

2 Geology of Bet Bet

The low rolling hills of the Lexton area are comprised mostly on Ordovician sedimentary rock, which is the basement rock for the Bet Bet targeted area (Figure 3). Devonian granites have intruded these sedimentary rocks to the west of the Bet Bet targeted area to form the high relief metamorphic ridges of the Ben More and Ben Major ranges. This metamorphic ridge is also the catchment boundary between the Loddon and Avoca catchments. There is minor outcropping of basalt on the eastern fringe of the Bet Bet targeted area. This is the result of volcanic eruptions and subsequent basalt flows of Mount Mitchell and surrounding volcanic cones.

The Ordovician sedimentary rock is comprised of ancient, hard and fractured deep marine sandstones and shales. The western edge of the Bet Bet targeted area is comprised of hard fresh granite of Devonian age. A veneer of low permeability clay and sandy weathered material (colluvium) covers much of the granite. Quaternary basalt flow overlies the sedimentary bedrock and defines the eastern boundary of the Bet Bet targeted area boundary. This flow covers most of the upland plains between Mount Bolton and Creswick. The Bet Bet targeted area, however, was not covered with this flow, and thus has an older landscape. The valley floor area comprises alluvial sediments of Quaternary and Tertiary age. The extensive drainage disruption that occurred in the southern Loddon catchment where the basalt overlies the Ordovician sedimentary rock did not occur in the Lexton area.

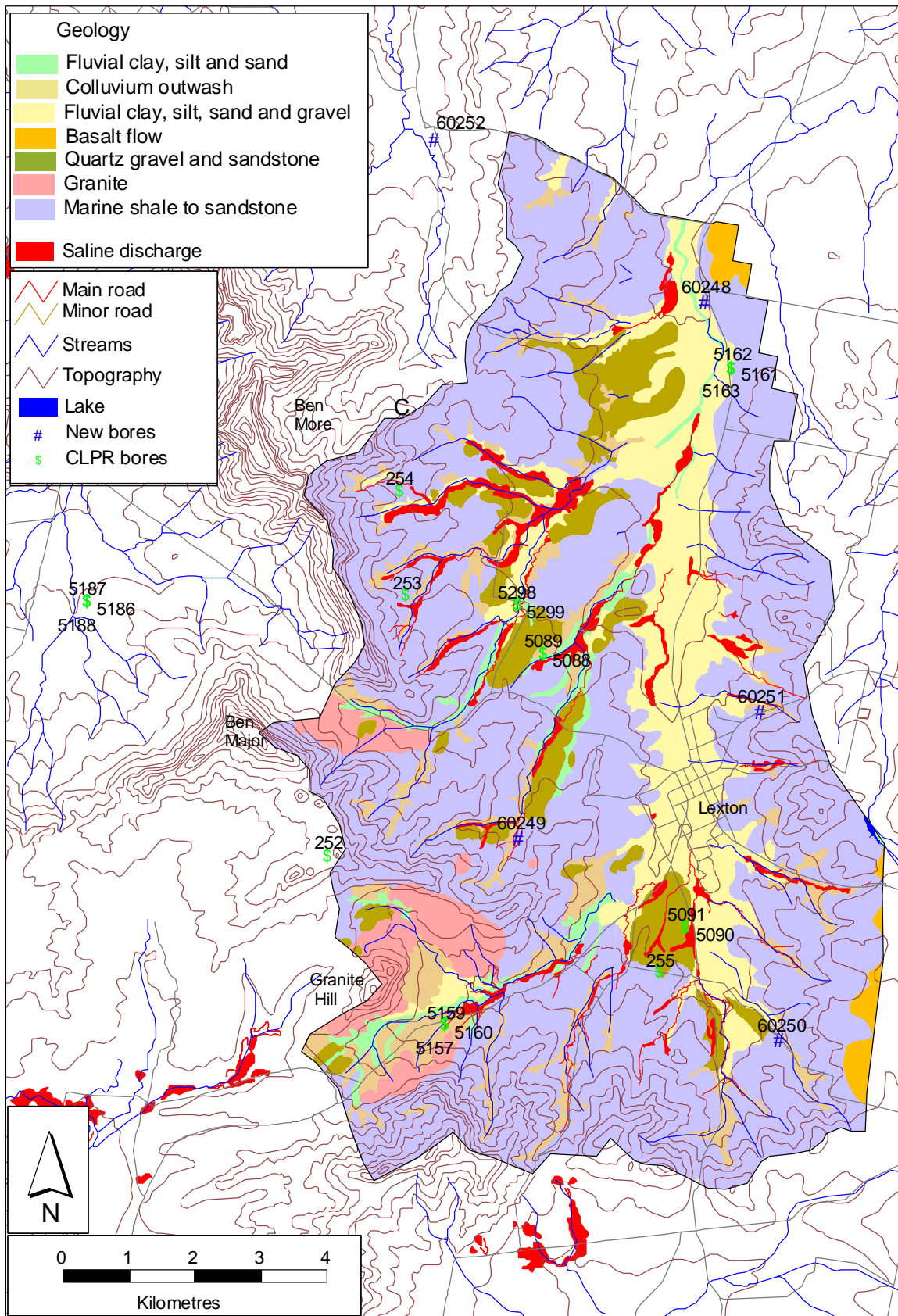


Figure 3 Map of geology, groundwater bores and saline discharge in the Bet Bet targeted area.

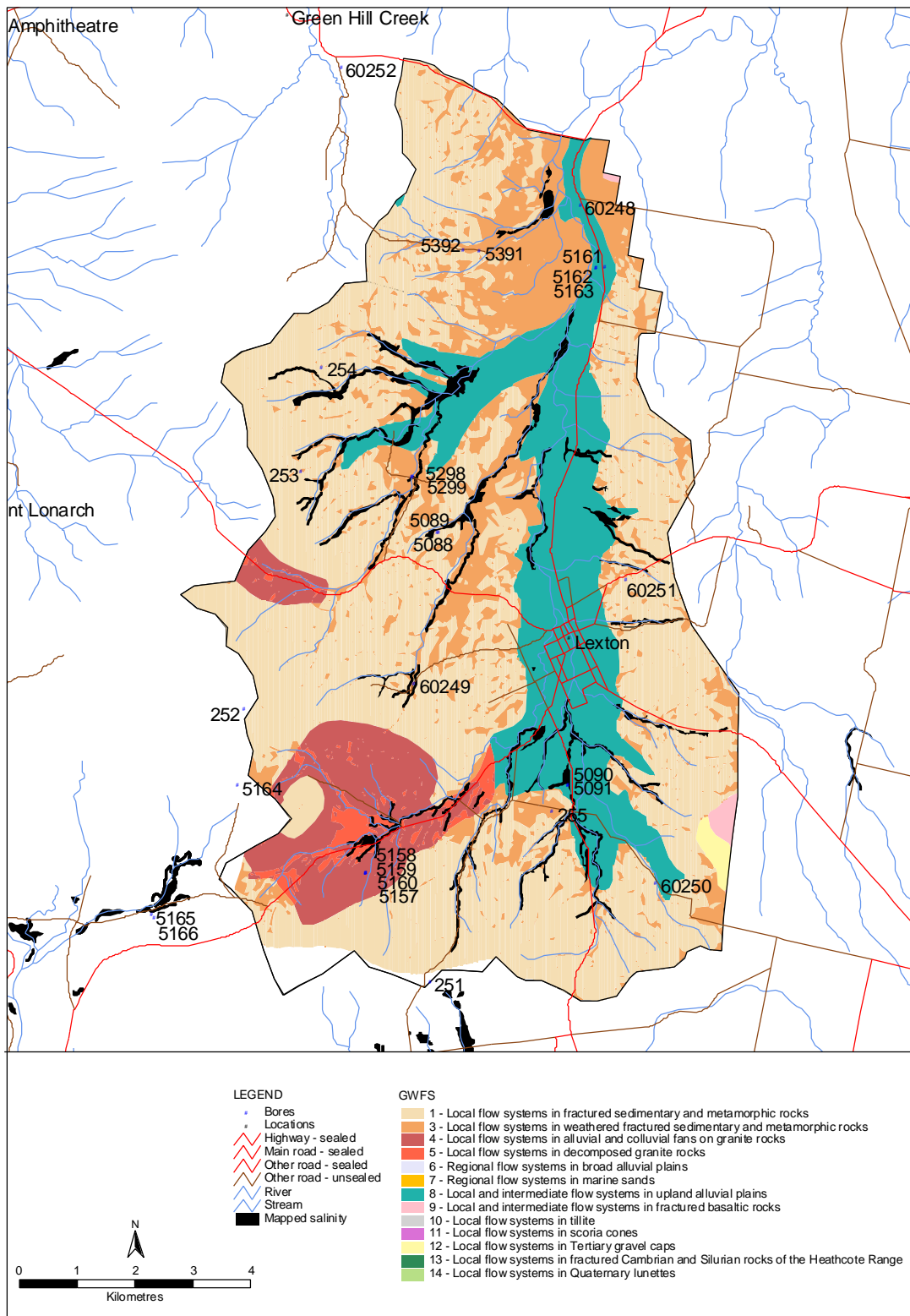


Figure 4 Groundwater flow systems in the Bet Bet targeted area

Groundwater trends in the Bet Bet targeted area

The Lexton area was one of the earliest recognised salinity affected areas in the Loddon dryland catchment area (Heislars 1996). As a result approximately 15 groundwater monitoring bores were installed in the mid to late 1980s (Table 1). Unfortunately many of these bores have either lapsed or have large gaps in the monitoring record (e.g. Bores 254, 5088-89, 5090-91, 5157, 5159, 5160 Appendix 1). However, there was enough information collected periodically from DPI monitors over the past 15 years to determine distinct groundwater trend behaviour.

A feature of the bores across the Lexton region is that strong groundwater fluctuations are observed in many of the hydrographs (e.g. Bore 5159 Appendix 1). Groundwater recharge is strongly seasonal, reflecting winter and spring rains in excess of plant requirements and soil water storage capacity. During dry periods, water levels can drop by around 4.0–6.0 m (e.g. Bores 254 and 5161).

Localised groundwater systems in the fractured sedimentary groundwater flow system tend to be very responsive to rainfall. In some cases there is up to 1 m difference between the winter and summer watertable level. An underlying falling groundwater trend is evident in some hydrographs (e.g. Bores 5160, 5159 Appendix 1). Bore 255 (Appendix 1) located above a discharge site, shows an extreme rate of recharge with water levels rising 5 m in a 12 month period over 1995–96. This indicates that the localised groundwater flow system in the fractured sedimentary rock rapidly recharges immediately after a rainfall event. Evidence of the 1994 drought can be seen as a 2 m fall in water level in bores located in local flow systems in fractured sedimentary and metamorphic rocks (e.g. Bores 253, 5161 Appendix 1).

Bores located in fluvial stream deposits and colluvial outwash from sedimentary hills tend to have a very high watertable (e.g. Bores 5088-89, 5162), which is characteristic of discharge areas. In the Bet Bet targeted area, some groundwater discharge occurs at the break-of-slope, but most is in streams. Being local groundwater systems, high recharge and discharge occurs over short periods of time, as exhibited in hydrographs for the transect of Bores 5159–63 (Appendix 1) across a discharge area. Overall data from groundwater bores shows that the Bet Bet targeted area is dominated by local groundwater systems and watertable fluctuation is very much dependant on local seasonal climatic variation.

A limitation of the data is that in many of the bores (e.g. Bores 254, 5157, 5159, 5160) there are gaps between 1993–1997 (seen on the hydrographs as a blank period). Thus the groundwater behaviour for this period is inferred. Also some bores have no readings after 1991 (e.g. Bores 5090-91). With ten years of missing data, groundwater behaviour and trends are inferred from bores located in similar groundwater flow systems. Some bores, installed in the 1980s, are missing bore logs and bore depth information (Table 1), and therefore aquifer details are inferred rather than known.

Table 1 Summary of key bore data in the Bet Bet targeted area

Bore no.	Total Depth (m)	Highest recorded waterlevel below ground level (m) (year)	Lowest recorded waterlevel below ground level (m)(year)	Record in years
253	53.0	16.5 (1991/92)	19.0 (1996)	7
254	53.0	22.5 (1991/92)	28.0 (2002)	13
255	69.0	6.5 (1991/92)	10.8 (1996)	12
5088	18.2	0.5 (1991/92)	2.2 (2002)	20
5089	6.0	0.6 (1991/92)	2.2 (2002)	20
5090	20.0	1.3 (1984)	2.5 (1990)	8
5091	7.0	1.3 (1984)	3.3 (1984)	8
5157	17.3	5.5 (1990)	10.0 (2003)	14
5159	15.2	0.5 (1991/92)	2.2 (2003)	14
5160	3.3	0.6 (1991/92)	2.2 (2003)	14
5161	19.2	6.2 (1989)	10.2 (1995)	10
5162	16.7	1.0 (1989)	2.5 (1995)	10
5163	-	1.0 (1989)	2.5 (1995)	10
5298	-	1.7 (1999)	2.7 (2003)	5
5299	-	1.5 (1998)	2.5 (2003)	2.5

4 New monitoring bores

Five new groundwater monitoring bores have been installed in the Bet Bet targeted area. These have been strategically placed to help fill the information gaps in the area. The majority of the current monitoring bores occur in clusters around Granite Hill, the Yalong Road discharge site, the Blackbottom Road discharge site and north of the Bet Bet targeted area on the Sunraysia Highway. These are monitored monthly by DPI staff.

Almost 12 months of recorded data has been collected so far, 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.

Table 2 Bore information for new bores drilled in the Bet Bet targeted area

Bore no.	Bore depth (m)	Depth to watertable (m) (November 2003)	EC ($\mu\text{S}/\text{cm}$) (November 2003)
60248	17.5	3.8	4850
60249	17.5	7.7	14 420
60250	22.0	7.4	5220
60251	22.0	13.8	13 890
60252	16.0	7.2	6540

The results from the bores drilled (Table 2) indicate that groundwater salinity levels are the highest in the fractured sedimentary rock groundwater flow systems. The salinity levels are highest in the central catchment area around Lexton. This could be attributed to evaporative concentration in shallow groundwater systems associated with the fractured sedimentary and metamorphic ranges that circle the Lexton township. The information to date indicates that a high salt load leaves the Bet Bet targeted area. Currently a new study is being conducted that measures the total salt loads leaving this area. This new project is in its infancy, therefore that data is not yet available.

5 Conclusion

The inclusion of the five new bores in the monitoring program has meant there is now a comprehensive groundwater monitoring network that covers the Bet Bet targeted area. This provides a means to assess hydrogeological processes contributing to the dryland salinity issues in the area, as well as to monitor any overall changes in groundwater trends and salinity levels that may result from new management options implemented in the future. These processes include:

- strong seasonal groundwater recharge reflecting local climatic conditions across the whole targeted area. (this is evident in the hydrographs located in Appendix 1)
- the area of highest salinity is in the low-lying, discharge areas associated with break-of-slope, with the majority of saline discharge occurring in streams
- the main groundwater flow systems in the Bet Bet targeted area are all local scale systems
- the new bores indicate that the central catchment area has the highest groundwater salinity.

Many of the groundwater investigation bores established in the late 1980s and early 1990s have lapsed (e.g. 5159, 5090-91). This is unfortunate, as it would have provided useful information relating to groundwater response to low rainfall years followed by high rainfall years.

6 Recommendations

The following recommendations are made:

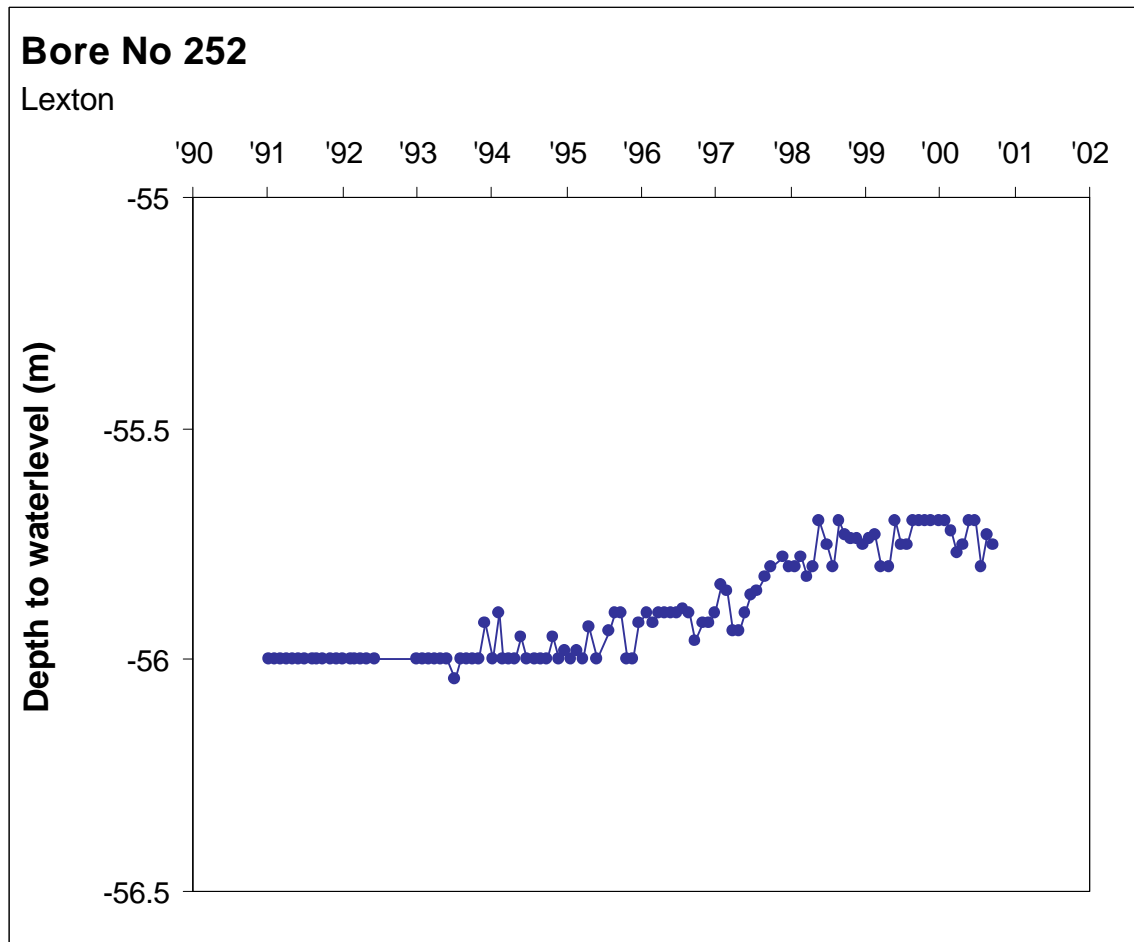
- Recommence the monitoring of bores that have lapsed, with six-monthly updates sent to engage monitors and maintain involvement by providing feedback on information they are collecting. These updates should also indicate the importance of their work in tackling the salinity issue in Bet Bet.
- Reinstate the six monthly salinity readings. Many of the bores do not have salinity readings, or the last reading was taken in 1997. The ongoing monitoring will also indicate the importance of low rainfall on salinity concentration in groundwater systems that are very responsive to local climatic variation, such as those at Lexton.

- Organise redevelopment and maintenance on the lapsed bores prior to reinstating them so that readings will be accurate, particularly those that have not been read for almost 10 years. Any more bores monitored by DPI will need to be funded through external funding sources such as NAP.
- Investigate management options such as groundwater utilisation.

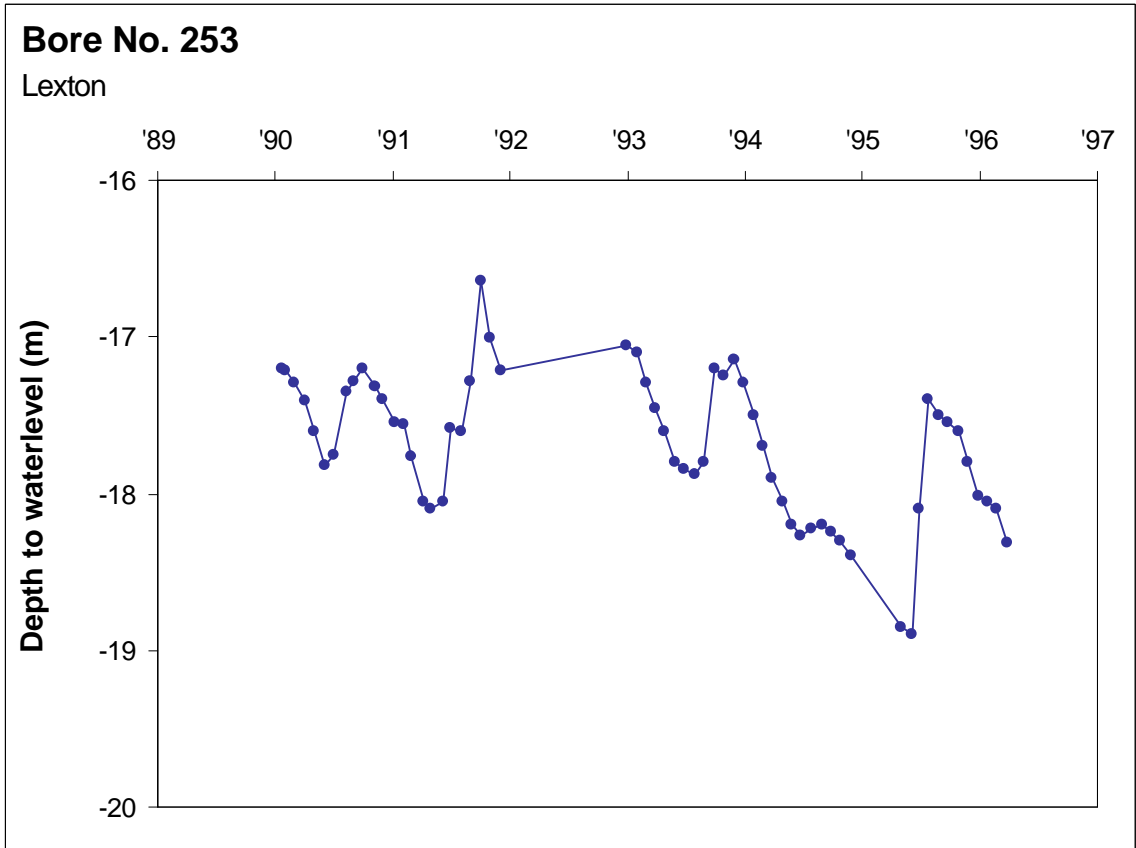
References

- 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.
- Heislors D (1996) Community groundwater monitoring report for the Loddon dryland salinity region. CLPR Monitoring Report no. 9. Department of Conservation & Natural Resources, Victoria.
- SKM (2003) Upper Bet Bet Targeted dryland salinity project area. Project Area Guidelines. Draft. Sinclair Knight Merz, Victoria
- Perry R (2003) Bet Bet targeted salinity project brochure. Department of Primary Industries, Victoria

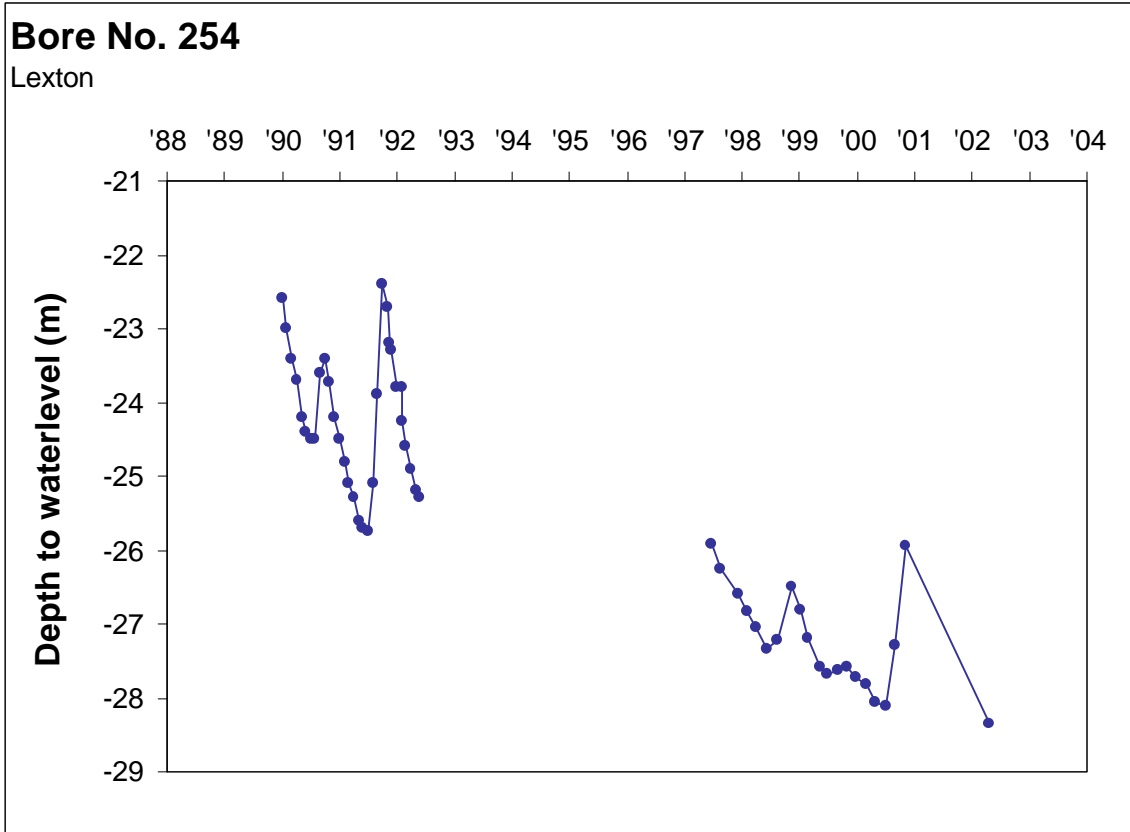
Appendix 1 Hydrographs of Bet Bet monitoring bores



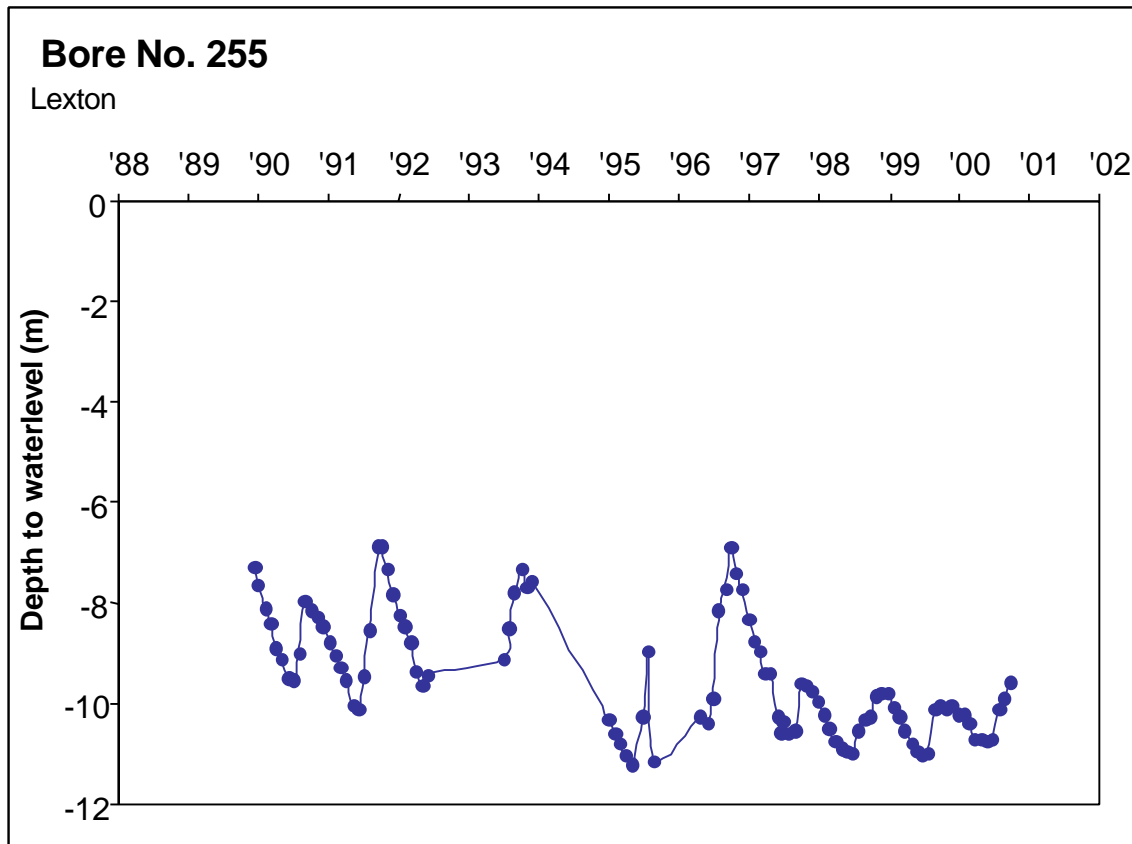
CLPR No:	252	Bore monitor:	Dal McErvale
Locality description:	Lexton, Ben Major Top of hill, crest		
Geological description:	Devonian granite and associated metamorphic rocks Clay, silt overlying hard granite/metamorphic rock		
Bore depth (m):	91.5	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	56 (March 2001)	Salinity (EC) (µS/cm):	-
Groundwater trend:	Shows an overall rising groundwater trend, regardless of low rainfall years. Recharge to this aquifer is not reliant on local rainfall. Recharge is possibly occurring from a regional source.		



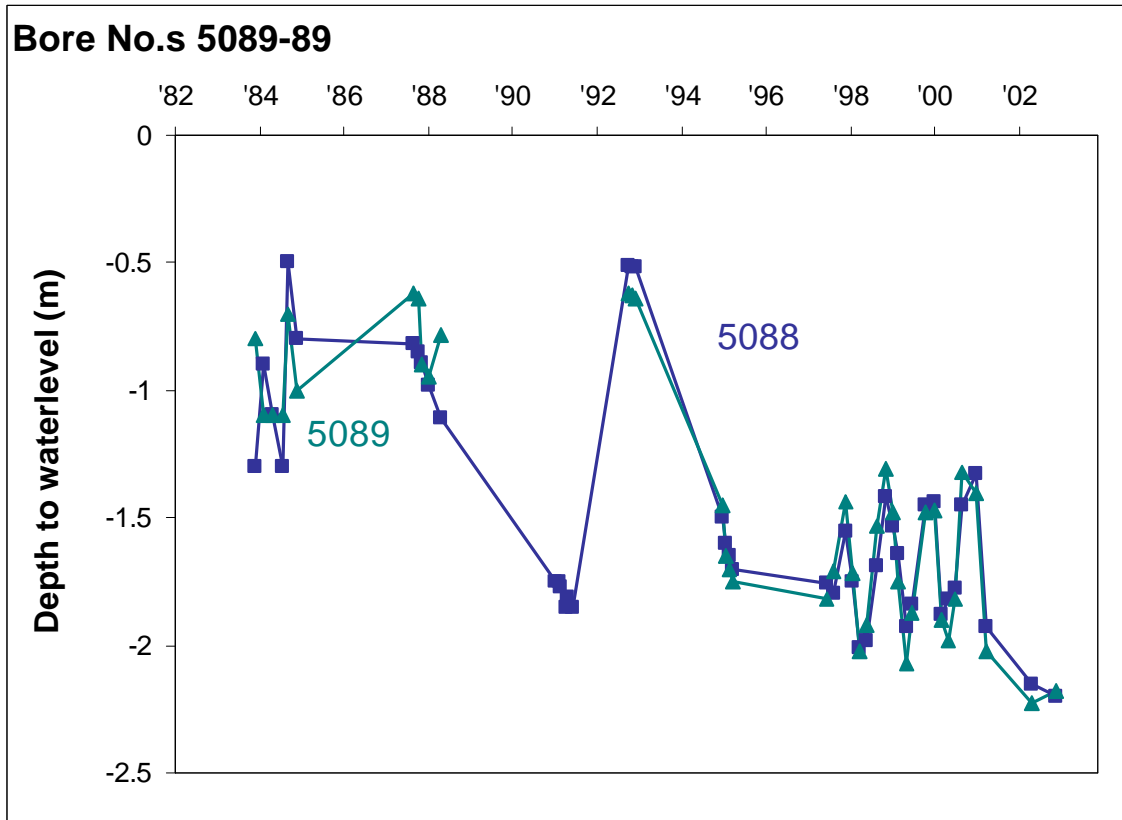
CLPR No:	253	Bore monitor:	DPI
Locality description:	Top of the hill on a steep slope		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	53	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	18.5 (in 1996)	Salinity (EC) (µS/cm):	-
Groundwater trend:	No readings since 1996. In process of reinstating monitoring of this bore.		



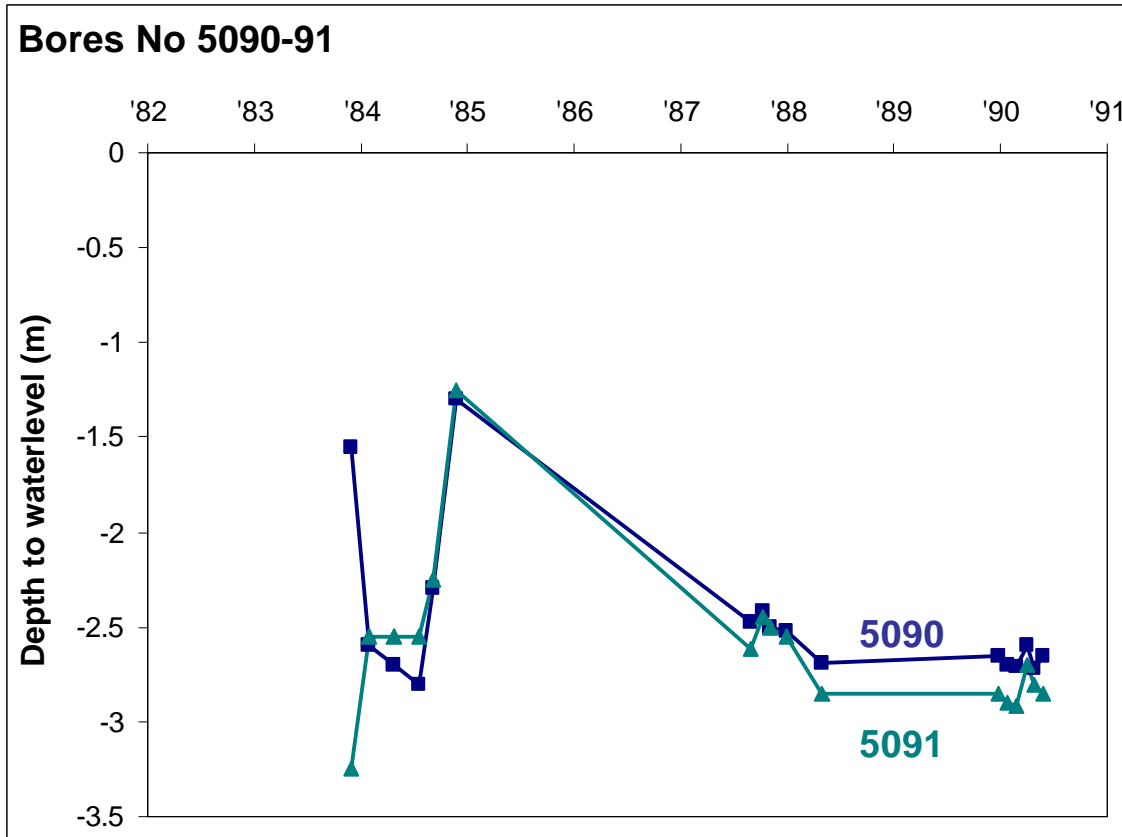
CLPR No:	254	Bore monitor:	DPI
Locality description:	Top of the hill above severe erosion and salinity off Yalong Road.		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	53	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	28	Salinity (EC) (µS/cm):	-
Groundwater trend:	Data gap from 1993–1996. Overall strong fall in groundwater level and trend.		



CLPR No:	255	Bore monitor:	Gerard Briody
Locality description:	Lexton. Top gully above saline discharge site.		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	69	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	10 (2001)	Salinity (EC) (µS/cm):	-
Groundwater trend:	Strong response to local climatic variation. A falling groundwater trend overall has been observed since 1993. It appears that in the past five years the overall falling trend has levelled out.		

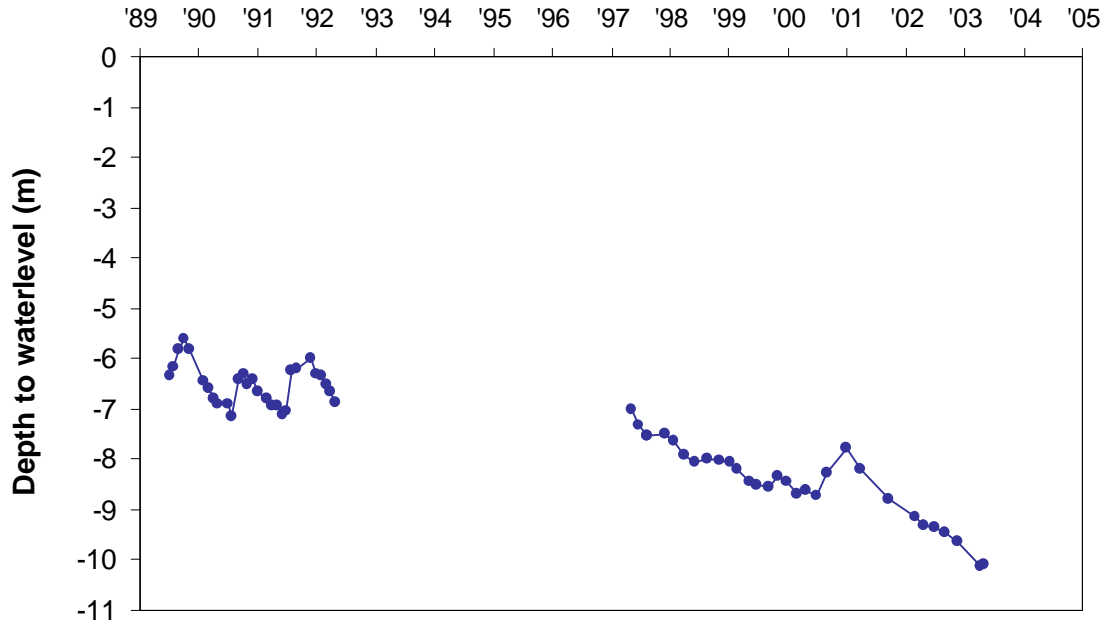


CLPR No:	5088, 5089	Bore monitor:	DPI
Locality description:	Lexton. On discharge site.		
Geological description:	Colluvium outwash, on top of fluvial clays, silts, sands and gravels		
Bore depth (m):	5088 = 18.2 5089 = 6	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	5088 = 2 5089 = 2	Salinity (EC) ($\mu\text{S}/\text{cm}$):	
Groundwater trend:	Erratic hydrograph behaviour due to the lack of regular reading in the early 1990s. Very responsive to local climatic variation with an overall falling groundwater trend.		



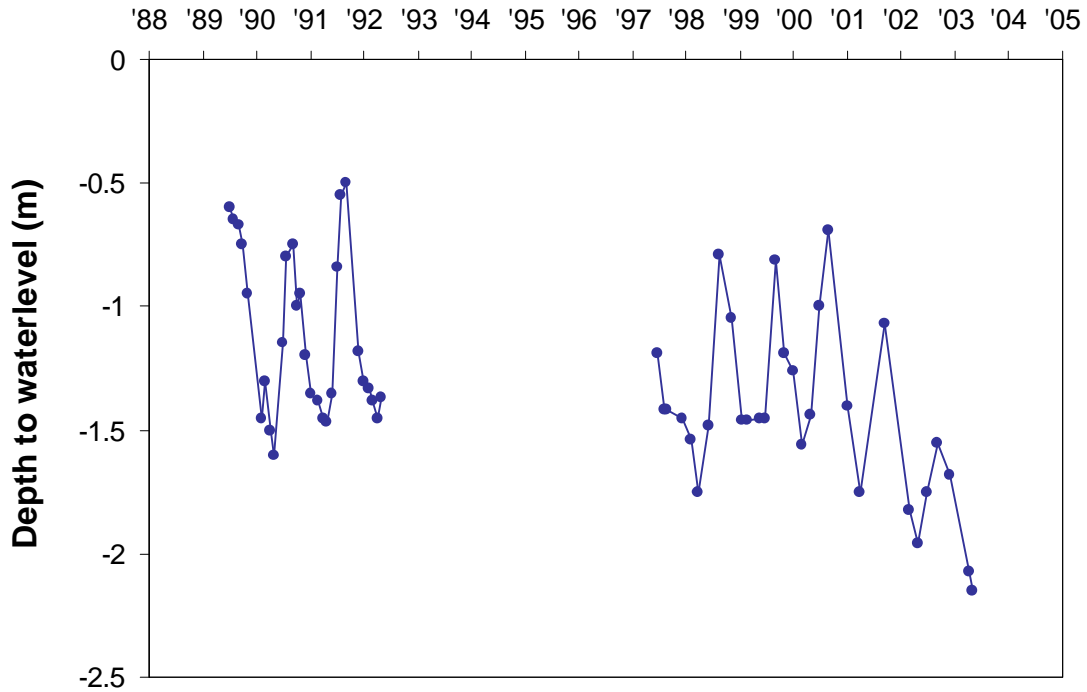
CLPR No:	5090, 5091	Bore monitor:	A. Hobson
Locality description:	Lexton. Just above discharge site off Blackbottom Road		
Geological description:	Colluvium outwash, on top of fluvial clays, silts, sands and gravels		
Bore depth (m):	5090 = 20 5091 = 7	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	5090 = 2.5 5091 = 2.7	Salinity (EC) (µS/cm):	-
Groundwater trend:	Erratic hydrograph behaviour due to lack of recorded information between 1985–88. Sporadic readings throughout the 1980s. No readings since 1991. Shows an overall falling trend responding to climatic variation. Would be worth reinstating.		

Bore no. 5157

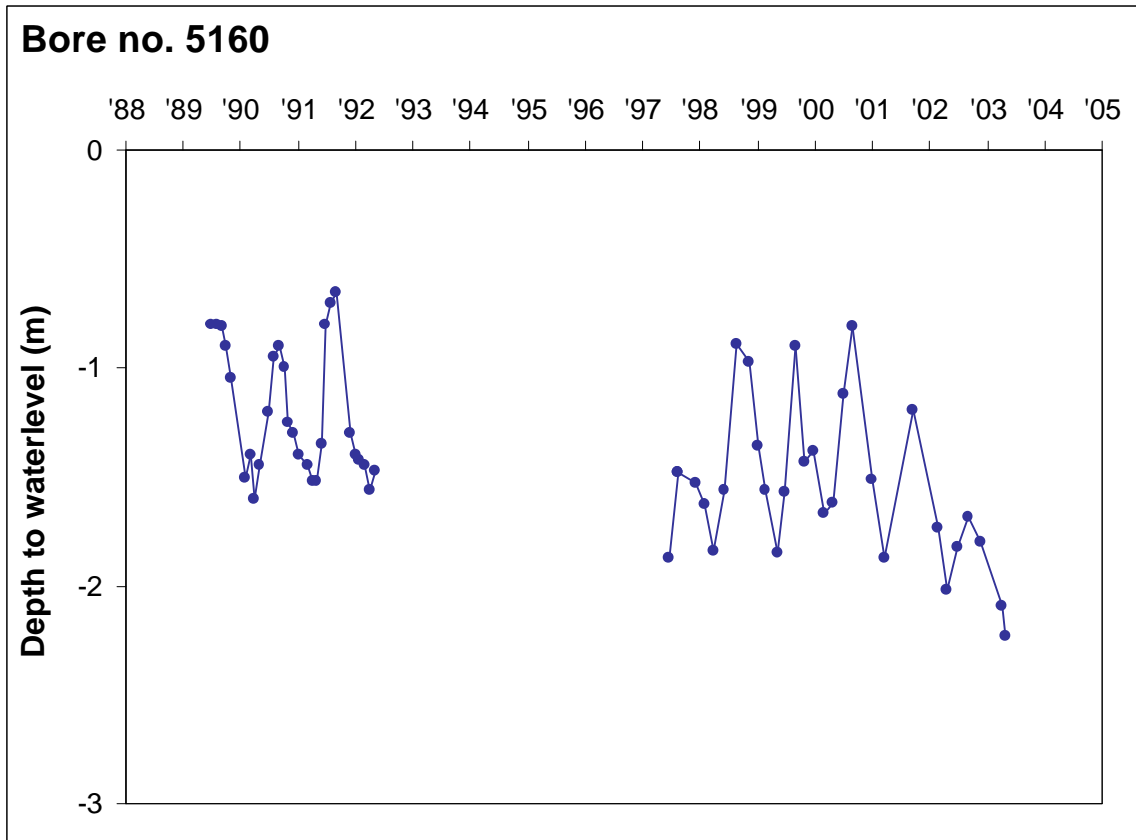


CLPR No:	5157	Bore monitor:	DPI
Locality description:	Lexton		
Geological description:	Devonian granite and associated metamorphic rocks Clay, sands overlying hard granite/metamorphic rock		
Bore depth (m):	17.3	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	10	Salinity (EC) (µS/cm):	10 252
Groundwater trend:	Missing data between 1993–1997. Strong fall in groundwater level since 1998.		

Bore no. 5159

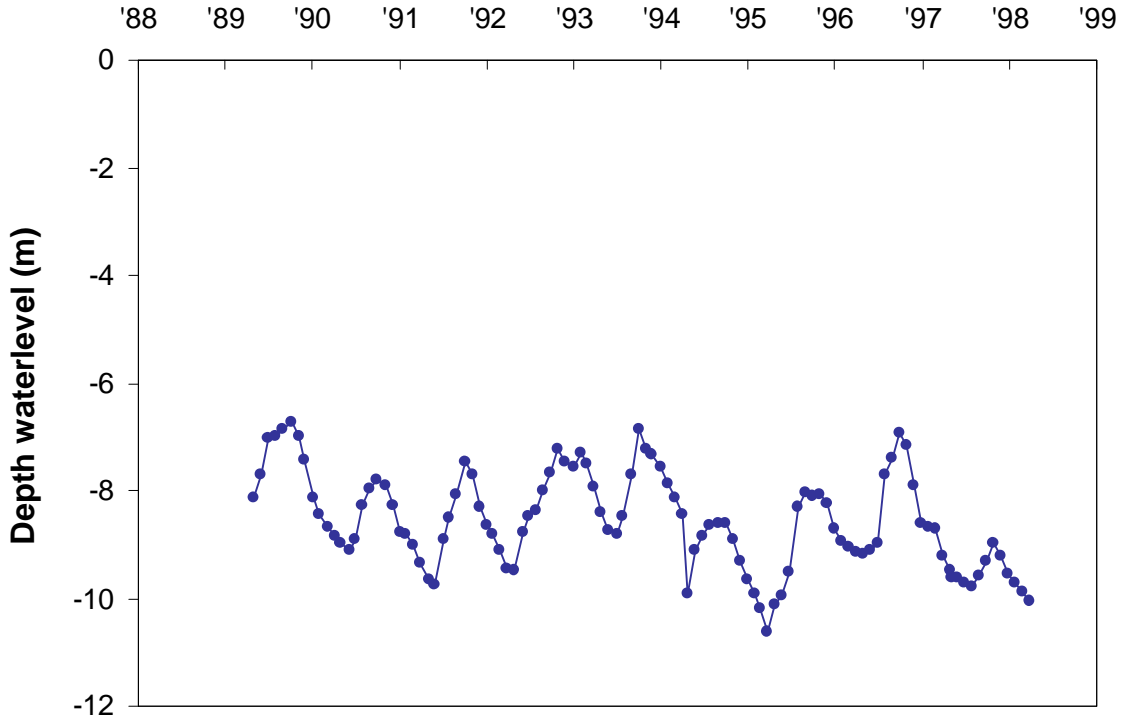


CLPR No:	5159	Bore monitor:	DPI
Locality description:	Lexton, on base of Granite Hill		
Geological description:	Ordovician granite and associated metamorphic rocks Clay, sands overlying hard granite/metamorphic rock		
Bore depth (m):	15.2	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2	Salinity (EC) (µS/cm):	-
Groundwater trend:	Strong response to local climatic variation. Overall falling groundwater trend.		

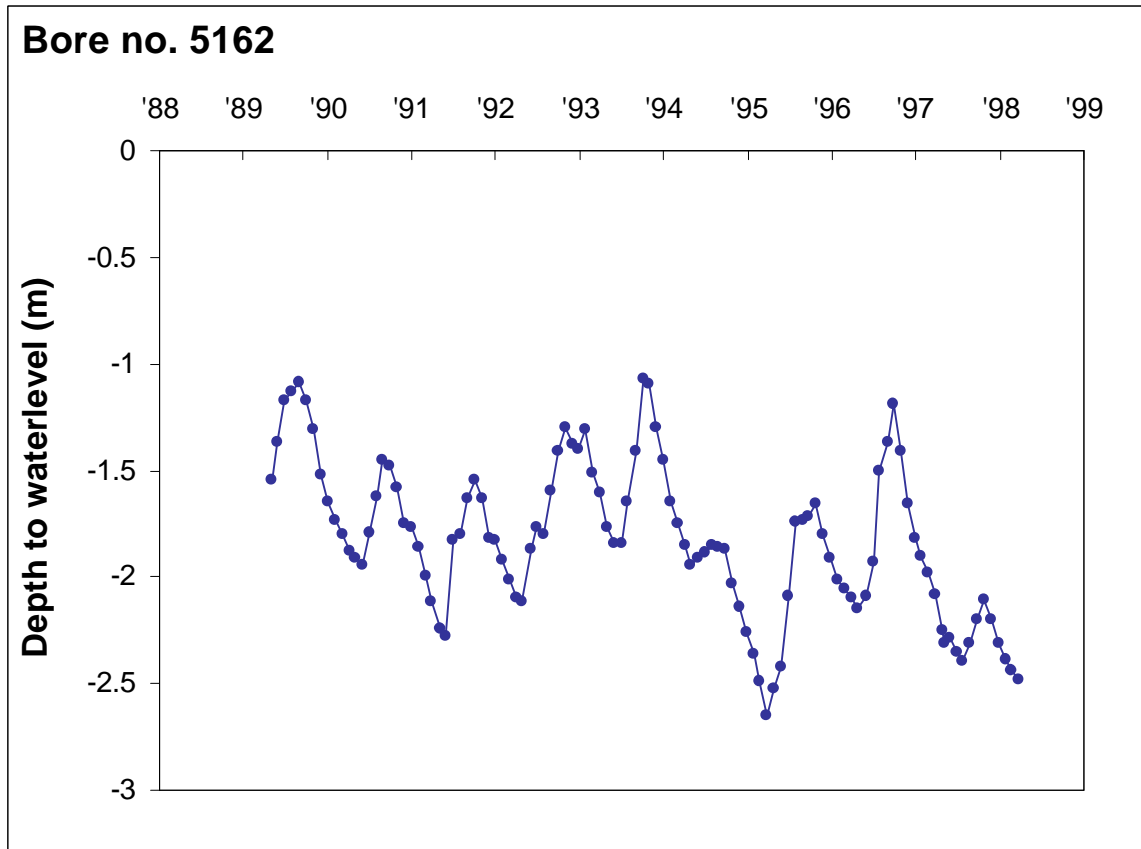


CLPR No:	5160	Bore monitor:	DPI
Locality description:	Lexton Monitors discharge site		
Geological description:	Ordovician granite and associated metamorphic rocks Clay, sands overlying hard granite/metamorphic rock		
Bore depth (m):	3.3	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2	Salinity (EC) (µS/cm):	-
Groundwater trend:	Missing data between 1993–1997. Strong response to local rainfall variation. Slightly falling groundwater level overall.		

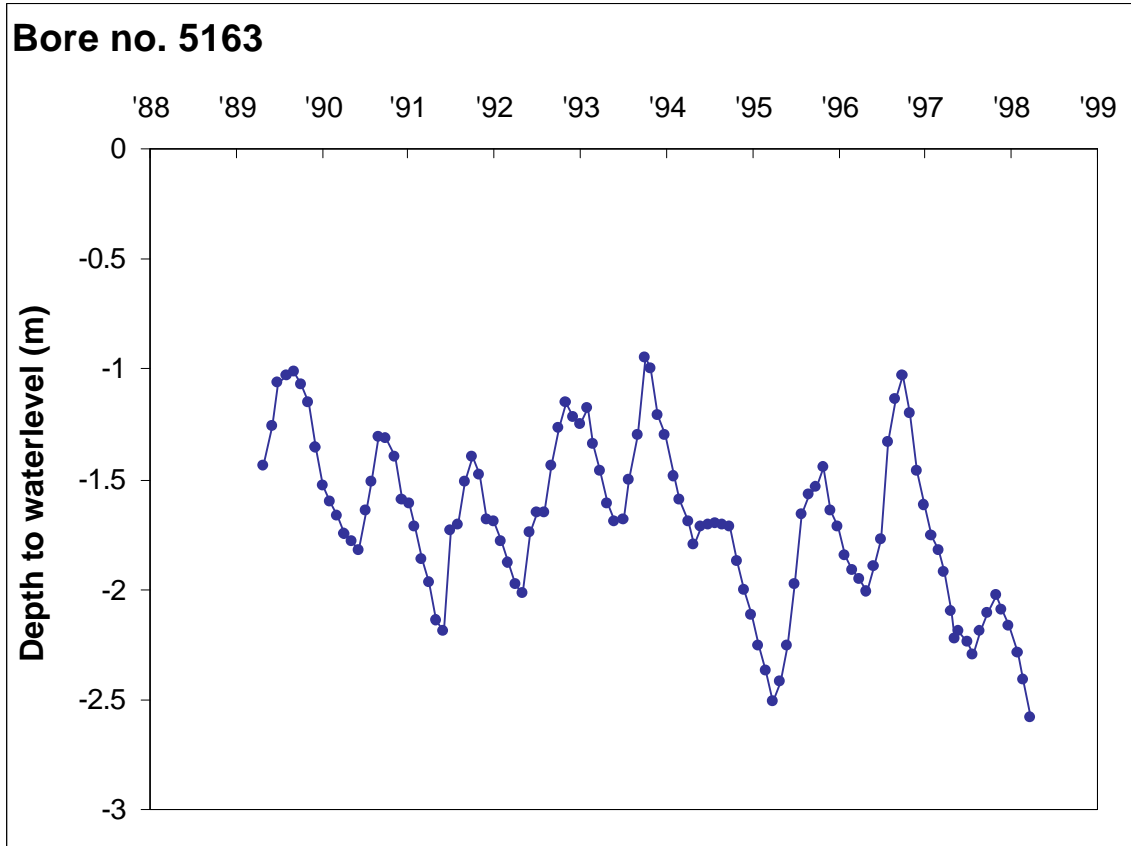
Bore no. 5161



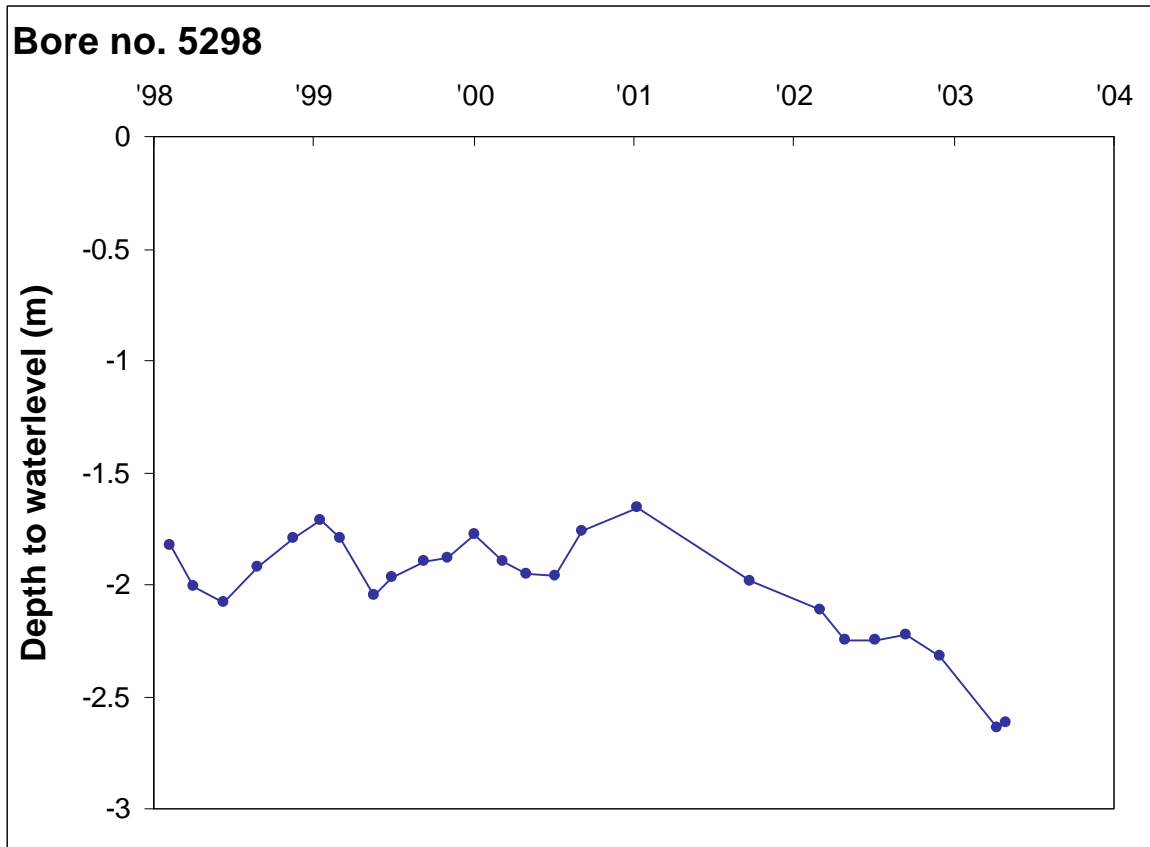
CLPR No:	5161	Bore monitor:	D. Jolly
Locality description:	North of Lexton on the Sunraysia Highway		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	19.2	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	10	Salinity (EC) (µS/cm):	10 254
Groundwater trend:	Even underlying groundwater trend with strong response to seasonal climatic variation. No data/lapsed since 1998.		



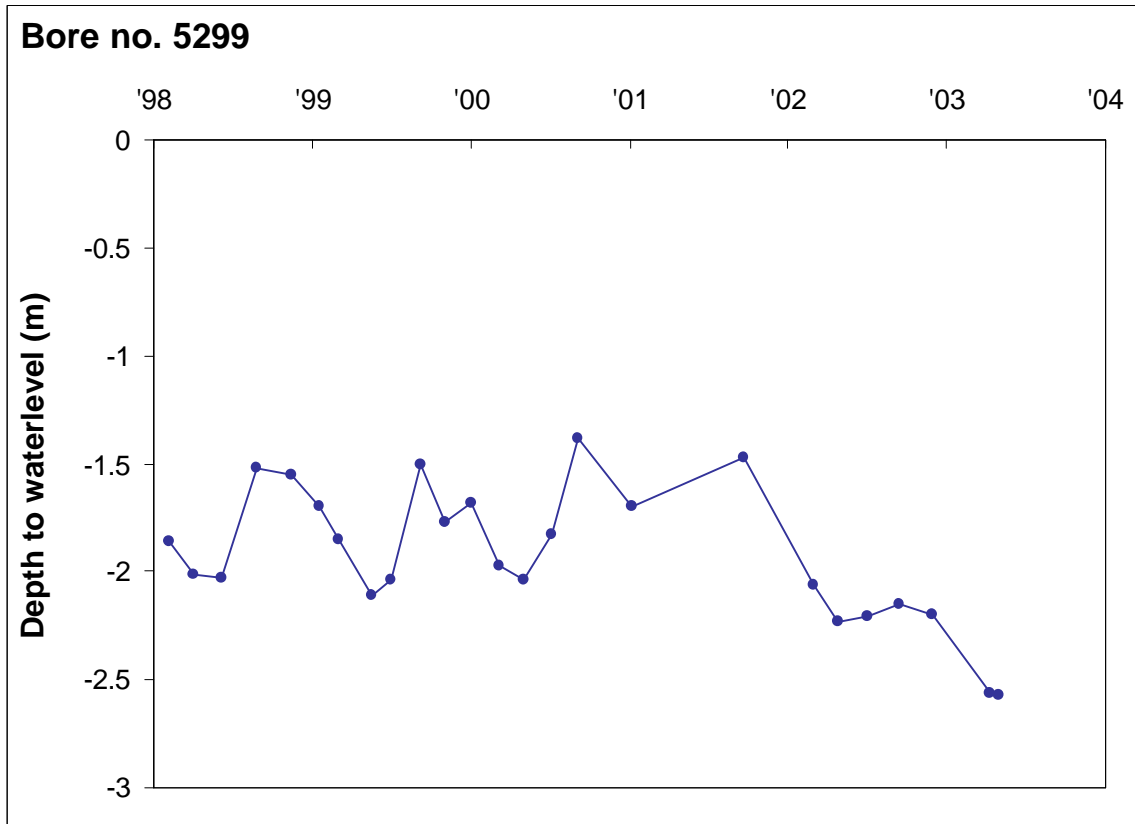
CLPR No:	5162	Bore monitor:	D. Jolly
Locality description:	North of Lexton on the Sunraysia Highway		
Geological description:	Fluvial clay, silt, sand and gravel		
Bore depth (m):	16.7	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2.5 (1998)	Salinity (EC) (µS/cm):	10 255
Groundwater trend:	Data only available to 1998. Shows it is very responsive to local climatic variation.		



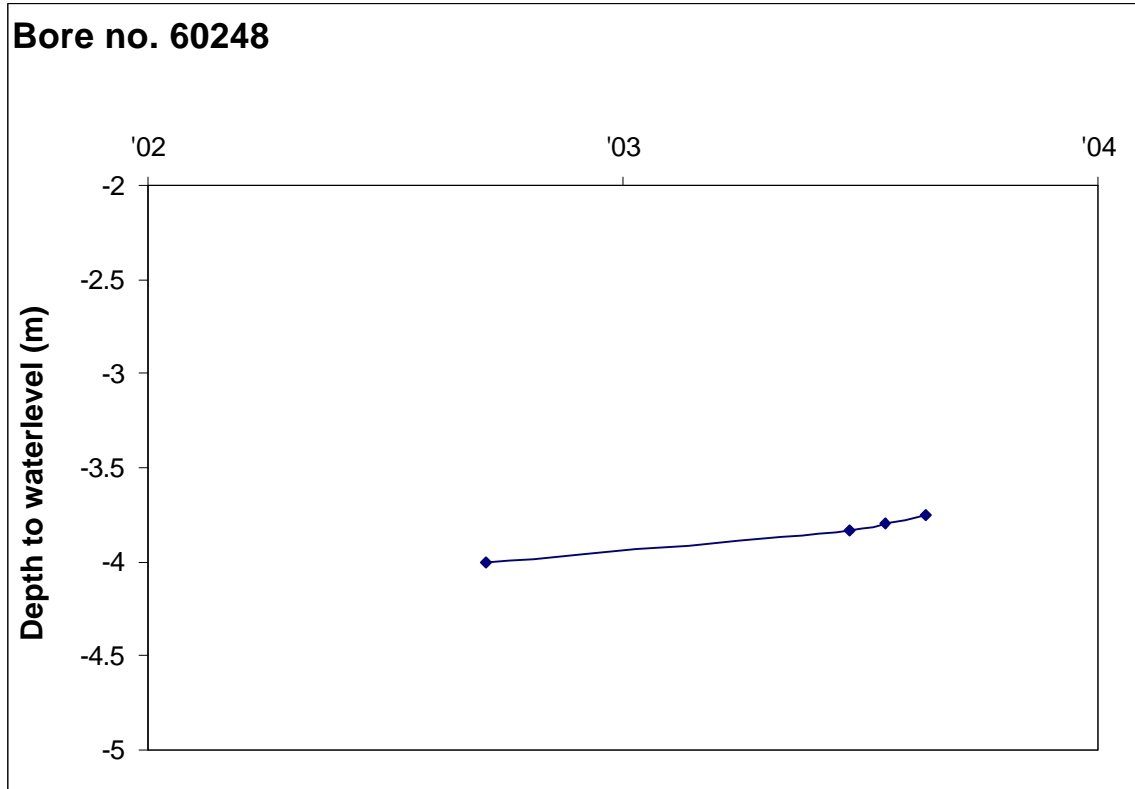
CLPR No:	5163	Bore monitor:	D. Jolly
Locality description:	North of Lexton on Sunraysia Highway		
Geological description:	Fluvial clay, silt, sand and gravel		
Bore depth (m):	n/a	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2.5	Salinity (EC) (µS/cm):	10 256
Groundwater trend:	Even underlying groundwater trend with strong response to seasonal climatic variation. No data/lapsed since 1998.		



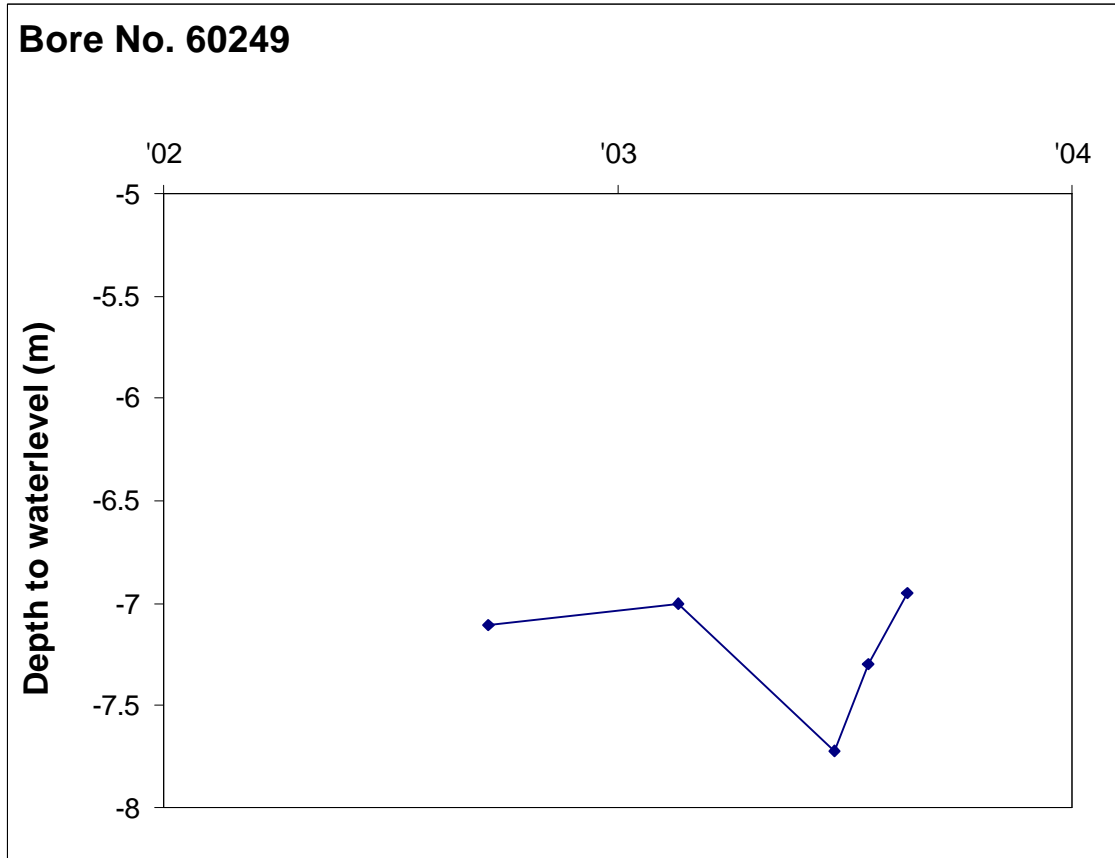
CLPR No:	5298	Bore monitor:	DPI
Locality description:	Yalong Road, in drainage line		
Geological description:	Fluvial clays, silts, sands and gravels.		
Bore depth (m):	n/a	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2.5	Salinity (EC) ($\mu\text{S}/\text{cm}$):	-
Groundwater trend:	Falling groundwater level. Responsive to local rainfall variation.		



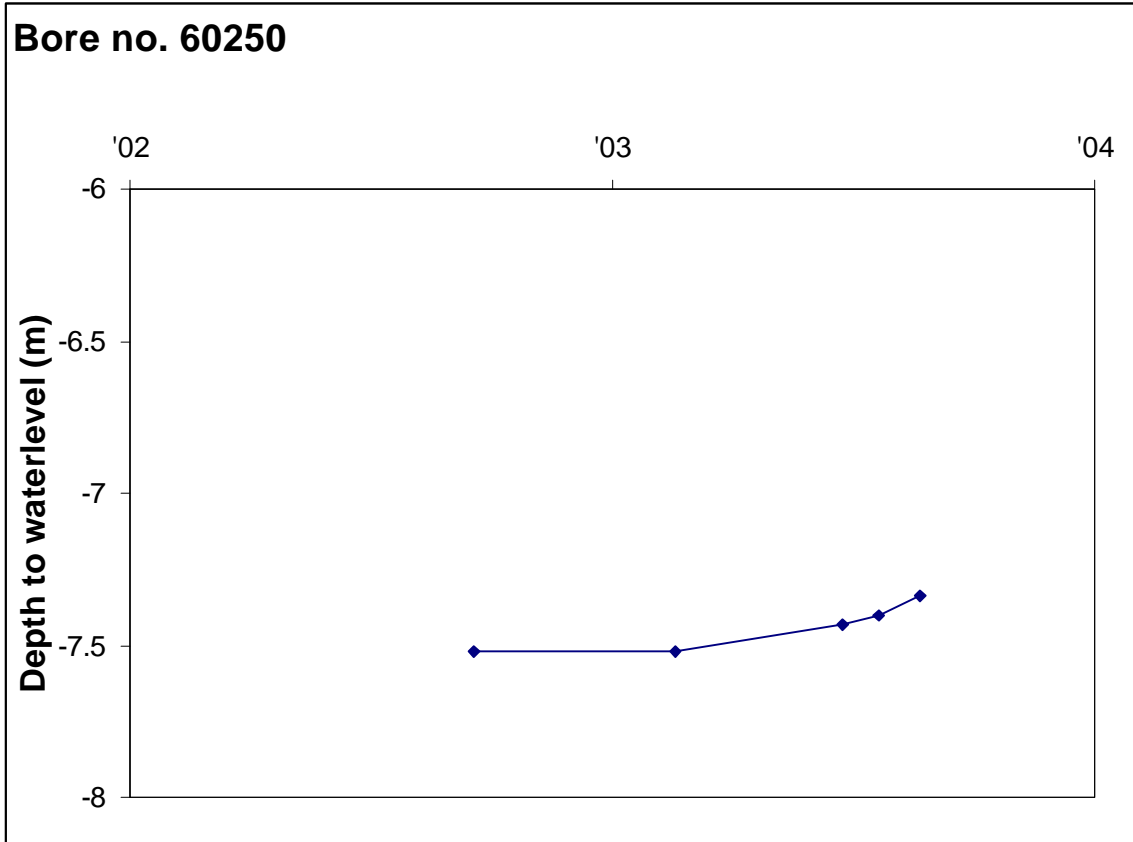
CLPR No:	5299	Bore monitor:	DPI
Locality description:	Roadside north-west of Lexton		
Geological description:	Fluvial clay silt, sand and gravel		
Bore depth (m):	n/a	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	2.5	Salinity (EC) (µS/cm):	-
Groundwater trend:	Responsive to climatic variation. An overall falling groundwater trend.		



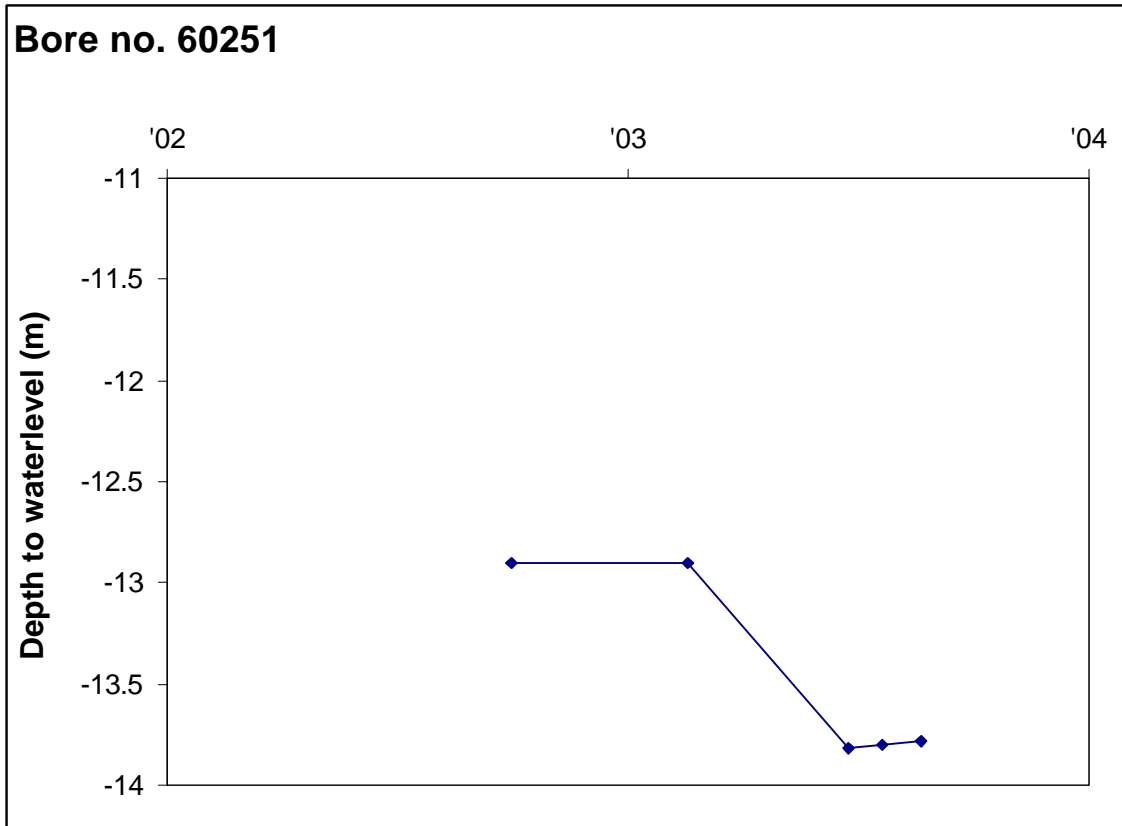
CLPR No:	60248	Bore monitor:	DPI
Locality description:	Roadside Lexton Sunraysia Highway Lower slope		
Geological description:	Fluvial clay, silt sand and gravel		
Bore depth (m):	17.5	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	3.8	Salinity (EC) (µS/cm):	4850
Groundwater trend:	An overall rising groundwater trend. Limited data. New bore.		



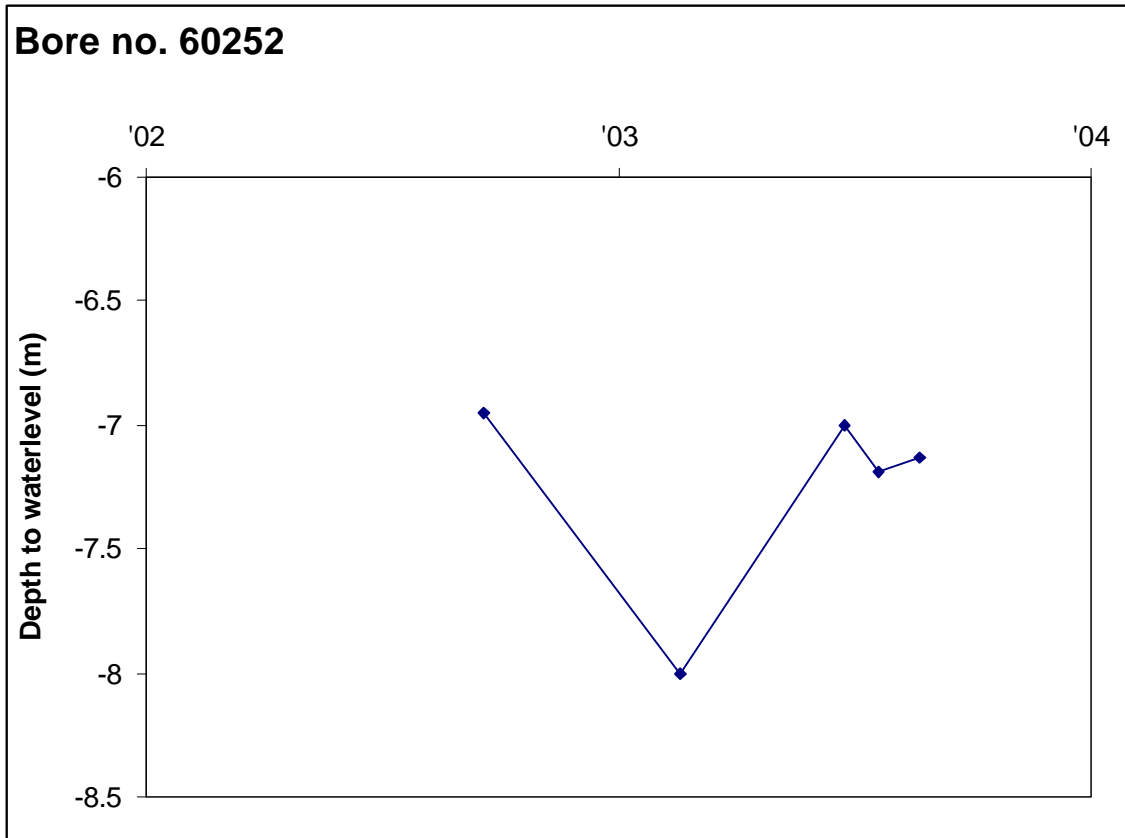
CLPR No:	60249	Bore monitor:	DPI
Locality description:	Roadside Lexton Rifle Range Road Mid-lower slope		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	17.5	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	7.7	Salinity (EC) (µS/cm):	14 420
Groundwater trend:	Responsive to climatic variation. An overall falling groundwater trend. New bore.		



CLPR No:	60250	Bore monitor:	DPI
Locality description:	Roadside Lexton Forest Road Upper slope		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	22	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	7.4	Salinity (EC) (µS/cm):	5220
Groundwater trend:	Responsive to climatic variation. An overall rising groundwater trend. New bore.		



CLPR No:	60251	Bore monitor:	DPI
Locality description:	Roadside Lexton Maryborough Road Mid-slope		
Geological description:	Ordovician sedimentary rock Hard fractured marine shale and sandstone		
Bore depth (m):	22	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	13.8	Salinity (EC) (µS/cm):	13 890
Groundwater trend:	Responsive to climatic variation. An overall falling groundwater trend. New bore.		



CLPR No:	60252	Bore monitor:	DPI
Locality description:	Roadside Lexton. Impeys Road		
Geological description:	Ordovician Sedimentary Rock (Hard, fractured marine shale and sandstone)		
Bore depth (m):	16	Average rainfall (mm/yr):	611
Current water depth 2003 (m):	7.2	Salinity (EC) (µS/cm):	6540
Groundwater trend:	Responsive to climatic variation. An overall falling groundwater trend. New bore.		