Tookayerta Permian Groundwater Management Zone

Groundwater assessment

Department for Environment and Water
March 2021

DEW Technical report 2020/16

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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

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1 Introduction

As part of the implementation of the Eastern Mount Lofty Ranges (EMLR) Water Allocation Plan, high demand zones have been identified where demand (in the form of licenced allocations) exceeds the consumptive use limit determined for groundwater management zones (GMWZ). The Tookayerta Permian GWMZ is one such zone that has a large discrepancy between the allocated volume (7,705 ML) and the consumptive use limit (2,843 ML). This report provides an assessment of the current condition of the groundwater resource and a review of the process and data used to determine the consumptive use limit.

1.1 Hydrogeology

The Tookayerta Permian GWMZ encompasses three glacially eroded valleys infilled by unconsolidated sands, silts and clays with occasional gravel beds, known collectively as the Permian Sand aquifer. Groundwater flows through the pore spaces in the Permian Sand aquifer in an easterly direction before discharging to either Tookayerta or Nangkita Creek; both considered highly connected to the aquifer. This discharge constitutes the baseflow of the streams and dominates flow for most of the year, particularly over the summer and between rainfall events. The Permian Sand aquifer is the most widely developed aquifer for irrigation, town water supply, mining, stock and domestic use. Figure 1.1 presents the geology and watertable elevation contours for the Permian Sand aquifer.

The surrounding basement rocks are generally considered to be poor fractured rock aquifers due to the fine grain-size and rapid decomposition of some of the schistose and granitic rocks to clay that can considerably reduce permeability and increase salinities as a result of reduced flushing of the aquifer.

Recharge to both these aquifers occurs directly from that portion of rainfall that percolates down to the watertable through the soil profile past the root zone of vegetation. Because of the sandy nature of the soils overlying the Permian Sand aquifer, recharge rates are higher than average.

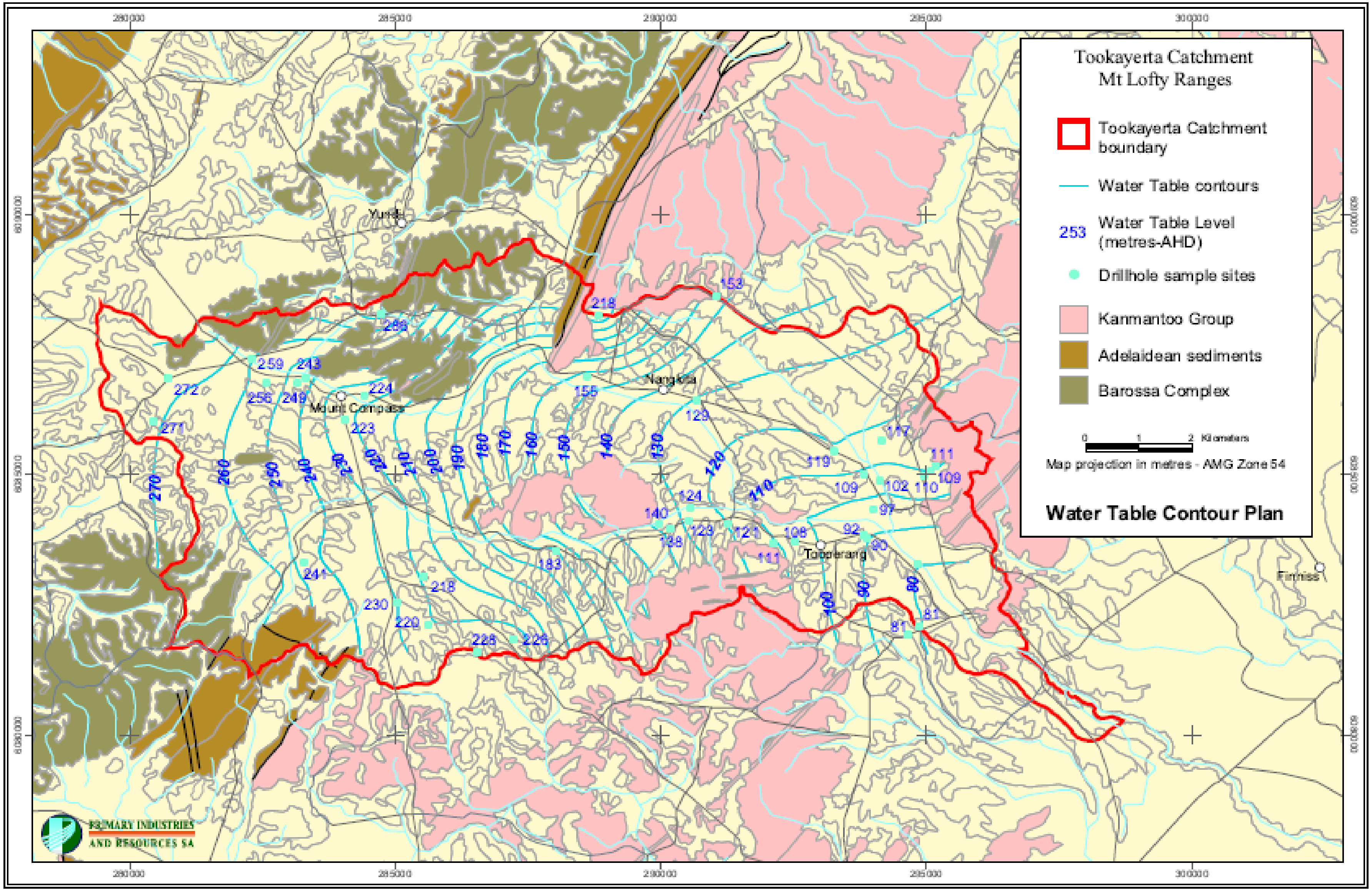


Fig. 1.1 Tookayerta geology and watertable elevation contours (after Barnett and Zulfic, 1999)

2 Groundwater use and allocation

Metered use for licensed purposes in 2018-19 was 3,008 ML with the allocation volumes totalling 7,705 ML. The metered extraction for the four years to 2018-19 is presented in Table 2.1, together with rainfall recorded at Mount Compass and the number of licences recorded as unused.

Table 2.1. Metered use

Year	*Metered use (ML)*	*Use as % of allocn*	*Use as % of sust limit*	*Rainfall (mm)*	*Unused licences*
2015-16	2200	29	77	567	36
2016-17	1484	19	52	1023	37
2017-18	2044	27	72	764	38
2018-19	3008	39	106	704	27

From Table 2.1, it can be seen that the number of active licences reporting metered use was stable over the first three years, indicating the main control on extractions appeared to be the rainfall recorded during the water use year. However during 2018-19, there was an increase in the number of active licences reporting metered extraction. This is most likely the reason for the apparent increase in use.

Figure 2.1 presents a spatial representation of the 2018-19 allocations. The highest allocation is 1020 ML for the irrigation for vineyards to the south, with 572 ML for pasture irrigation near Tooperang, 554 ML and 496 ML for pasture irrigation to the west and south of Mount Compass respectively and 480 ML for sand mining.

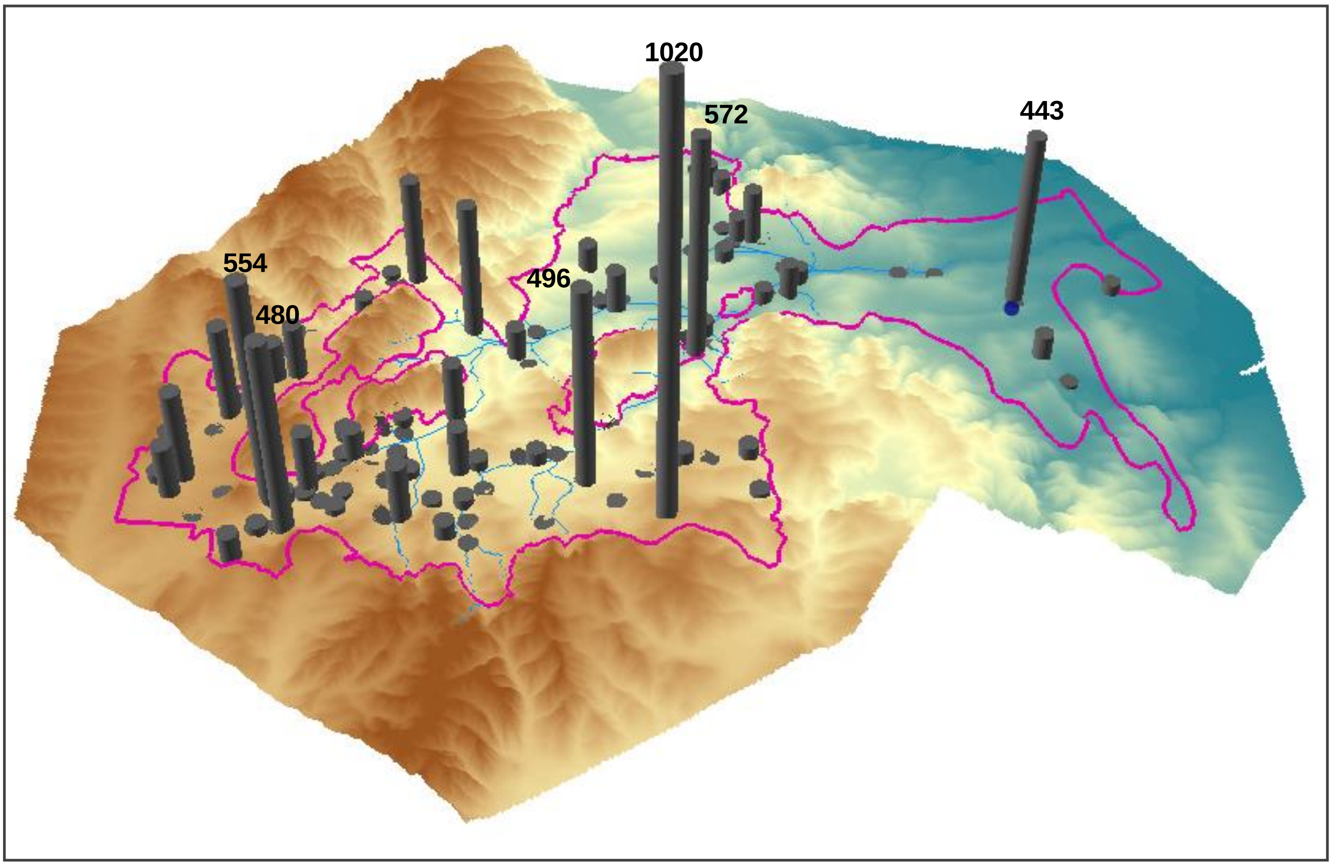


Fig. 2.1 Allocation volumes

Figure 2.2 presents a spatial representation of the 2018-19 extractions. The highest extractions from individual wells are 253 ML for pasture irrigation in the Nangkita area, 221 ML for sand mining west of Mount Compass, 257 ML for vegetable irrigation in the plains area to the east and 176 ML for vineyard irrigation to the south. Extraction by SA Water for the Mt Compass town water supply was 64 ML. When compared with the allocations in Figure 2.1, there is not a clear relationship.

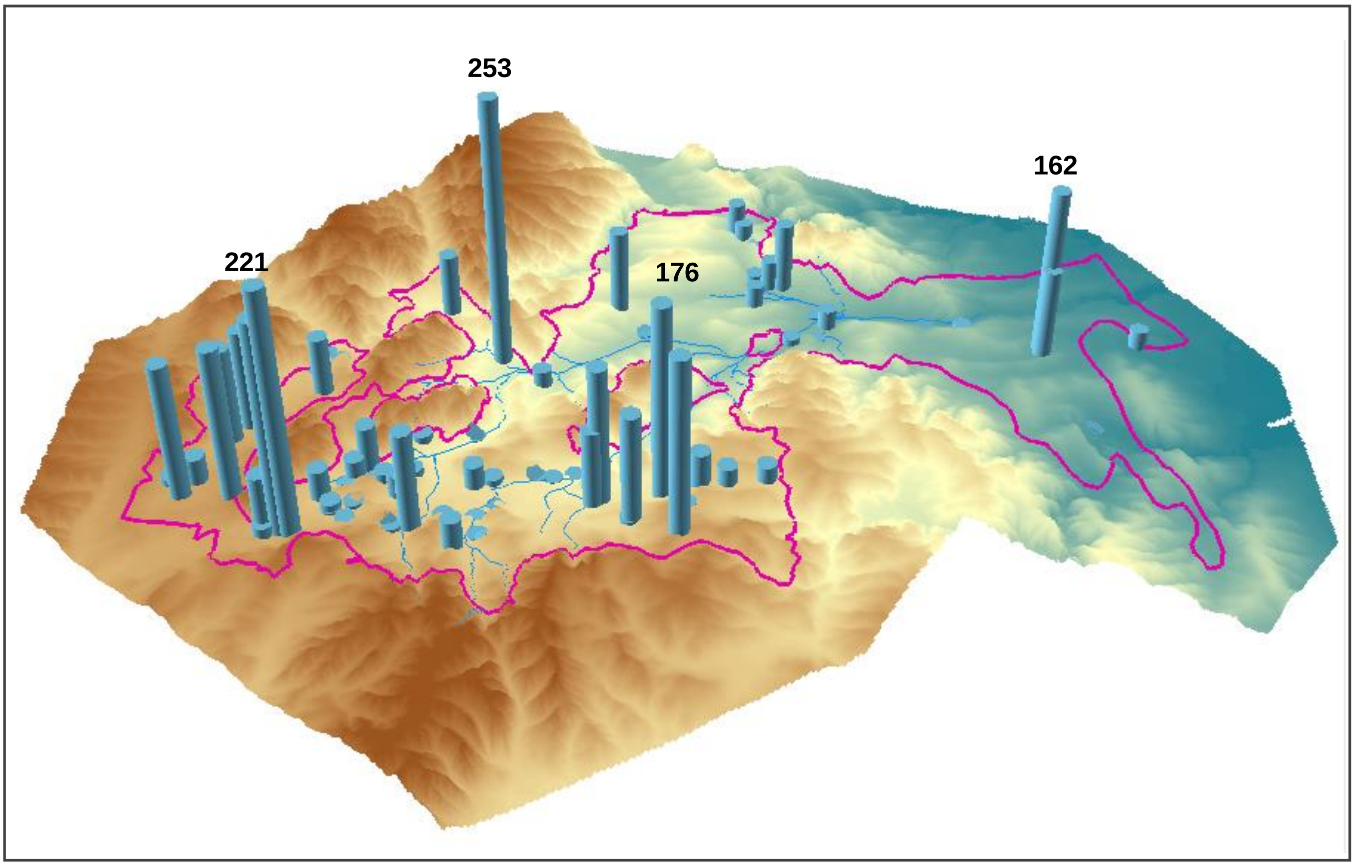


Fig. 2.2 Metered use

Figure 2.3 presents the frequency distribution of use versus allocation and shows that 27 licences (30 percent of total) are undeveloped, or are yet to install meters and provide water use data. There are a small number of licences that are using more than 100 percent, but this could be due to roll over provisions.

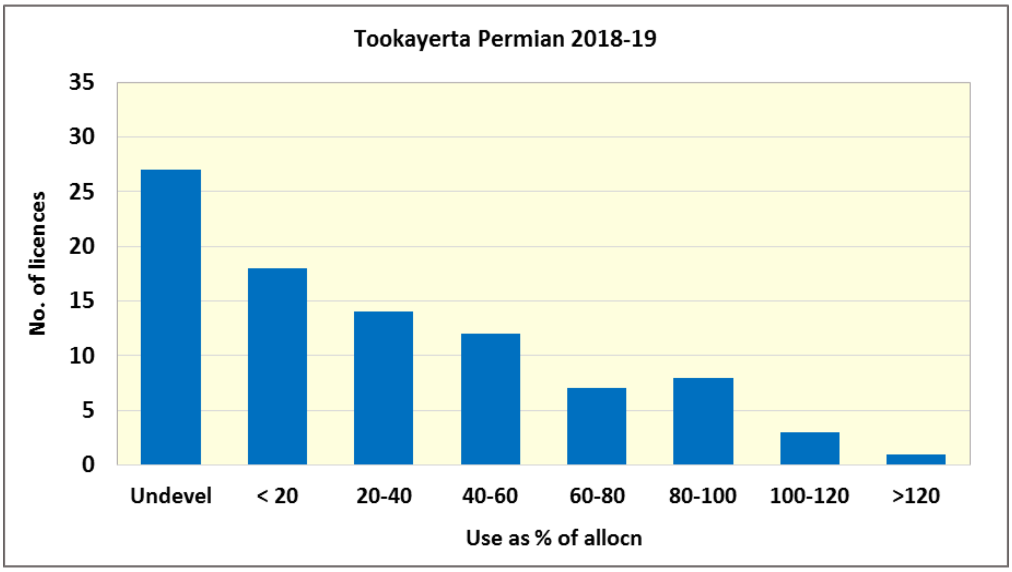


Fig. 2.3 Frequency distribution of use versus allocation

The spatial distribution of the use versus allocation data is presented in Figure 2.4. This shows an even distribution of licence development throughout the GWMZ and there does not appear to be any geographical or hydrogeological constraints on the development of the groundwater resource.

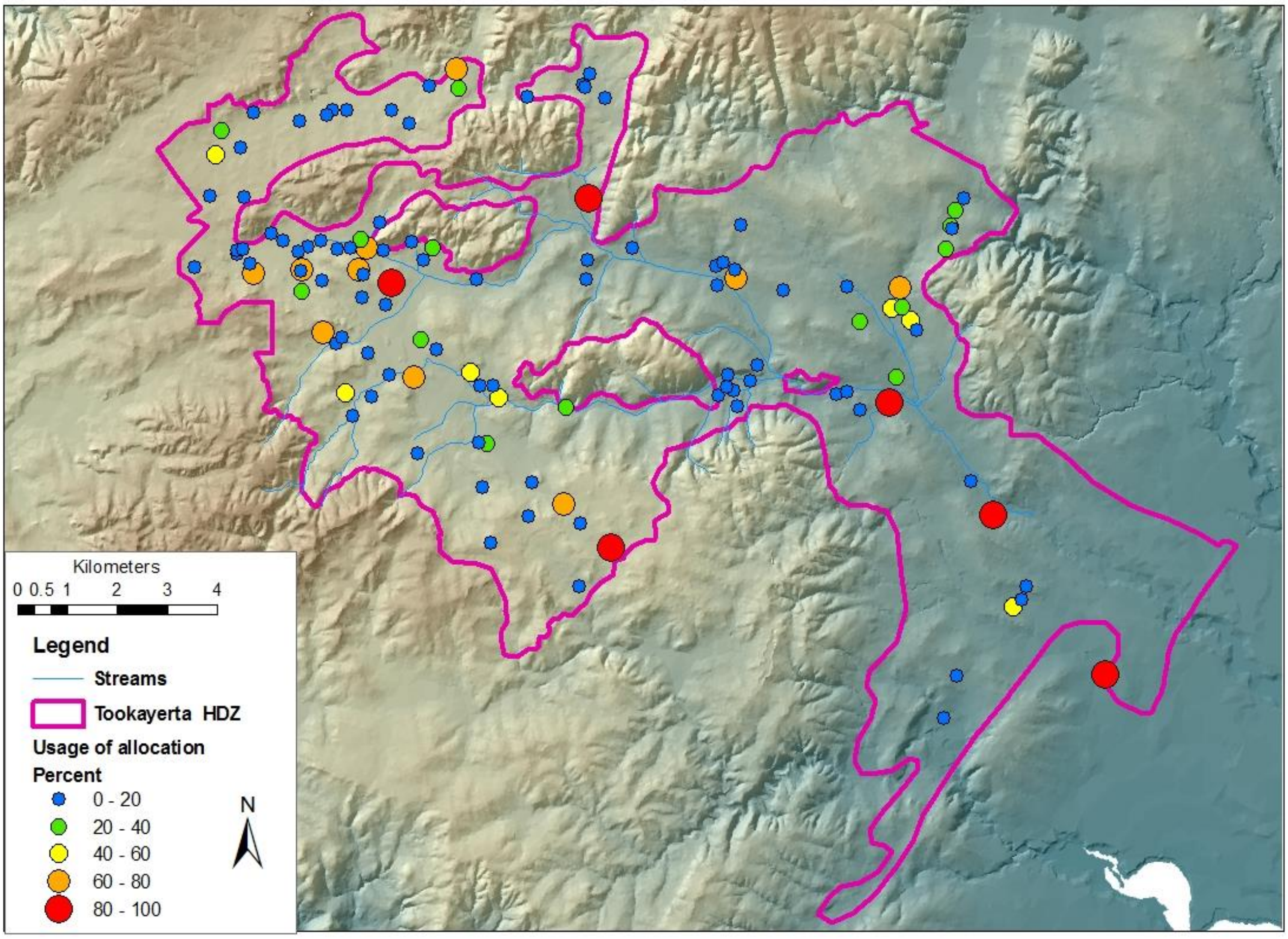


Fig. 2.4 Location of licence development

Figure 2.5 presents the locations of the 32 licences that have not yet developed their allocation, or are not yet providing water use data. This data indicates that one of the largest three allocations in the GWMZ is in this category.

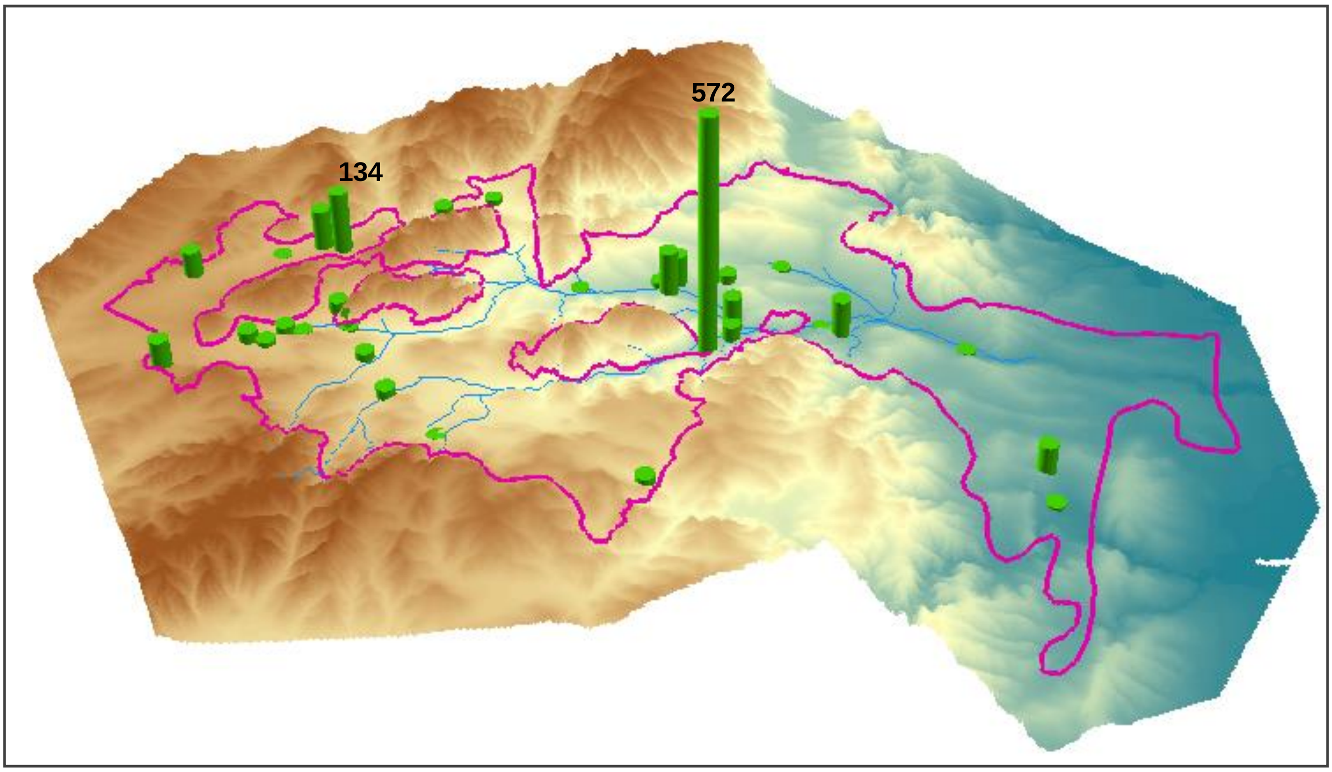


Fig. 2.5 Undeveloped allocations

3 Historical groundwater use

In the absence of the metering of extractions, historical land use can enable a comparison of probable irrigation water use in different years. Inspection of aerial photographs by Lawrence and Loan (1994) determined the historical land use in the Tookayerta Creek catchment, part of which was irrigated land as shown in Table 3.1.

Table 3.1. Historical land use (ha)

Land use	*1949*	*1979*	*1984*	*1989*	*1992*
Irrigated land	138	618	276	444	438

If it is assumed that all irrigated land was used for dairying during this period, the table infers a peak in groundwater extraction for dairying in the late 1970's and a subsequent decreasing trend. However the increasing area of berry fruits, olives and vineyards under irrigation since the 1990's would have counteracted this trend to a certain extent.

In order to estimate volumes of historical extraction within the Tookayerta Permian GWMZ (being larger than the area studied by Lawrence and Loan), re-examination of historical satellite imagery and aerial photography was undertaken, together with GIS coverages of land use data. The meter data and imagery for 2015-16 was used to establish a benchmark against which previous years could be compared. This water use year was chosen because of the availability of imagery and the fact that 2016-17 was a very wet year. Metered application rates (ML/ha) were used to extrapolate to unmetered irrigated areas and the observed irrigated areas in historical imagery. The years of 1999, 2002 and 2006 had suitable imagery and GIS data for analysis. Figure 3.1 presents the results in ML/year. The data for 1979 and 1989 represents only dairy irrigation and is included for a comparison with later years. Because not all licensees have been submitting meter data, the total volumes are uncertain and the graph should be used mainly for comparisons between years.

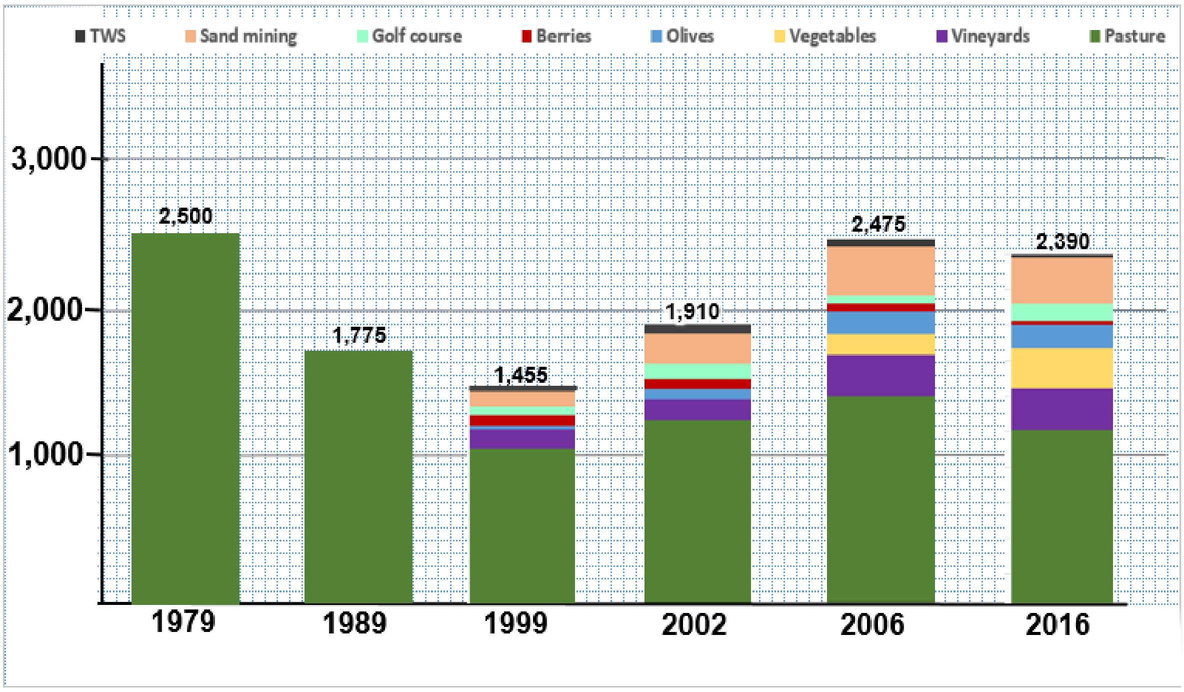


Fig. 3.1 Extraction history in the Tookayerta Permian GWMZ (ML/yr)

Figure 3.1 demonstrates that extraction for pasture irrigation has declined significantly since 1979 and seems to have stabilized in the range of 1100 to 1400 ML/year since 2002. In 2016, this represented about 50 percent of total extractions. Extraction for other purposes have increased since the mid 1990's, but also appear to have stabilized, noting that there will be annual variations in extractions due to changes in annual rainfall, especially during the irrigation season.

3.1 Drilling history

The drilling history of the 448 water wells located within the Tookayerta Permian GWMZ also aids in the estimation of historical groundwater use. The requirement for well construction permits after 1976 enables an accurate analysis of wells were drilled after that date, noting 81 wells drilled before 1976 and have no records. Figure 3.2 presents the data for the 448 wells and shows a clear peak in drilling activity in the ten year period between 1995 and 2005. Examination of Figure 3.1 suggests this increase in drilling activity coincides with an increase in groundwater extraction for purposes other than pasture irrigation.

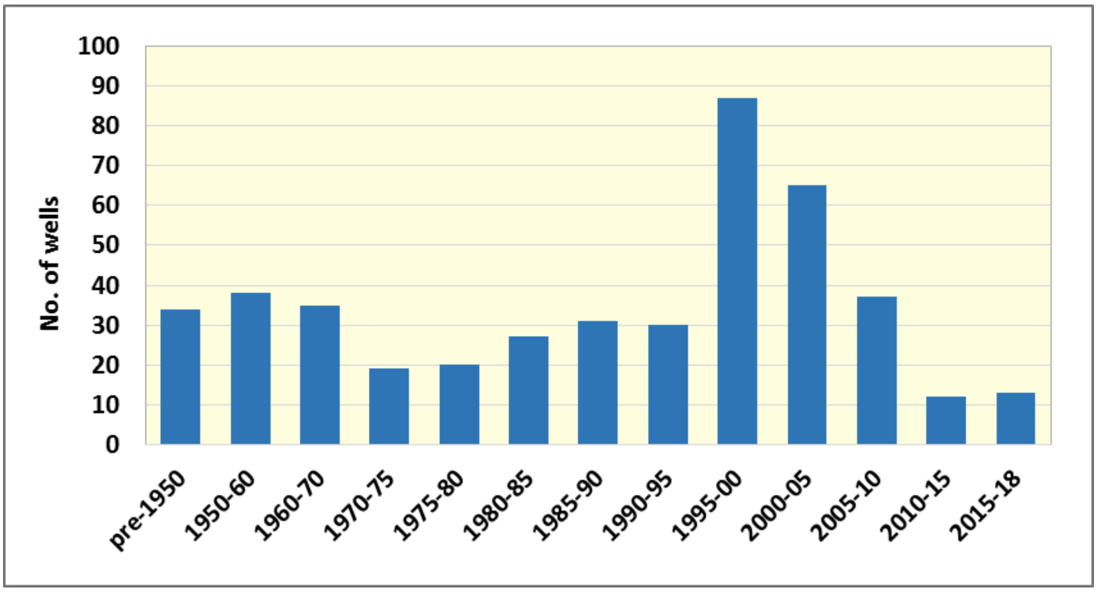


Fig. 3.2 Drilling history

3.2 Vegetation considerations

Also of interest from the historical land cover (Lawrence and Loan, 1994) is how the area of native vegetation and forestry has varied over the years as shown in Table 3.2. The figures show the significant decrease in evapotranspiration which occurred as the clearing of the catchment progressed. This would have led to increasing recharge to the groundwater system and subsequently, increasing baseflow to streams. The EMLR WAP assumes a reduction in recharge of 1.66 ML/ha under hardwood plantations and 1.82 ML/ha under softwood plantations. If a conservative estimate of 1.0 ML/ha is assumed for dense native vegetation, then recharge has increased by at least 3000 ML/year since the turn of the century when the catchment was largely native vegetation.

Table 3.2 Historical land cover (ha)

Crop	*1893*	*1949*	*1979*	*1992*
Native vegn	4152	1668	582	654
Pine			108	216
Total	4152	1668	690	870

4 Groundwater level trends

Monitoring began in the Tookayerta Permian GWMZ in 1989 with a network of six observation wells in the vicinity of Mount Compass township to monitor water levels in the vicinity of the town water supply wells. In 1998, a catchment-wide network of 27 wells was established by Compass Creek Care. These have been incorporated (where appropriate) in the DEW observation network. A further six wells were added in 2015. The current DEW observation network consists of 33 wells as shown in Figure 4.1.

As there are several different trends being displayed in different parts of the GWMZ, it has been subdivided into areas so that the trends can be examined in the local context of extraction, land use and geomorphology. Hydrographs are presented showing the water levels from observation wells, together with the cumulative deviation of the mean monthly rainfall. This measures the difference between the actual measured rainfall and the average rainfall on a monthly basis. An upward trend in this line indicates above average rainfall and conversely, a downward trend indicates below average rainfall.

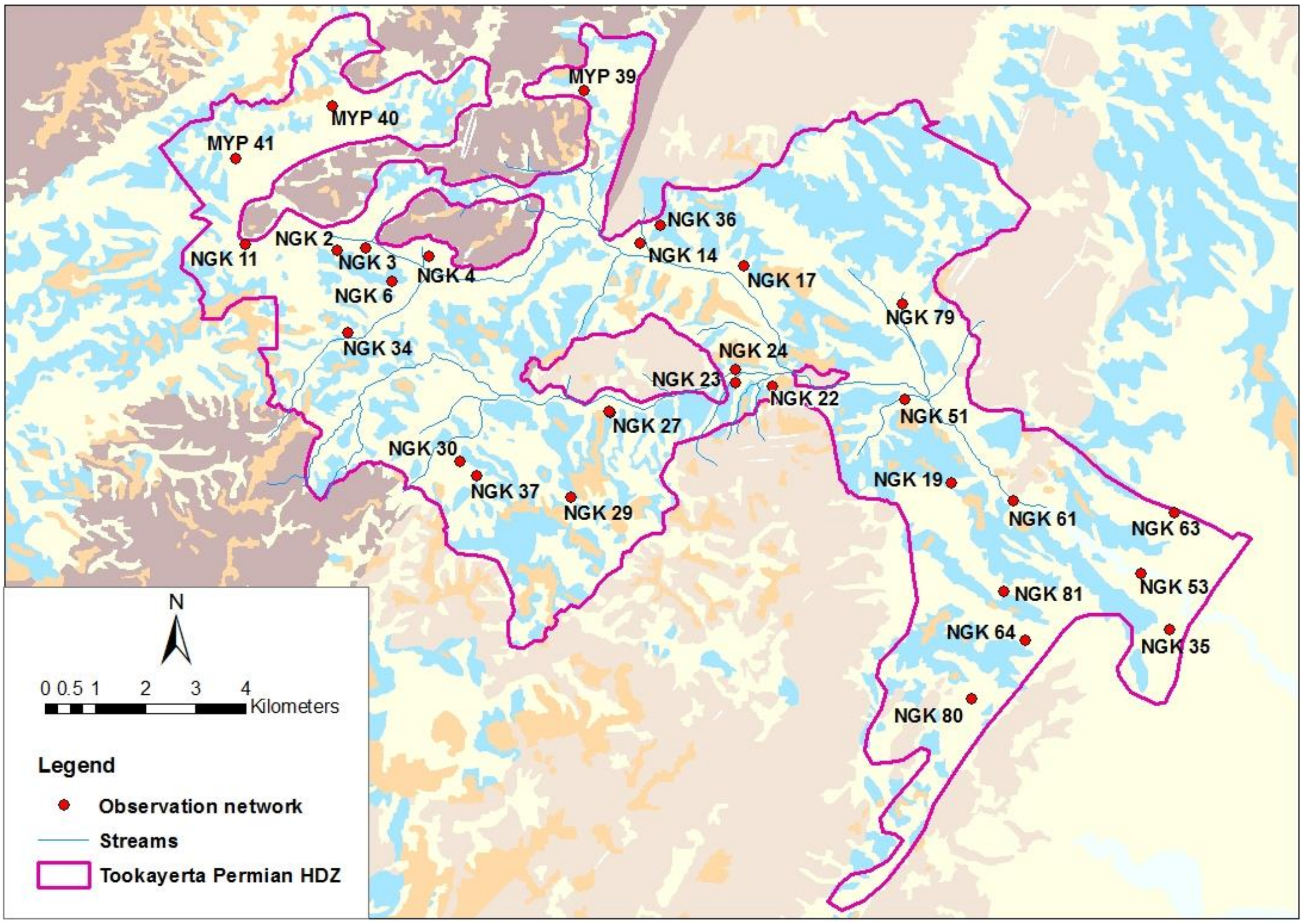
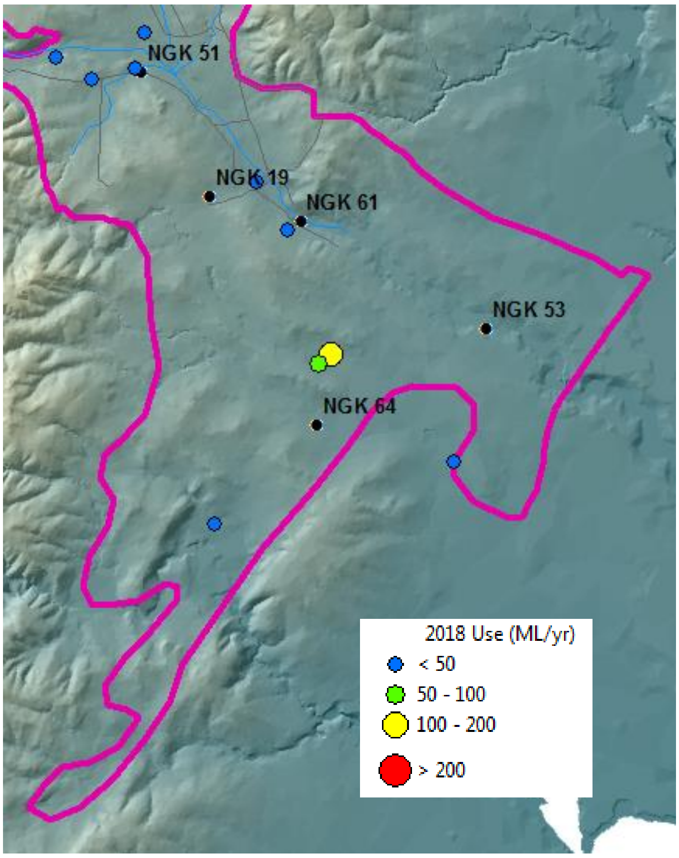


Fig. 4.1 Groundater level observation network

4.1 Lower catchment



Most observation wells in the lower catchment are located within 200 m of Tookayerta Creek. Overall, the trends shown in Figure 4.2 have been stable since 2004 despite a declining rainfall trend recorded at Mount Compass after 2005. A slight decline in 2019 is noticeable due to the dry year, but a recovery in 2020 is expected due to above average rainfall. Observation well NGK 19 is located further from the creek and is higher in elevation and consequently shows a stronger relationship to rainfall. Observation well NGK 64 shows a longer period of decline. This may reflect the impacts of nearby irrigation, however the trend appears to have stabilised after 2014.

There is limited pumping in the area with the main extractions being for vegetable irrigation. Figure 2.4 suggests there is a low likelihood of significant increases in extraction in the future.

The stable water level trends are a positive indicator for sustainability of the Fleurieu Swamps as a high value environmental asset located in the Tookayerta Creek watercourse and Black Swamp further downstream.

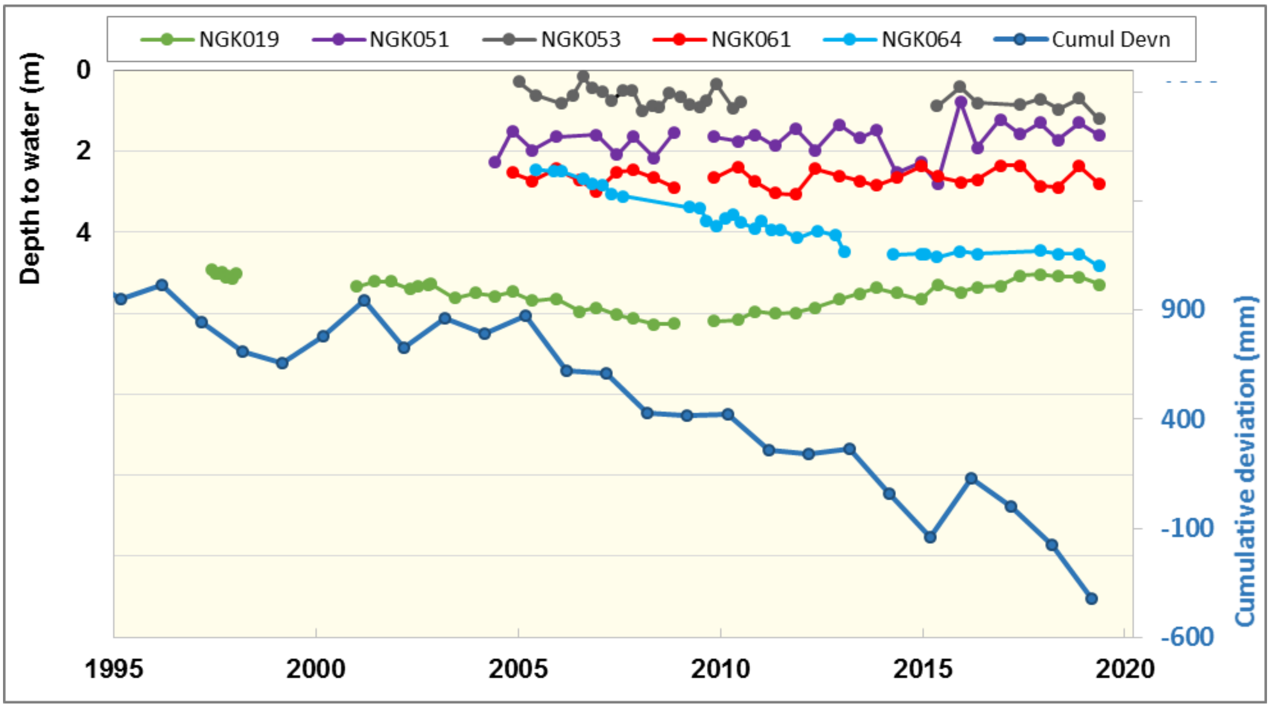
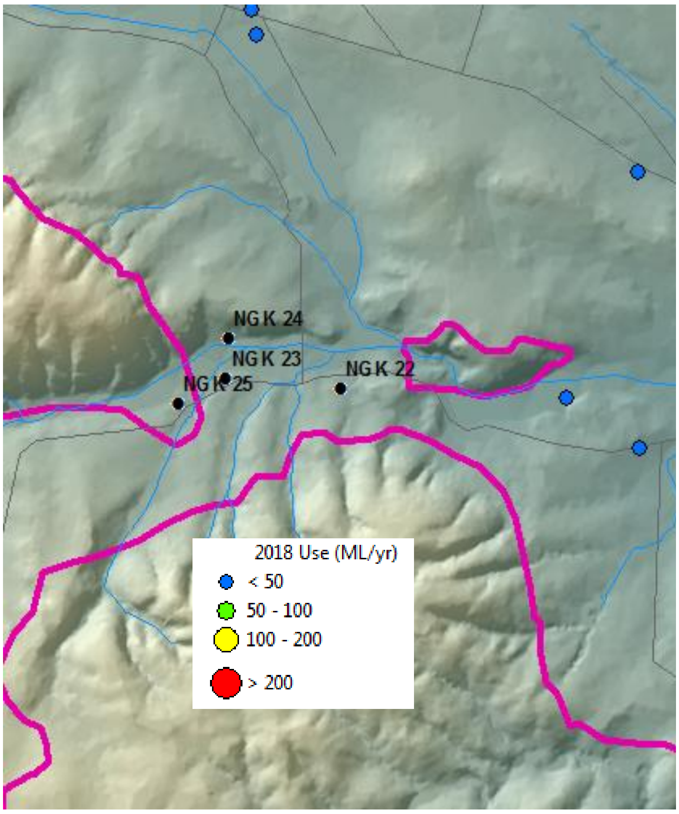


Fig. 4.2 Hydrographs for the Lower Catchment

4.2 Tooperang



Observation wells in the Tooperang area are also located within 200m of Tookayerta Creek. Overall, trends are stable since 2004 despite a declining rainfall trend since 2005 recorded at Mount Compass. Seasonal fluctuations of 3-5 m are observed. A slight rising trend is discernible since 2010 (after the millennium drought) with a significant rise occurring during the wet 2016-17 summer that also may coincide with a reduction in local extraction since then.

There is no metered extraction reported in the area despite one of the largest allocations issued being located close by. It is probable that the allocation has been developed but has not yet reported the current use. However there is a small likelihood that increases in extraction may occur in future if further development of the allocation occurs.

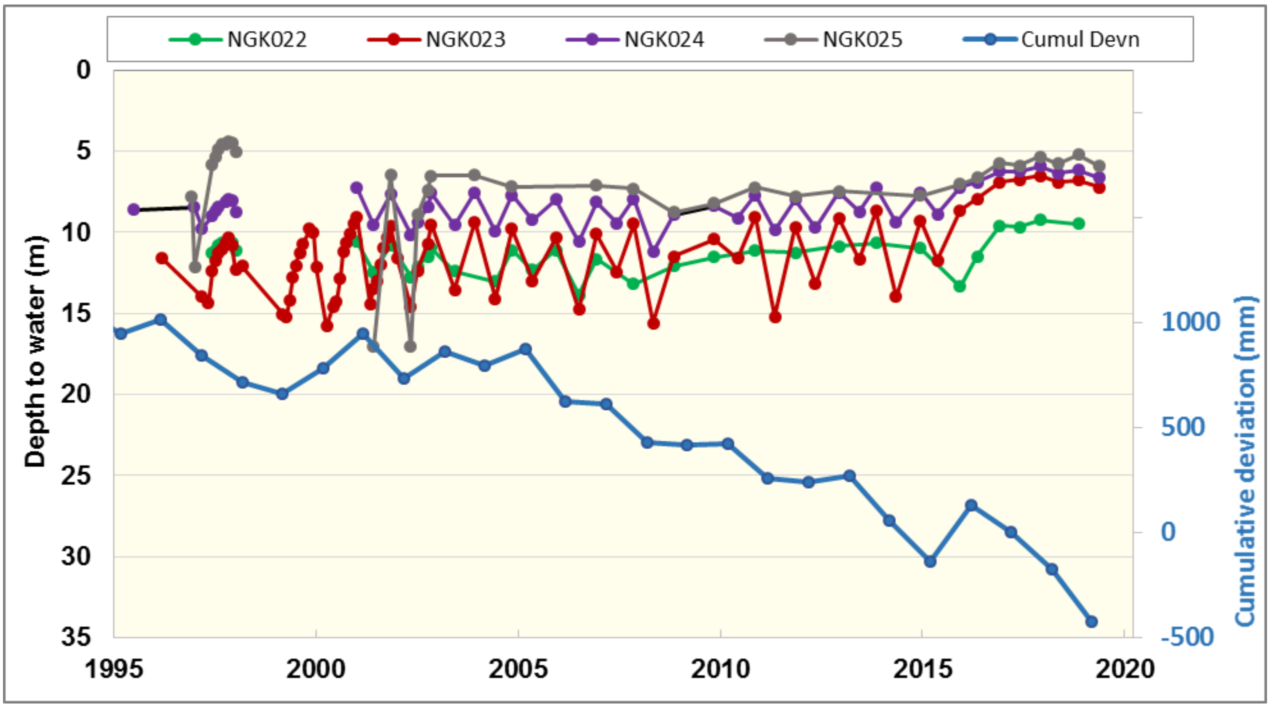
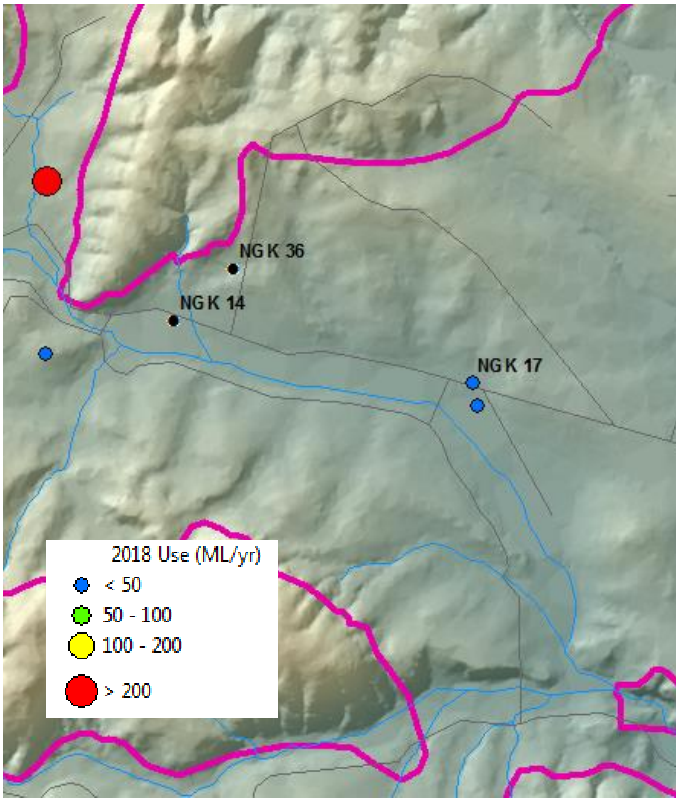


Fig. 4.3 Hydrographs for the Tooperang area

4.3 Nangkita



Observation wells in the Nangkita area are located further from Nangkita Creek than other areas and show smaller seasonal fluctuations. A gradual declining trend in response to below average rainfall is observed until 2010. Trends are stable since then with no rising trend discernible, perhaps because of the deeper watertable.

There is limited pumping in the area. Figure 2.4 suggests there is some likelihood of increases in extraction being reported in the future.

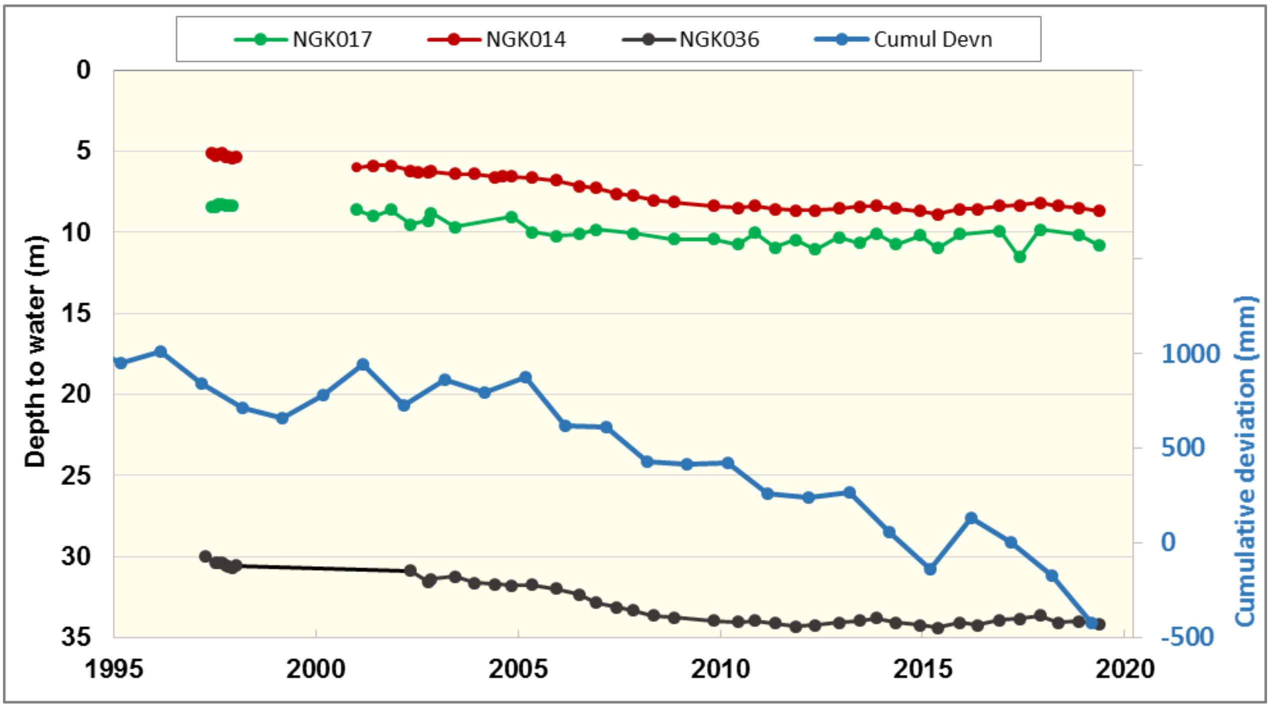
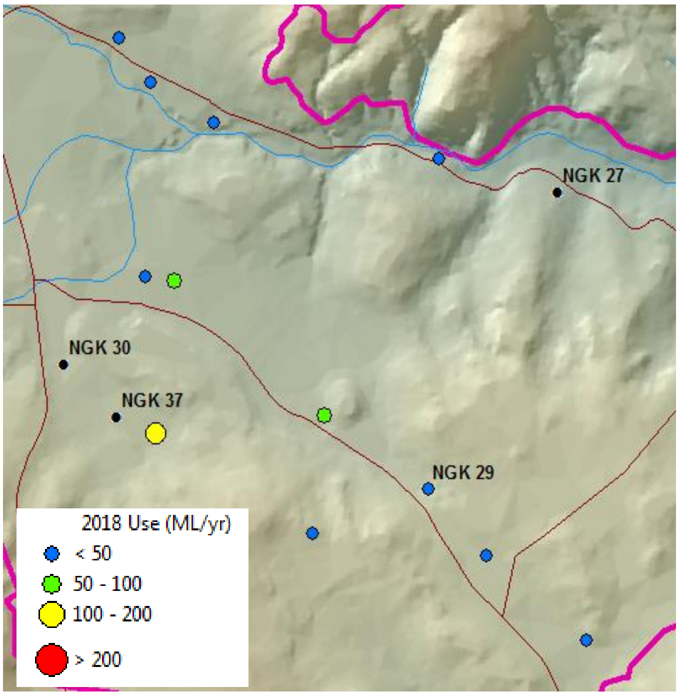


Fig. 4.4 Hydrographs for the Nangkita area

4.4 Southern catchment



Of the observation wells located in the southern catchment, only NGK 27 is located within 500m of Tookayerta Creek. Overall, trends are similar to other areas with a declining trend until 2010 and a stable trend since then.

Observation well NGK 37 has greater seasonal fluctuations than the other wells due to its proximity to extraction for vineyard irrigation, however the overall trend is similar with a stable trend since 2010.

There is moderate pumping in the area with the main extractions being for vineyard irrigation. Figure 2.4 suggests there is a likelihood of moderate increases in reported extraction in the future.

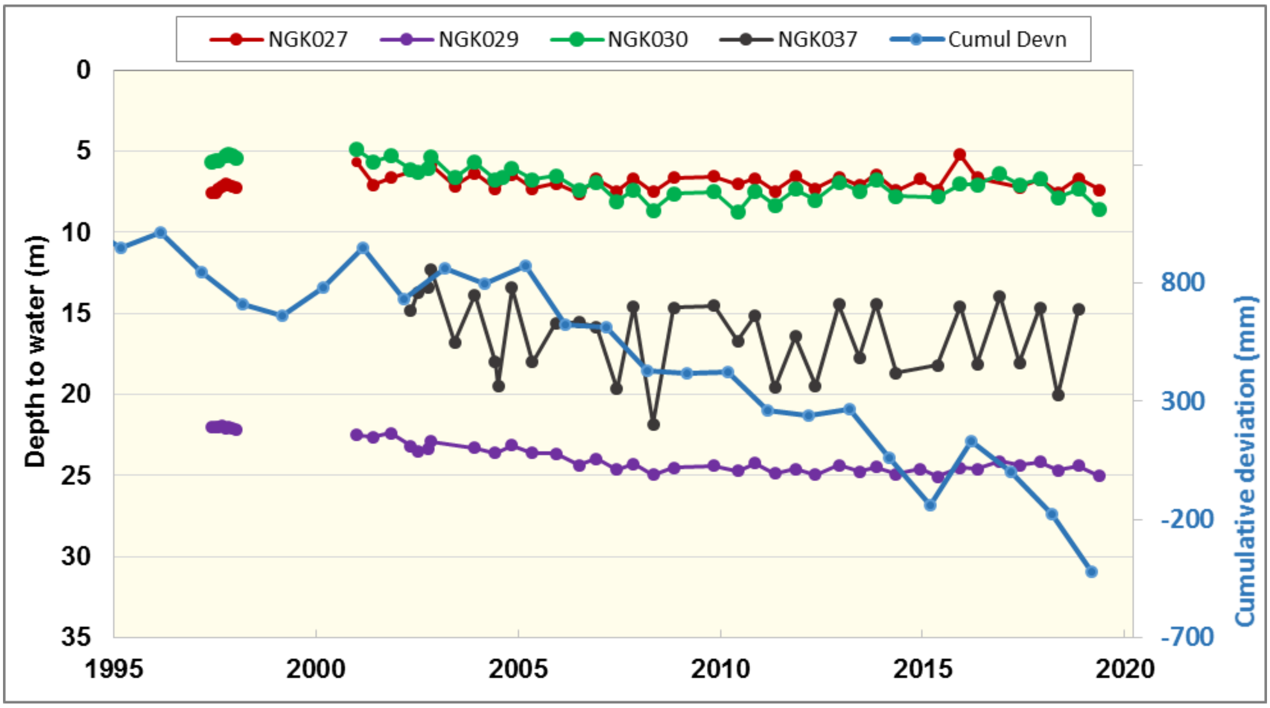
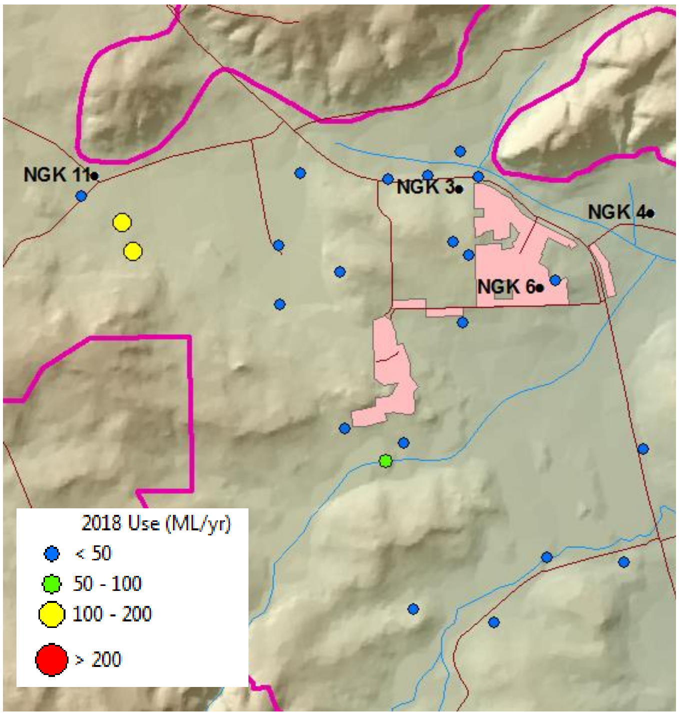


Fig. 4.5 Hydrographs for the Southern catchment

4.5 Mount Compass



Observation wells in the Mount Compass area have the longest records and show a reasonably close relationship to rainfall recorded in the township, especially prior to 2010. During the millennium drought, a decline of several metres and increased seasonal drawdowns were observed. Overall, trends are stable since 2010 despite a declining rainfall trend since 2005.

Observation well NGK 6 is completed in a shallow fractured rock aquifer and situated close to three other bores also pumping from the same aquifer. The lower permeability of this aquifer results in bigger seasonal fluctuations than those recorded in the Permian Sand aquifer.

There is limited pumping in the area with the main extractions being for sand mining in the west. The seasonal drawdowns in observation well NGK 11 may indicate impacts from this extraction. Figure 2.4 suggests there is a likelihood of moderate increases in reported extraction in the future.

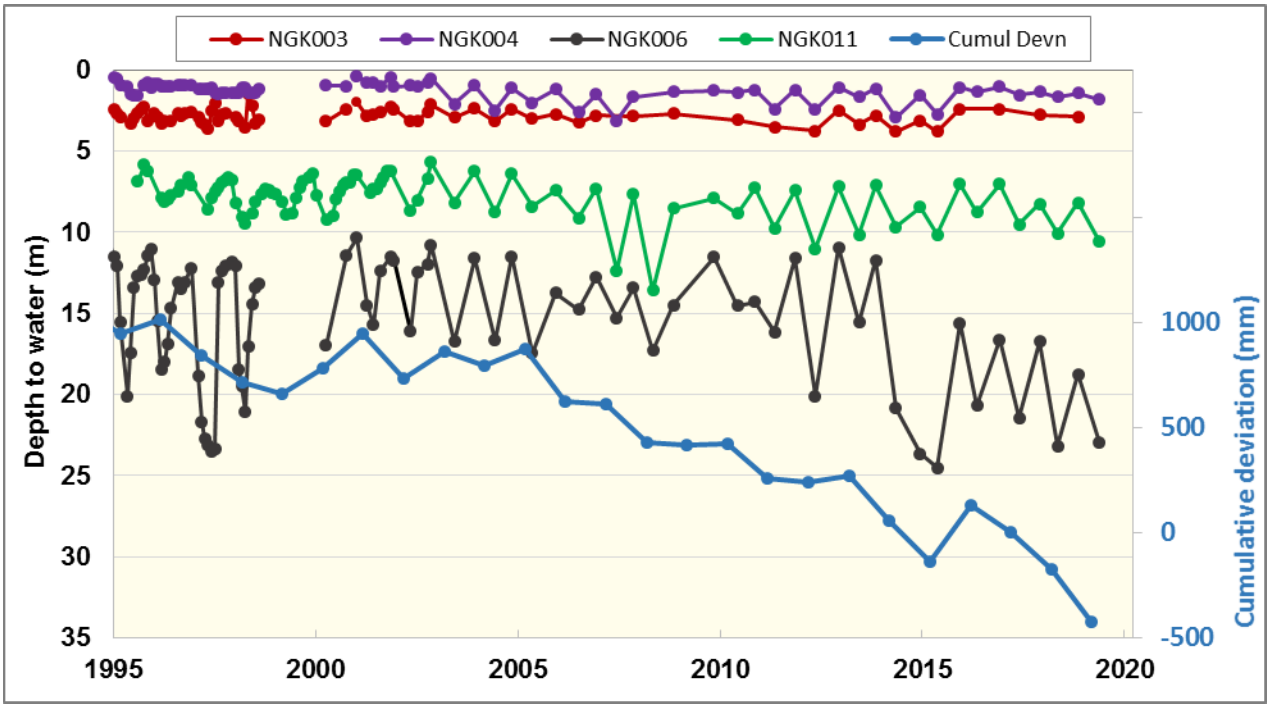


Fig. 4.6 Hydrographs for the Mount Compass area

4.6 Summary

Figure 4.7 presents a representative range of hydrographs over a longer time frame than reported elsewhere in this report. It shows that the period of below average rainfall since 1993 followed a period of above average rainfall from 1985 to 1993. The groundwater level response shows a close but subdued relationship with rainfall. Observation wells that are situated close to streams or swamps (NGK002, NGK019) show small seasonal fluctuations and limited seasonal ranges. Even the very wet 1992-93 barely raised the water levels above normal in NGK002, indicating that the Permian Sand aquifer is virtually 'full' with any extra recharge rapidly draining to the streams as baseflow.

The stable water level trends over the long term are a positive indicator for sustainability of the Fleurieu Swamps (a high value environmental asset located in the Tookayerta Creek watercourse) and Black Swamp further downstream.

There is no evidence of any significant impacts caused by extraction from the Permian Sand aquifer.

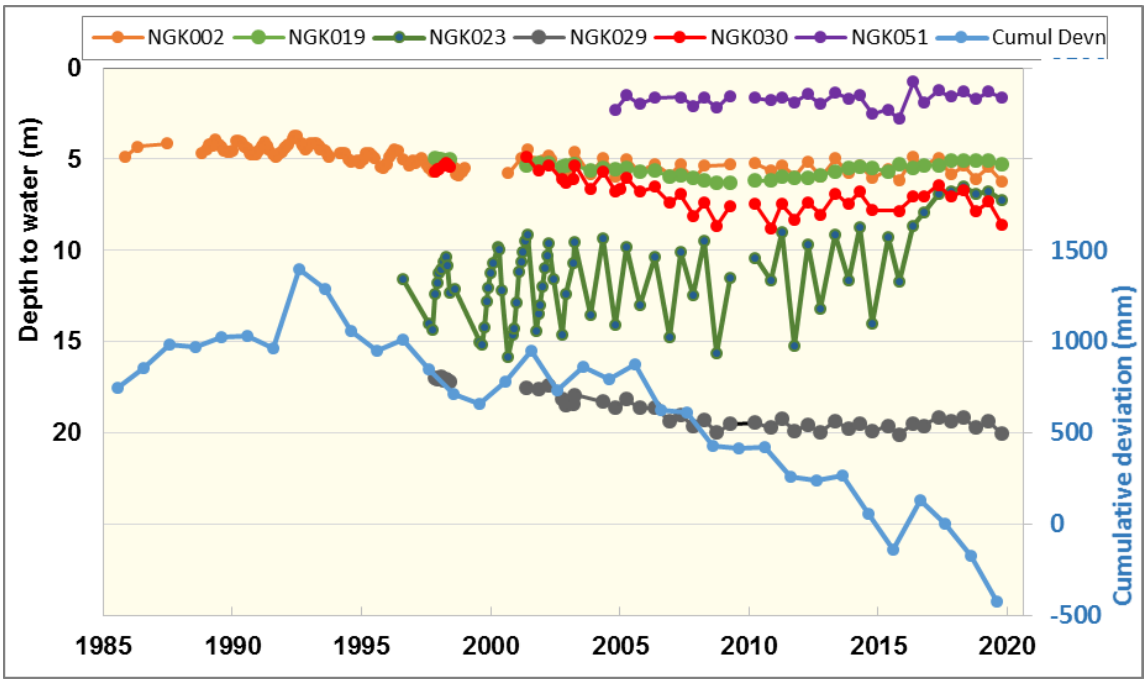


Fig. 4.7 Representative hydrographs for the Tookayerta Permian GMZ

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5 Recharge investigations

As the Permian Sand aquifer is unconfined, the determination of the sustainable yield has been based on the estimation of recharge to the aquifer. This approach carries uncertainty because recharge rates can vary greatly throughout any given area with differing land use and soil types and it can change dramatically from year to year depending on the rainfall. Recharge cannot be measured directly - it can only be estimated using a variety of different methods that each have large error bands.

There have been several previous investigations into determining recharge rates for the Tookayerta Permian GWMZ. Several of these were based on the Tookayerta surface water catchment area. This different to the GWMZ area that is mostly based on geology, so this discrepancy has been taken into account when comparing the different estimates of recharge. The various investigations are examined in chronological order.

5.1 Barnett and Zulfic, 1999

This investigation used the water balance and chloride balance to obtain estimates for the sustainable yield. The water balance approach essentially involves calculating all other components of the balance with the outstanding quantity being attributed to recharge. The chloride mass balance (CMB) compares the chloride content in rainfall with that in groundwater in order to estimate recharge. Given the data uncertainties, it is not surprising that a range of recharge values were calculated that were within the same order of magnitude. These estimates were for the surface water catchment area.

Water balance	66 – 144 mm/year	(6700–14 500 ML/year)
Chloride	33 – 60 mm/year	(3300–6100 ML/year)

5.2 Harrington, 2004

Salt and chloride mass balances were performed in this investigation to estimate the mean annual groundwater component of stream flow and provide first order approximations of groundwater recharge rates. Rates of 35- 124 mm/yr were calculated which amounts to 3500 – 12,500 ML/year.

5.3 Banks et al, 2007

This report stated that chlorofluorocarbon (CFC) data provided evidence for rapid recharge processes to the Permian Sands aquifer occurring in areas where the sands are outcropping. Hydrochemistry and the stable isotope data provided further evidence for rapid recharge processes as the isotopic signature of the groundwater samples is similar to rainfall events in winter and therefore suggests that the majority of recharge would occur at this time.

CFCs were used successfully to estimate the recharge rate to the unconfined Permian Sand aquifer, with average recharge estimated to be between 100 and 150 mm/year. Estimates using the chloride mass balance method were typically lower than the CFC technique, with groundwater recharge calculations ranging from 1 to 191 mm/year and averaging 64 mm/year.

Table 5.1 presents a summary of the recharge rates determined by the investigations described above.

Table 5.1. Summary of recharge estimates (mm/year)

Year	***Chloride***	***Water balance***	***CFCs***
1999	33 - 60	66 - 144	
2004	35 - 124		
2007	1 - 191		100 - 150

6 Estimate of WAP resource capacity

The sustainable limit for each GWMZ defined in the EMLR WAP was calculated by using a water balance approach covering the inflows and outflows from the GWMZ. The formula incorporating these components that was used to calculate the volume available for licenced allocation, and the volumes (ML) applied for the Tookayerta Permian GWMZ in the EMLR WAP, are as follows:

Allocation = Recharge – Baseflow – Throughflow – Non-licenced groundwater use
2,843 11,058 7,215 1,000 311

6.1 Recharge

The recharge estimates for the Tookayerta Permian GWMZ were based on a chloride mass balance estimate that gave recharge as a percentage of rainfall. The CMB sample locations covered an area with an average annual rainfall of ~685 mm. However, the Tookayerta catchment has a distinct rainfall gradient from west to east, with much of the catchment having a higher rainfall than 685 mm. Consequently the Tookayerta Permian GWMZ was split into two parts, with the western part ascribed an annual rainfall of 875 mm and the eastern part ascribed 650 mm. This resulted in a higher overall recharge estimate for the catchment than the original CMB estimate of 11 percent of the 675 mm average annual rainfall.

Figure 6.1 presents the adopted recharge volume for the WAP (11,058 ML) compared to previous estimates which demonstrate the large uncertainties in estimating recharge. A question remains as to whether any of the methods employed takes into account the impacts of vegetation clearance in the GWMZ which has occurred up until about 1950. As discussed previously, this could have increased recharge by at least 3000 ML/year.

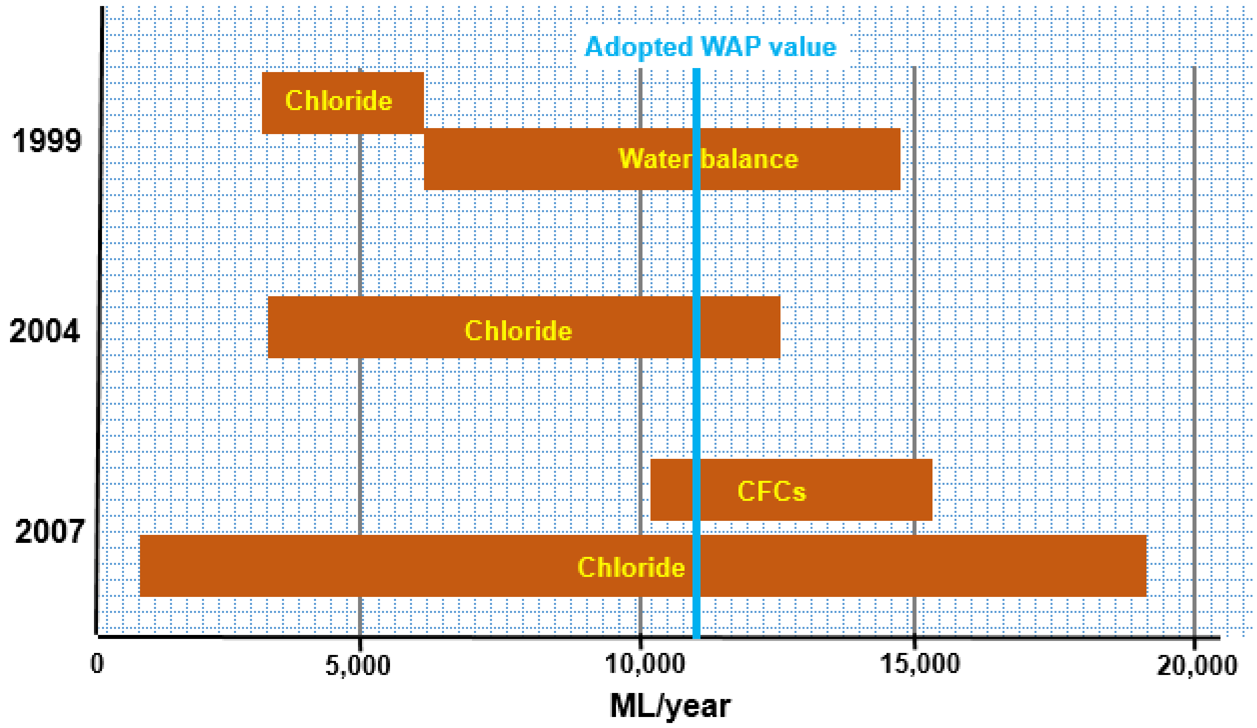

Fig. 6.1 Recharge estimates (ML/year)

6.2 Baseflow

Previous surface water assessments and modelling were undertaken using from community collected surface water level data which was converted to flow data using a theoretical rating. A new surface water monitoring station (A4261020) was installed on Tookayerta Creek in 2012. Following analysis of the additional streamflow data and an attempt to re-calibrate the surface water model, it was recommended that the estimates of base flow contribution remain unchanged from those previously reported (Braithwaite and Miller, 2020).

6.3 Aquifer response

Given the uncertainties around recharge estimates, it is important to consider how the aquifer is responding to both the demands being placed upon it and the climatic influences. Long term monitoring has shown climate to be the predominant influence on groundwater level trends and that there are no adverse impacts resulting from current levels of extraction. Because there are several irrigators that have apparently not yet installed meters and not reported their extraction, the exact volume of current extractions is unknown, but is estimated to be in the range of 3000 to 3200 ML/year. Based on the estimated ranges of recharge and discharge, a sustainable extraction limit of 4000 ML/year can be adopted.

6.4 Summary

Adoption of a value of 4000 ML/year for the sustainable extraction limit would, according to the water balance formula used in the WAP, require a recharge volume of 12 215 ML/year. Figure 6.1 shows that a recharge volume of this magnitude is well within the ranges of various recharge estimates.

7 Summary and recommendations

Long term groundwater level monitoring shows a close but subdued relationship with rainfall indicating that the Permian Sand aquifer is virtually ‘full’ with any extra recharge rapidly draining to the streams as baseflow. The trends are relatively stable and this maintains the sustainability of the high value Fleurieu Swamps. There is no evidence of any significant impacts caused by extraction from the aquifer. The current monitoring network is adequate for assessing the condition of the resource.

An analysis of historical water use found a peak in groundwater extraction occurred in the late 1970’s for the irrigation of dairy pastures. The magnitude of this peak extraction cannot be ascertained with certainty. There was a subsequent decreasing trend in use for this purpose, however the increasing area of berry fruits, olives and vineyards under irrigation since the 1990’s would have counteracted this trend to a certain extent.

Although not quite yet fully reported, the total licenced extraction in the Tookayerta Permian GWMZ is estimated to be in the range 3000 to 3200 ML/year with most licencees’ use being well below their allocation volume which totals 7705 ML/year.

It is recommended that the sustainable extraction limit be increased from 2843 ML/year to 4000 ML/year. This equates to an assumed recharge volume of 12 215 ML/year that is well within the ranges of various recharge estimates.

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