Surface Water Technical Advice Memo

Subject: Rainfall and streamflow trends for MLR WAPs Review			
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Background

The water allocation plans (WAPs) for the Eastern and Western Mount Lofty Ranges Prescribed Water Resources Areas (PWRAs) are currently being reviewed. Hydro-ecological investigations are being undertaken by the Department for Environment and Water (DEW) to inform the review, which is beingled by the Hills and Fleurieu Landscape Board. This technical memo presents the methodology and results of the assessment of the rainfall and streamflow data undertaken for the PWRAs as part of the investigations.

Scope

The following information is provided for the Eastern and Western Mount Lofty Ranges PWRAs, to inform the WAPs review process.

1. **Rainfall data + trend graphs**, using long-term data with average and trend lines included, and 1 graph per catchment.
2. **Streamflow data + trend graphs**, consistent with the rainfall graph request (1 per catchment, using long term data where possible).

Rainfall

WMLR PWRA historical rainfall

Rainfall varies spatially across the PWRA, with a mean annual rainfall of around 900 mm to 1000 mm in the headwaters of the Central Hills catchments around the townships of Uraidla and Summertown and in the headwaters of the Fleurieu Coastal catchments (Figure 1). Rainfall reduces rapidly downhill along the valleys to a minimum of around 450 mm in the plains around Gawler in the north-west and to 550 mm around Victor Harbour in the south (WMLR WAP[i], Section 1).

EMLR PWRA historical rainfall

Rainfall varies spatially across the PWRA, with a mean annual rainfall of around 800 mm to 850 mm in the headwaters of the southern catchments around the townships of Mount Compass and Meadows. Rainfall reduces rapidly along the valleysto less than 400 mm on the eastern plains around the townships of Mannum, Murray Bridge, Langhorne Creek and Milang (EMLR WAP[ii], Section 1.4).

Long-term rainfall (1900-2021)

Rainfall data used in development of the WAPs was for the period 1974 to 2006. To evaluate the behaviour of rainfall since development of the WAPs and in the context of a changing climate, assessment of long-term trends of rainfall across the PWRAs was undertaken in this investigation. Further detailed analysis of rainfall trends, possible shift in climate and climate projections is foreseen to be undertaken in the future as part of WAPs amendment process as detailed in '*Hydro-ecological investigations to inform Water Allocation Plan (WAP) reviews for the Eastern and Western Mount Lofty Ranges Prescribed Water Resources Area's (PWRA)*' project plan.

The long-term climate period chosen for this investigation is from 1900 to 2021. There are numerous BoM rainfall monitoring stations across the PWRAs but only a small sub-set have non-infilled data from 1900 onwards. Rainfall monitoring stations selected for assessment (Table 1 and Figure 1) were based on (i) representation of the spatial variability (high, medium and low) of rainfall across the PWRAs, (ii) representation of catchments identified in the WMLR and EMLR WAPs, where possible and (iii) stations with a majority of the records being recorded BoM monitored data from the site in contrast to stations where missing data have been infilled by correlating with data from nearby stations.

Table 1. Rainfall reporting stations for WMLR and EMLR PWRAs

No.	Station name (Station ID)	Catchment	Mean annual rain (mm) *(1900 – 2021)*	Number of years in the last decade		
				Wet	Dry	Average
WMLR PWRA						
1	Uraidla (23750)	Torrens	1085	1	3	6
2	Bridgewater Post Office (23707)	Onkaparinga	1026	1	5	4
3	Lobethal (23726)	Onkaparinga	874	1	4	5
4	Hahndorf Post Office (23720)	Onkaparinga	837	2	4	4
5	Yankalilla Inman Valley (23723)	Inman-Hindmarsh	745	2	4	6
6	Mount Pleasant (23737)	Torrens	658	1	3	6
7	Willunga (23753)	Willunga	640	1	4	4
8	Second Valley (23744)	Southern Fleurieu	603	4	3	3
9	Port Elliot Caravan Park (23742)	Inman-Hindmarsh	495	3	4	3
EMLR PWRA						
1	Mount Barker (23733)	Bremer	758	1	4	5
2	Macclesfield (23728)	Angas	723	2	4	4
3	Harrogate (23722)	Bremer	563	2	5	3
4	Strathalbyn (23747)	Angas	494	3	4	3
5	Palmer (24525)	Reedy Creek	409	1	4	5
6	Langhorne Creek (24515)	Angas-Bremer Plains	387	3	3	4
7	Tepko (24533)	Salt Creek	347	2	5	3

Rainfall records for stations listed in Table 1 ('Rainfall reporting stations') were analysed and are presented in various forms, including annual rainfall totals, long-term average, 10-year moving average, long-term trend and extent of deviation of each year's rainfall from long-term average. In the case of rainfall deviation from the long-term average, each year's rainfall was expressed as a percentile[1] of the total period of data availability (i.e., 1900 to 2021). Rainfall data were then given a description based on their percentile and decile as described in Table 2. Example plots for the rainfall station at Uraidla (23750) are presented below in Figures 2(i) and 2(ii), with plots for the remaining reporting stations included in APPENDIX A and APPENDIX B.

*Table 2. Percentile and decile descriptions**

Decile	Percentile	Description	Colour
N/A	100	Highest on record	
10	90 to 100	Very much above average	
8 and 9	70 to 90	Above average	
4, 5, 6, and 7	30 to 70	Average	
2 and 3	10 to 30	Below average	
1	0 to 10	Very much below average	
N/A	0	Lowest on record	

* Deciles and descriptions as defined by the BoM[iii]

[1] The nth percentile of a set of data is the value at which n% of the data is below it. For example, if the 75th percentile annual rainfall is 500 mm, 75% of the years on record had annual rainfall of less than 500 mm. Median streamflow: 50% of the records were above this value and 50% below. Decile: a division of a ranked set of data into ten groups with an equal number of values. In this case e.g., the first decile contains those values below the 10th percentile.

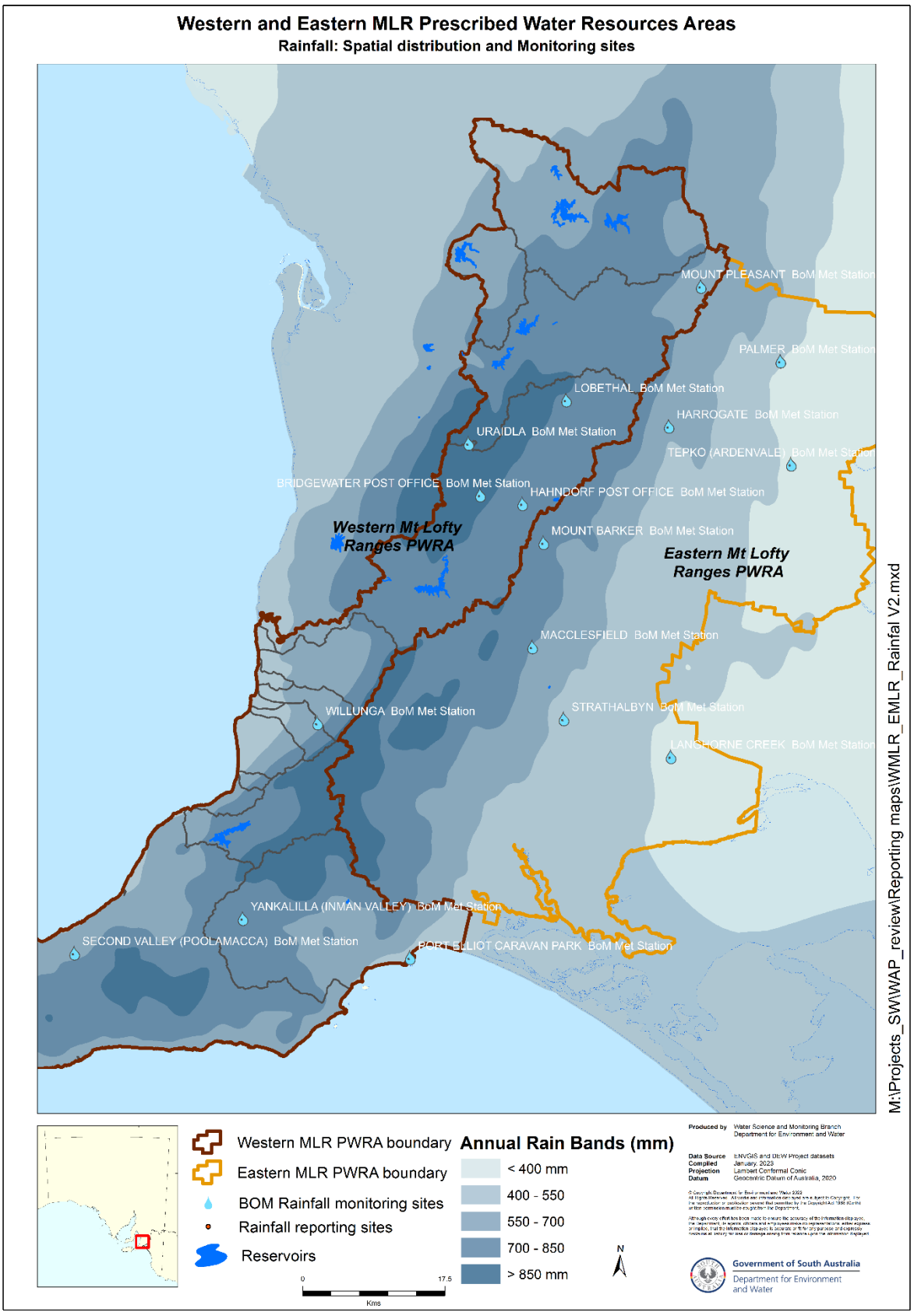


Figure 1. Rainfall distribution and reporting stations, WMLR and EMLR PWRAs

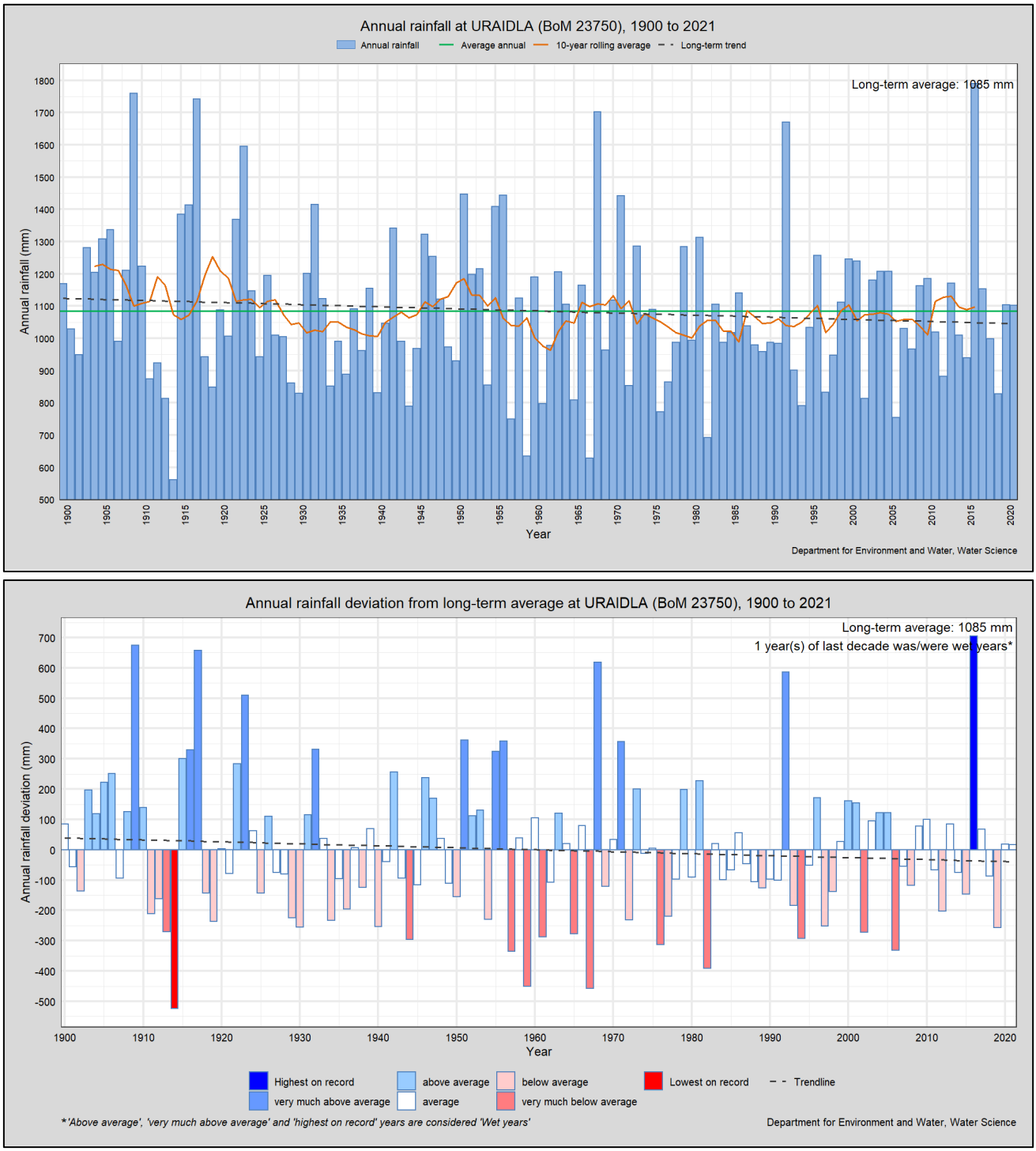


Figure 2. (i) Long-term (1900-2022) annual rainfall at Uraidla (top) (ii) Deviation of annual rainfall from long-term average

Figure 2(i) displays (a) annual rainfall records for the Uraidla (23750) BoM rainfall station for the period 1900 to 2021, (b) the average for the entire period (1085 mm), (c) the 10-year moving average, and (d) the linear trend of annual rainfall over the period, which is seen in this case as a decreasing trend.

Figure 2(ii) displays annual rainfall as the deviation of each year's rainfall from the long-term average, with the data bars coloured using the classification presented in Table 2. In the case of Uraidla rainfall, in the last decade:

- only one year (2016) was classified as 'wet' (in the '*above average', 'very much above average'* and *'highest on record'* categories);
- three years were classified as 'dry' ('b*elow average*', '*very much below average*' and '*lowest of record*' categories); and
- six years were classified as 'average'.

Similarly, data from the other reporting stations across both PWRAs indicate a low number (between 1 and 3) of 'wet' years during the last decade (Table 1 and figures in APPENDIX B). Substantial stream flows (flows that make it to the catchment outlet) are generally generated only during 'wet' years in highly developed catchments, such as those in the WMLR and EMLR PWRA catchments due to high initial interception losses from runoff being captured in on-stream dams.

It is to be noted that the frequency of 'wet' rainfall years (bars with different shades of blue) is considerably lower during the last decade in comparison to pre-drought decades (Figures 2(ii) and Figures in APPENDIX B). This is reflected in the annual streamflow generated during this period, as presented in the following section.

Streamflow

Streamflow is gauged at streamflow monitoring sites operated by DEW, the Landscape Boards and other agencies. The monitoring sites are generally located at the outlet of a catchment or a sub-catchment to monitor the flow generated upstream of the monitoring location. Monitoring sites have been progressively constructed across the state since late 1960s and early 1970s with varying levels of availability of good quality data.

The set of monitoring sites chosen for this assessment ('Streamflow reporting stations') contains those that have good quality data for the longest common period ('Reporting period'), which in this case is 1974 to 2021. The streamflow reporting stations for the PWRAs are listed in Table 3 and shown in Figure 3. Years that have incomplete data (i.e., days with no data recorded) are displayed as 'Partial data' and years with no records are displayed as 'Data unavailable' in the charts.

Streamflow records for stations listed in Table 3 ('Streamflow reporting stations') were analysed and are presented in various forms, including annual streamflow totals, long-term average, 5-year moving average, long-term trend and extent of deviation of each year's streamflow from long-term average. In the case of streamflow deviation from the long-term average, each year's streamflow was expressed as a percentile of the total period of data availability (i.e., 1974 to 2021). Streamflow data were then given a description based on their percentile and decile as described in Table 2.

Average annual streamflow for the stations and the linear trend line in the charts were calculated using data only from years with complete records i.e., years with 'Partial data' and 'Data unavailable' were not used in the calculations.

Annual streamflow data from the Scott Creek, Onkaparinga (A5030502) monitoring station are presented below in Figures 4(i) and 4(ii), with plots for the remaining reporting stations included in APPENDIX C and APPENDIX D.

Table 3. Streamflow reporting stations for WMLR and EMLR PWRAs (1974 to 2021)

No.	Station name (Station ID)	Catchment	Average annual flow* (ML)	Number of wet years in the last decade
WMLR PWRA				
1	Torrens River at Mount Pleasant (A5040512)	Torrens	3,361	1
2	Sixth Creek at Castambul (A5040523)	Torrens	7,192	1
3	Kersbrook Creek u/s of Millbrook (A5040525)	Torrens	2,606	1
4	Scott Creek at Scott Bottom (A5030502)	Onkaparinga	3,361	1
5	Lenswood Creek at Lenswood (A5030507)	Onkaparinga	3,410	2
6	Cox Creek at Uraidla (A5030526)	Onkaparinga	1,297	2
7	Myponga River upstream (u/s) Dam (A5020502)	Myponga	7,944	2
8	Inman River u/s Victor Harbor STW (A5010503)	Inman	8,381	3
EMLR PWRA				
1	Finniss River near Yundi (A4260504)	Finniss	22,742	2
2	Bremer River near Hartley (A4260533)	Bremer	15,571	N/A
3	Angas River at Angas Wier (A4260503)	Angas	4,901	4
4	Currency Creek near Higgins (A4260530)	Currency	5,782	N/A

** Data only from years with complete records used in calculations*

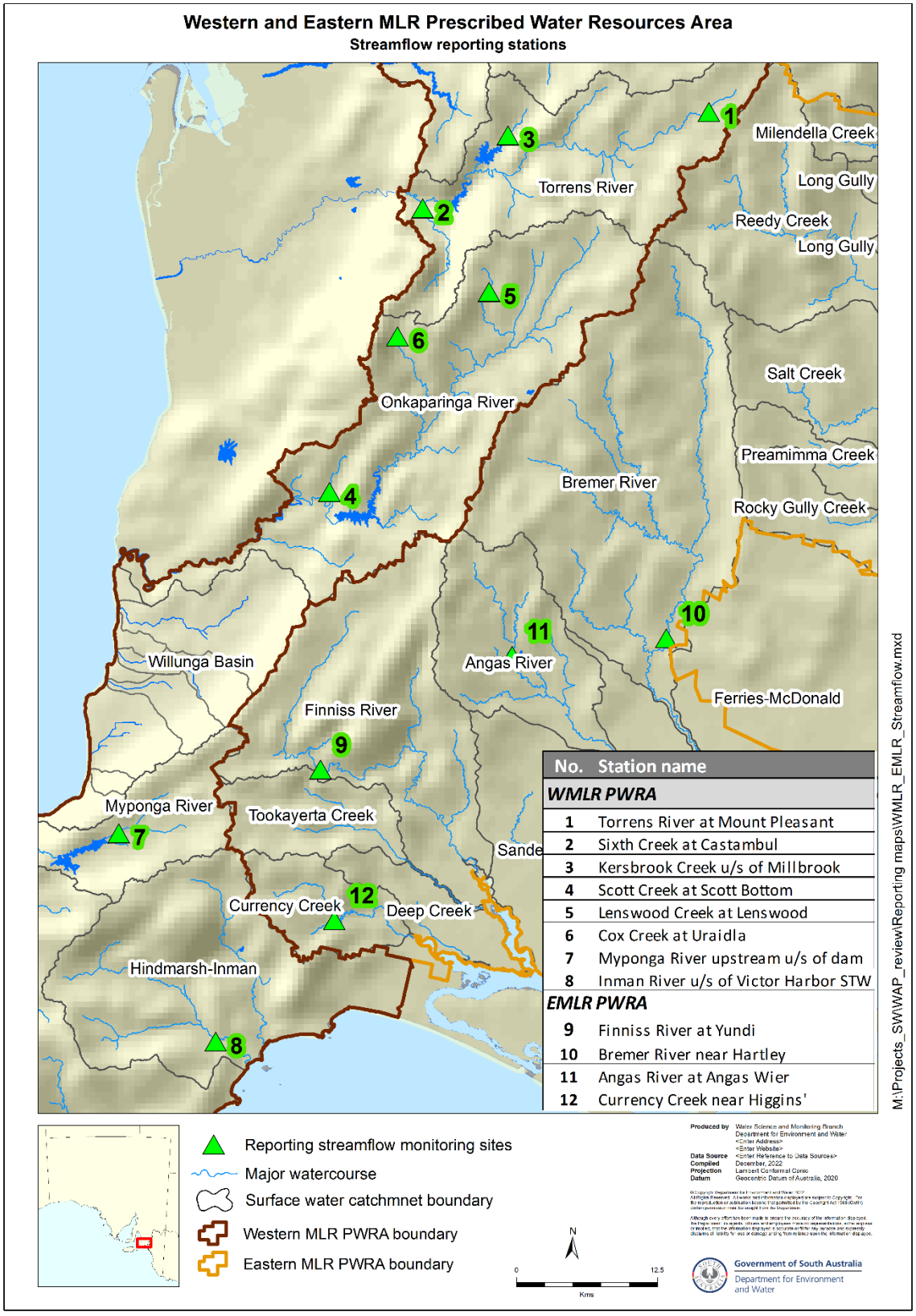
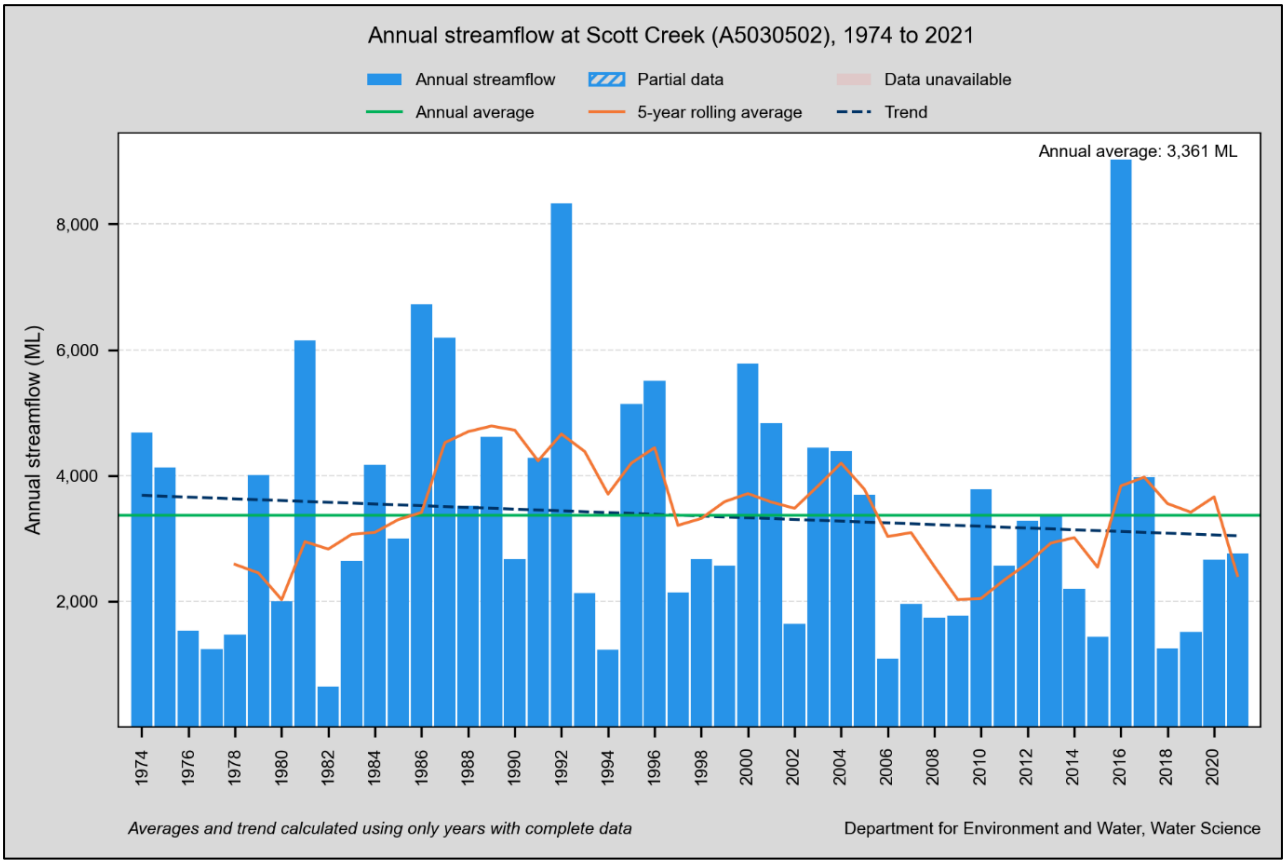


Figure 3. Streamflow reporting stations, WMLR and EMLR PWRAs



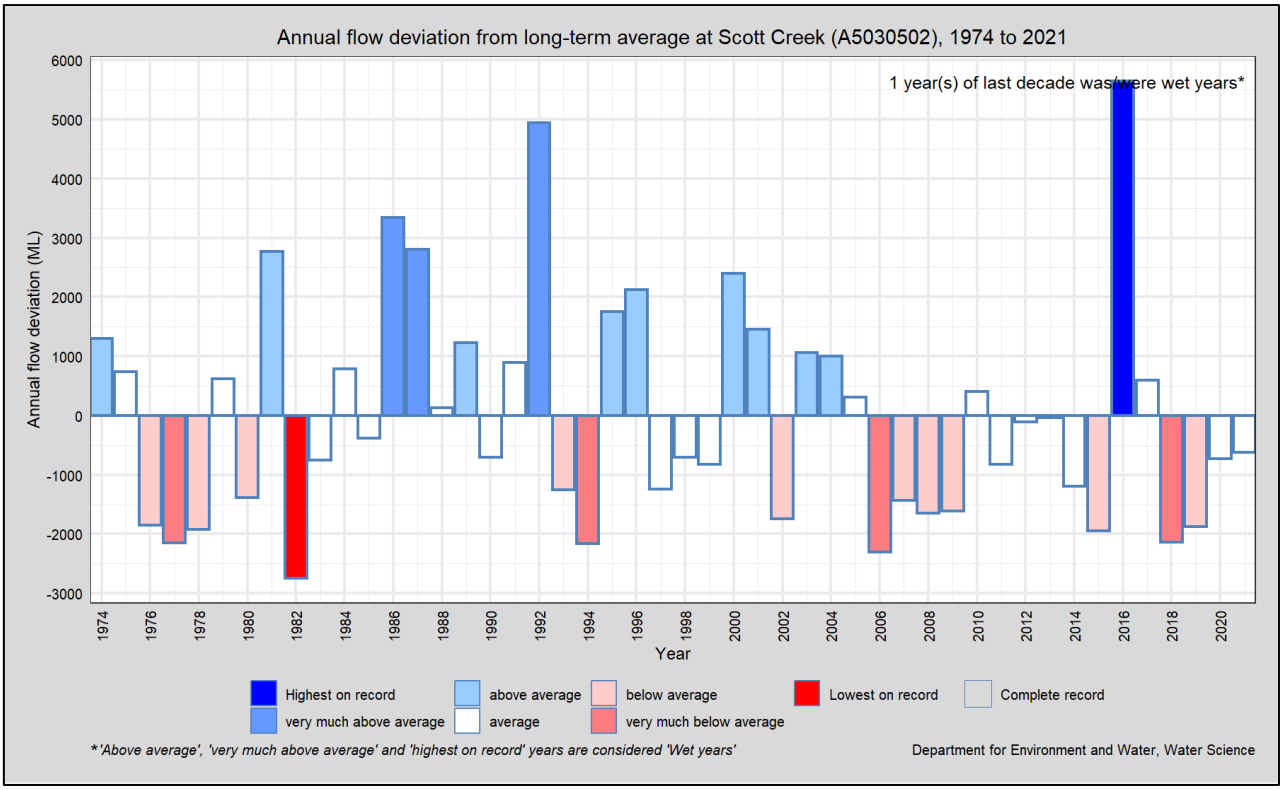


Figure 4. (i) Annual streamflow at Scott Creek, Onkaparinga (top) (ii) Deviation of annual streamflow from long -term average

Figure 4(i) displays (a) annual streamflow records for Scott Creek, Onkaparinga (A5030502) for the period 1974 to 2021, (b) the average for the entire period (3361 ML), (c) the 5-year moving average and (d) the linear trend of annual streamflow over the period, which is seen in this case as a decreasing trend.

Annual streamflow data is displayed in Figure 4(ii) as the deviation of each year's streamflow from the long-term average, with the data bars coloured using the classification presented in Table 2.

Data presented in figures 4(i) and 4(ii) for the annual streamflow at Scott Creek, Onkaparinga (A5030502) indicates that:

- there is a declining trend in annual streamflow since 1974;
- during the last decade, only one year (2016) was 'wet', in the '*above average', 'very much above average'* and *'highest on record'* categories; and
- the frequency of 'wet' years (bars with different shades of blue) is considerably lower during the last decade, in comparison to pre-drought decades (Figure 4(ii)). This is consistent with the rainfall data for the catchment, presented earlier in Table 1 and the relevant charts.

Summary

Results of the analysis of rainfall and streamflow records from monitoring stations across the WMLR and EMLR PWRAs show:

- a declining trend in rainfall (since 1900) and streamflow (since 1974) across the PWRAs;
- that in the last decade:
    - only a very few (1 to 3) years were wetter-than-average rainfall years across both PWRAs;
    - 1 to 2 years were wetter-than-average streamflow years in the central and northern catchments; and
    - 2 to 4 years were wetter-than-average streamflow years in the eastern and southern catchments.
- the frequency of wetter-than-average rainfall and streamflow years was lower during the last decade, in comparison to the pre-drought decades; and
- the declining trend appears to be more pronounced in the central and northern sections of the PWRAs, with further detailed investigation required to confirm this.

The results presented in this memo reflect the large-scale climate change projections for the area and are consistent the results of detailed investigations[iv] undertaken recently as part of review of the WAP for the Barossa PWRA[v].

A simple linear trend analysis was used in this investigation. Further detailed investigations that are specific to the catchments in the PWRAs including:

- climate behaviour in the recent past, including comparison of drought, pre-drought and post-drought rainfall and streamflow behaviour; and in the context of WAP-development and post WAP-development climate periods, possible shift in climate during that period,
- climate projections for the future and
- impacts of the above on recent and future streamflow

are recommended when reviewing and/or amending the WAPs, particularly in regard to changing climate in the recent past and its implications to surface water resource capacity, ecologically significant flow regimes, and ecologically sustainable extraction limits defined in the WAPs.

APPENDIX A Long-term rainfall trends, WMLR and EMLR PWRA Reporting stations

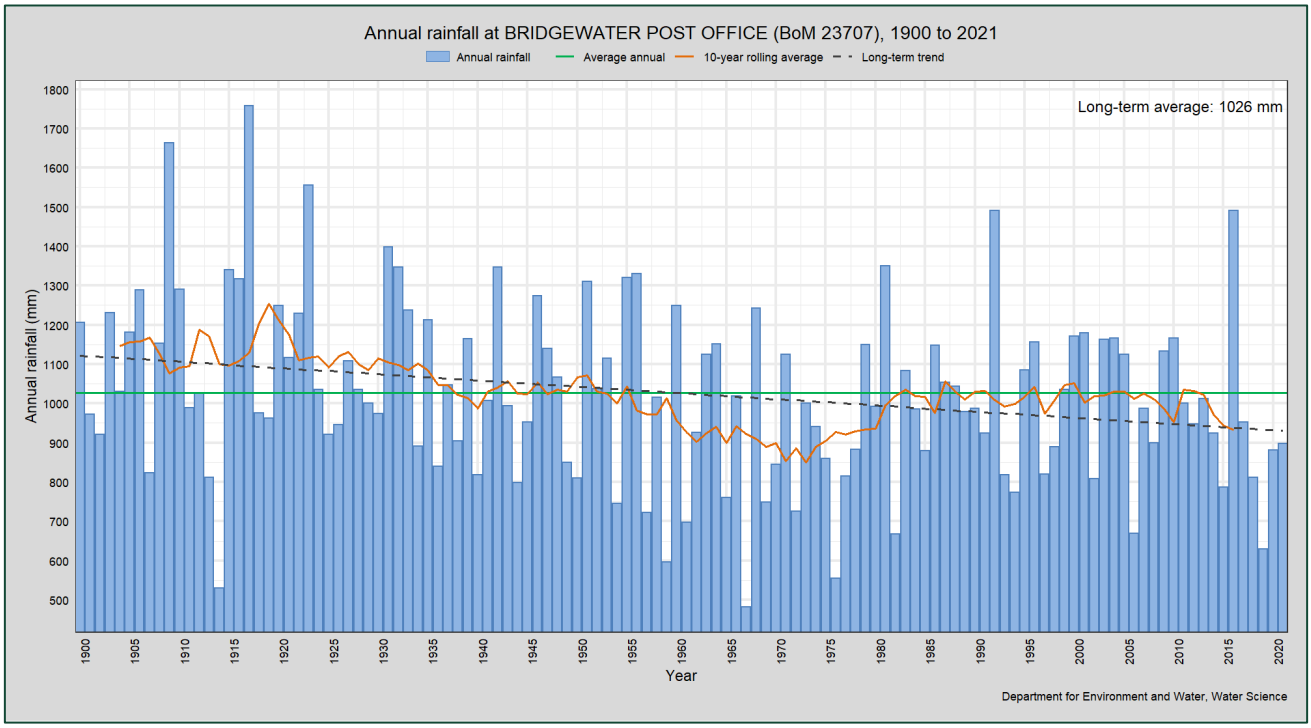


Figure 5. Long-term annual rainfall trend, Bridgewater Post Office (23707)

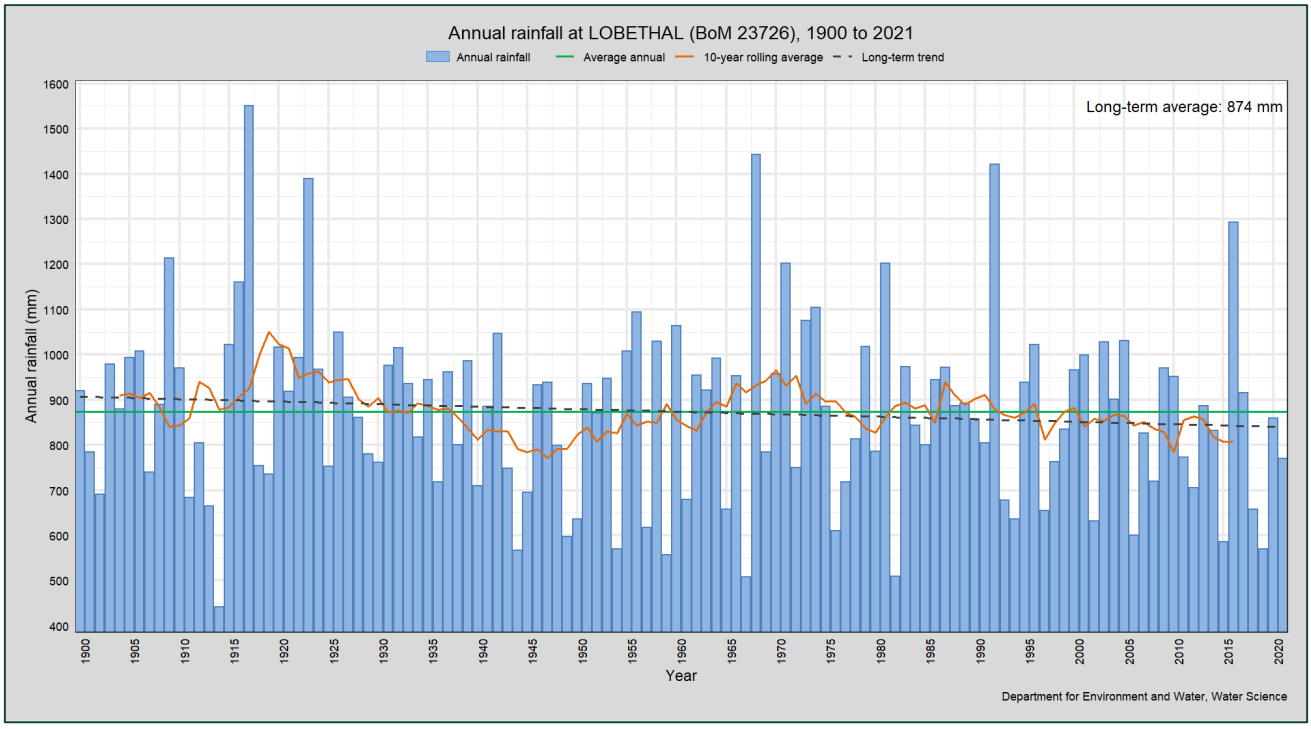


Figure 6. Long-term annual rainfall trend, Lobethal (23726)

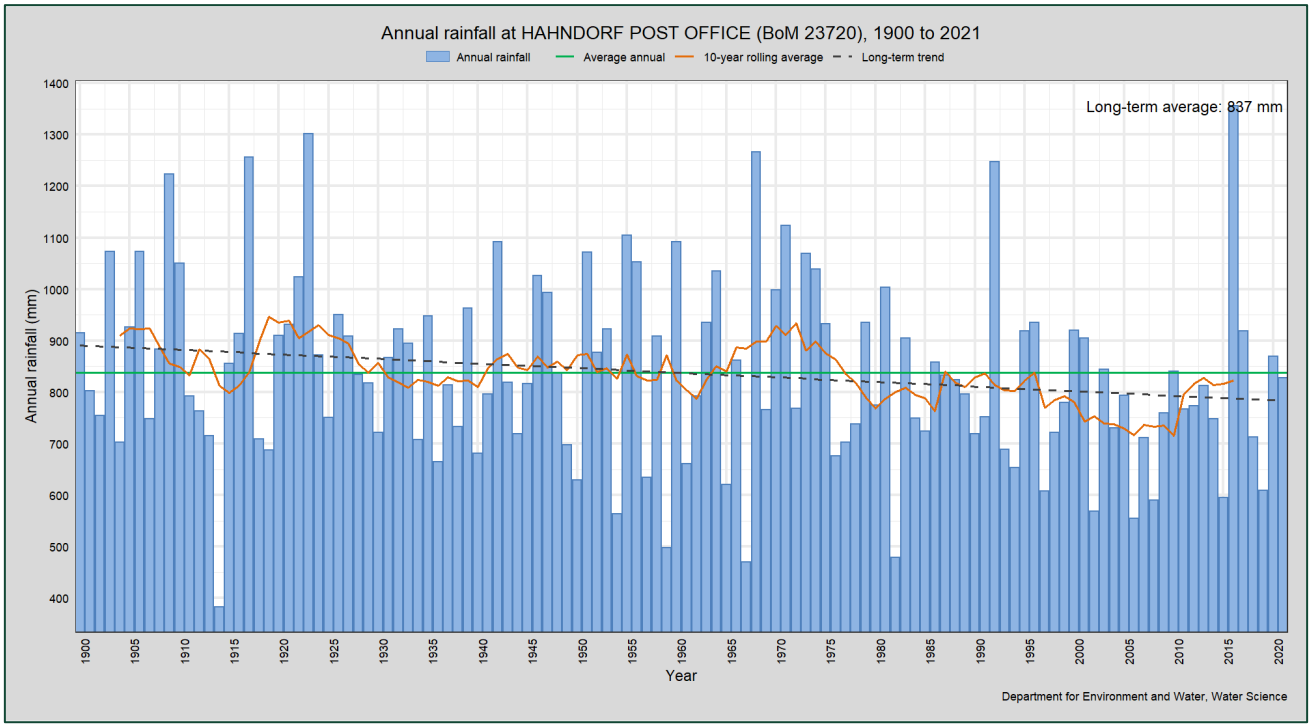


Figure 7. Long-term annual rainfall trend, Hahndorf Post Office (23720)

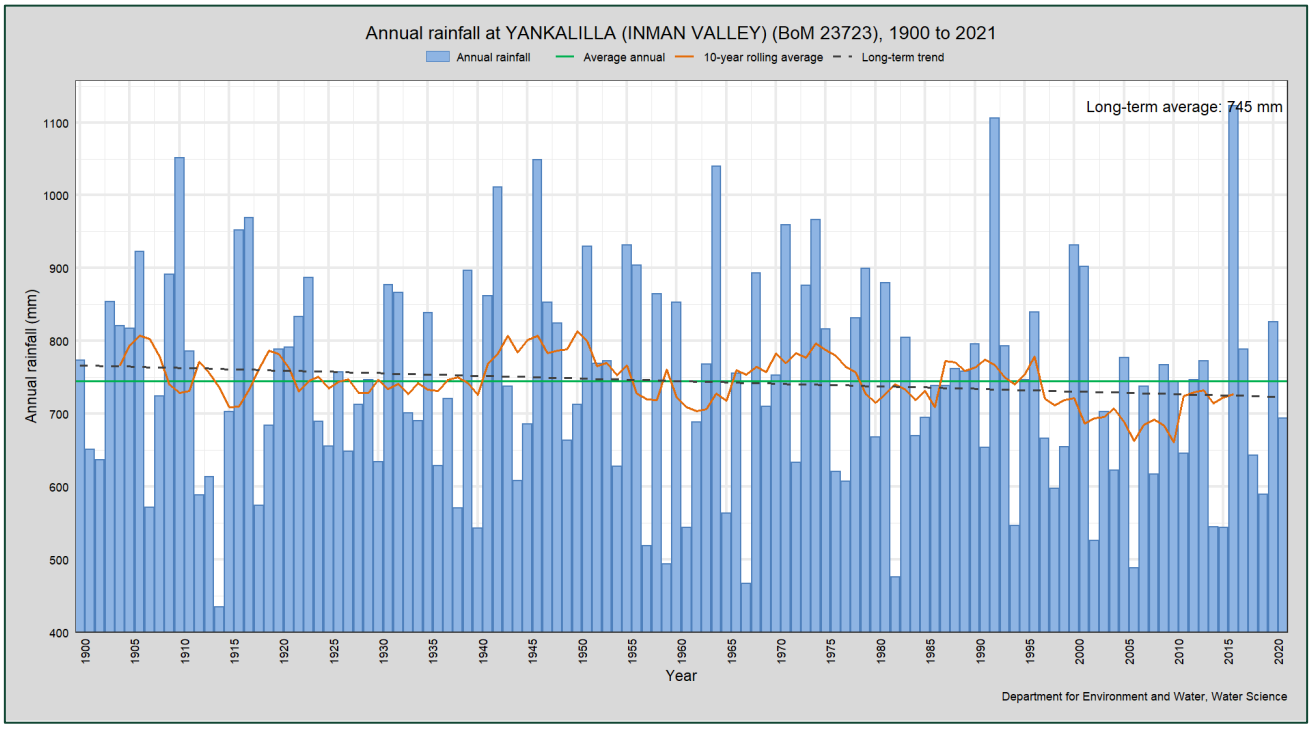


Figure 8. Long-term annual rainfall trend, Yankalilla (Inman Valley) (23723)

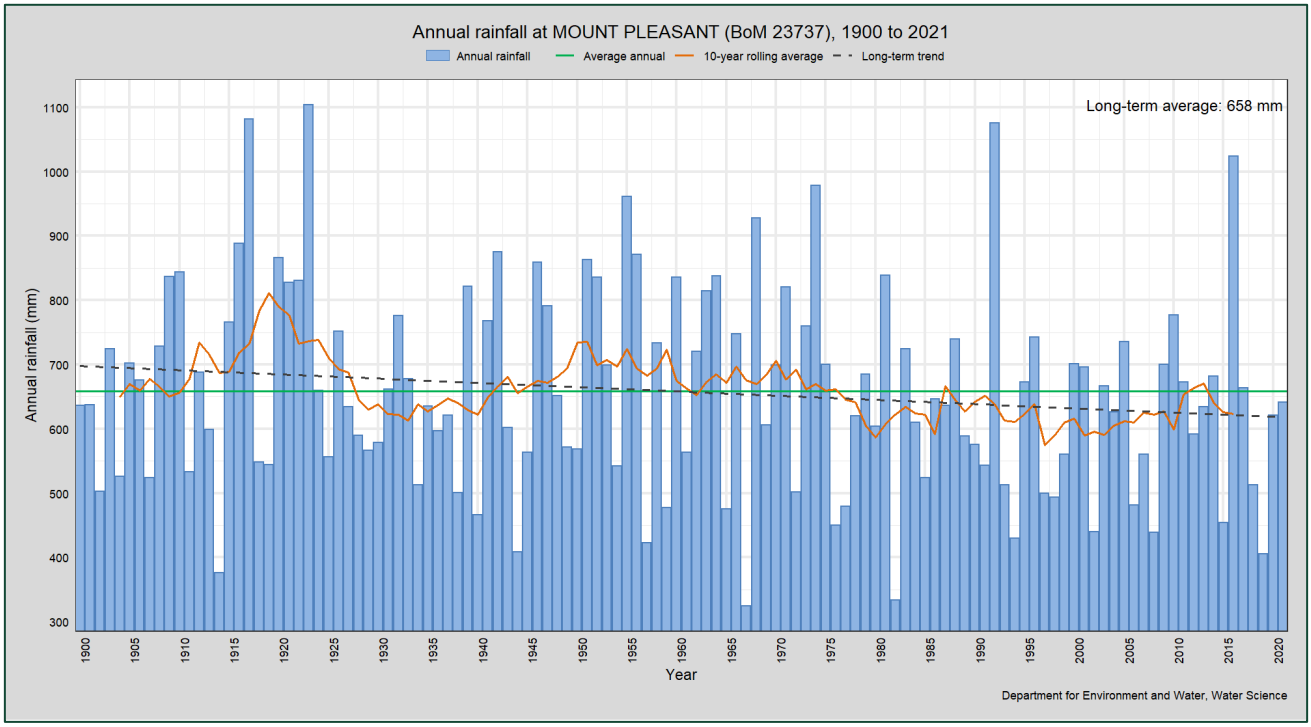


Figure 9. Long-term annual rainfall trend, Mount Pleasant (23737)

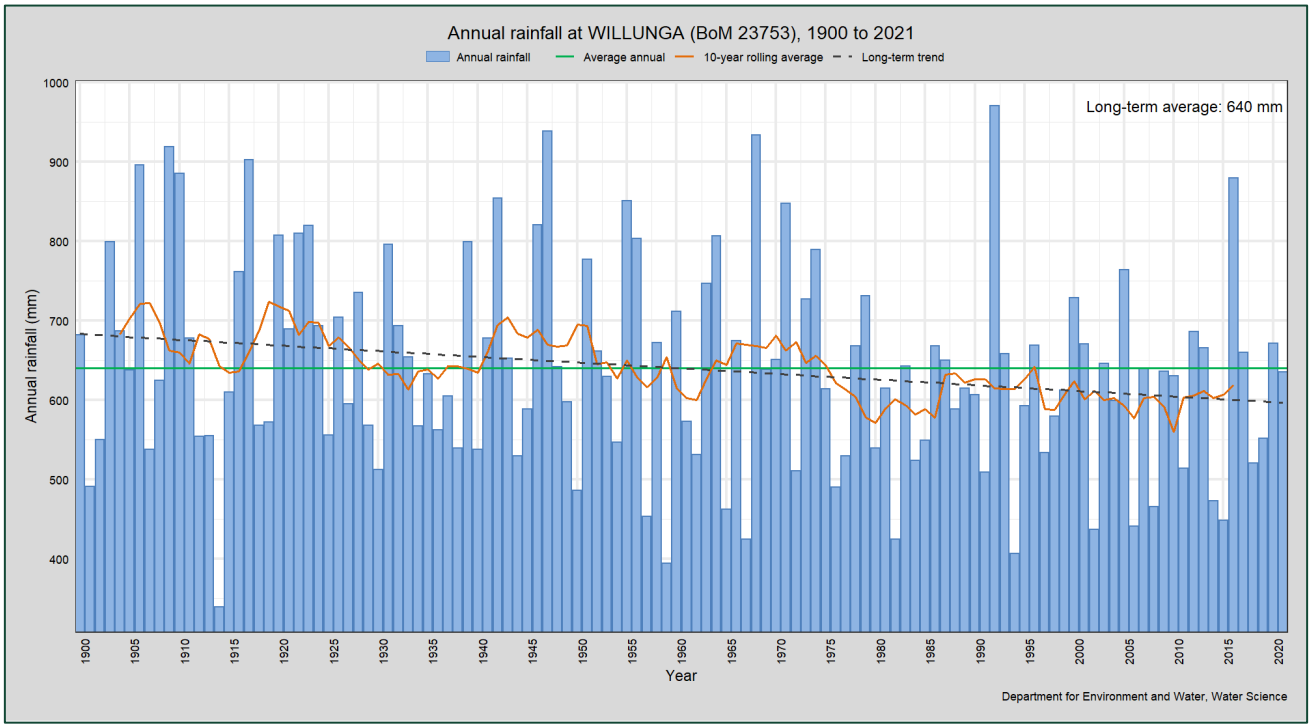


Figure 10. Long-term annual rainfall trend, Willunga (23753)

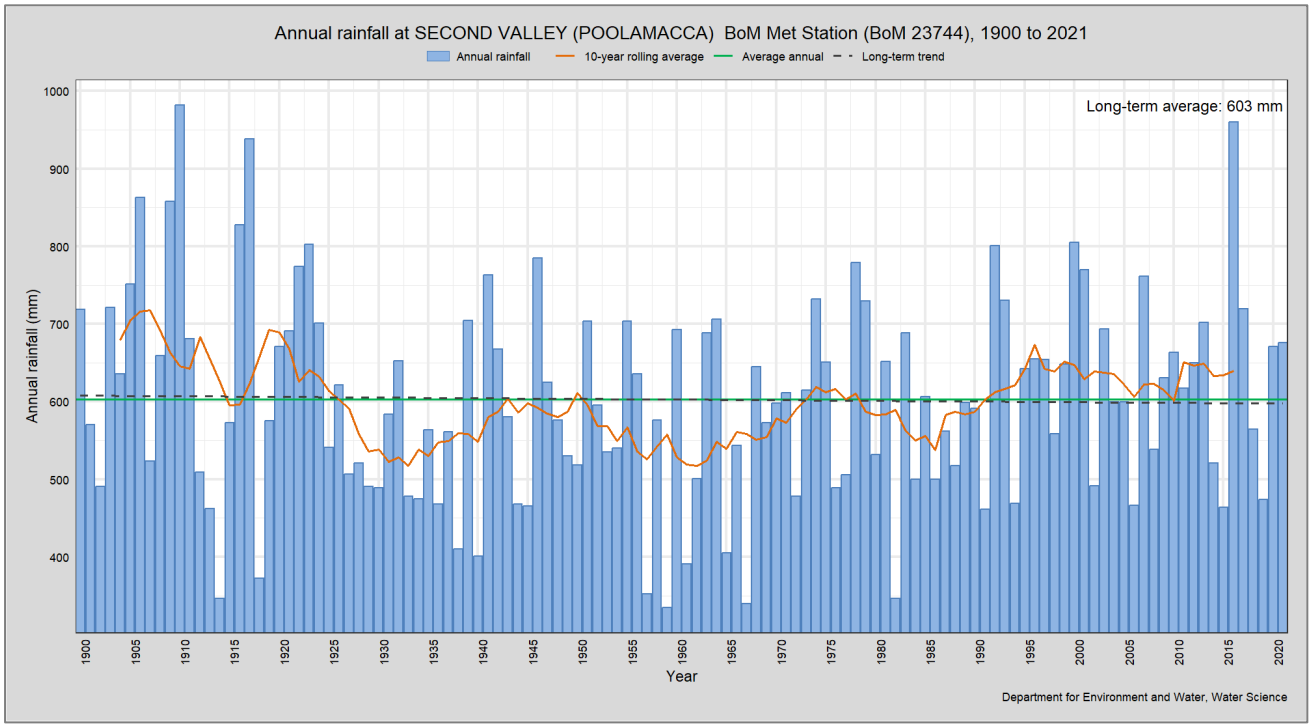


Figure 11. Long-term annual rainfall trend, Second Valley (23744)

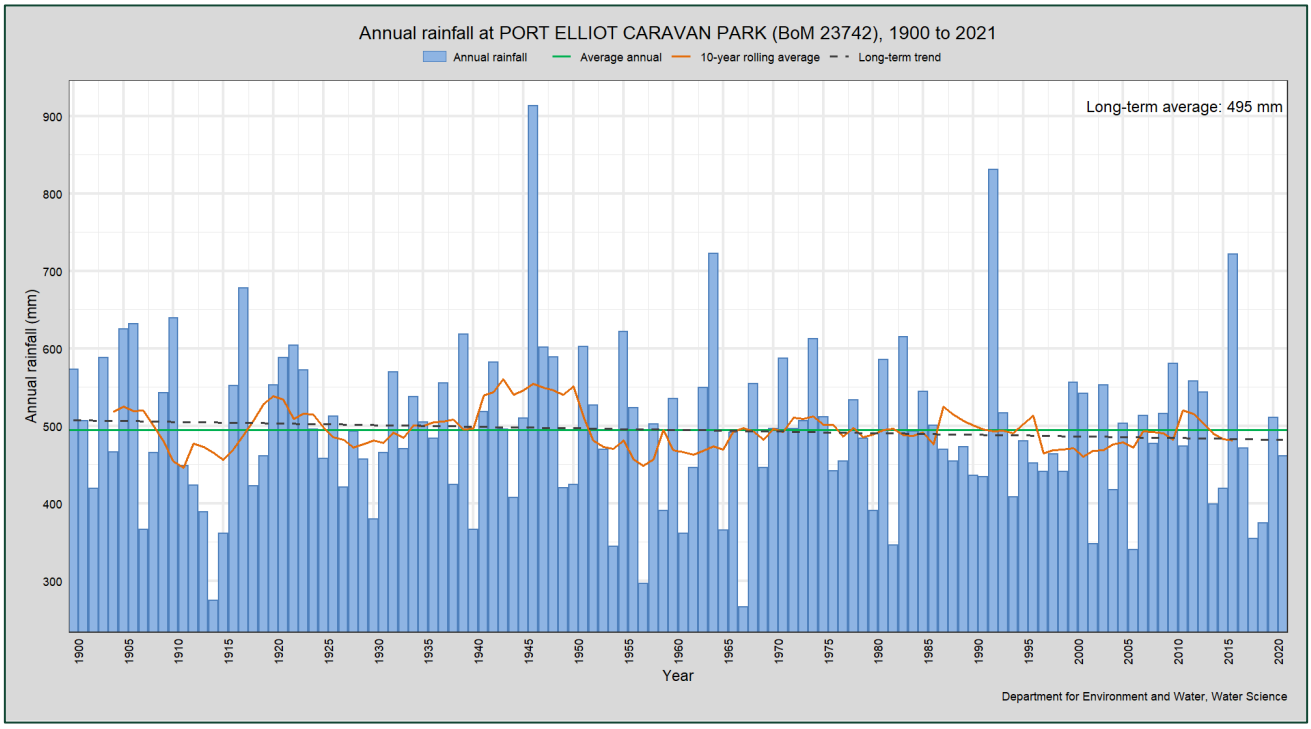


Figure 12. Long-term annual rainfall trend, Port Elliot Caravan Park (23742)

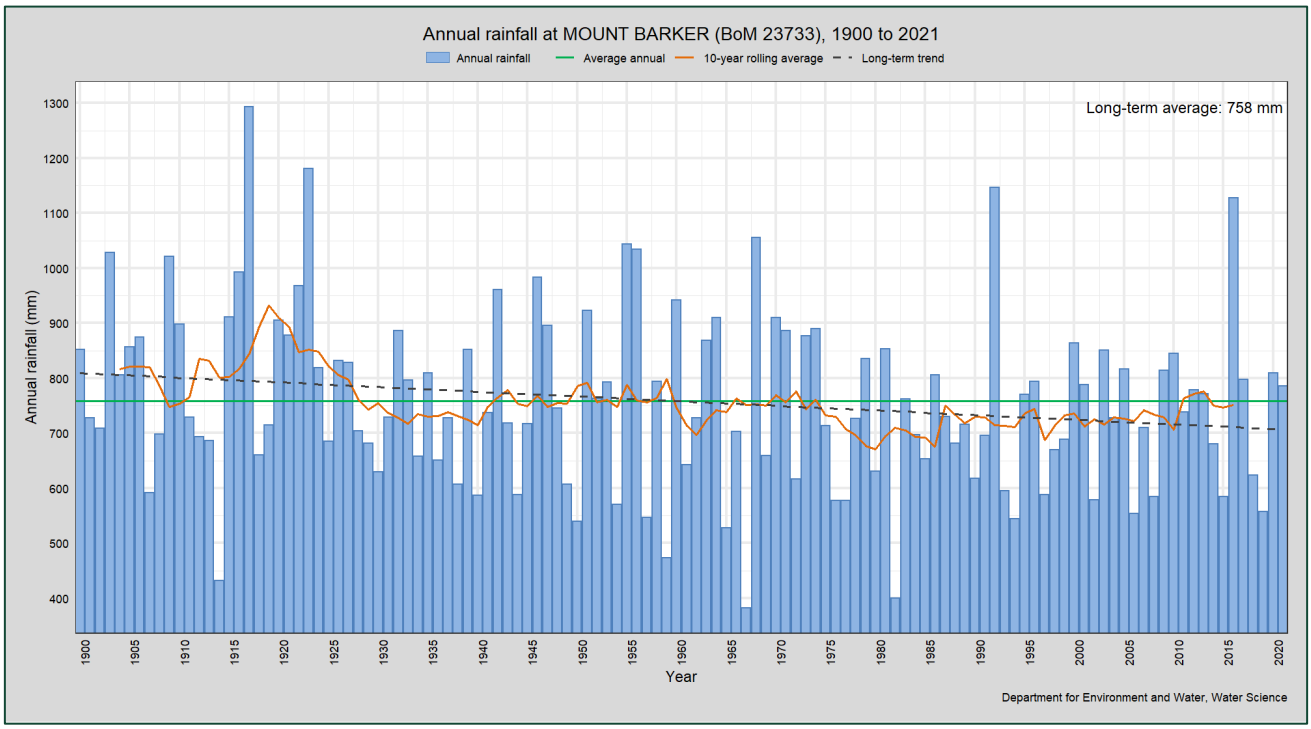


Figure 13. Long-term annual rainfall trend, Mount Barker (23733)

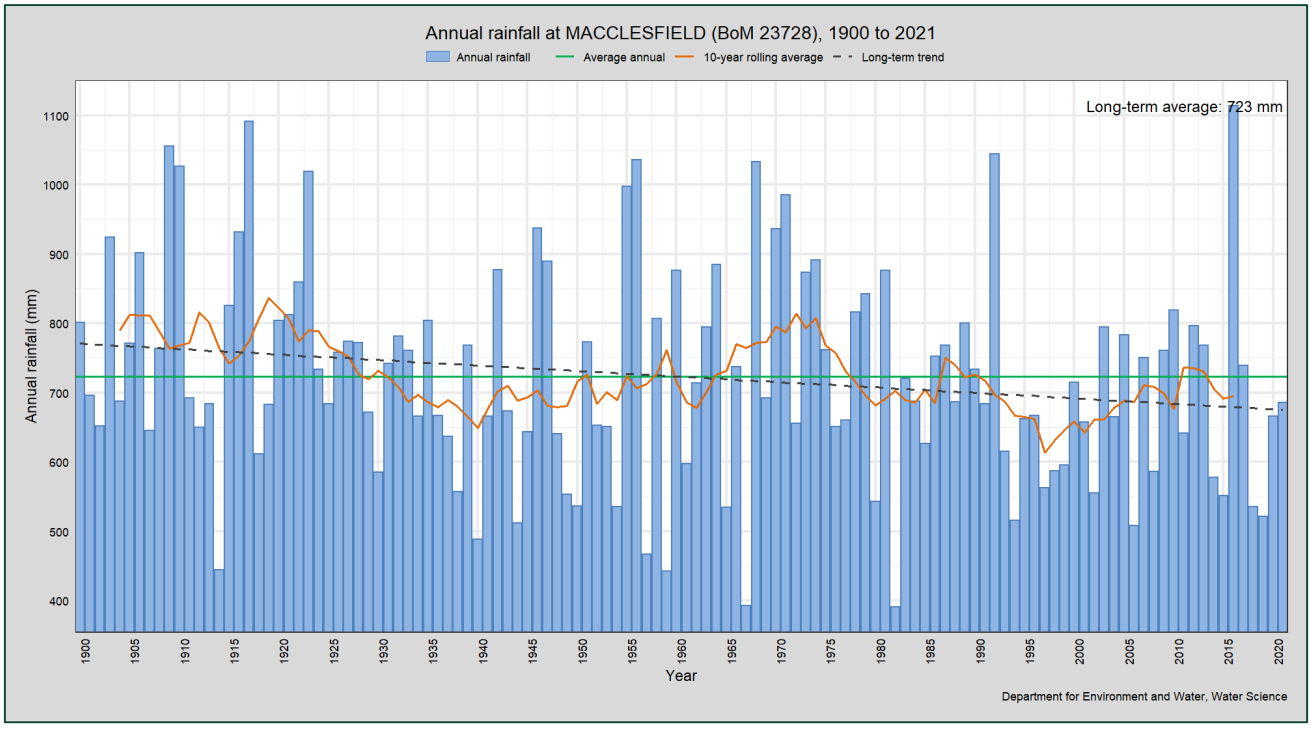


Figure 14. Long-term annual rainfall trend, Macclesfield (23728)

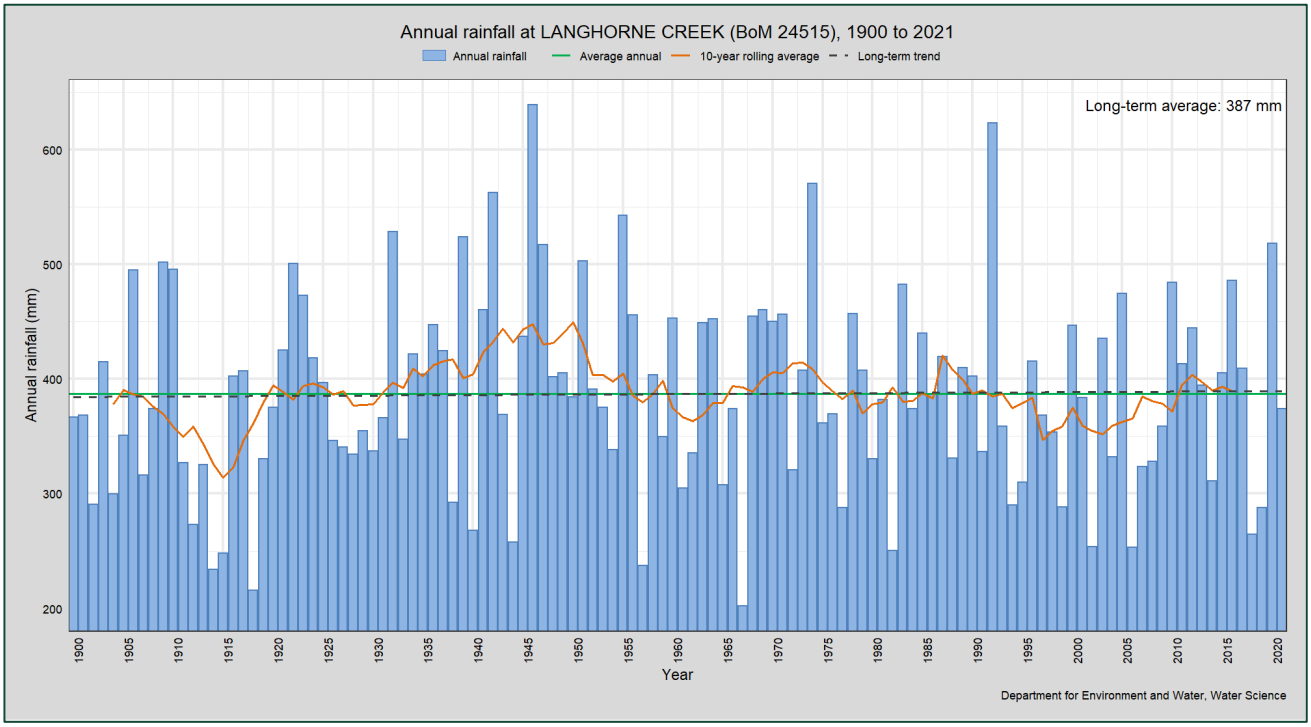


Figure 15. Long-term annual rainfall trend, Langhorne Creek (24515)

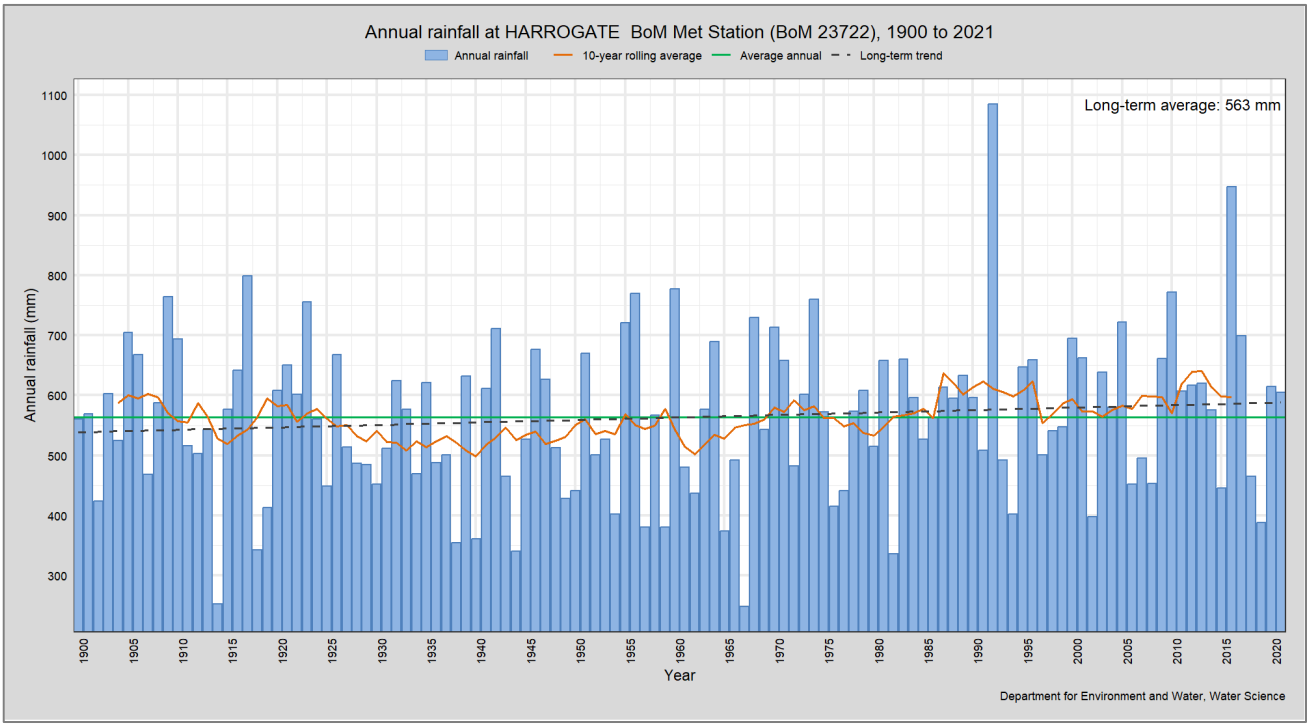


Figure 16. Long-term annual rainfall trend, Harrogate (23722)

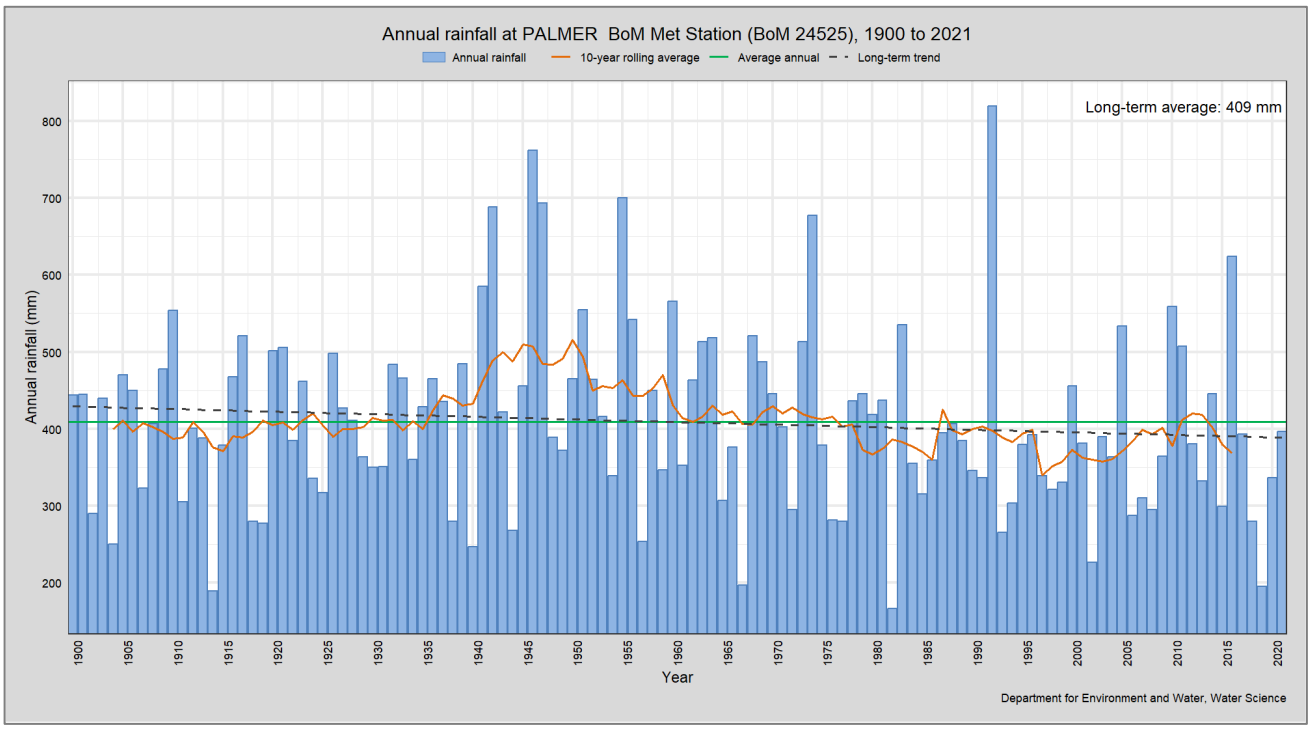


Figure 18. Long-term annual rainfall trend, Palmer (24525)

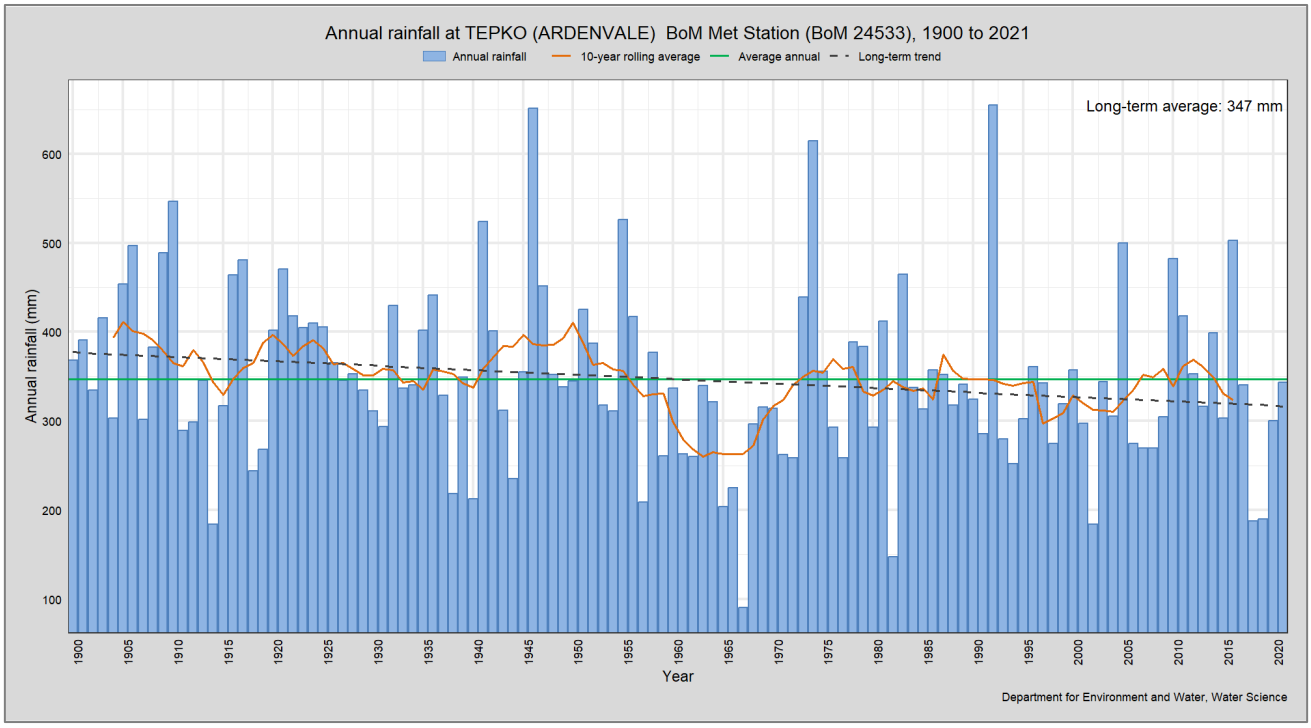


Figure 17. Long-term annual rainfall trend, Tepko (24533)

APPENDIX B Deviation of annual rainfall, WMLR and EMLR PWRA Reporting stations

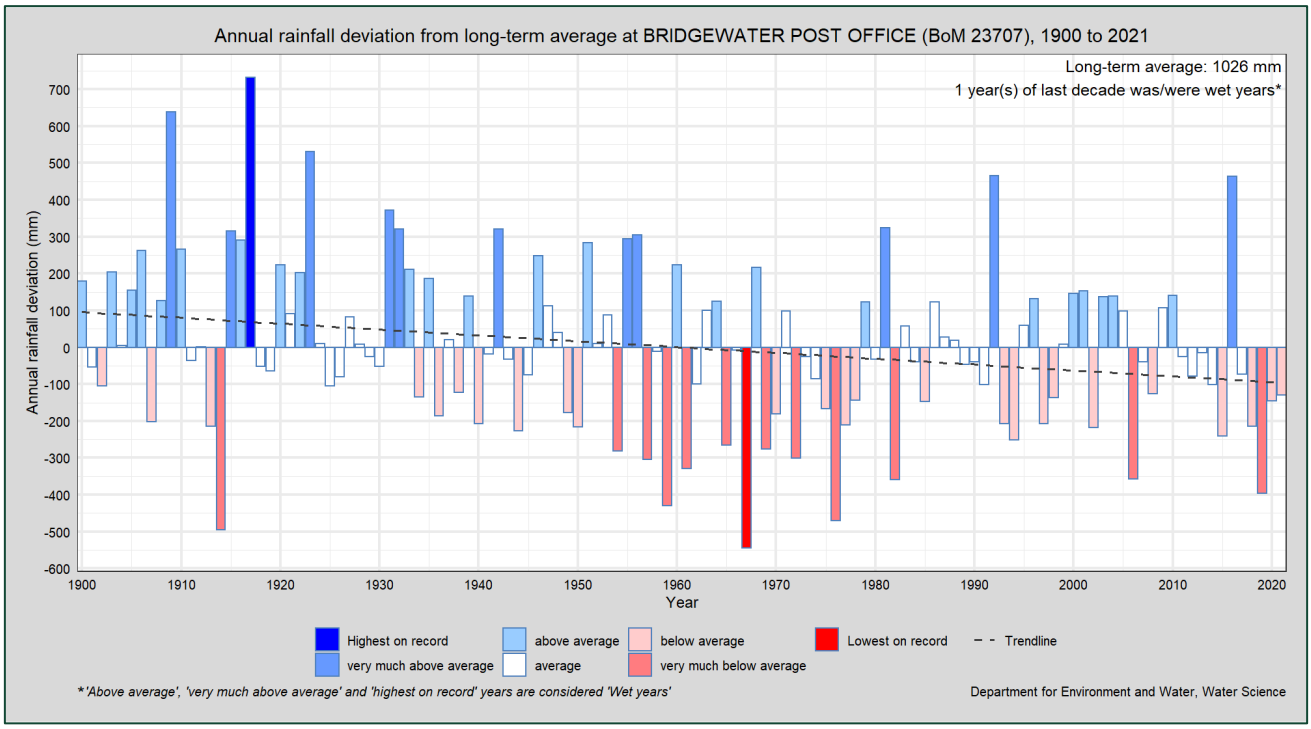


Figure 19. Deviation of annual rainfall from long-term average, Bridgwater Post Office (23707)

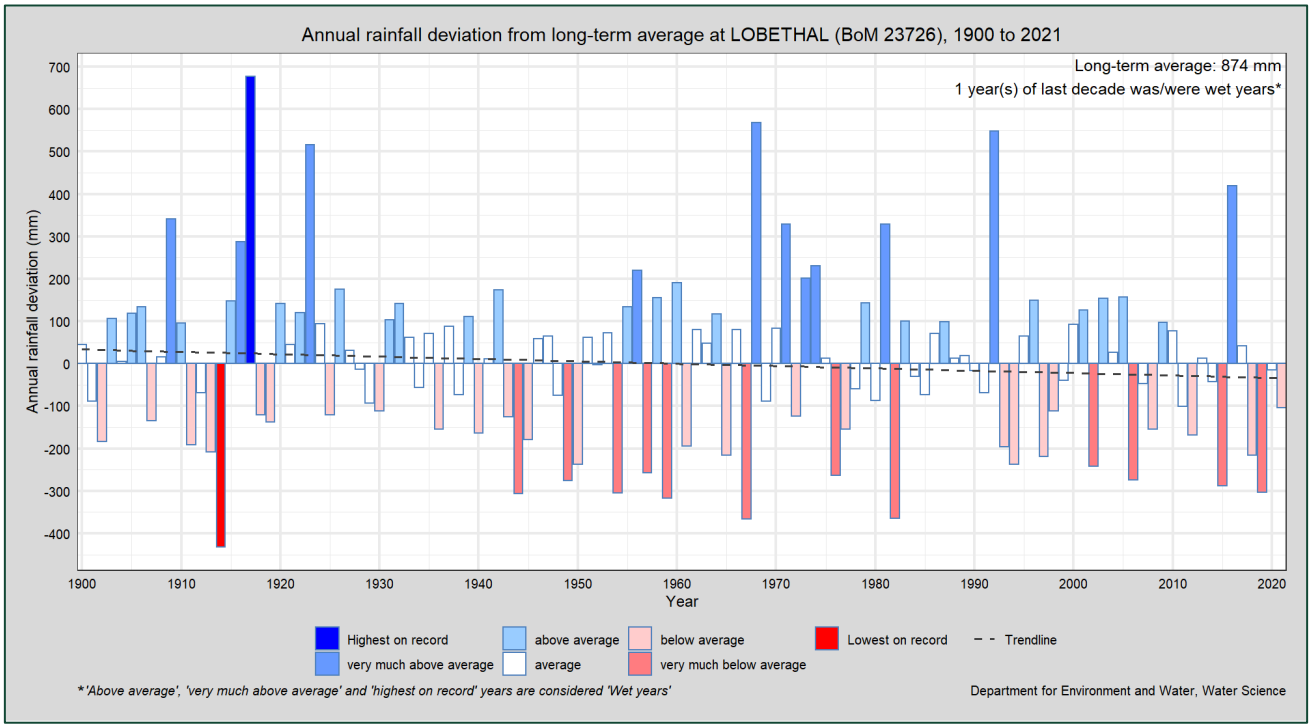


Figure 20. Deviation of annual rainfall from long-term average, Lobethal (23726)

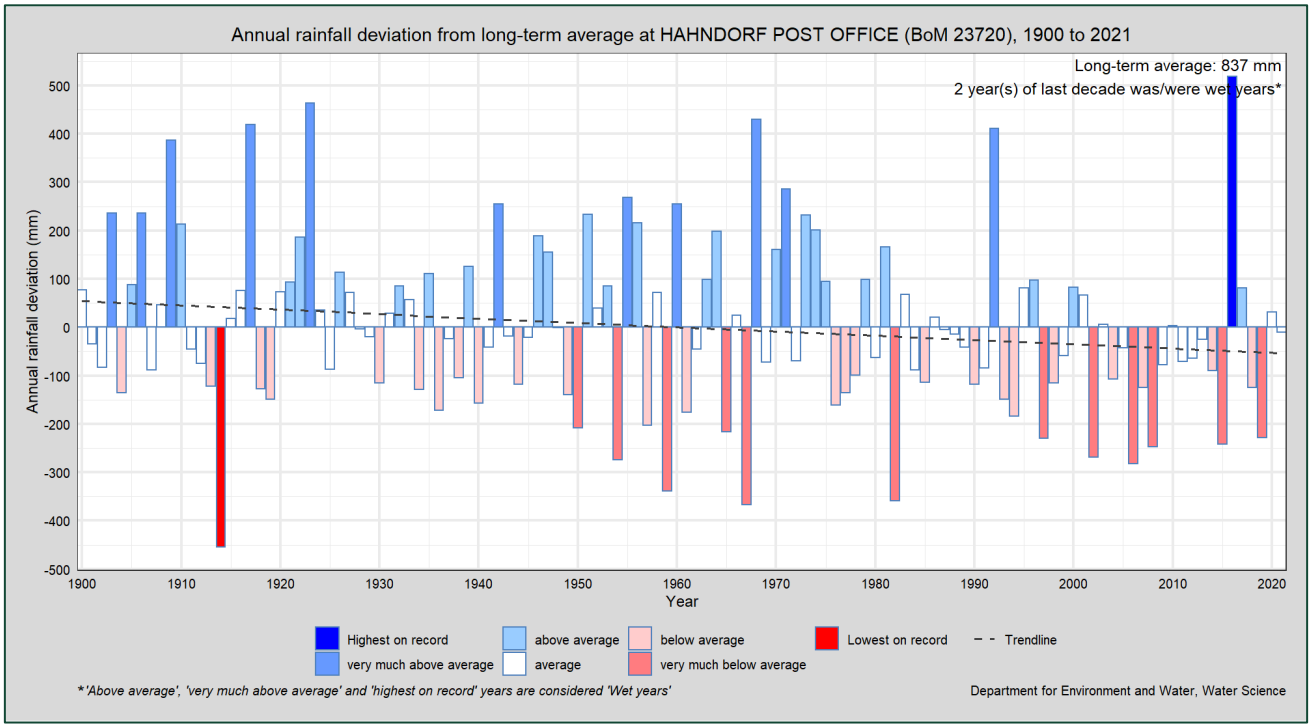


Figure 21. Deviation of annual rainfall from long-term average, Hanhdorf Post Office (23720)

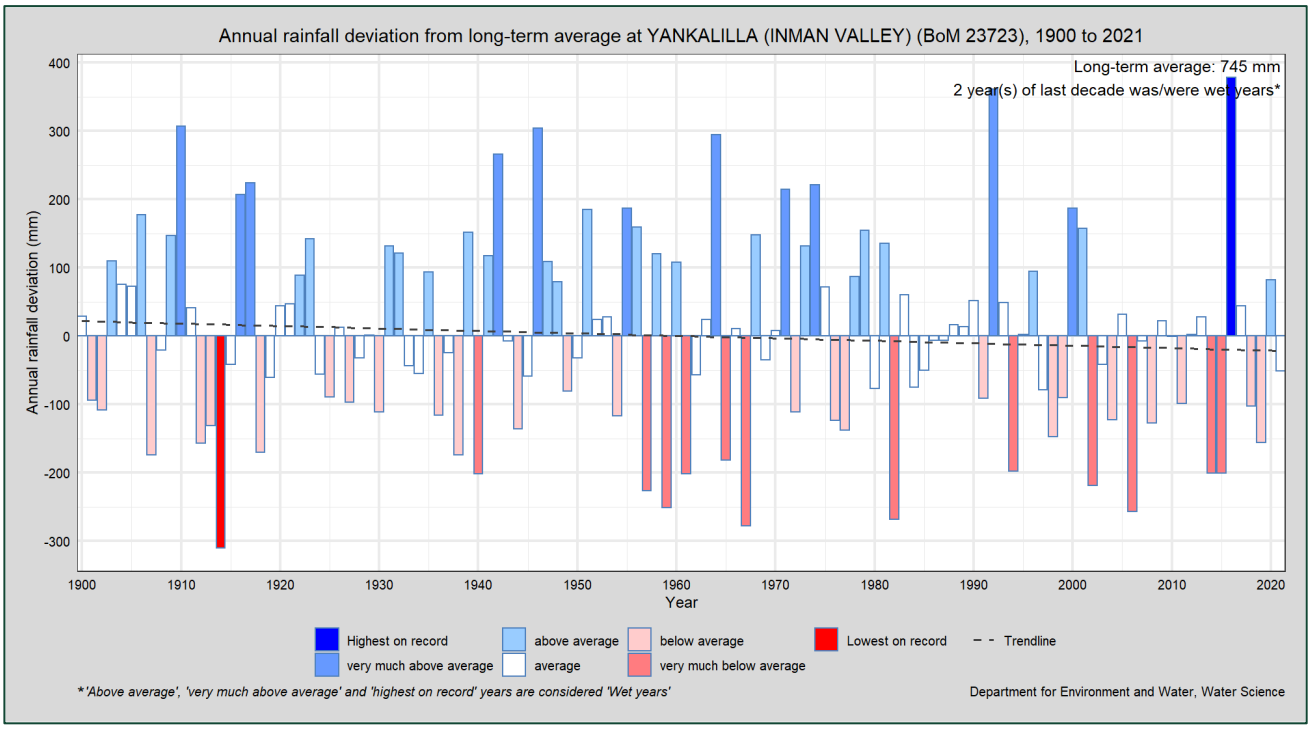


Figure 22. Deviation of annual rainfall from long-term average, Yankalilla (Inman Valley) (23723)

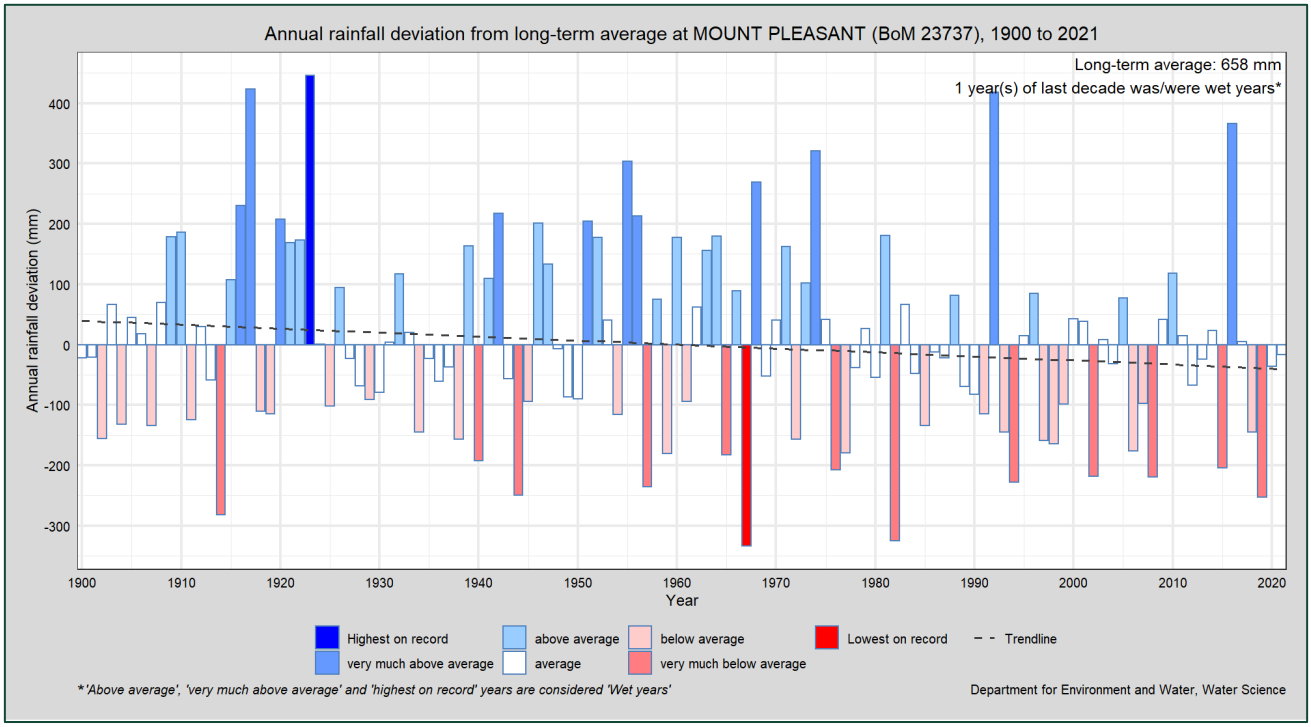


Figure 23. Deviation of annual rainfall from long-term average, Mount Pleasant (23737)

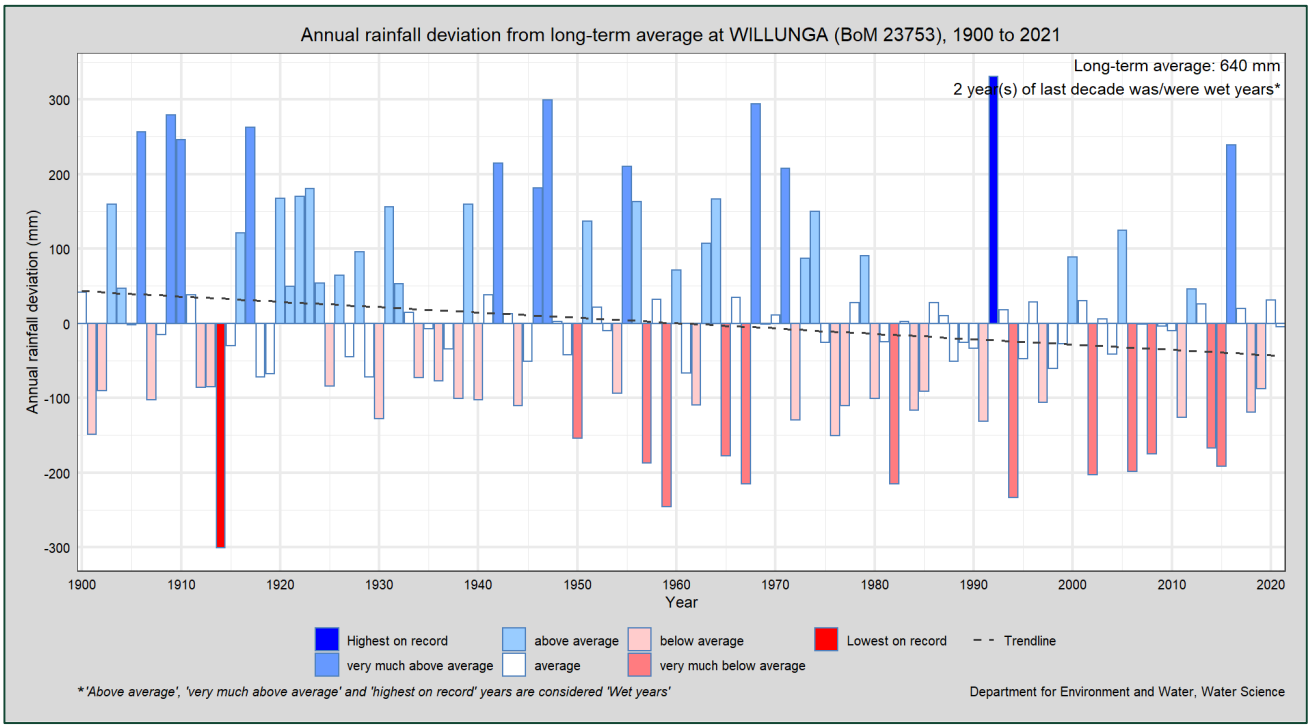


Figure 24. Deviation of annual rainfall from long-term average, Willunga (23753)

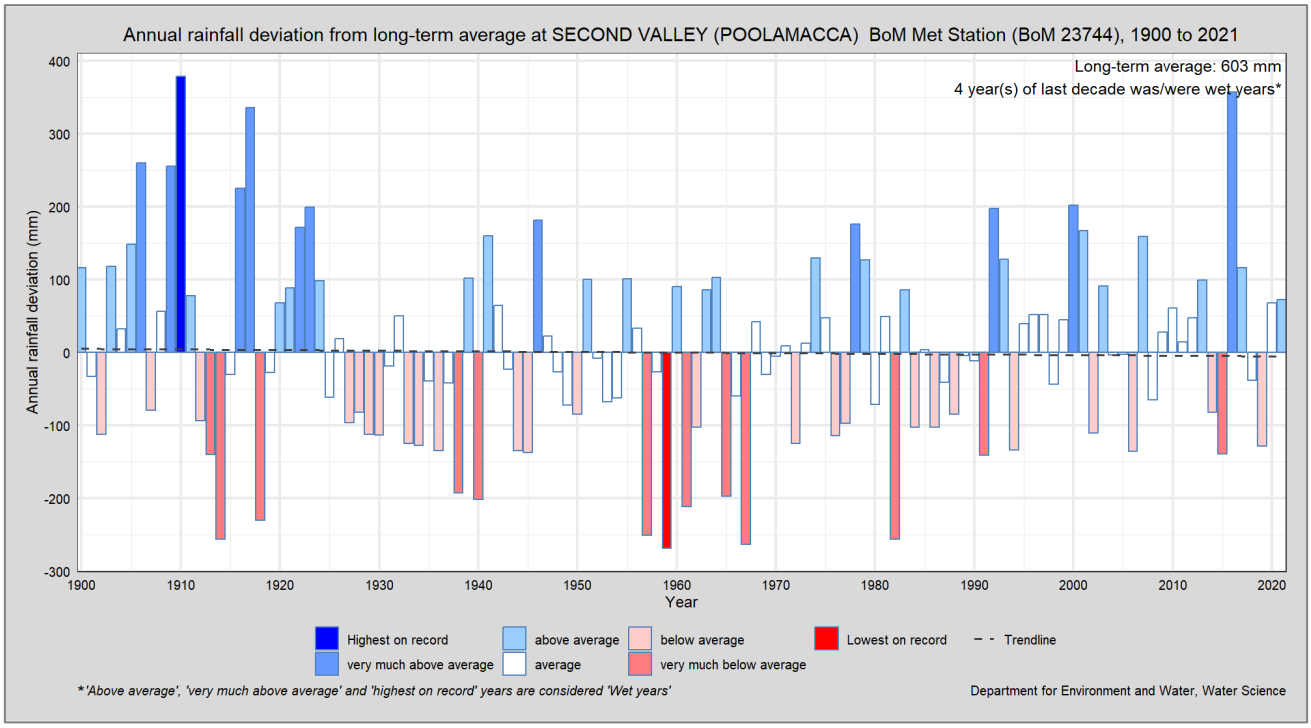


Figure 25. Deviation of annual rainfall from long-term average, Second Valley (23744)

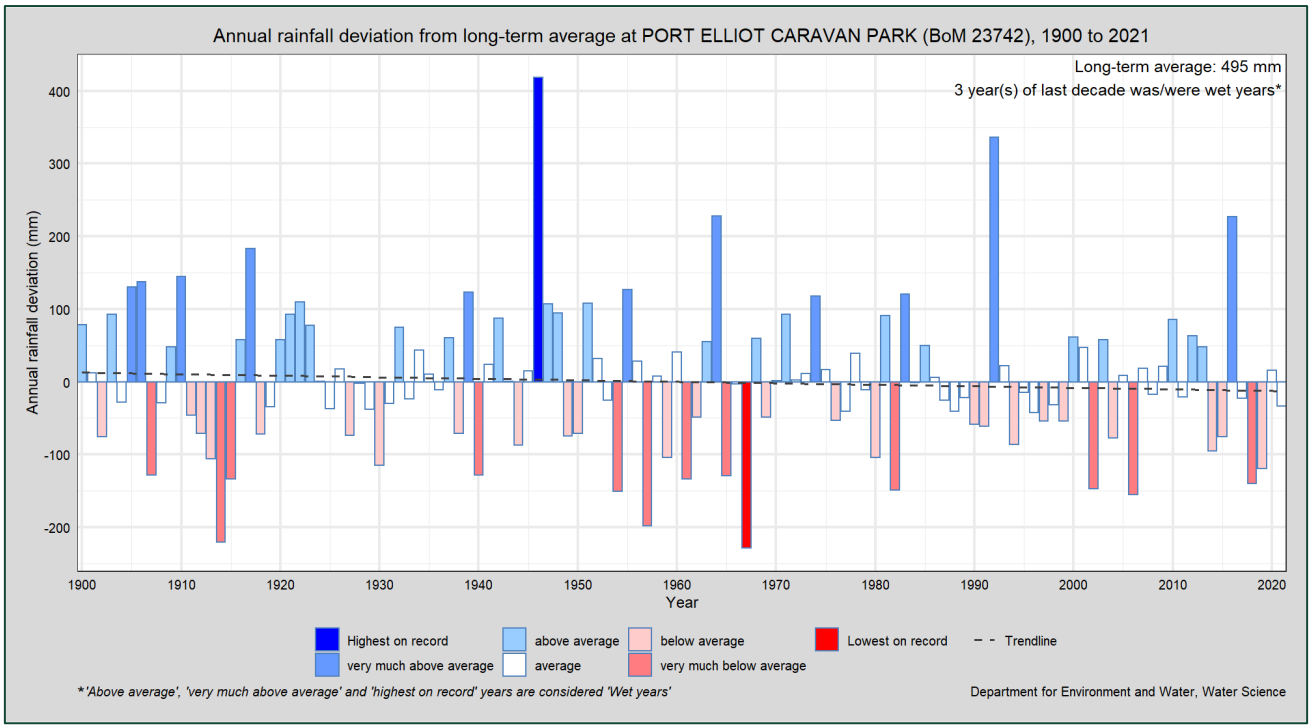


Figure 26. Deviation of annual rainfall from long-term average, Port Elliot Caravan Park (23742)

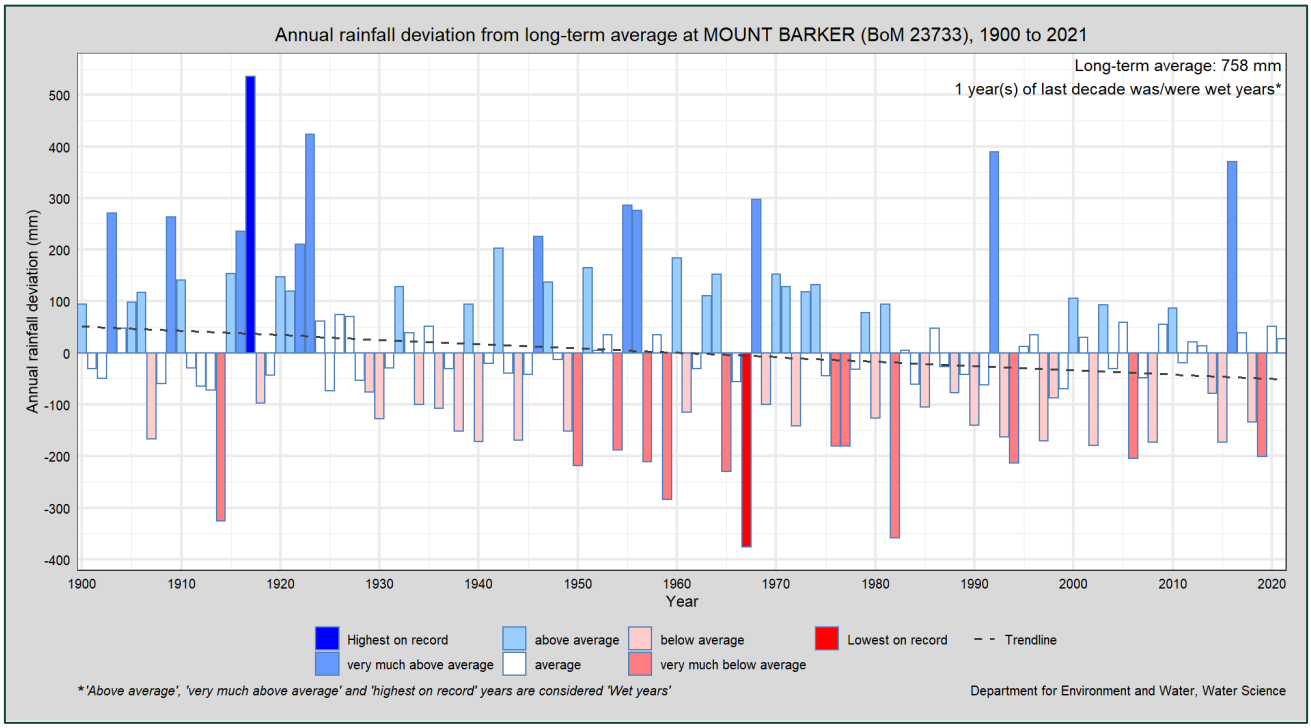


Figure 27. Deviation of annual rainfall from long-term average, Mount Barker (23733)

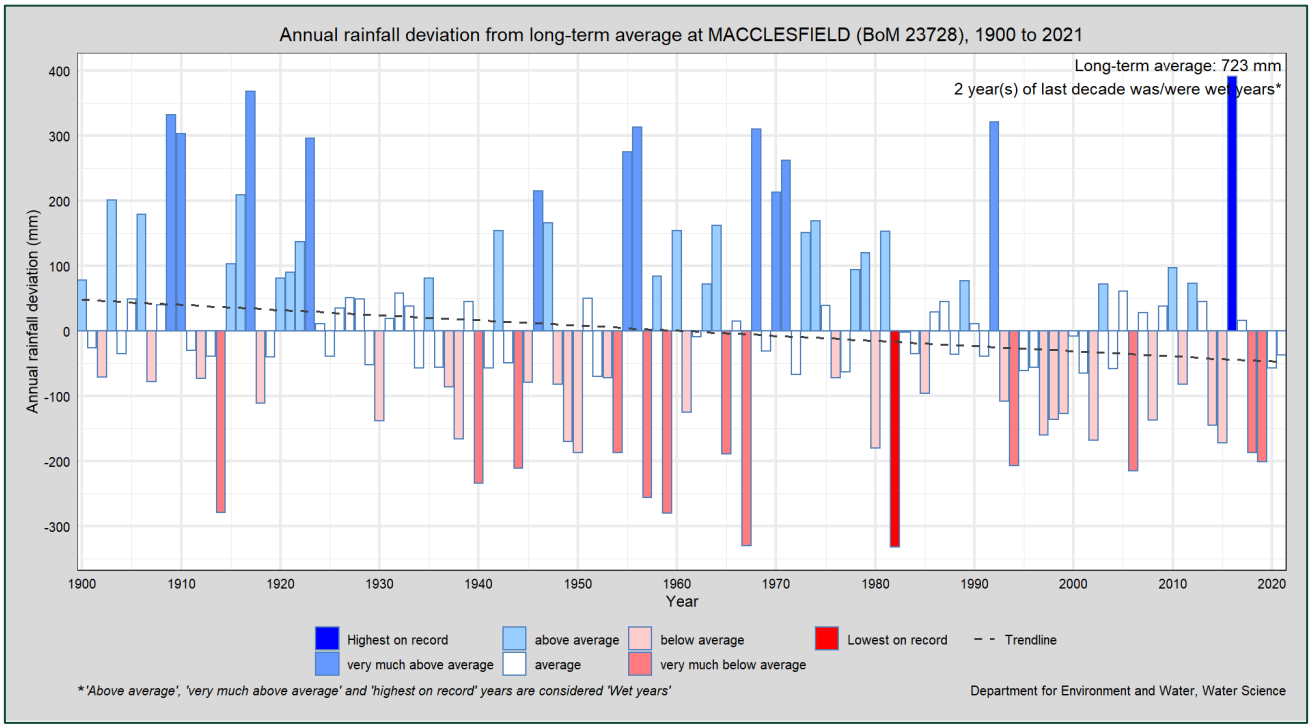


Figure 28. Deviation of annual rainfall from long-term average, Macclesfield (23728)

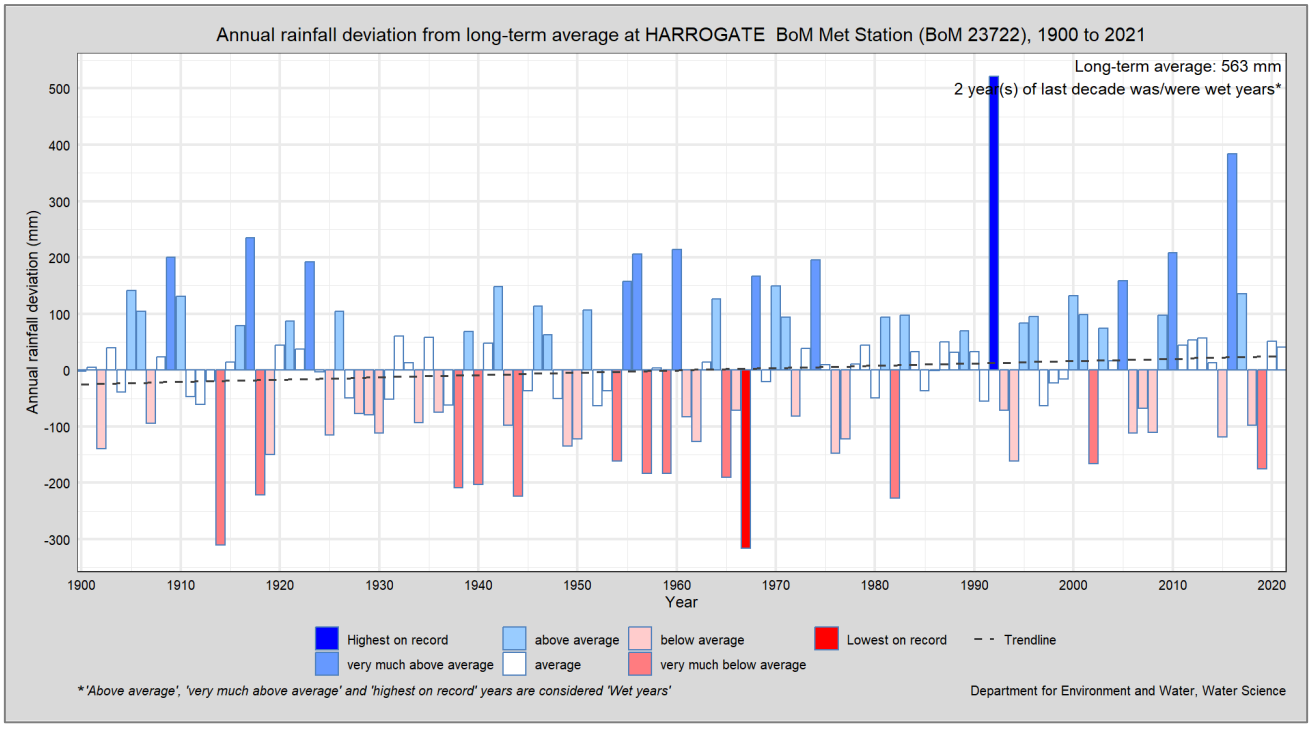


Figure 29. Deviation of annual rainfall from long-term average, Harrogate (23722)

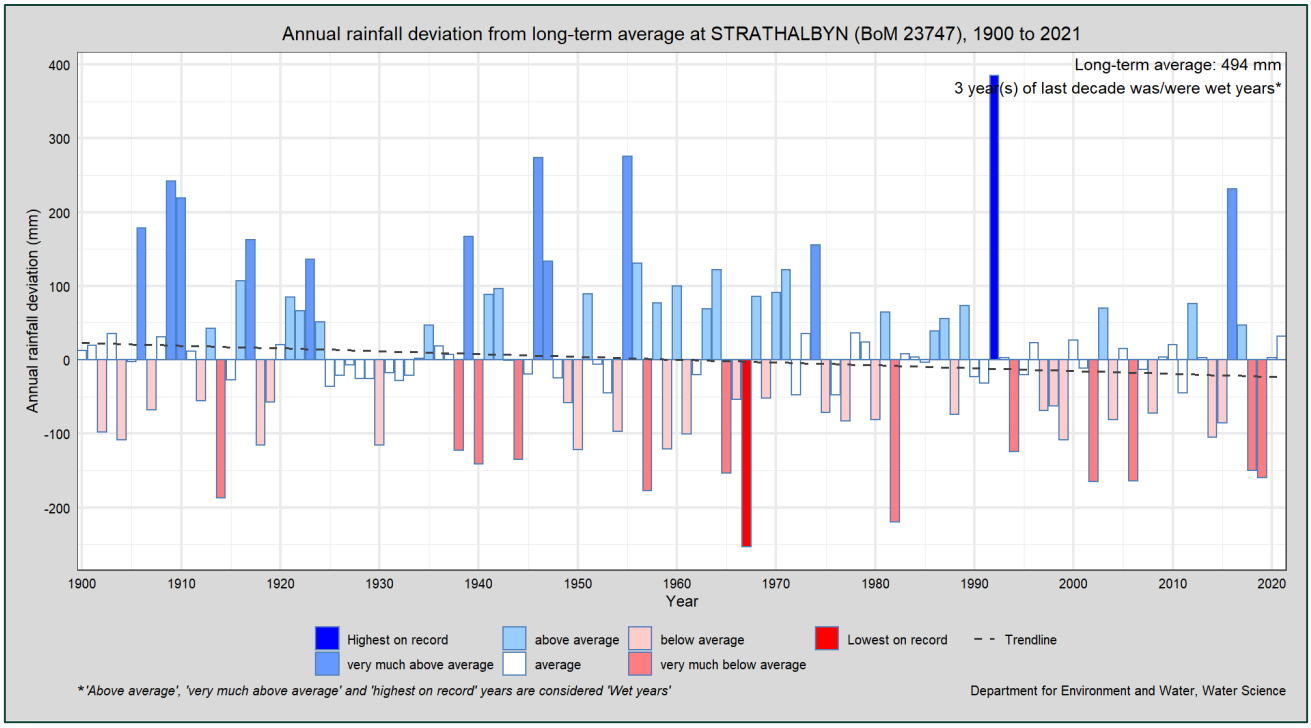


Figure 30. Deviation of annual rainfall from long-term average, Strathalbyn (23747)

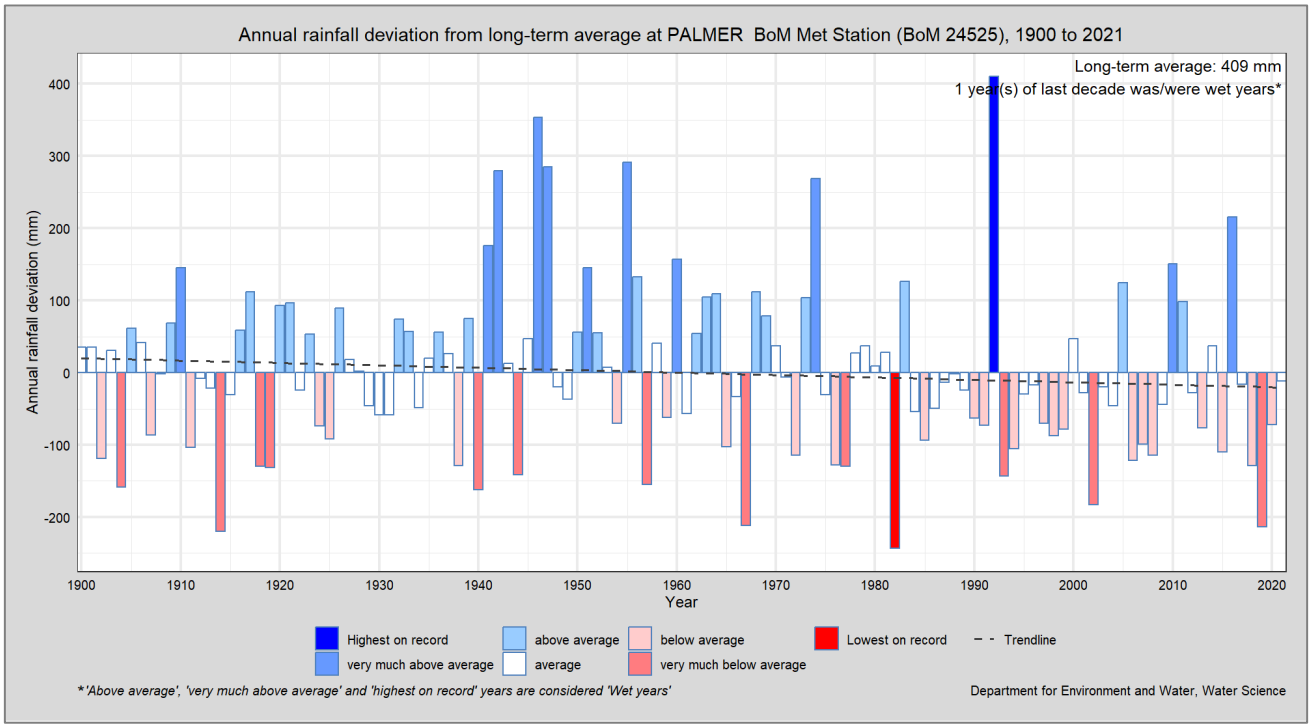


Figure 31. Deviation of annual rainfall from long-term average, Palmer (24525)

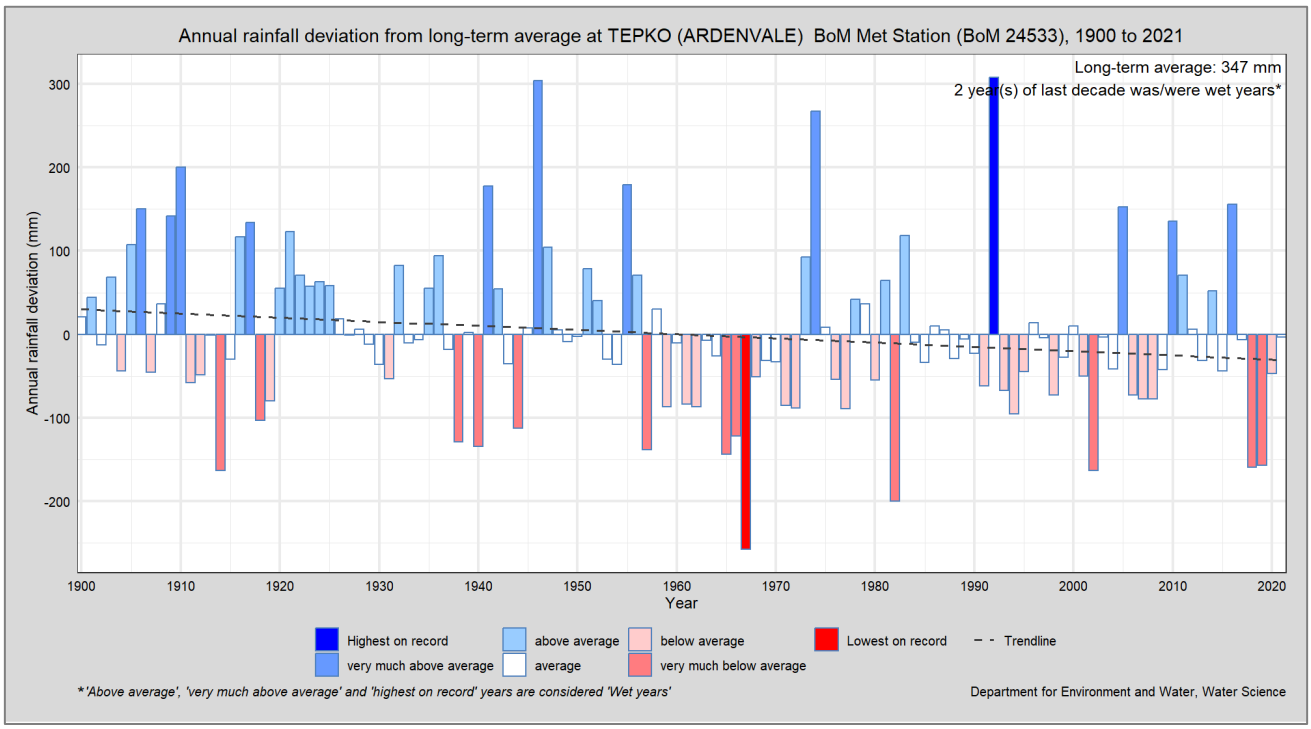


Figure 32. Deviation of annual rainfall from long-term average, Tepko (24533)

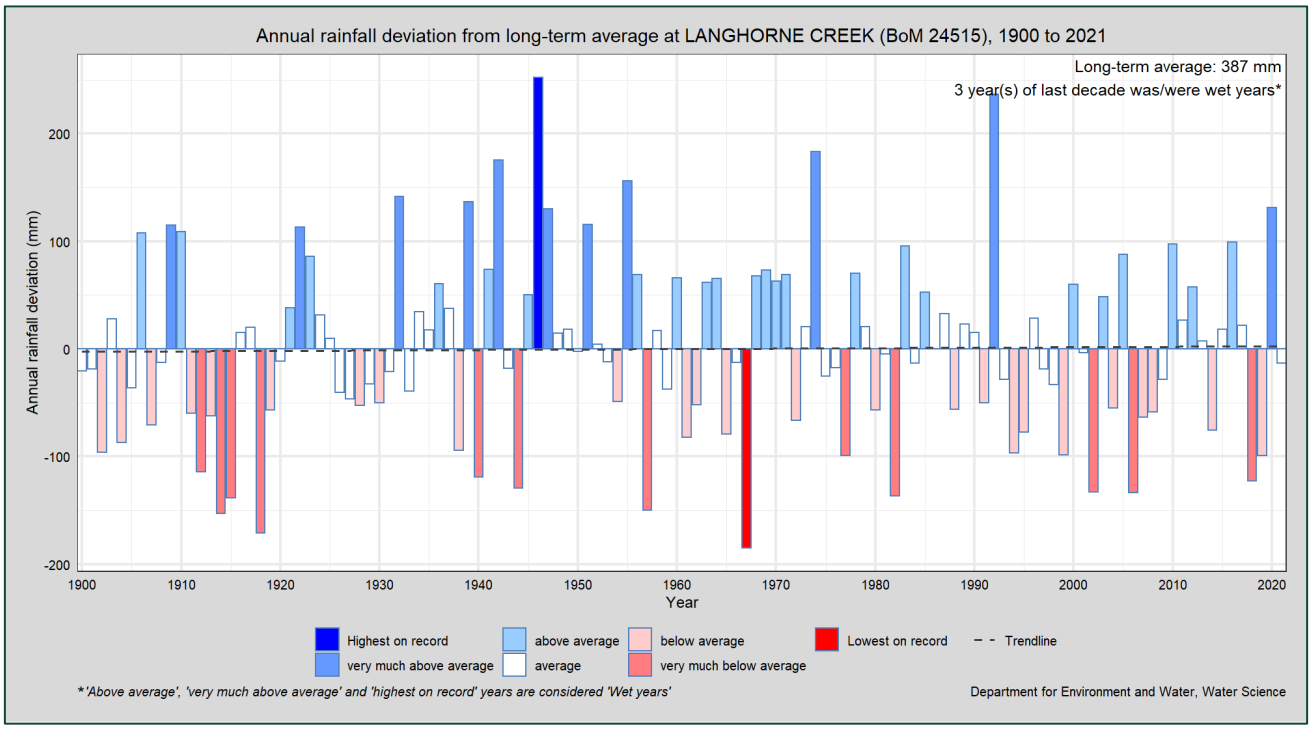


Figure 33. Deviation of annual rainfall from long-term average, Langhorne Creek (24515)

APPENDIX C Annual streamflow trends, WMLR and EMLR PWRAs

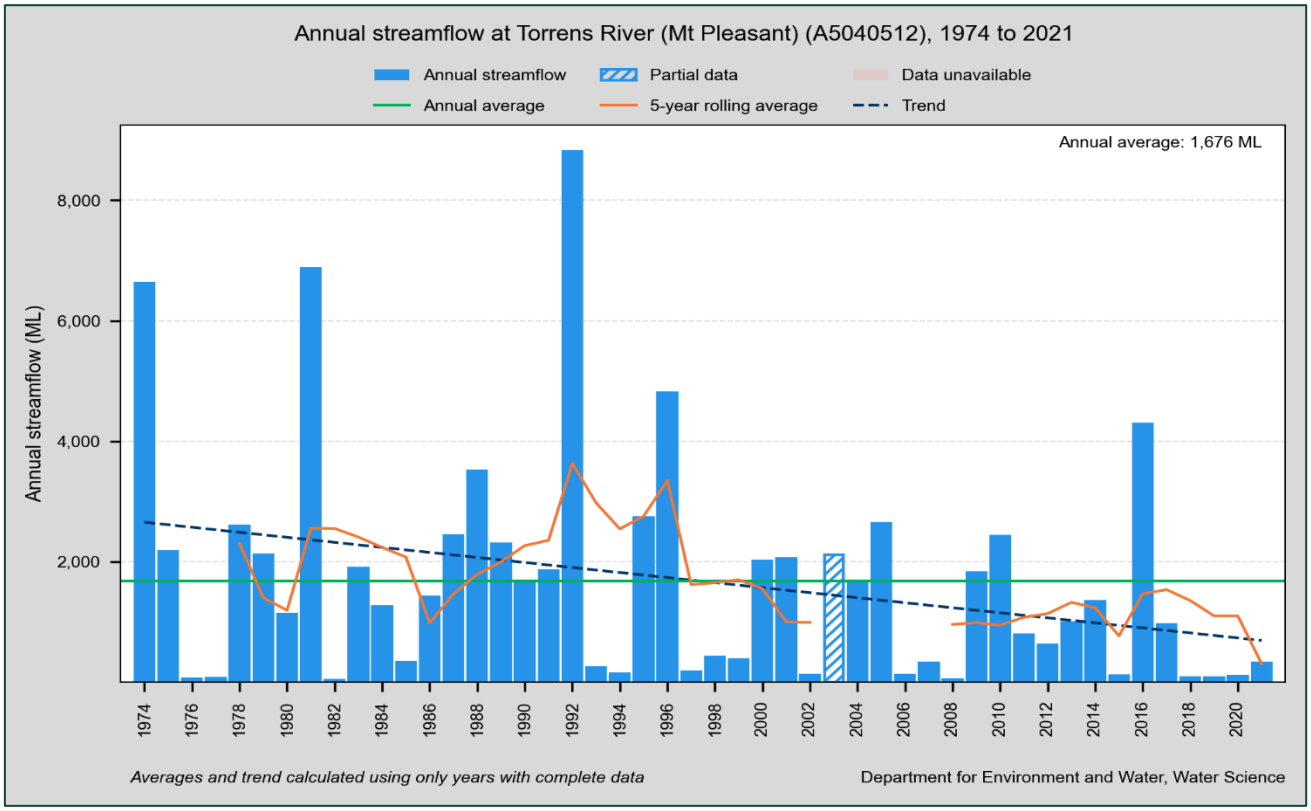


Figure 35. Annual streamflow trend, Torrens River (Mt Pleasant) (A5040512)

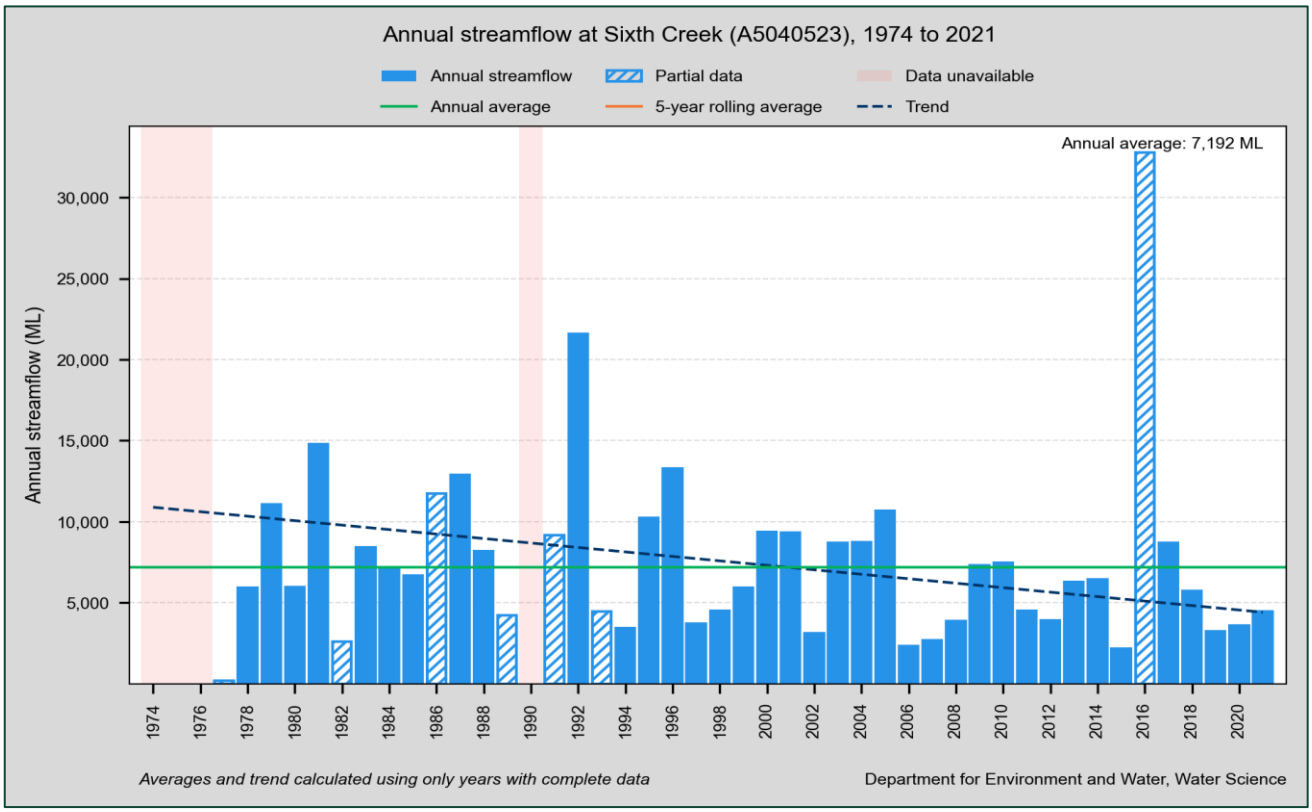


Figure 34. Annual streamflow trend, Sixth Creek at Castambul (A5040523).

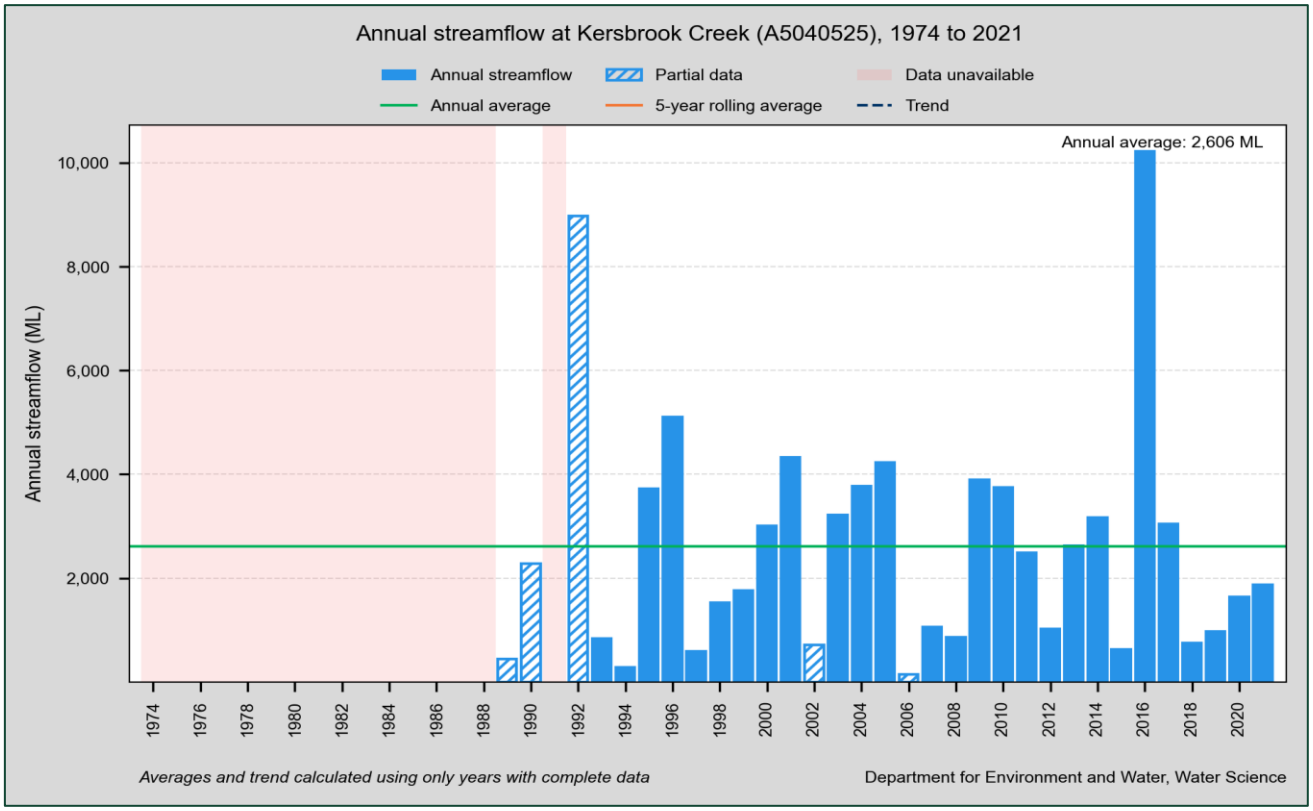


Figure 37. Annual streamflow trend, Kersbrook Creek u/s of Millbrook (A5040525)

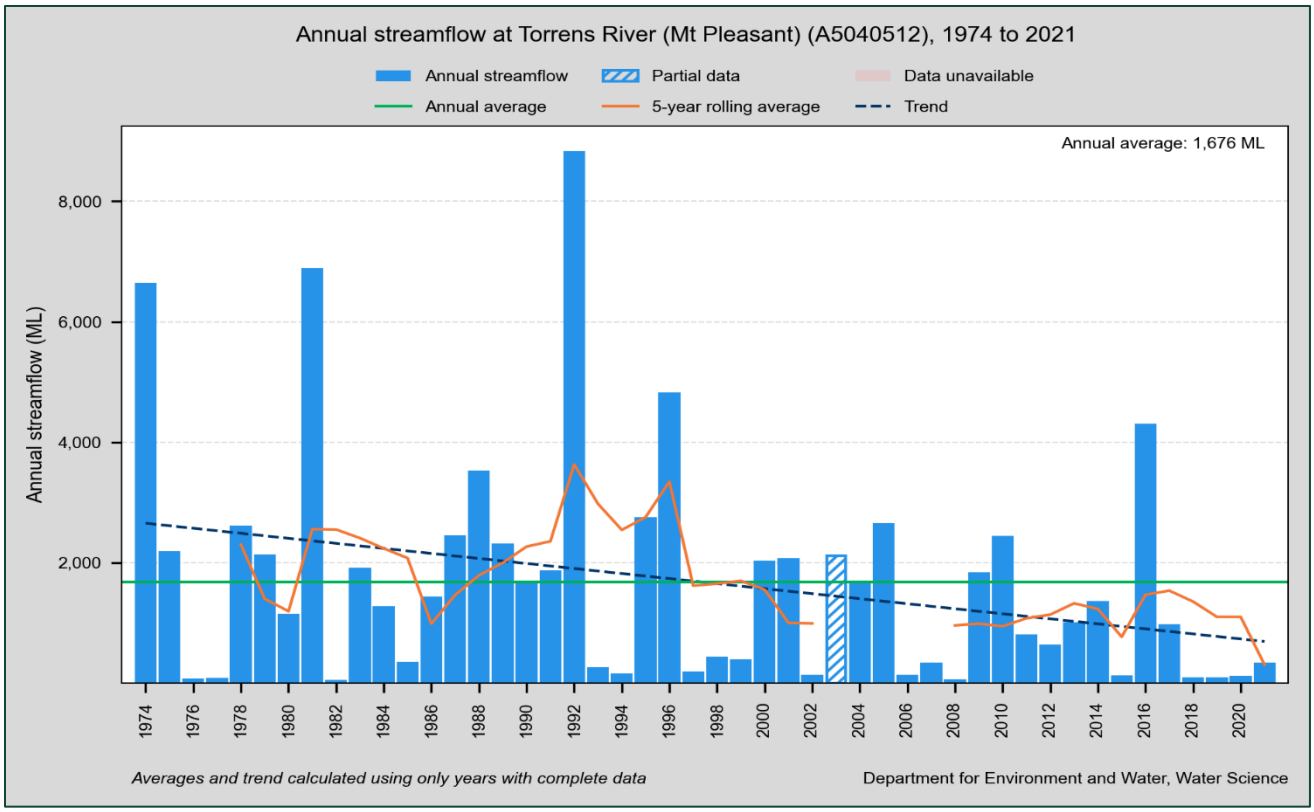


Figure 36. Annual streamflow trend, Torrens river at Mt Pleasant (A5040512)

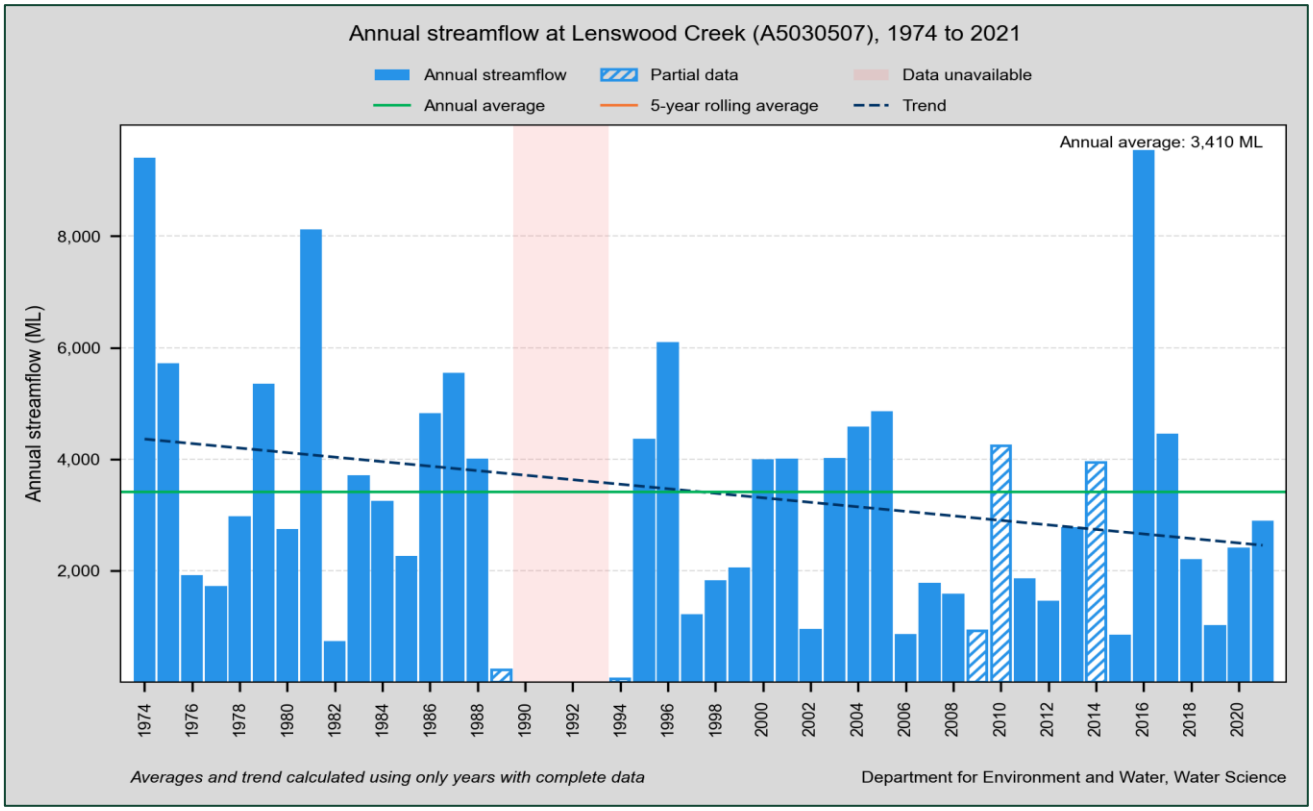


Figure 39. Annual streamflow trend, Lenswood Creek (A5030507)

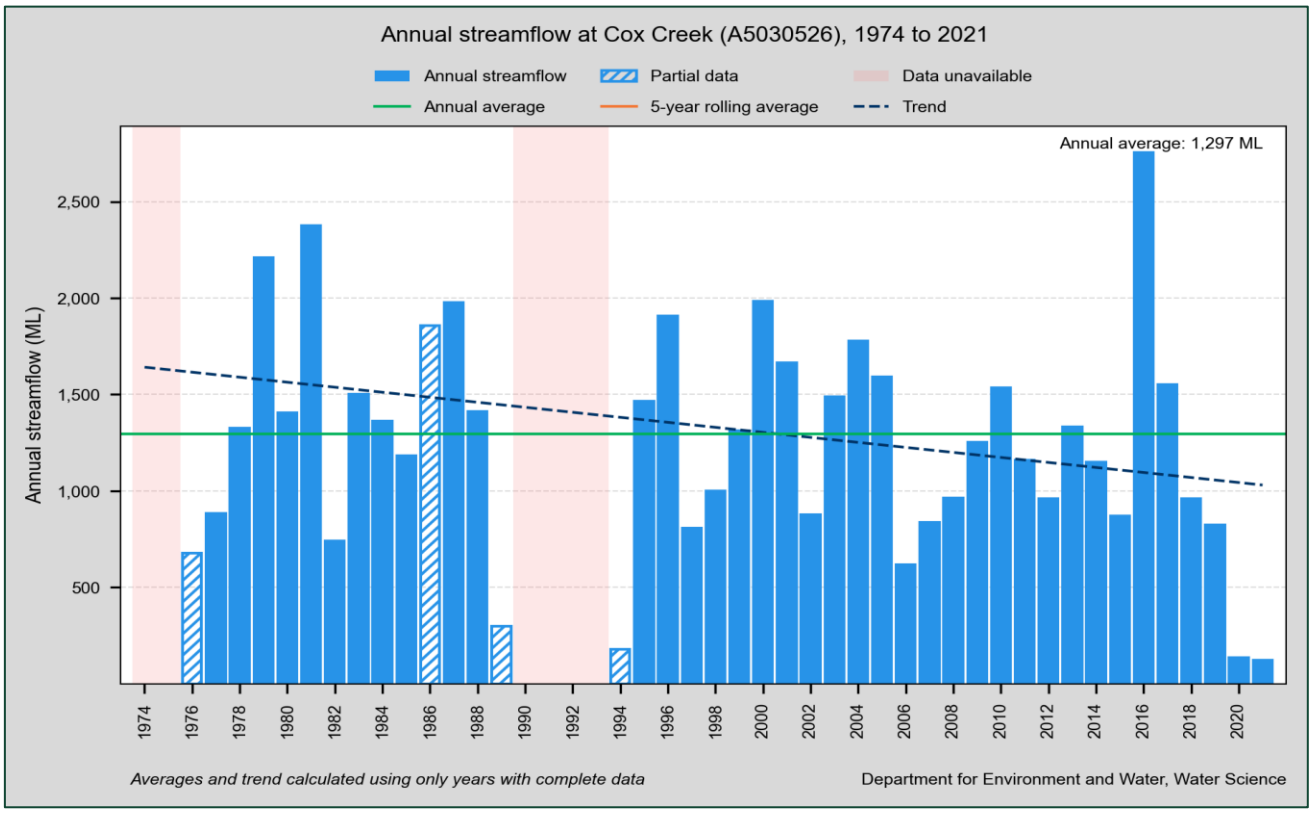


Figure 38. Annual streamflow trend, Cox Creek (A5030526)

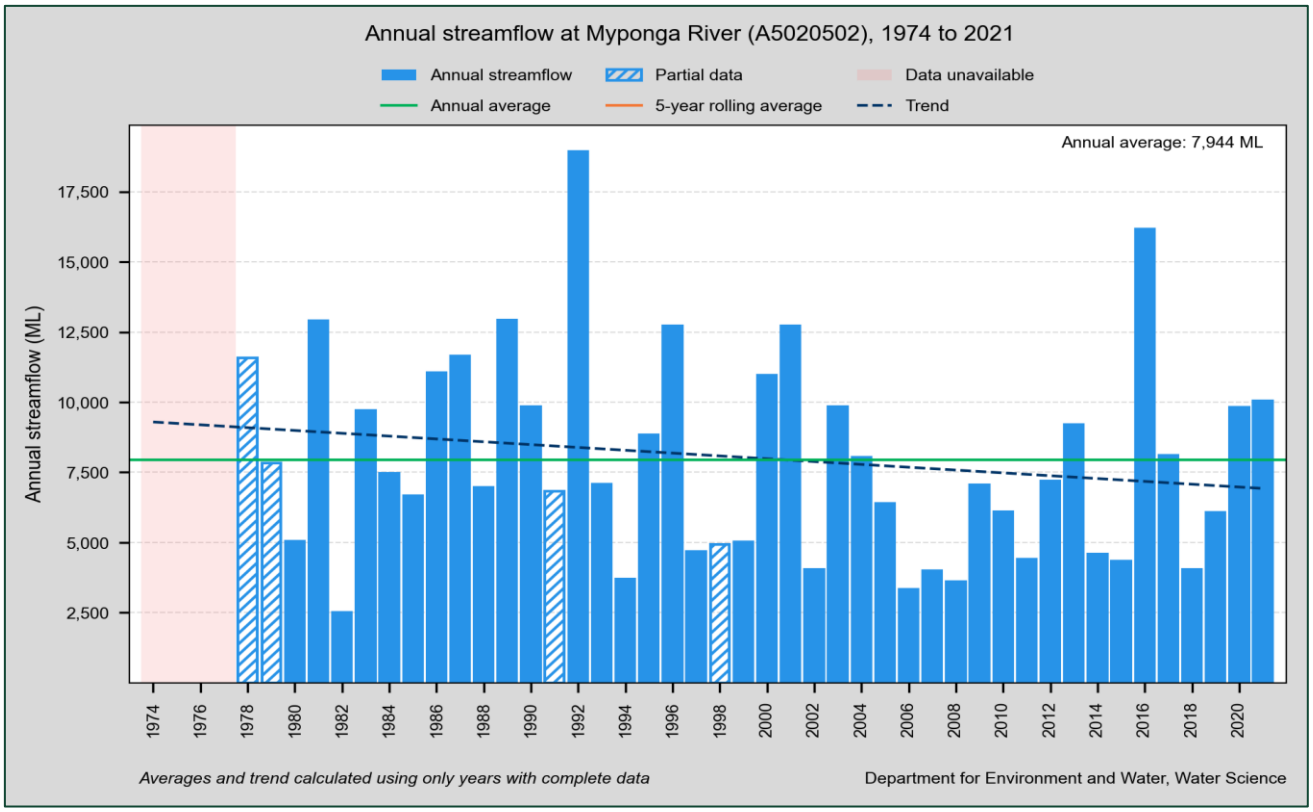


Figure 41. Annual streamflow trend, Myponga River u/s of dam (A5020502)

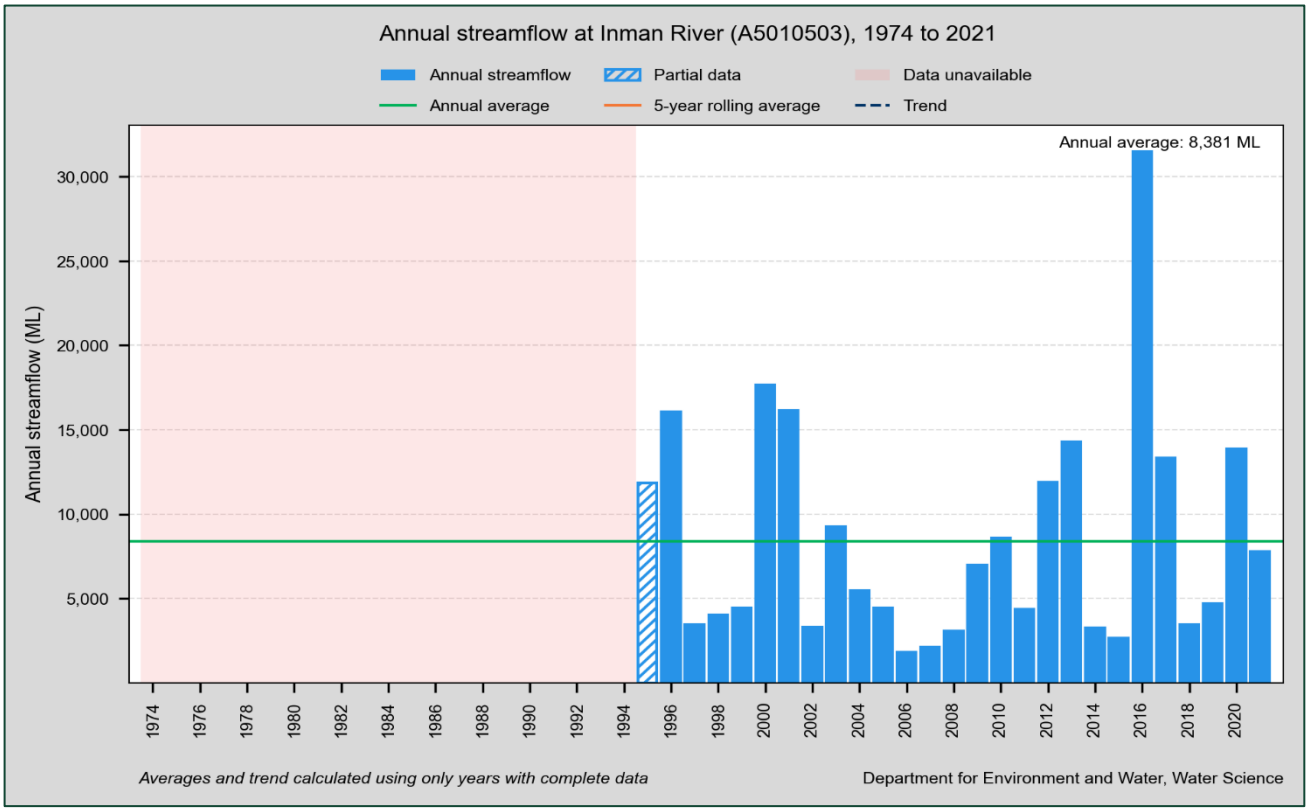


Figure 40. Annual streamflow, Inman River u/s Victor Harbor STW (A5010503)

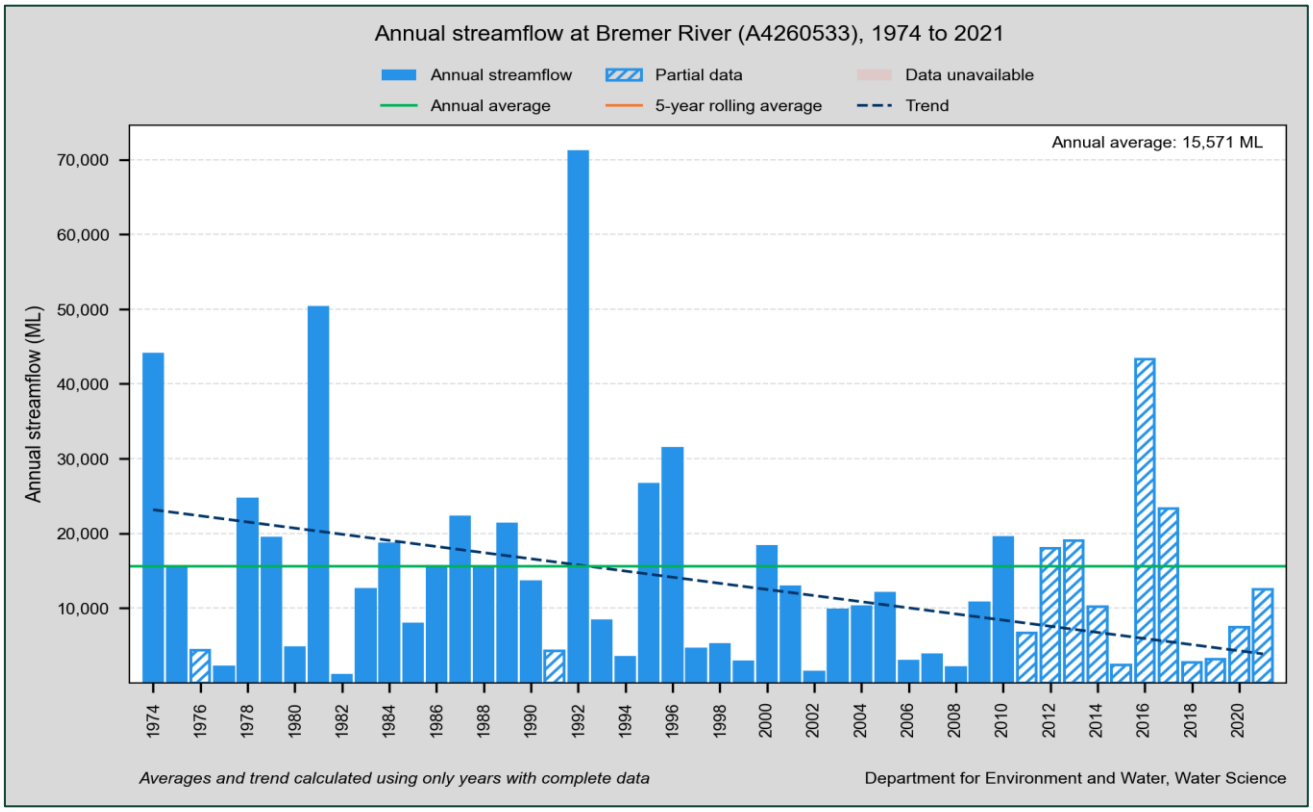


Figure 42. Annual streamflow trend, Bremer river near Hartley (A4260533)

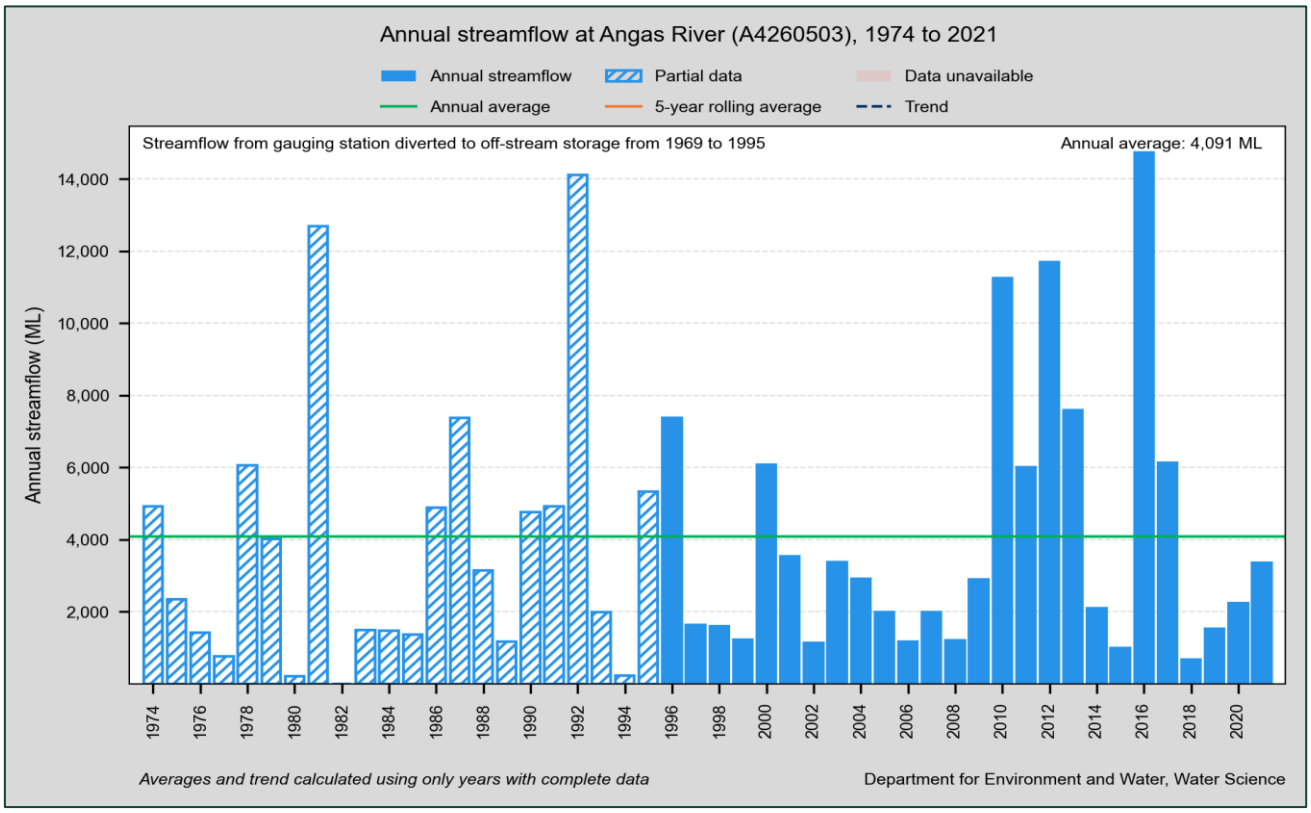


Figure 43. Annual streamflow trend, Bremer river at Angas Weir (A4260503)

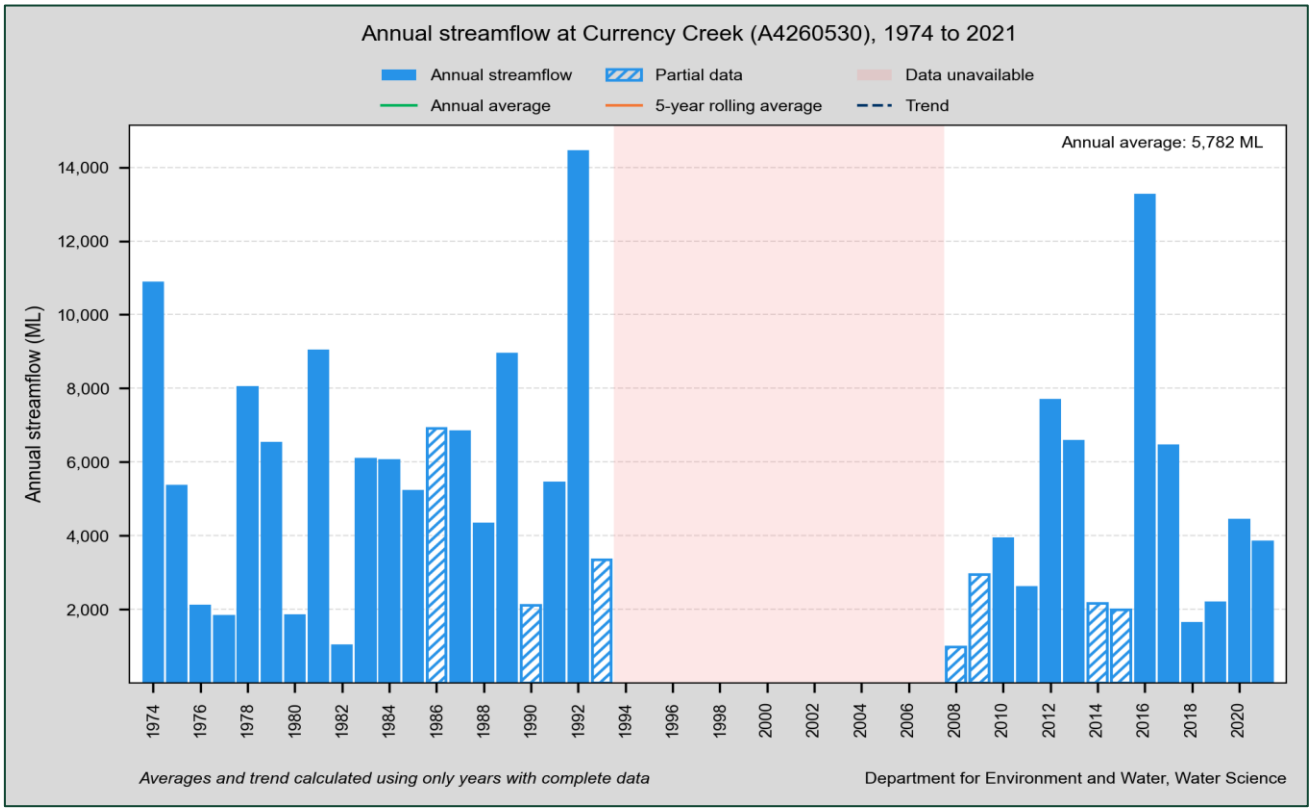


Figure 44. Annual streamflow trend, Currency Creek near Higgins (A4260530)

APPENDIX D Deviation of annual streamflow, WMLR and EMLR PWRA Reporting stations

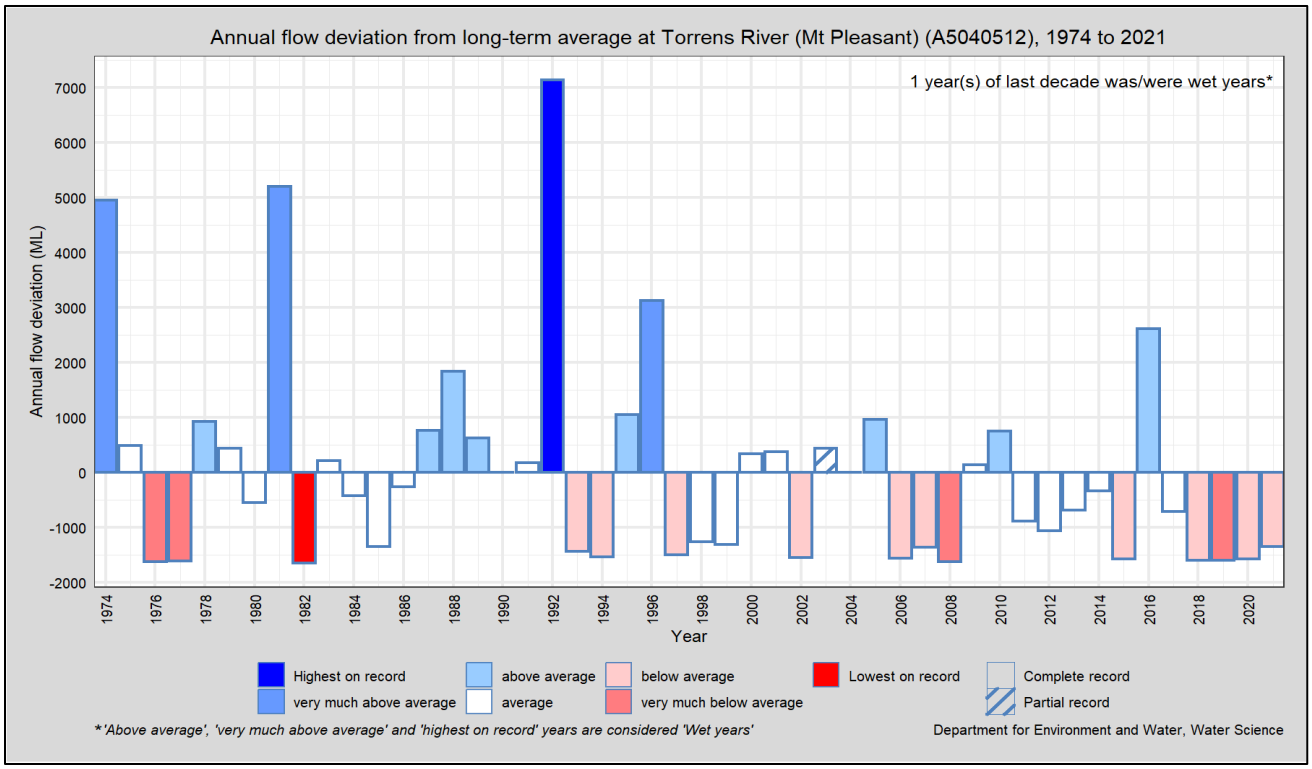


Figure 46. Deviation of annual streamflow from long-term average, Torrens river at Mt Pleasant (A5040512)

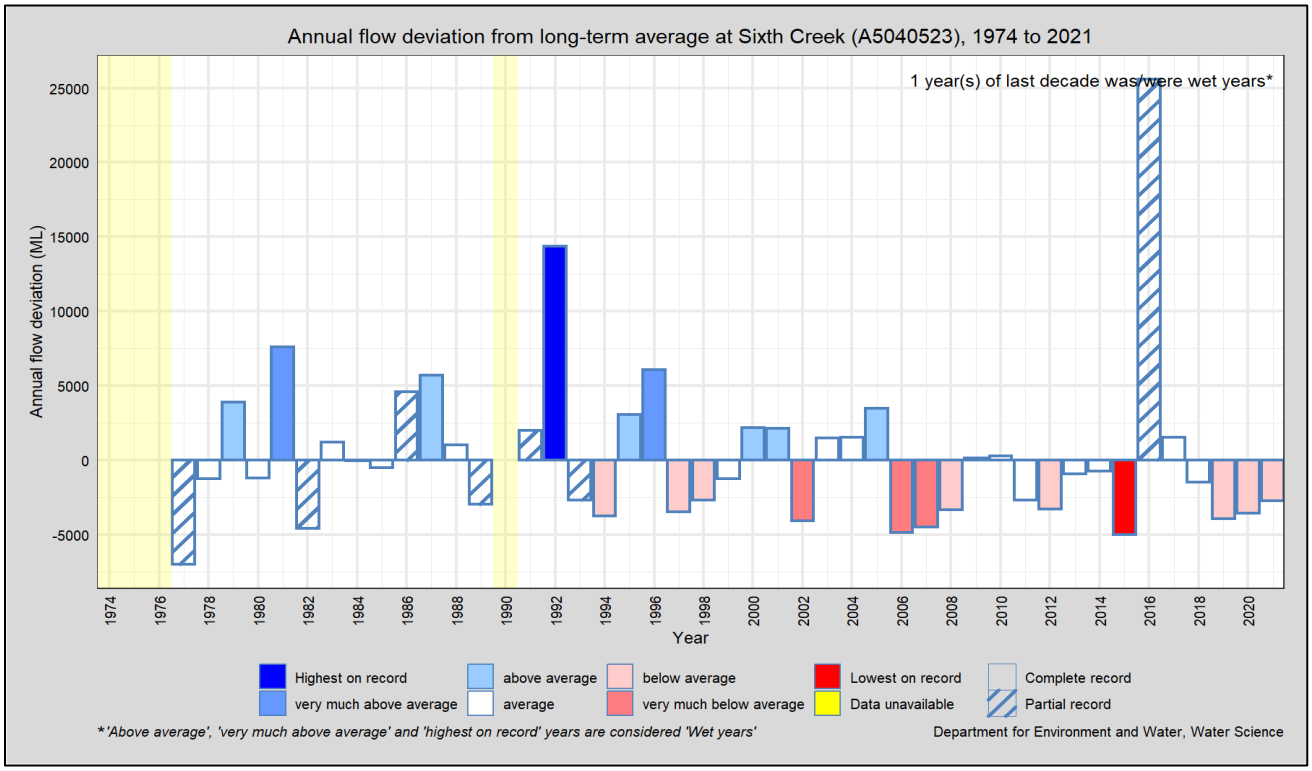


Figure 45.Deviation of annual streamflow from long-term average, Sixth Creek at Castambul (A5040523)

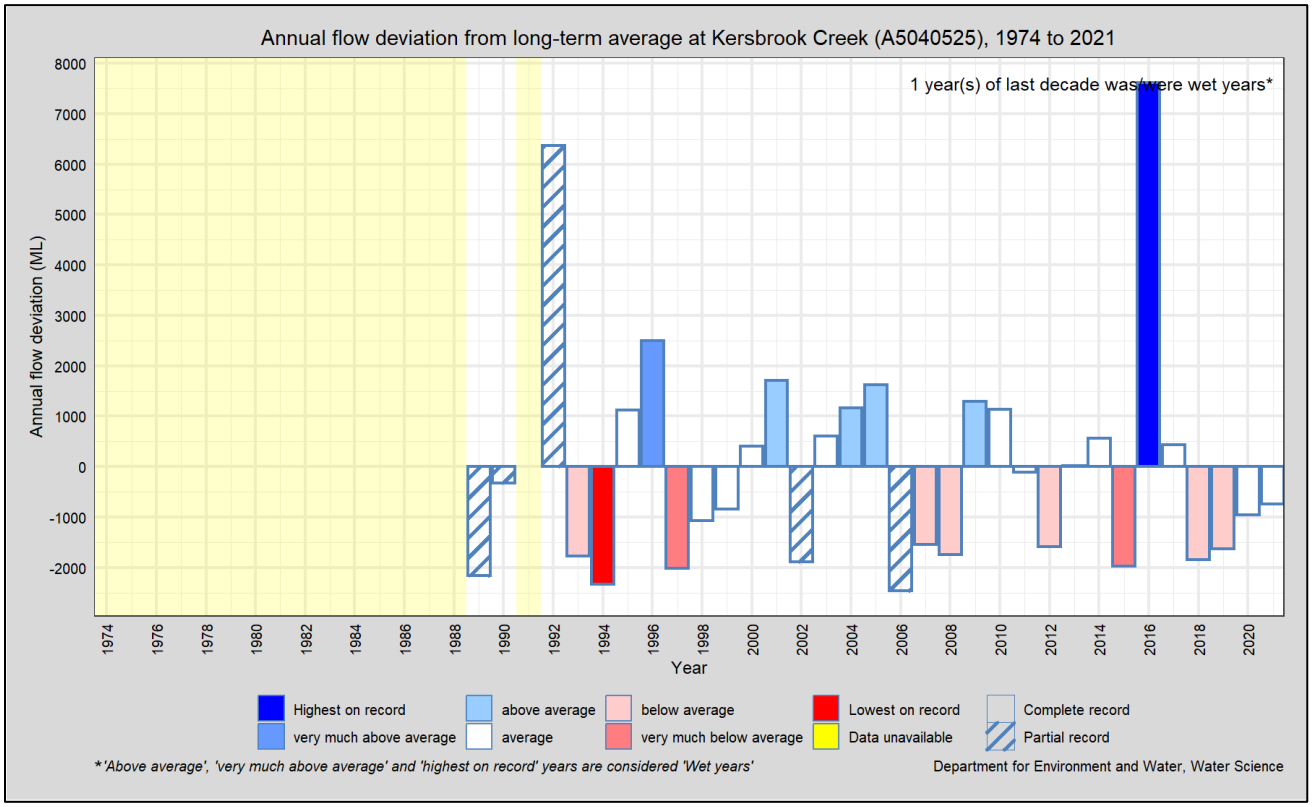


Figure 48. Deviation of annual streamflow from long-term average, Kersbrook creek u/s of Millbrook (A5040525)

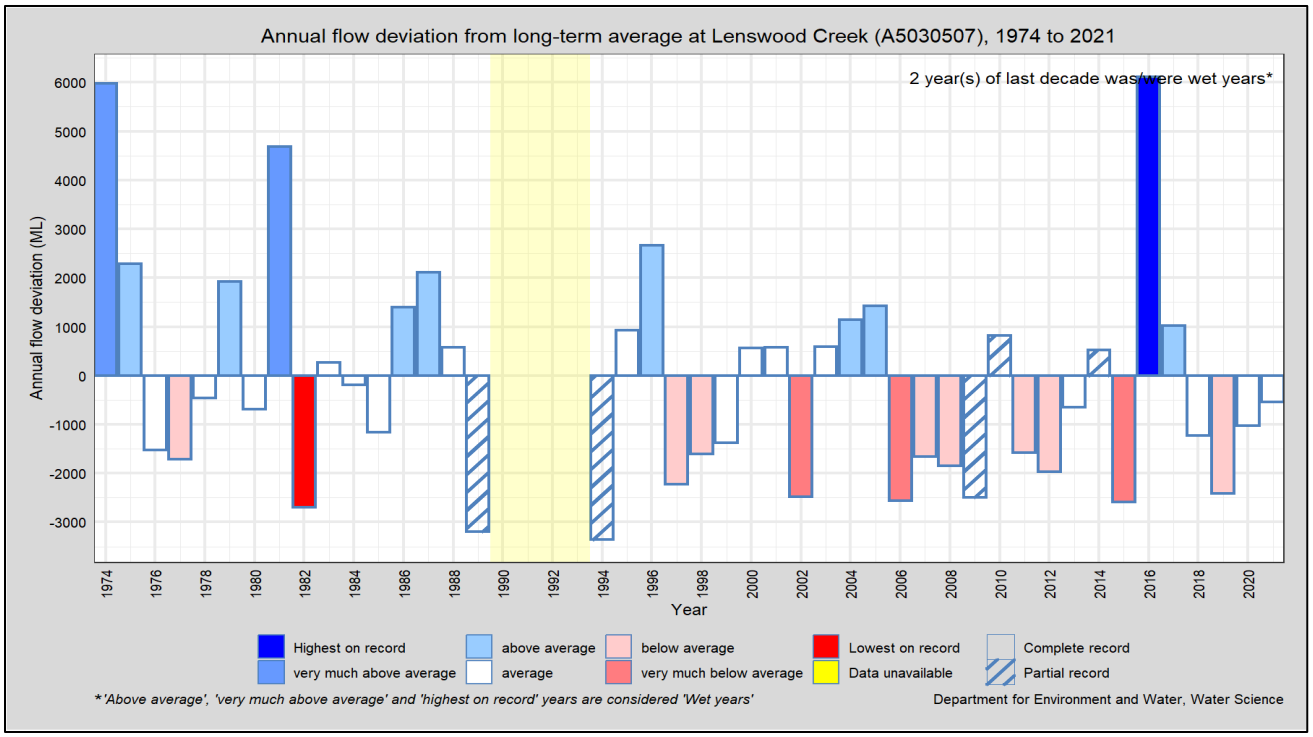


Figure 47. Deviation of annual streamflow from long-term average, Lenswood Creek at Lenswood (A5030507)

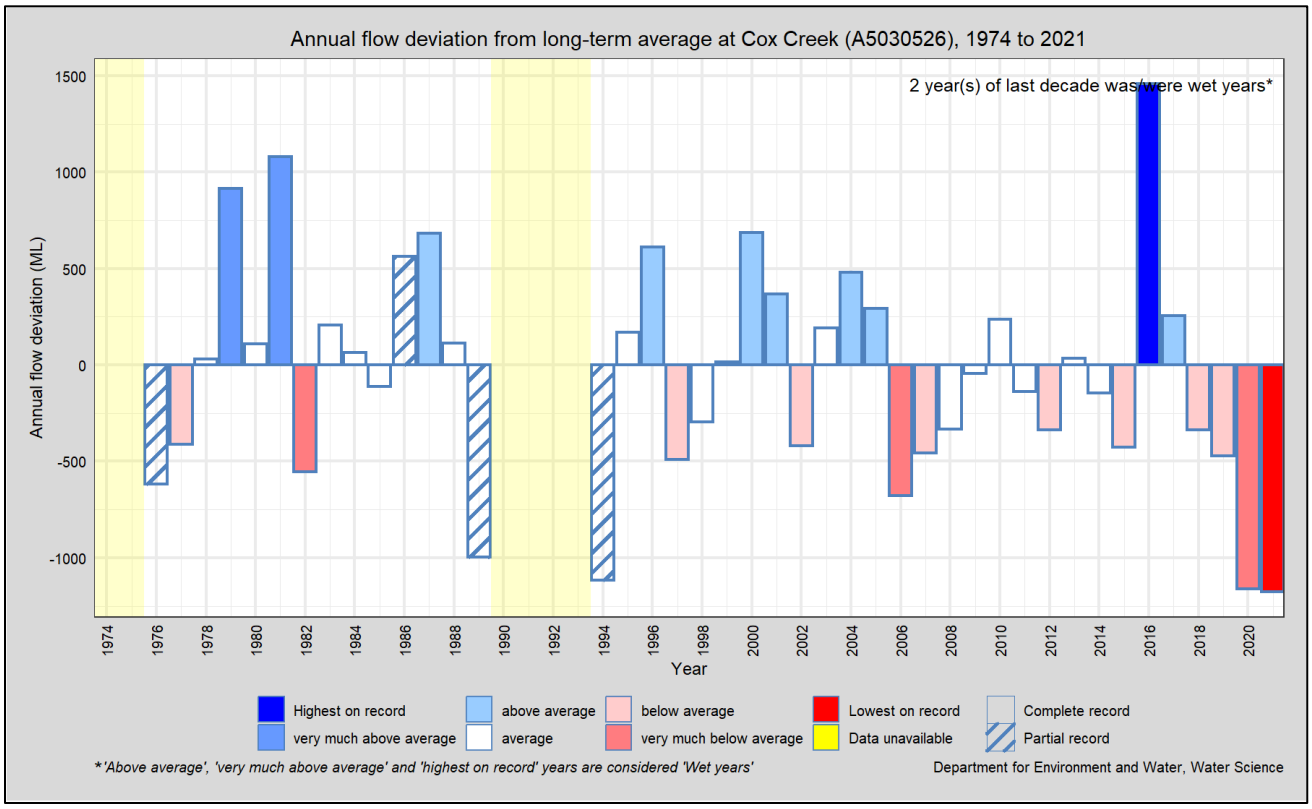


Figure 50. Deviation of annual streamflow from long-term average, Cox creek at Uraidla (A5030526)

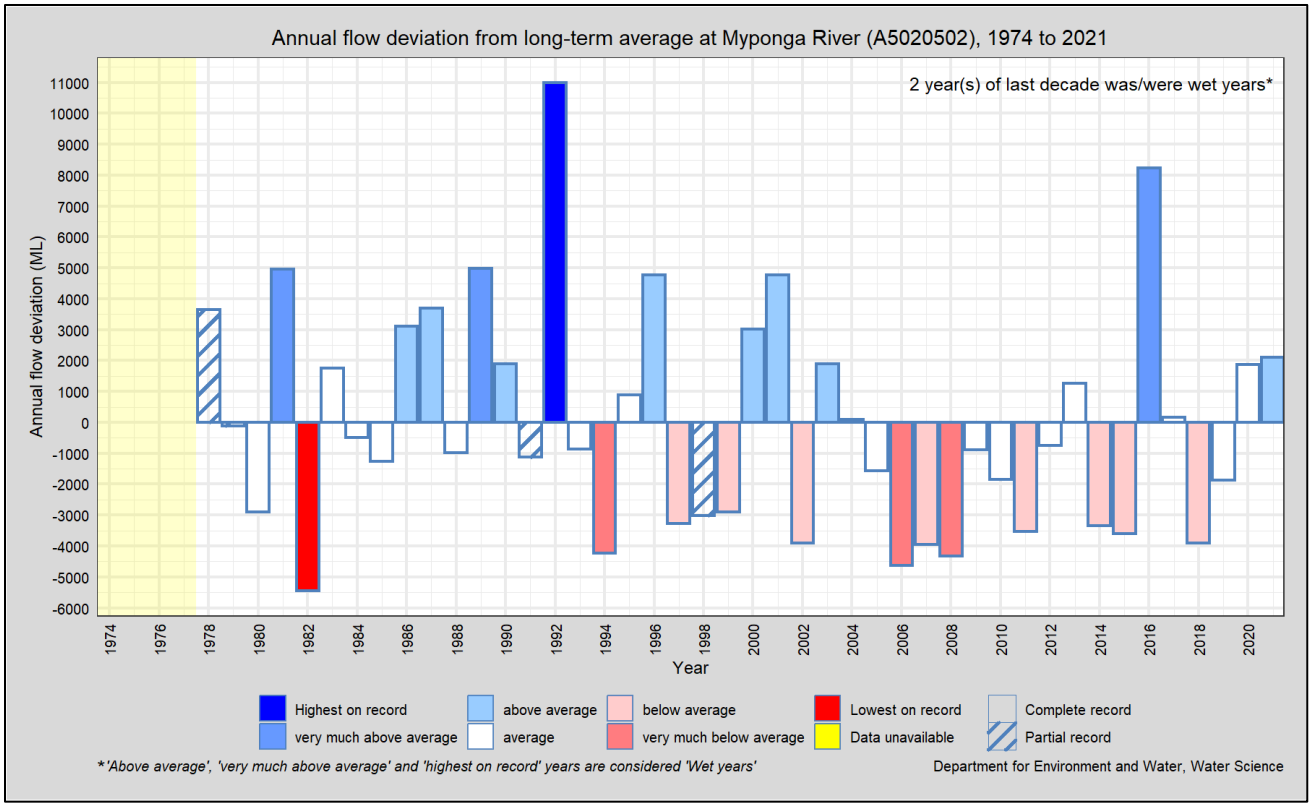


Figure 49. Deviation of annual streamflow from long-term average, Myponga River u/s of Dam (A5020502)

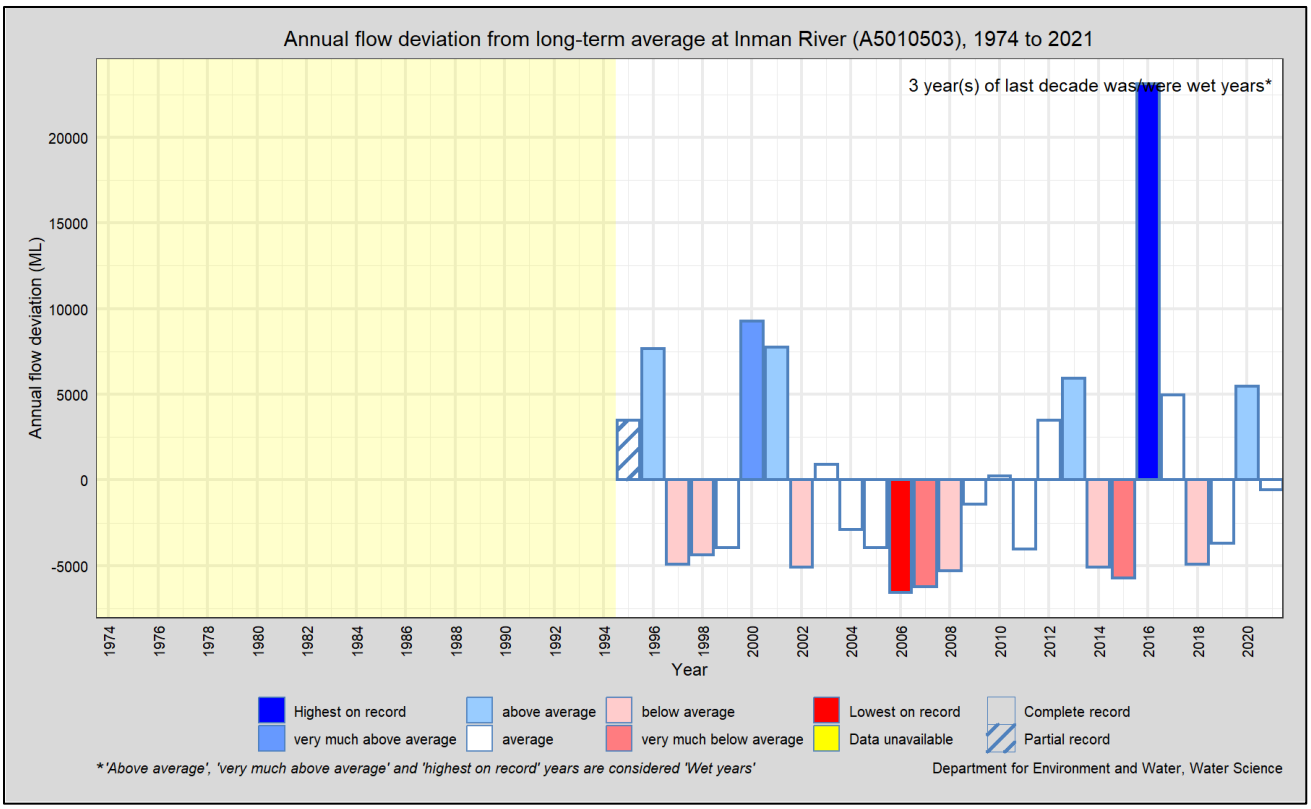


Figure 52. Deviation of annual streamflow from long-term average, Inman River u/s Victor Harbour STW (A5010503)

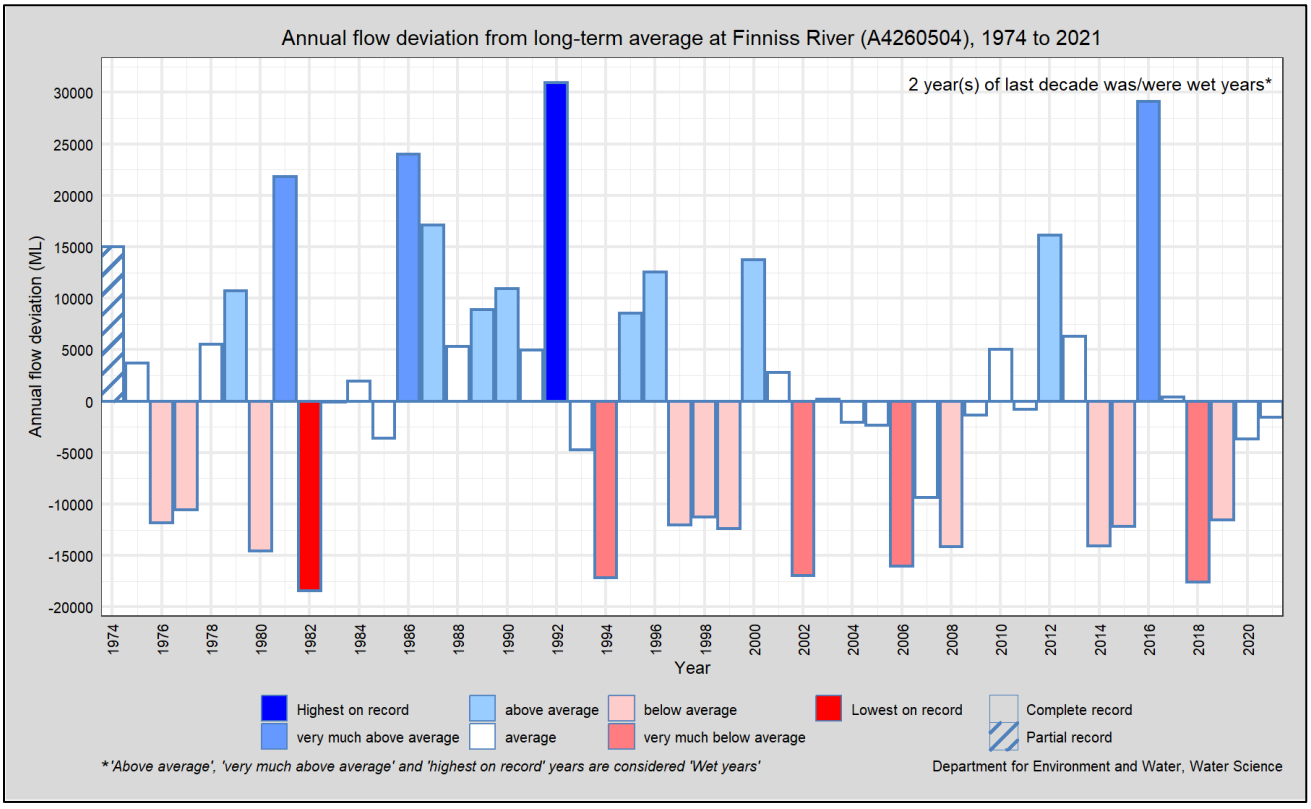


Figure 51. Deviation of annual streamflow from long-term average, Finniss river at Yundi (A4260504))

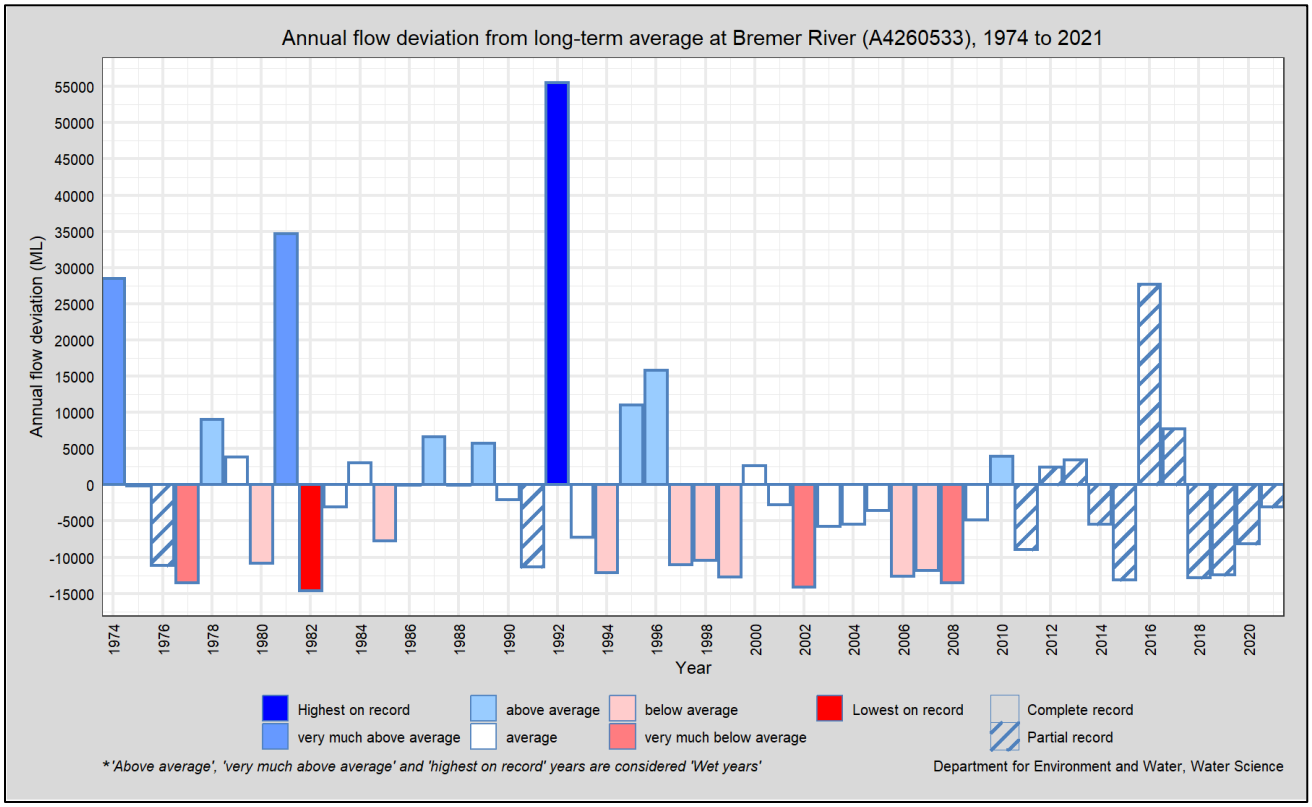


Figure 54. Deviation of annual streamflow from long-term average, Bremer River near Hartley (A4260533)

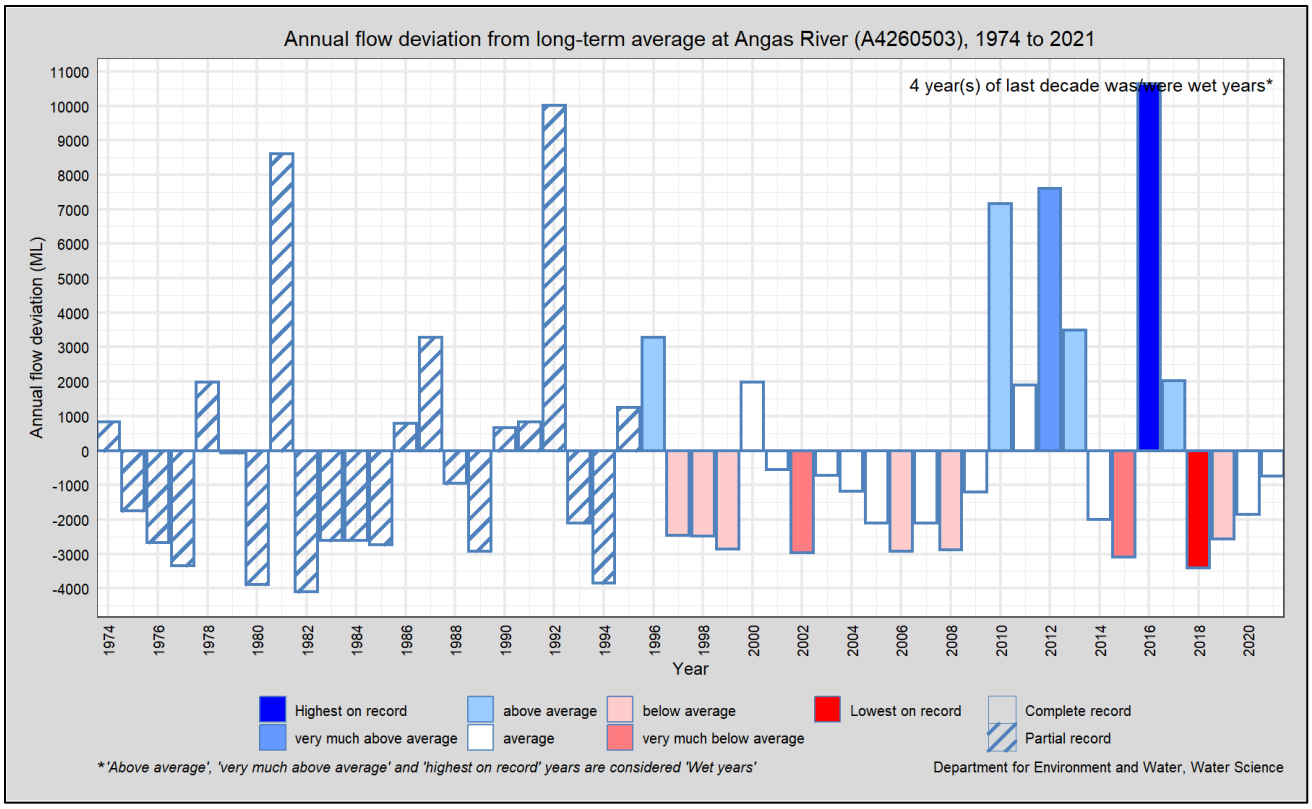


Figure 53. Deviation of annual streamflow from long-term average, Angas river at Angas Wier (A4260503)

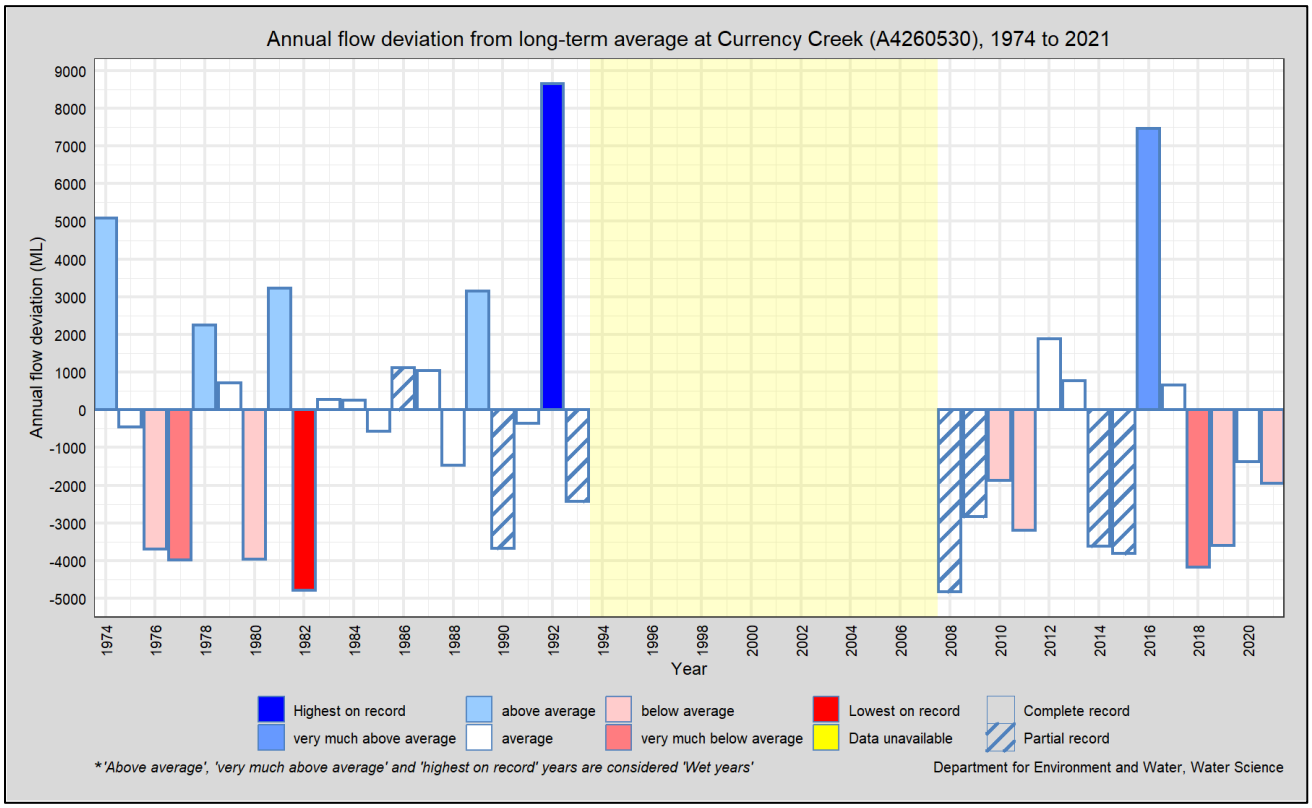


Figure 55. Deviation of annual streamflow from long-term average, Currency Creek near Higgins (A4260530)

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[i] Water Allocation Plan for the Western Mount Lofty Ranges Prescribed Water Resources Area, Adelaide and Mount Lofty Ranges Natural Resources Management Board, Government of South Australia, 2013.

[ii] Water Allocation Plan for the Eastern Mount Lofty Ranges Prescribed Water Resources Area, South Australian Murray-Darling Basin Natural Resources Management Board, Government of South Australia, 2013.

iii Bureau of Meteorology Rainfall Map information http://www.bom.gov.au/climate/austmaps/about-rain-maps.shtml

[iv] Savadamuthu et al., 2023. *Changing climate and the uncertainties in allocating water for consumption and environment needs in highly developed catchments*. Department for Environment and Water, Government of South Australia, Adelaide. 25th International Congress on Modelling and Simulation, Darwin, NT, Australia, 9 to 14 July 2023.

[v] Department for Environment and Water (2022). *Modelling the impacts of current water use, urban development and climate projections on surface water resources in the Barossa Prescribed Water Resources Area*, DEW-TR-2022-13, Government of South Australia, Department for Environment and Water, Adelaide.