

2 Geology of Timor West

The Timor West targeted area is a region of complex geology and hydrology where dryland salinity is a major concern (Day 1985). The important geological units include Ordovician metamorphosed siltstone and sandstone, Devonian granite, Shepparton Formation, sub-surface Miocene basalt and Tertiary deep leads (Figure 3).

Devonian granite and its associated metamorphic aureole, outcrop in the centre of the Timor West targeted area (Mount Hooghly), with broad alluvial plains extending to the south and east. The plains separate two steep prominent metamorphic ridges the Bealiba and Black ranges.

The Black Range is found on the eastern edge of a batholith of Devonian granite. Surrounding this is a metamorphic aureole consisting predominantly of muscovite schist, hornfels, slates and quartzites. This is skirted on both sides by colluvial aprons onto alluvial upland landscape (Day 1985).

Beginning at Dunluce a wide alluvial valley stretches south between the metamorphic ridges of the Black Ranges and Mount Hooghly, branching down between Bet Bet and Emu creeks. The deep alluvium cover reaches depths of up to 80 m and contains occasional limestone deposits at shallow depth.

A small area of basalt outcrops near Wareek. A 15 m thick tongue of basalt buried beneath 5–15 m of alluvium extends eastwards through the Bet Bet Valley. There are remnant Tertiary gravels capping hills in the Dunluce area and buried Tertiary deep lead sediments beneath the alluvium of the Bet Bet Valley. These include the Madam Hopkins and Bet Bet deep leads (Day 1985).

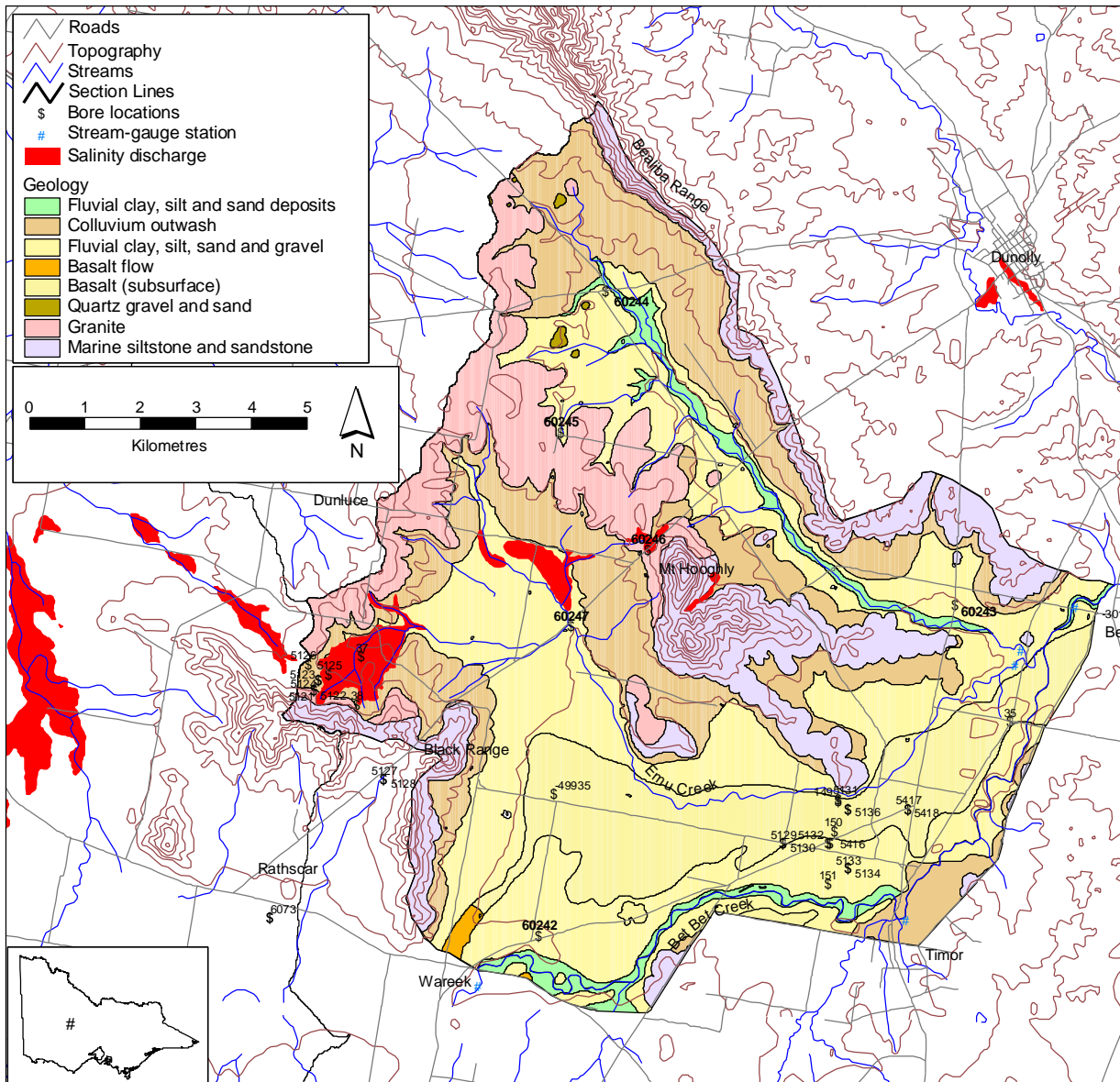


Figure 3 Map of geology of the Timor West targeted area

Current groundwater trends in Timor West

There are 19 groundwater monitoring bores across the Timor West targeted area with six new bores installed to fill the gaps in the groundwater monitoring network. A primary aim of long-term groundwater monitoring is to detect changes in groundwater trends that may be attributable to land use change or the adoption of certain land management practices. It is a feature of the Timor West targeted area that strong groundwater fluctuations are observed in hydrographs as groundwater systems in the area tend to be very responsive to local climatic variation.

Representative hydrographs in the Timor West area show groundwater response in the different aquifers. Bores 5121-22 (Appendix 1) show that the metamorphic ridge around the Black Range is highly responsive to climatic variation.

Fluctuations in the groundwater level of 2–3 m can occur during times of high rainfall, with the sharp drop in water level (seen as a trough in the hydrograph) indicating that the groundwater moves quickly. The hydrograph for 5121-22 shows a strong falling trend since 1997, which is indicative of groundwater trends in response to the period of low rainfall for the Timor West area.

Bore 37 (Appendix 1) shows very strong fluctuations in water level, as groundwater levels are less than 1 m from the ground surface. This bore is 18 m deep, indicating possible upward groundwater pressure. Bores 5123-24, like 5121-22, rise and fall in response to climatic variation, but are less amplified. When rainfall

was high in the late 1980s, when rainfall was high, water levels began to rise, in some cases by 3 m in three years (e.g. Bores 5125, 5123-24). Water levels began to fall dramatically in 1996, when annual rainfall was below average.

Bore 5125 exhibits groundwater trend behaviour indicative of high recharge in a deeply weathered, fractured rock aquifer, typical of the metamorphic ridges in the Timor West area. The strong peaks and sharp falls indicate a groundwater system that is very responsive to local climatic variation and recharge occurs quickly. However, the Shepparton Formation has a more subdued response and slower recharge rate as seen in the hydrographs for Bores 5133-34 (Appendix 1) around the Timor township. This aquifer is responsive, but not to the extreme of the metamorphic ridge aquifer.

Bore 151 and Bore 36 (located in the Bet Bet Deep Lead, east of the targeted area) both monitor the Bet Bet Deep Lead. The hydrographs for both bores show a subdued response to local climatic variation, which indicates connectivity between the Bet Bet Deep Lead and overlying Shepparton Formation to the surface. Some of the bores installed in the early 1980s have no record of a bore log, thus the aquifers through which these bores pass are inferred rather than known. This is a limitation in the available data. Also, many of the bores (e.g. Bores 5416, 5129, 149) exhibit data gaps between 1993–1997 (shown on the hydrographs as a blank period). Thus the groundwater behaviour for this period is inferred also.

Table 1 lists 19 bores monitored on a regular basis in the Timor West area. Many of these bores have 15-20 years of recorded data and therefore have a good record of change in groundwater trends over the past decade. It is noticed in the hydrographs of these bores (Appendix 1) that the highest recorded groundwater level occurred in the late 1980s and the lowest was taken from recent recordings.

Table 1 shows that when it is very wet, water levels rise to within 3 m of the surface at most bore sites. During dry periods water levels can in some cases drop by nearly 10 m (e.g. Bore 5121). What is interesting to note is that most bores have quite shallow waterlevels, even during the recent dry period. Many of these bores have 15-20 years of recorded data and therefore have a good record of change in groundwater trends over the past decade.

Table 1 Summary of key bore data in Timor West targeted area

Bore no.	Total depth (m)	Highest recorded waterlevel below ground level (1989)	Lowest recorded waterlevel below ground level (2002)	Record in years
35	60.0	2.5	4.5	18
36	90.0	2.5	4.5	17
37	18.0	0.2	1.5	17
38	27.0	0.7	4.0	6
149	15.0	0.2	2.3	21
150	30.7	0.5	2.7	20
5121	18.5	0.2	9.8	16
5122	6.0	0.2	9.7	16
5123	18.5	2.7	7.1	17
5124	6.0	2.7	7.1	17
5125	6.0	0.3	2.7	17
5126	6.0	0.2	1.4	22
5131	3.0	2.0	2.6	8
5132	8.8	0.4	2.5	23
5133	4.9	1.7	4.5	23
5134	3.0	1.7	3.0	13
5136	20.0	0.7	2.4	22
5417	5.2	3.2	5.5	23
5418	17.0	5.2	6.5	23
49935	22.0	No data	No data	15

4 New monitoring bores

Six new groundwater monitoring bores have been installed. These have been strategically placed to help fill the information gaps in the area. The majority of the current monitoring bores occur as clusters around salinity discharge areas on the slopes of the Black Range at Wiseman's Hill and around the Timor West township.

Almost 12 months of recorded data has been collected from the newly installed bores, and while this does indicate a fall in groundwater level in all of these bores, there is still limited data from which to determine any long-term groundwater trend. It will be interesting to see how the bores respond to a wet winter-spring period.

The new bores also indicate that groundwater salinities increase towards the north of the targeted area, where groundwater movement is more subdued. Bore 60247 (Table 2) located at the base of Mount Hooghly (Figure 4) has the highest groundwater salinity reading (more than 20 000 EC). This bore is located near a discharge site associated with Mount Hooghly. Watertable responses are much more subdued in the landscapes around Mount Hooghly due to extensively developed clayey sub-soils and weathered material with low permeability. These areas characteristically have shallow perched watertables, surface waterlogging and excess runoff which can lead to salinity and erosion.

Currently a new study is being conducted that measures the total salt loads leaving the Timor West targeted area. This project is in its infancy and the information is not yet available.

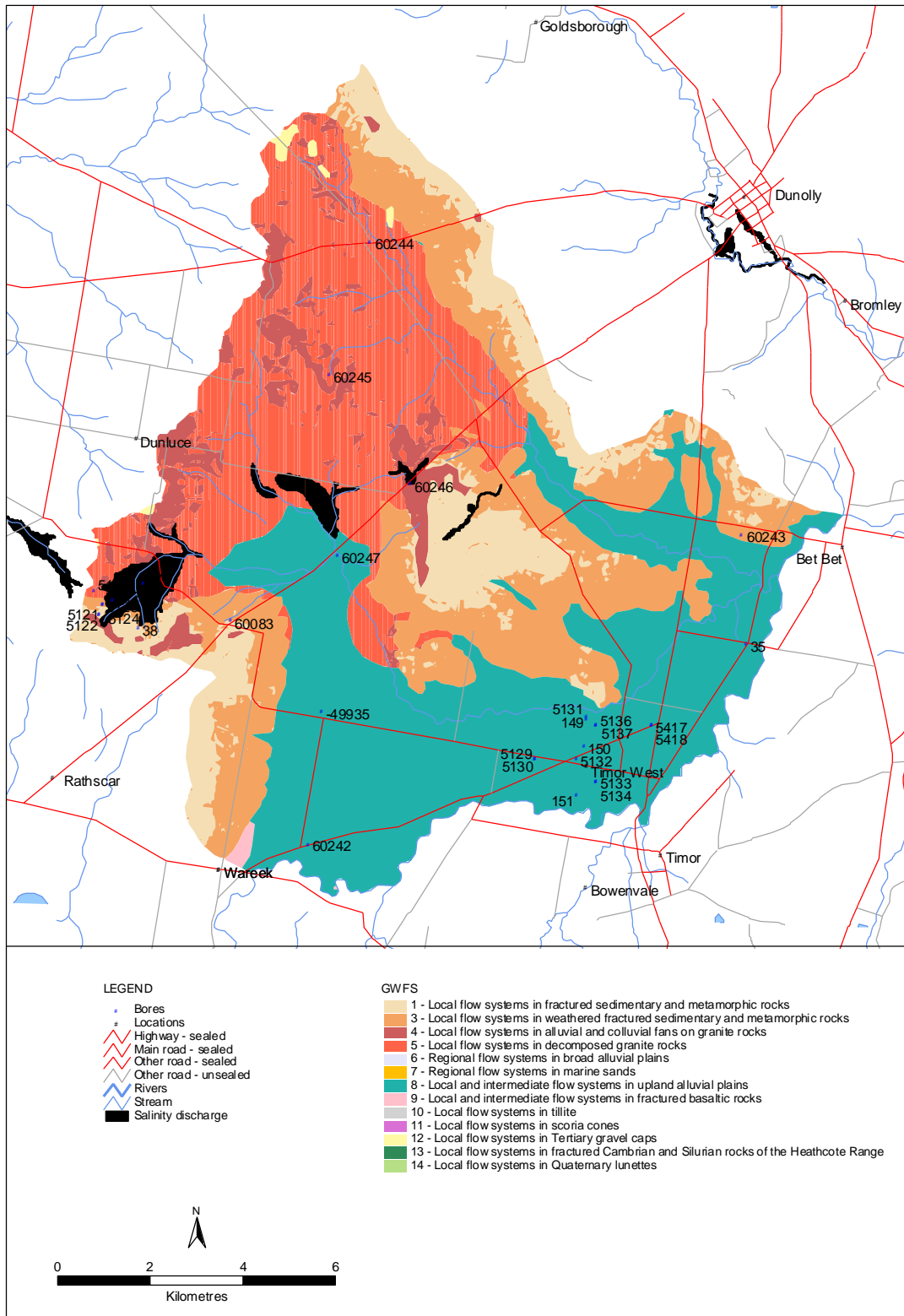


Figure 4 Map of groundwater flow systems in Timor West

Table 2. Bore information for new bores drilled in Timor West targeted area

Bore no.	Bore depth (m)	Depth to watertable (m) (May 2003)	EC ($\mu\text{S}/\text{cm}$)
60242	12.0	9.70	1800
60243	11.5	6.60	3000
60244	20.5	14.65	13 000
60245	30.0	Dry bore	-
60246	12.0	8.03	3100
60247	17.0	13.54	>20 000

5 Conclusion

The inclusion of the six new bores in the monitoring program has meant there is now a comprehensive groundwater monitoring network that covers the Timor West targeted area. This provides a means to assess hydrogeological processes contributing to the dryland salinity issues in the area. These processes include:

- Subdued watertable responses in the landscapes around Mount Hooghly due to extensively developed clayey sub-soils and weathered material with low permeability. In these areas, shallow perched watertables, surface waterlogging and excess runoff lead to salinity and erosion.
- Extreme watertable response in the metamorphic ridge around the Black Range. In some cases groundwater fluctuations of up to 3 m have occurred in one year. This is due to the deeply weathered and fractured nature of the Black Range.
- Discharge at the base of Black Range and Mount Hooghly is the result of local groundwater systems, where recharge (mid-lower slope) and discharge (base of slope) occur very close together. The change in morphology from hills to flat plains causes groundwater to discharge at the break-of-slope.
- Regional groundwater processes with excess groundwater entering the catchment area via the Bet Bet Deep Lead. This is also linked to surface conditions as the hydrograph behaviour exhibited in Bores 36 and 151 (Appendix 1) indicates surface climatic conditions affect the deep lead.
- Underlying basalt acts as a fresh water conduit between the alluvial and the underlying deep leads and Ordovician bedrock.

Groundwater levels have fallen considerably since 1996. Some bores (e.g. 5417, Appendix 1) are dry with the watertable having dropped below the base of these bores, which, in the 20 plus years of monitoring history in the Timor West targeted area, has never happened before.

Inclusion of the six new groundwater monitoring bores has developed a comprehensive monitoring network covering the Timor West targeted area. They also indicate that salinity in the targeted area is not just associated with the discharge sites at the break-of-slope, but high groundwater salinity in bores located away from major discharge sites (e.g. Bore 60244, Table 2, Figure 4).

6 Recommendations

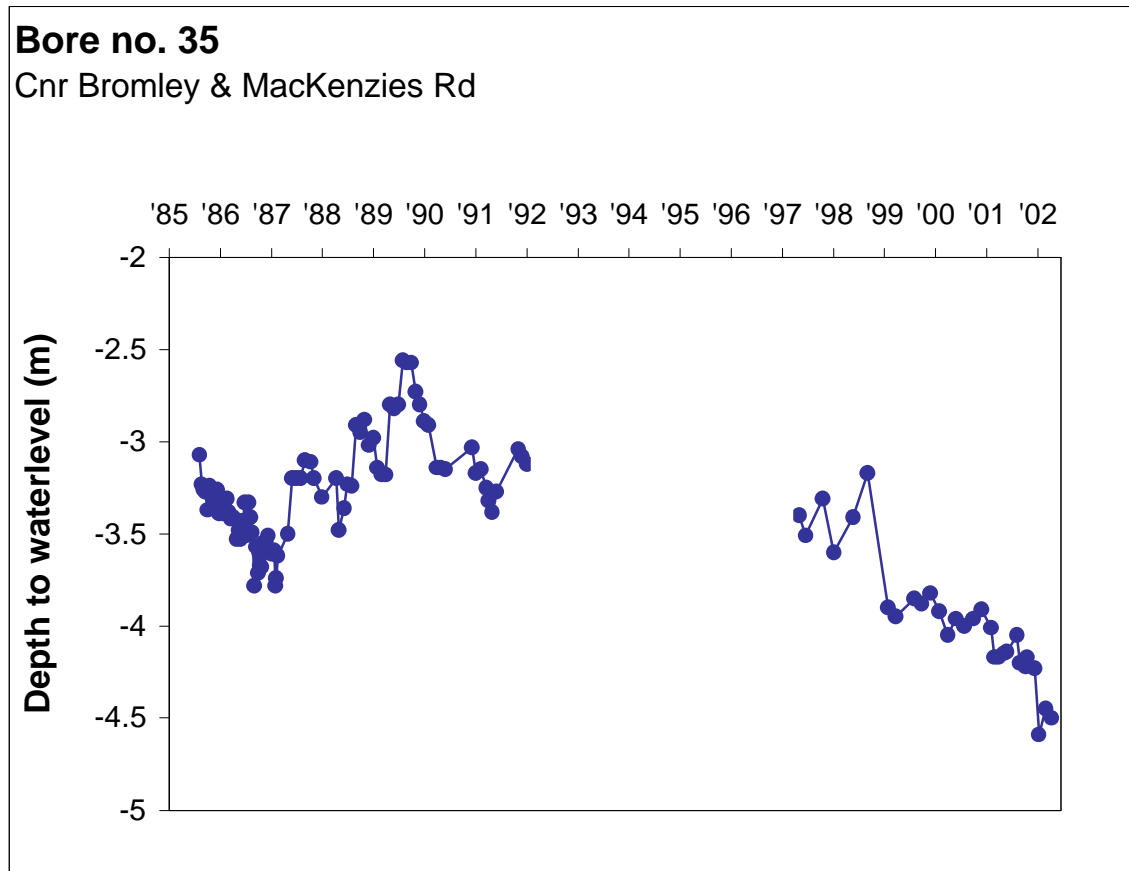
The following recommendations have been:

- continue monitoring of all groundwater bores (old and new)
- continue monitoring salinity in all bores (old and new)
- perform a more detailed investigation of the sub-surface basalt and its impact on the groundwater systems and salinities in the Timor West targeted area.

References

- Coram JE, Dyson PR and Evans WR (2001) An evaluation framework for dryland salinity. National Land and Water Resources Audit Dryland Salinity Project, Bureau of Rural Sciences, Canberra.
- Day C (1985) A study of the geomorphic, soil and geohydrological conditions of the Timor West/Black Ranges area. Land Protection Service, Conservation Forests and Lands.
- Perry R (2003) Timor West targeted salinity project brochure. Department of Primary Industries, Victoria

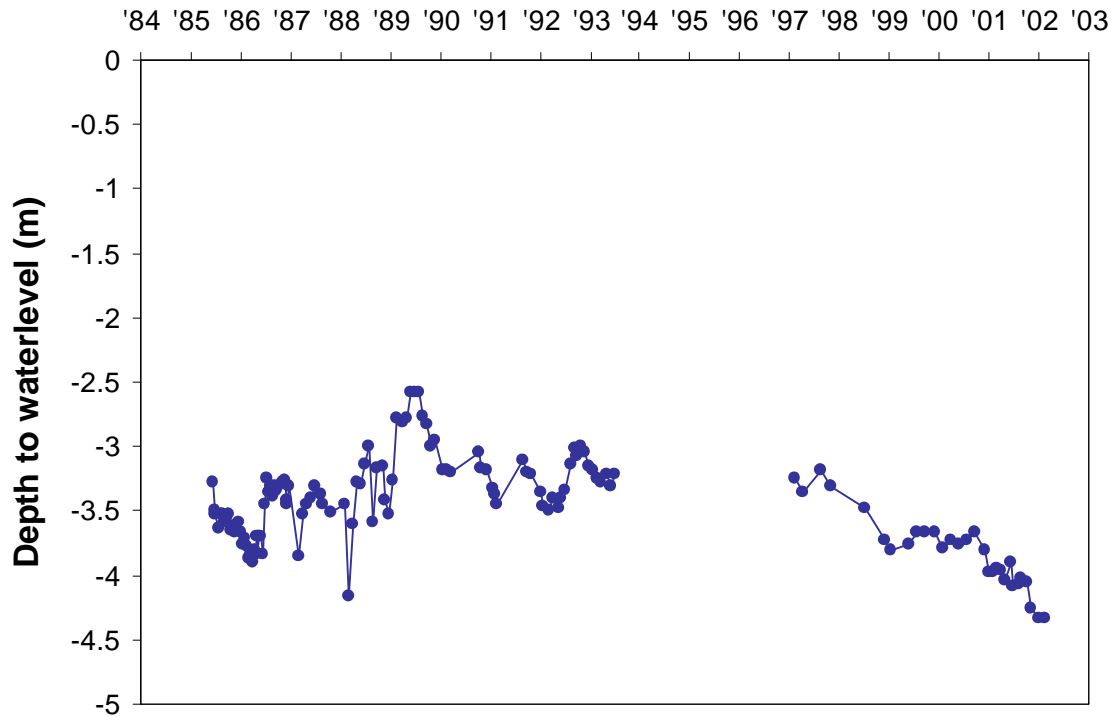
Appendix 1 Hydrographs of Timor West monitoring bores



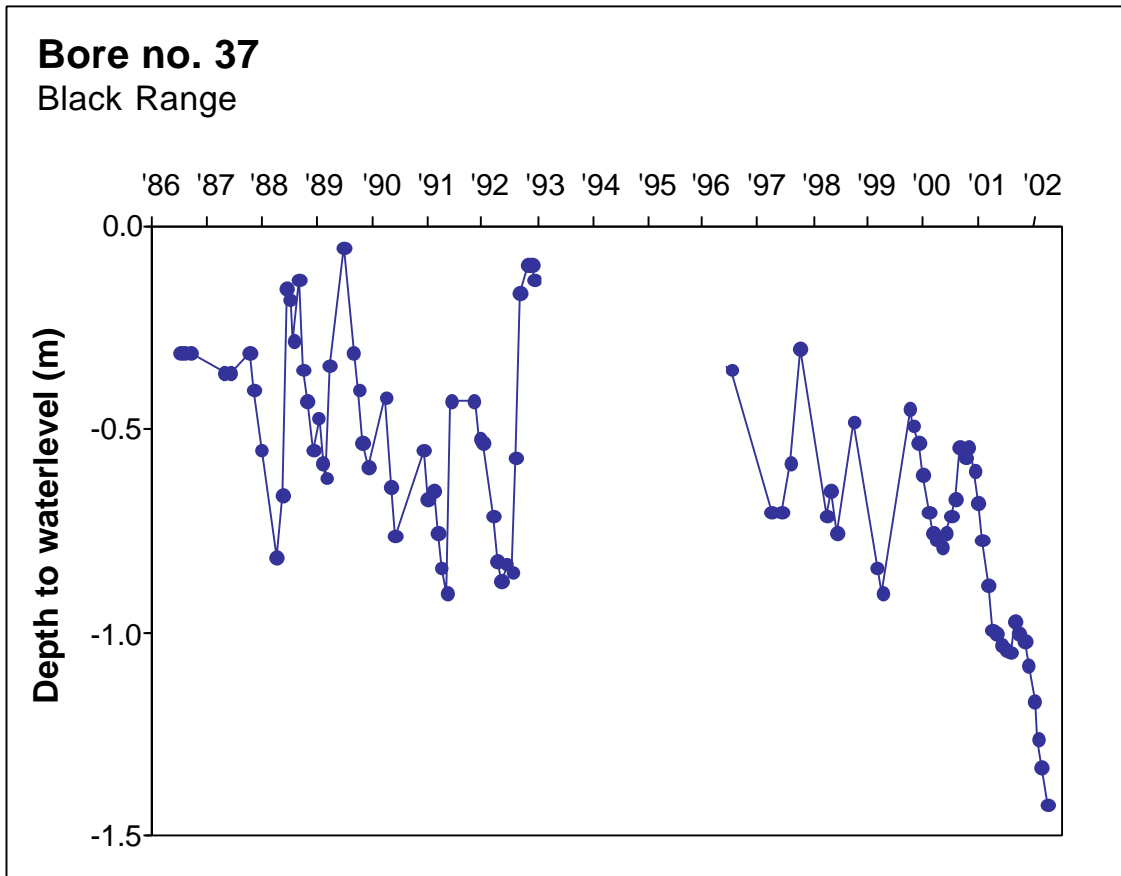
CLPR No:	35	Bore monitor:	DPI
Locality description:	Corner of Bromley and McKenzies Roads Located in Bet Bet Deep Lead Bore located on plain, flat landscape		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	60	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	4.5	Salinity (EC) ($\mu\text{S}/\text{cm}$):	2700
Groundwater trend:	Responsive to seasonal climatic variation with an overall falling groundwater trend.		

Bore no. 36

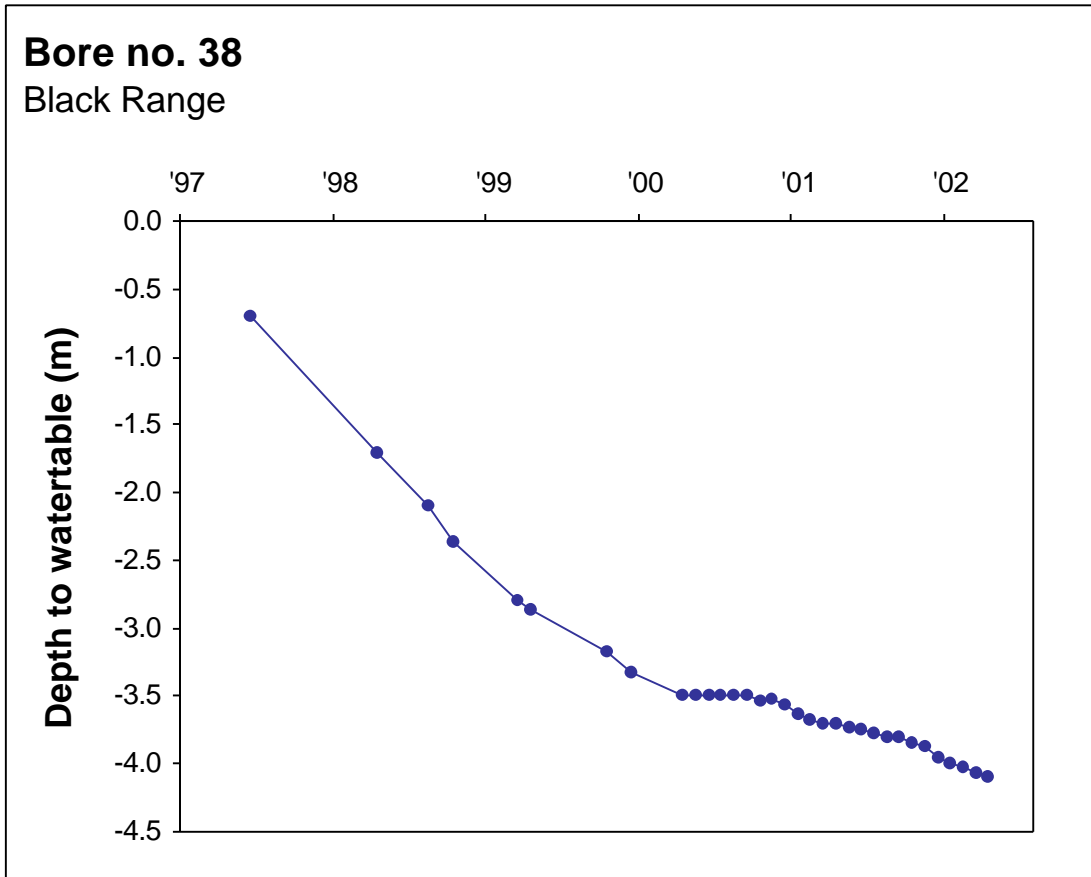
Betley



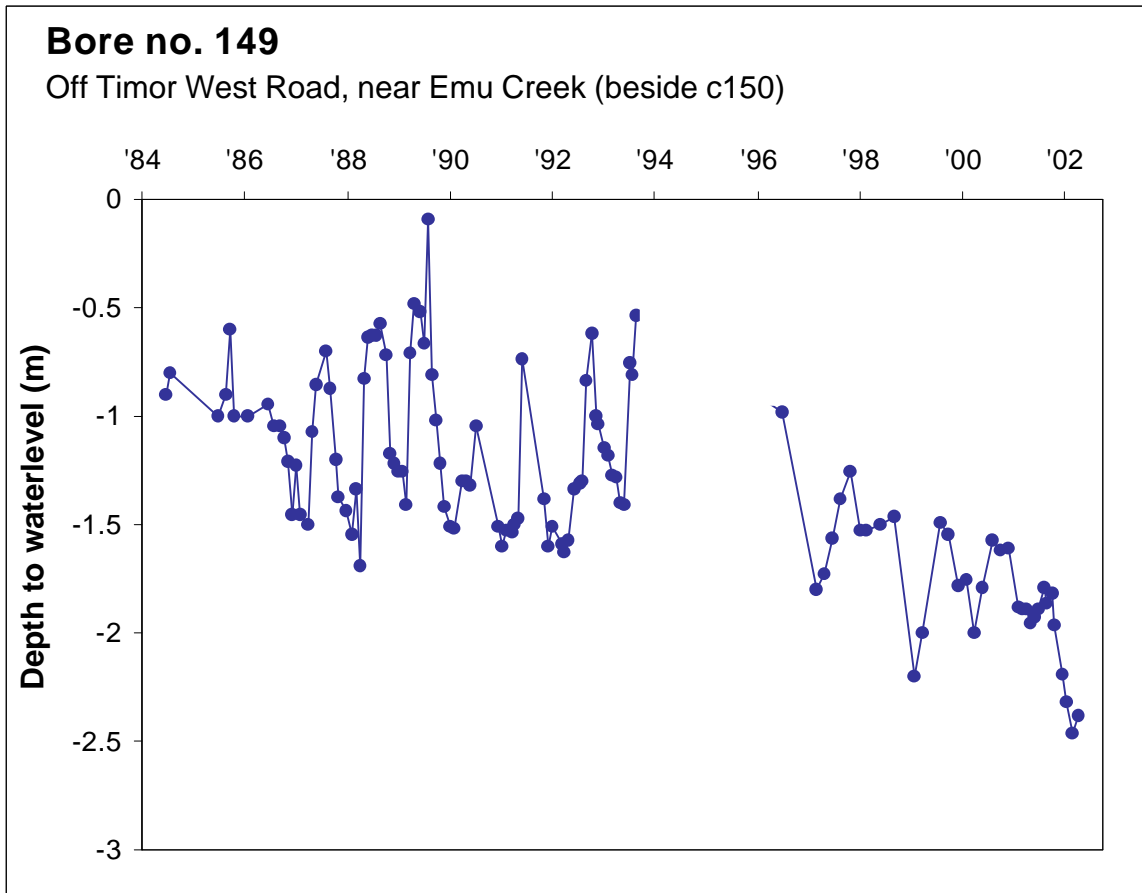
CLPR No:	36	Bore monitor:	DPI
Locality Description:	Betley Bet Bet Deep Lead Bore located in plain, flat landscape		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	90	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	4.3	Salinity (EC) (µS/cm):	—
Groundwater trend:	Even groundwater trend, slight fall in waterlevel since 2002.		



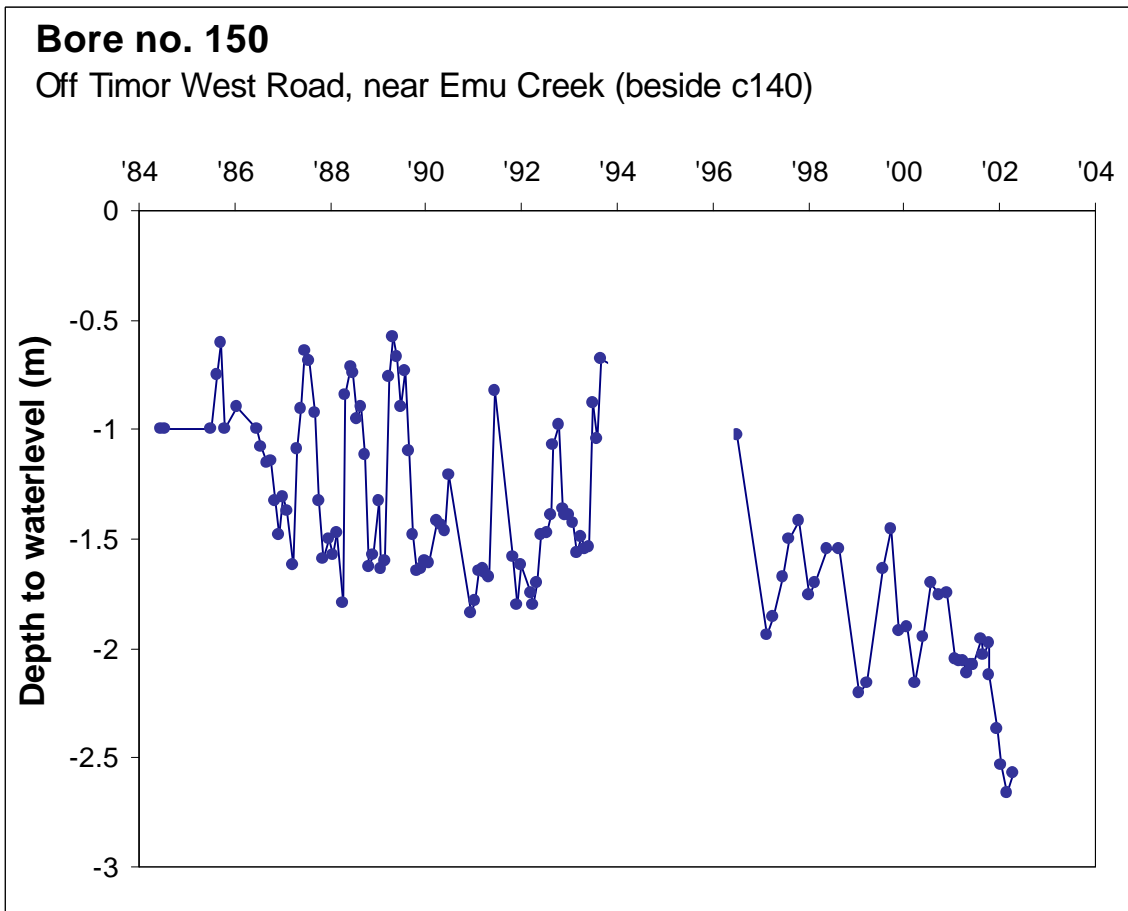
CLPR No:	37	Bore monitor:	Alex Wiseman
Locality description:	Black Range Bore located mid-slope		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	18	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	1.8	Salinity (EC) (µS/cm):	—
Groundwater trend:	Very responsive to seasonal rainfall variation, falling trend overall, prominent since 1996		



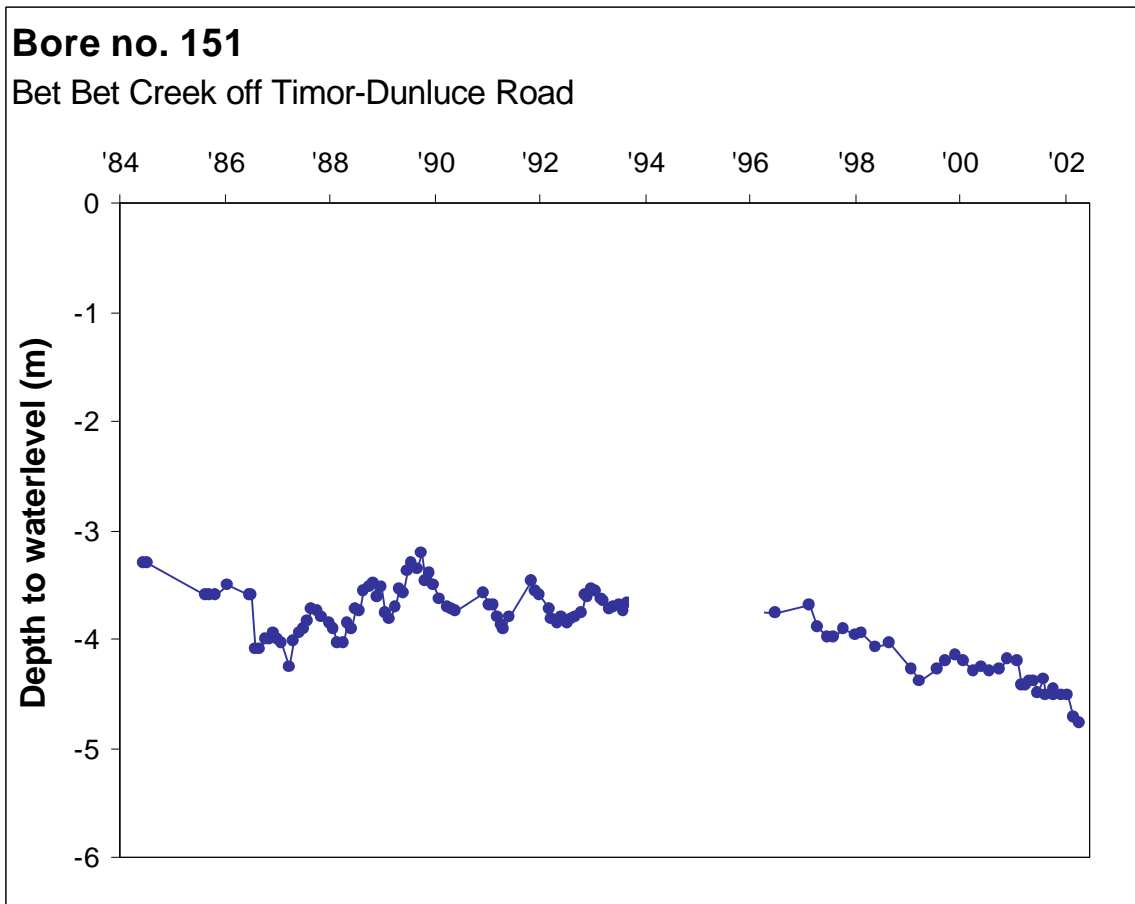
CLPR No:	38	Bore monitor:	Alex Wiseman
Locality description:	Black Range Bore located in plain, flat landscape		
Geological description:	Devonian Granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	27	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	4.0	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong falling trend. Located beside 5121-22. Representative of the last six years.		



CLPR No:	149	Bore monitor:	DPI
Locality description:	Timor West Rd, Timor West Bore located on lower slope, river flat landscape		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	15	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	2.5	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong response to seasonal climatic variation, overall falling trend, steeper falling trend since 1998.		



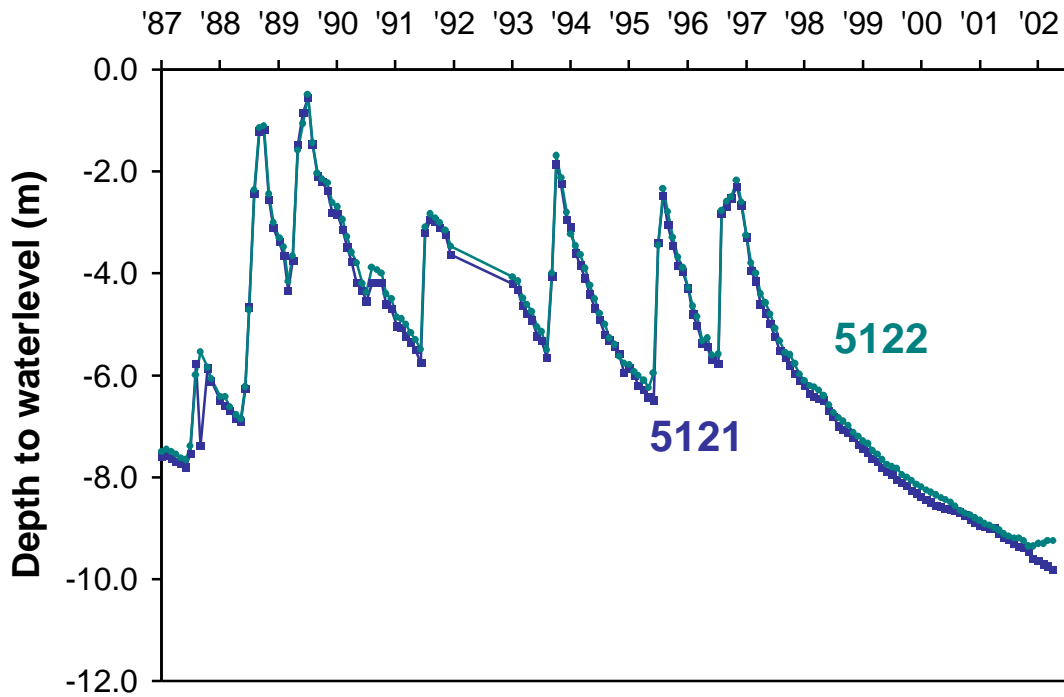
CLPR No:	150	Bore monitor:	DPI
Locality description:	Timor West Rd, Timor West Bore located on lower slope, riverflat landscape.		
Geological description:	Shepparton Formation Fluvial clay, silts, sand and gravel.		
Bore depth (m):	30.7	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	2.5	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong response to seasonal rainfall. Overall long-term falling trend, falling steeper since 1996.		



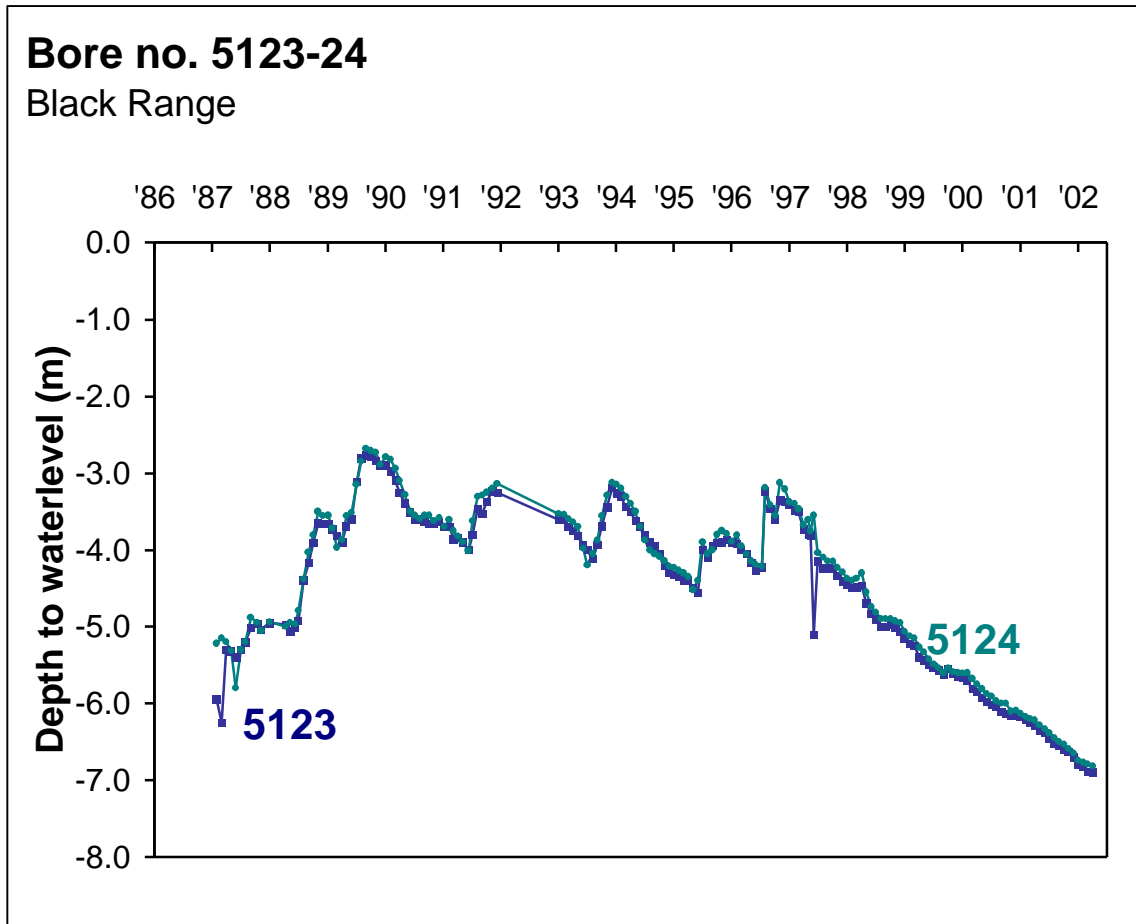
CLPR No:	151	Bore monitor:	DPI
Locality description:	Bet Bet Creek Bet Bet Deep Lead Bore located on lower slope, riverflat landscape.		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying deep lead deposits of coarse sand gravel overlying Tertiary deep lead sediments.		
Bore depth (m):	72	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	4.5	Salinity (EC) (µS/cm):	14 000
Groundwater trend:	Even trend. Some response to climatic variation. Slight falling trend since 1998.		

Bore no. 5121-22

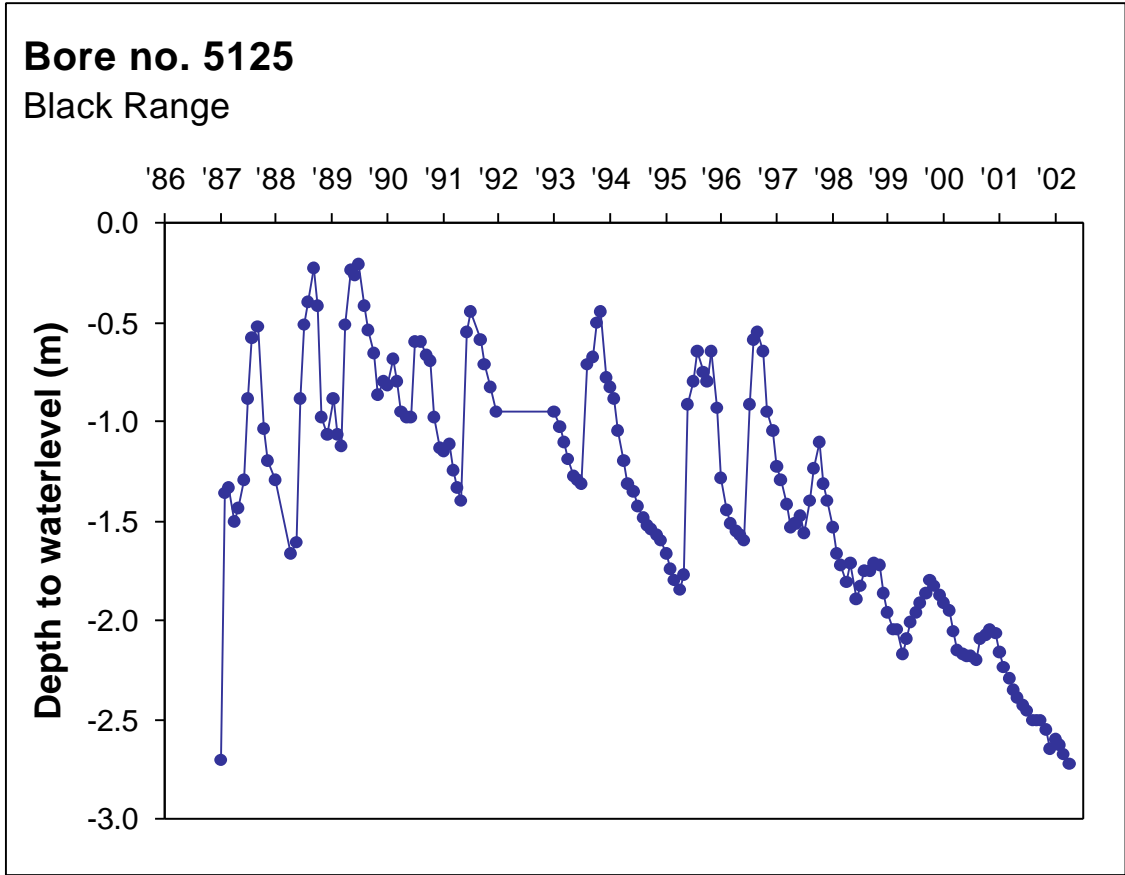
Black Range



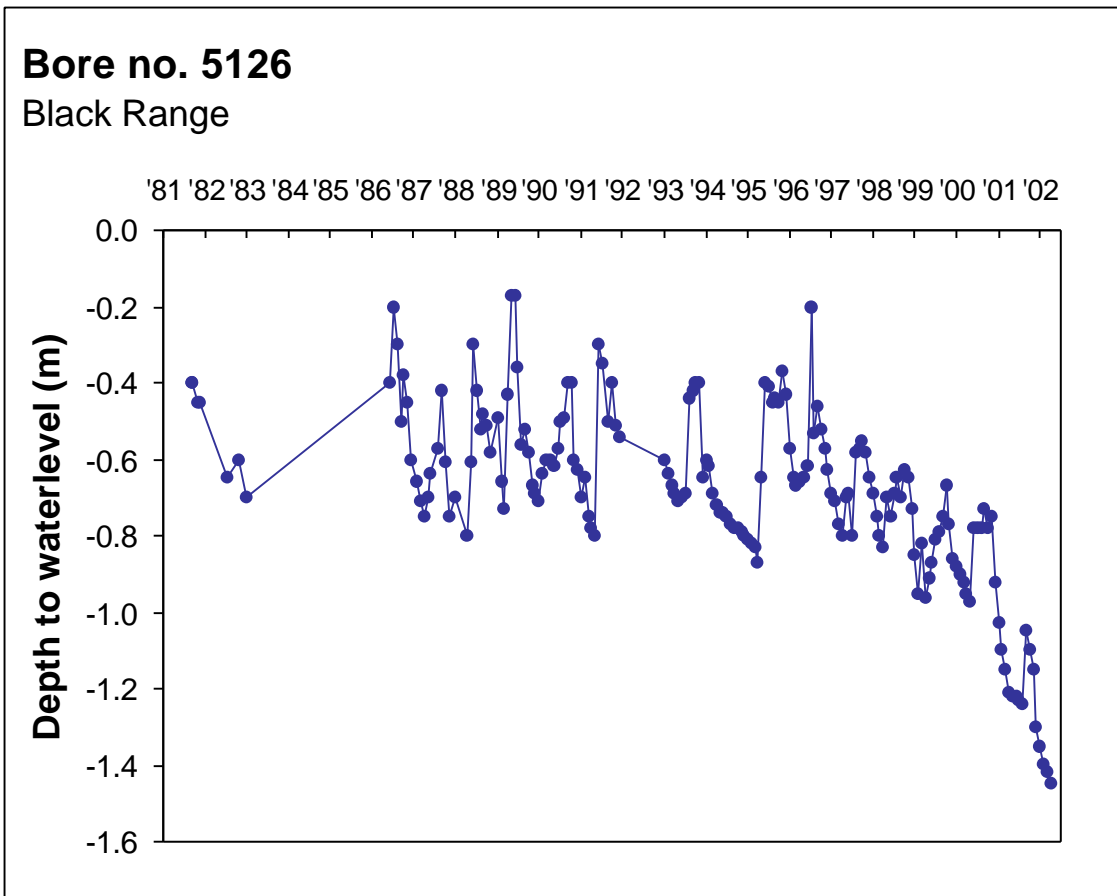
CLPR No:	5121, 5122	Bore monitor:	Alex Wiseman
Locality description:	Black Range Bore located mid-slope		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	5121 = 18.5 5122 = 10.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5121 = 9.8 5122 = 9.6	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong response to seasonal rainfall variation until mid 1997, very strong falling trend since late 1996.		



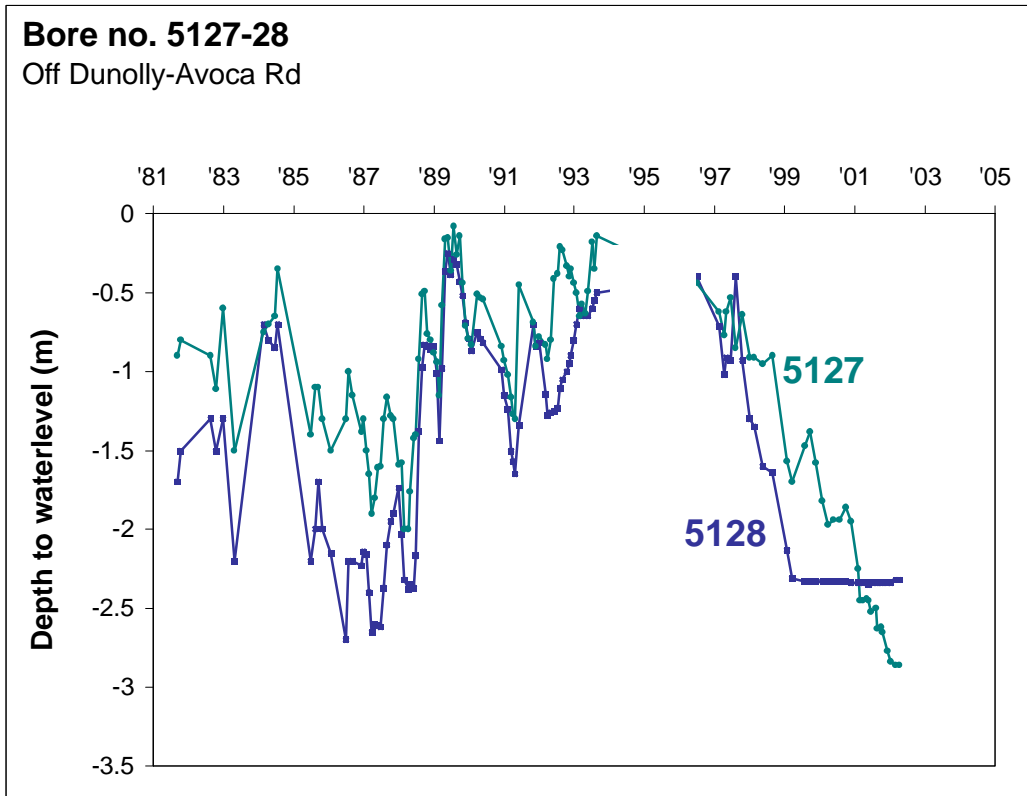
CLPR No:	5123, 5124	Bore monitor:	Alex Wiseman
Locality description:	Black Range Bore located lower slope		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	5123 = 18.5 5124 = 10.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5123 = 8.0 5124 = 8.0	Salinity (EC) (µS/cm):	5123 = 7930 5124 = 4370
Groundwater trend:	Strong response to seasonal rainfall variation until mid 1997, very strong falling trend since late 1996.		



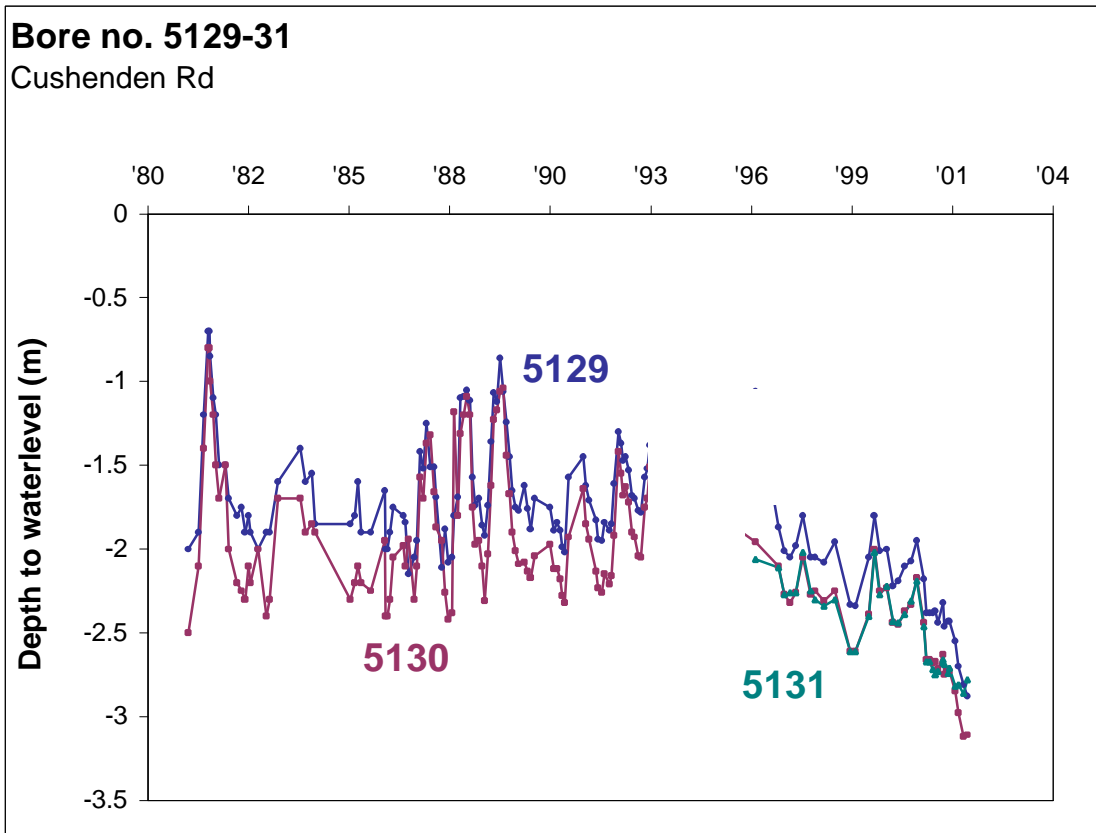
CLPR No:	5125	Bore monitor:	Alex Wiseman
Locality description:	Black Range Bore located in low-lying point, in discharge site		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	6.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	2.7	Salinity (EC) (µS/cm):	5200
Groundwater trend:	Strong response to seasonal rainfall variation until mid 1997, very strong falling trend since late 1996.		



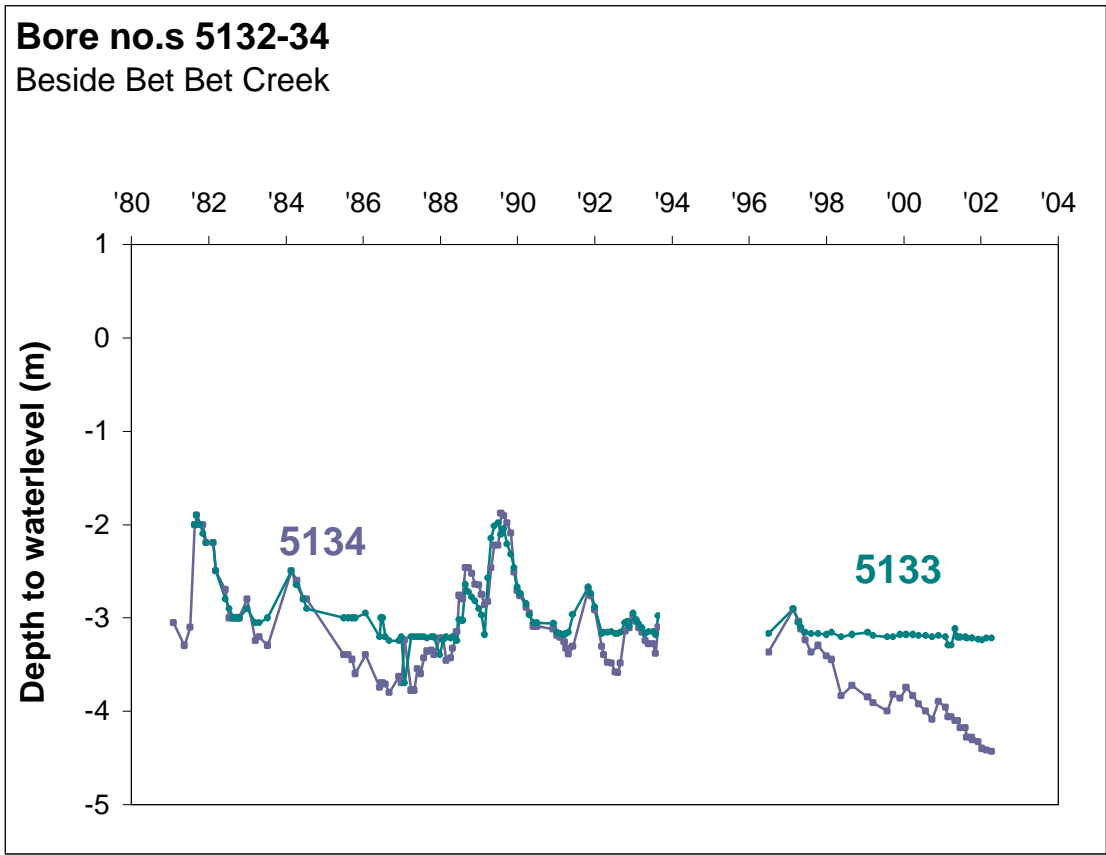
CLPR No:	5126	Bore monitor:	Alex Wiseman
Locality description:	Black Range		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	6.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	1.4	Salinity (EC) (µS/cm):	14 020
Groundwater trend:	Strong response to seasonal climatic variation. Even trend until 1996, when there is a strong fall in the hydrograph.		



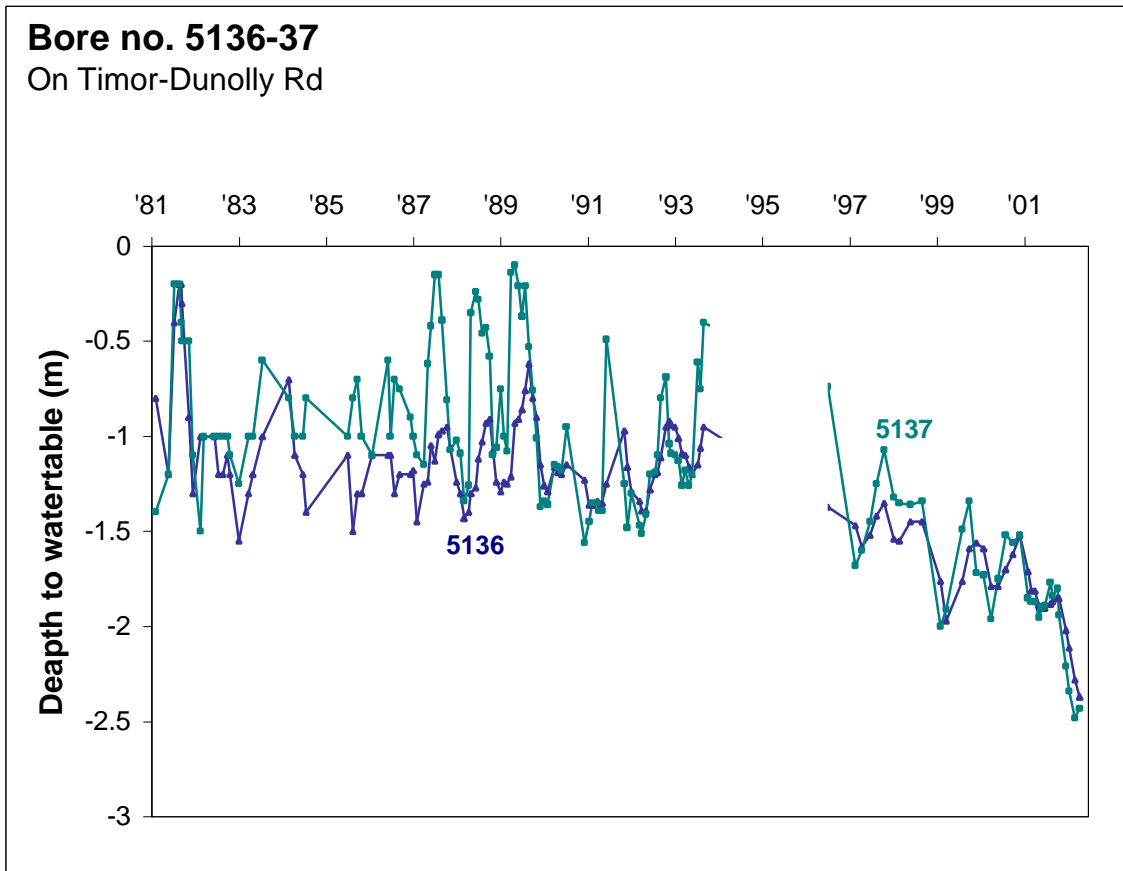
CLPR No:	5127, 5128	Bore monitor:	CLPR
Locality description:	Dunolly–Avoca Road Black Range		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	5127 = 2.9 5128 = 2.3	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5127 = 2.9 5128 = 2.3	Salinity (EC) (µS/cm):	5127 = 15 840 5128 = 6160
Groundwater trend:	Strong response to local climatic variation obvious in the hydrograph. In both bores the watertable has fallen below the bottom of each bore.		



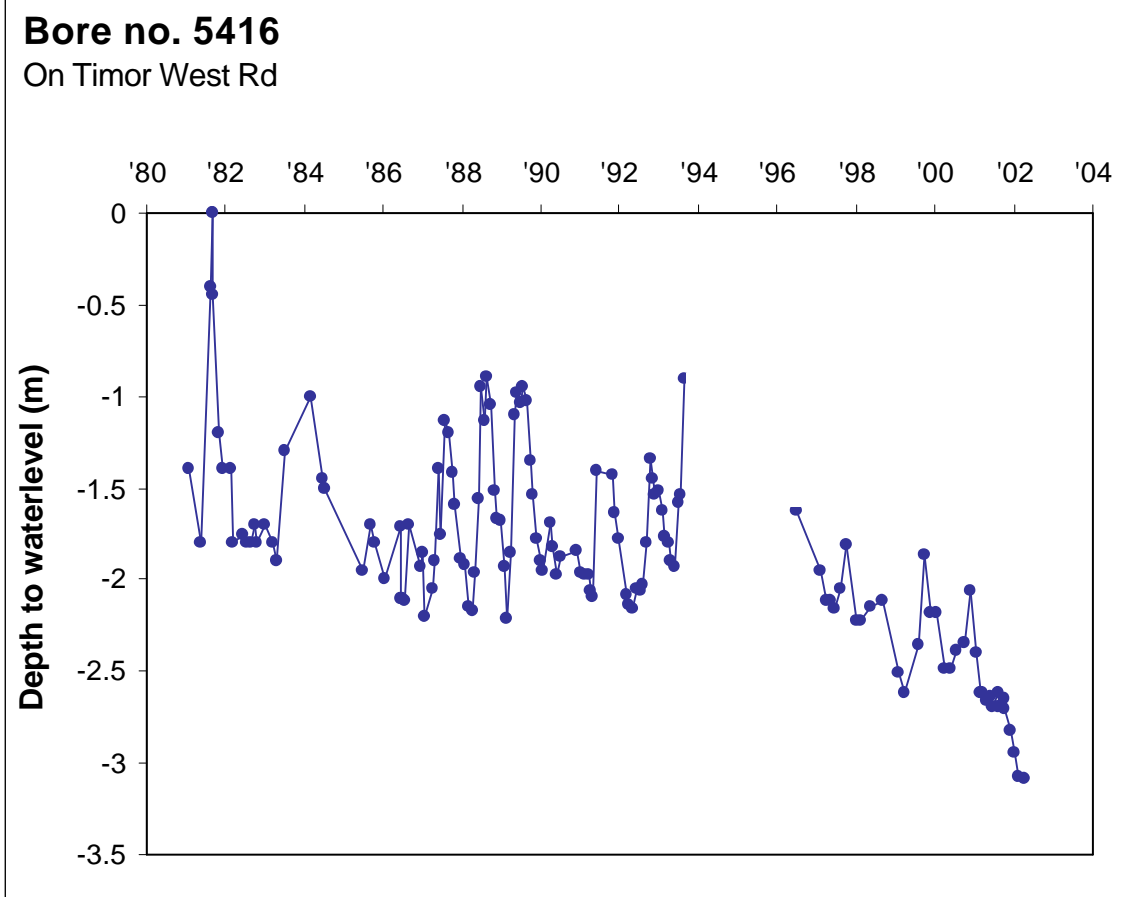
CLPR No:	5129, 5130, 5131	Bore monitor:	CLPR
Locality description:	Cushenden Road Timor		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying subsurface basalt flow (Quaternary olivine volcanics) overlying Ordovician sedimentary bedrock		
Bore depth (m):	5129 = 16.5 5130 = 6.7 5131 = 3.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5129 = 3.2 5130 = 3.2 5131 = 2.7	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong response to local climatic variation with a strong overall falling trend observed since late 1996.		



CLPR No:	5132, 5133, 5134	Bore monitor:	CLPR
Locality description:	Beside Bet Bet Creek		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying subsurface basalt flow (Quaternary olivine volcanics) overlying Ordovician sedimentary bedrock		
Bore depth (m):	5133 = 5.0 5134 = 3.0	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5133 = 3.0 5134 = 4.0	Salinity (EC) (µS/cm):	5133 = 5150 5134 = —
Groundwater trend:	Varied response to local climatic variation. Relatively even trend. 5132 shows that the watertable has fallen below the bore depth, 5133 shows a slight falling trend since 1998 and 5134 shows a possible data error.		



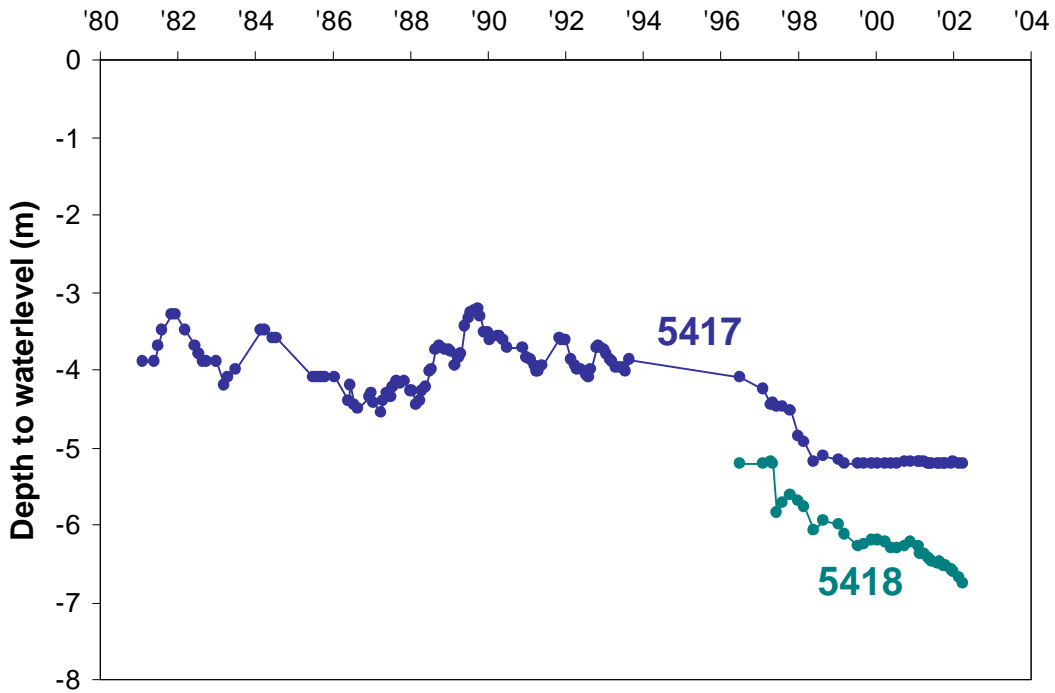
CLPR No:	5136, 5137	Bore monitor:	CLPR
Locality description:	Timor–Dunolly Road		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying subsurface basalt flow (Quaternary olivine volcanics) overlying Ordovician sedimentary bedrock		
Bore depth (m):	5136 = 20 5137 = 3	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5136 = 2.5 5137 = 2.5	Salinity (EC) (µS/cm):	—
Groundwater trend:	Strong response to local climatic variation. Strong fall in overall trend since 1996, even trend until 1996.		



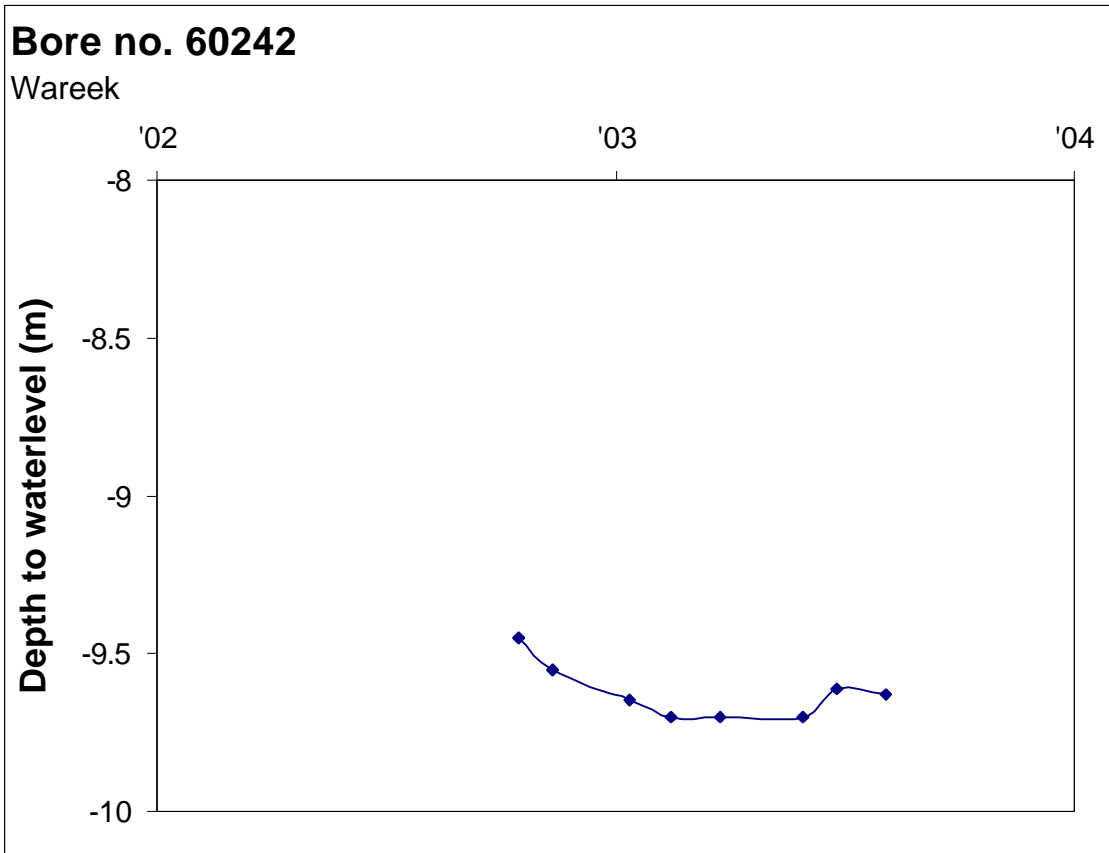
CLPR No:	5416	Bore monitor:	CLPR
Locality description:	Timor West Road Timor West		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying subsurface basalt flow (Quaternary olivine volcanics) overlying Ordovician sedimentary bedrock		
Bore depth (m):	4.41	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	3.1	Salinity (EC) (µS/cm):	3950
Groundwater trend:	Overall falling groundwater trend. Strong response to local climatic variation. Steeper fall in overall trend since 1996.		

Bore no 5417-18

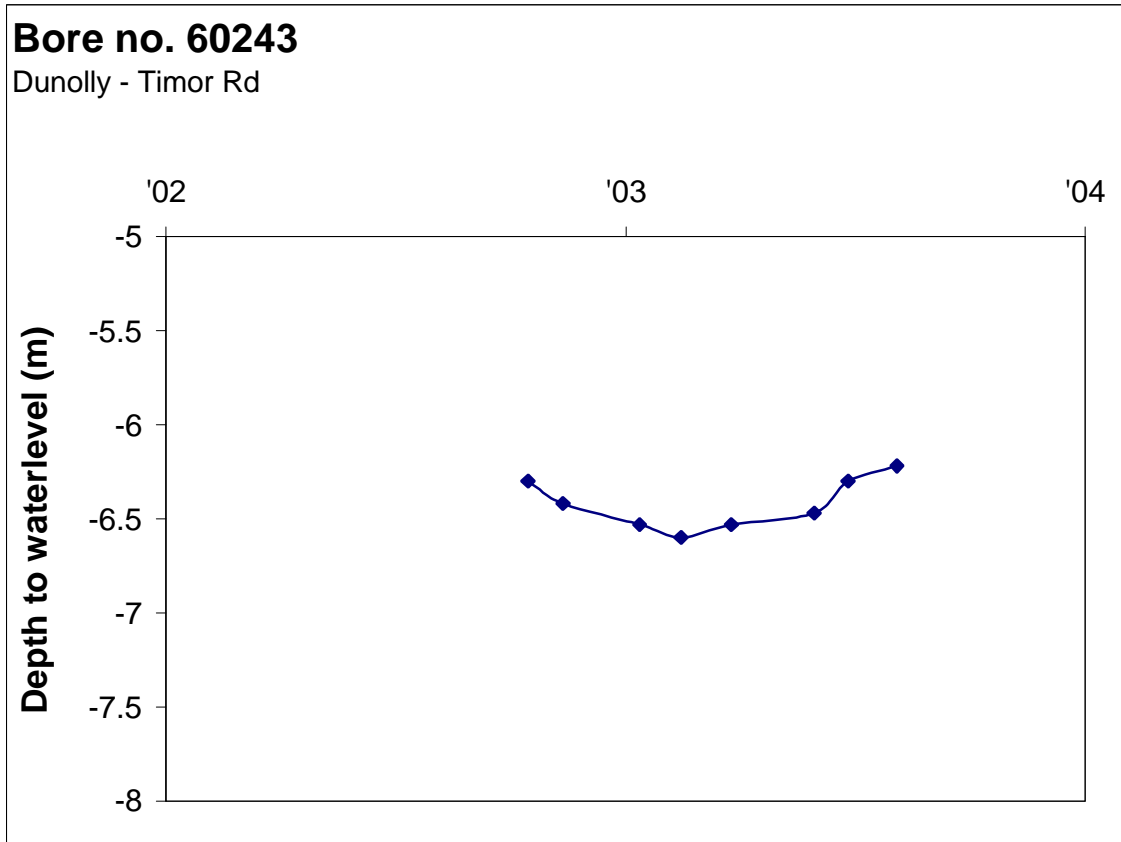
On Timor-Dunolly Rd



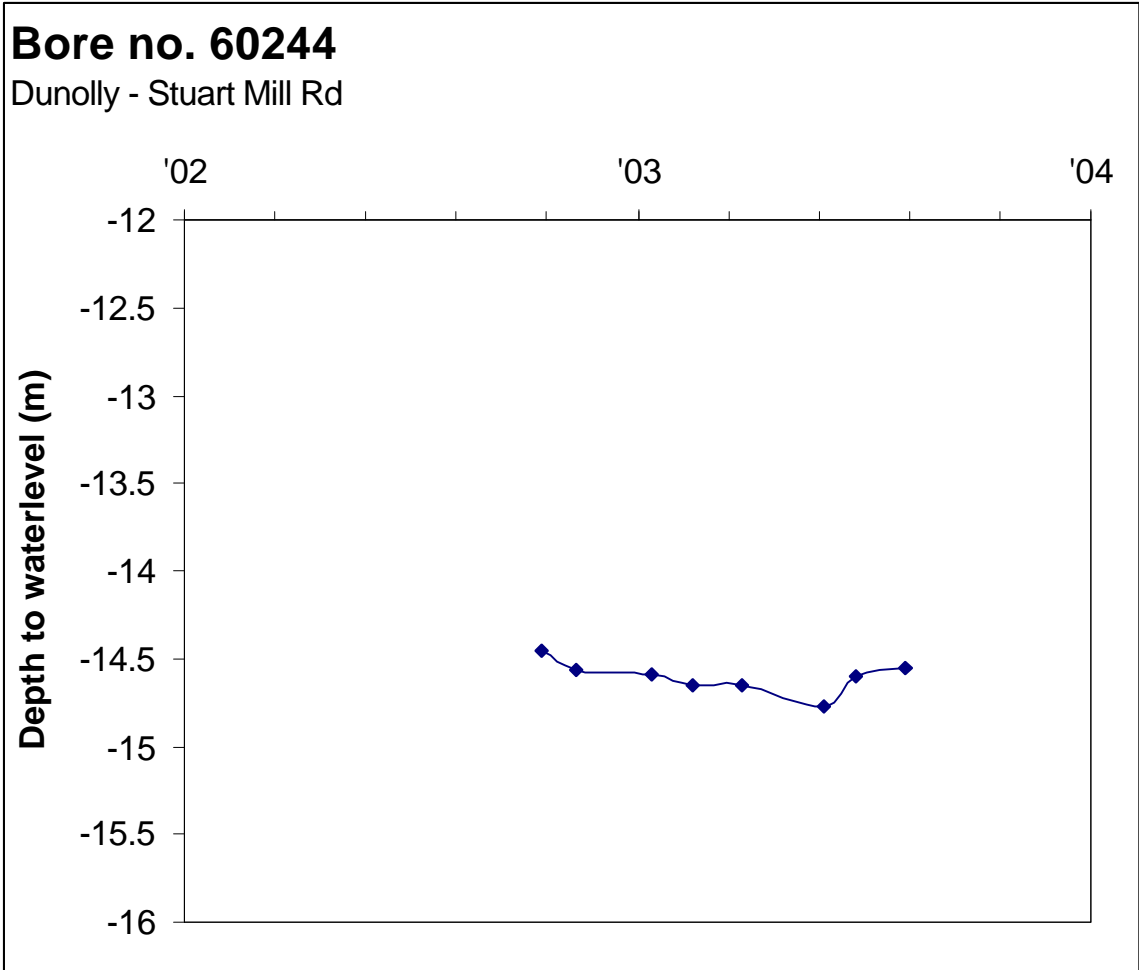
CLPR No:	5417, 5418	Bore monitor:	CLPR
Locality description:	Timor–Dunolly Road Timor		
Geological description:	Shepparton Formation (fluvial clay, silt, sand and gravel) overlying subsurface basalt flow (Quaternary olivine volcanics) overlying Ordovician sedimentary bedrock		
Bore depth (m):	5417 = 5.22 5418 = 17.1	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	5417 = 5.22 5418 = 6.8	Salinity (EC) (µS/cm):	5417 = 13 600 5418 = 8510
Groundwater trend:	Even groundwater trend with a slight response to local climate. Falling steeply since 1996. 5417, waterlevel has fallen below bore depth.		



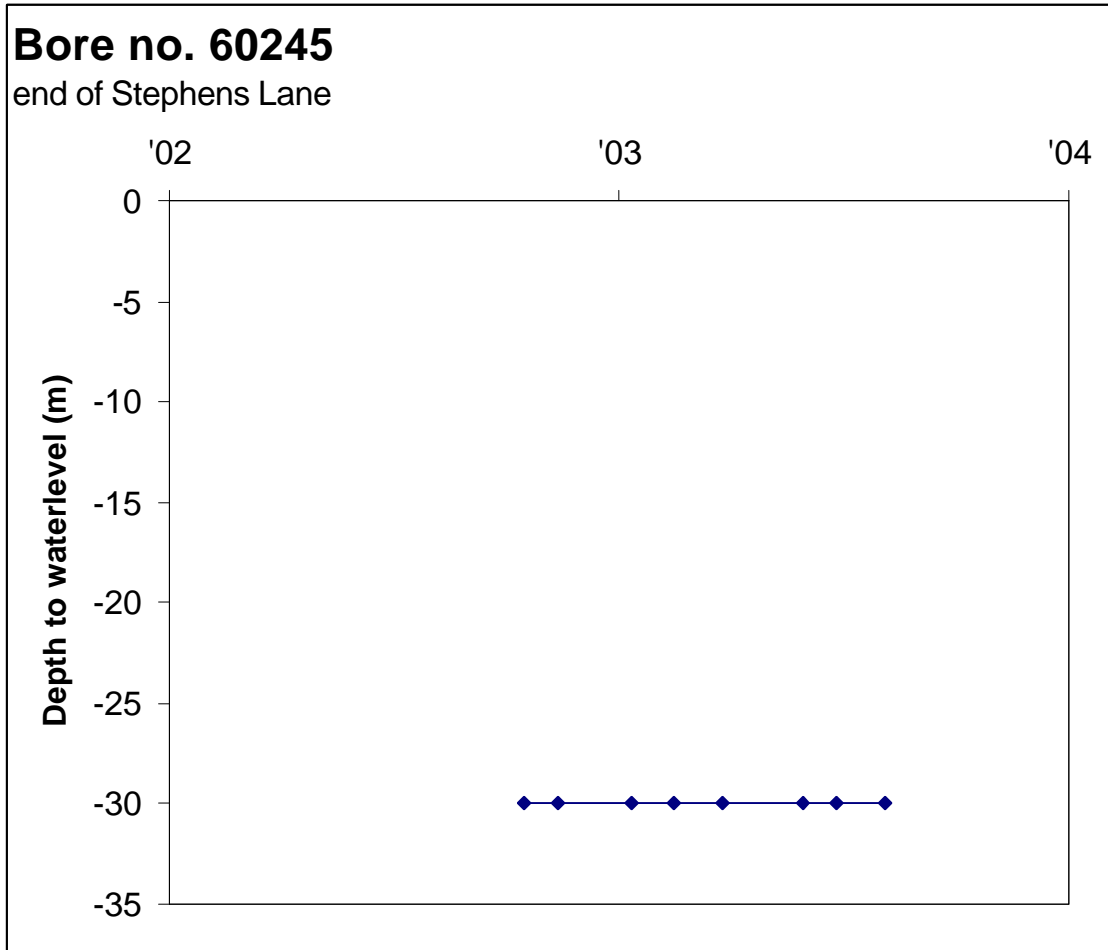
CLPR No:	60242	Bore monitor:	David Schuppan
Locality description:	Wareek Bore located in lower slope		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	12	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	9.6	Salinity (EC) (µS/cm):	1800
Groundwater trend:	New bore. Shows a falling groundwater trend		



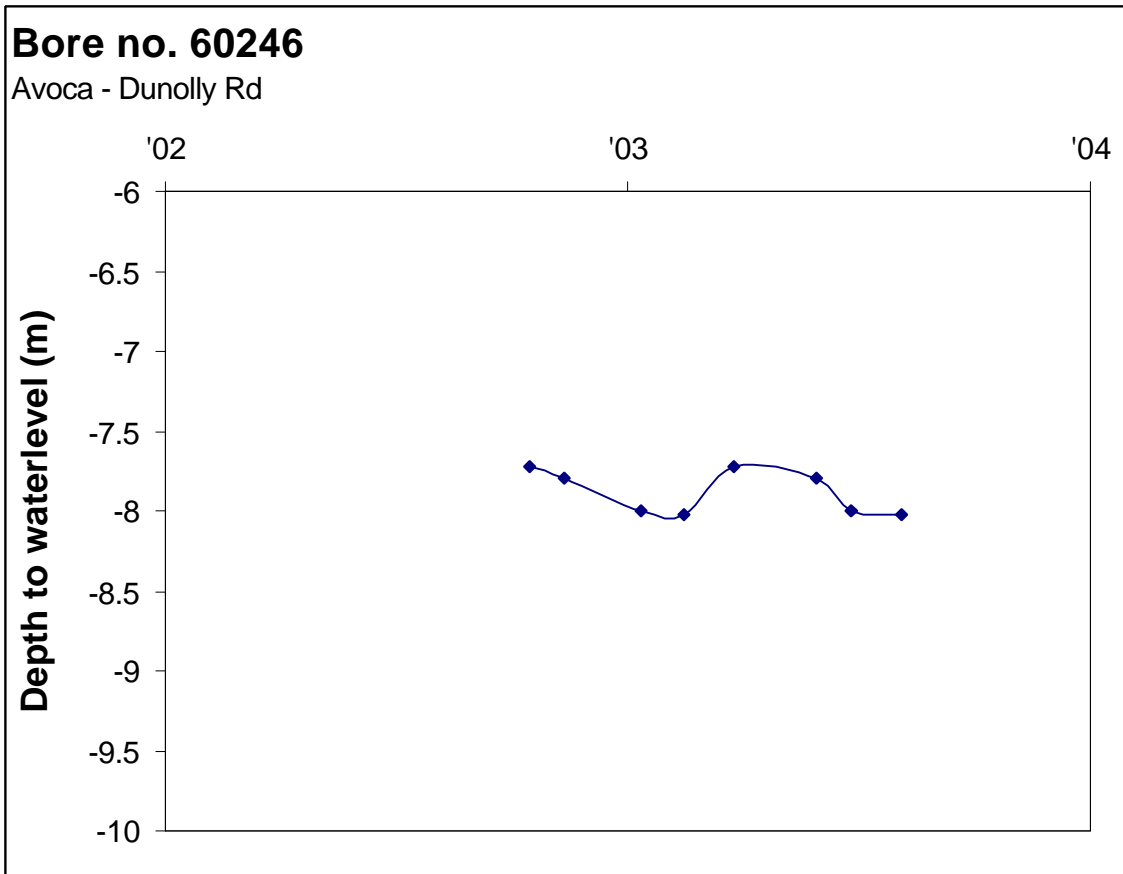
CLPR No:	60243	Bore monitor:	David Schuppan
Locality description:	Timor- Dunolly Road		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	11.5	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	6.2	Salinity (EC) (µS/cm):	3000
Groundwater trend:	New bore. Shows an even groundwater trend. Waterlevel has risen in response to recent rainfall.		



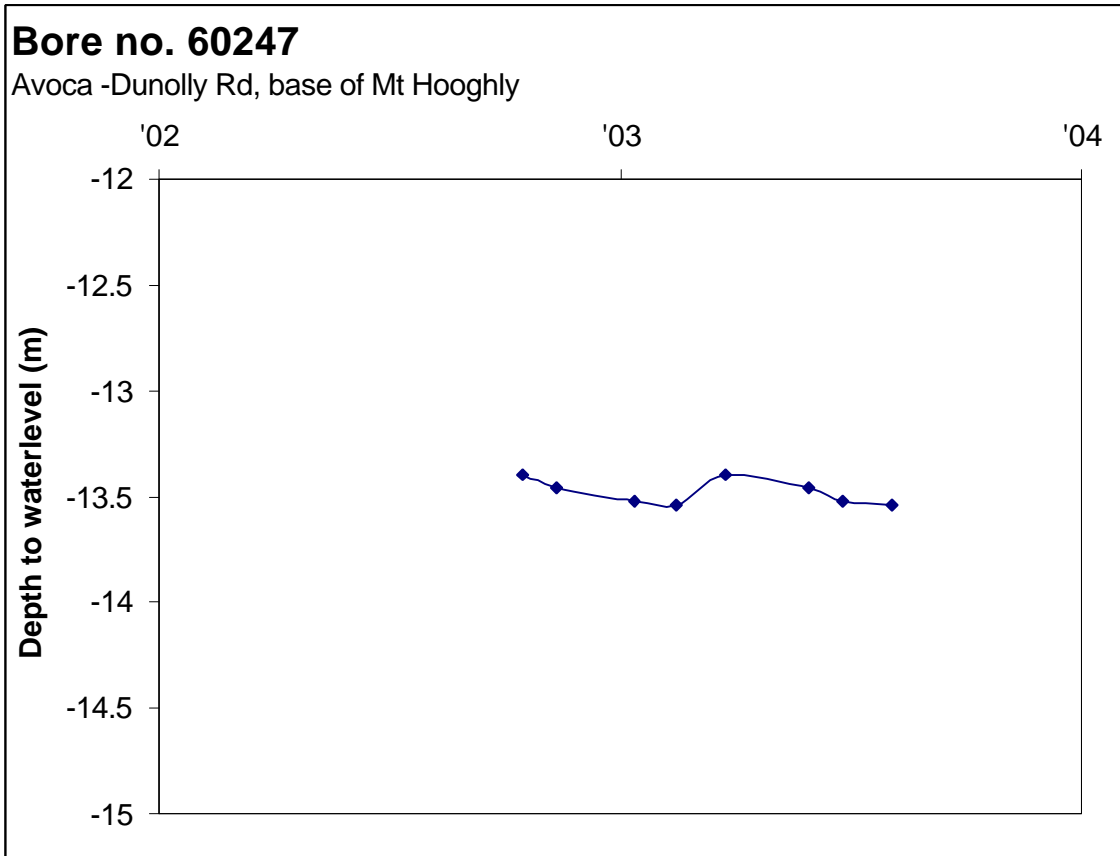
CLPR No:	60244	Bore monitor:	David Schuppan
Locality description:	Dunolly–Stuart Mill Rd Bore located in flat, plain landscape		
Geological description:	Shepparton Formation Fluvial clay, silt, sand deposits		
Bore depth (m):	20.5	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	4.6	Salinity (EC) (µS/cm):	13000
Groundwater trend:	New bore. Shows an even groundwater trend. Waterlevel has risen in response to recent rainfall.		



CLPR No:	60245	Bore monitor:	David Schuppan
Locality description:	North-west of Mr Hooghly. Bore located in mid slope, end of Stephens Rd		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	30	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	Dry bore	Salinity (EC) (µS/cm):	Dry bore
Groundwater trend:	Dry bore. Watertable deeper than depth of bore.		



CLPR No:	60246	Bore monitor:	David Schuppan
Locality description:	Dunolly–Avoca Rd. Bore located mid slope.		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sand overlying hard, fresh, granite/metamorphic rock		
Bore depth (m):	12	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	8.0	Salinity (EC) (µS/cm):	3100
Groundwater trend:	New bore. Shows a falling groundwater trend		



CLPR No:	60247	Bore monitor:	David Schuppan
Locality description:	Avoca–Dunolly Rd Bore located in lower, river flat		
Geological description:	Shepparton Formation Fluvial clay, silt, sand and gravel		
Bore depth (m):	17	Average rainfall (mm/yr):	449
Current water depth 2003 (m):	9.6	Salinity (EC) (µS/cm):	>20 000
Groundwater trend:	New bore. Shows a falling groundwater trend and responsive to local climatic variation.		