

McLaren Vale Prescribed Wells Area groundwater resource assessment

Department for Environment and Water

March 2022

DEW Technical note 2022/08



**Government
of South Australia**

Department for
Environment and Water

Department for Environment and Water
Government of South Australia
January 2022

81-95 Waymouth St, ADELAIDE SA 5000
Telephone +61 (8) 8463 6946
Facsimile +61 (8) 8463 6999
ABN 36702093234

www.environment.sa.gov.au

Disclaimer

The Department for Environment and Water and its employees do not warrant or make any representation regarding the use, or results of the use, of the information contained herein as regards to its correctness, accuracy, reliability, currency or otherwise. The Department for Environment and Water and its employees expressly disclaims all liability or responsibility to any person using the information or advice. Information contained in this document is correct at the time of writing.



With the exception of the Piping Shrike emblem, other material or devices protected by Aboriginal rights or a trademark, and subject to review by the Government of South Australia at all times, the content of this document is licensed under the Creative Commons Attribution 4.0 Licence. All other rights are reserved.

© Crown in right of the State of South Australia, through the Department for Environment and Water 2022

ISBN 978-1-922027-39-9

Report prepared by:

Steve Barnett
Water Science Unit
Water Science and Monitoring Branch
Water and River Murray Division
Department for Environment and Water

Preferred way to cite this publication

Department for Environment and Water (DEW) 2022. McLaren Vale Prescribed Wells Area groundwater resource assessment. DEW Technical Note 2022/08, Government of South Australia, Adelaide.

Download this document at <https://www.waterconnect.sa.gov.au>

Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Contents

Foreword	ii
1 Introduction	6
2 Climate	7
3 Hydrostratigraphy	8
3 Quaternary aquifer	10
3.1 Extraction and allocation	10
3.2 Groundwater flow direction	11
3.3 Water level trends	12
3.4 Salinity distribution	12
3.5 Connection with surface water and/or GDEs	12
3.6 Sustainability issues	12
3.7 Resource capacity	13
4 Port Willunga Formation aquifer	14
4.1 Extraction and allocation	15
4.2 Groundwater flow direction	16
4.3 Water level trends	16
4.4 Salinity distribution	18
4.5 Salinity trends	18
4.6 Connection with surface water and/or GDEs	19
4.7 Sustainability issues	19
4.7.1 Pressure declines	19
4.7.2 Depressurisation of the confined aquifer	19
4.7.3 Sea water intrusion	20
4.7.4 Climate change	20
4.8 Resource Condition Limits	20
4.9 Resource capacity	20
5 Pirramimma Sand aquifer	21
5.1 Extraction and allocation	22
5.2 Groundwater flow direction	23
5.3 Water level trends	23
5.4 Salinity distribution	24
5.5 Salinity trends	24
5.6 Connection with surface water and/or GDEs	25
5.7 Sustainability issues	25
5.7.1 Salinity increases	25
5.7.2 Watertable declines	26
5.7.3 Climate change	27
5.8 Resource capacity	27
5.9 Resource Condition Limits	27

6	Maslin Sands aquifer	28
6.1	Extraction and allocation	29
6.2	Groundwater flow direction	30
6.3	Water level trends	30
6.4	Salinity distribution	30
6.5	Salinity trends	32
6.6	Connection with surface water and/or GDEs	32
6.7	Sustainability issues	32
6.7.1	Salinity increases	32
6.7.2	Watertable declines	33
6.7.3	Depressurisation of the confined aquifer	34
6.7.4	Sea water intrusion	34
6.7.5	Climate change	34
6.8	Resource capacity	35
6.9	Resource Condition Limits	35
7	Permian Sands aquifer	36
7.1	Resource capacity	37
7.1.1	Unconfined Permian Sands	37
7.1.2	Confined Permian Sands	37
8	Fractured Rock aquifer	38
8.1	Extraction and allocation	39
8.2	Groundwater flow direction	40
8.3	Water level trends	40
8.4	Salinity distribution	41
8.5	Salinity trends	42
8.6	Connection with surface water and/or GDEs	42
8.7	Sustainability issues	42
8.7.1	Climate change	42
8.8	Resource capacity	43
8.8.1	Hills Face Zone	44
8.8.2	Bakers Gully Zone	44
8.8.3	Northern Zone	44
9	Summary and recommendations	45
10	Appendix A	47
11	References	49

List of figures

Figure 1. Location of the McLaren Vale PWA	6
Figure 2. Rainfall data from the Willunga rainfall station	7
Figure 3. Geological cross section of the Willunga Embayment	9
Figure 4. Extent of the Quaternary aquifer and location of licenced wells	10
Figure 5. Watertable elevation for the Quaternary aquifer	11
Figure 6. Water level hydrographs for the Quaternary aquifer	12
Figure 7. Salinity distribution for the Quaternary aquifer	13
Figure 8. Extent of the PWF aquifer and location of licenced wells	14
Figure 9. Metered extraction from the PWF aquifer	15
Figure 10. Use vs allocation for the PWF aquifer averaged over 2018-19 and 2019-20	15
Figure 11. Selected hydrographs for the PWF aquifer	16
Figure 12. (a) Potentiometric surface for the PWF aquifer (b) Head difference between Quaternary and PWF aquifers	17
Figure 13. Salinity distribution for the PWF aquifer in 2021	18
Figure 14. Long term salinity trends for the PWF aquifer	18
Figure 15. Cross section of the PWF confined aquifer	19
Figure 16. Extent of the Pirramimma Sand aquifer and location of licenced wells	21
Figure 17. Metered extraction from the PS aquifer	22
Figure 18. Use vs allocation for the PS aquifer averaged over 2018-19 and 2019-20	22
Figure 19. Watertable elevation surface for the PS aquifer	23
Figure 20. Selected hydrographs for the PS aquifer	23
Figure 21. Salinity distribution for the PS aquifer in 2021	24
Figure 22. Long term salinity trends for the PS aquifer	24
Figure 23. Representative rising salinity trends and extraction in the PS aquifer	25
Figure 24. Thickness of the PS aquifer	26
Figure 25. Extent of the Maslin Sands aquifer and location of licenced wells	28
Figure 26. Metered extraction from the MS aquifer	29
Figure 27. Use vs allocation for the MS aquifer	29
Figure 28. Potentiometric surface for the Maslin Sands aquifer	30
Figure 29. Selected hydrographs for the Maslin Sands aquifer	31
Figure 30. Salinity distribution for the MS aquifer in 2021	31
Figure 31. Long term salinity trends for the MS aquifer	32
Figure 32. Representative rising salinity trends and extraction in the MS aquifer	33
Figure 33. Thickness of the MS aquifer	34
Figure 34. Extent of the Permian Sands and location of licenced wells	36
Figure 35. Extent of the Fractured Rock aquifer and location of licenced wells	38
Figure 36. Metered extraction from the FRA aquifer	39
Figure 37. Use vs allocation for the FRA aquifer	39
Figure 38. Potentiometric surface for the FRA	40
Figure 39. Selected hydrographs for the FRA aquifer	41
Figure 40. Salinity distribution for the FRA aquifer in 2021	41
Figure 41. Long term salinity trends for the FRA aquifer	42
Figure 42. Recharge zones for the unconfined FRA aquifer	43

1 Introduction

This technical note presents a hydrogeological assessment of the groundwater level, salinity and extraction trends in the McLaren Vale Prescribed Wells Area (PWA) and sustainability issues to inform a risk assessment being carried out for a review of the Water Allocation Plan, which controls groundwater management in the area. It contains recommendations for consideration in decision-making on management options for the area. These recommendations are limited to considering whether current extraction can be maintained in the next 10 years while retaining the character of the resource.

This technical note is additional to and complements the annual technical notes prepared for the same region as part of DEW's routine water resource status reporting.

The McLaren Vale PWA covers an area of approximately 320 km², with the Onkaparinga River forming part of the northern boundary, while much of the south-eastern boundary follows the ridge of the Sellicks Range (Figure 1).



Figure 1. Location of the McLaren Vale PWA

2 Climate

Rainfall is a very important part of the groundwater balance because it is a source of replenishment or recharge to aquifers by infiltration through the soil, or by percolation from streamflow in drainage lines. A lack of rainfall during winter and spring may increase demand for irrigation extraction.

The climate of the McLaren Vale region is characterised by hot, dry summers and cool to cold, wet winters. Rainfall data is presented for the Bureau of Meteorology station at Willunga (station 23753) where the long term annual average rainfall is 636 mm.(Figure 2). The cumulative deviation from mean annual rainfall (plotted in orange) identifies periods where rainfall trends are above or below average. An upward slope indicates a period where the rainfall is greater than the average, while a downward slope indicates a period where the rainfall is below the average.

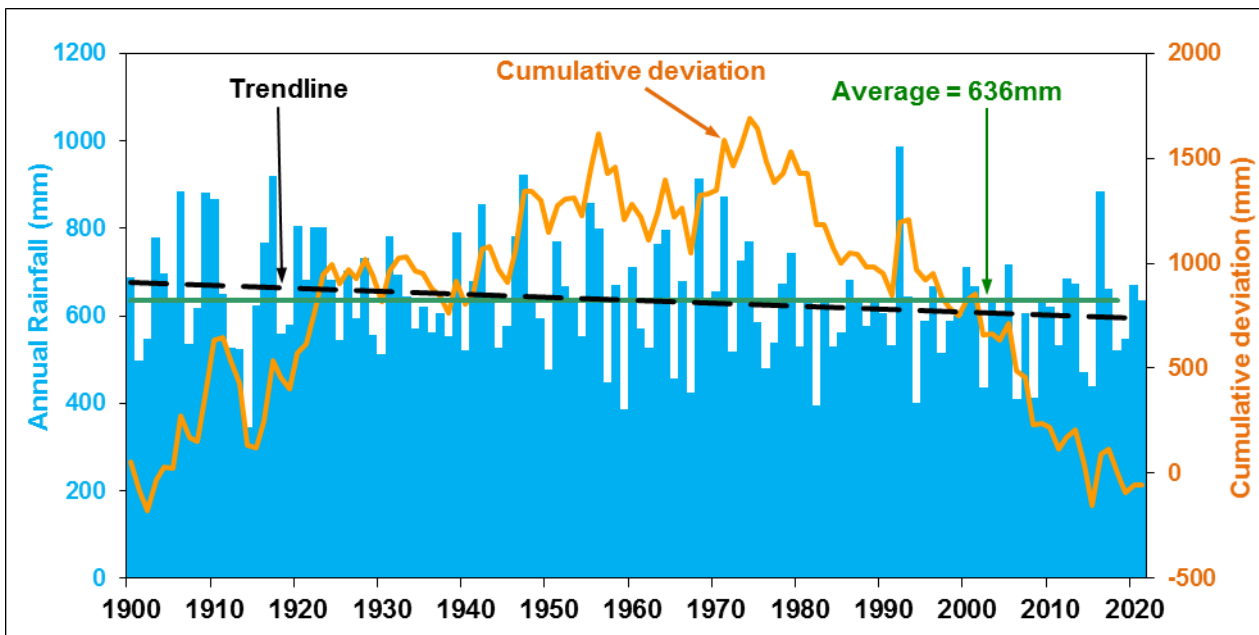


Figure 2. Rainfall data from the Willunga rainfall station

Willunga has experienced an extended period of below average rainfall since 1975, with the exception of wet years in 1992–93, 2000 and 2016-17. The trendline in Figure 2 shows that the average annual rainfall is declining

Climate change projections carried out by the Goyder Institute (Charles and Fu, 2014) indicated that by 2050, the Adelaide and Mt Lofty Ranges NRM Region could experience a decrease in average annual rainfall by between 6.3% and 8.4%, and an increase in average annual maximum temperature by between 1.3 and 1.8°C.

These projections indicate that over the long term, climate change will impact predominately unconfined aquifers through a reduction in recharge, with those aquifers with limited storage capacity being more vulnerable than those with large storage. The higher temperatures may increase irrigation demand, however extraction limits and metering will mitigate this risk.

The projections do not predict that every year between now and 2050 will experience gradually decreasing rainfall. There will still be climate variability and periods of above average rainfall that will recharge aquifers and reduce demand for irrigation. It is still not possible to predict which years will be wet or dry which is why an adaptive management approach is best suited for the groundwater resources of the McLaren Vale PWA.

3 Hydrostratigraphy

For a number of years, groundwater was understood to occur in four major aquifers: Quaternary aquifer; Port Willunga Formation aquifer; Maslin Sands aquifer; Fractured Rock aquifer.

In particular, the Port Willunga Formation aquifer was assumed to comprise not only the Tertiary marine limestone, but also the Pirramimma Sand Member which was considered to be a marginal sand facies of the Port Willunga Formation (Cooper, 1977). Consequently, construction of water level contours and interpretation of water level and salinity trends assumed that these two units had such a very high hydraulic connection that they could be considered to be one continuous aquifer.

Fairburn (1998) described the Pirramimma Sandstone as an early Pleistocene fluvial sandstone, comprising a mainly buff coloured, fine-grained, well-sorted and poorly consolidated sandstone up to 50 m thick. Recent investigations involving the interpretation an additional 300 drillers' logs and 50 mineral well logs enabled the aquifer extents and elevation surfaces to be defined with a much greater resolution than could be achieved previously. This work defined the extent of this extensive sand unit which attains a maximum thickness of over 110 m near the Willunga Fault and concluded that it had a pre-Pliocene age (Barnett and Bourman, 2022). Due to differences in geological age, lithology, unconfined and confined conditions, water level monitoring trends and sustainability issues, the Pirramimma Sand should be considered to be a separate aquifer from the Port Willunga Formation limestone for management purposes, even though they are hydraulically connected.

The new stratigraphic data was used to construct Figure 3 which presents a cross section through the Willunga Embayment. It is recommended the following hydrostratigraphic units be used for management into the future;

Quaternary aquifer

Sands and interbedded clays form shallow unconfined aquifers which are generally low yielding and provide mostly stock and domestic supplies, with limited extraction for irrigation. Recharge is predominantly derived from local rainfall and infiltration of runoff provided by streams.

Port Willunga Formation aquifer

The Port Willunga Formation aquifer consists of Tertiary marine limestones and is confined by Quaternary sediments over its full extent in the south-western part of the basin. This aquifer recharge by downward leakage from the Quaternary aquifer and possibly lateral flow across the Willunga Fault from the fractured rock aquifer.

Pirramimma Sands aquifer

This aquifer comprises a fine-grained poorly consolidated sand which forms an unconfined aquifer extending over the central and north-eastern portions of the basin. It is recharged by rainfall and possibly lateral flow across the Willunga Fault from the fractured rock aquifer.

Maslin Sands aquifer

The Maslin Sands aquifer directly overlies basement rocks and comprises fine to coarse sands and clays. The aquifer is recharged by rainfall in the north-east of the PWA where it crops out. Elsewhere, the aquifer is confined and separated from the overlying Port Willunga Formation Aquifer by the Blanche Point Formation aquitard which consists of low-permeability marine mudstone and limestone.

Permian Sand aquifer

Isolated occurrences of Permian Sands occur near the northeastern and northwestern boundaries of the PWA which are recharged from rainfall.

Fractured Rock aquifers

Fractured Rock aquifers occur in basement rocks (slates, quartzites, shales and limestone) which form ranges to the east of the Willunga Fault and also along the Onkaparinga Gorge to the north. Infiltration of rainfall provides recharge to the aquifer in these areas.

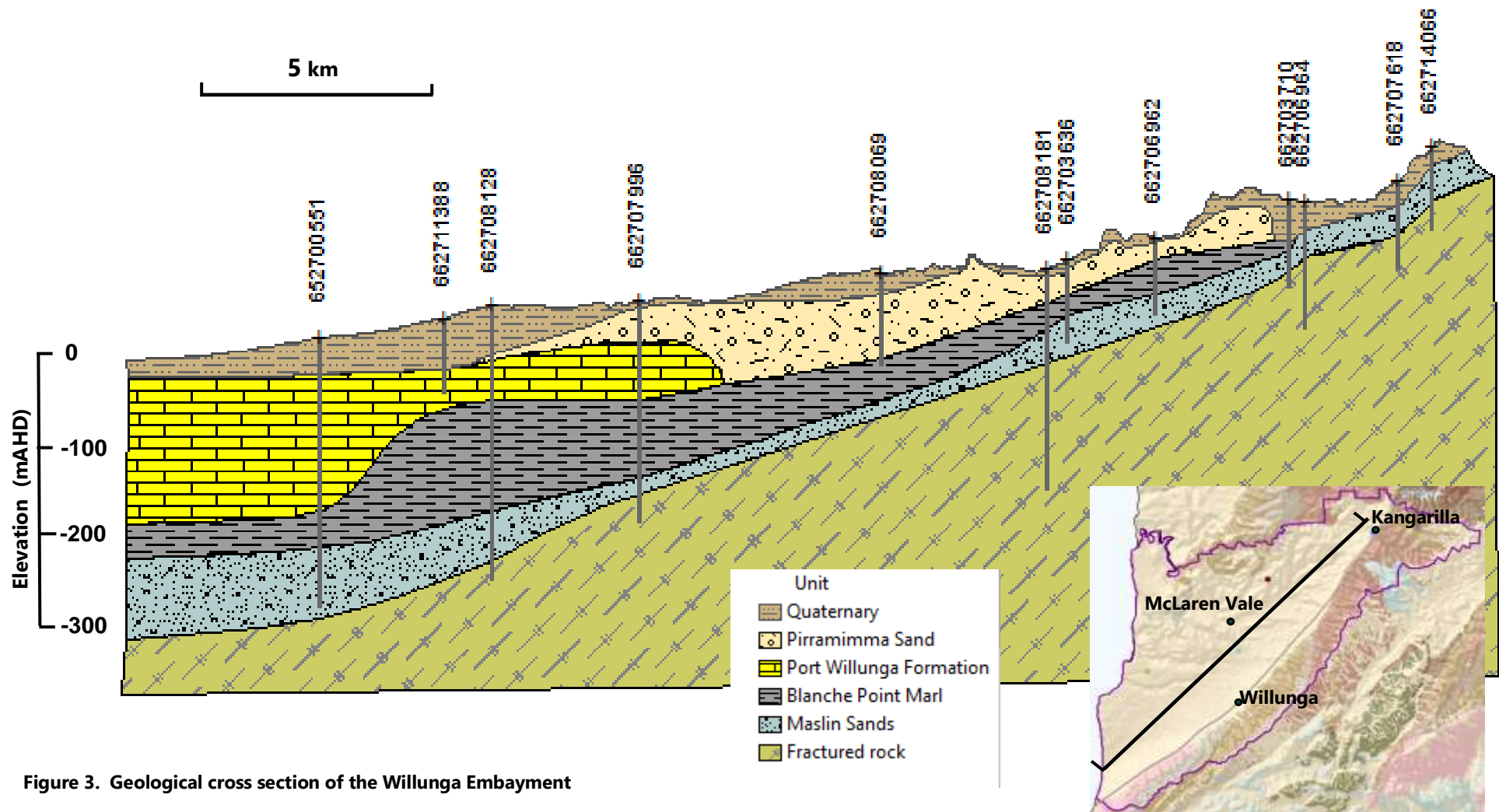


Figure 3. Geological cross section of the Willunga Embayment

3 Quaternary aquifer

Analysis of drillers' logs and the creation of the 3D aquifer surfaces has enabled all wells which are completed in the Quaternary aquifer to be determined. This has allowed much more information on the watertable elevation and salinity to be consolidated than has previously been available, and enabled a better delineation of the extent of the aquifer which is presented in Figure 4. Also shown are the locations of licenced wells (in yellow) and the observation wells whose hydrographs are presented later in Figure 6.

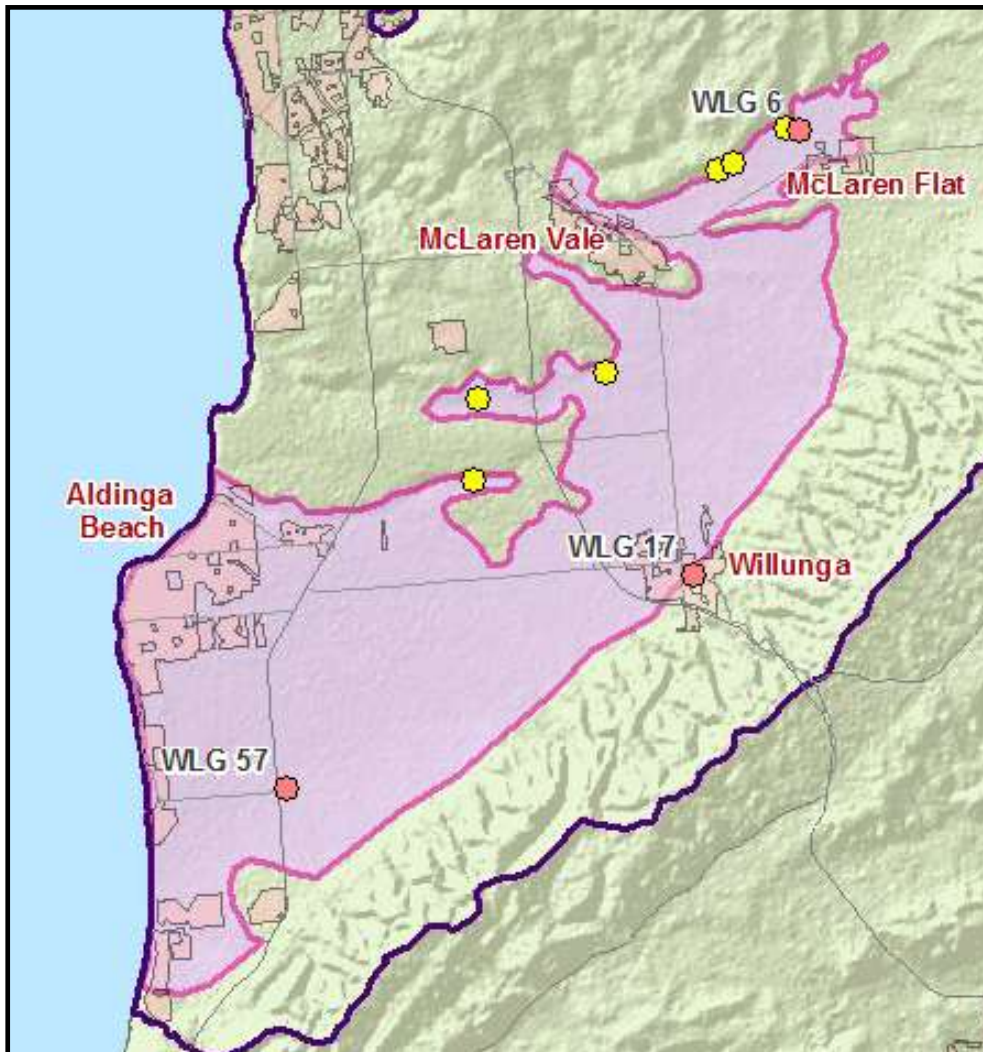


Figure 4. Extent of the Quaternary aquifer and location of licenced wells

3.1 Extraction and allocation

There are currently only six licences utilizing the Quaternary aquifer because of the predominantly low yields. They extract a total of about 6.5 ML/year from a total allocation of 10.8 ML.

3.2 Groundwater flow direction

The watertable elevation map (Figure 5) is constructed using water levels from about 150 wells. Although these levels were measured at different times, a broad regional trend is clearly visible. The highest elevations occur adjacent to the Willunga Scarp to the east indicating recharge from streamflow and possibly lateral flow from the fractured rock aquifer. Groundwater flow is generally to the northwest and west following the direction of surface drainage and declining topography. This flow direction is quite different to that in the underlying aquifers which is generally in a southwest direction.

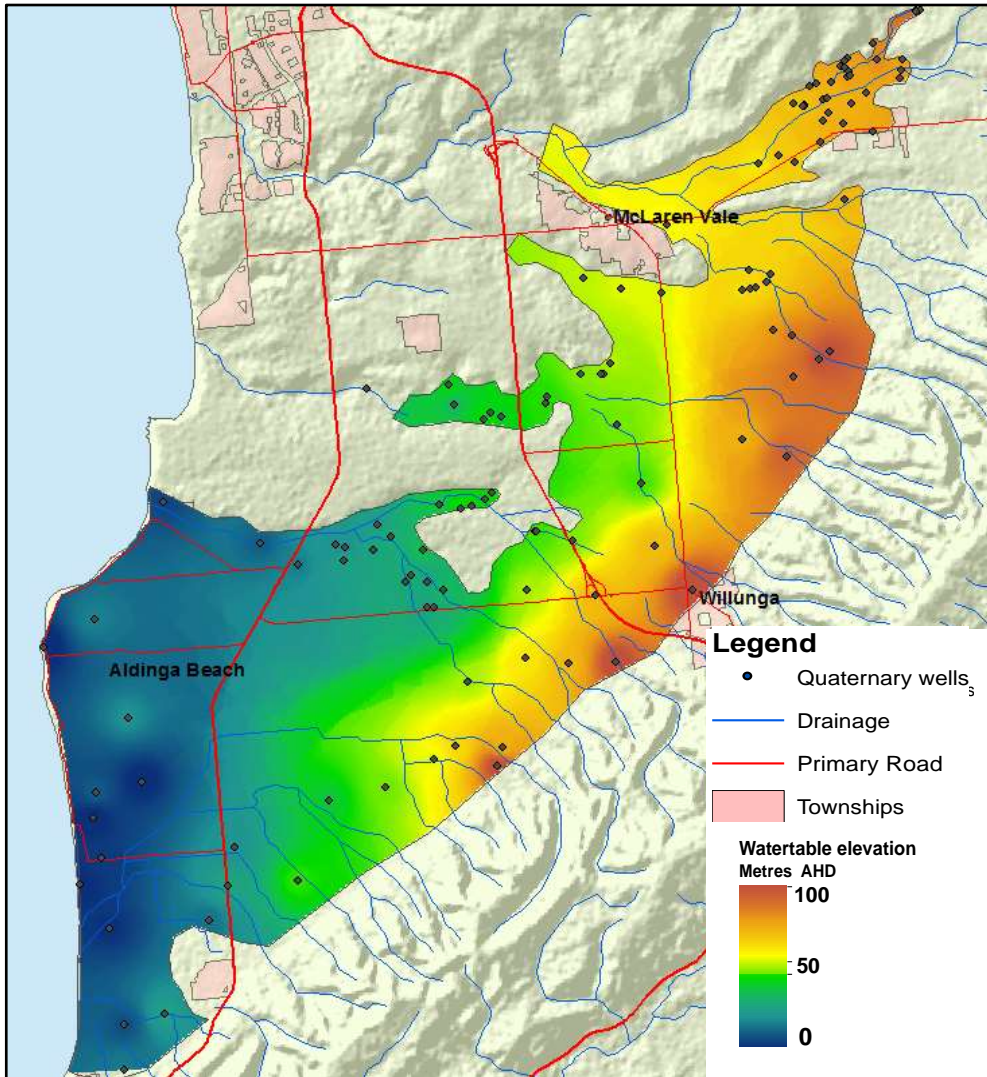


Figure 5. Watertable elevation for the Quaternary aquifer

The significant feature of the watertable in the Quaternary aquifer is that it is at a higher elevation compared to underlying Port Willunga Formation or Pirramimma Sand aquifer water levels, resulting in widespread potential for downward leakage from the Quaternary aquifer

3.3 Water level trends

Regular water level monitoring is carried out in several Quaternary aquifer observation wells with a selection presented in Figure 6 (locations of these wells in Figure 4). The seasonal fluctuations indicate that recharge is occurring with a reasonably close relationship with observed rainfall patterns. There has been a long term decline of about 2 – 3 m since 2000.

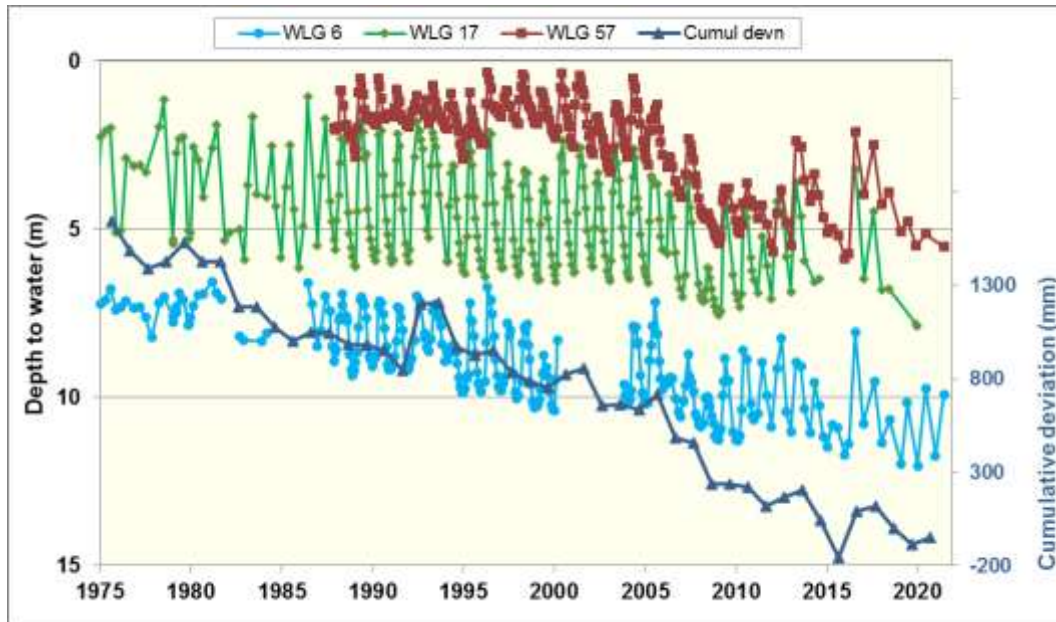


Figure 6. Water level hydrographs for the Quaternary aquifer

3.4 Salinity distribution

Figure 6 shows the salinity of the Quaternary aquifer derived from all records from 167 wells. Broad trends can be observed (noting that about 45 % of the samples were tested before 1970). Lower salinities are associated with streams flowing out onto the plain from the Willunga Scarp which suggest that recharge has been occurring from these streams. Salinities are significantly higher near the coast which probably reflects the influence of evaporative discharge from the watertable that is closer to the ground surface than further to the northeast. Salinities are also possibly higher in areas some distance from drainage lines than Figure 6 suggests, but there is little data to confirm this. There is no regular monitoring of Quaternary aquifer salinities.

3.5 Connection with surface water and/or GDEs

As Quaternary sediments occur at the land surface and in drainage lines, this aquifer is likely to have high connectivity with surface water and is likely to support GDEs in some locations.

3.6 Sustainability issues

There has been an overall decline in groundwater levels reflecting the declining rainfall trends notably during the latter period of the millennium drought (2005–2010) otherwise levels have been relatively stable. At the current level of total extractions in the order of 6.5 ML/year, there are no significant resource sustainability issues relating to groundwater extraction.

3.7 Resource capacity

No extraction limit has been set previously for the Quaternary aquifer. The only investigation into recharge to the Quaternary aquifers occurred at Pedlar Creek just to the northeast of McLaren Vale (Harrington, 2002). This is not representative of the main part of the aquifer which is recharged by intermittent streams flowing out from the Willunga Scarp. Due to the low demand, a conservative 'fit for purpose' limit of 50 ML/year could be applied.

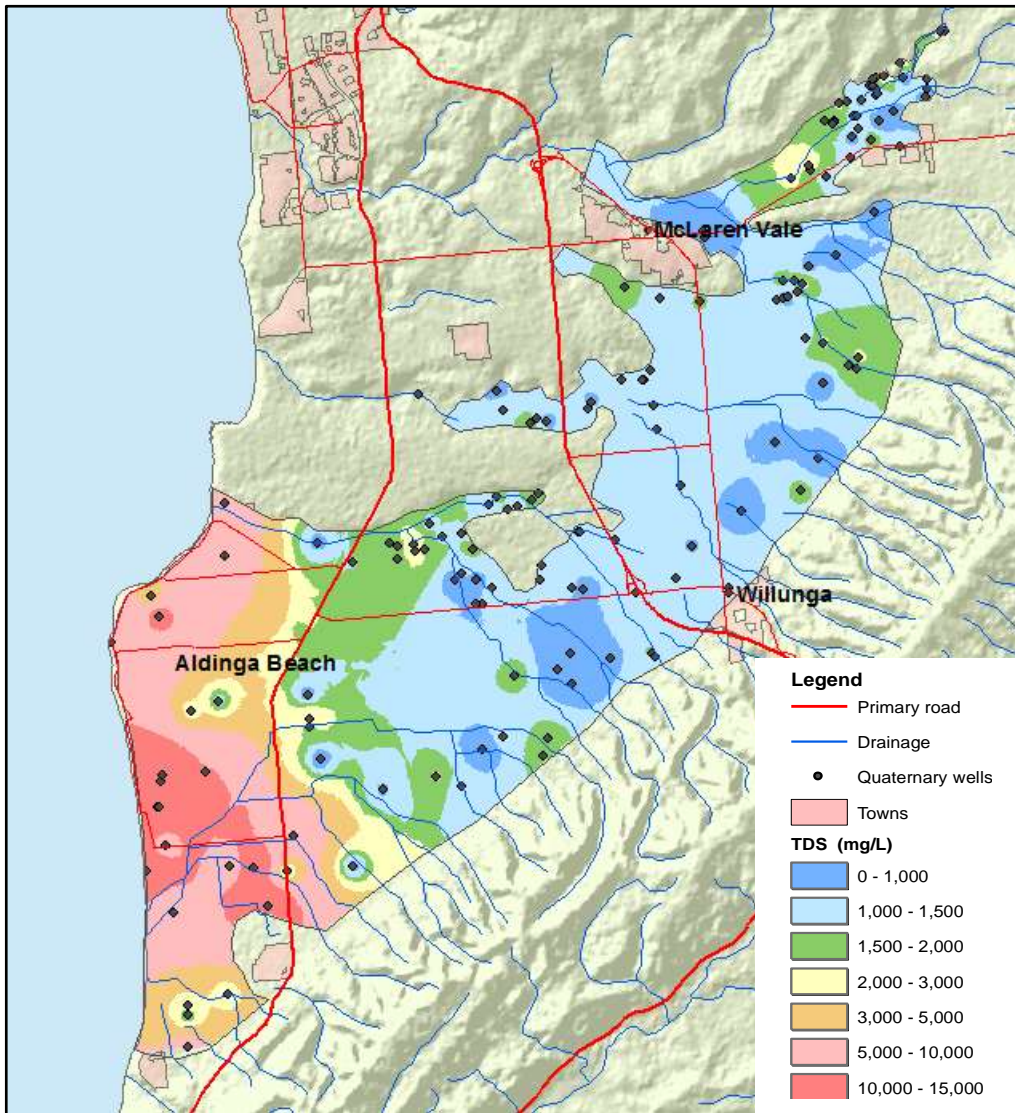


Figure 7. Salinity distribution for the Quaternary aquifer

4 Port Willunga Formation aquifer

The Port Willunga Formation (PWF) aquifer consists of Tertiary marine limestones and excludes any sand aquifer which is now interpreted to be included in the Pirramimma Sand aquifer. It only occurs in the south-western part of the basin and is confined by Quaternary sediments over its full extent. The aquifer reaches a maximum thickness of about 150 m near the coast.

Figure 8 presents the extent of the PWF aquifer, together with the licenced wells (in yellow) and the observation wells whose hydrographs are presented in Figure 11.

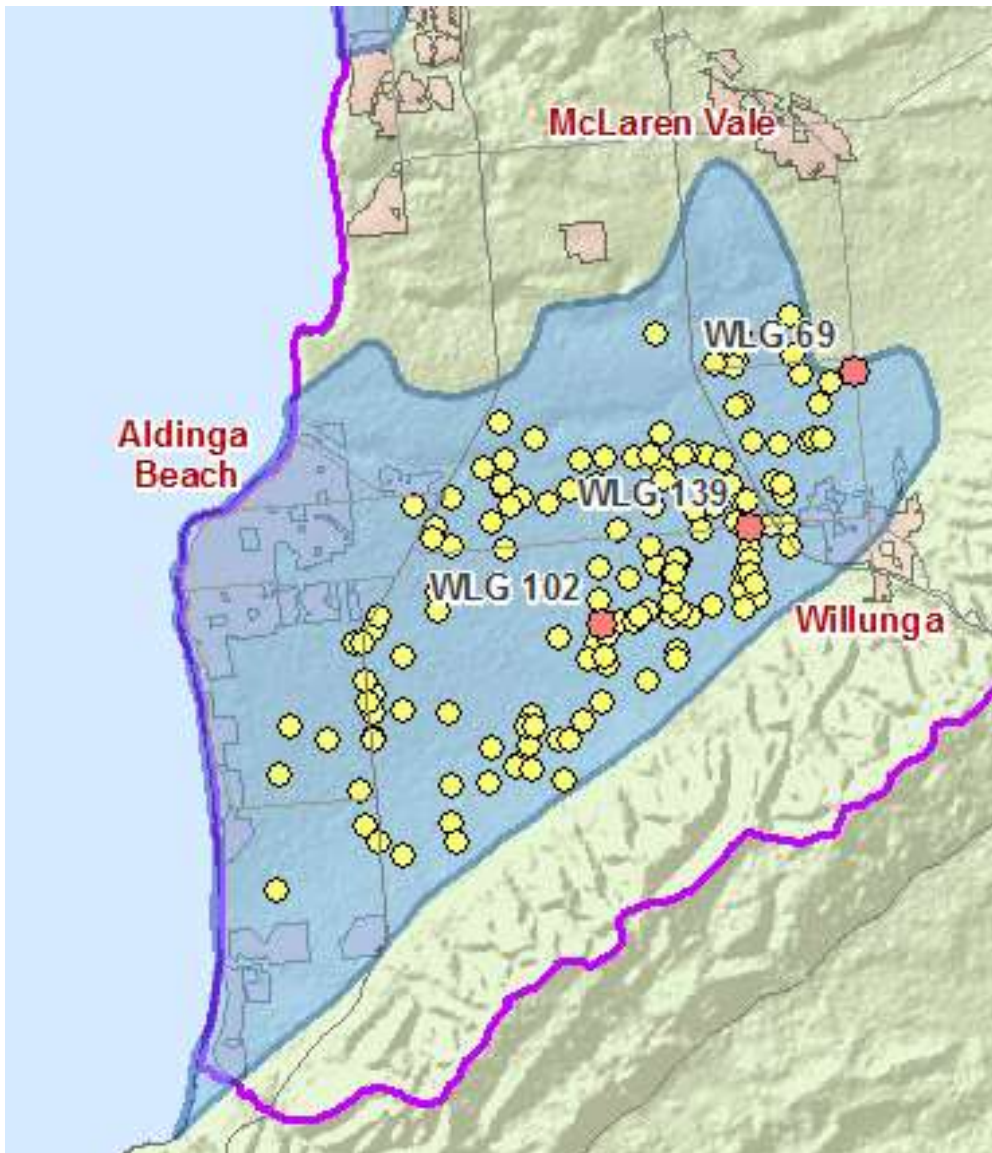


Figure 8. Extent of the PWF aquifer and location of licenced wells

4.1 Extraction and allocation

Figure 9 shows that metered extraction from the PWF aquifer since 1996-97 has been fairly consistent and below 1,500 ML/year, with seasonal variations caused by variations in rainfall. It is close to the 2020 allocation volume of 1,683 ML. The metered extraction as a percentage of the individual licenced allocations averaged over the last two years (2018-20 and 2019-20) is presented in Figure 10 and shows a very high degree of development of the allocations which reflects the high demand and high value of the irrigated produce,. It also suggests that there is limited potential for significant increases in extraction due to the activation of unused allocations.

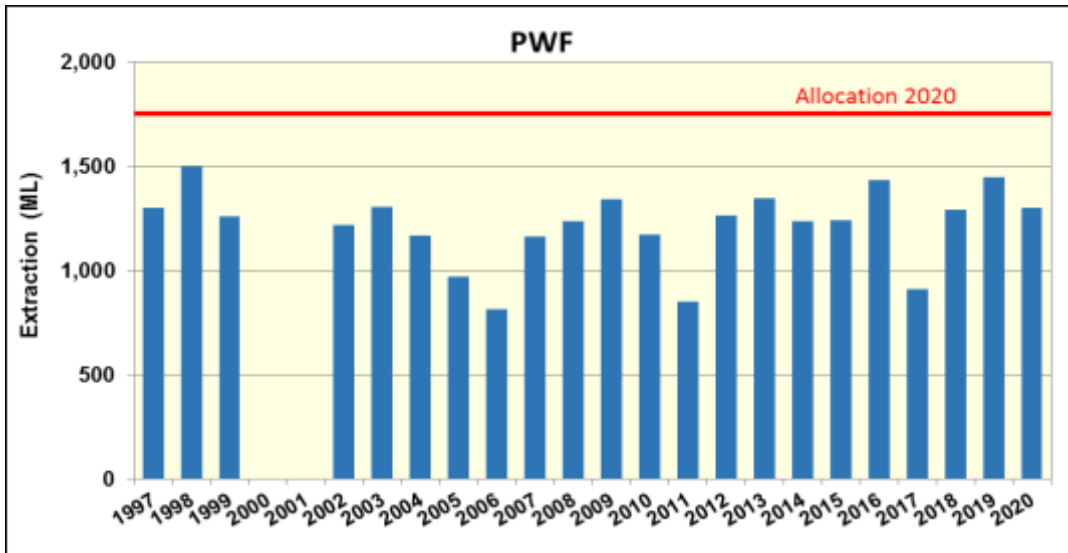


Figure 9. Metered extraction from the PWF aquifer

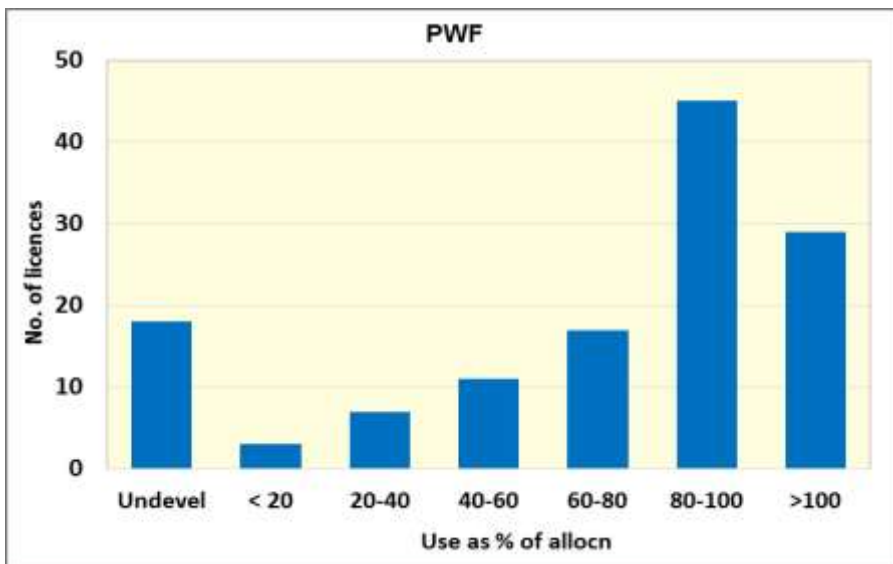


Figure 10. Use vs allocation for the PWF aquifer averaged over 2018-19 and 2019-20

4.2 Groundwater flow direction

Figure 12a presents the potentiometric surface for the PWF aquifer showing groundwater flow toward the coast in a southwesterly direction. The flattening of the gradient in the southwestern half of the aquifer corresponds to a significant thickening of the aquifer and the resultant increase in transmissivity.

4.3 Water level trends

Water level monitoring has been carried out since the late 1980s. Long term trends from 1988 to 2020 show a gradual decline varying up to 0.15 m/year at the furthest extent inland (WLG 69). Figure 11 shows the pressure levels trends for WLG 69, WLG 102 and WLG 139 which show a close correlation with rainfall trends. The trend in total extraction volumes for the PWF aquifer shown in Figure 9 is reasonably stable after 2002 and consequently, the decline in pressure levels since then cannot be correlated with extraction from the aquifer (as this has not increased).

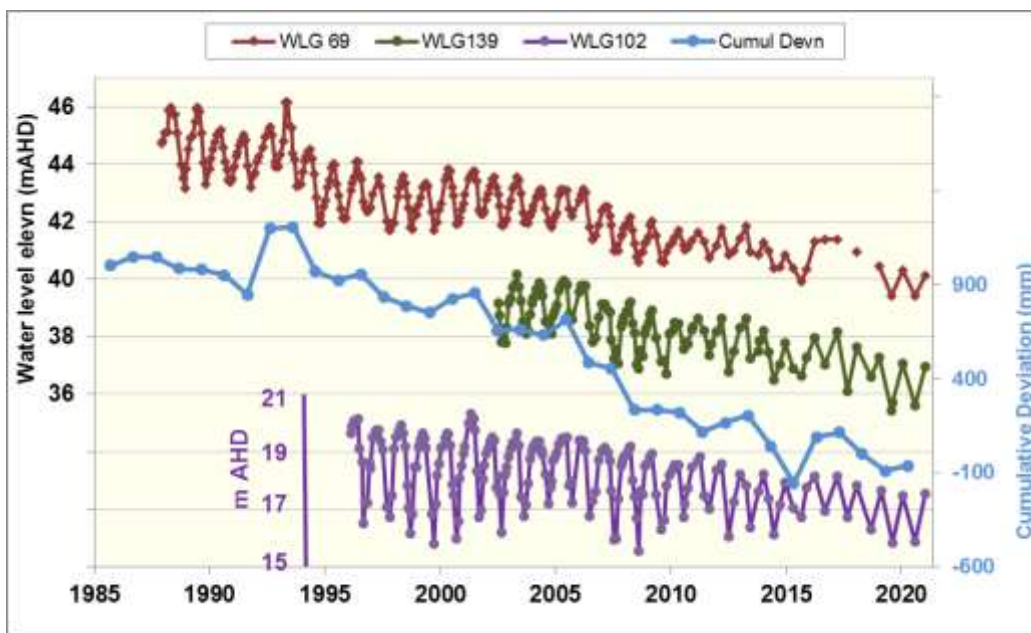


Figure 11. Selected hydrographs for the PWF aquifer

Although it is expected that the Quarternary unconfined aquifer would have a close relationship with rainfall (as shown in Figure 6), it is unusual for a confined aquifer pressure levels to have a similar trend. Figure 12b depicts the significant head difference between the Quaternary aquifer and the PWF aquifer of up to 60 m driving downward leakage from the Quaternary Aquifer. A good connectivity between the two aquifers could cause the similar trends with hydrostatic loading probably also contributing to this similarity.

The PWF aquifer averages about 100 m in thickness with a conservative estimate of groundwater storage volumes in the order of 440,000 ML (the elastic storage due to pressurization of the aquifer has been ignored). The current extraction which averages 1,400 ML/year represents only a very small percentage of this storage, however most of this storage volume is not considered useable because of high salinities (Figure 13) and the adverse impacts that could occur if significant increases in extraction occurred.

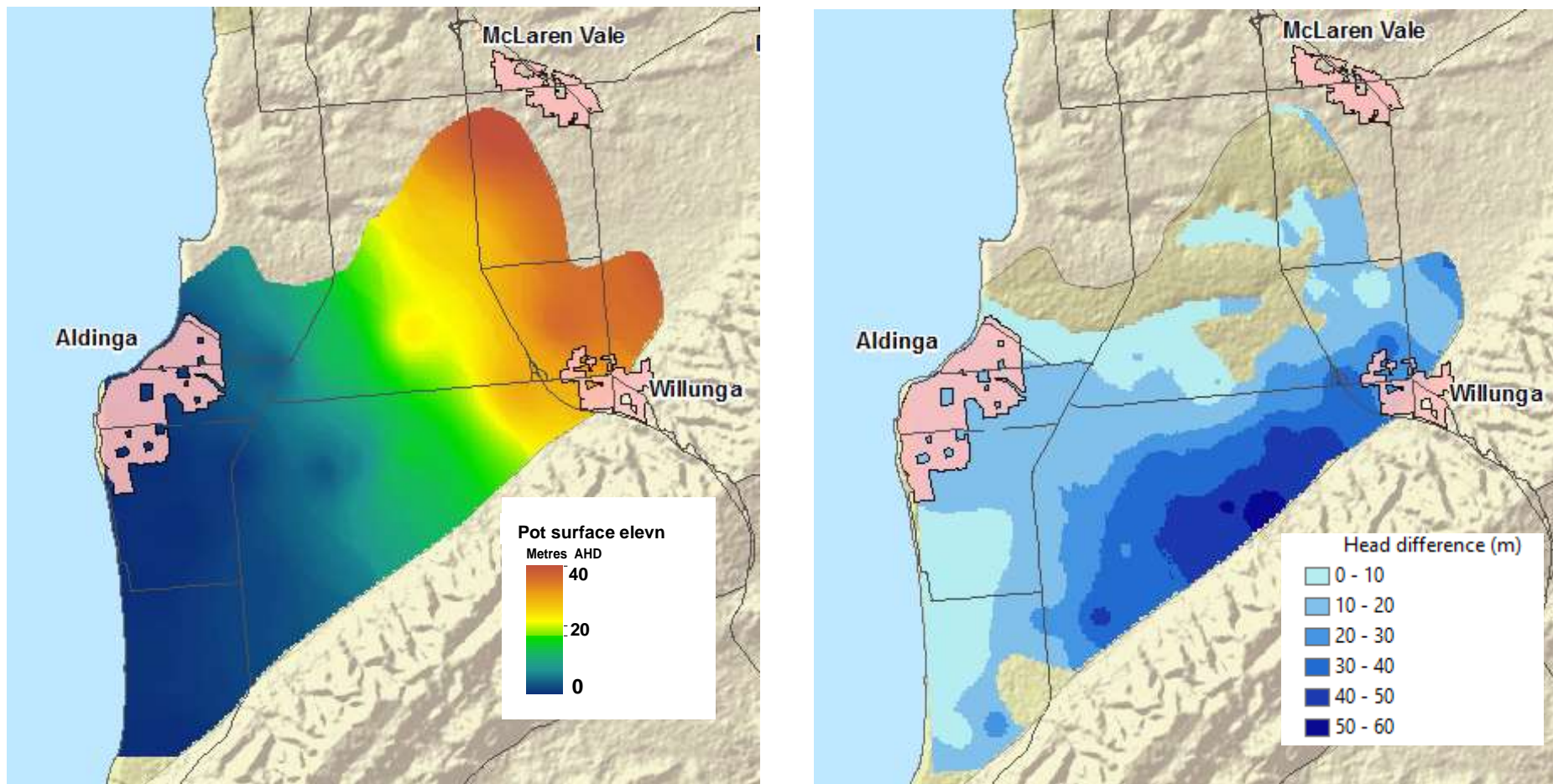


Figure 12. (a) Potentiometric surface for the PWF aquifer (b) Head difference between Quaternary and PWF aquifers

4.4 Salinity distribution

Figure 13 shows the extent of the PWF aquifer and the salinity distribution following the 2021 sampling program. Most of the irrigation wells have salinities below 1200 mg/L, with values increasing toward the coast.

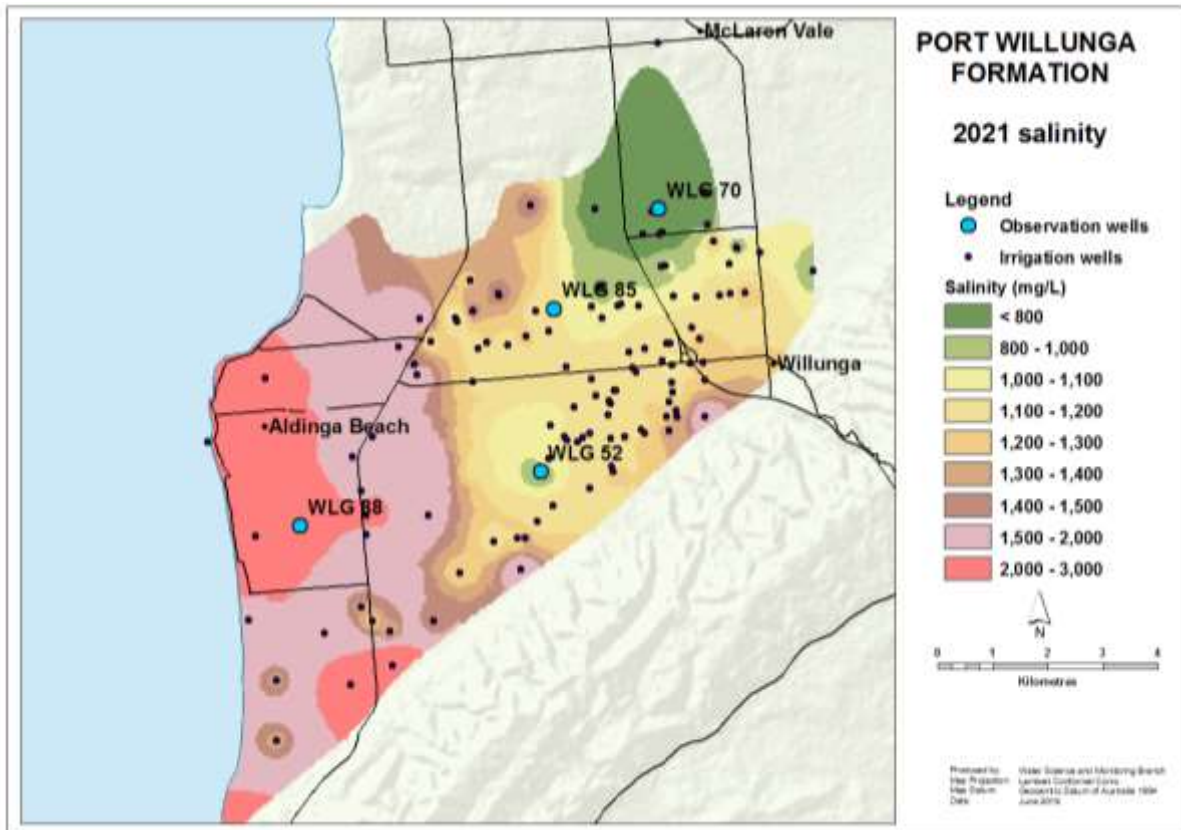


Figure 13. Salinity distribution for the PWF aquifer in 2021

4.5 Salinity trends

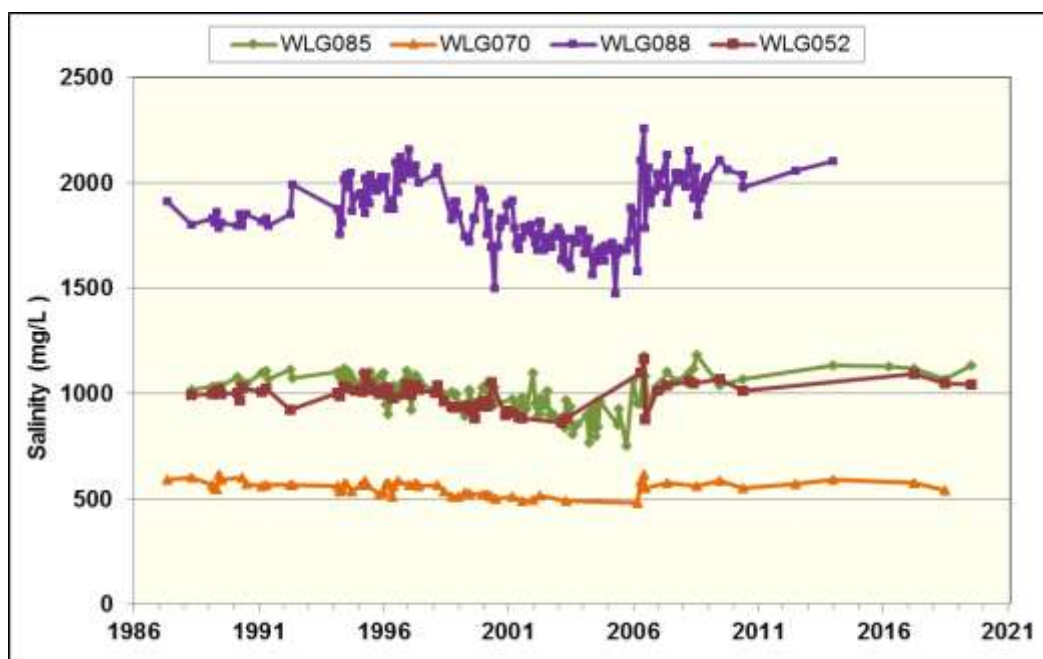


Figure 14. Long term salinity trends for the PWF aquifer

Figure 14 shows long term trends from four representative irrigation wells (locations shown in Fig. 13) which are generally stable, or showing slightly declining trends, apart from the well showing a slight rising trend which is located in a higher salinity zone of the PWF aquifer. There appears to be a relationship with rainfall, as shown by the decline in salinity coinciding with higher rainfall between 1998 and 2006, and the increase in salinity during the millennium drought.

4.6 Connection with surface water and/or GDEs

Because the PWF aquifer is confined and overlain by Quaternary sediments, it has no connection with surface water and does not support any GDEs within the PWA

4.7 Sustainability issues

4.7.1 Pressure declines

There has been a gradual decline in pressure levels over the last 15 years. The decline is attributed predominantly to be driven by rainfall trends rather than extraction.. Overall, the decline has not resulted in adverse salinity trends and as the simple cross section from to the coast to the landward extent of the PWF aquifer in Figure 15 shows, the pressure levels are still 10-15 m above the top of the confined PWF limestone aquifer which remains fully saturated.

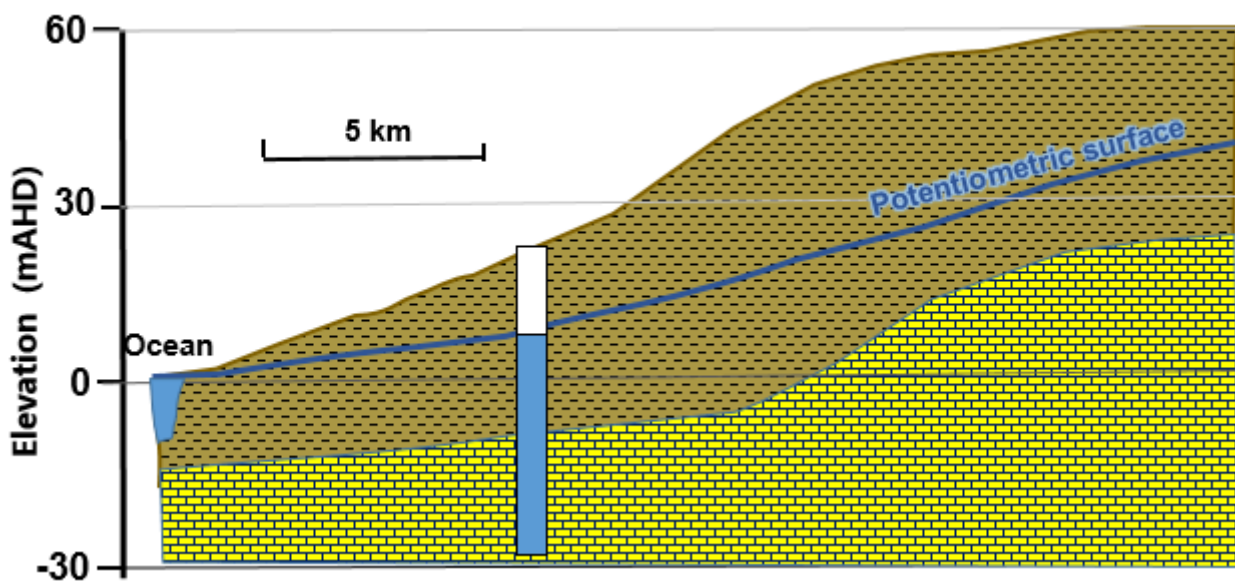


Figure 15. Cross section of the PWF confined aquifer

4.7.2 Depressurisation of the confined aquifer

In other PWAs in South Australia, maintaining pressurization within the confined aquifers (i.e. not allowing the confined aquifer to become unconfined), has been a management objective. This process of depressurisation reduces the hydrostatic pressure supporting the confining layer on top of the confined aquifer against the weight of the overlying unconfined aquifer and the groundwater contained within it. This could result in fracturing of the confining layer and downward leakage from the overlying unconfined aquifer into the confined aquifer.

However in this case, there is no discrete confining layer separating the PWF aquifer from an overlying Quaternary unconfined aquifer and there already appears to be good connectivity with this aquifer. If the observed declining trend was to continue at the current rate, depressurization of the aquifer would only occur after 50+ years. Even if this did occur, there may be no adverse impacts on the resource.

4.7.3 Sea water intrusion

The risk of sea water intrusion (SWI) is a sustainability issue for this resource. Investigations by the National Centre for Groundwater Research and Training (NCGRT) found that quantification of groundwater flow at the interface was difficult because of variable density effects and tidal effects (Post et al, 2018). There was net seaward horizontal flow in the upper part of the PWF aquifer (from where extraction occurs) in a transect near Aldinga Beach during the period analysed. There was no evidence of active sea water intrusion.

The risk is considered low due to distance of most irrigation extraction from the coast and no sign of cones of depression in pressure level contours that could lead to a flow reversal from seaward to landward. It is essential to maintain a net positive pressure gradient and throughflow (seaward horizontal flow) towards the coast to minimise the risk

4.7.4 Climate change

As the pressure level trends show a relationship with rainfall, the PWF aquifer could be considered sensitive to climate change. The gradually declining pressure levels that would result from a drying climate would not result in the aquifer being classified as vulnerable to climate change over the next 50 years because of the large storage capacity and robustness of the resource.

4.8 Resource Condition Limits

In other confined aquifers in SA, the RCL of maintaining pressurization within the aquifer (i.e. not allowing it to become unconfined), has been chosen. However in this case, there is no discrete confining layer separating the PWF aquifer from an overlying unconfined aquifer and there already appears to be good connectivity with the Quaternary aquifer.

Nevertheless, a RCL of maintaining pressurization is recommended as a precautionary approach to maintain confined aquifer conditions in the PWF. An additional RCL to maintain a positive pressure gradient toward the coast over the long term to prevent salt water intrusion is also recommended. This RCL will have the additional benefit of maintaining groundwater discharge to culturally sensitive springs along the coast related to the Tjilbruke Dreaming (Crane, 2017).

4.9 Resource capacity

No extraction limit has been previously set specifically for the PWF aquifer. Examination of aerial photography reveals that virtually all the area of irrigation quality groundwater has already been planted with vineyards.

Given the sustainability issues, the observed monitoring trends and stable extraction that have been observed for the last decade, the 2020 level of allocation (1,683 ML) would be sustainable for the term of the water allocation plan with no new allocations to be granted for the PWF aquifer.

5 Pirramimma Sand aquifer

This sand aquifer was previously considered to be part of the PWF aquifer. The Pirramimma Sand (PS) aquifer extends over most of the central portion of the Willunga Basin and reaches a maximum thickness of about 80 m. It is mostly unconfined. Figure 16 presents the extent of the PS aquifer as well as the licenced wells (in yellow) and the observation wells whose hydrographs are presented in Figure 16.

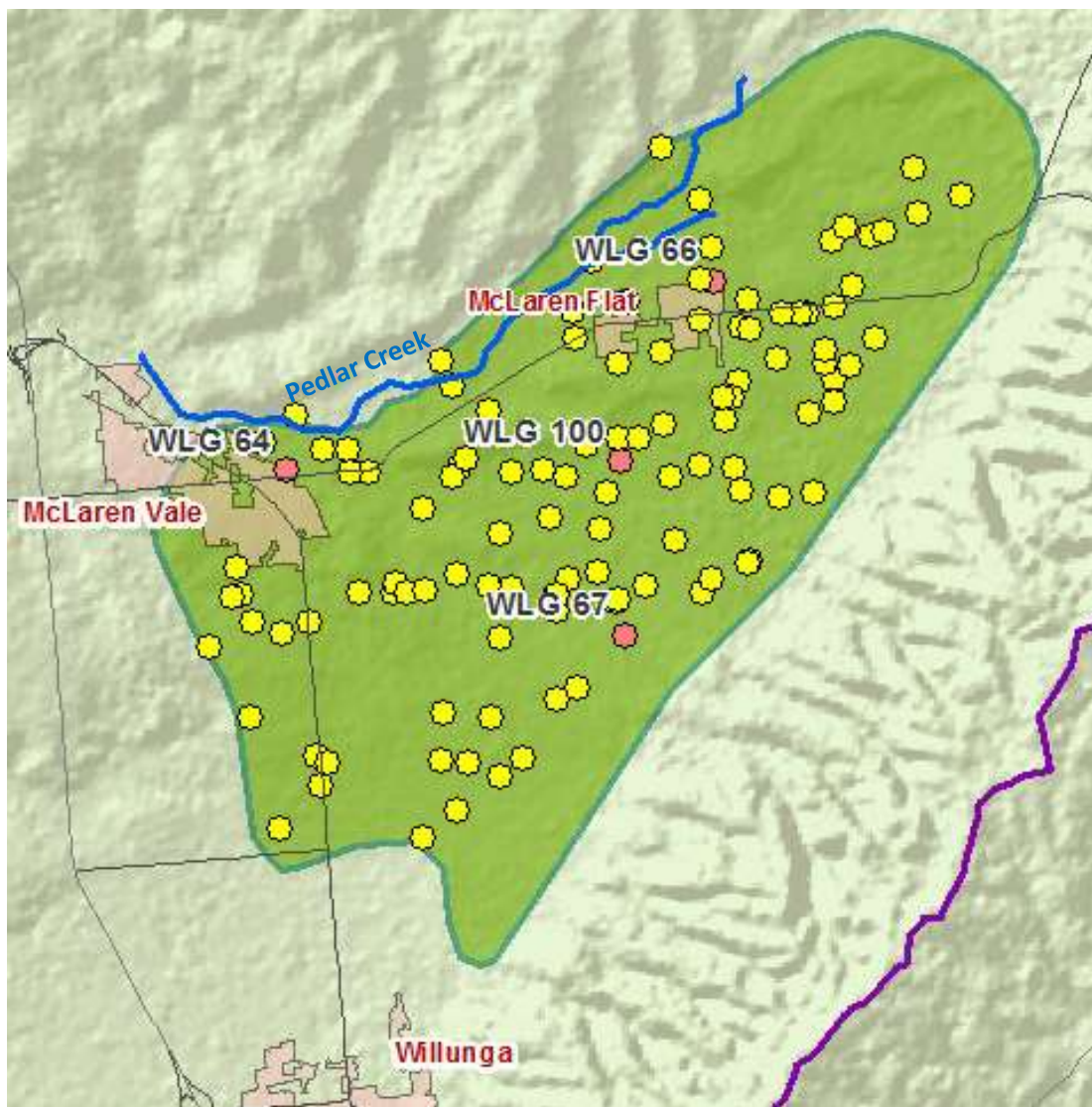


Figure 16. Extent of the Pirramimma Sand aquifer and location of licenced wells

5.1 Extraction and allocation

Figure 17 shows that metered extraction from the PS aquifer since 2004-05 has been fairly consistent and below 1,750 ML/year, with seasonal variations caused by variations in rainfall. It is close to the 2020 allocation volume of 1,850 ML. The metered extraction as a percentage of the individual licenced allocations averaged over the last two years (2018-19 and 2019-20) is presented in Figure 18 and shows a very high degree of development of the allocations, which may reflect the high value of the irrigated produce. It also suggests that there is limited potential for significant increases in extraction due to the activation of unused allocations.

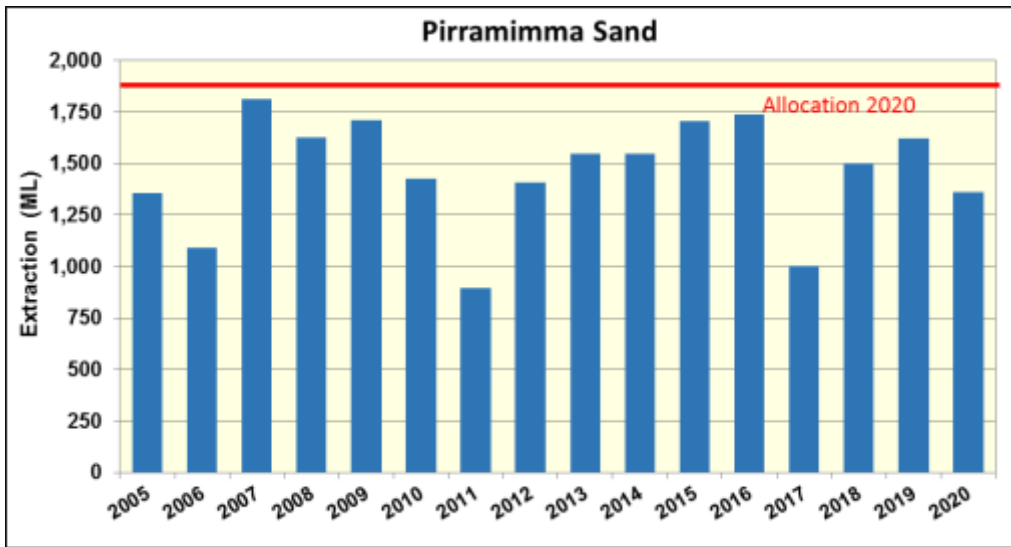


Figure 17. Metered extraction from the PS aquifer

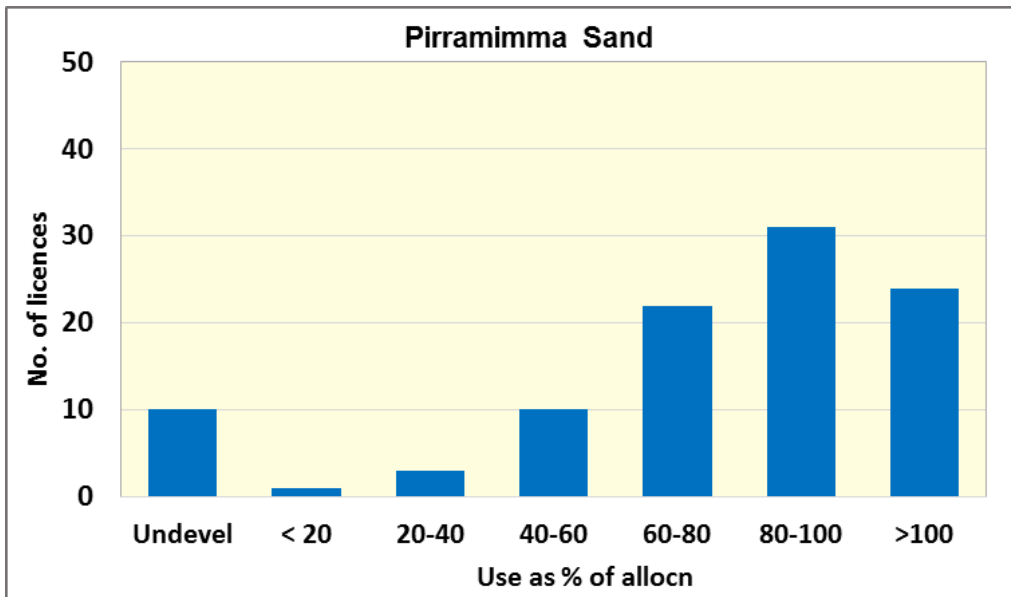


Figure 18. Use vs allocation for the PS aquifer averaged over 2018-19 and 2019-20

5.2 Groundwater flow direction

Figure 19 presents the potentiometric surface for the PS aquifer showing groundwater flow towards the coast in a southwesterly direction.

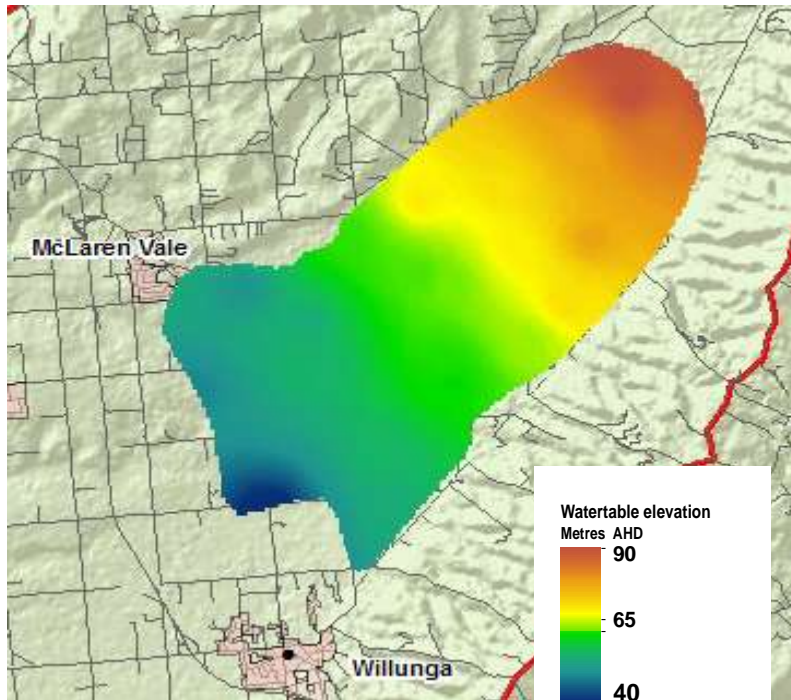


Figure 19. Watertable elevation surface for the PS aquifer

5.3 Water level trends

Water level monitoring has been carried out since the late 1980s. Long term trends from 1988 to 2020 show a gradual decline varying from 0.07 to 0.15 m/year as shown in Figure 20. There appears to be a very muted relationship with rainfall patterns which is most likely due to the depth to the watertable which is mostly over 20 m, and the presence of overlying Quaternary clays in some areas.

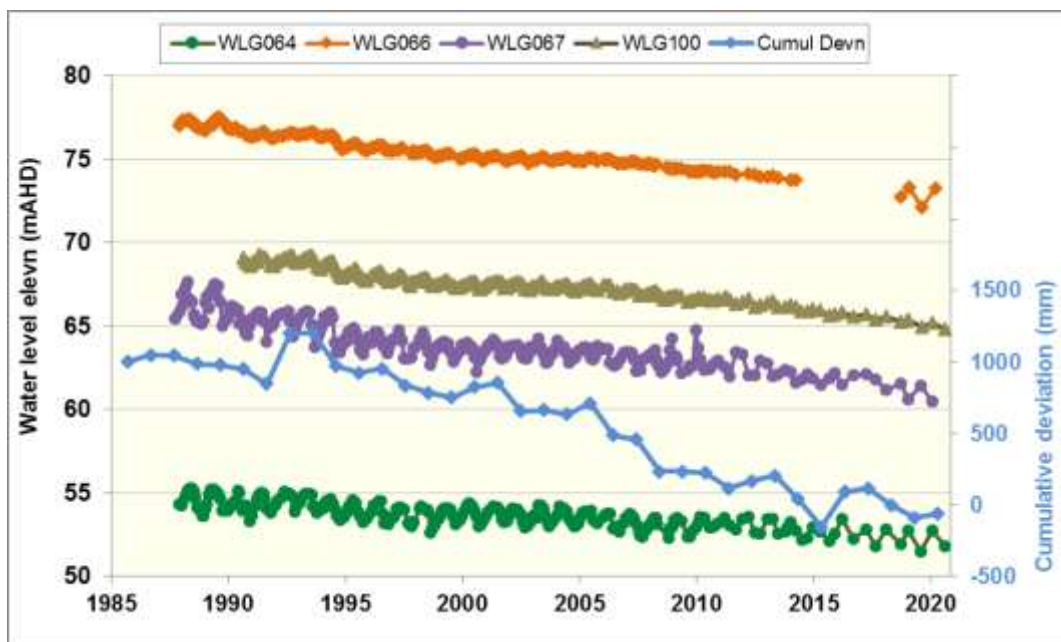


Figure 20. Selected hydrographs for the PS aquifer

5.4 Salinity distribution

Figure 21 shows the extent of the PS aquifer and the salinity distribution following the 2021 sampling program. The aquifer can be divided into two parts. To the southwest of McLaren Flat, salinities are generally below 1,000 mg/L. To the east, salinities range up to 1,750 mg/L which is well above the tolerance level for wine grapes. The location of observation wells featured in Figure 22 are also shown.

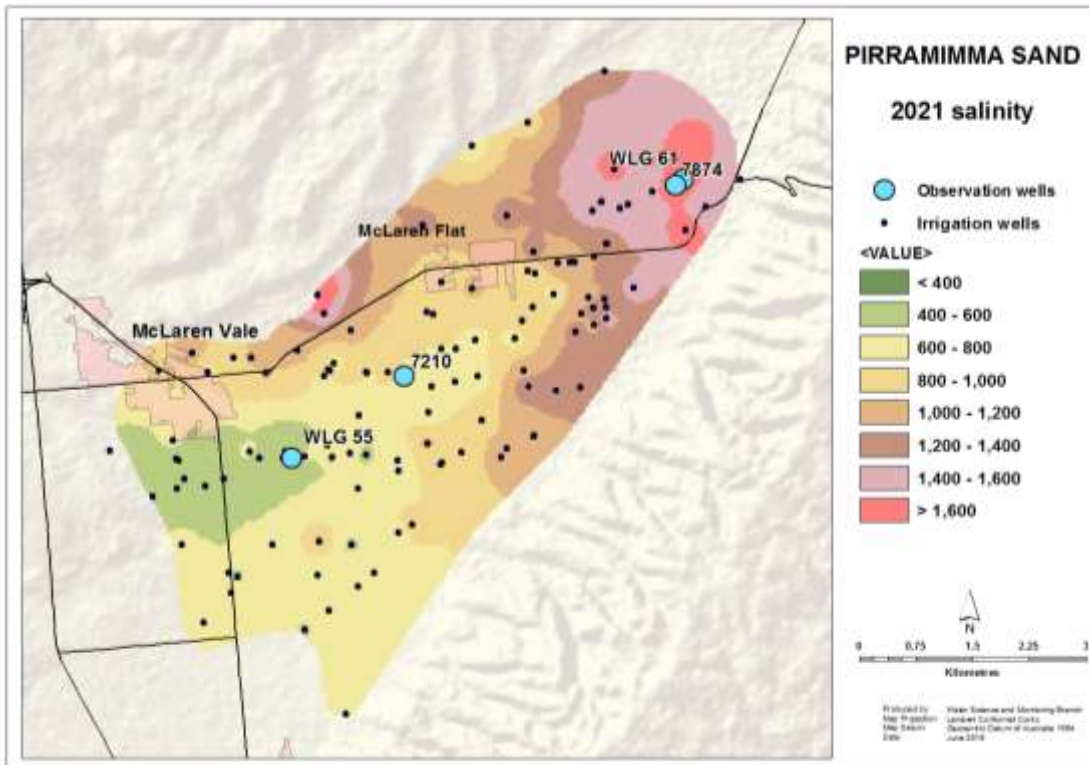


Figure 21. Salinity distribution for the PS aquifer in 2021

5.5 Salinity trends

Long term trends are presented in Figure 22 for four representative irrigation wells (locations shown in Figure 21), which indicate that trends in the lower salinity zone to the southwest of McLaren Flat are relatively stable, while those to the east are rising significantly.

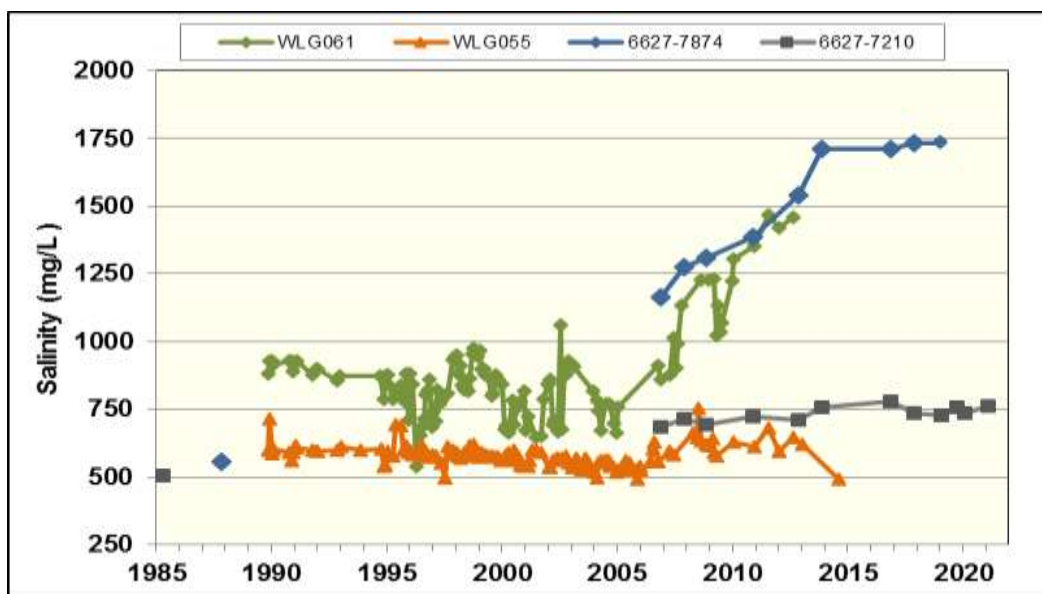


Figure 22. Long term salinity trends for the PS aquifer

5.6 Connection with surface water and/or GDEs

Over most of the extent of the PS aquifer, the depth to the watertable is over 20 m. The only area where possible connection with surface water and GDEs occurs is along the northern boundary of the aquifer in the vicinity of Pedlar Creek (Figure 16).

5.7 Sustainability issues

5.7.1 Salinity increases

The most immediate sustainability issue is the rise in salinity to the east of McLaren Flat. Barnett and Judd (2019) attributed the cause of the increase to be upward leakage from the underlying Blanche Point Marls (BPM) aquitard, which was driven by long term increases in extraction and the local drawdowns associated with pumping from individual irrigation wells. Salinities in the BPM aquitard appear to be in the range 1500 – 2000 mg/L, which provides an upper limit for potential salinity rises due to this upward leakage.

Figure 23 shows salinity trends in representative irrigation wells in two areas within the PS salinity stress zone. Wells in Area A display a significant rise in salinity levels during the 1990s and early 2000s to over 1500 mg/L, however these have stabilized since 2009. This is due to a decline in extraction and the fact that salinities in the BPM are not too much higher than those in the PS aquifer.

Wells in Area B are showing a different response. Because extraction levels were initially lower than in Area A, the salinity levels showed very little increase prior to 2009. However, as the extractions have increased after 2009, the salinity levels have also started to rise.

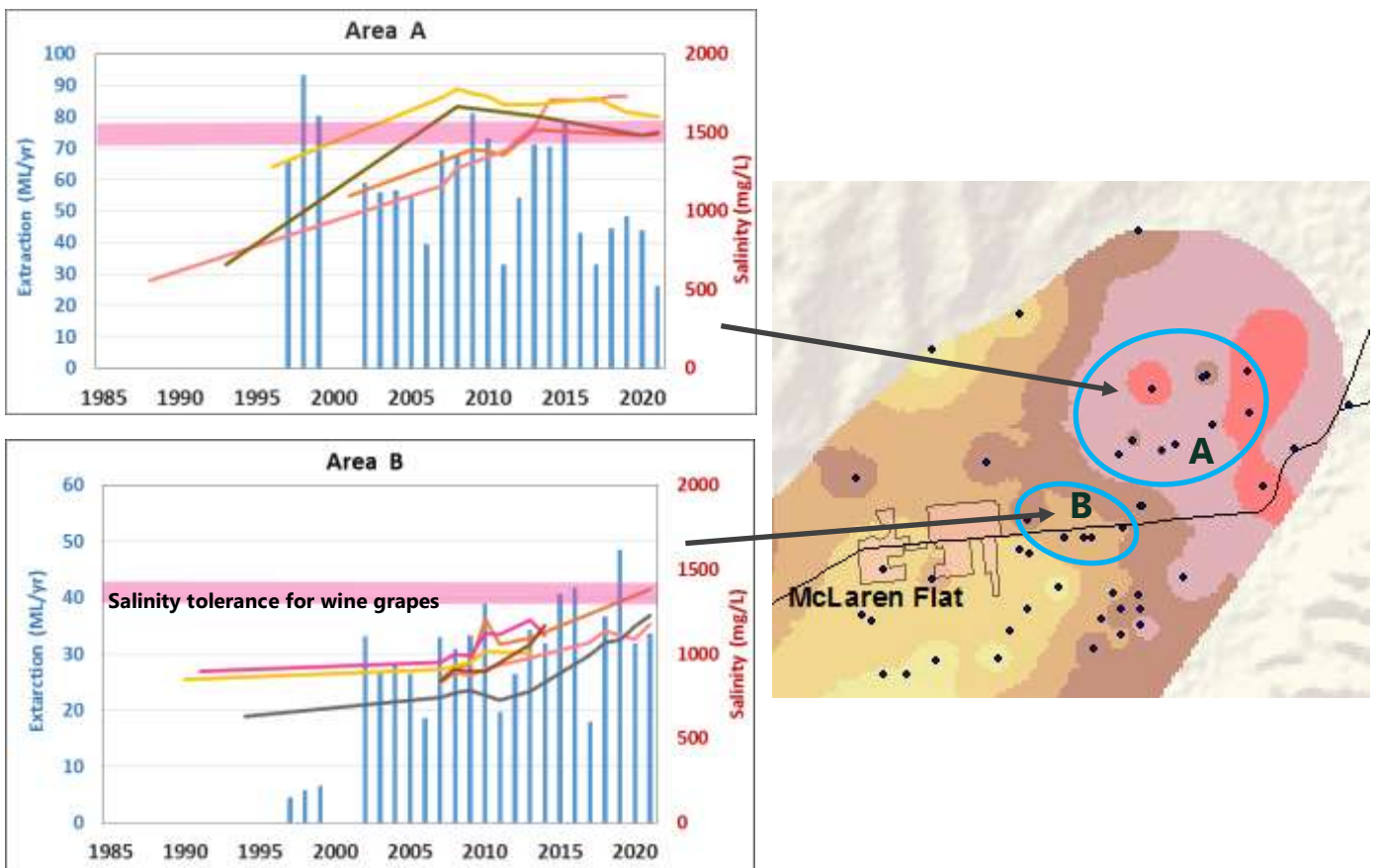


Figure 23. Representative rising salinity trends and extraction in the PS aquifer

To a certain extent, Figure 23 indicates that this sustainability issue in Area A could be self-managing – as salinity levels rose above the salinity tolerance for wine grapes (nominally 1500 mg/L), irrigators reduced groundwater extraction and may have reverted to alternative water sources (such as recycled effluent). This reduction in pumping from individual wells has led to the stabilised salinity levels. This scenario does not apply to Area B where salinity levels are still generally quite suitable for vineyard irrigation despite recent increases. However, based on observed salinity trends at current levels of extraction, salinities are expected to increase further.

The high degree of development of allocations indicated in Figure 18 suggests that a reduction in allocations within the areas of rising salinities could result in lower extraction volumes that will stabilize salinity levels as shown in Area A and limit future increases in extraction that may occur if salinities reduce to more useable levels.

5.7.2 Watertable declines

There has been a gradual decline in watertable levels over the last 15 years. As with the PWF aquifer, this decline is predominantly driven by rainfall trends and not significantly by extraction. The decline has not resulted in adverse salinity trends regionally. Figure 24 shows the thickness of the PS aquifer which ranges up to 80 m adjacent to the Willunga Fault.

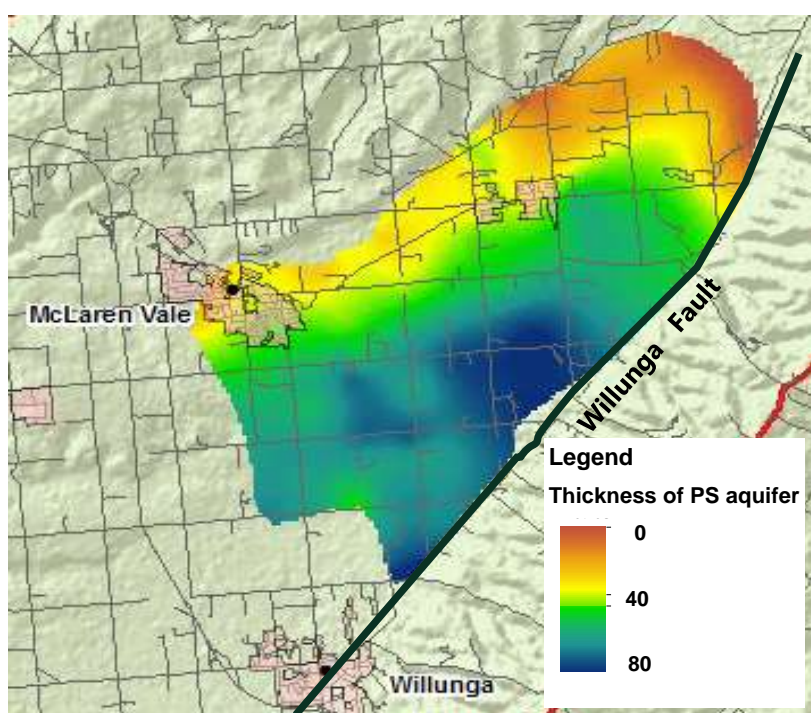


Figure 24. Thickness of the PS aquifer

Figure 24 also provides an explanation of why the upward leakage responsible for the salinity increases is located east of McLaren Flat. This is where the aquifer is thinnest and underlying BPM aquitard is closest to the bottom of the irrigation wells.

By assuming a conservative porosity value of 0.05 (to allow for clayey or silty layers within the aquifer), the total volume of water stored in the aquifer has been calculated at 80,000 ML. The hydrographs in Figure 19 show a long term decline of about 4 m since 1993, which represents a net loss of storage of about 7,000 ML or 9 % of the total. It can be concluded that over most of the extent of the aquifer, water level declines will not be an important sustainability issue during the term of the WAP due to the capacity of the resource. Recharge trends will influence the longer term capacity of the resource as discussed under climate change.

The area of highest risk to aquifer productivity from watertable decline is in the northeast where the aquifer is thinnest. A reduction in extraction in this area to address salinity increases will also help mitigate the risk from watertable decline.

5.7.3 Climate change

As the water level trends show a muted relationship with rainfall, the PS aquifer could be considered sensitive to climate change and associated gradually declining water levels. One area for focus (due to the thinner aquifer and salinity increases) is in the northeast. The remainder of the aquifer, whilst similarly subject to declining levels is considerably thicker and therefore has greater capacity to sustain extractions in the medium-term.

5.8 Resource capacity

No extraction limit has been previously set specifically for the PS aquifer. Examination of aerial photography reveals that virtually all the area of irrigation quality groundwater has already been planted with vineyards. Considering the observed monitoring trends outside of the area of PS salinity increase and that extraction has been stable for the last decade, it is recommended that no new allocations be issued for the PS aquifer in this area and the sustainable extraction limit be set at the current level of allocation (1,600 ML). Within the area of PS salinity increases, allocation reductions are strongly recommended to reduce extractions in order to reduce further salinity increases due to upward leakage and mitigate the risk of declining water levels.

5.9 Resource Condition Limits

RCLs are not recommended for this aquifer. Management actions have been recommended to deal with observed salinity increases. Water level declines have been very gradual so far and if continued, the resource will be able to sustain the current level of extraction for several decades.

6 Maslin Sands aquifer

The Maslin Sands aquifer consists of interbedded thick sand layers and clay layers which are carbonaceous in places. It extends over most of the PWA and unconfined in the higher topography to the north and east where it crops out. Elsewhere, the aquifer deepens to the southwest and is confined by the Blanche Point Formation aquitard.

Figure 25 presents the extent of the unconfined and confined portions of the Maslin Sands (MS) aquifer. Also shown are the licenced wells (in yellow) and the location of observation wells whose hydrographs are presented in Figure 28.

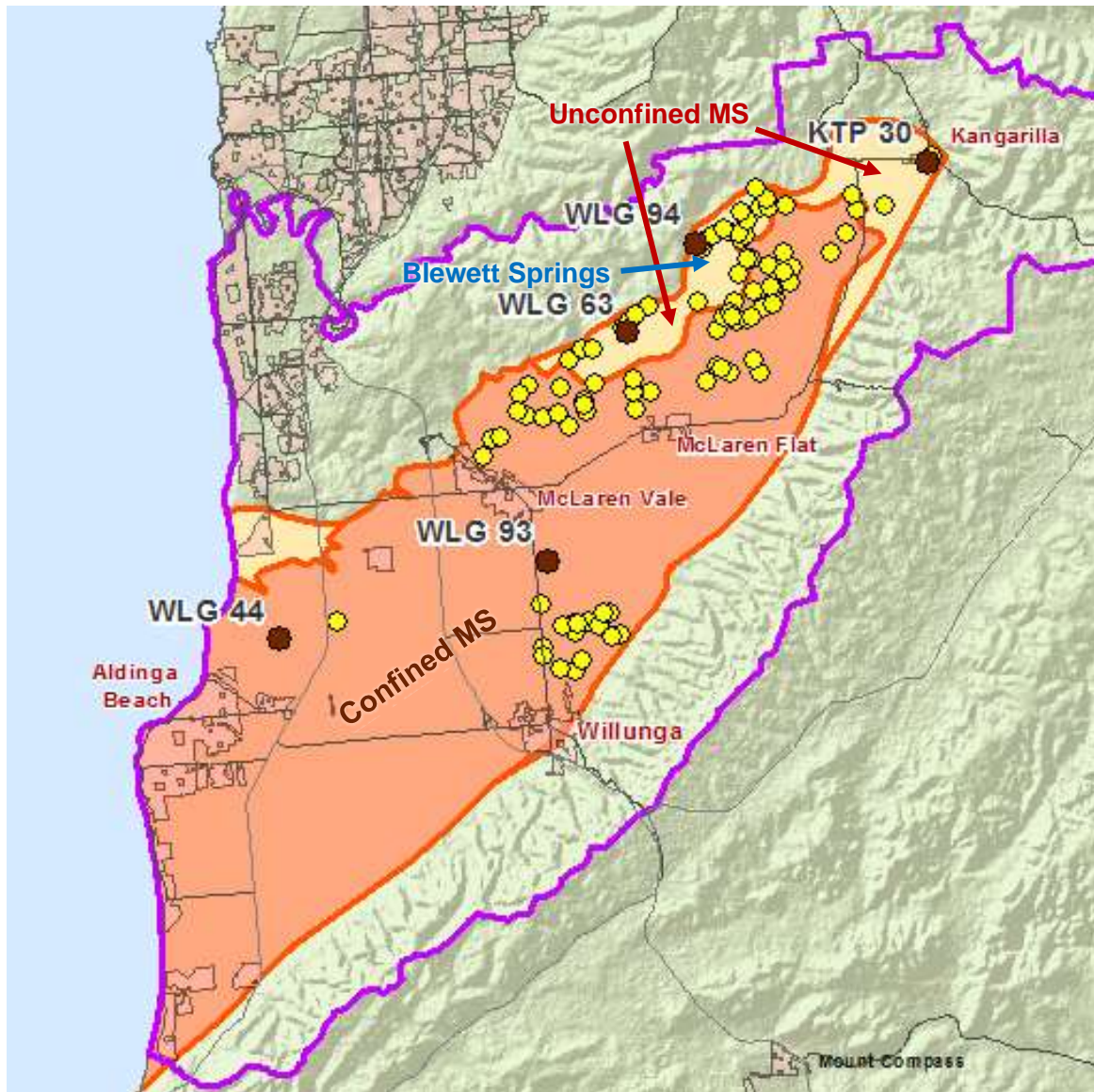


Figure 25. Extent of the Maslin Sands aquifer and location of licenced wells

6.1 Extraction and allocation

Figure 26 shows that metered extraction from the Maslin Sands aquifer since 2004-05 has been fairly consistent and mostly below 1,000 ML/year, with seasonal variations caused by changes in rainfall. It is generally well below the 2020 allocation volume of 1,278 ML. The metered extraction as a percentage of the individual licenced allocations averaged over the last two years is presented in Figure 26 and similar to the aquifers discussed previously, shows a very high degree of development of the allocations. There is limited potential for significant increases in extraction due to the activation of unused allocations.

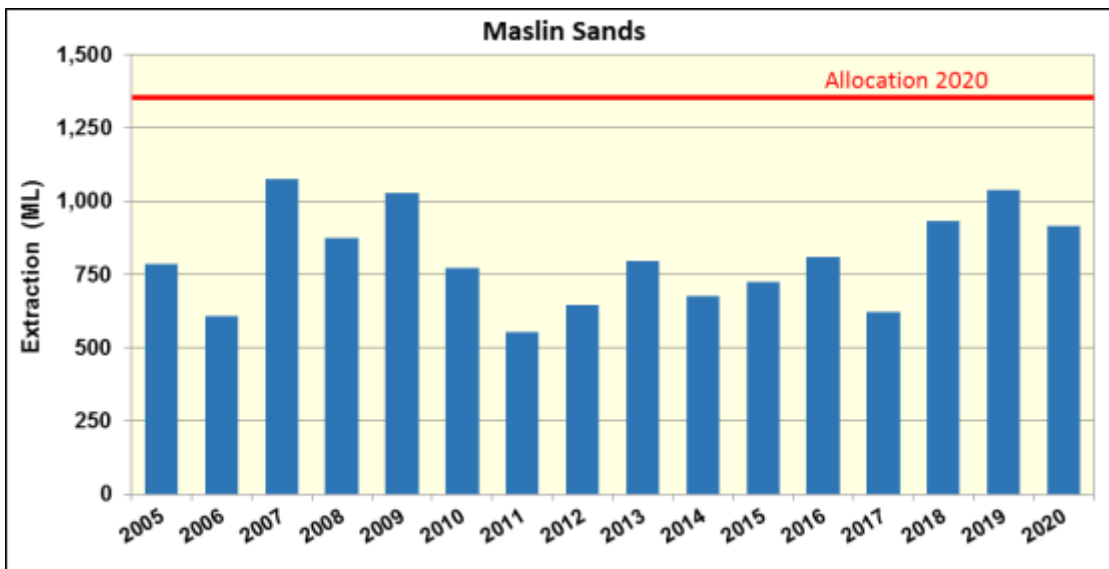


Figure 26. Metered extraction from the MS aquifer

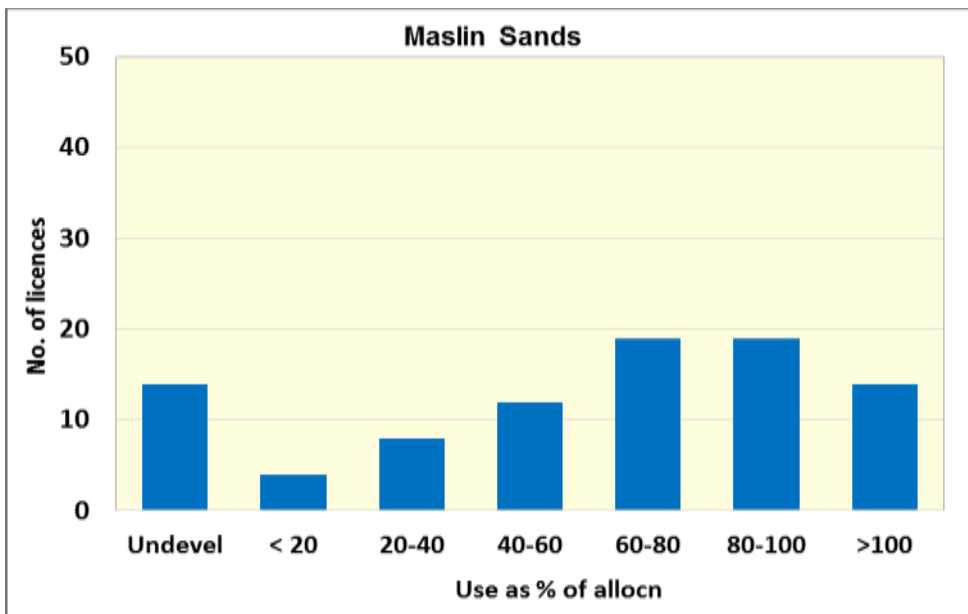


Figure 27. Use vs allocation for the MS aquifer

6.2 Groundwater flow direction

As with the other aquifers, the potentiometric surface for the MS aquifer presented in Figure 28 shows groundwater flow toward the coast in a southwesterly direction.

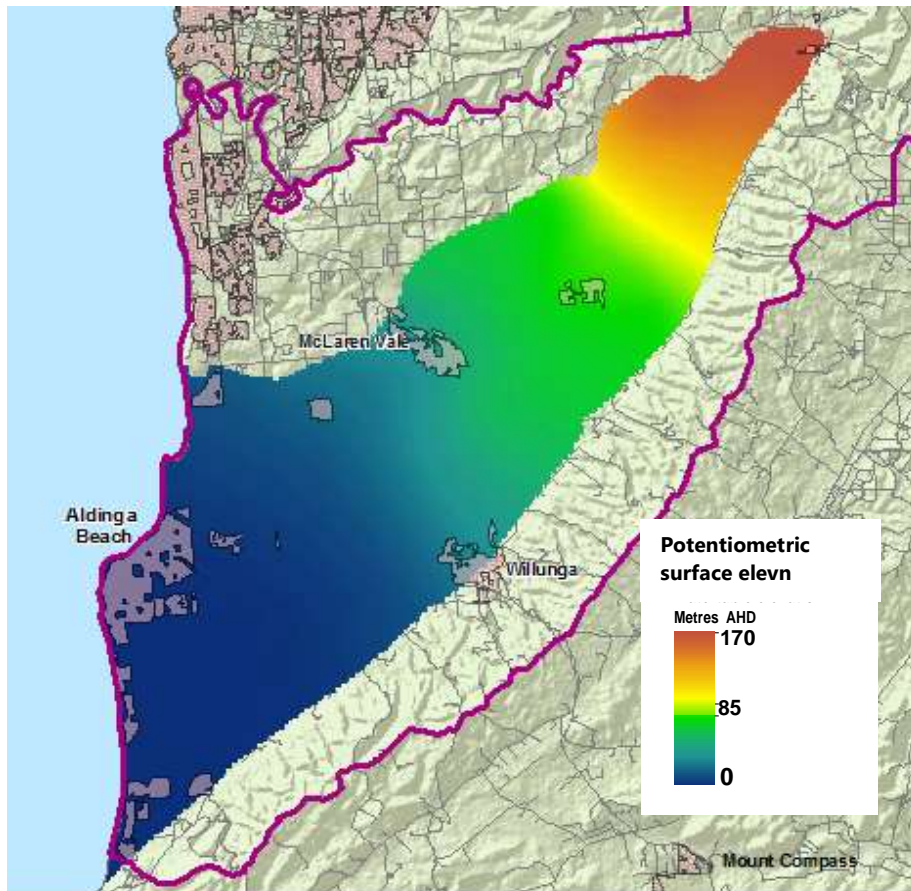


Figure 28. Potentiometric surface for the Maslin Sands aquifer

6.3 Water level trends

Water level monitoring has been carried out since the late 1980s. Figure 29 presents the long term trends which appear to have a very muted relationship with rainfall patterns. Wells in the northern unconfined portion of the aquifer (WLG 63, 94 and KTP 30) show a gradual decline since 2005 varying from 0.04 to 0.07 m/year, mainly driven by periods of below average rainfall (Well WLG 63 plotted in red refers to the right axis). Further to the southwest, pressure levels in the confined portion of the aquifer have been gradual declining since 1990 at rates varying from 0.05 to 0.10 m/year (WLG 44, 93).

6.4 Salinity distribution

Figure 30 shows the extent of the MS aquifer and the salinity distribution following the 2021 sampling program. The aquifer can be divided into two parts. To the southeast toward the Willunga Fault, salinities are generally below 1,000 mg/L. Toward the northern extent of the aquifer, salinities range up to 2,000 mg/L, which is well above the tolerance level for the irrigation of wine grapes (nominally 1500 mg/L). Near the coast to the southwest, salinity levels exceed 40,000 mg/L.

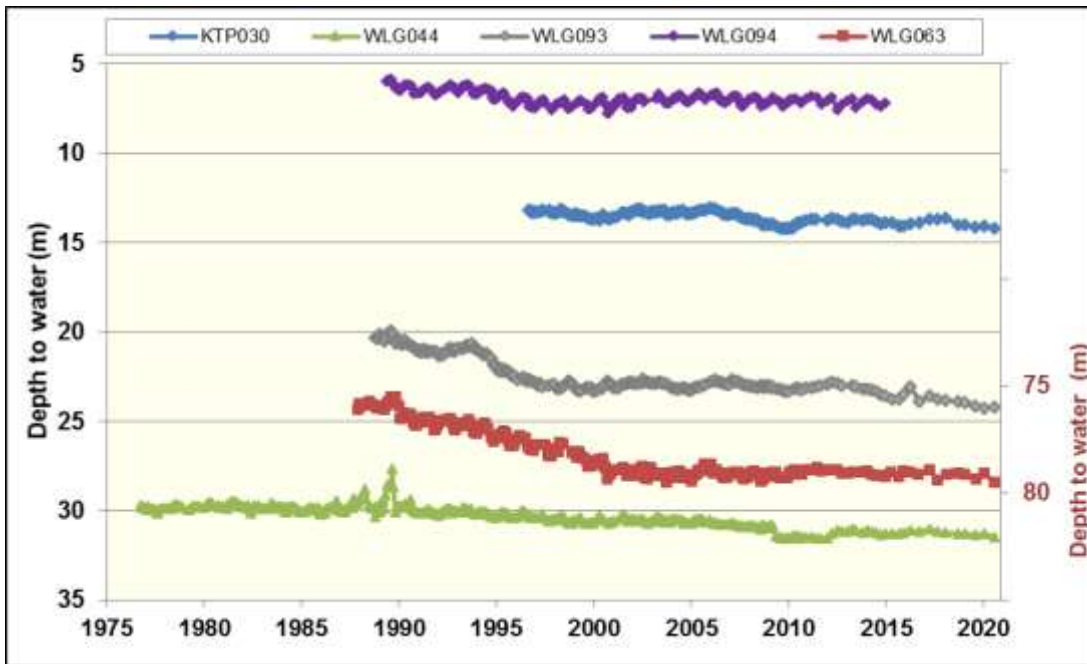


Figure 29. Selected hydrographs for the Maslin Sands aquifer

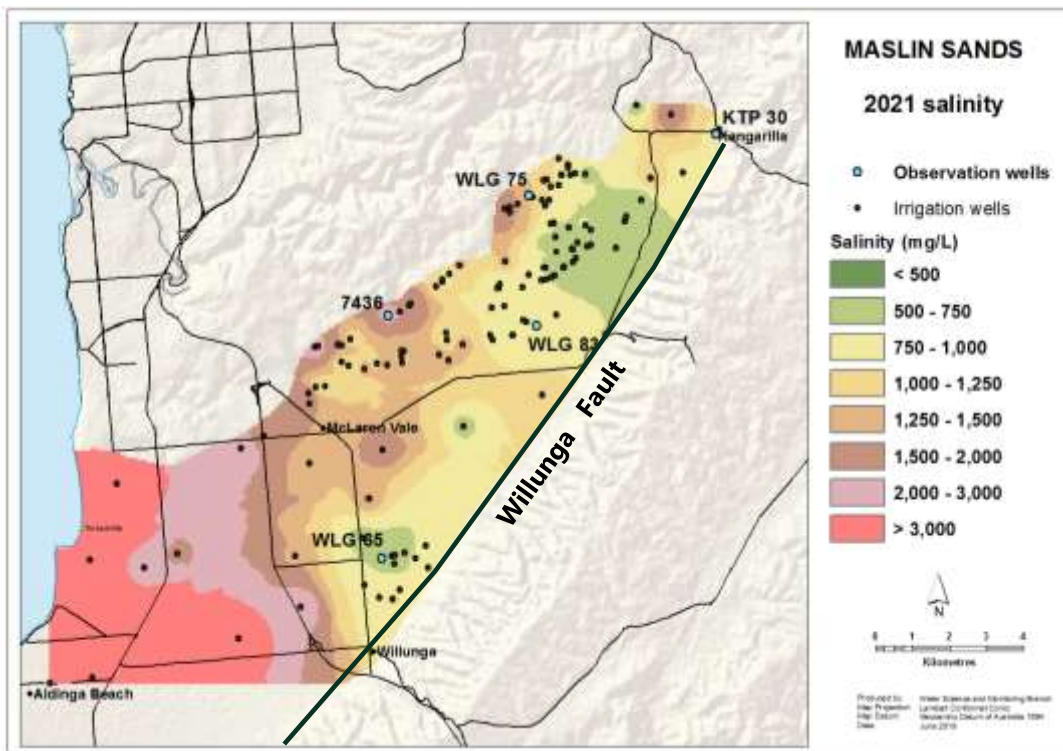


Figure 30. Salinity distribution for the MS aquifer in 2021

6.5 Salinity trends

Figure 31 shows long term trends from five representative irrigation wells (locations shown in Figure 29) which indicate that trends are relatively stable. Along the northern margin of the aquifer, salinity levels are rising significantly where the MS aquifer is thinning against rising basement.

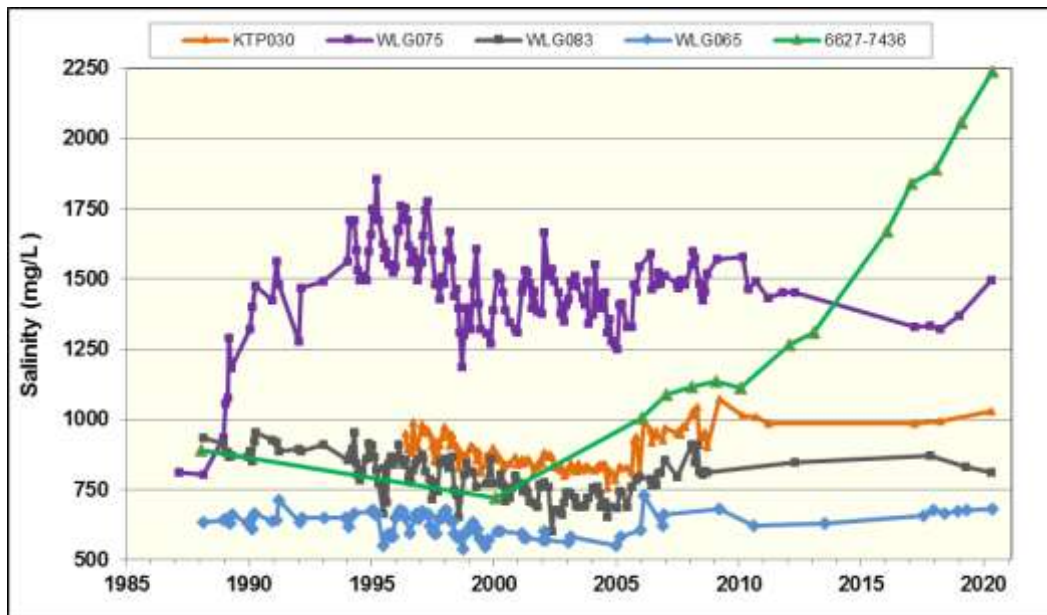


Figure 31. Long term salinity trends for the MS aquifer

6.6 Connection with surface water and/or GDEs

The only area where the potential exists for interaction with GDEs or surface water is in the unconfined portion of the aquifer in the northeast of the PWA. Even in this area, the depths to the watertable are generally over 20 m because of the hilly terrain. However there are two exceptions where the watertable is close to the surface; near Blewett Springs (Figure 25) and the low lying area to the northwest of Kangarilla.

6.7 Sustainability issues

6.7.1 Salinity increases

The most immediate sustainability issue for the MS aquifer is the rise in salinity levels along the northern margin to the northwest of McLaren Flat. Barnett and Judd (2019) attributed the cause of the increase to be upward leakage from the underlying fractured rock aquifer, which was similarly driven by long term increases in extraction and the local drawdowns associated with pumping from individual irrigation wells. The salinities in the FRA range up to 6000 mg/L. These salinities are much higher than those in the BPM aquitard which are contributing to salinity rises in the PS aquifer, resulting in ongoing rising trends in the MS aquifer with no sign of stabilization in some wells.

Figure 32 shows salinity trends in representative irrigation wells within two areas where MS salinities are increasing. Wells in Area A display a significant rise in salinity levels commencing during the mid 2000s to over 1500 mg/L in response to increasing extraction. Despite a decline in extraction due to the high salinities, the trend shows no sign of stabilisation. Wells in Area B also displayed a rising trend commencing during the mid 2000s, but because extraction levels have been declining gradually, the salinity levels appear to have stabilised.

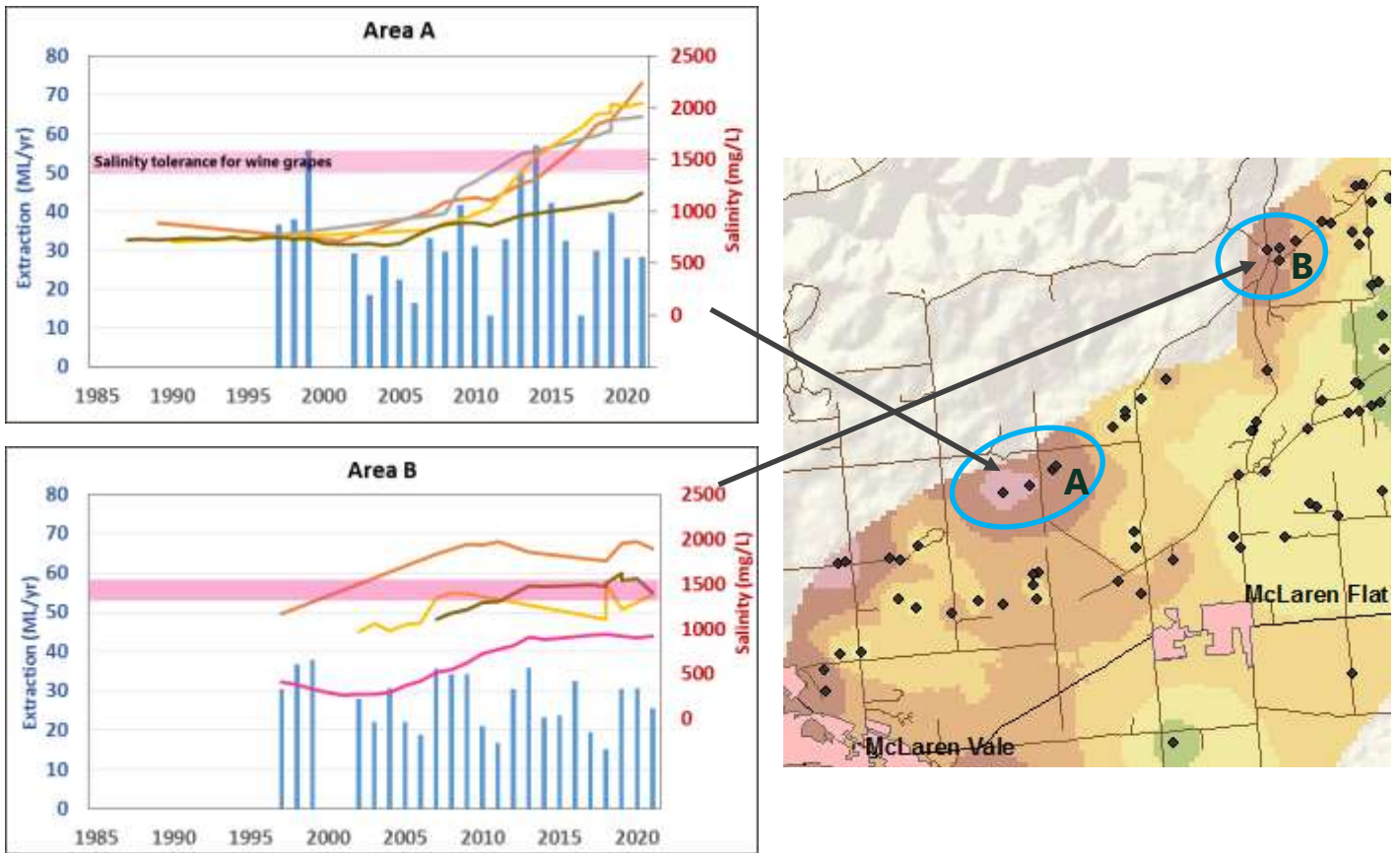


Figure 32. Representative rising salinity trends and extraction in the MS aquifer

As with the PS aquifer, a reduction in extraction within the areas of MS salinity increase would stabilize salinity levels. The high degree of development of allocations indicated in Figure 27 suggests that a reduction in allocations within the areas of MS salinity increase could result in lower extraction volumes and prevent future increases in extraction that may occur if salinities reduce to useable levels.

6.7.2 Watertable declines

The gradual decline in watertable levels over the last 15 years also is predominantly driven by rainfall trends and not significantly by extraction. The decline has not resulted in adverse salinity trends regionally. Figure 33 shows the thickness of the MS aquifer which ranges up to 250 m at the coast.

By assuming a conservative porosity value of 0.05 (to allow for clayey or silty layers within the aquifer), the total volume of water stored in the aquifer has been conservatively calculated at 435,000 ML (the elastic storage due to pressurization of the aquifer where it is confined, has been ignored). The unconfined portion of the aquifer to the north encompasses only about 10 % of the aquifer extent (20 km²) and volume (40,000 ML). The unconfined hydrographs in Figure 29 show a long term decline averaging about 2 m since 1993, which represents a loss of storage of about 2,000 ML or 5 % of the total.

The area of highest risk to aquifer productivity from watertable decline is along the northern boundary where the unconfined portion of the aquifer is thinnest. Reduction in extraction to address salinity increases will also help mitigate the risk from watertable decline.

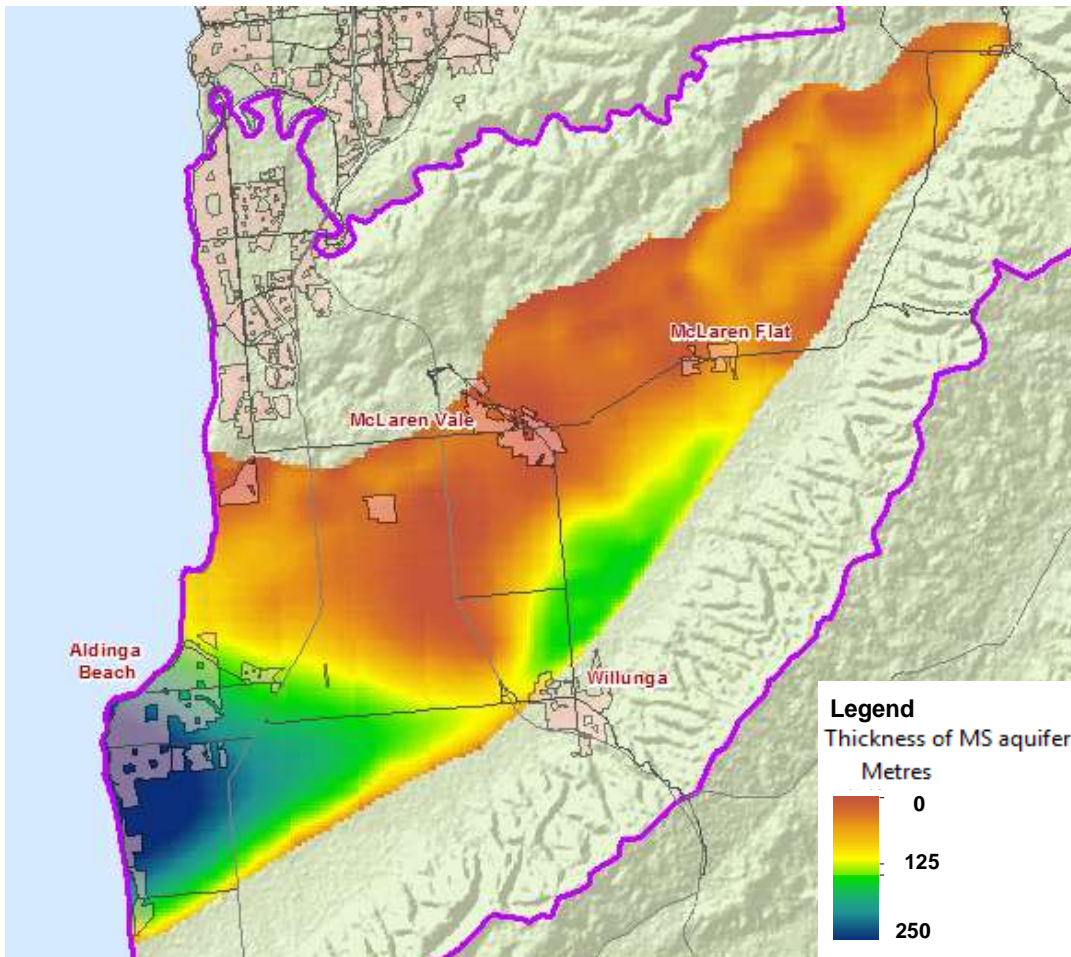


Figure 33. Thickness of the MS aquifer

6.7.3 Depressurisation of the confined aquifer

As discussed earlier, depressurization of a confined aquifer may compromise the structural integrity of the confining layer. However this risk is considered negligible because the Blanche Point Marl confining layer averages about 30 m in thickness and pressure declines of 50 m would be required for depressurization of the MS confined aquifer to occur because of its depth (Figure 2). The observed gradual declines pressure levels in Figure 29 range up to 4 m since 1990 and do not present a risk to the resource for the foreseeable future.

6.7.4 Sea water intrusion

Another sustainability issue is the risk of sea water intrusion (SWI). Investigations by the National Centre for Groundwater Research and Training (NCGRT) have found naturally occurring saline groundwater over 40,000 mg/L in the MS aquifer near the coast but no evidence of active sea water intrusion. The risk of SWI is considered low due to the distance of most irrigation extraction from the coast and no sign of cones of depression in pressure level contours that could lead to a flow reversal from seaward to landward.

6.7.5 Climate change

Because both the pressure and watertable level trends show a muted relationship with rainfall, the MS aquifer could be considered sensitive to climate change. However as discussed above, the gradually declining pressure levels that would result from a drying climate would not result in the aquifer being classified as vulnerable to climate change over the term of the WAP because of the capacity of the resource. The area that could be classified as vulnerable to gradually declining watertable levels resulting from a drying climate would be along the northern margin.

6.8 Resource capacity

No extraction limit has been previously set specifically for the MS aquifer. Given the observed monitoring trends and that extraction has been stable for the last decade, a an extraction limit in the northeast of the PWA where most extractions occur (outside of the areas of salinity rises), set at the current level of allocation (1,138 ML) would be sustainable.with no new allocations to be issued in this area.

In the deeper confined parts of the aquifer to the southwest of the PWA, additional extraction could occur with minimal risk to the resource.

6.9 Resource Condition Limits

In other confined aquifers in SA, an RCL of maintaining pressurization within the aquifer (i.e. not allowing it to become unconfined), has been chosen. However in this case, because of the negligible risk of depressurization occurring due to the depth of the aquifer (Section 6.7.3), applying this RCL is not recommended.

With regards to the prevention of SWI, maintaining a positive gradient toward the coast over the long term is essential.

7 Permian Sands aquifer

The Permian Sands aquifer occurs in two isolated locations within the PWA. The northeastern corner of the PWA contains a small area of outcropping unconfined Permian Sands which extends further to the south toward Kuitpo Forest. In addition, to the northwest of the PWA near the settlement of Maslins Beach, investigation drilling for construction sand resources has defined a confined Permian Sands aquifer underlying the Maslin Sands aquifer.

Figure 34 presents the extent of the two occurrences of Permian Sand. There are two licenced wells in the Confined Permian which extract about 160 ML/yr for industrial purposes. There is no licenced extraction from the Unconfined Permian.

There are no monitoring wells completed in the Permian Sands aquifer, but due to the low extraction, there are expected to be no sustainability issues.

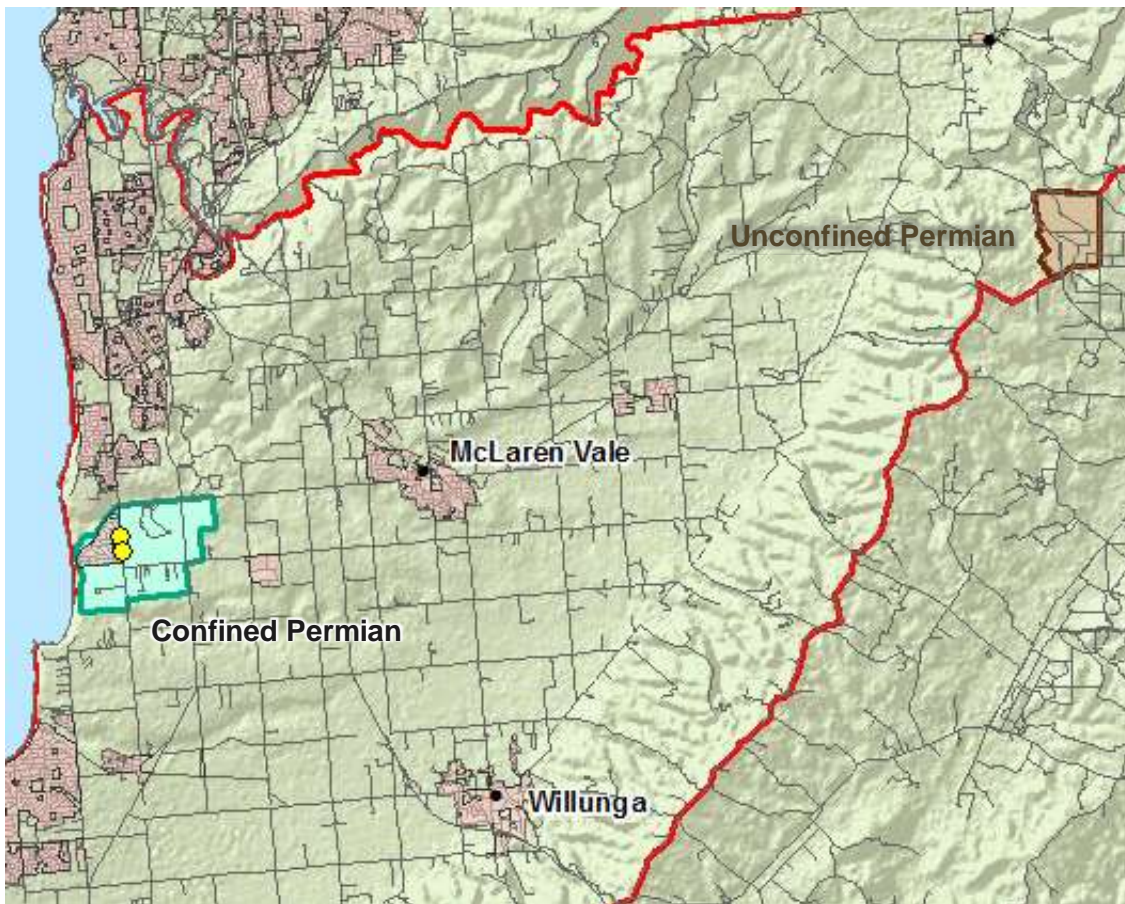


Figure 34. Extent of the Permian Sands and location of licenced wells

7.1 Resource capacity

7.1.1 Unconfined Permian Sands

About 80 % of this area is occupied by forestry activities and therefore the likelihood of any licenced extraction is quite low. A nominal figure of 50 ML/yr is proposed as the extraction limit.

7.1.2 Confined Permian Sands

Licensed extraction from the two wells in this area occurs for industrial purposes which is the highest value use of this resource, given that salinities are in the range of 4,000 to 9,000 mg/L. Due to the aquifer being confined, the extraction of about 160 ML/yr has minimal impact on other licenced users, the nearest being 2.5 km away using the overlying Maslin Sands aquifer. A nominal figure of 250 ML/yr is proposed as the extraction limit.

8 Fractured Rock aquifer

The fractured rock aquifer (FRA) occurs throughout the whole PWA, either as unconfined aquifer where it outcrops at the ground surface on the margins of the Willunga Embayment, or as a confined aquifer underlying the Tertiary and Quaternary sediments.

Figure 35 presents the boundaries of the unconfined FRA which covers the areas of higher topography surrounding the PWA where the aquifer outcrops or is covered by thin unsaturated Tertiary sediments, while the confined FRA includes the central part of the basin where the aquifer occurs at depths of over 75 m and is confined by the overlying Tertiary sediments. Also shown are the licenced wells (in yellow) and the observation wells whose hydrographs are presented in Figure 38.

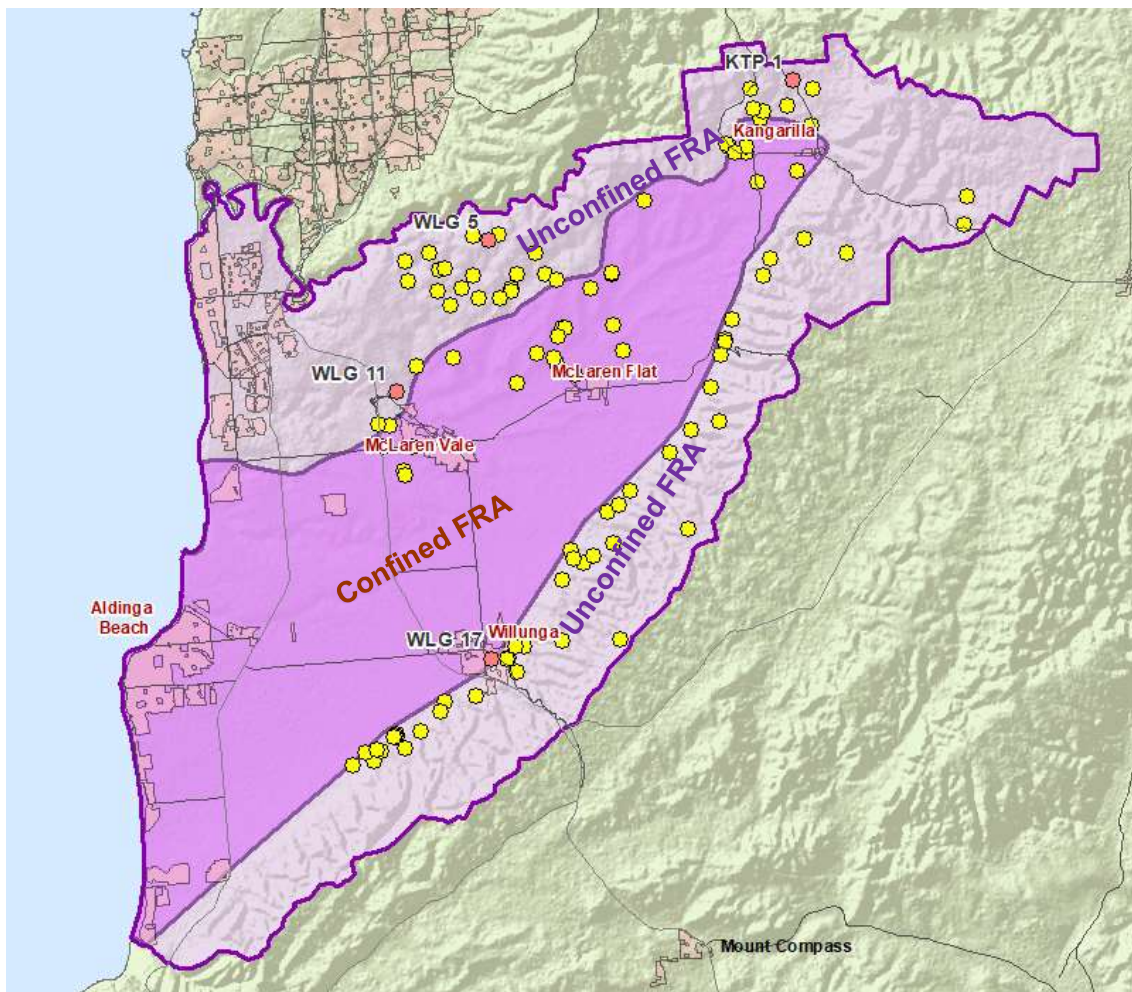


Figure 35. Extent of the Fractured Rock aquifer and location of licenced wells

8.1 Extraction and allocation

Figure 36 shows that metered extraction from the FRA aquifer since 2004-05 has been fairly consistent and mostly below 1,000 ML/year, with seasonal variations caused by changes in rainfall. It is generally well below the 2020 allocation volume of 1,653 ML. The metered extraction as a percentage of the individual licenced allocations averaged over the last two years is presented in Figure 37 and shows a lower degree of development of the allocations than the other aquifers discussed previously. This under-development of allocations is probably due to variable well yields and generally higher salinities than other aquifers which also suggests a low potential for significant increases in extraction.

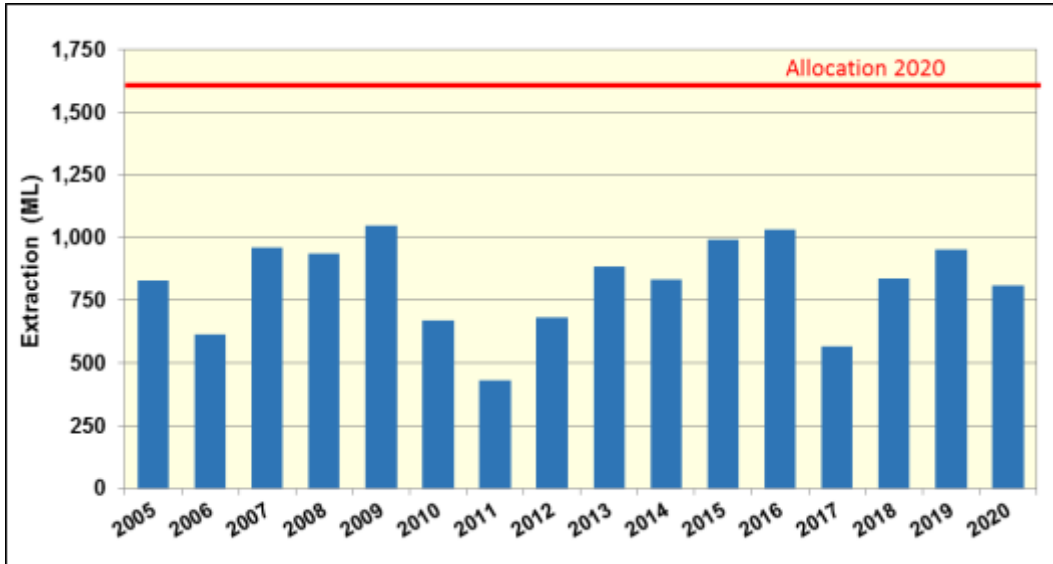


Figure 36. Metered extraction from the FRA aquifer

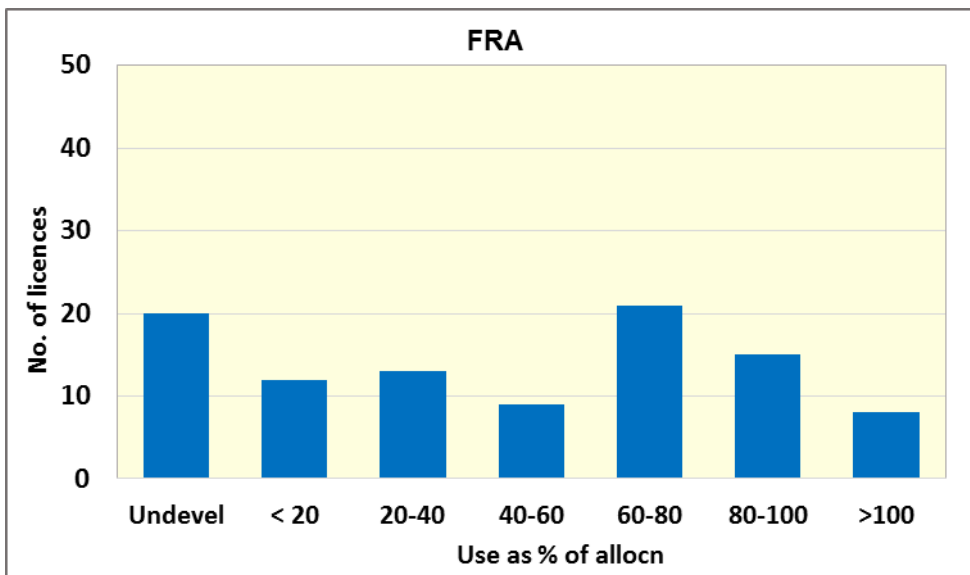


Figure 37. Use vs allocation for the FRA aquifer

8.2 Groundwater flow direction

The potentiometric surface elevation in Figure 38 for both the unconfined and confined portions of the FRA shows a general groundwater movement from areas of high topography toward the southwest and the coast. It also suggests that the Willunga Fault is a barrier to groundwater flow, maintaining high water levels to the east of the fault zone.

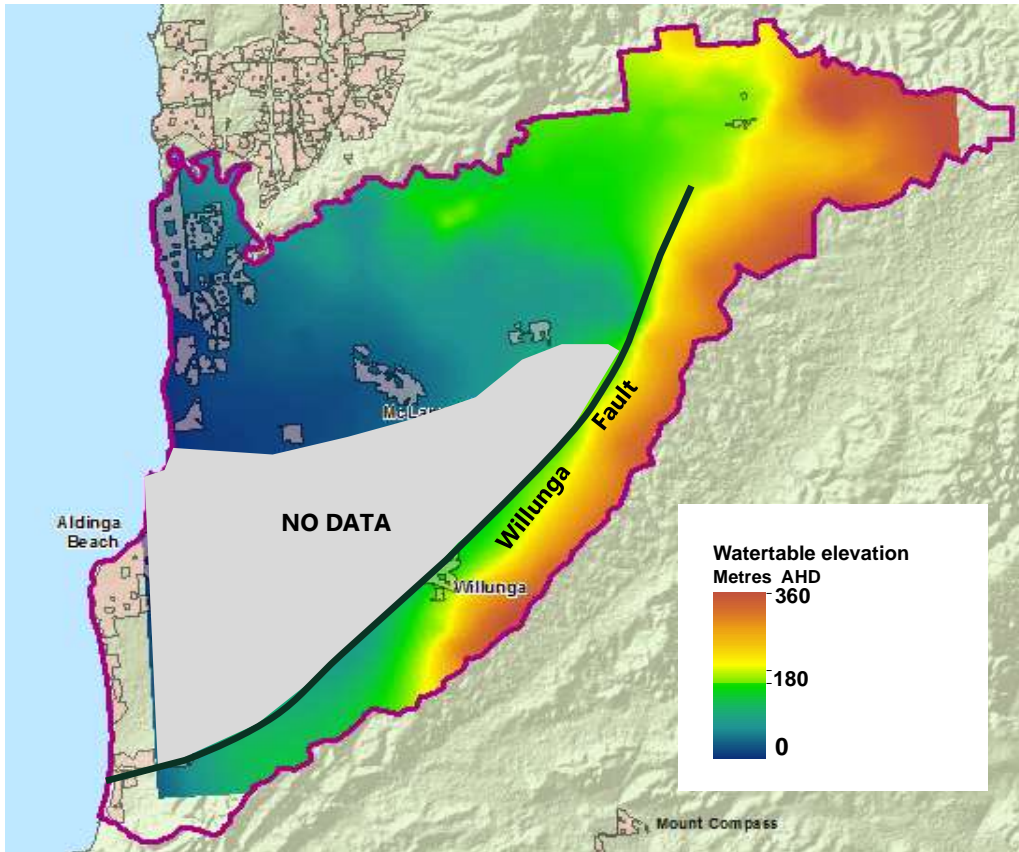


Figure 38. Potentiometric surface for the FRA

8.3 Water level trends

Water level monitoring has been carried out since the mid 1970s. Because this is generally an unconfined aquifer, the water levels in Figure 39 show a relationship with rainfall patterns with water level declines mainly driven by periods of below average rainfall (prior to 1992-93 and during the millennium drought). Long term trends vary from relatively stable to a gradual decline.

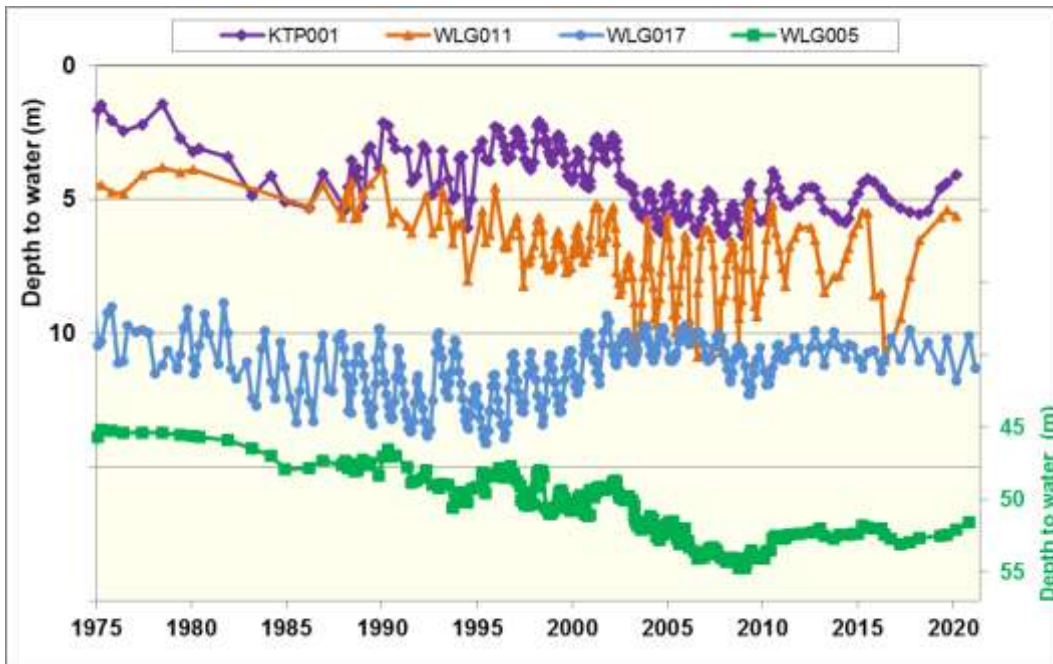


Figure 39. Selected hydrographs for the FRA aquifer

8.4 Salinity distribution

As shown in Figure 40, salinities in the FRA are quite variable with the lowest salinities (below 750 mg/L) found to the northeast where the FRA is overlain by sedimentary aquifers (Maslin and Permian Sands). The highest salinities occur along the northern boundary of the PWA where values are over 3,000 mg/L. This is well above the salinity tolerance level for the irrigation of wine grapes (nominally 1500 mg/L).

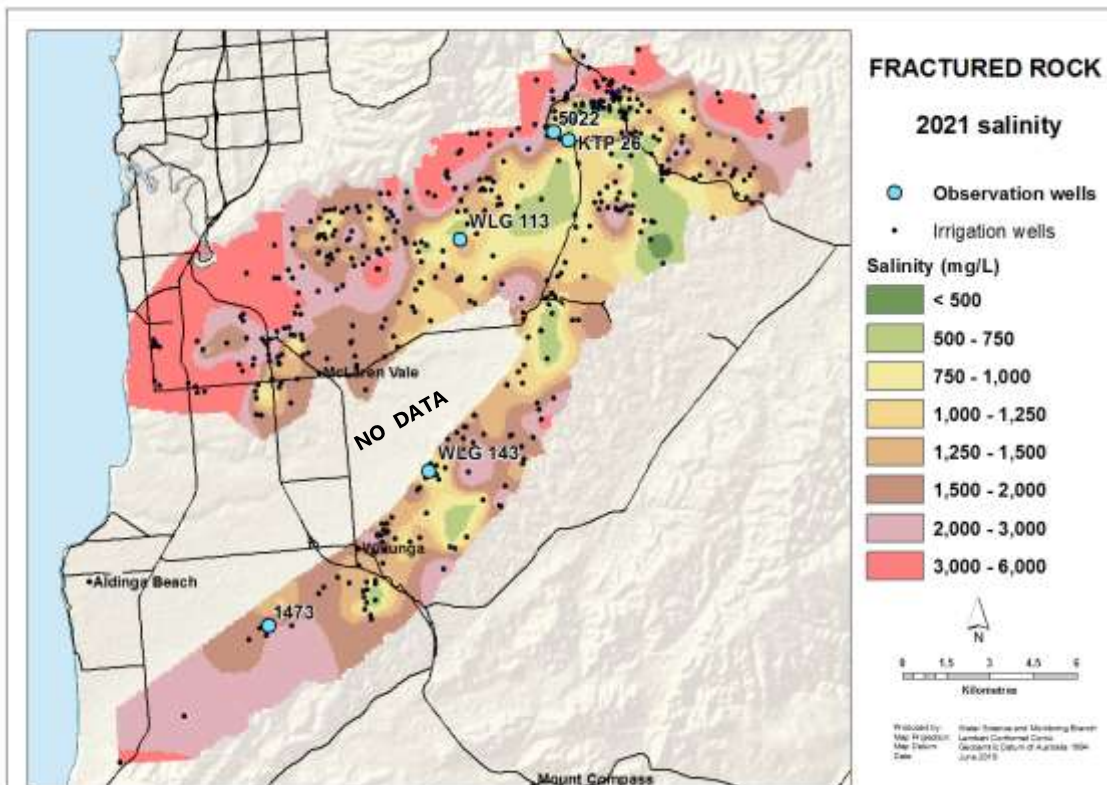


Figure 40. Salinity distribution for the FRA aquifer in 2021

8.5 Salinity trends

Figure 41 shows long term trends from five representative irrigation wells (locations shown in Fig. 33) which indicate that trends are relatively stable, with periods of more frequent sampling showing a response to rainfall between 1990 and 2010.

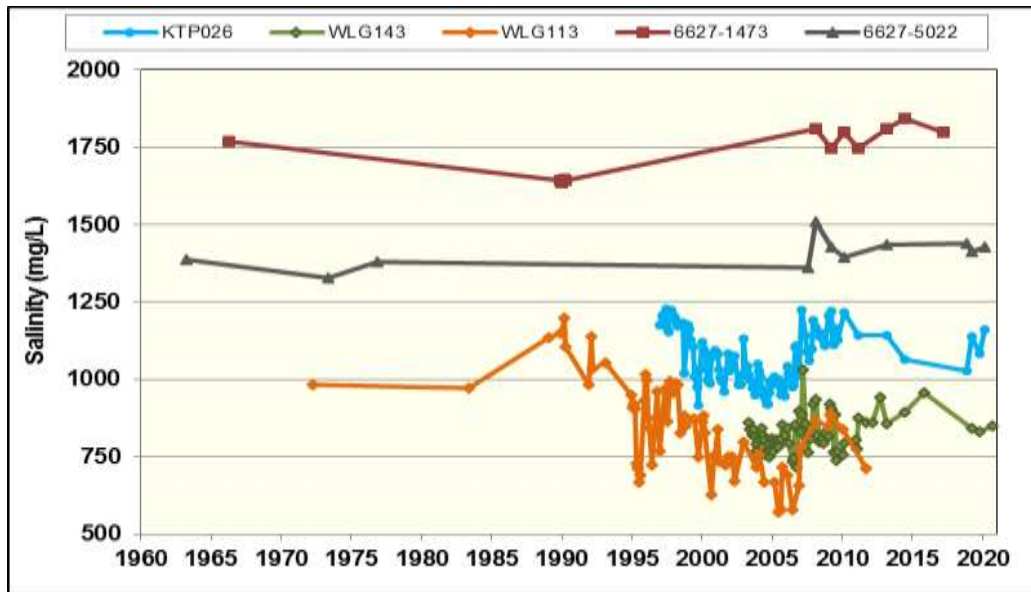


Figure 41. Long term salinity trends for the FRA aquifer

8.6 Connection with surface water and/or GDEs

The FRA connect with surface water in two main locations. The most noticeable is along the Onkaparinga Gorge where the river is deeply incised into basement rocks. Water level data from wells suggest the FRA discharges toward the river from within one kilometer, but at greater distances from the river, groundwater flow is south toward the Willunga Embayment.

Elsewhere, the smaller creeks flowing out westward onto the plain from the escarpment may receive baseflow near the base of the range. The most prominent of these creeks are Wiira Creek and Kangarilla Creek.

8.7 Sustainability issues

Fractured rock aquifers have complex fracture systems and well yields are highly variable. The impacts of extraction are generally very localized. The long term monitoring trends show no overall significant sustainability issues in terms of declining water levels or increasing salinity.

8.7.1 Climate change

As both the water level and salinity trends in the FRA show a muted relationship with rainfall, it could be considered sensitive to climate change. A long term gradual decline in water levels that would result from a drying climate could lead to the dewatering of joints and fractures and a reduction in well yields. A reduction in recharge could result in reduced freshening of the aquifer and gradual increases in salinity. The FRA could therefore be classified as vulnerable to impacts from climate change in the long term. Management actions are unlikely to mitigate this risk.

8.8 Resource capacity

No extraction limit has been previously set specifically for the FRA aquifer. However, investigations have been carried out to estimate recharge rates to determine the resource capacity for fractured rock aquifers in both the Eastern and Western Mount Lofty Ranges PWRAs which abut the McLaren Vale PWA (EMLR - Banks et al, 2007; WMLR - Green and Zulfic, 2008). The same methodologies can be applied to the unconfined portions of the FRA in the McLaren Vale PWA where sufficient information is available. In order to do this, the FRA needs to be divided into appropriate recharge zones based on surface water catchments and geology as shown in Figure 42, together with the annual rainfall isohyets.

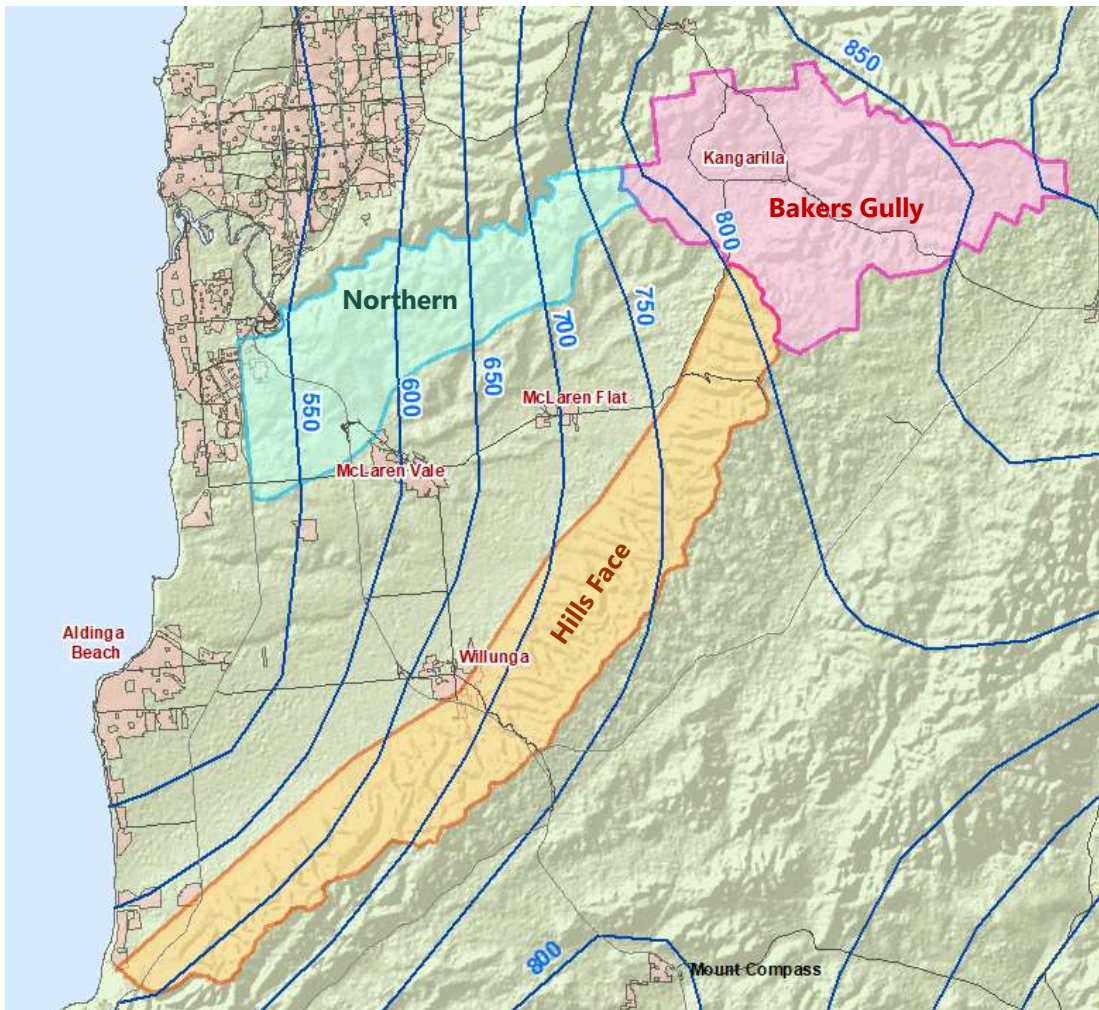


Figure 42. Recharge zones for the unconfined FRA aquifer

Appendix A presents the calculations for the licenced allocation volume for each recharge zone using the EMLR and WMLR methodology, with a summary presented below in Table 1. It should be noted that these calculations are theoretical and are subject to large uncertainties. Table 1 also shows that current metered use for the three zones averages about 55% of the allocated volume, which is probably due to salinity or well yield constraints. This suggests there does not appear to be any unmet demand for additional irrigation supplies from the FRA. The recommended extraction limits in Table 1 takes into account the characteristics of each zone with the rationale for these volumes discussed below.

Table 1. FRA zones recommended extraction limits (ML/year) (refer also Appendix A)

Zone	Calculated Volume For Licensed Allocation	Current Allocation	Current Use	Recommended extraction limit
Hills Face	5,860	850	462	1,000
Bakers Gully	1,362	188	114	300
Northern	1,845	563	280	600

8.8.1 Hills Face Zone

This highly visible zone has very steep slopes with generally only the upper and lower portions suitable for irrigated agriculture. Due to the steep topography, much of the rainfall would run off rather than infiltrate to recharge the FRA. Recharge would also be inhibited by the considerable area of revegetation and native scrub (about 880 ha). The extrapolated recharge rates would therefore be probably overstated. Given the lack of demand, a modest extraction limit of 1,000 ML/yr is recommended, which represents a small increase above current allocation levels.

8.8.2 Bakers Gully Zone

This zone has a more subdued topography than the Hills Face Zone and a higher density of settlement. It also has a significant coverage of plantation forestry and native vegetation. The area has a high rainfall (over 800 mm/year) and areas of low salinity in the FRA, which suggests significant recharge occurs. As with the Hills Face zone, usage is only about 60 % of the allocation, suggesting low demand. A modest extraction limit of 300 ML/year is recommended, which represents a small increase above current allocation levels.

8.8.3 Northern Zone

The Northern GMZ lies on the northern boundary of the PWA where the Onkaparinga River is strongly incised into the basement rocks to form the Onkaparinga Gorge. The southern boundary of this zone is defined by the northern extent of overlying Maslin Sand aquifer. Apart from the vegetated flanks of the gorge, most of the area is covered with vineyards. There is a strong rainfall gradient increasing from west to east. Usage is only 50 % of the allocation, which is probably a reflection of low demand due to high groundwater salinities. A modest extraction limit of 600 ML/year is recommended, which represents a small increase above current allocation levels.

9 Summary and recommendations

This assessment of the groundwater level, salinity and extraction trends in the McLaren Vale Prescribed Wells Area (PWA) and sustainability issues was carried out to inform a risk assessment being carried out for a review of the Water Allocation Plan.

Overall, extraction trends in all aquifers have been relatively stable over the last 10 – 15 years. There have been gradual declines in water levels observed since the mid 1990s in most aquifers which corresponds with the period of below average rainfall experienced since 1975. In the long term and noting the impacts of climate change, there is a risk to the sustainability of the resource if these declines continue. However, given the volume of groundwater stored in the aquifers, there is opportunity to undertake further assessment and analysis.

This could include work to:

- determine the relative contribution of extraction and below average rainfall to the observed water level declines.
- determine the feasibility of constructing a groundwater model - such a model would be complex with five interconnected aquifers; similarly, whether there is sufficient data to make a model feasible - the information required to reduce the uncertainty in predictions may not be available.
- determine how effective a groundwater model may be in analysing extraction scenarios and management options (again, as this is a complex groundwater system with a number of hydraulic connections, there may be large error bands around any model output).

Salinity levels are generally stable, except for two 'hot spot' areas where significant rises have occurred due to upward leakage of more saline groundwater from underlying layers. Management actions are proposed in areas where the unconfined Maslin Sand and Pirramimma Sand aquifers have limited thickness, in order to address the observed salinity increases and also to mitigate the risks of watertable decline due to climate change.

Sustainability risks such as sea water intrusion and aquifer de-pressurisation have been evaluated. The risk of sea water intrusion in both the Port Willunga Formation and Maslin Sands aquifers is considered low due to the distance of most irrigation extraction from the coast and no sign of cones of depression in pressure level contours that could lead to a flow reversal from seaward to landward. The observed gradual declines pressure levels in both aquifers do not present a risk of de-pressurisation to the resource for the foreseeable future.

An assessment of the capacity of each aquifer was also carried out. The following Table 2 summarises the recommended extraction limits.

Table 2. Recommended extraction limits

Aquifer	Extraction limit (ML/yr)	Comment
Quaternary	50	Conservative nominal volume based on existing demand
Port Willunga Formation	1,683	Current allocation volume
Pirramimma Sand	1,600	Current allocation volume
Maslin Sands	1,138	Current allocation volume
Permian Sands Unconfined	50	Conservative nominal volume
Confined	250	Conservative nominal volume based on existing demand

Fractured Rock	Hills Face	1,000	Conservative nominal volume based on existing demand
	Bakers Gully	600	Conservative nominal volume based on existing demand
	Northern	300	Conservative nominal volume based on existing demand
	Remainder	50	Current allocation volume

10 Appendix A

The recommended groundwater extraction and allocation limits for management zones within the Eastern and Western Mt Lofty PWRAs were based on groundwater recharge estimates derived from detailed hydraulic and hydrochemical investigations (EMLR - Banks et al, 2007; WMLR - Green and Zulfic, 2008). These initial estimates were adjusted to take into the interception of groundwater recharge by plantation forestry and the volumes of current use of groundwater for non-licensed purposes.

Therefore for each recharge zone, the volume of underground water for licensed allocation has been derived from these quantities according to the formula:

$$ULA = UGR - BF - FI - NL$$

Where;

ULA is the volume of groundwater for licensed allocation,

UGR is the net annual groundwater recharge volume,

BF is the baseflow,

FI is the reduction in recharge due to interception by forestry, and

NL is the non-licensed groundwater use.

Recharge (UGR)

The value for Bakers Gully was taken directly from previous studies, whereas the value for the Hills Face was extrapolated from adjacent MLR GMZs to the east where appropriate. There were no previous studies close to the Northern zone. The isohyets (Fig. 41) show this zone experiences about a 20 % lower rainfall than the other two zones, and consequently, a 20 % lower recharge rate was applied.

Baseflow (BF)

These values were also taken directly from previous work (Savadamuthu and Teoh, 2010). Calculations made specifically for this study showed negligible baseflow inputs into the Onkaparinga Gorge downstream of Bakers Gully .

Forestry interception (FI)

The recharge is assumed to be reduced by 85% beneath plantation forestry or natural vegetation. Table V below shows the approximate areas of this type of land use in each zone.

Table A1. Area of vegetation

Zone	Area (ha)
Bakers Gully	866
Hills Face	880
Northern	260

Non-licensed use (NL)

Most of the area within the unconfined FRA GMZs do not have access to SA Water reticulated water. However, relatively high groundwater salinities may limit domestic use and the steep topography and extensive coverage of vineyards may limit pastoral use. Non-licensed use was extrapolated from adjacent MLR GMZs with similar topography and land use.

Table A2. Calculated allocation limits (ML/yr)

GMZ	Net Annual Recharge Volume (UGR)	Annual Baseflow Volume (BF)	Forestry Interception (FI)	Non-licensed Use (NL)	Volume For Licensed Allocation (ULA)
Bakers Gully	3020 (63 mm/yr)	1,170	463	25	1,362
Hills Face	6347 (64 mm/yr)	0	479	8	5,860
Northern	1965 (50 mm/yr)	0	110	10	1,845

11 References

- Aldam, R., 1990. Willunga Basin groundwater investigation - Summary report. South Australia. Department of Mines and Energy. Report Book, 90/71.
- Banks, E.W., Wilson, T., Green, G. and Love, A.J., 2007. Groundwater recharge investigations in the Eastern Mount Lofty Ranges. South Australia. Department of Water, Land and Biodiversity Conservation. Report DWLBC 2007/20.
- Barnett, S.R. and Bourman, R.P., 2022. Some revisions of the hydrostratigraphy and structural geology of the Willunga Embayment. *MESA Journal* 96: 22–26. Department for Energy and Mining, South Australia. Adelaide.
- Barnett, S.R. and Judd, R.J., 2019. McLaren Vale Prescribed Wells Area – Groundwater salinity investigation. DEW Technical note 2019/02, Government of South Australia, Department for Environment and Water, Adelaide.
- Charles, S.P. and Fu, G., 2014. Statistically Downscaled Projections for South Australia – Task 3 CSIRO Final Report. Goyder Institute for Water Research Technical Report Series No. 15/1, Adelaide, South Australia.
- Cooper, B.J., 1977. New and revised stratigraphic nomenclature for the Willunga Embayment. South Australia. Geological Survey. *Quarterly Geological Notes*, 64:2-5.
- Crane, 2017. Coastal Springs of the Tjilbruke Trail: Identifying Source Aquifers from Beach Groundwater Discharge Seeps Using Multiple Environmental Tracers (St Vincent Gulf Coast, South Australia). Honours thesis, College of Science and Engineering, Flinders University.
- Department for Water, 2010. McLaren Vale PWA - Groundwater level and salinity status report 2009–10. Government of South Australia. Department for Water.
- Fairburn, W., 1998. The Willunga Embayment —a stratigraphic revision. South Australia. Department of Mines and Energy, *MESA Journal* Vol 11: 35-41.
- Green, G. and Zulfic, D., 2008. Summary of groundwater recharge estimates for the catchments of the Western Mount Lofty Ranges Prescribed Water Resources Area. South Australia. Department of Water, Land and Biodiversity Conservation. DWLBC Technical note 2008/16.
- Harrington, G.A., 2002. Recharge mechanisms to Quaternary sand aquifers in the Willunga Basin, South Australia. South Australia. Department of Water, Land and Biodiversity Conservation. Report, DWLBC 2002/016.
- Herczeg A.L. and Leaney F.W., 2002. Groundwater flow systems and recharge in the McLaren Vale Prescribed Wells Area. Report Prepared for the OCWMB. CSIRO Technical Report 10/02.
- Morris, M., 2011. Modelling saltwater intrusion in the Willunga Basin, South Australia. Research Project 2:
- Post, V.E.A., Banks, E. and Brunke, M., 2018. Groundwater flow in the transition zone between freshwater and saltwater: a field-based study and analysis of measurement errors. *Hydrogeology Journal* 26:1821–1838.
- Savadamuthu, K. and Teoh, K., 2010. Surface Water Resource Capacity Estimates for the Western Mount Lofty Ranges Prescribed Water Resources Area. DFW Technical Note 2010/05. Department for Water, Adelaide.