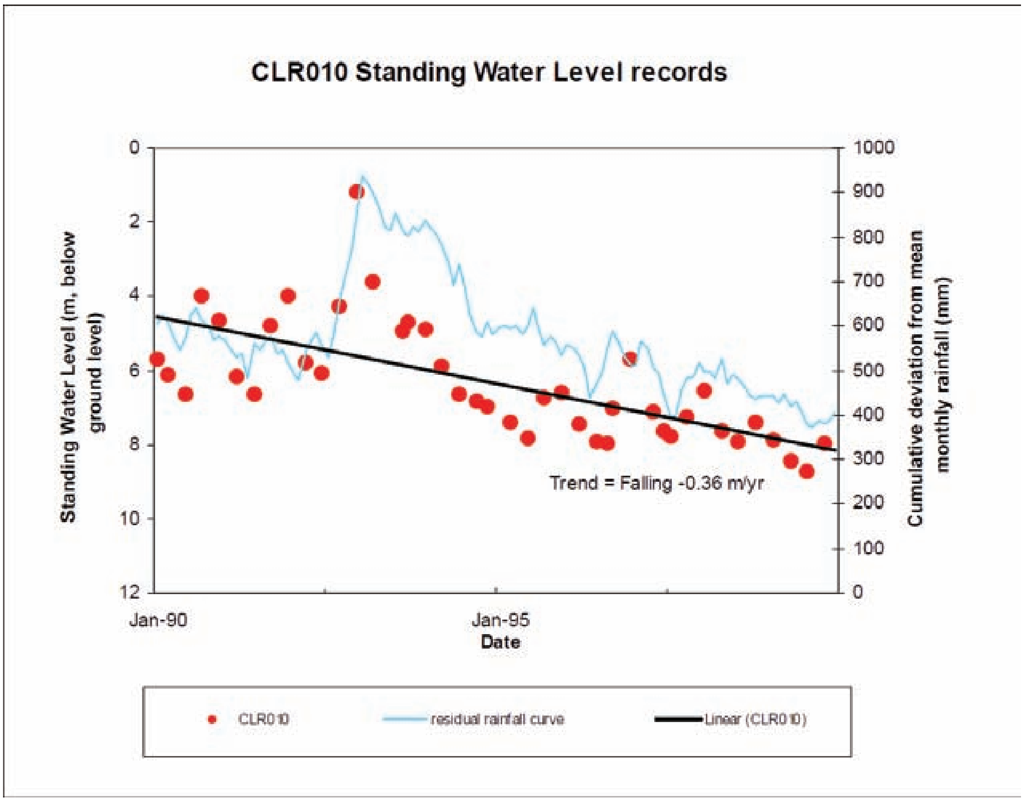


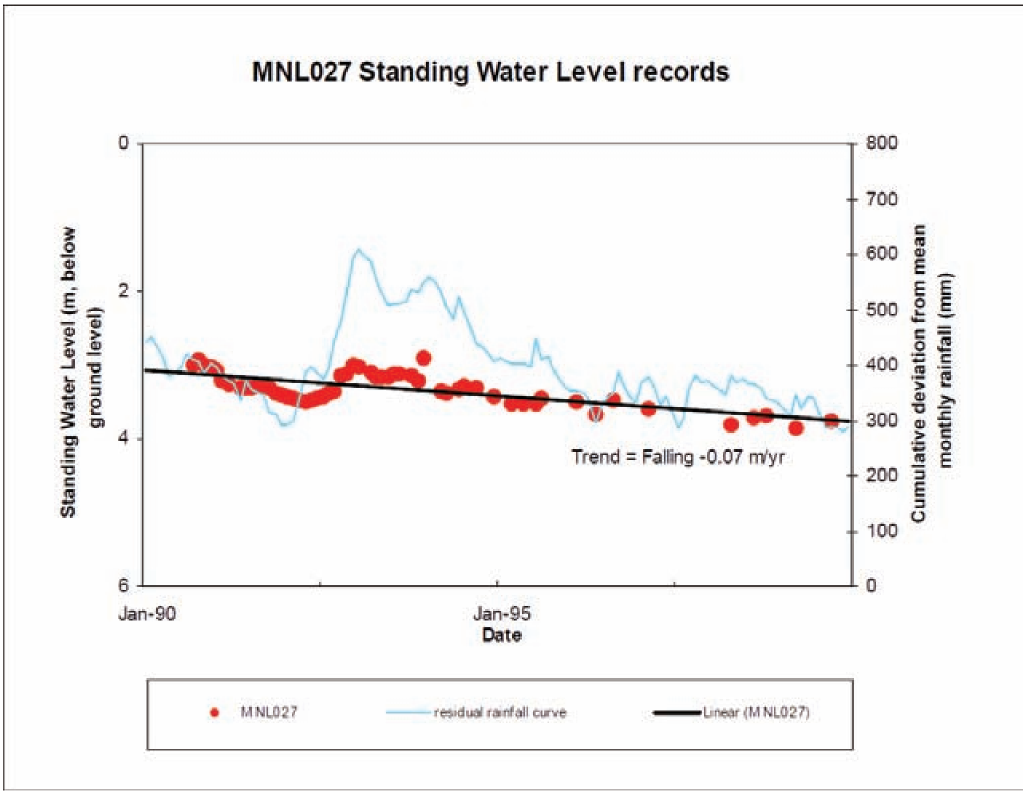
N&Y Region – rising trend examples (sites CLR057, MNL015)



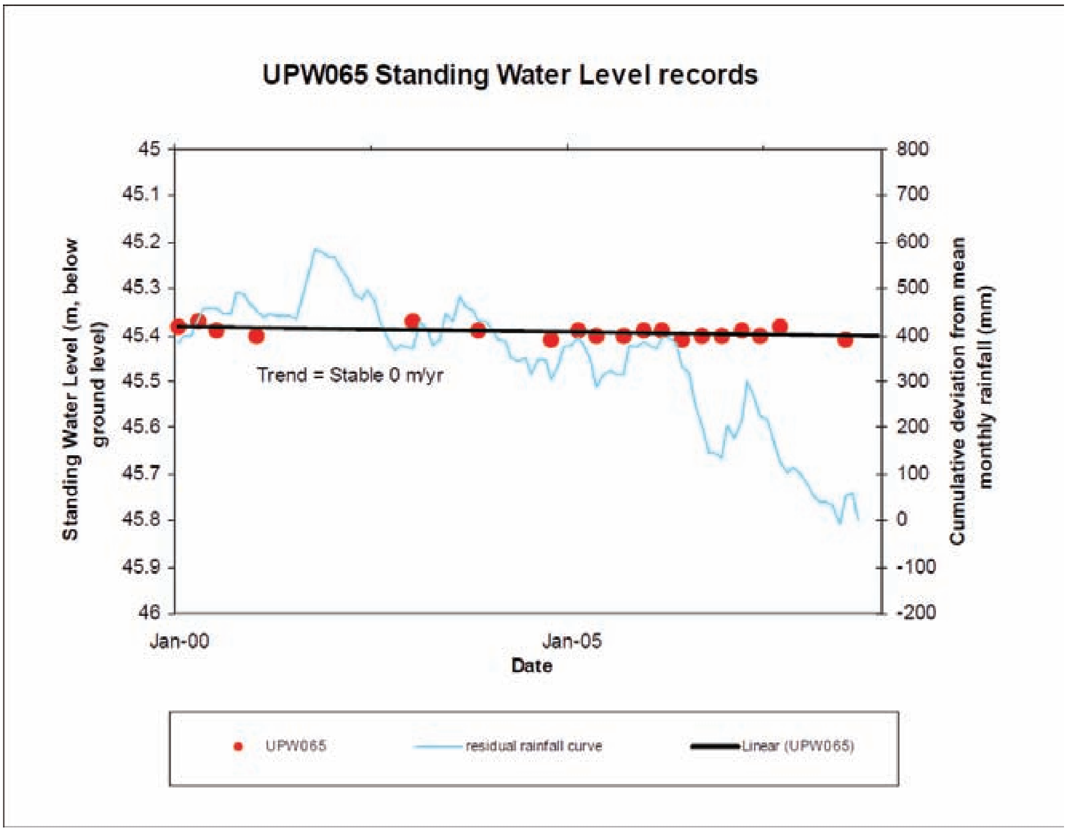


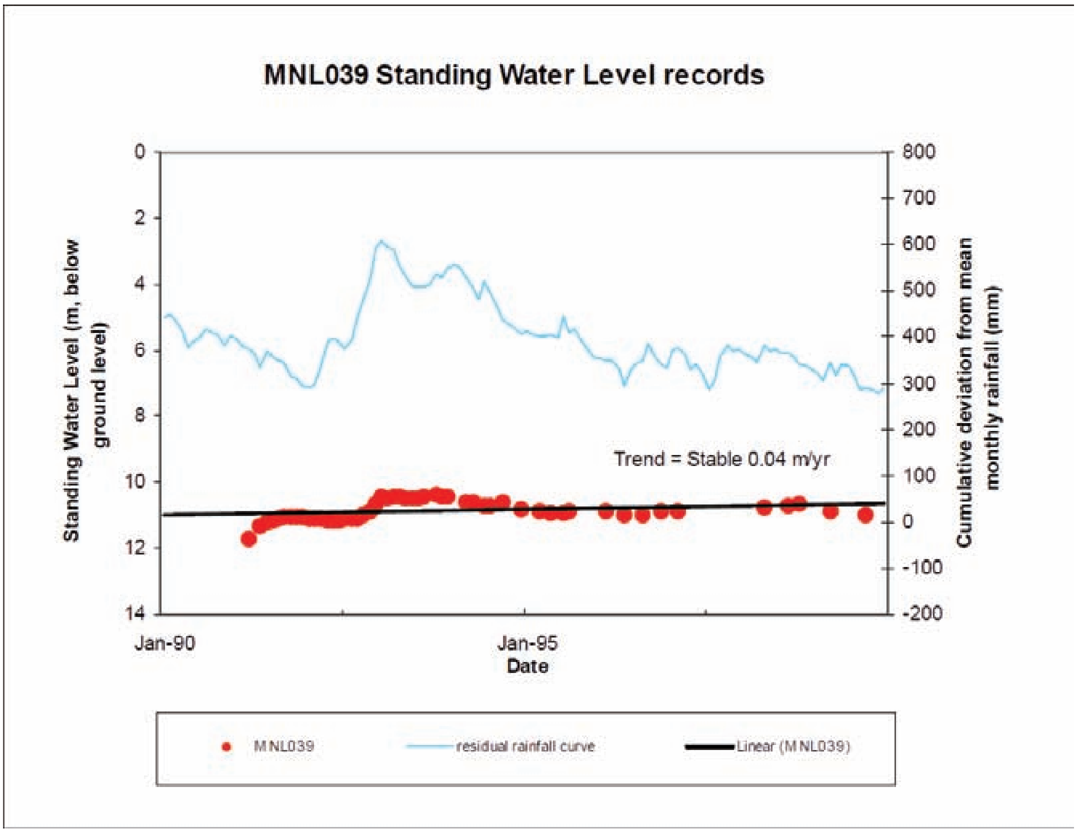
N&Y Region – falling trend examples (sites CLR010, MNL027)



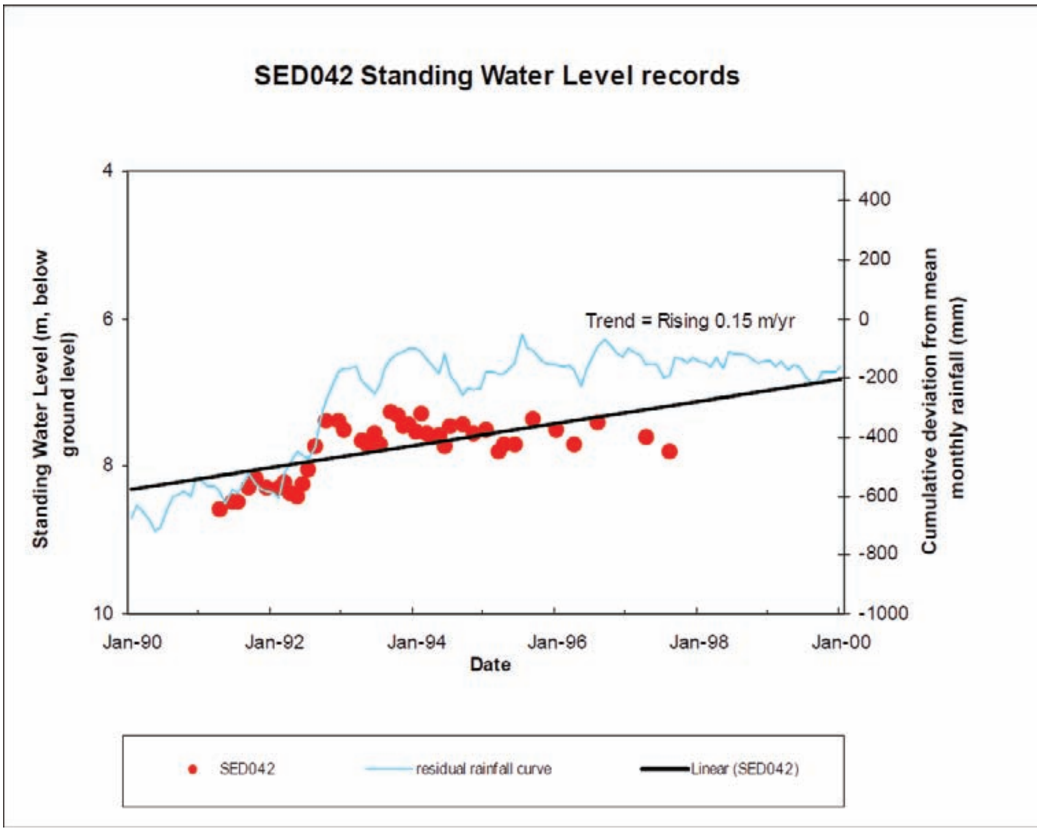


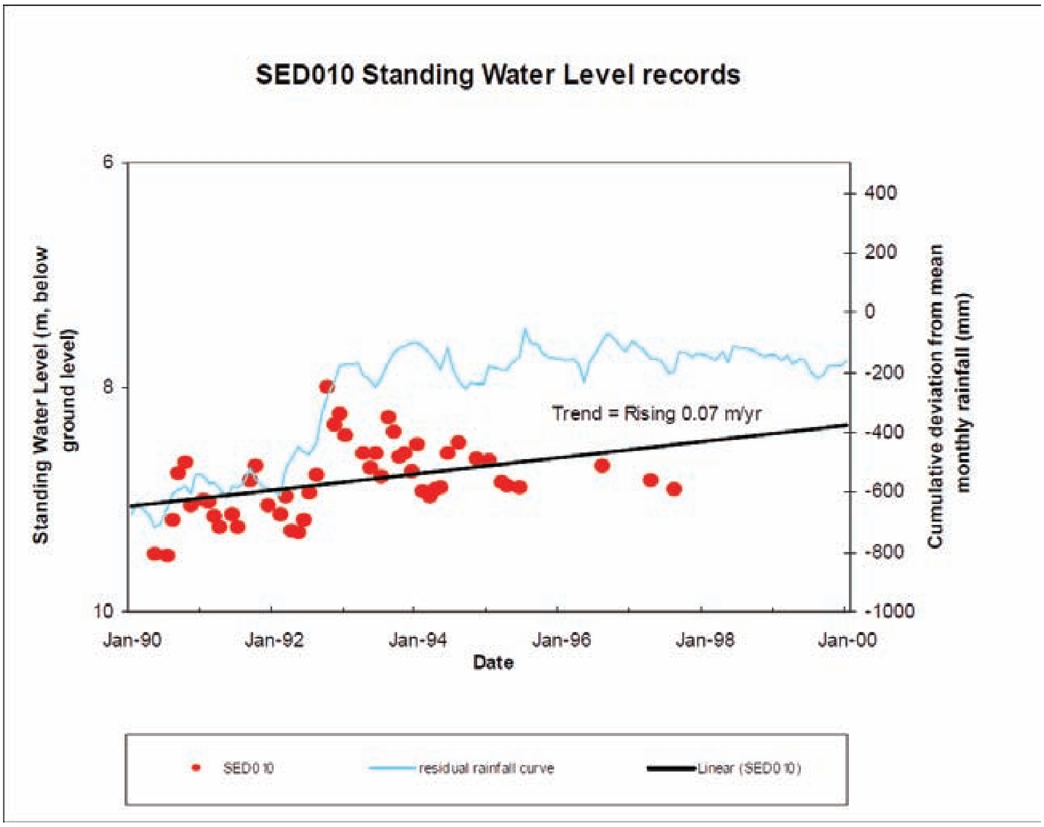
N&Y Region – stable trend examples (sites UPW065, MNL039)


UPW065 Standing Water Level records
Standing Water Level (m, below ground level)
45
45.1
45.2
45.3
45.4
45.5
45.6
45.7
45.8
45.9
46
Cumulative deviation from mean monthly rainfall (mm)
800
700
600
500
400
300
200
100
0
-100
-200
Trend = Stable 0 m/yr
Jan-00
Jan-05
Date
UPW065
residual rainfall curve
Linear (UPW065)

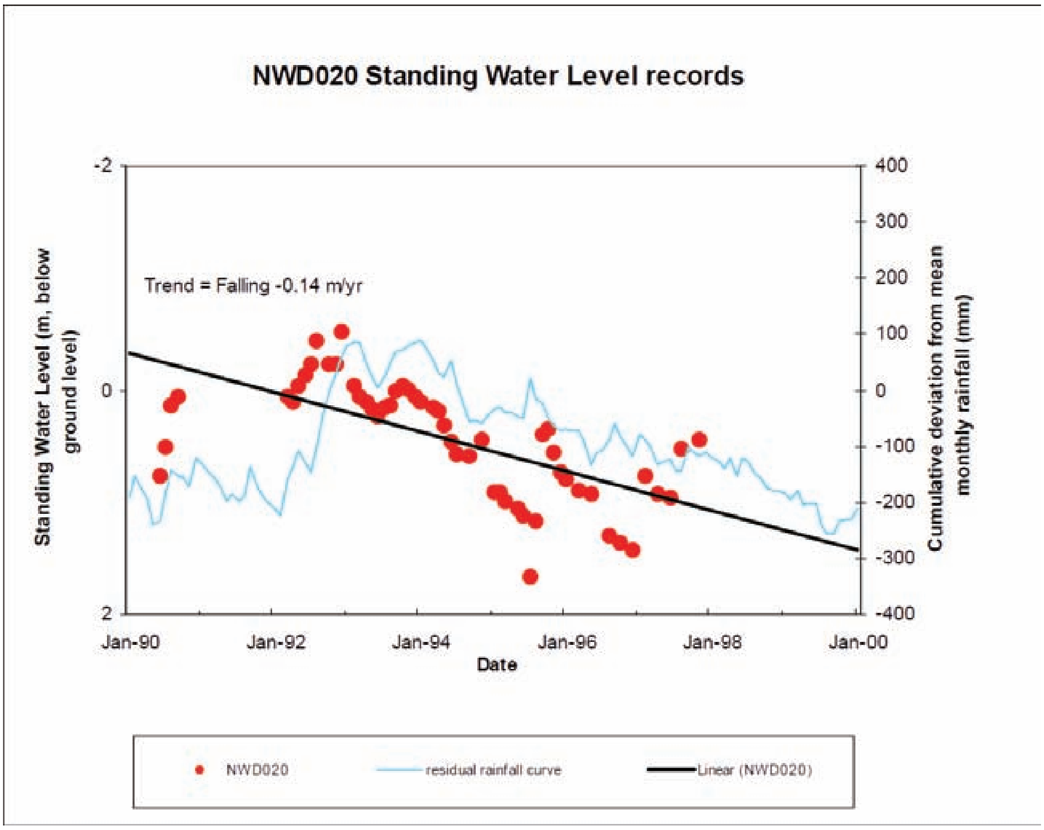

MNL039 Standing Water Level records
Standing Water Level (m, below ground level)
0
2
4
6
8
10
12
14
Cumulative deviation from mean monthly rainfall (mm)
800
700
600
500
400
300
200
100
0
-100
-200
Trend = Stable 0.04 m/yr
Jan-90
Jan-95
Date
MNL039
residual rainfall curve
Linear (MNL039)

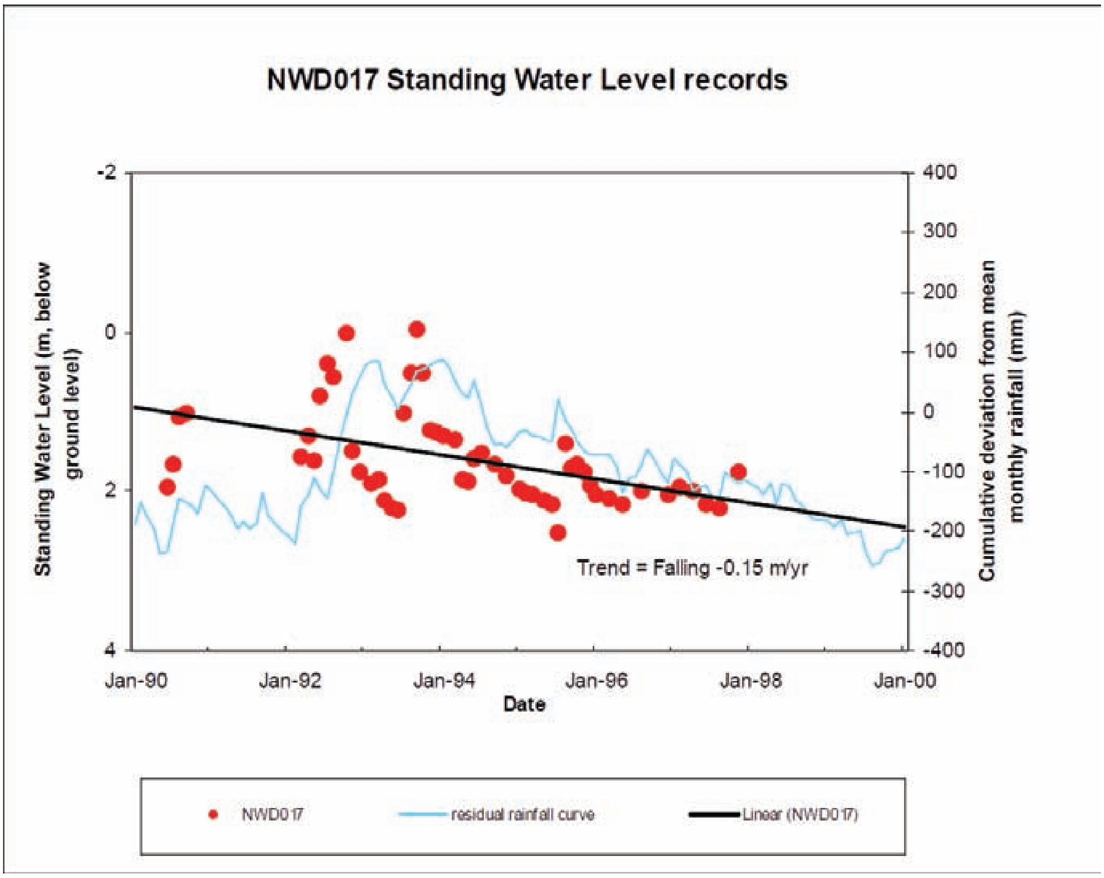
KI Region – rising trend examples (sites SED042, SED010)



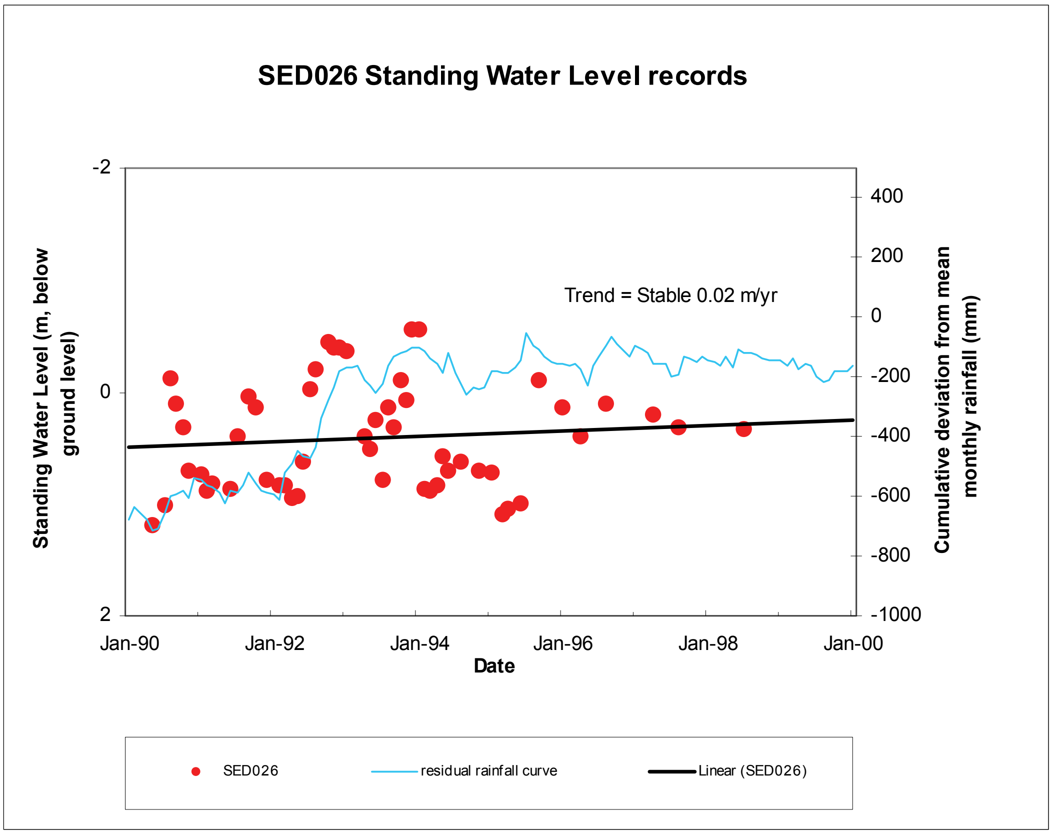


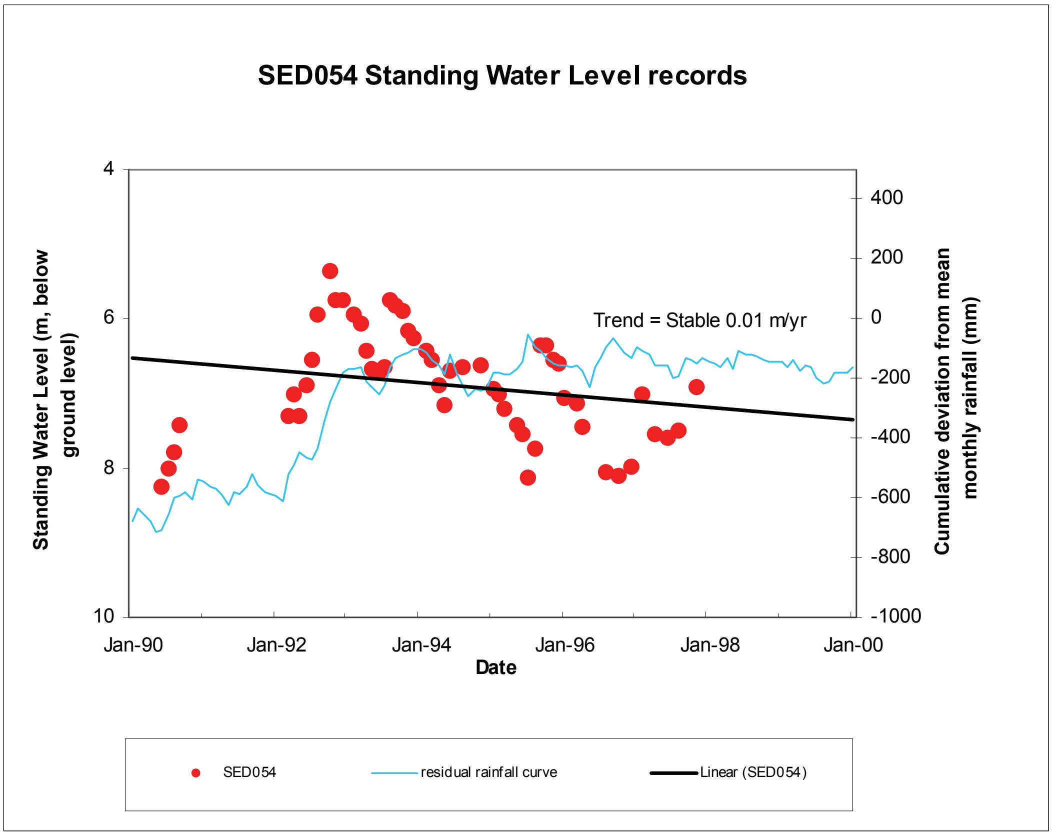
KI region - falling trend examples (Sites NWD020, NWD017)


NWD020 Standing Water Level records
Trend = Falling -0.14 m/yr
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
-2
0
2
400
300
200
100
0
-100
-200
-300
-400
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Date
NWD020
residual rainfall curve
Linear (NWD020)

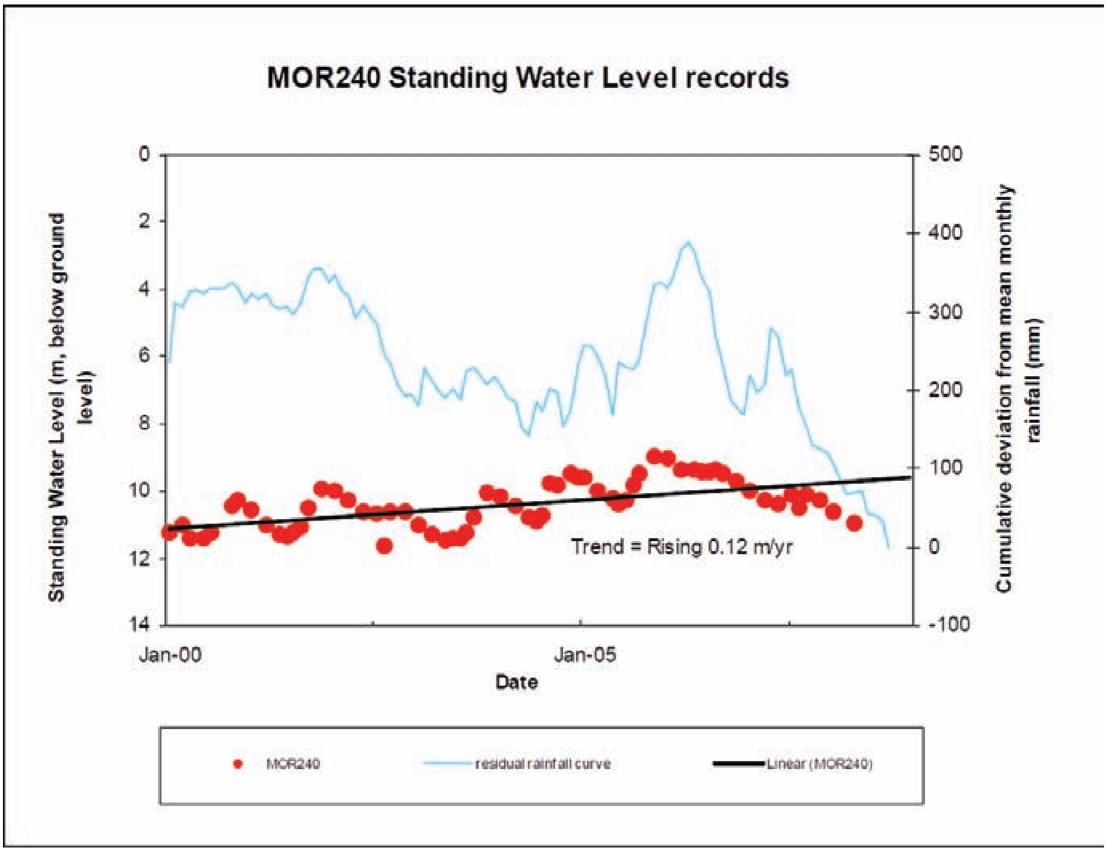

NWD017 Standing Water Level records
Trend = Falling -0.15 m/yr
Standing Water Level (m, below ground level)
Cumulative deviation from mean monthly rainfall (mm)
-2
0
2
4
400
300
200
100
0
-100
-200
-300
-400
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Date
NWD017
residual rainfall curve
Linear (NWD017)

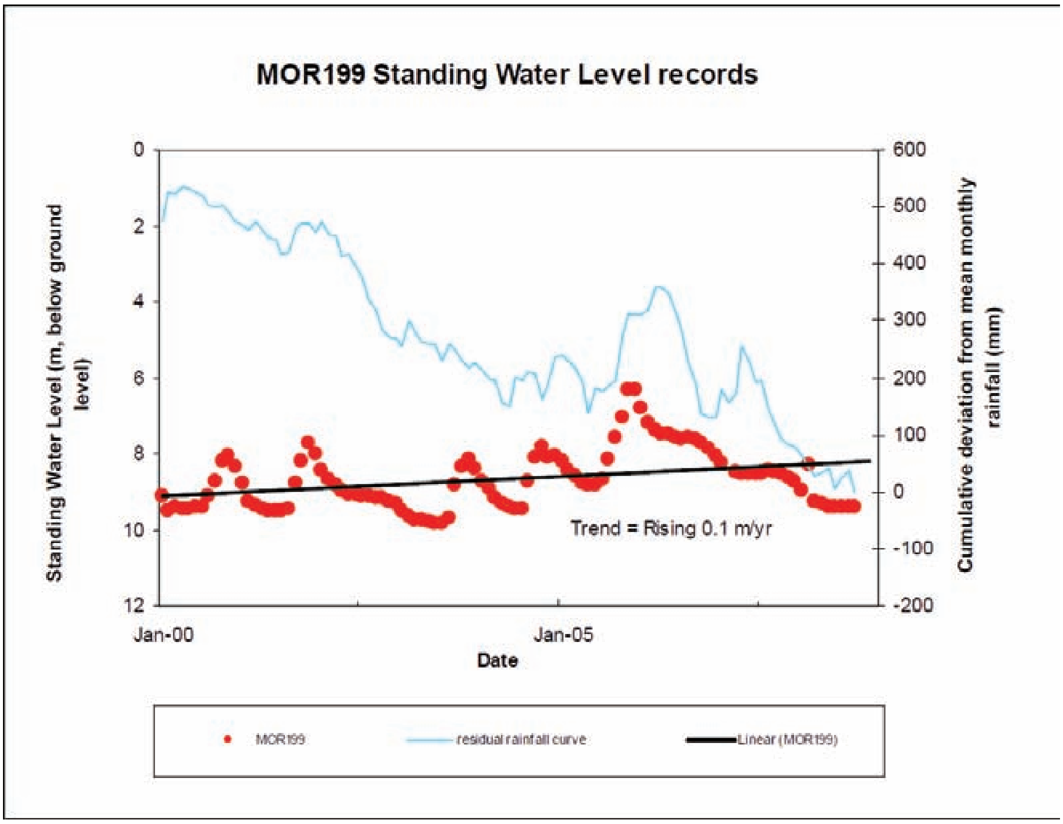
KI Region - stable trend examples (Sites SED026, SED054)



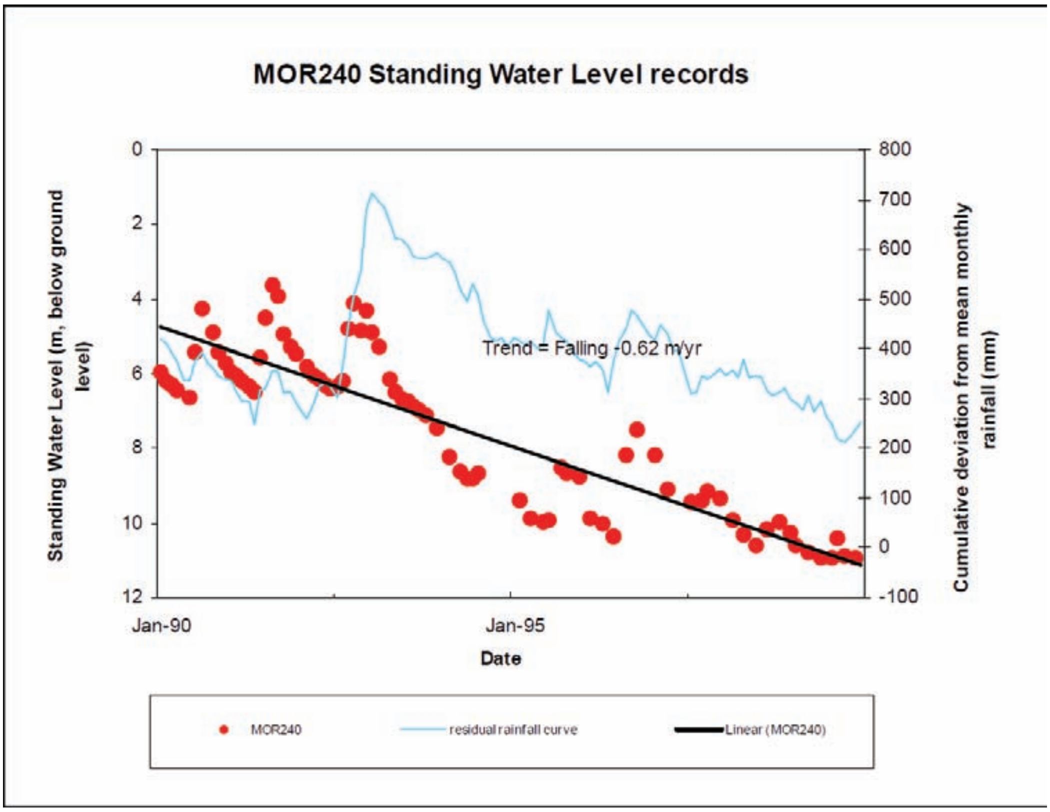


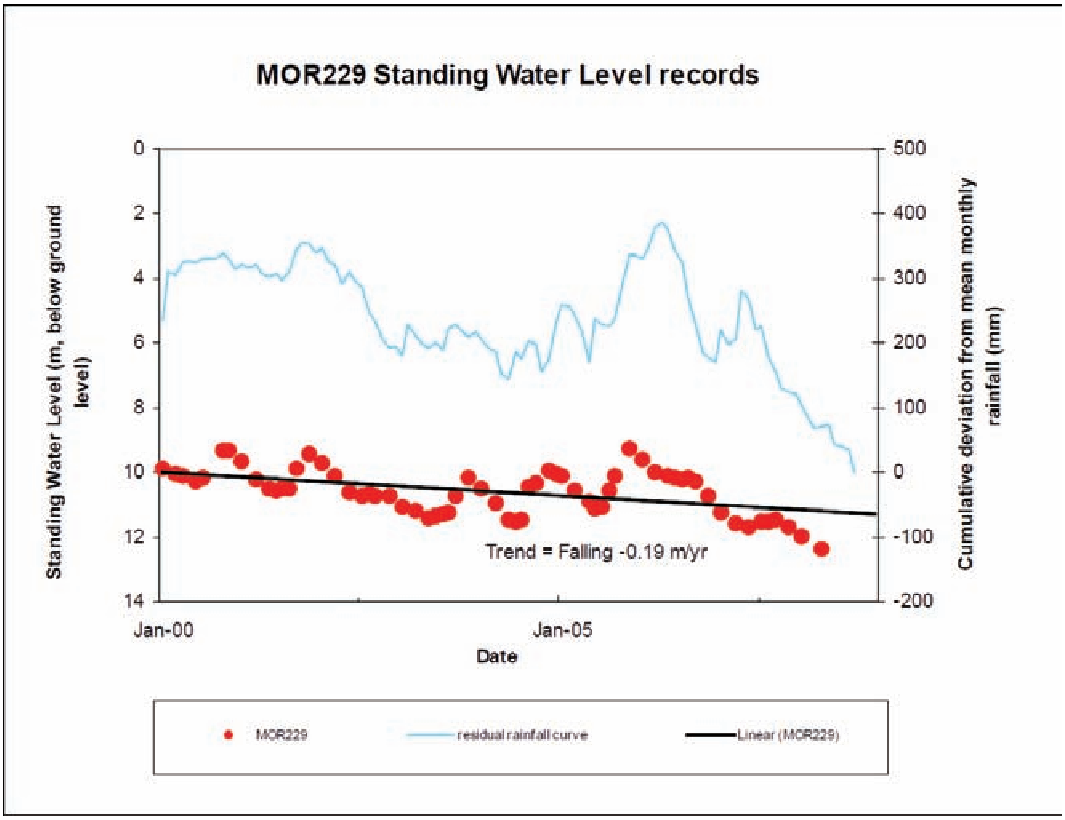
AMLR Region - rising trend examples (Sites MOR240, MOR199)



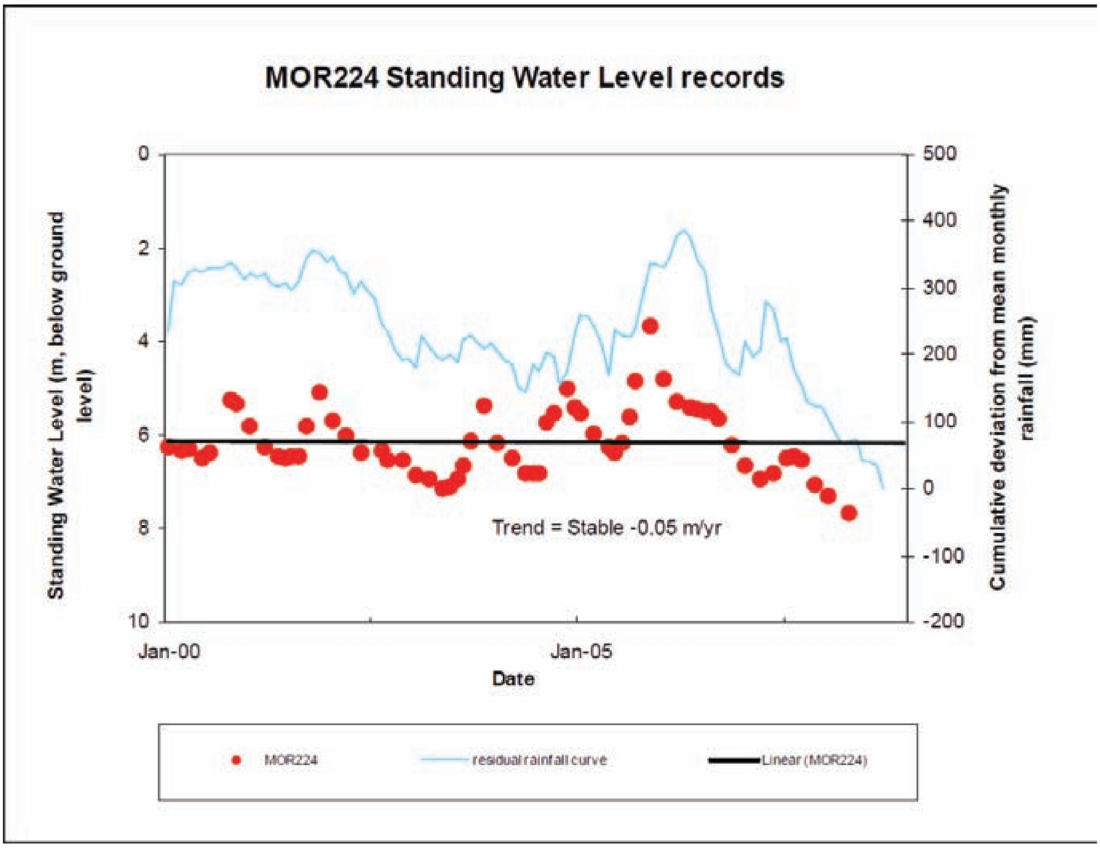


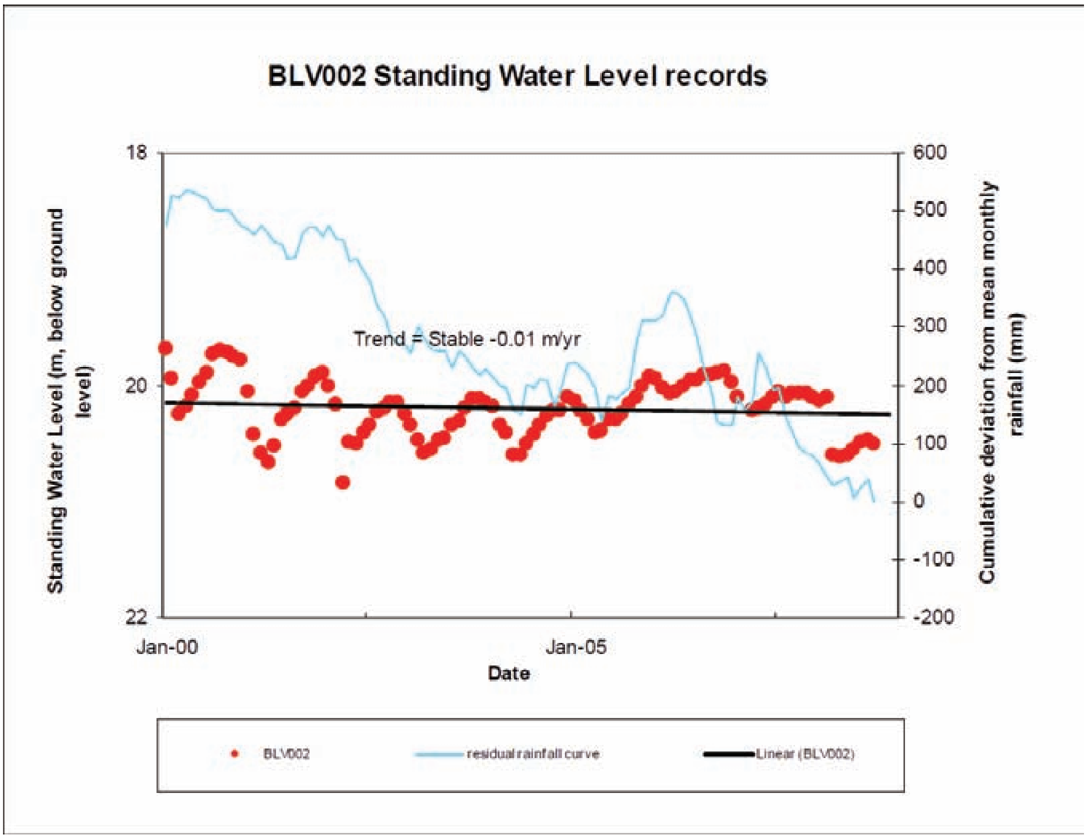
AMLR Region - falling trend examples (Sites MOR240, MOR229)



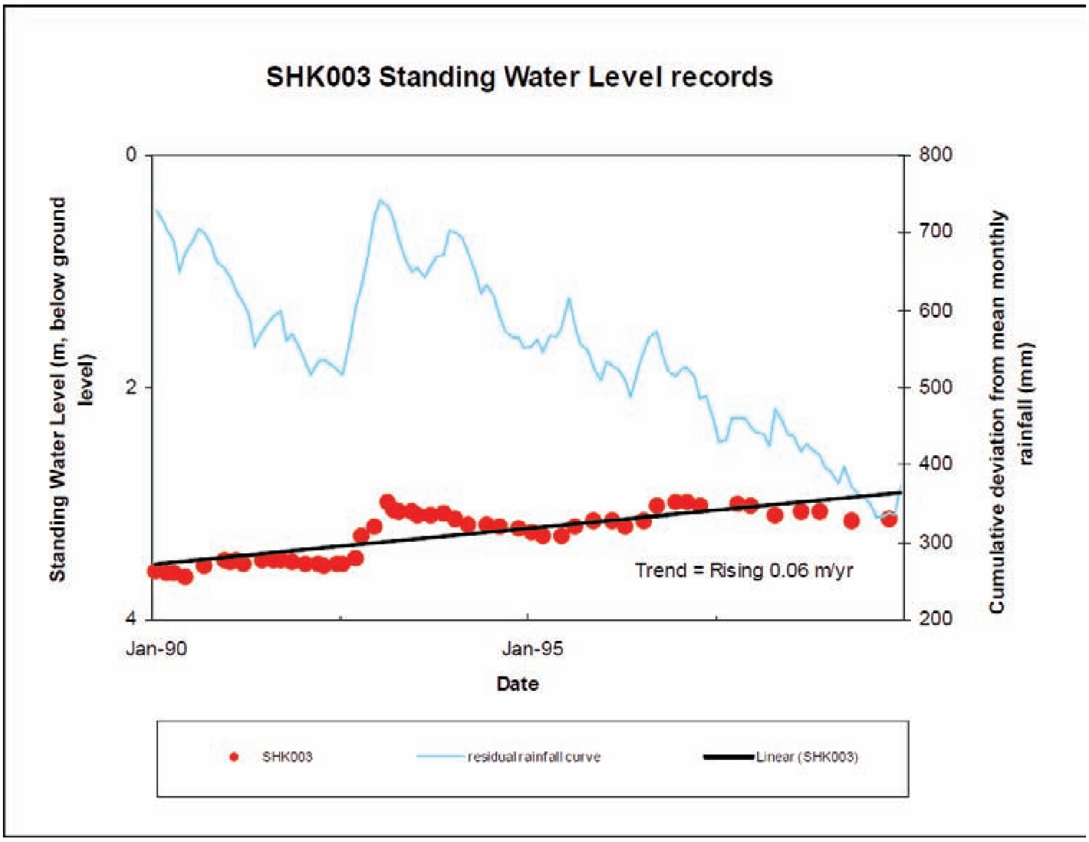


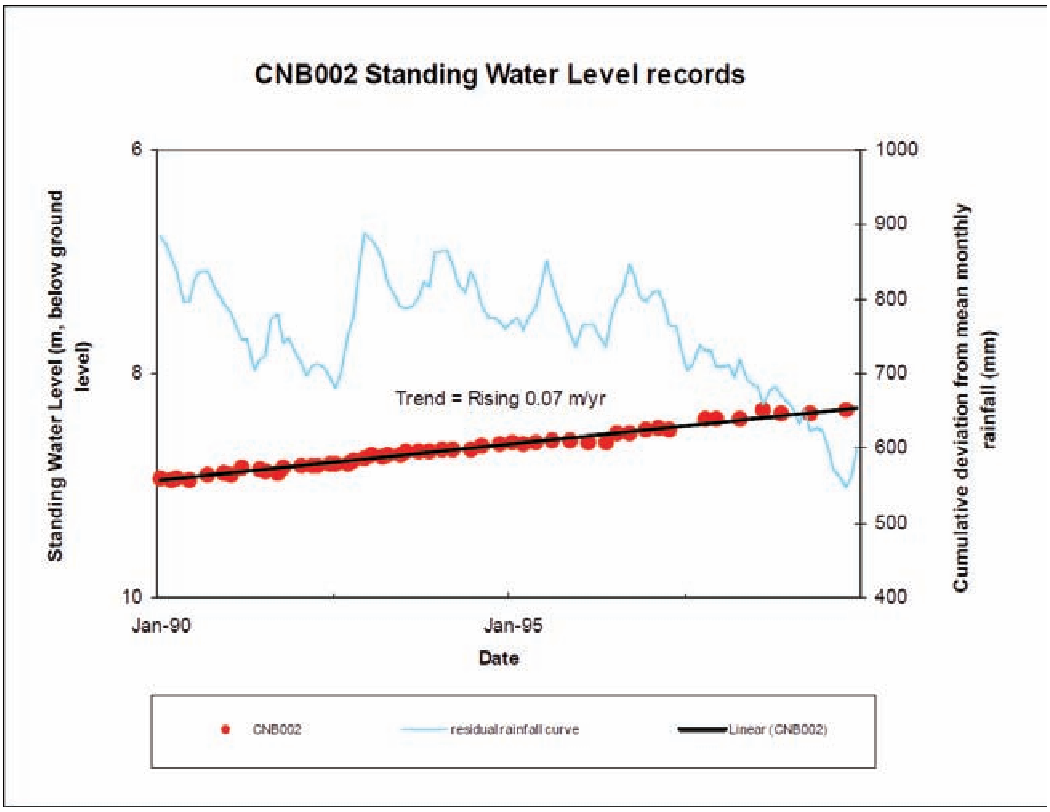
AMLR Region - stable trend examples (Sites MOR224, BLV002)



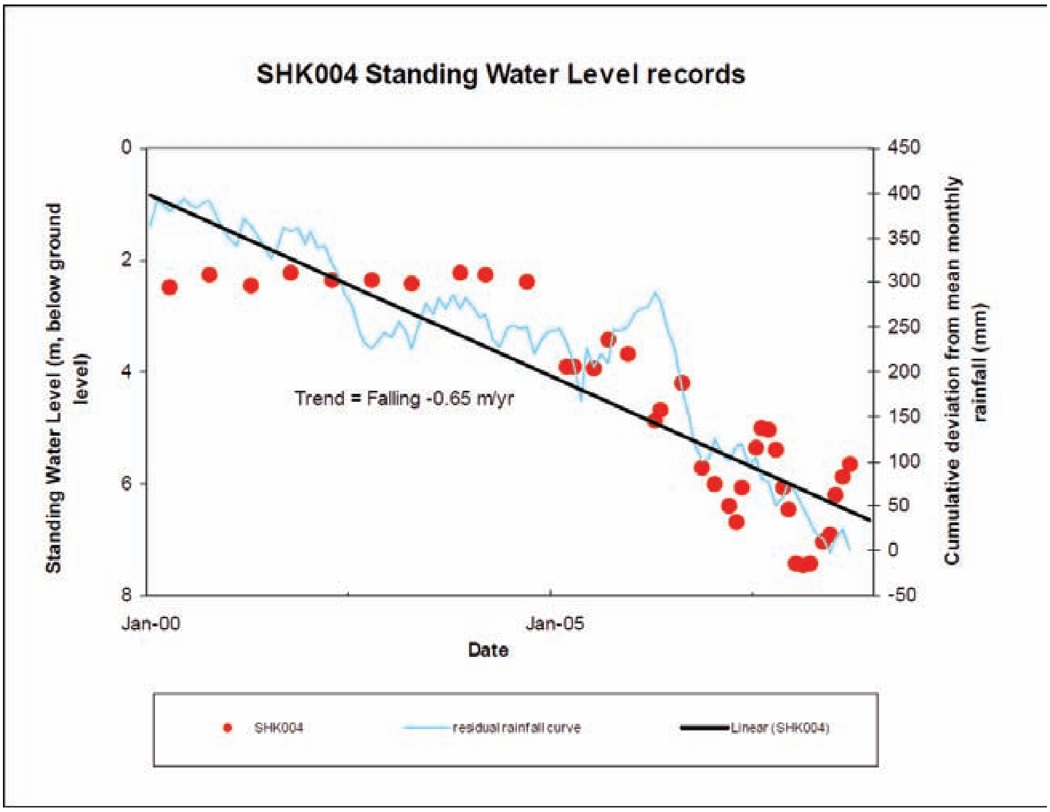


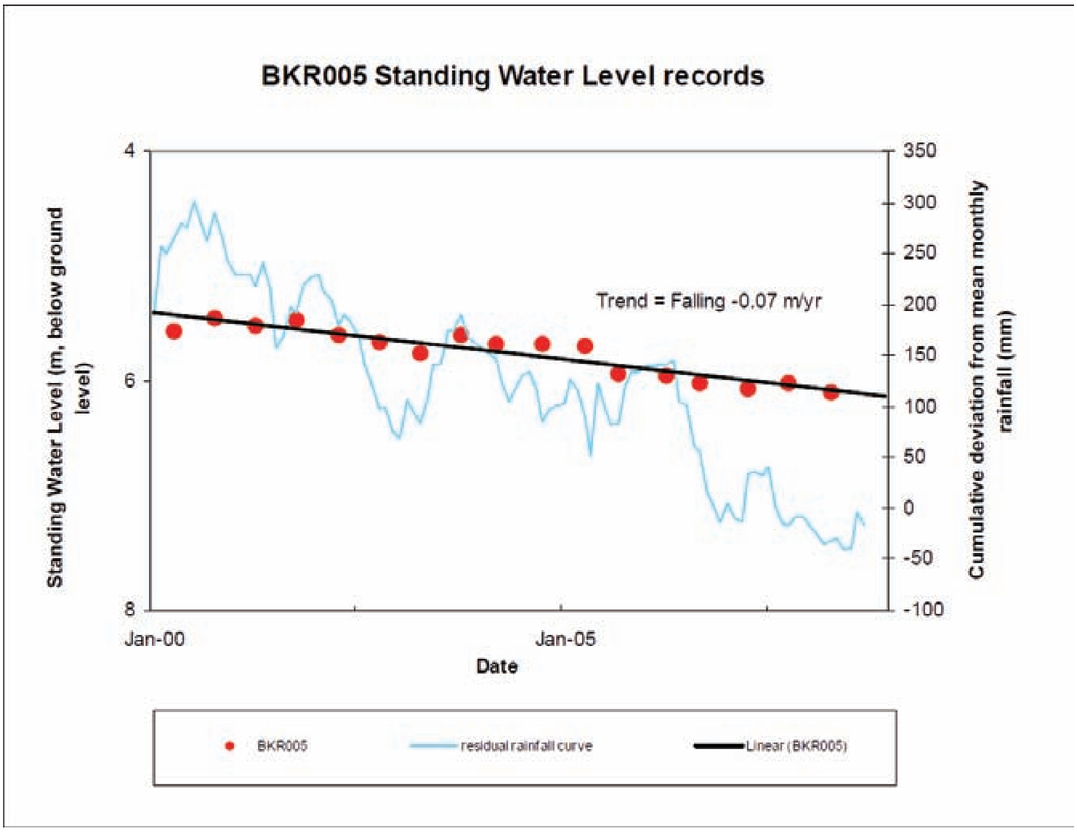
SE & SAMDB Region - rising trend examples (Sites SHK003, CNB002)



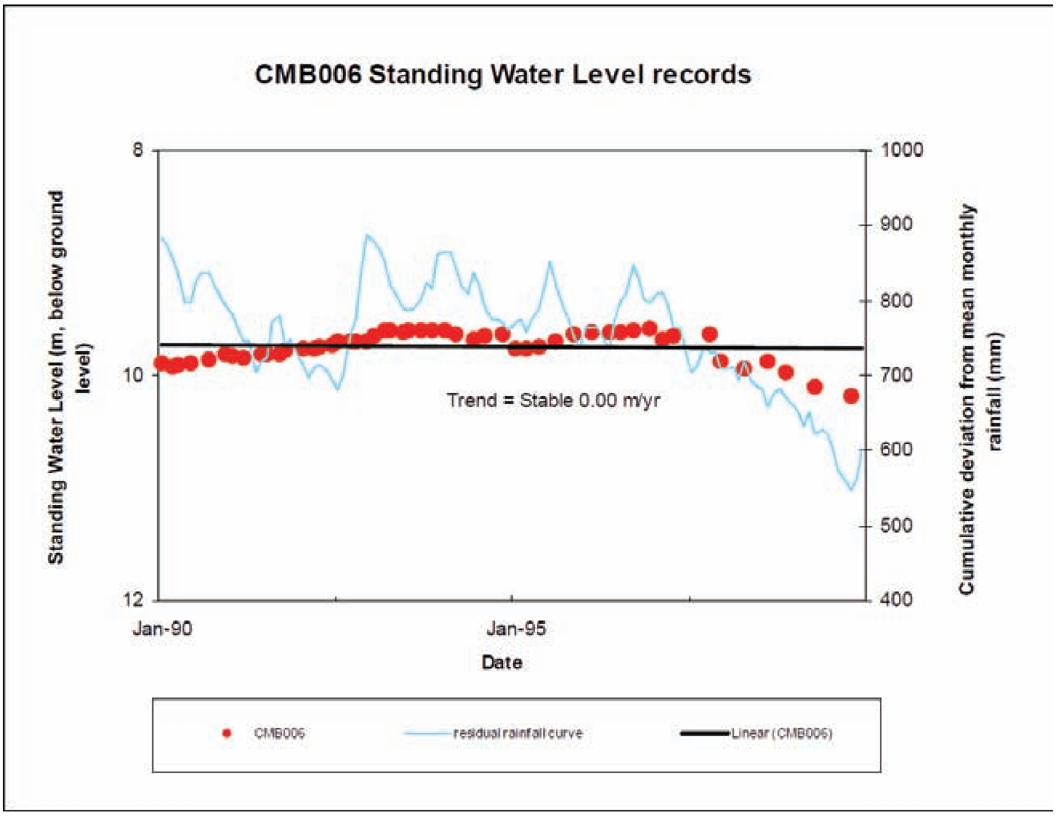


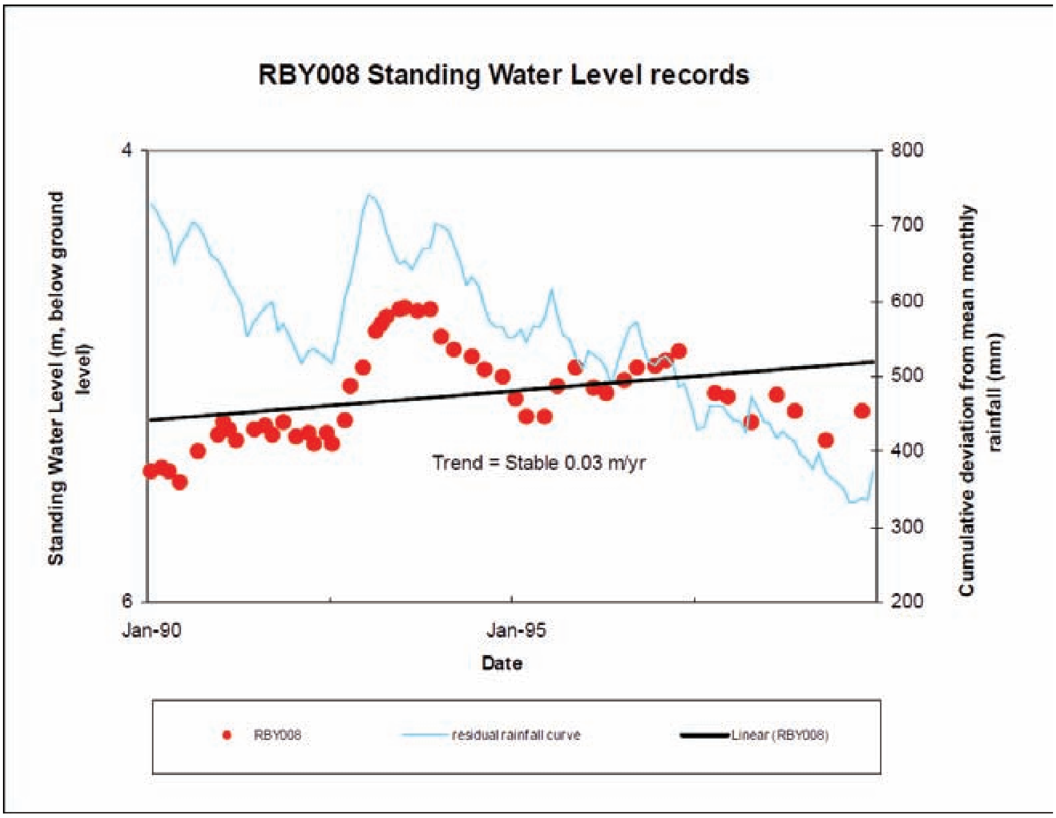
SE & SAMDB Region - falling trend examples (Sites SHK004, BRK005)





SE & SAMDB Region - stable trend examples (Sites CMB006, RBY008)





Appendix B. Regional Obswell Networks

Adelaide and Mt Lofty Ranges

Network Code	Network Name	No. of Wells
4TH CREEK	4th creek bore monitoring	10
BAROSSA	Barossa and Lyndoch Valleys	270
BIRDHAND	Bird in Hand Mine	28
CHARLESTON	Upper Onkaparinga catchment monitoring network	15
COCK_CREEK	Upper Onkaparinga catchment monitoring network	13
CURR_CRK	EMLR - Deep Creek and Finnnis catchments	1
ECHUNGA	Upper Onkaparinga catchment monitoring network	10
EPA	EPA Statewide Monitoring Network	37
HINDMRSH	Hindmarsh Tiers	22
INVERBRACK	Upper Onkaparinga catchment monitoring network	10
KEYNETON	Keyneton	44
METRO	Metropolitan Adelaide	397
MLR_RECH	MLR GW recharge investigation sites	35
MYPONGA	Myponga	28
NAP_LIC	Northern Adelaide Plains Licensed Wells	931
NAP_VHC_35	Shallow piezo network for NAPSWQ	35
NAP-S	NAP (seasonal)	377
OCWMB	Onkaparinga Catchment Water Management Board Shallow Groundwater Quality Monitoring	37
ONETREE	One Tree Hill	37
PICADILY	Picadilly Valley	19
STHNFLEU	Southern Fleurieu Wetlands Observation Network	42
TCWQ	TC Water Quality Monitoring Program	34
TORRENS	Torrens River Catchment	13
VHC_TESTWW	Virginia HC-Test pumping wells	19
WBWC	Willunga Basin Water Company shallow observation network	21
WILLUNGA	Willunga	190

South East

Network Code	Network Name	No. of Wells
BLUELAKE	Blue Lake	54
COASTPLN	Murray Basin-Coastal Plain	20
COM-CAR	Comaum-Caroline	633
COONALPN	Coonalpyn - Peake	25
EPA	EPA Statewide Monitoring Network	78
KCA	Kimberly Clark Australia	53
LACKON NTH	Lacepede Kongorong PWA Nth	574
LACKON STH	Lacepede Kongorong PWA Sth	784
MALLEE	Mallee	9
MESSENT	Messent Conservation Park	17
MOSQ	Mosquito Creek Catchment	7
NANGWARY	Nangwarry Recharge	14
NCTE	Naracoorte Ranges	218
NCTE-IRR	Naracoorte Irrigation	35
PAD-IRR	Padthaway Irrigation	104
PADTH	Padthaway	214
SAFRIES	SA Fries	50
SE-CONF	SE Confined Aquifer	217
TATIARA	Tatiara	210
TAT-IRR	Tatiara Irrigation	121
TCWQ	TC Water Quality Monitoring Program	29
TINTNARA	Tintinara	168
TINTY_TOWN	Tintinara Township network (unconf)	9
USE REGION	Upper South East Dryland Salinity and Flood Management Program	210
WLL_WET	Willalooka Wetlands	41

Kangaroo Island

Network Code	Network Name	No. of Wells
CYGNET	Cygnet River (KI) salinity network	22
DUDLEY	Dudley Peninsula (KI) salinity network	15
ELEANOR	Eleanor River (KI) salinity network	88
KI_RR	KI Rocky River Shallow Piezometer Network	32
MCGILVRAY	MacGillivray Plains (KI) salinity network	13
SOUWEST	Southwest Catchments (KI) salinity network	8
TCWQ	TC Water Quality Monitoring Program	6

SA Murray Darling Basin

Network Code	Network Name	No. of Wells
AB_SHALLOW	Angas Bremer shallow obs well network.	179
ANGBRM	Angas-Bremer	401
ASHBOURN	Ashbourne	18
BERIBARM	Berri-Barmera	128
BOOKPURN	Bookpurnong	14
BOOKY_SIS	Bookpurnong Salt Interception Obs network	37
BREMBARK	Bremer-Barker catchment group	19
BRUKUNGA	Brukunga	49
CADELL	Cadell Irrigation Area and surrounds	14
CHOW_PROP	Chowilla monitoring network	128
CHOW_RRG	Chowilla River Red Gum trial 2 August 2004	55
CHOWILLA	Chowilla	13
COASTPLN	Murray Basin-Coastal Plain	44
COOM_LCR	Coomandook Landcare Network	23
CURR_CRK	EMLR - Deep Creek and Finnnis catchments	47
GURAGURA	Gurra Gurra Wetland Complex network	18
HAROGATE	Harrogate Landcare group	38
JANELIZA	Jane Eliza	5
KATRAPKO	Katarapko Island	33
KEYNETON	Keyneton	25
LOWLAKE	Lower Lakes drawdown monitoring sites	24
LOWPIKE	Lower Pike River	69
LOXTON	Loxton	34
LOXTON_SIS	Loxton salt interception scheme	160
MALLEE	Mallee	222
MARNE	Marne River	100
MB-NORTH	Murray Basin-Northern Region	40
MB-RIVLD	Murray Basin-Riverland	38
MB-WEST	Murray Basin-Western Margin	74
MCFIELD	Macclesfield	25
MINDARIE	Mindarie mineral sands mining network	71
MLR_RECH	MLR GW recharge investigation sites	12
MOBILONG	Mobilong and Toora reclaimed swamps	12
MOORNEWR	Moorook-New Residence Area	31
MTBARKER	Mount Barker	12
MTCOMPAS	Mount Compass	39
MURTHO	Murtho	13

MYPOLONG	Mypolonga Irrigation Area	31
NOORA	Noora	57
OCWMB	Onkaparinga Catchment Water Management Board Shallow Groundwater Quality Monitoring	2
PEAKE	Peake-Roby-Sherlock PWA	41
PIKEMURTHO	This network encompasses both Pike and Murtho Regions.	130
RIVERS	Mid-North rivers	1
RMK-COOL	Renmark-Cooltong	220
STOKYARD	Stockyard Plain	40
SUNLANDS	Sunlands-Qualco Irrigation Area	45
SUNLD_IS	Sunlands Interception Scheme	82
TAYLOR	Taylorville	36
TCWQ	TC Water Quality Monitoring Program	15
TUNGKILO	Tungkillo Landcare Group	47
WAIK_IS	Waikerie Interception Scheme	75
WAIK2_IS	Waikerie Phase 2 Interception Scheme	55
WAK-HLD	Waikerie-Holder	67
WOOLP_IS	Woolpunda Interception Scheme	37
WOOLPNDA	Woolpunda	83

Eyre Peninsula

Network Code	Network Name	No. of wells
COFINBAY	Coffin Bay Township	14
COU-FLIN	County Flinders	98
COU-FLIN-C	County Flinders Coffin Bay Bore Run	15
COU-FLIN-L	County Flinders - Lincoln Basin Bore Run	13
COU-FLIN-U	County Flinders - Uley South Bore Run	49
COU-FLIN-W	County Flinders - Uley Wanilla Bore Run	21
COU-MUSG	County Musgrave	133
COWELL	Cowell	13
CUMMINS	Cummins	45
DARKPEAK	Darke Peak	5
EPA	EPA Statewide Monitoring Network	10
PENONG	Penong	15
STREAKY	Streaky Bay	54
TODRIVER	Tod River Catchment	1
VENUSBAY	Venus Bay-Port Kenny	20
WANILLA	Wanilla	27

Northern and Yorke

Network Code	Network Name/Catchment	No. of wells
BALAK	Wakefield River	19
BOOBOR	Broughton River	29
CARRIBIE	Southern Yorke Peninsula	14
CLARE	Broughton River	126
CLARE_SAW	Clare SA Water Network	21
GEORGTWN	Broughton River	6
GILBERT	Light River	5
JAMESTWN	Broughton River	34
KYBUNGA	Diamond Lake	3
LOCHIEL	Lake Bumbunga	16
MINLATON	Minlaton-Ramsay	43
MINTARO	Broughton River	6
PIRIE	Mambray Coast	15
REDHILL	Broughton River	18
TCWQ	TC Water Quality Monitoring Program	2
UPPYORKE	Upper Yorke Peninsula	26
WALLOWAY	Lake Frome	6
WANDERAH	Broughton River	9
WILLOCH	Willochra Creek	16

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

DENR – Department of Environment and Natural Resources (Government of SA)

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

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

GFS — Groundwater Flow System

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground

Observation well — A narrow well 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 well; 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

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 well (for the purposes of this report SWL is equivalent to watertable or depth to groundwater)

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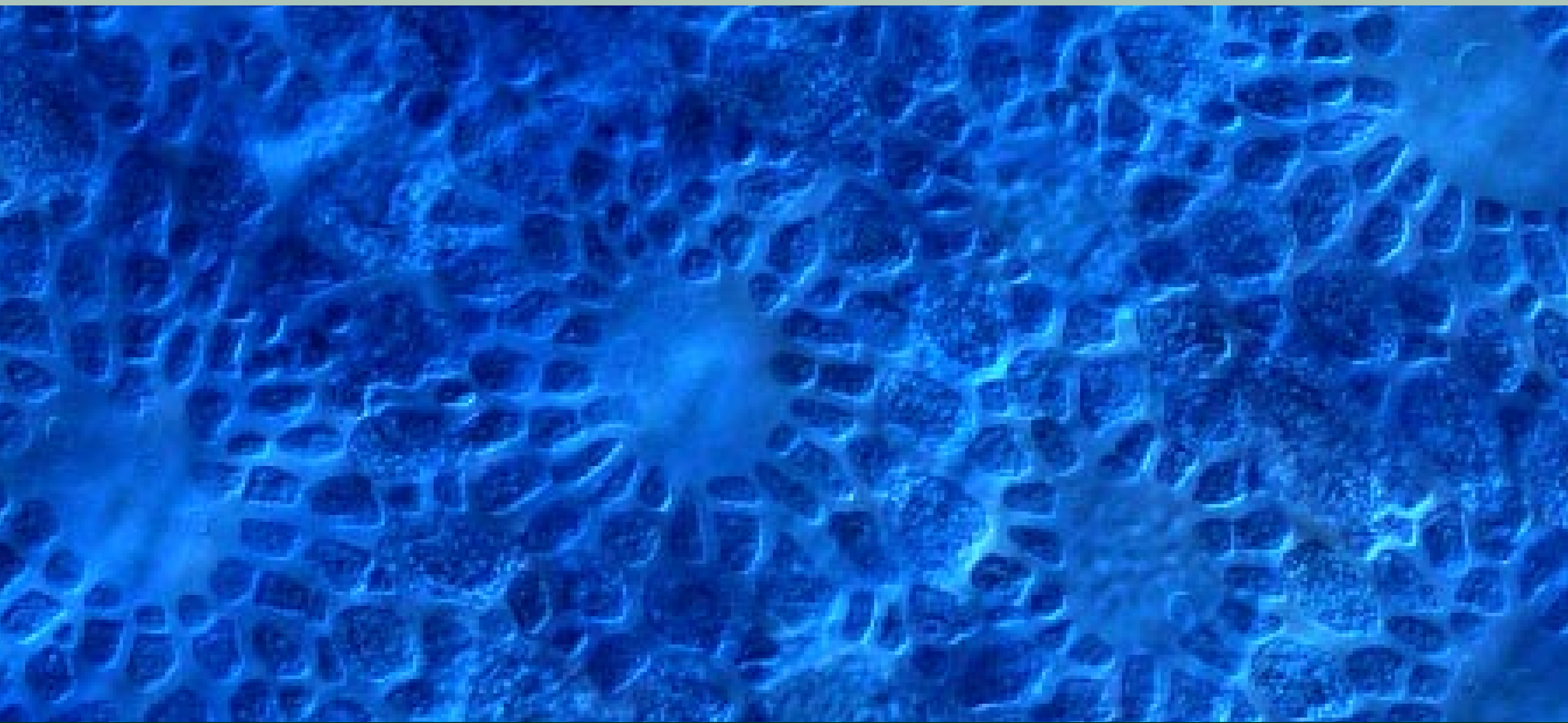

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or see SA White Pages for your local
Department of Environment and Natural Resources office.
Online information available at: http://www.environment.sa.gov.au

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