Salinity Trends in the McLaren Vale PWA
Stephanie Villeneuve
Nikki Harrington
Executive Summary

The McLaren Vale prescribed wells area (PWA) is located south of Adelaide, South Australia and includes the major sedimentary and fractured rock aquifers of the Willunga Basin. The groundwater resource helps support a large viticulture industry in the basin.

The McLaren Vale PWA Groundwater Status Report 2009-10 emphasized the trends towards falling water level and increasing salinity occurring in each of the main aquifers in the basin and suggested additional work was needed to identify possible causes. Further investigation of salinity and water level in the Willunga observation and McLaren Vale irrigation well networks has found that salinity levels in many of the wells have stabilized in response to increased winter rainfall in 2009/10. Water levels in some wells have also shown a rising response to this increase in rainfall.

In the Willunga observation and McLaren Vale irrigation well networks, four and 19 wells respectively, were identified as continuing to increase in salinity. Water levels associated with three of the four wells with increasing salinity in the Willunga observation network show a continued decline with no response to recent increased rainfall.

Work done herein has shown a possible relationship between increasing salinity and the proximity of well screens to the Blanch Point Formation (aquitard). It is therefore suggested that sampling for He and $^{14}$C in wells with increasing salinity and well screens close to the aquitard be undertaken. This could provide information on possible aquitard contributions to increasing salinity. In addition, continued regular sampling of Willunga observation and McLaren Vale irrigation well networks is crucial in order to monitor changes in salinity and water level. Understanding the source of salinity and how it varies spatially and temporally may assist in locating future wells and managing pumping schedules of existing wells to ameliorate water quality issues.

Climate patterns appear to be the main driving force behind both water level decline and increasing salinity. If rainfall decreases so does recharge to the aquifers, water levels fall and salinity increases. Concurrently, irrigation demand increases and groundwater extractions go up, thereby exacerbating water level declines. Should the higher winter rainfall of 2009/10 and higher summer rainfall of 2011 be an anomaly and the rates return to that of below average rainfall (2011 winter rainfall was indeed below average for the Willunga Basin) then the trend towards increasing salinity is likely to resume.
Contents
Executive Summary ........................................................................................................................................ ii
Table of Figures ............................................................................................................................................... iv
Introduction ....................................................................................................................................................... 1
Groundwater Salinity Trends .......................................................................................................................... 2
  Willunga Observation Well Network ............................................................................................................ 2
  McLaren Vale Irrigation Well Network ......................................................................................................... 7
  Salinity Trends and Water Levels ................................................................................................................ 11
  Salinity Trends and Possible Processes ........................................................................................................ 14
Recommendations for Future Work .............................................................................................................. 18
References ...................................................................................................................................................... 19
Appendix A: Rainfall .......................................................................................................................................... 20
Appendix B: Groundwater Use ..................................................................................................................... 22
Table of Figures

Figure 1: Lithology and hydrostratigraphy of the Willunga Basin (from AMLRNRM, 2007).......................1
Figure 2: Location of wells in the Willunga network with observations on salinity trends. The four wells in this network showing a continuing increase in salinity are highlighted in red...........................................3
Figure 3: Time series TDS values for wells completed in the Quaternary, Willunga network.......................4
Figure 4: Time series TDS values for wells completed in the Port Willunga Formation, Willunga network.................................................................4

Figure 5: Time series TDS values for wells completed in the Blanch Point Formation, Willunga network..5
Figure 6: Time series TDS values for wells completed in the Maslin Sands, Willunga network...............5
Figure 7: Time series TDS values for wells completed in the Fractured Rock, Willunga network..............6
Figure 8: Location of current wells in the McLaren Vale irrigation network that were sampled in 2011 and for which rising salinity trends were detected.........................................................................................8
Figure 9: Time series TDS values for wells completed in the Port Willunga Formation, McLaren Vale irrigation network.........................................................................................................................................................9
Figure 10: Time series TDS values for wells completed in the Blanch Point Formation, McLaren Vale irrigation network..................................................................................................................................................9
Figure 11: Time series TDS values for wells completed in the Maslin Sands, McLaren Vale irrigation network........................................................................................................................................................................10
Figure 12: Time series TDS values for wells completed in the Fractured Rock, McLaren Vale irrigation network............................................................................................................................................................10

Figure 13: Time series TDS and depth to water for WLG057 in the Quaternary, Willunga network.........12
Figure 14: Time series TDS and depth to water for wells in the Port Willunga Formation, Willunga network................................................................................................................................................................12

Figure 15: Time series TDS and depth to water for wells in the Maslin Sands, Willunga network............13
Figure 16: Time series TDS and depth to water for WLG143 in the Fractured Rock, Willunga network....13
Figure 17: Histogram of Willunga and McLaren Vale network wells grouped by salinity trend and plotted against screen top below water level..................................................................................................15

Figure 18: Wells in the Port Willunga Formation with a continuing rise in salinity plotted with depth to the top of the Blanch Point Formation. The number in purple is the depth of the bottom of the screen for each well, where known........................................................................................................................................................................16

Figure 19: Wells in the Maslin Sands with a continuing rise in salinity plotted with depth to the bottom of the Blanch Point Formation. The number in purple is the depth of the top of the screen for each well, where known........................................................................................................................................................................17

Figure 20: a) Annual winter rainfall and cumulative deviation from mean winter rainfall and b) annual summer rainfall and cumulative deviation from mean summer rainfall, for the Willunga meteorological station................................................................................................................................................................20

Figure 21: a) Annual winter rainfall and cumulative deviation from mean winter rainfall and b) annual summer rainfall and cumulative deviation from mean summer rainfall, for the Mt Bold meteorological station................................................................................................................................................................21

Figure 22: Historic licensed groundwater use for the McLaren Vale PWA (excludes stock and domestic use)...........................................................................................................................................................................................22
Figure 23: Historic licensed groundwater use for the McLaren Vale PWA by aquifer................................22
Figure 24: Spatial distribution of groundwater extractions from the major aquifers in the McLaren Vale PWA in 2010/11................................................................................................................................................................23
Introduction

The McLaren Vale prescribed wells area (PWA) covers approximately 320 square kilometers and is located about 35 km south of Adelaide, South Australia. It is bounded by the Onkaparinga River to the north, the Gulf St Vincent to the west, and the ridge of the Sellicks Range in the southeast. The McLaren Vale PWA includes the aquifers of the Willunga Basin, a thick sequence of Cainozoic sediments bounded to the east and south by the Willunga Fault, and the fractured rock aquifer, which underlies the basin and outcrops to the north and forms the hills east of the fault.

Groundwater in the McLaren Vale PWA occurs in four main aquifers: Quaternary Aquifer, Port Willunga Formation Aquifer, Maslin Sands Aquifer and the Fractured Rock Aquifer with the Blanch Point Aquitard separating the Port Willunga Formation from the Maslin Sands (Figure 1). The reader is directed to the McLaren Vale PWA Groundwater Status Report 2009-10 (DFW, 2011) for a review of the hydrogeology of the Willunga Basin, as well as groundwater flow and salinity distribution maps of the main aquifers.

A major finding of the Groundwater Status Report (DFW, 2011) was the trend towards rising salinities since 2007 in each of the major aquifers and it recommended that additional work be done to identify possible causes. The purpose of this report is to further examine these trends, with the most up to date salinity sampling results, and investigate their spatial distribution and possible relationship to water level and bore depth.

Figure 1: Lithology and hydrostratigraphy of the Willunga Basin (from AMLRNM, 2007).
Groundwater Salinity Trends

Groundwater salinity information in the McLaren Vale PWA is available from two primary sources: the Willunga observation well network, and the McLaren Vale irrigation well network. Salinity is herein reported as Total Dissolved Solids (TDS) which is calculated from measured electrical conductivity. Salinity trends were chosen by visual inspection of the time series data of each well with particular attention paid to the 2007-2011 time period. Where possible, trends were assigned as either rising, stable-rising, stable, stable-falling or falling. During the inspection of the data, the winter (April – October) and summer (November – March) results were considered as two parts of a whole. In doing this, it was possible to identify trends in what might otherwise just look like scatter.

Willunga Observation Well Network

There are 119 wells in the Willunga network, 26 current and 93 historic wells. Although the majority of the historic wells were not included in this assessment, those with a salinity measurement in 2011 were considered. Wells in the Willunga network are typically sampled at least once a year, some more frequently.

Of the 26 current wells in the Willunga network, trends were assigned to 21 wells. Out of 93 historic wells, 9 of the 10 that were sampled in 2011 could be assigned a trend. Together these 30 wells are presented spatially and by aquifer in Figure 2. Each well has been annotated with comments on the trends and the four wells with a distinct continuing rise in salinity are highlighted with red text.

Time series graphs of the salinity trends for these wells are shown in Figure 3 through Figure 7. Wells in the northeastern portion of the PWA are plotted with the Mt Bold winter rainfall cumulative deviation, and wells in the central and southwestern portions of the PWA are plotted with the Willunga winter rainfall cumulative deviation (see Appendix A for rainfall data). Please note that the axis on the cumulative deviation has been reversed from the normal presentation. This has been done to emphasize the relationship between rainfall and salinity trends. Thus in all of the following graphs, a decrease in slope of the cumulative deviation indicates above average rainfall, and an increase in slope indicates below average rainfall.

Many of the wells presented in Figure 3 through Figure 7 show similar trends: a decrease in salinity from the late 1980s to 2006 followed by an increase in salinity between 2006 and 2010. A number of these wells also show a stabilization or fall in salinity since 2010. Of particular interest is the number of wells where the salinity trends appear to be closely related to trends in rainfall (higher than average rainfall, decreasing salinity; lower than average rainfall, increasing salinity). This relationship is quite clear with some wells, in particular WLG055, WLG073 and WLG061 in Figure 4 and KTP029, KTP030, WLG074 and WLG080 in Figure 6 although the amplitude is more pronounced in some. It is likely that the decrease in salinity towards the end of the record is a response to higher winter rainfall in 2009 and 2010. Some of the wells also show a seasonal fluctuation in salinity with higher salinity in the summer months than in the winter. Wells where this relationship is less obvious, such as WLG118 in Figure 3 and WLG024 and WLG112 in Figure 7, may reflect more limited datasets.

Out of 30 wells in the Willunga Observation network, four were singled out as showing trends with continuing increases in salinity. The salinity trends for wells WLG057 (Figure 3) and WLG061 (Figure 4)
appear to follow the trends in rainfall; however recent sampling has not shown them to be stabilizing. The salinity trends for wells WLG051 (Figure 4) and KTP022 (Figure 6) are similar with a more damped response to rainfall and less seasonal fluctuation in the salinity (particularly KTP022). There are several additional wells which may still be rising (WLG117 in Figure 5; WLG112 and WLG107 in Figure 7), but more data is required to establish this.

Figure 2: Location of wells in the Willunga network with observations on salinity trends. The four wells in this network showing a continuing increase in salinity are highlighted in red.
Figure 3: Time series TDS values for wells completed in the Quaternary, Willunga network.

Figure 4: Time series TDS values for wells completed in the Port Willunga Formation, Willunga network.
Figure 5: Time series TDS values for wells completed in the Blanch Point Formation, Willunga network.

Figure 6: Time series TDS values for wells completed in the Maslin Sands, Willunga network.
Figure 7: Time series TDS values for wells completed in the Fractured Rock, Willunga network.
McLaren Vale Irrigation Well Network

There are 349 current wells in the McLaren Vale irrigation network. Many of the wells in this network are sampled once a year, some more frequently. Although a large source of salinity data, many of these wells were not sampled prior to 2007, and with yearly sampling, have only four salinity measurements (or less) so trends are harder to establish. In many cases the limited data do not support the selection of either a rising or a falling salinity trend and have not been assigned a trend or assigned a status of ‘stable’ pending additional sampling. Those wells where a rising trend was clearly present are illustrated spatially in Figure 8. From a data set containing 349 wells, 19 wells have a rising trend continuing through 2011. However, with some of these wells it is possible that additional sampling will find that the salinity has stabilized.

Time series graphs of the salinity trends for these 19 wells are shown in Figure 9 through Figure 12. Wells in the northeastern portion of the PWA are plotted with the Mt Bold winter rainfall cumulative deviation, and wells in the central and southwestern portions of the PWA are plotted with the Willunga winter rainfall cumulative deviation.

Due to the more limited dataset, the relationship between rainfall and salinity that was observed in the Willunga network wells is only apparent for well 6627-09113. This well clearly shows lower salinity in the 1990s trending towards higher salinity during the drought (Figure 9). Seasonal fluctuations in salinity are also observed in these wells. In several cases, what appears at first glance to be a decrease in salinity of the most recent sample is rather a reflection of sampling during the winter months (e.g., 6527-00825, 6627-10570 and 6627-03545 in Figure 9; 6627-09629 in Figure 11).

It is worth emphasizing the limitations of this dataset. Unlike with the Willunga network, many of the wells in the McLaren Vale network have limited or no older data with which to compare the recent sampling.
Figure 8: Location of current wells in the McLaren Vale irrigation network that were sampled in 2011 and for which rising salinity trends were detected.
Figure 9: Time series TDS values for wells completed in the Port Willunga Formation, McLaren Vale irrigation network.

Figure 10: Time series TDS values for wells completed in the Blanch Point Formation, McLaren Vale irrigation network.
Figure 11: Time series TDS values for wells completed in the Maslin Sands, McLaren Vale irrigation network.

Figure 12: Time series TDS values for wells completed in the Fractured Rock, McLaren Vale irrigation network.
Salinity Trends and Water Levels

In addition to rising salinity trends, the McLaren Vale PWA Groundwater Status Report 2009-10 (DFW, 2011) also emphasized a trend towards declining water levels in the Port Willunga Formation, Maslin Sands and Fractured Rock aquifers.

Figure 13 to 16 present the depth to water and salinity data for selected observation wells in the Willunga network. Several observations can be made from these figures. The first is that some of the wells where the salinity appears to have recently stabilized also show a slight recovery in water level (KTP029 and KTP030 in Figure 15; WLG143 in Figure 16). This trend appears to be largely climate driven: when rainfall is below average recharge to the aquifers decreases. If this is compounded by below average summer rainfall (see Figure 20 and Figure 21 in Appendix A), irrigation extractions increase (see Figure 22 in Appendix B) and these two factors cause the water levels to fall (depth to water increases). This is accompanied by an increase in salinity, the possible sources of which will be discussed in the following section. As rainfall increases so does recharge, irrigation extractions decrease and water levels experience some recoveries and salinities stabilize. Interestingly, the water level in well WLG057 (Figure 13), a Quaternary well in the southwest with very high salinity, does appear to have responded to the higher rainfall in 2009/10, but the salinity has continued to increase.

The second observation is that the two wells in the Port Willunga Formation with a continuing increase in salinity (WLG051 and WLG061 in Figure 14) are associated with a consistent decline in water level. They display some seasonality in water level but appear largely unaffected by recent rainfall. KTP022 (Figure 15) in the unconfined Maslin Sands to the northeast is similar with a continuing increase in salinity and decline in water level since 2003 and no appreciable response to increased rainfall in 2009/10. Although the increase in salinity and decline in water level are likely climate driven, the question remains as to why these wells are unresponsive to recent increases in rainfall. While these wells are completed in aquifer units, it is possible that, due to anisotropy, the well screens are in lower permeability strata that are slower to respond to external stimuli. KTP022 (Figure 15) is the most likely candidate for this, as it has a short screen length (~3 m) and, despite being located in the unconfined area of the Maslin Sands to the northeast, does not show very much seasonality in the salinity samples. In comparison KTP029 (Figure 15), which is up gradient of KTP022 in the Maslin Sands (Figure 2), is not completed as deep as KTP022 and it shows more seasonal variability and both salinity and water level appear to have responded to the increased rainfall.

In contrast to the above observations, the water level in WLG088 (Figure 14) seems to be fairly stable in the long term, despite changes in salinity. This well is in the southwest closer to the coast (Figure 2) in an area where there is less groundwater extraction for irrigation (see Figure 24 in Appendix B).

Unfortunately there is no water level data available for the wells in the McLaren Vale irrigation network that were identified as continuing to rise in salinity. It is therefore not possible, at this time, to see if this water level relationship holds for more wells.
Figure 13: Time series TDS and depth to water for WLG057 in the Quaternary, Willunga network.

Figure 14: Time series TDS and depth to water for wells in the Port Willunga Formation, Willunga network.
Figure 15: Time series TDS and depth to water for wells in the Maslin Sands, Willunga network.

Figure 16: Time series TDS and depth to water for WLG143 in the Fractured Rock, Willunga network.
**Salinity Trends and Possible Processes**

There are several possible processes which may be responsible for the increase in salinity observed in the McLaren Vale PWA. These include: irrigation, water-rock interactions, and pumping induced leakage from aquitards.

Irrigation can cause groundwater salinity to increase via several processes. The salinity of irrigation water increases due to evaporation and transpiration, so that when surplus water reaches the water table it can have a higher salinity then it did initially. In addition, the irrigation water may dissolve and mobilize salts present in the soil profile as it infiltrates. Figure 17 is a histogram of wells from both the Willunga and McLaren Vale networks for which water level and well completion information is available. The wells have been grouped according to their salinity trend and are plotted against ‘Screen Top Below WL’, which is a measurement of the distance between the top of the well screen and the last measured water level. A negative value indicates that the water level is found within the screen and a positive measurement indicates the water level is above the screen. If the water level is close to the screen top then it is possible that irrigation drainage could contribute to well salinity. However if the water level is far above the screen top, then it is likely that the water sampled by the well is relatively old, and hence unlikely that irrigation water is contributing to well salinity. In addition to this, both depth to the water table and nature of the aquifer (confined vs unconfined) will impact the susceptibility of a well to irrigation drainage. Irrigation drainage is less likely to reach a well in a confined aquifer, and will take much longer to impact wells in areas with deep water tables.

If irrigation drainage were a possible source for the increasing salinity one would expect to see a higher frequency of ‘Stable-Rising’ and ‘Rising’ wells where the Screen Top Below WL is less than 10 m (Figure 17). There does not, however, appear to be any particular relationship between salinity trend and Screen Top Below WL. The four wells with rising trends and a screen top below water level of less than 10 m are WLG057 (Figure 3), WLG051 and WLG061 (Figure 4) and 6527-01264 (Figure 9). WLG057 is in the Quaternary with a completion depth of 5.5-11.5 m and a water level 0.07 m above the screen; it is possible that the rise in salinity is due to irrigation drainage. WLG061, which is in the unconfined Port Willunga Formation to the northeast, has a completion depth of 73.5-83.5 m and a water level 4 m below the top of the screen. Due to the large water table depth, irrigation drainage is unlikely to be contributing to the observed increase in salinity. WLG051 and 6527-01264 are in the confined Port Willunga Formation along its southeastern boundary and so it is unlikely that the increase in salinity in these wells is due to irrigation drainage.
Figure 17: Histogram of Willunga and McLaren Vale network wells grouped by salinity trend and plotted against screen top below water level.

Water-rock interactions are driven by chemical equilibration between the groundwater and the host rock. This process relies partly on the residence time of groundwater in an aquifer (or aquitard). If water flows rapidly from the recharge to discharge zones, there may not be enough time for these interactions to occur. In the Willunga Basin, where groundwater may be several thousands of years old, this process could be affecting groundwater chemistry in the long term. It is unlikely, however, to be the cause of short term fluctuations in salinity such as those seen in the last decade.

Pumping induced leakage from aquitards is a possible source of increasing salinity under certain situations: if the well screen top or bottom is close to the aquitard and there is a vertical component to groundwater flow (lower pressure in the aquifer than the aquitard). Using the hydrostratigraphy of the McLaren Vale region, the depth to the top (Figure 18) and bottom (Figure 19) of the Blanch Point Formation was contoured. By examining the separation between a well screen and the aquitard it is possible to identify wells that might be pulling water from the aquitard. For example, the bottom of the well screen for WLG061 (Figure 18) is at a depth of 83.5 m (below ground surface) and the 80 m contour line for the top of the Blanch Point Formation passes just above the well. The well screen for this well may be close to the top of the aquitard. Using this method, it is possible to see that nearly half of the wells in the Port Willunga Formation with a continuing rise in salinity have screen bottoms near the top of the Blanch Point Formation (Figure 18: WLG061, 6627-11064, 6627-10493, 6627-09113, 6627-09856 and 6627-09884). Likewise, of the five wells with a continuing increase in salinity in the Maslin Sands, three have well screen tops that may be close to the bottom of the Blanch Point Formation (Figure 19: KTP022, 6627-07928, and 6627-09629). Similarly, leakage from the Fractured Rock aquifer could also be a possible source of increasing salinity. Additional groundwater sampling, specifically for He and \(^{14}\)C, in the above mentioned wells may shed some light on this possible process. Helium and \(^{14}\)C are used as groundwater age dating tools and if leakage from the aquitard is occurring then one would expect to see an older groundwater signature from these wells.
Ultimately each of these processes is affected by changes in the climate. If winter rainfall decreases, aquifer recharge is reduced and water levels fall. If this is accompanied by low summer rainfall then irrigation extractions increase and the impact on water levels, and consequently on salinity, is exacerbated.

Figure 18: Wells in the Port Willunga Formation with a continuing rise in salinity plotted with depth to the top of the Blanch Point Formation. The number in purple is the depth of the bottom of the screen for each well, where known.
Figure 19: Wells in the Maslin Sands with a continuing rise in salinity plotted with depth to the bottom of the Blanch Point Formation. The number in purple is the depth of the top of the screen for each well, where known.
**Recommendations for Future Work**

Many of the wells that were showing an increase in salinity post-2007 have since stabilized following higher than average winter rainfall in 2009/10 and higher than average summer rainfall in 2011. Should periods of low rainfall occur in the future, however, it is likely that salinity levels would again begin to rise.

Analysis of trends was hampered by a lack of monitoring data and a short period of time since the increase in rainfall. It is therefore recommended to:

1. Continue regular monitoring of salinity and water levels in the Willunga and McLaren Vale networks. An additional 6-12 months’ worth of data will help to further establish trends. In 2010 the Willunga salinity network had 64 current observation wells and that number has since dropped to 26. This reduction makes it more difficult to determine regional trends. It is recommended that sampling be reinstated for some of these wells, in particular those that were sampled in 2010 or 2011 and have at least five years of regular sampling (e.g., WLG051, WLG072, WLG112, WLG117, WLG024, WLG098, KTP027).

Preliminary analysis of data has shown a possible correlation between increasing salinity and the proximity of well screens to the aquitard. Future work to address this includes:

2. An investigation into salinity and groundwater gradients within the aquifers as well as across the aquitard. The Willunga Super Science phase 2 drilling project, which is set to begin shortly, will see the installation of 7 multi-level piezometer nests in a northeast-southwest transect though the McLaren Vale PWA. Multi-level wells will be completed in the Port Willunga Formation, Chinaman Gully and Blanch Point Formations, and the Maslin Sands. This will allow for the identification of salinity stratification and general groundwater quality sampling at various depths through the sedimentary sequence. The multi-level nests will also monitor water level and be able to ascertain if there is a vertical component to groundwater flow, and thus any driving force for inter aquifer leakage. In addition, the aquitard is being cored at each location and sampled for He and $^{14}$C, which will be used to determine the age of the resident groundwater.

3. In conjunction with the above drilling and sampling program it is recommended that wells identified in this report as having well screens close to the aquitard be sampled for He and $^{14}$C. This could shed some light on possible cross-formational contributions of water to increasing salinity.

4. It is also recommended that electromagnetic (EM) methods be used to measure the salinity profiles in wells that are cased with PVC. Increasing salinity towards the aquitard would be an indication of leakage.
References


Appendix A: Rainfall

Rainfall in the McLaren Vale PWA is seasonal, with higher rates falling in the winter months and lower rates in the summer. Rainfall data from two meteorology stations were used here: Mt Bold (station 23734), northeast of the McLaren Vale PWA in the Mount Loft Ranges, and Willunga (station 23753). In order to highlight broad trends in rainfall the cumulative deviation from mean winter rainfall (April-October) and cumulative deviation from mean summer rainfall (November-March) was calculated for each station for the period from 1983-2011. NOTE: The cumulative deviation axes are plotted in reverse such that a decrease in the slope of the cumulative deviation indicates above average rainfall, and an increase in slope indicates below average rainfall.

Average annual winter rainfall at Willunga for the 1983-2011 time period was 490 mm. Figure 20a shows above average winter rainfall from the mid-1980s to early 1990s and a more recent decline. Average annual summer rainfall at Willunga for the same period was 119 mm. Figure 20b shows below average summer rainfall from 1984 to 2002, with the exception of high rainfall years in 1993/94 and 1999/2000, and above average summer rainfall since 2004. The dataset is incomplete because if the rainfall for one month is missing, it is not possible to calculate a proper average for that season.

![Figure 20: a) Annual winter rainfall and cumulative deviation from mean winter rainfall and b) annual summer rainfall and cumulative deviation from mean summer rainfall, for the Willunga meteorological station.](image)

Average annual winter rainfall at Mt Bold for the 1983-2011 period was 646 mm. Figure 21a shows above average winter rainfall from the mid-1980s to the early 1990s and a stretch of below average rainfall from 2002-2008. What is more obvious from this data is the subsequent increase in winter rainfall that occurred in 2009/10. Average annual summer rainfall at Mt Bold for the same time period was 162 mm. Figure 21b shows recurring below average summer rainfall punctuated by years with higher rainfall.
Figure 21: a) Annual winter rainfall and cumulative deviation from mean winter rainfall and b) annual summer rainfall and cumulative deviation from mean summer rainfall, for the Mt Bold meteorological station.
Appendix B: Groundwater Use

Groundwater extractions in the McLaren Vale PWA from 2004 to 2011 are presented in Figure 22 (excluding stock and domestic use). Extractions in 2010/11 totalled 2656 ML, a decrease of 33% from the previous year, and a decrease of nearly 50% from the highest extractions in 2008/09. The 2010/11 extraction rate is far below the limit of 6600 ML/yr for the PWA. Also included in Figure 22 are the summer rainfall cumulative deviations for the Willunga and Mt Bold stations (Note: cumulative deviation axis is reversed). When both meteorological stations experience above average summer rainfall (2005/06 and 2010/11) there are substantial decreases in extraction rates. Figure 23 illustrates the extractions by major aquifer, with the Port Willunga Formation supplying most of the water. Figure 24 provides the spatial distribution of groundwater extractions from each aquifer in 2010/11.

![Figure 22](image1.png)

Figure 22: Historic licensed groundwater use for the McLaren Vale PWA (excludes stock and domestic use).

![Figure 23](image2.png)

Figure 23: Historic licensed groundwater use for the McLaren Vale PWA by aquifer.
Figure 24: Spatial distribution of groundwater extractions from the major aquifers in the McLaren Vale PWA in 2010/11.