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RL/rl: (15 Mile Groundwater Investigations)
Project No. 265
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SHIRE OF FLINDERS

15-MILE AREA GROUNDWATER INVESTIGATIONS

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1.0 INTRODUCTION

The Shire of Flinders, centred at the town of Hughenden in North Queensland, is carrying out investigations into the development of irrigated agriculture at the 15 Mile Reserve, to the west of the town.

As part of the investigations a geophysical survey has been carried out, several test boreholes have been drilled and, lately, four test production bores have been installed and undergone pumping tests, to assess the sustainability of groundwater as a source of water supply for irrigation development.

One of the constraints to groundwater development is that production bores should be located at least 1km from the centre of the Flinders River to preclude triggering of the licensing conditions of the Gulf Water Resource Plan. The Shire of Flinders has also indicated that they would prefer the test drilling sites to be in reasonable vicinity of 15 Mile No 1 Bore so that any successful bores can be used as one integrated irrigation system.

2.0 SCOPE OF WORK

The scope of work undertaken for the groundwater investigation is as follows:

1. Desktop review of all the existing geophysical and drilling information from “15 Mile” investigations as well as any data held in the DNRM groundwater database.

2. Conduct a 24 hour pump-test on 15 Mile No 1 Bore to Australian Standard AS2368 including recovery measurement on the pumped bore and nearby holes and/or piezometers.

3. Recommend the preferred locations for construction of two (2) large diameter production bores.

4. Conduct a standard 24 hour pump-test on each (production) bore to Australian Standard AS2368 including recovery measurement on the pumped bore and nearby holes and/or piezometers.

5. Present test data and results as per AS2368 requirements.

6. Analyse results of the pump-test on the production bores and recommend long term, sustainable pumping rates and pump intake depths.

7. Recommend preferred location/s for expansion of the bore-field, based on the pump test results and the information gained about the aquifer and the general “hydrological regime”.

3.0 ELEMENTS OF THE GROUNDWATER INVESTIGATION

3.1 Geophysical Survey

Geo9 Pty Ltd undertook a geophysical survey of the 15 Mile Reserve and the downstream Glendalough Station in 2015[1]. The purpose of the survey was to provide a better understanding of the likely distribution and extent of alluvial aquifers adjacent to the Flinders River.

Several traverses were undertaken at right angles to the 15 Mile Reserve and the results were interpreted. Perhaps of most use for groundwater investigation was the electroseismic hydraulic conductivity tomography (ESKT) interpretation. This is reproduced in Figure 1.

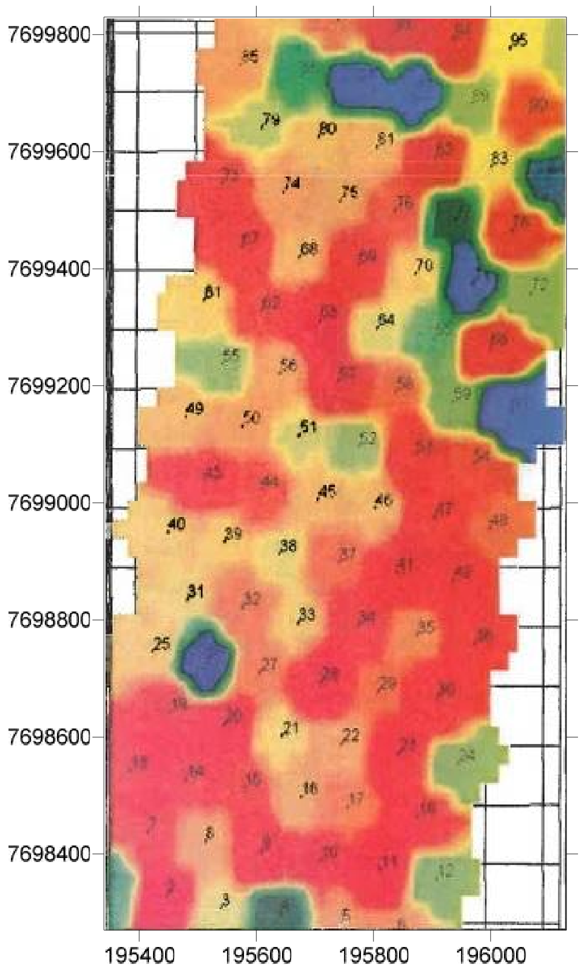


Figure 1: ESKT above 285m AHD
(source Geo9, July 2015)

[1] Geo9 Pty Ltd, July 2015. Electroseismic Survey of 15 Mile Reserve and Glendalough Station Flinders River Catchment, Hughenden Queensland. Prepared for Queensland Department of Agriculture and Fisheries.

The areas coloured red represent the thickest and potentially the most productive aquifer material. The areas coloured yellow, green and blue diminish in potentially productive aquifer material.

3.2 Test Drilling Program

Two test drilling programs were carried out based on the ESKT profile shown in Figure 1. The first was undertaken by Drillex in late 2016 and the second by Ayr Boring Company (ABC) in June and July 2017.

Figure 2 shows the locations of the test boreholes from both of these drilling campaigns.

Figure 2: Locations of Test Boreholes Drilled During 2016 and 2017

Strata logs were recorded for all the test boreholes. Notes of where groundwater was intersected were recorded.

3.3 15 Mile Aquifer Defined

Two Department of Natural Resources and Mines groundwater monitoring bores were drilled in the early 1970's as part of the state's ambient groundwater monitoring bore program. These were designated registered number (RN) 91500046 and 91500047. The strata logs from these two groundwater monitoring bores were assessed together with the strata logs from the Drillex and ABC campaigns.

In addition to the subsurface strata a visual assessment of the thickness of sand in the banks of the Flinders River adjacent to the 15 Mile Reserve was made by the author. It is obvious that the sand overlying the stiff dark grey clay in the banks is no more than about 2m thick.

A number of criteria were adopted to assess the potential of the strata for production bores. These were:

Qualitative permeability was based on the ratio of sand to clay below the water table. The interpreted aquifer limits are shown in Figure 3 below.

- The area within the yellow border is where the ratio of sand to clay is interpreted to be greater than 1 i.e. the proportion of sand moderately exceeds the proportion of clay. The area within the green border is where the ratio of sand to clay is interpreted to be greater than two i.e. much more sand than clay.

- Areas outside of the yellow border are where the ratio of sand to clay is interpreted to be less than one i.e. the proportion of clay exceeds the proportion of sand i.e. virtually only clay or mudstone. This is interpreted as of poor aquifer potential.

- The blue lines are interpreted palaeo-channels that contain the deepest and thickest sand.

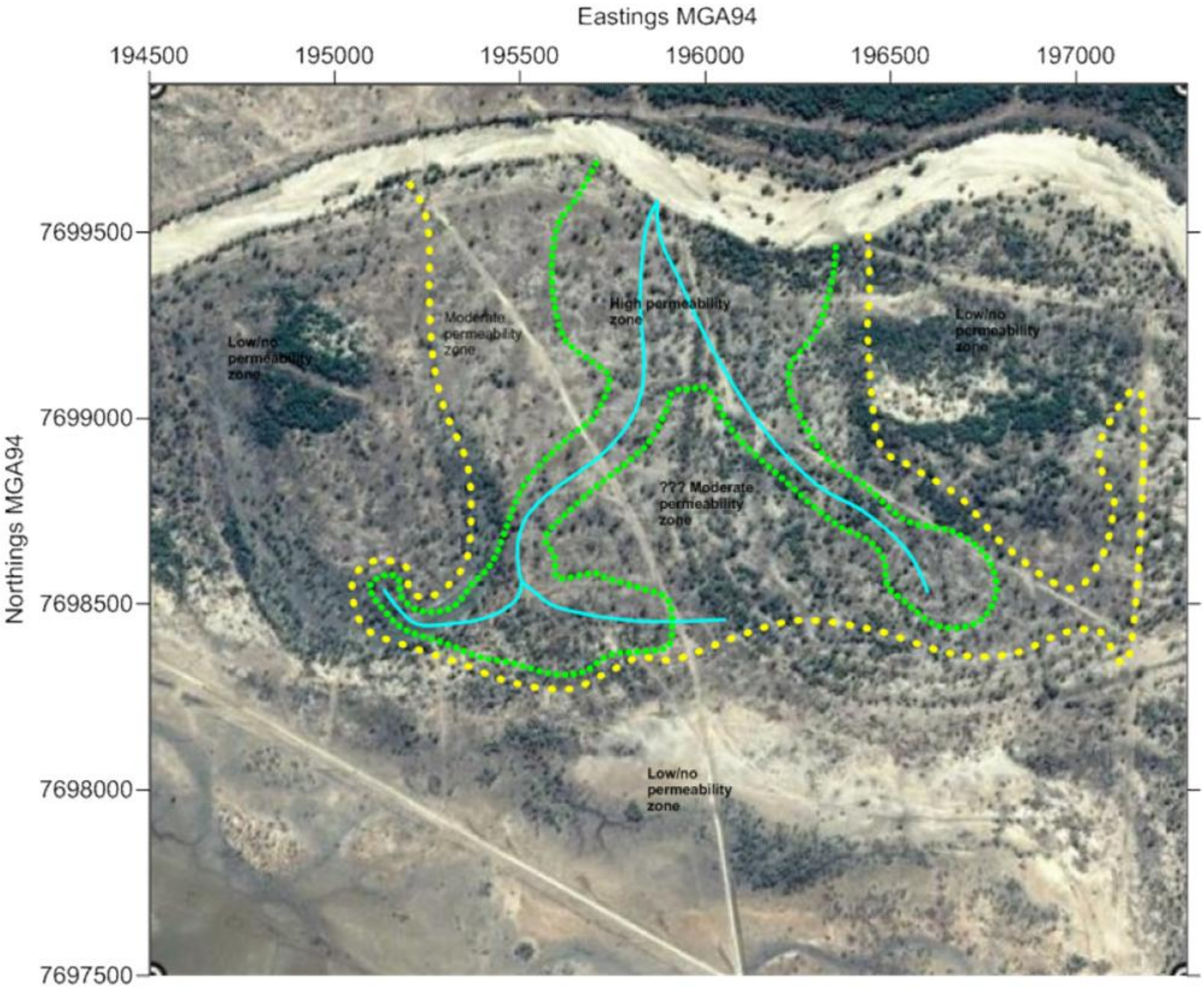


Figure 3: Interpreted Aquifer Extent of 15 Mile Reserve Alluvial Aquifer

Based on this interpretation and on the Geo9 ESKT layer four test production bores were installed. These were designated 15 Mile No1, 15 Mile No2, 15 Mile No3 and 15 Mile No4. The locations of these test production bores, and the 15 Mile Reserve observation bores are shown on Figure 4.

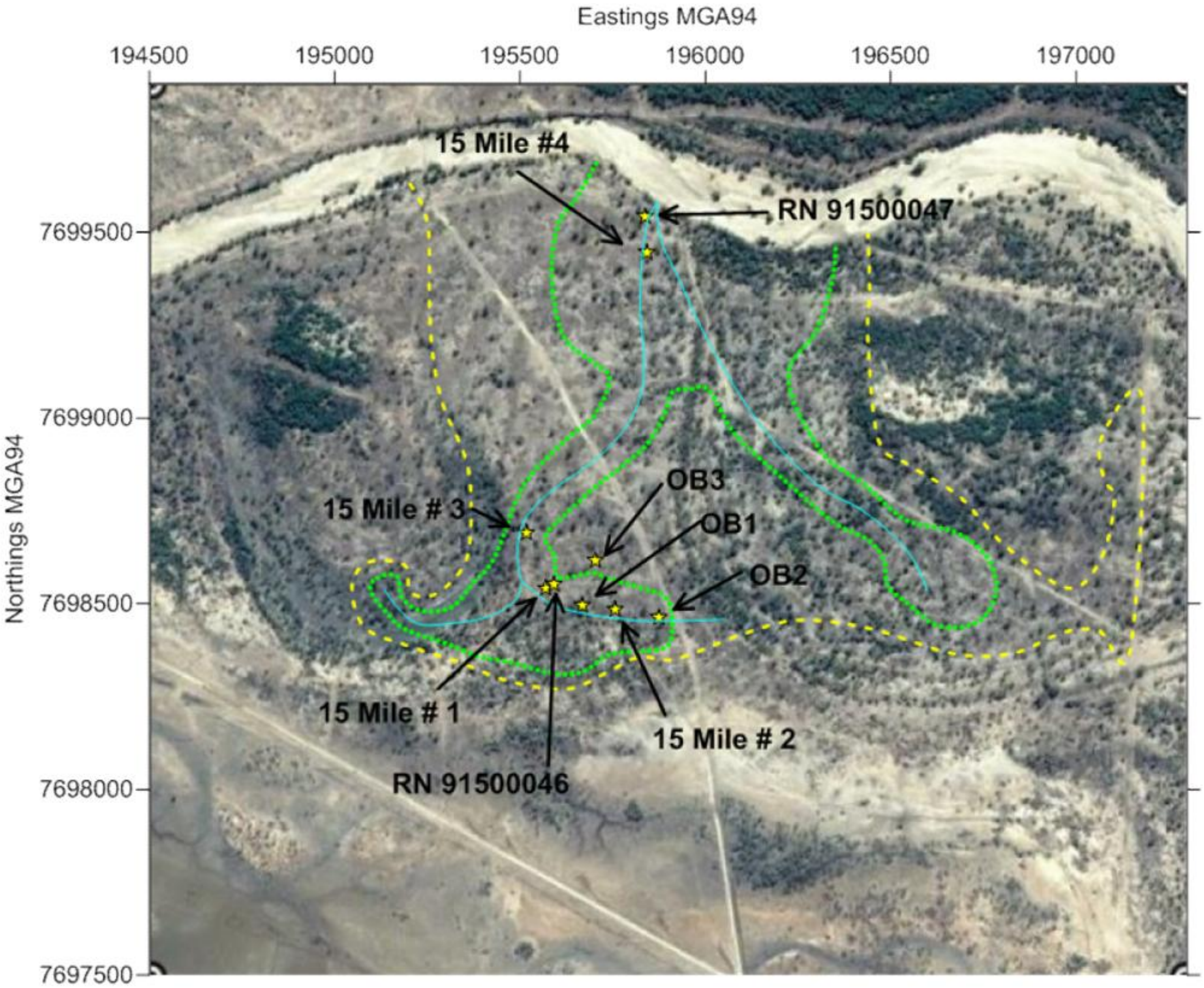


Figure 4: Locations of 15 Mile Reserve Production and Observation Bores

The locations of these test production bores, and the 15 Mile Reserve observation bores are also shown on Geo9 ESKT coverage in Figure 5.

It can be seen from Figure 5 that three of the four test production bores are located in the potentially most productive aquifer as interpreted from the ESKT. 15 Mile No 3 Bore is located on the fringes of the potentially most productive aquifer as interpreted from the ESKT.

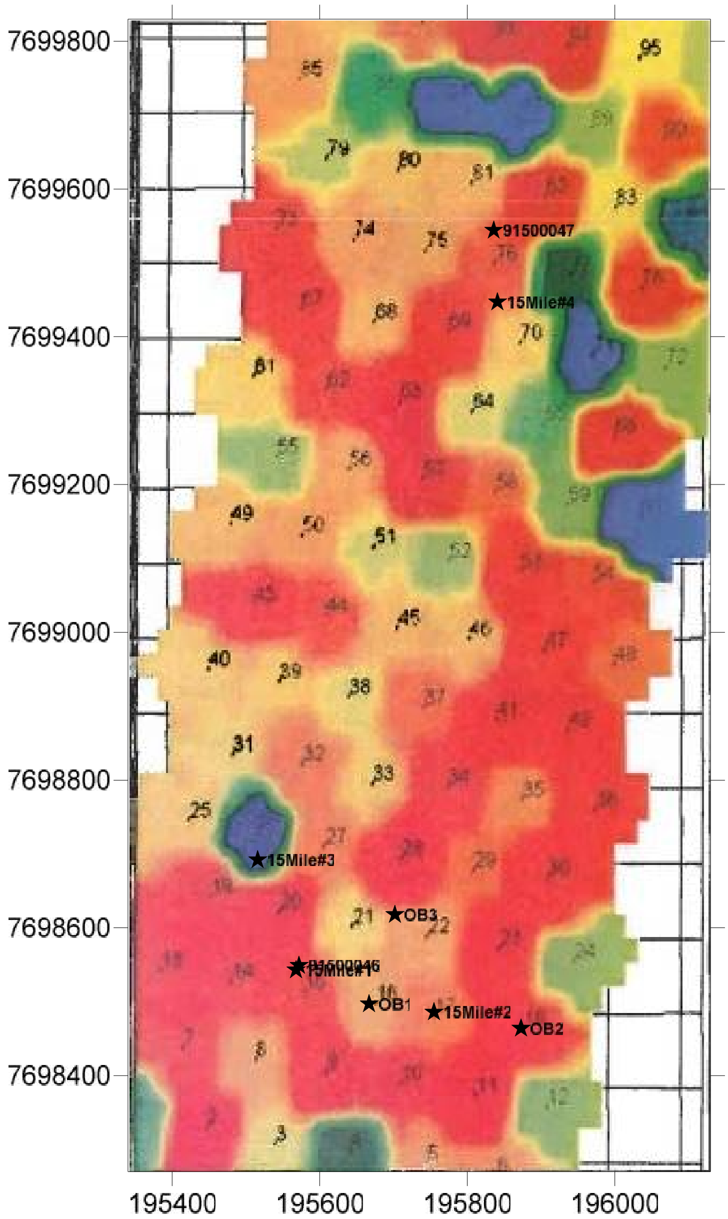


Figure 4: Locations of 15 Mile Reserve Production and Observation Bores in Relation to Geo9 ESKT above 285m AHD

The drilling and construction logs for the four test production bores are shown in Appendix 1.

3.4 Aquifer Description

It can be seen from Figures 5 to 8 that the 15 Mile Reserve alluvial aquifer (hereafter referred to as the aquifer) consists of coarse-grained to fine-grained sand and fine-grained gravel that is intercalated with clay bands. It is usually encountered at a depth of about 10m below ground level (bgl) and extends to a depth of between 15 to 18m below ground level.

The aquifer is unconfined as the water level in each of the bores does not rise above the depth at which it is encountered. The aquifer has an average saturated thickness of about 6m.

The aquifer is underlain by the Ranmoor Member of the Wallumbilla Formation – the cap rock for the Great Artesian Basin sequence that also underlies the wider Hughenden region. The drilling logs describe the Ranmoor Member as stiff grey clay or black mudstone. There is very little porosity associated with this geological unit and it is regarded as hydrogeological basement for this assessment.

4.0 PUMPING TESTS

Pumping tests were carried out on 15 Mile No1, 15 Mile No2, 15 Mile No3 and 15 Mile No4 bores from June until August 2017. The pumping tests comprised a standard 24 hour pump-test on each bore to Australian Standard AS2368 including recovery measurement on the pumped bore and nearby holes and/or piezometers.

Table 1 outlines brief details of the pumping tests.

TABLE 1: BRIEF DETAILS OF PUMPING TESTS

Bore_ID	***Dates of test***	***Test type***	***Static water level prior to testing m below ground level measuring point***	***Pump suction m below ground level measuring point***	***Discharge rate L/s***
15 Mile No 1	12 June 2017	Step drawdown/ Constant discharge	10.74	15.5	16 (Pump broke suction after approximately 13 hours)
15 Mile No 1	14 June 2017	Constant discharge	10.87	15.5	12
15 Mile No 2	31 July 2017	Constant discharge	11.28	14.0	22.5
15 Mile No 3	1 August 2017	Step drawdown/ constant drawdown	10.4	15.5	23 reducing to 19.5
15 Mile No 4	14 June 2017	Constant discharge	17.7	8.78	5.5

4.1 Data Analysis

The drawdown and recovery data were analysed using Microsoft Excel for time-water level plots to illustrate the pumping behaviour of the bores.

The water levels in the pumping bores were plotted against the time elapsed since pumping started. The resulting charts include recovery water levels. Figures 5 to 9 show time – water level charts for each pump test that was performed.

15 Mile No 1 Bore

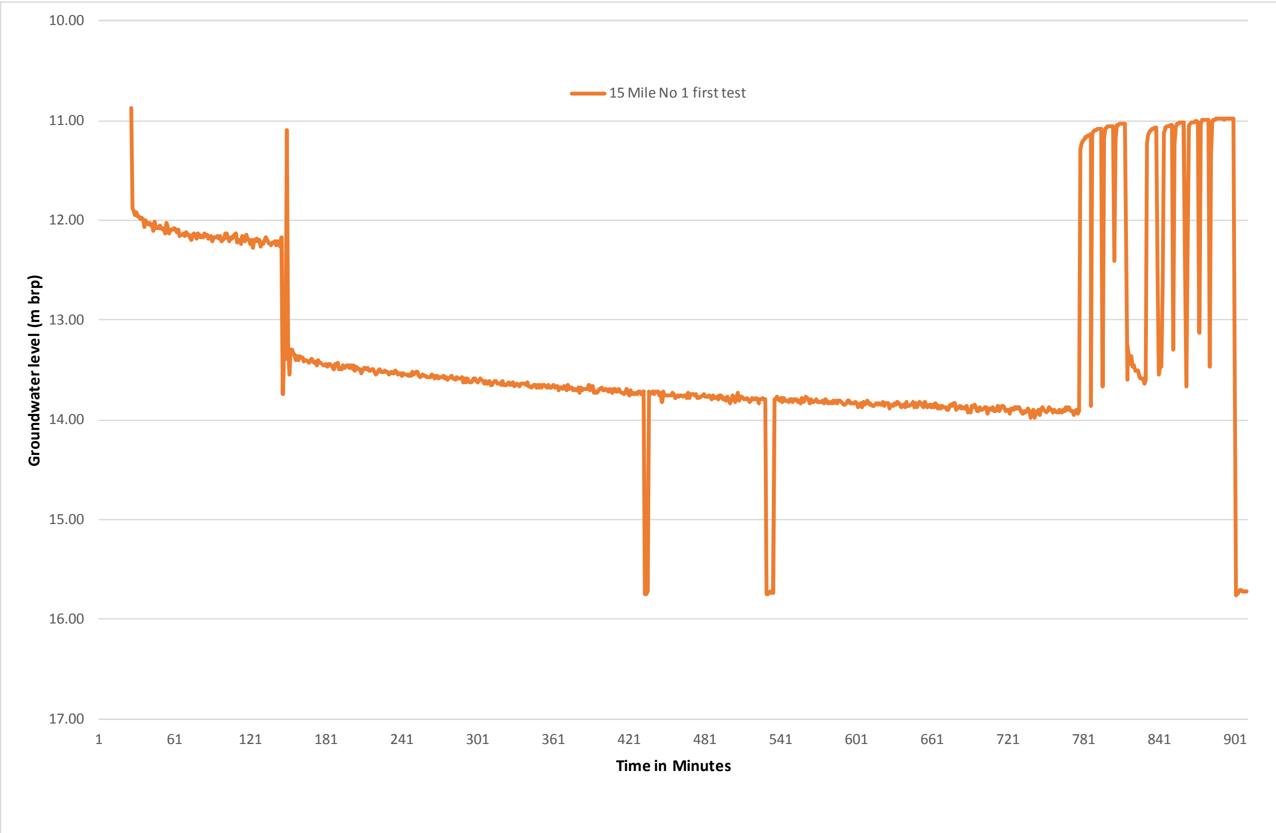


Figure 5: Time – Water Level Chart for 15 Mile No 1 Bore (First Test)

During this test the pump broke suction when the water level in the bore reached the bottom of the screen (14m). The pump was set to recommence after a lay off period of four minutes. During the lay off period time the water level in the bore recovered almost to the pre-test water level.

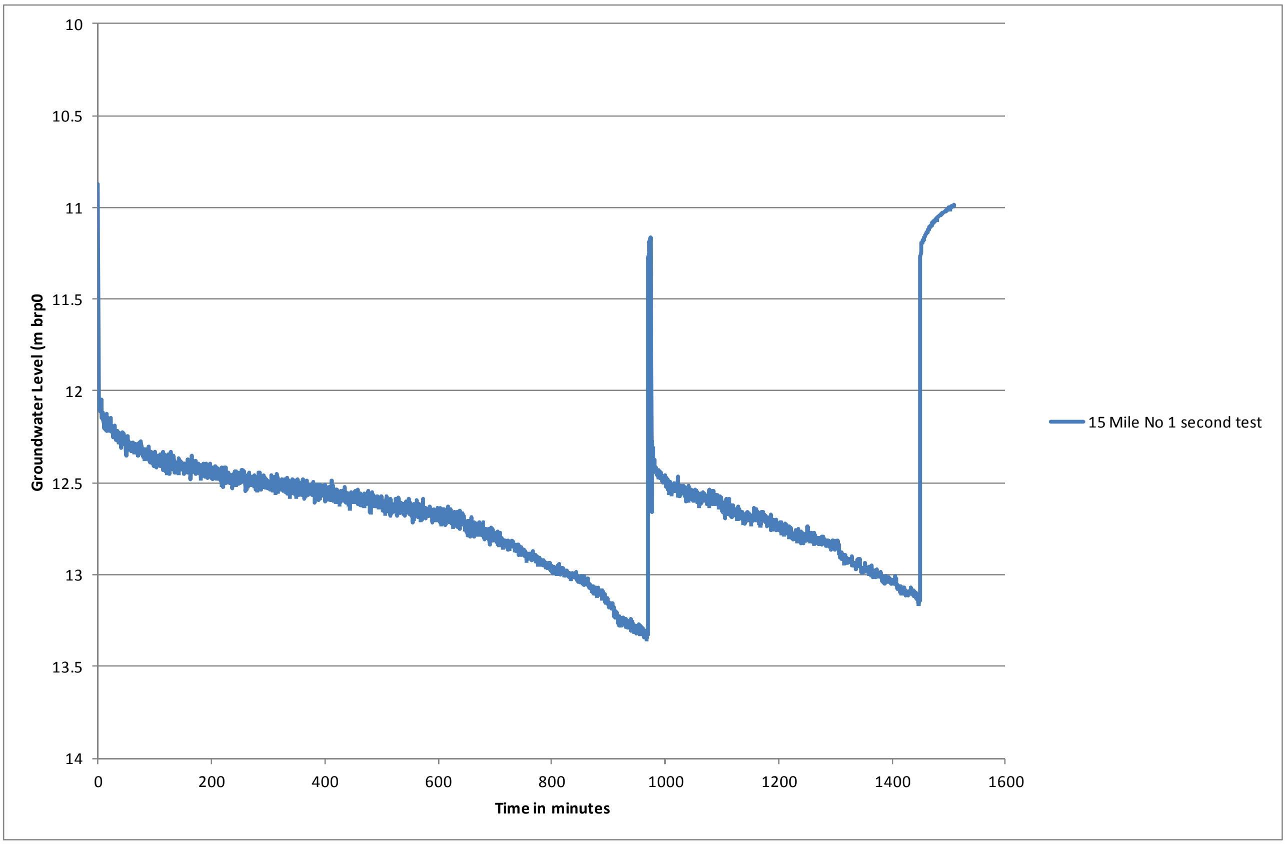


Figure 6: Time – Water Level Chart for 15 Mile No 1 Bore (Second Test)

A second test was commenced after 18 hours of recovery in the bore, but at a lower discharge rate (12L/s). The same trend is evident when the water level approaches the bottom of the screen, as shown by the increase in slope of the water level trend after about 900 minutes. Once again the pump tripped out after 16 hours for a four-minute period. During this four-minute period the water level recovered almost to the pre-test water level.

As the recovery in the bore water level was almost instantaneous on every occasion that the pump stopped, the aquifer is not dewatering. Rather there is strong evidence of water entry losses into the screened interval. Because of these entry losses the long term pumping rate must be de-rated accordingly.

The bore would benefit from vacuum-sealing at the bore head. Alternatively the bore could be decommissioned and replaced with a bore of larger diameter casing (300mm internal diameter) and a slightly reduced length of screen (3m from 12 to 15m depth).

Either measure would permit better water entry and reduce localised drawdown around the bore.

The sustainable pumping rate for this bore in its current construction is assessed at 12L/s.

15 Mile No 2 Bore

This bore was pumped at a more or less constant discharge of 22.5L/s for 24 hours. The water level during the pumping phase behaved as is expected for an unconfined aquifer with radial inflow. At the conclusion of pumping the bore recovered rapidly and the aquifer showed no evidence of being dewatered.

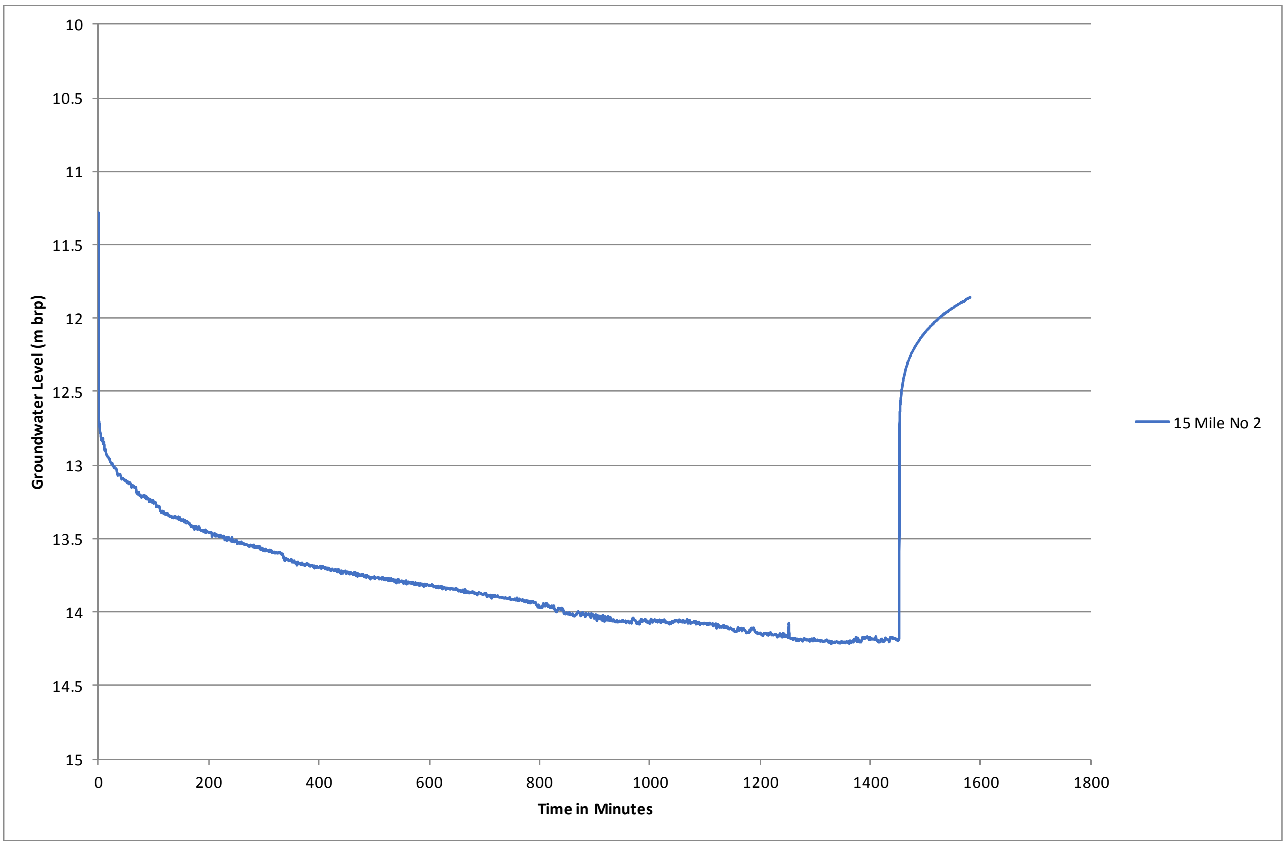


Figure 7: Time – Water Level Chart for 15 Mile No 2 Bore

The sustainable pumping rate for this bore is assessed at 22.5L/s.

15 Mile No 3 Bore

This bore was pumped at a variable discharge of between 23L/s for the first 21 hours and 19L/s for the last three hours of the pumping phase. It was clear to the operator that the pump was beginning to break suction after 21 hours had elapsed. At the conclusion of pumping the bore recovered rapidly and the aquifer showed no evidence of being dewatered.

Pumping of this bore resulted in minor drawdown in 15 Mile No 1 bore which is some 160m away. There is radial flow towards the pumped bore within the aquifer.

The sustainable pumping rate for this bore is assessed at 19L/s.

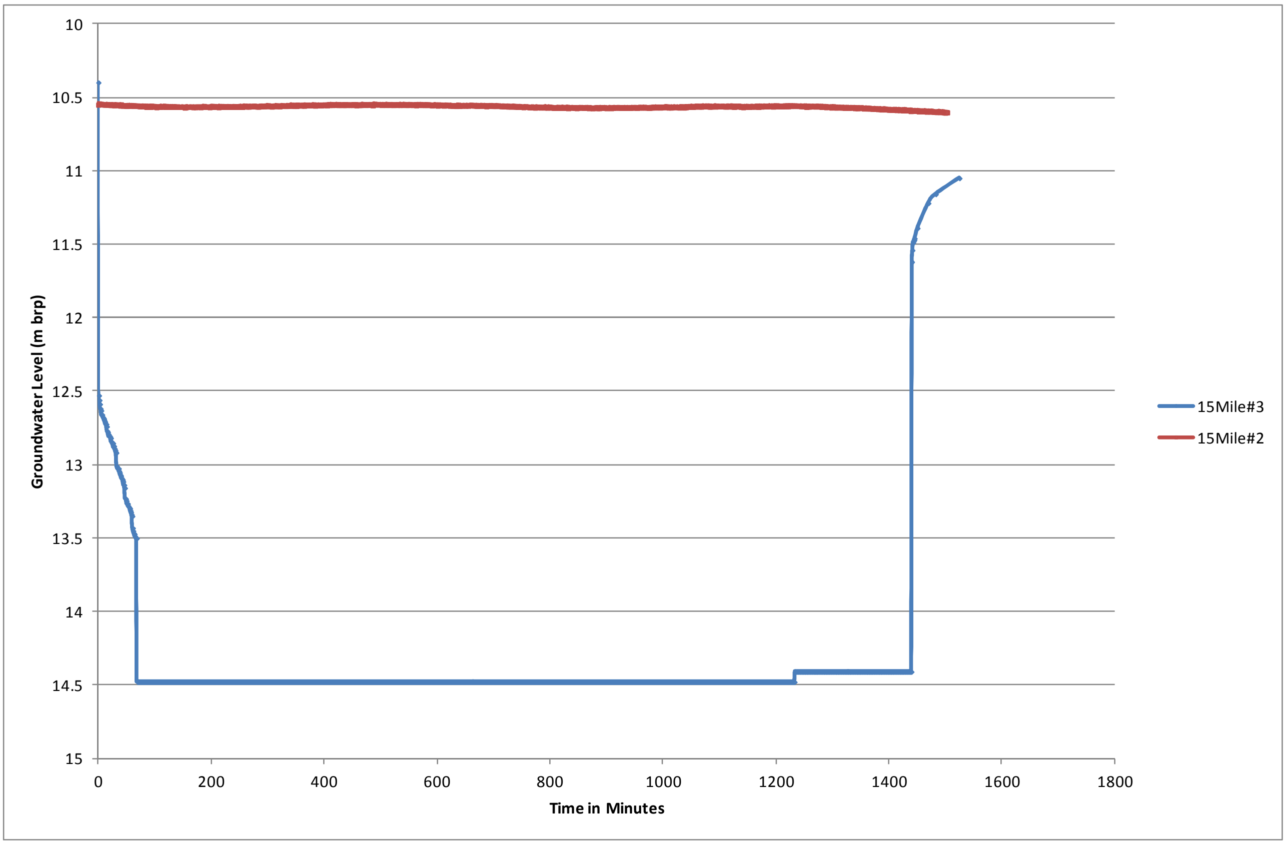


Figure 8: Time – Water Level Chart for 15 Mile No 3 Bore

15 Mile No 4 Bore

This bore was pumped at a constant discharge of 5L/s for 24 hours. The water level during the pumping phase behaved as is expected for an unconfined aquifer with radial inflow. At the conclusion of pumping the bore recovered rapidly and the aquifer showed no evidence of being dewatered.

The sustainable pumping rate for this bore is assessed at 5.5L/s.

A bore of larger casing diameter and screen would deliver up to 15L/s at this site.

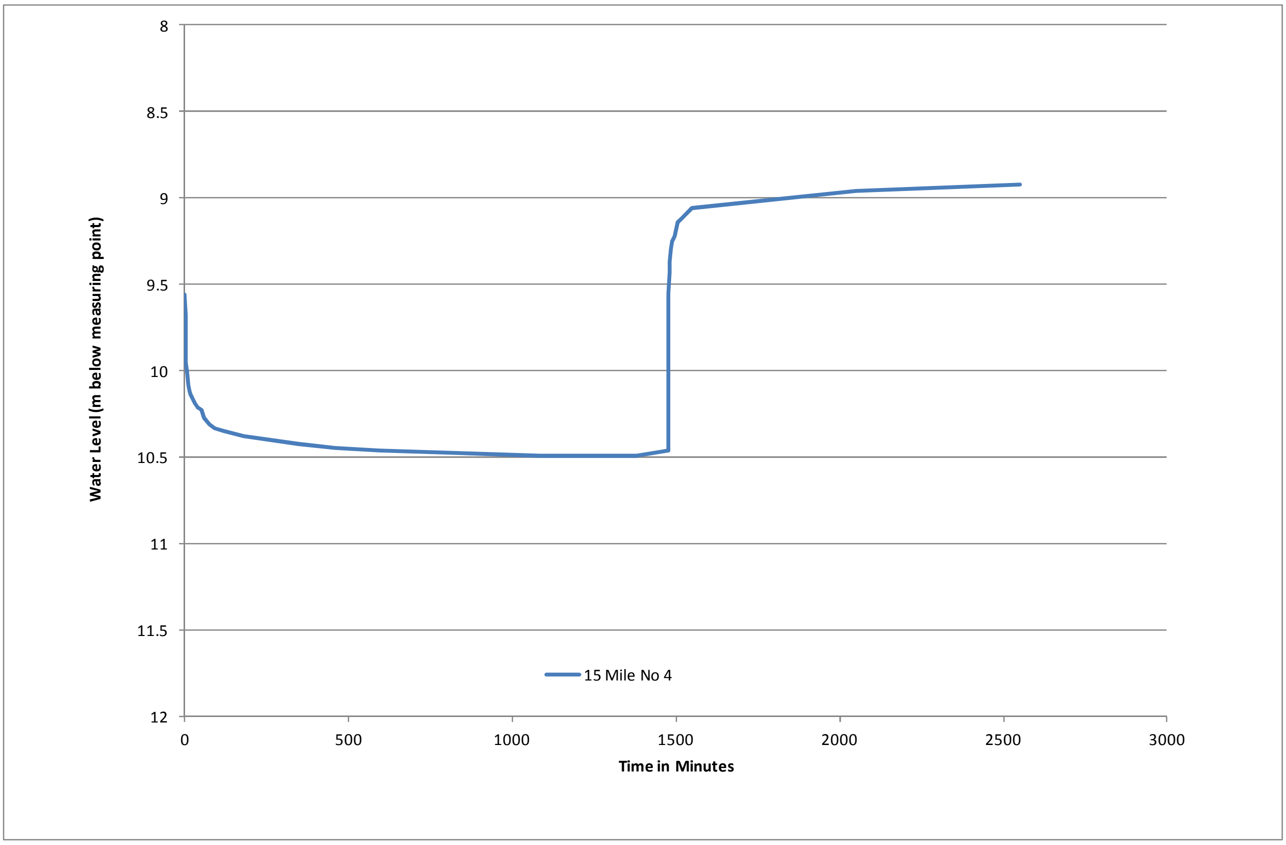


Figure 9: Time – Water Level Chart for 15 Mile No 4 Bore

Derivation of Aquifer Parameters

The drawdown data from the pumping tests were analysed using AquiferTest 2016.1 to derive hydraulic parameters of the aquifer and permit an estimate of useable groundwater in aquifer storage. Appendix 2 shows the methodology and graphical analytical solutions for the pumping test data.

5.0 RECHARGE TO THE 15 MILE AQUIFER

Groundwater levels from the DNRM groundwater monitoring bores were used to assess recharge mechanisms to the aquifer.

5.1 Groundwater Level Response to Rainfall

The groundwater levels from RN 91500046 (near production bore 15 Mile No 1) and 91500047 (near the Flinders River) were plotted against monthly rainfall received at Hughenden (Figure 10).

It is clear from Figure 10 that high intensity of incident monthly rainfall (above about 100mm per month) results in significant rise in groundwater level in both the DNRM groundwater monitoring bores. The higher amplitude of water level response to rainfall in RN 91500047 is attributed to the lower transmissivity of the aquifer at this location (deep drainage entering the profile is 'held up' by the lower transmissivity aquifer), whereas the aquifer at RN 91500046, being of much higher transmissivity, allows a much more even response to rainfall.

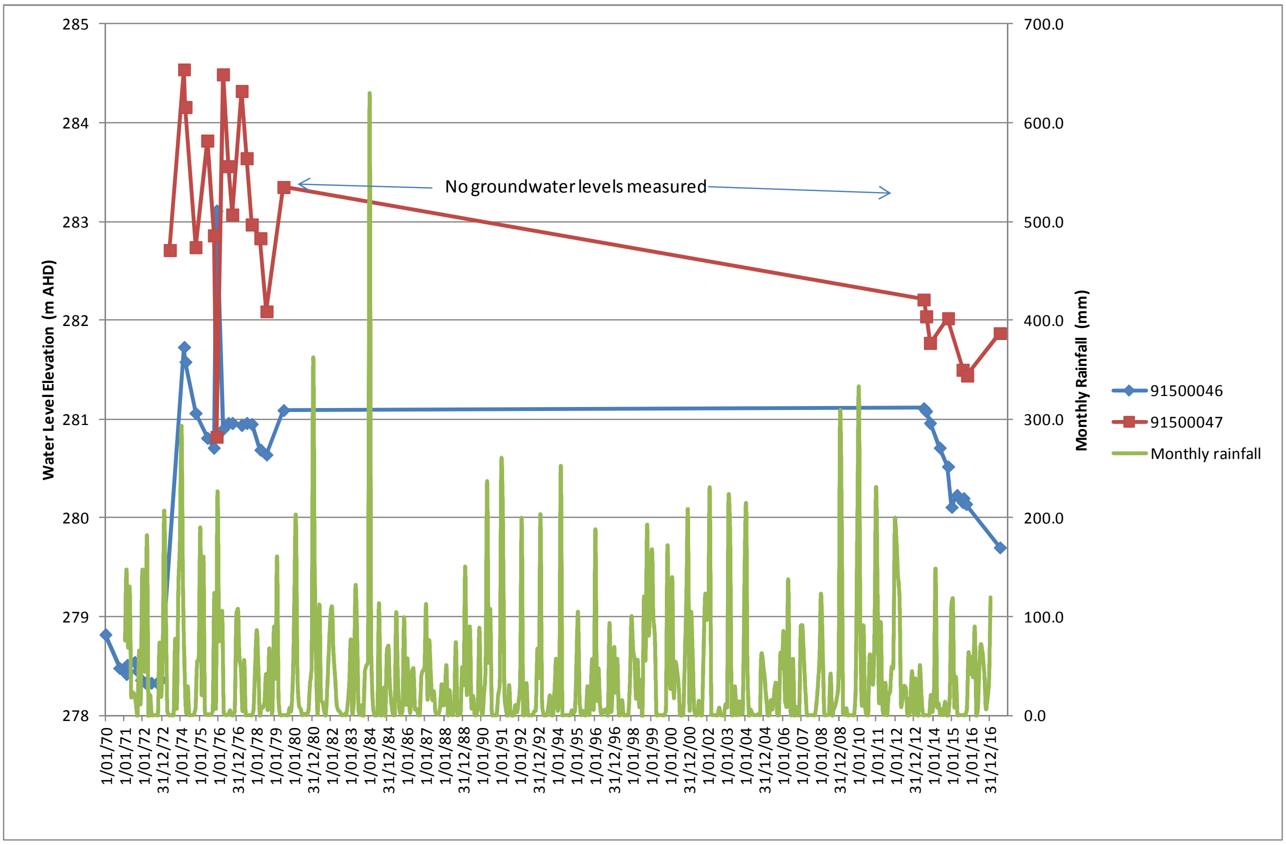


Figure 10: Groundwater Level versus Monthly Rainfall for DNRM Groundwater Monitoring Bores

5.2 Groundwater Level Response to River Flow

The groundwater levels from RN 91500046 and 91500047 were plotted against monthly river discharges recorded at Glendower Crossing, upstream of Hughenden. The location of the river gauging station is shown on Figure 11. The graph of groundwater level versus river discharge is shown in Figure 12.

It is clear that river flow results in rises in groundwater level in RN 91500047 but not in RN 91500046.

Figure 11: Location of Glendower Crossing River Gauging Station and 15 Mile Reserve

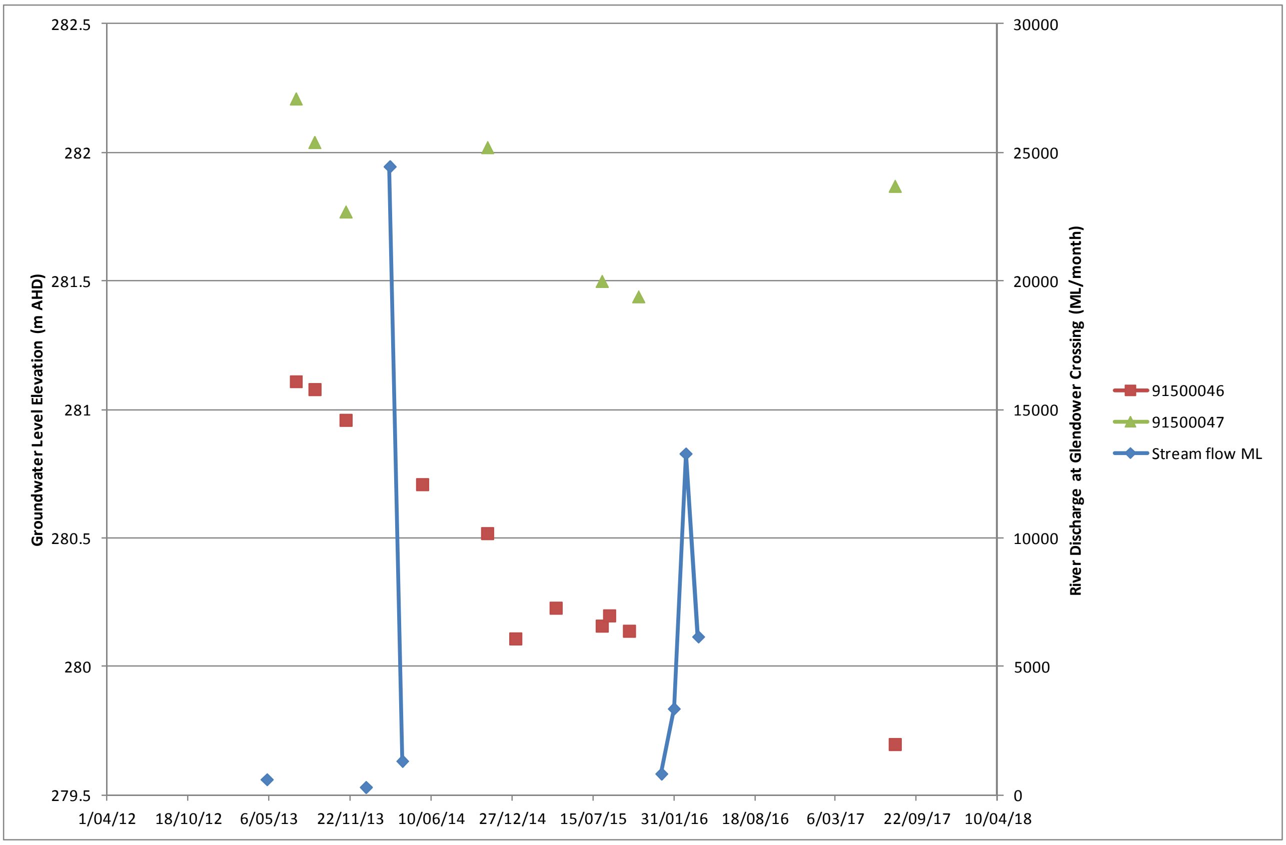


Figure 12: Groundwater Level versus Monthly River Discharge

5.3 Episodic Recharge

Anecdotal evidence suggests that episodic recharge to the aquifer probably occurs during and after intensive rainfall events which cause the gullies and lagoons on the 15 Mile Reserve to flow or store higher than usual volumes of water.

5.4 Groundwater Flow Directions

Groundwater flow directions were assessed by taking a snapshot of groundwater levels in all available groundwater bores on 30th July 2017. There was no pumping of the aquifer for four weeks prior to these measurements. The groundwater elevation of the water table was calculated by subtracting the depth to groundwater from the surface elevation of the bore. In addition, an excavation had been constructed at Canterbury Park crossing in the Flinders River (shown as Cant Xing on Figure 20). This excavation contained water and its water level was surveyed to AHD.

Figure 13 shows contours on the top of the water table to AHD. The directions of groundwater flow were assessed from the contours.

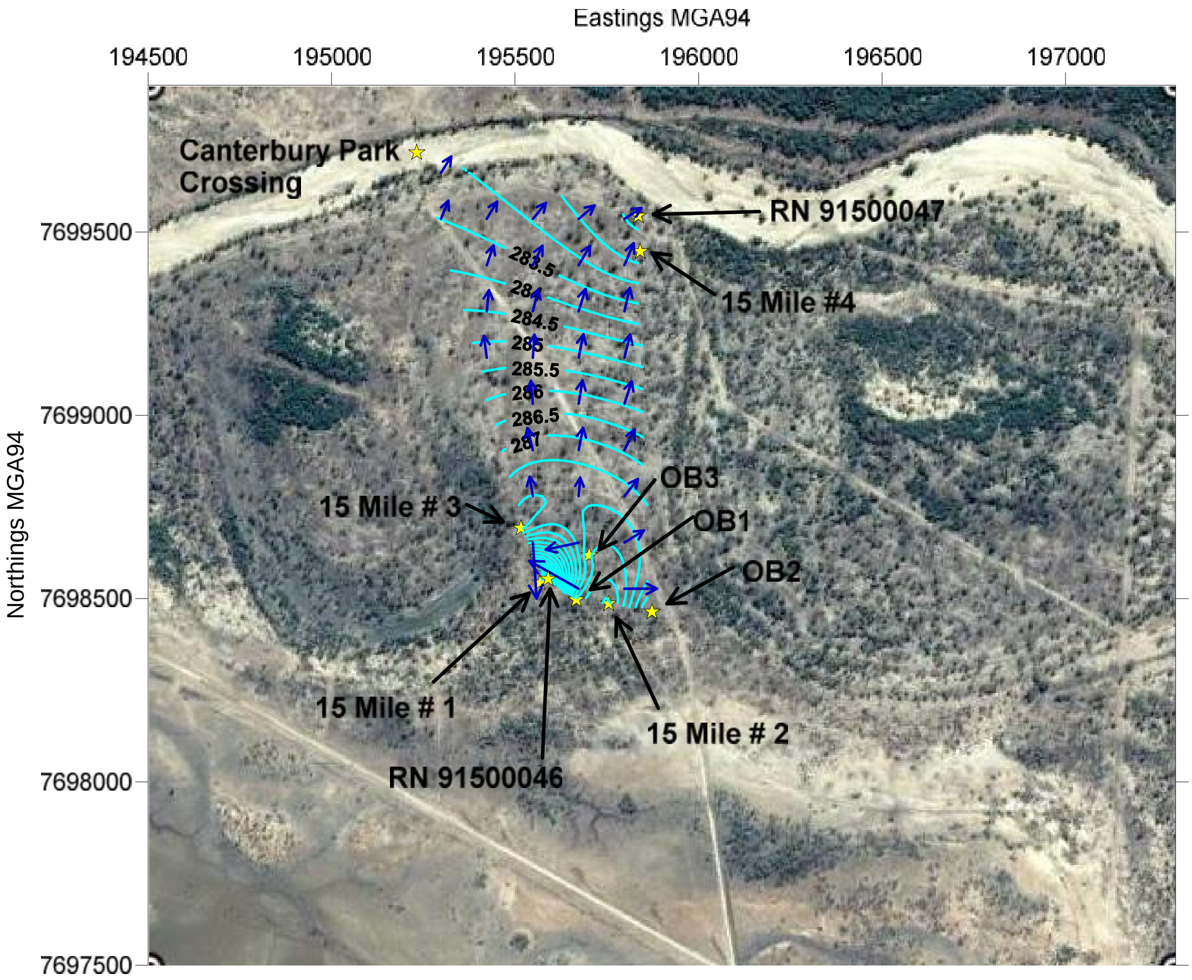


Figure 13: Contours on the Top of the water table to AHD

Figure 13 shows that:

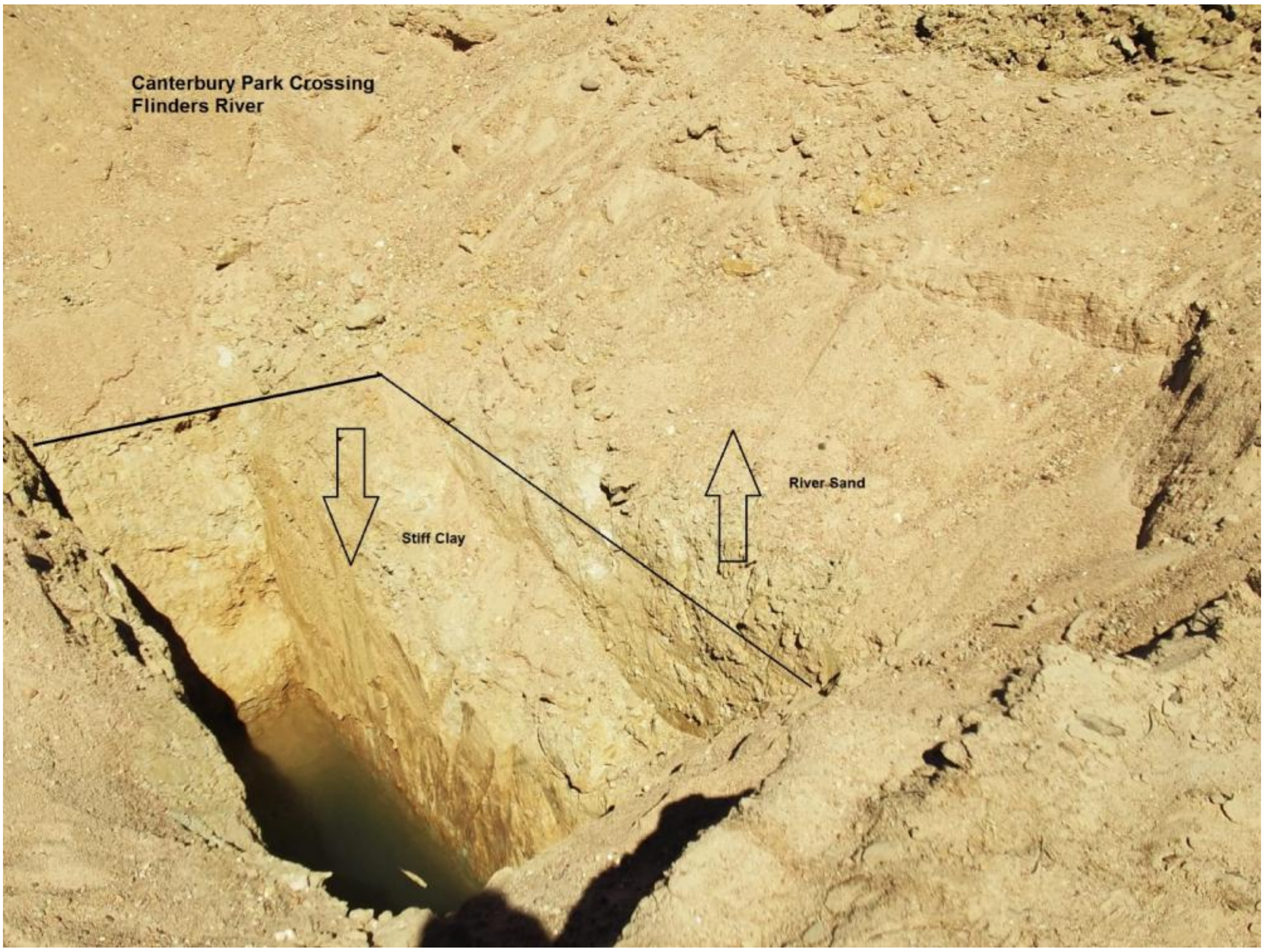
1. The primary groundwater flow direction in the aquifer is to the north and north east towards the Flinders River; and

2. The gradient of the water table is 0.008 towards the north.

5.5 Characteristics of the Flinders River Bed and Banks at 15 Mile Reserve

The bed of the Flinders River adjacent to the 15 Mile Reserve consists of stiff, dark grey clay that is overlain by only 1.5 to 2m of coarse sand. The banks from Canterbury Park Crossing to

Hornibrook Hole, 2.5km downstream, consist of this same stiff, dark grey clay. Photograph1 shows the excavation in the Flinders River Bed at Canterbury Park Crossing.



Photograph 1: Excavation in the Flinders River Bed at Canterbury Park Crossing

This photograph was taken some two weeks after the excavation was constructed. It is clear from the photograph that the clay is competent. It should also be noted that the water in the excavation stands about one metre below the sand.

The observations of the bed and banks are regarded as further evidence that the river has no significant contribution to the groundwater in the aquifer other than that sement of the aquifer that is immediately adjacent to the river.

5.6 Primary Groundwater Recharge Mechanism

From the evidence presented in Section 5, the primary recharge mechanism to the aquifer is infiltration of rainfall. Run of the river flows have little influence on the aquifer other than in the segment immediately adjacent to the river.

6.0 AQUIFER STORAGE ANALYSIS AND PUMPING SCHEDULE

6.1 Volume in Aquifer Storage

The volume of groundwater in storage within the 15 Mile Reserve alluvial aquifer, has been assessed. The assessment methodology is presented in Appendix 3.

The total volume of groundwater in storage is 922ML not all of which will be available for extraction as some groundwater remains attached to the aquifer matrix even when pumping occurs. This is known as 'dead storage'.

If it is assumed that approximately 20% of the total storage is 'dead storage' **the estimated volume of groundwater available for use is about 740ML, assuming that regular annual rainfall recharge occurs**.

6.2 Suggested Pumping Schedule

The following pumping schedule could be implemented assuming that reasonably regular rainfall recharge occurs:

- The three production bores located greater than 1km from the river could be equipped to their sustainable pumping rates;
- The three production bores could be pumped for up to 12 hours per day (possibly at night to take advantage of lower electricity tariffs should power be provided to the 15 Mile Reserve);
- The aquifer would benefit from a 12-hour pumping, 12-hour recovery schedule to allow radial recharge flow to occur;
- The bores could be pumped for 300 days per year;
- The nett draft on the aquifer under this schedule would be 693ML/annum which is within the estimated aquifer storage.

6.3 Ongoing Groundwater Monitoring

The success of the suggested pumping schedule depends on regular annual rainfall recharge to the aquifer and the maintenance of adequate saturated thickness in the aquifer.

It is critical that monthly measurements of groundwater level should be taken in the five groundwater monitoring bores that exist in the aquifer environs (RN 91500046, RN 91500047, OB1, OB2 and OB3).

Table 2 shows the coordinates of the five groundwater monitoring bores.

TABLE 2: COORDINATES OF GROUNDWATER MONITORING BORES		
Easting MGA94	***Northing MGA94***	***Site***
195667	7698497	OB1
195873	7698464	OB2
195702	7698618	OB3
195836	7699544	91500047
195572	7698549	91500046

It is also recommended that the production bores should be equipped with automatic groundwater level data loggers set to capture daily groundwater level in each bore, and that accurate water meters be installed on each pumping bore. Weekly groundwater abstraction volumes should be measured and recorded. The data that result should be assessed at the end of the wet season and at the end of the dry season and adjustments to the pumping schedule could be required.

7.0 GROUNDWATER QUALITY

Table 3 contains the results of major ion analyses for the waters in the vicinity of the 15 Mile Reserve.

TABLE 3: MAJOR ION ANALYSES OF 15 MILE RESERVE AREA WATERS													
Sample ID		***15Mile No1***	***15Mile No4***	***Flinders River U/S Hughenden***	***15Mile No 3***	***15Mile OB1***	***15Mile OB2***	***15Mile OB3***	***Canterbury Park Crossing***	***Hornibrook Hole***	***Canterbury Park Well***	***Canterbury Park Bore***	***15Mile No 2***
Date		13/6/17	13/6/17	15/6/17	2/8/17	2/8/17	2/8/17	2/8/17	1/8/17	1/8/17	31/7/17	31/7/17	1/8/17
Calcium	mg/L	40.8	27.3	71.1	31.6	106	48.3	16.2	22.2	38.1	34.2	54.2	60.2
Magnesium	mg/L	16	9.7	47.4	11	35.6	21.1	4.8	12.5	10.9	14.6	19.1	25.1
Sodium	mg/L	52.8	34.6	227	80.9	113	70	215	56.2	13	24.3	61.6	95.3
Potassium	mg/L	1.8	3.2	10.4	1.8	3.4	3.5	3.7	3.1	8	2.6	2.9	2.5
Bicarbonate	mg/L	107	81.5	113	139	201	138	159	102	87.9	110	147	158
Sulfate	mg/L	72.7	31	234	64	196	83.9	122	31.1	16.1	19.6	72.1	129
Chloride	mg/L	24.9	7	134	18.9	50.1	26.8	114	8.8	6.2	6.8	16.8	34.7
Conductivity	µS/cm	552	332	1198	561	1061	623	1058	373	284	353	598	802
pH	pH	7.48	7.01	7.61	6.46	6.56	6.35	6.48	6.53	6.35	6.32	6.47	6.47

Table 3 shows that:

- The groundwater is generally of higher electrical conductivity than the surface water. This is attributed to the groundwater being in contact with the Ranmoor member of the Wallumbilla Formation. The Ranmoor Member contains relatively high proportions of sodium chloride (salt) and calcium sulphate (gypsum) in its clay matrix. These anions and cations exchange with the groundwater in the aquifer above it;
- The electrical conductivity of all the waters is moderately low;
- All of the groundwater is slightly acidic;
- Water with an electrical conductivity of less than 1,000µS/cm and pH of between 6.5 and 8.5 is generally suitable for drinking water. Most of the waters in the vicinity of the 15 Mile Reserve fit these criteria.

7.1 Groundwater Electrical Conductivity and Ionic Composition

Table 4 shows comparisons of the electrical conductivity of waters sampled and their ionic types.

The electrical conductivity of the near river waters (surface water and groundwater) is generally lower that the 15 Mile Reserve groundwaters.

In general the near river waters are predominated by the bicarbonate (HCO_3) anion whereas the 15 Mile Reserve groundwaters are dominated by the sulphate (SO_4) and chloride (Cl) anions owing to ionic exchange with hydrogeological basement (the Ranmoor Member).

TABLE 4: ELECTRICAL CONDUCTIVITY AND IONIC TYPING				
Province	***Site***	***Electrical Conductivity µS/cm***	***pH***	***Ionic Type***
Near river waters	Flinders River upstream of Hughenden	1198	7.61	Na-SO4
	Flinders River at Canterbury Park Crossing	240	7.15	Na-HCO3
	Flinders River at Hornibrook Hole	140	7.34	Ca-HCO3
	RN 91500047	780	7.8	Na-HCO3
	Canterbury Park Well	353	6.32	Ca-HCO3
	Canterbury Park bore	598	6.47	Ca-SO4
15 Mile Reserve groundwaters	RN 91500046	735	8.2	Na-HCO3
	15 Mile No 1	552	7.48	Na-HCO3
	15 Mile No 2	802	6.47	Na-SO4
	15 Mile No 3	561	6.46	Na-SO4
	15 Mile No 4	332	7.01	Na-HCO3
	OB1	950	6.07	Ca-SO4
	OB2	550	6.31	Na-SO4
	OB3	960	7.02	Na-Cl

7.2 Trilinear Diagrams

A Piper trilinear diagram of the major anions and cations was constructed from the data in Table 4 (Figure 14).

There is sufficient evidence to show that the near river waters and 15 Mile Reserve groundwaters are not from the same source, as shown in the groupings in Figure 15.

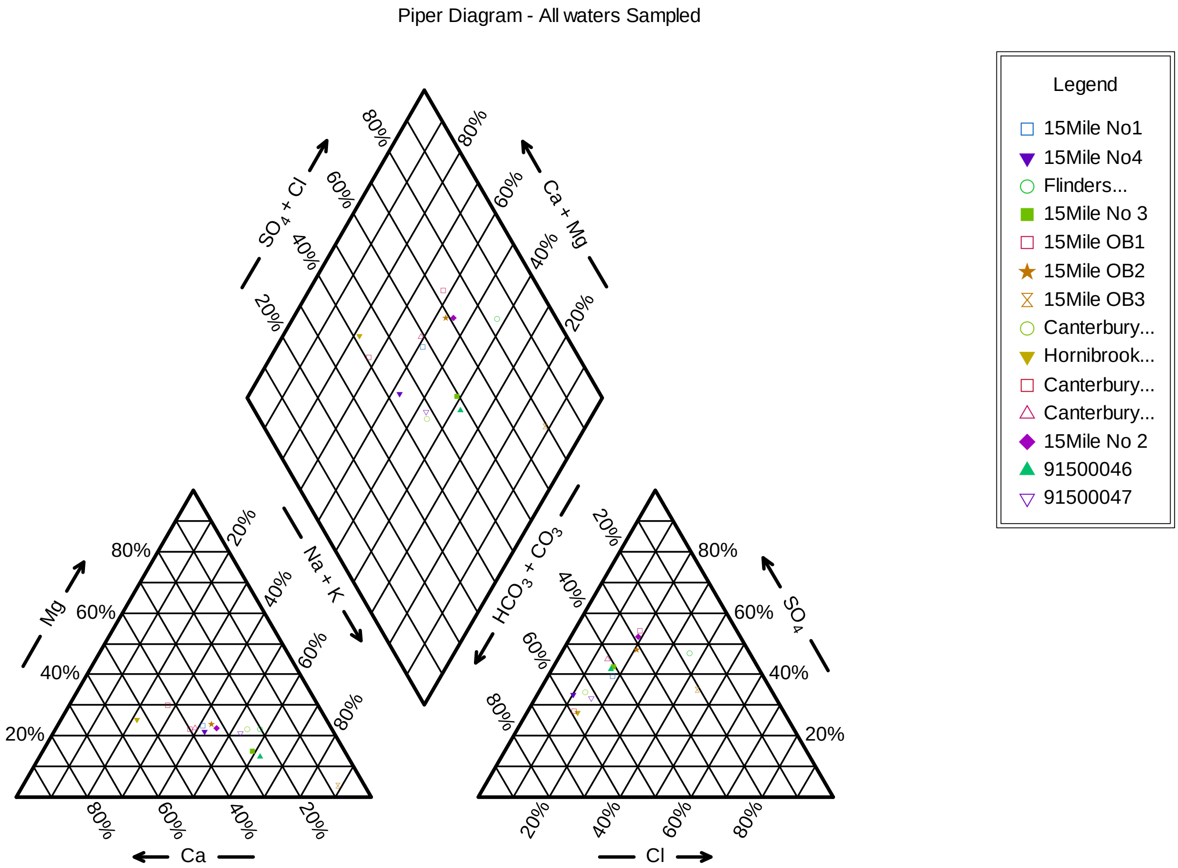


Figure 14: Piper Trilinear Plot of 15 Mile Reserve Vicinity Waters

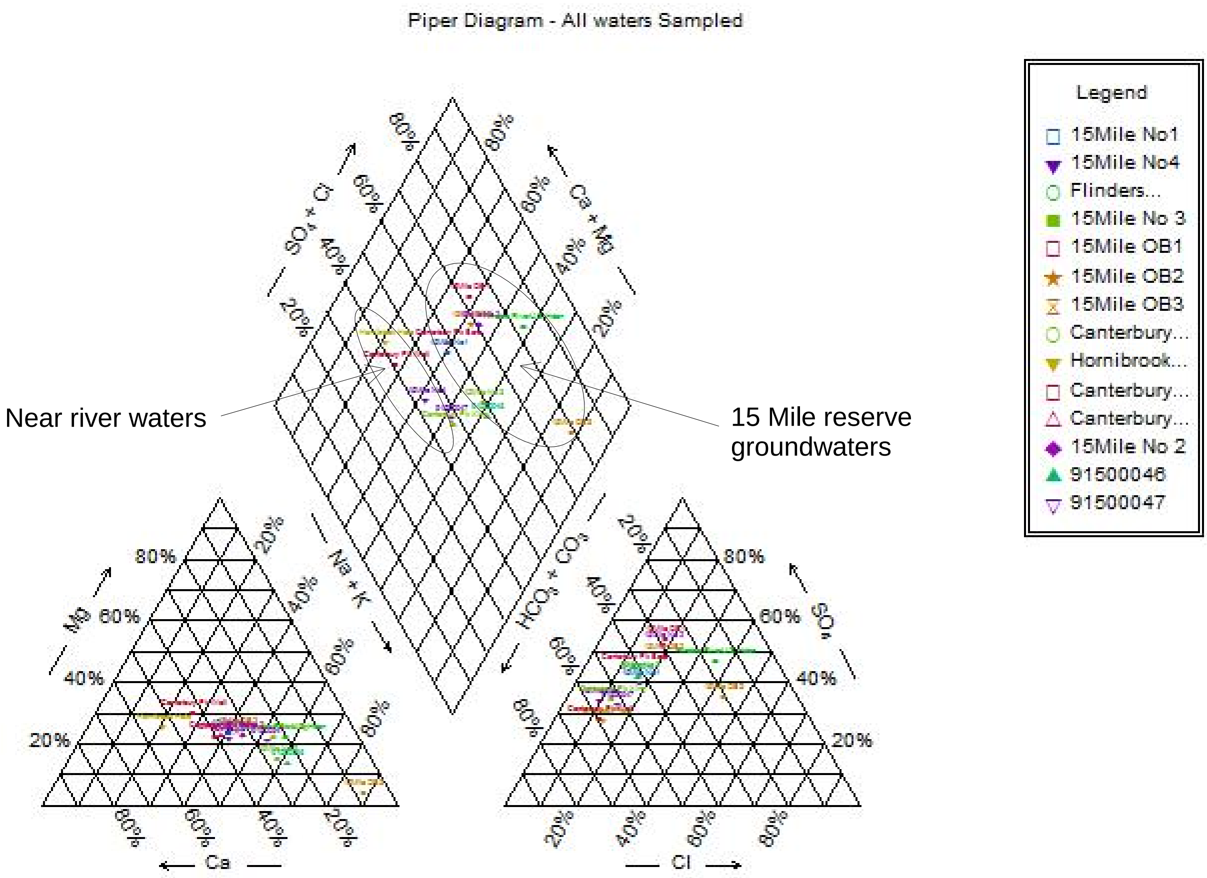


Figure 15: Groupings of 15 Mile Reserve Vicinity Waters

8.0 SOURCE OF GROUNDWATER IN 15 MILE RESERVE AQUIFER

Based on the following facts:

1. Groundwater recharge to the aquifer is heavily impacted by incident rainfall;
2. Episodic recharge from surface water flows and storage in lagoons probably occurs;
3. Run of the river flows have no impact on groundwater level in the aquifer near the three larger production bores;
4. Groundwater flow is to the north and north east from the aquifer towards the river;
5. The groundwater gradient is 0.008 towards the north; and
6. The near river waters are ionically dissimilar and different in electrical conductivity from the 15 Mile Reserve groundwaters

It is concluded that the Flinders River is not a significant contributor to the groundwater in the 15 Mile Reserve alluvial aquifer.

9.0 ADDITIONAL INVESTIGATION SITE

An additional groundwater investigation site has been selected based on the interpretation of the extent of the palaeochannel shown on Figure 16. Should a drilling rig be available drilling of a test bore would be warranted. It is recommended that the test bore be completed as a groundwater monitoring bore if a production bore is not feasible.

The coordinates of the additional test site are shown in Table 5.

TABLE 5: COORDNATES OF ADDITIONAL GROUNDWATER INVESTIGATION SITE		
Easting	***Northing***	***Site***
195965	7698494	Additional test site

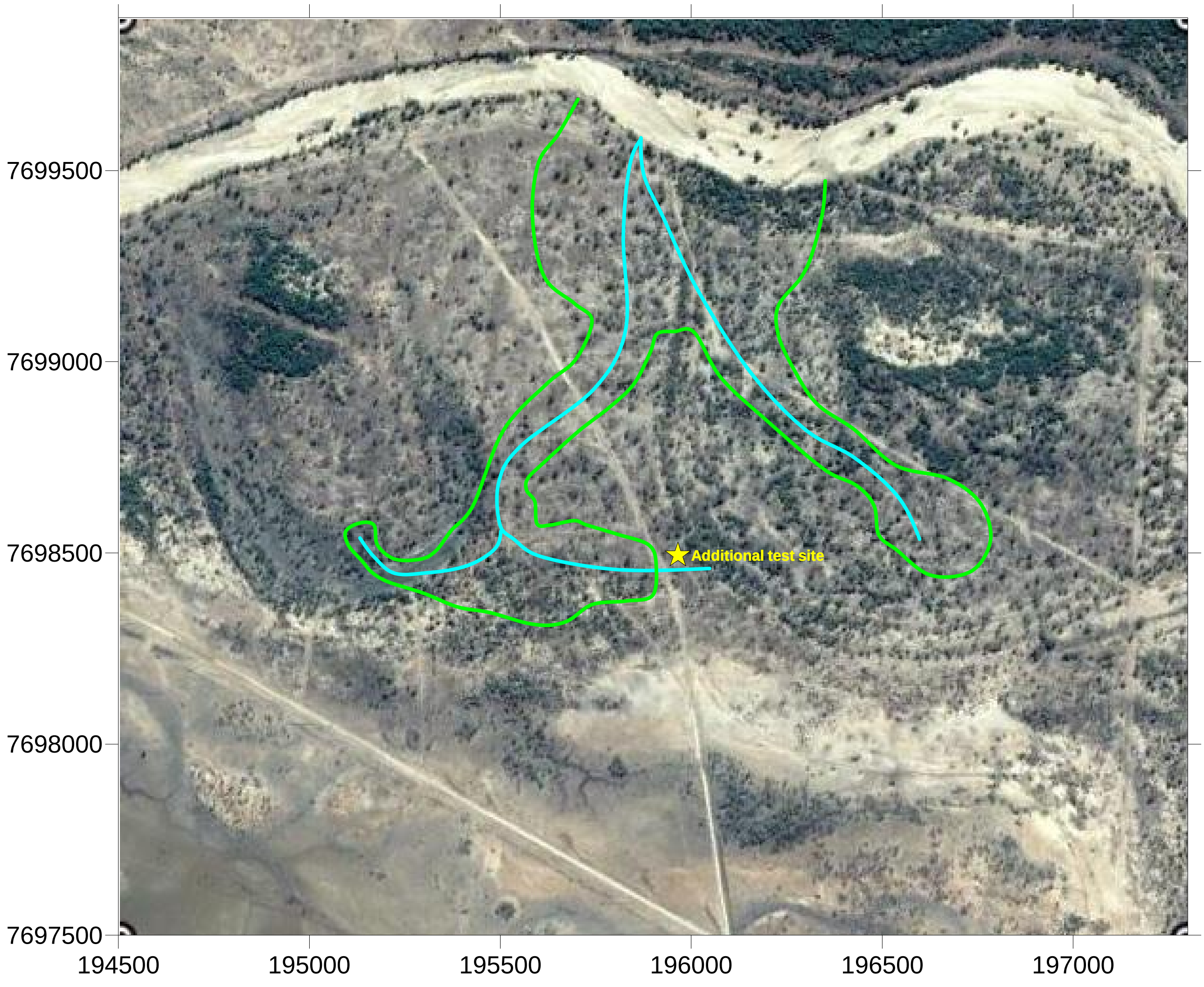


Figure 16: Additional Groundwater Investigation Site

10.0 ACKNOWLEDGEMENTS

The assistance of Shire of Flinders councilors and staff throughout the field component of this investigation, and the assistance of Jeff Benjamin for technical review and comment on the report, is gratefully acknowledged.

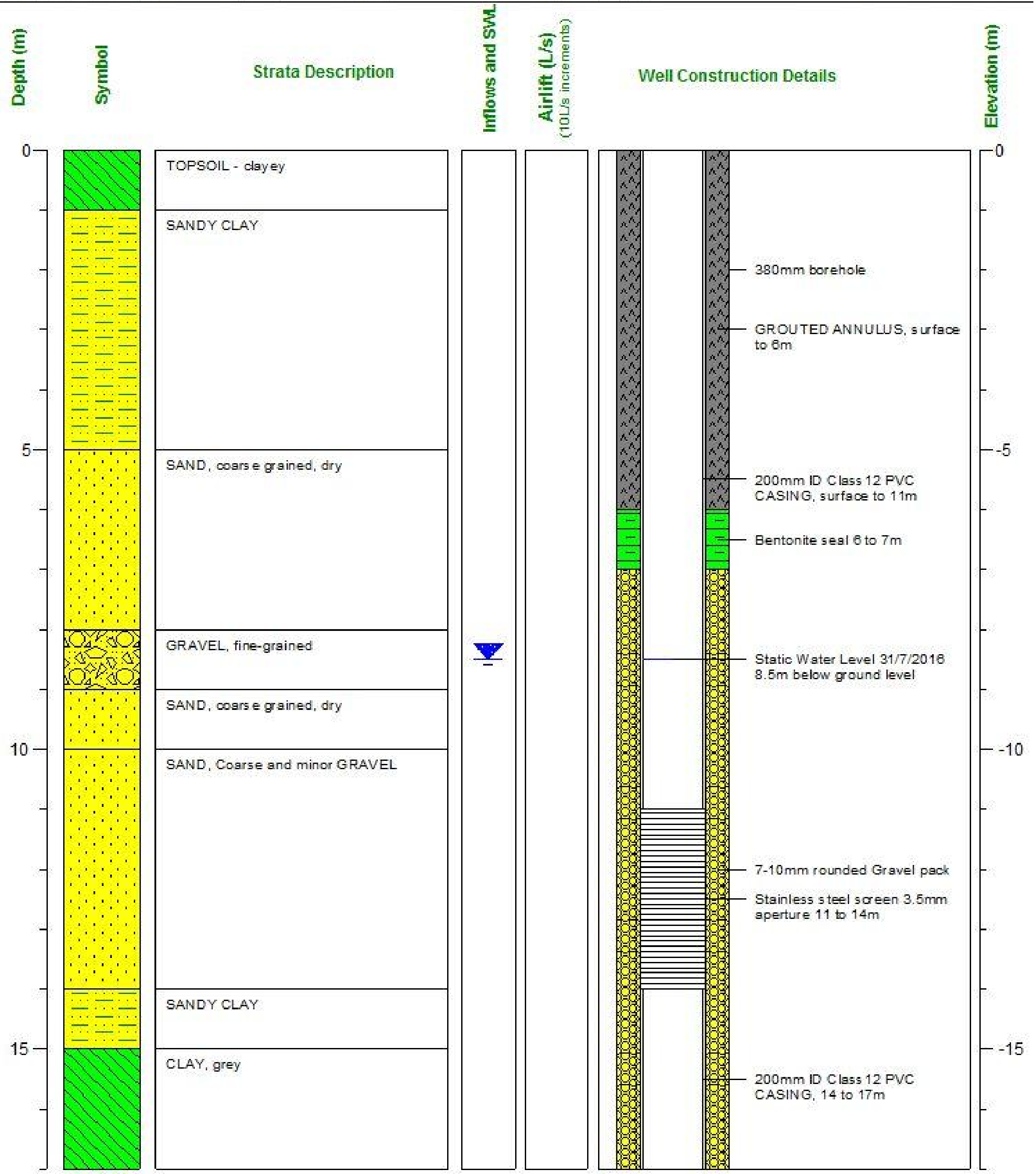
Rob Lait and Associates Pty Ltd

ROB LAIT
Principal Hydrogeologist

APPENDIX 1: DRILLING AND CONSTRUCTION LOGS OF 2017 PRODUCTION AND MONITORING BORES

Borehole No: 15 Mile No 1 | **Client: Flinders Shire Council**

Location: !5 Mile Reserve | **Date Drilled:** 31/7/2016 | **Project No:** 265
Easting: 195568 | **Northing:** 7698543 | **Elevation (m):**
Method: Mud Rotary | **Driller:** Drillex | **Drilling Rig:**



Page 1 of 1 **Notes:**

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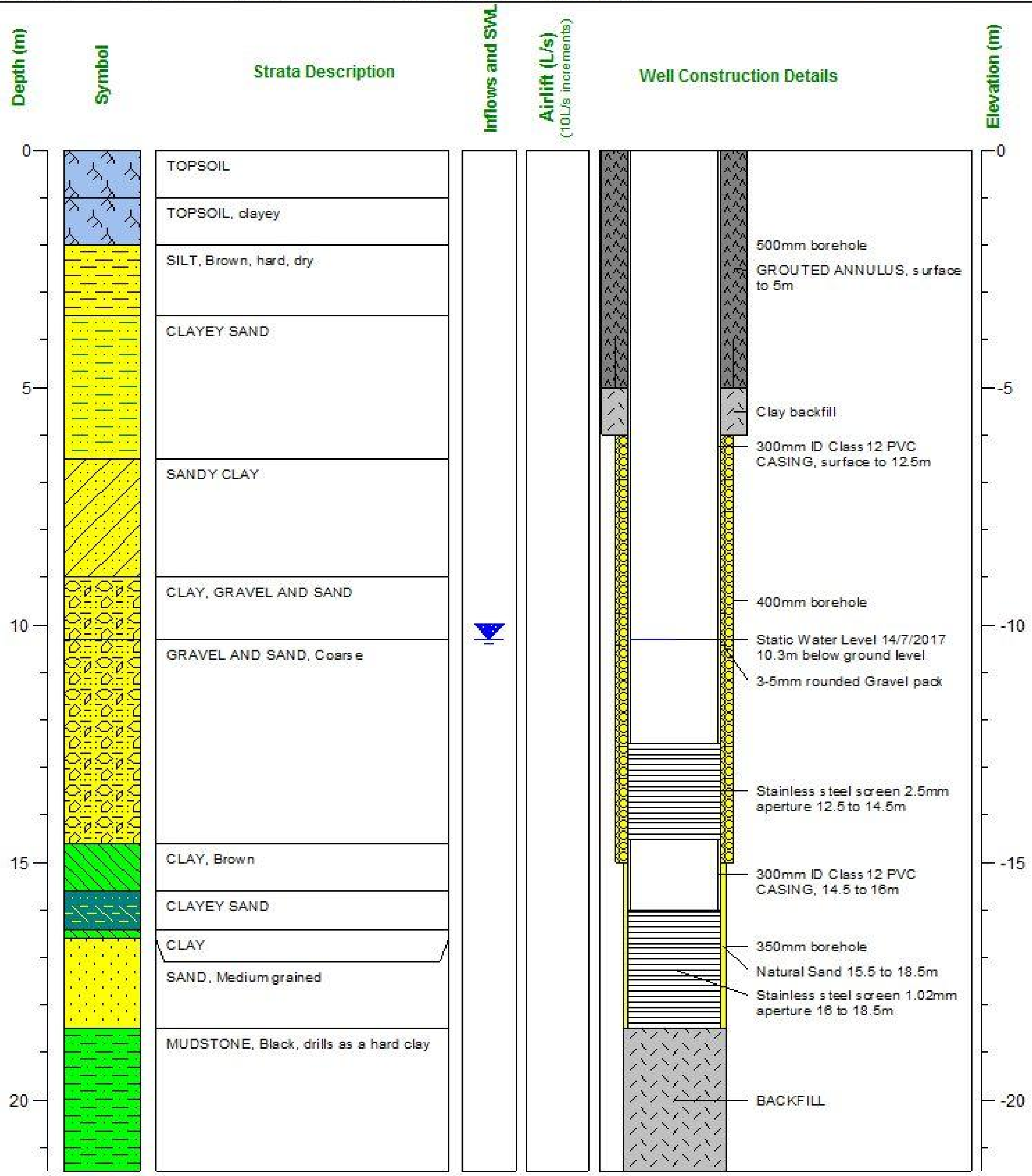
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile No 2 **Client: Flinders Shire Council**

Location:	!5 Mile Reserve	**Date Drilled:**	**14/7/2017**	**Project No:**	265
Easting:	195711	**Northing:**	7698606	**Elevation (m):**	
Method:	Cable Tool	**Driller:**	Ayr Boring Company	**Drilling Rig:**	



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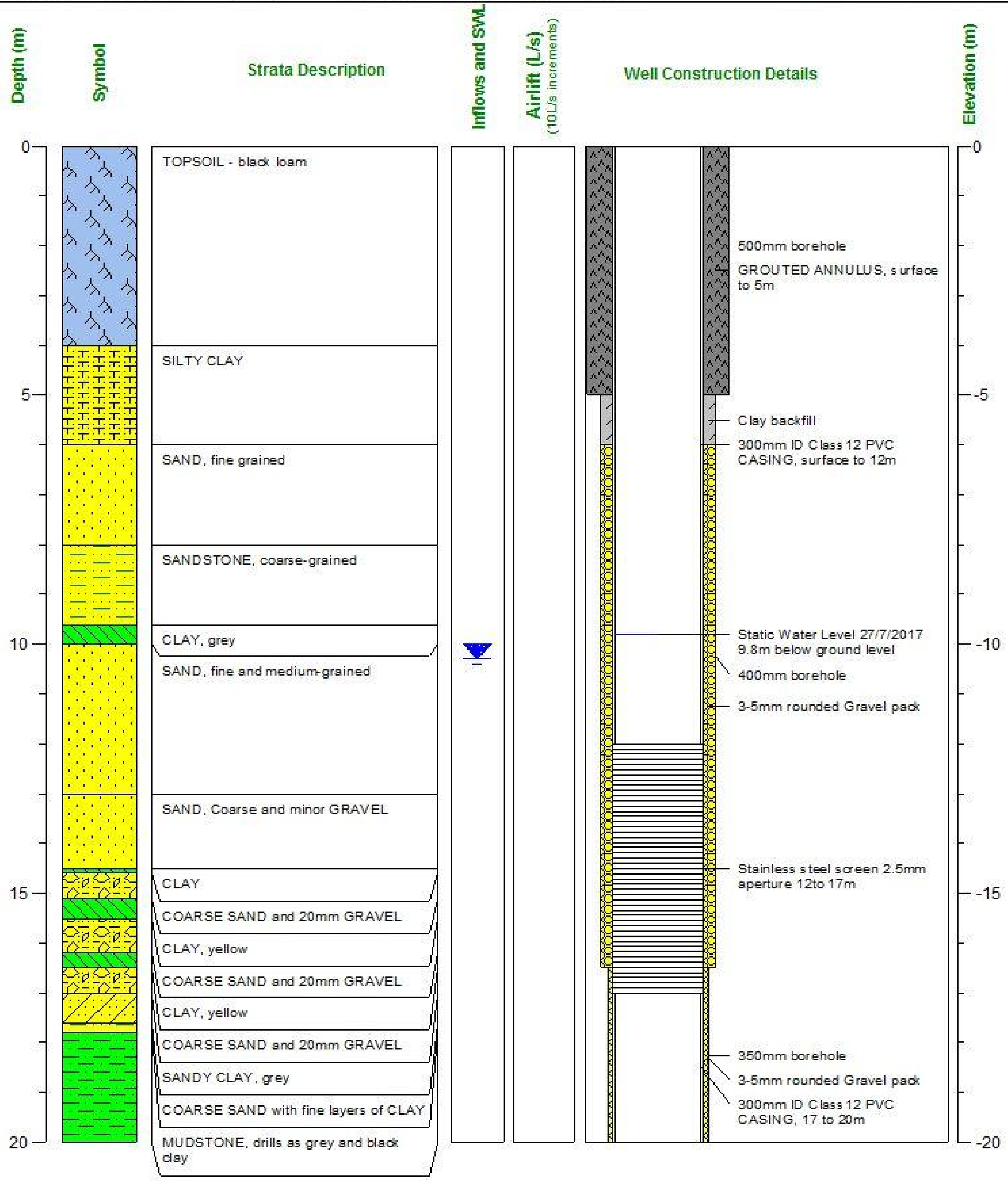
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile No 3 **Client: Flinders Shire Council**

Location:	!5 Mile Reserve	**Date Drilled:**	27/7/2017	**Project No:**	265
Easting:	195516	**Northing:**	7698692	**Elevation (m):**	
Method:	Cable Tool	**Driller:**	Ayr Boring Company	**Drilling Rig:**	



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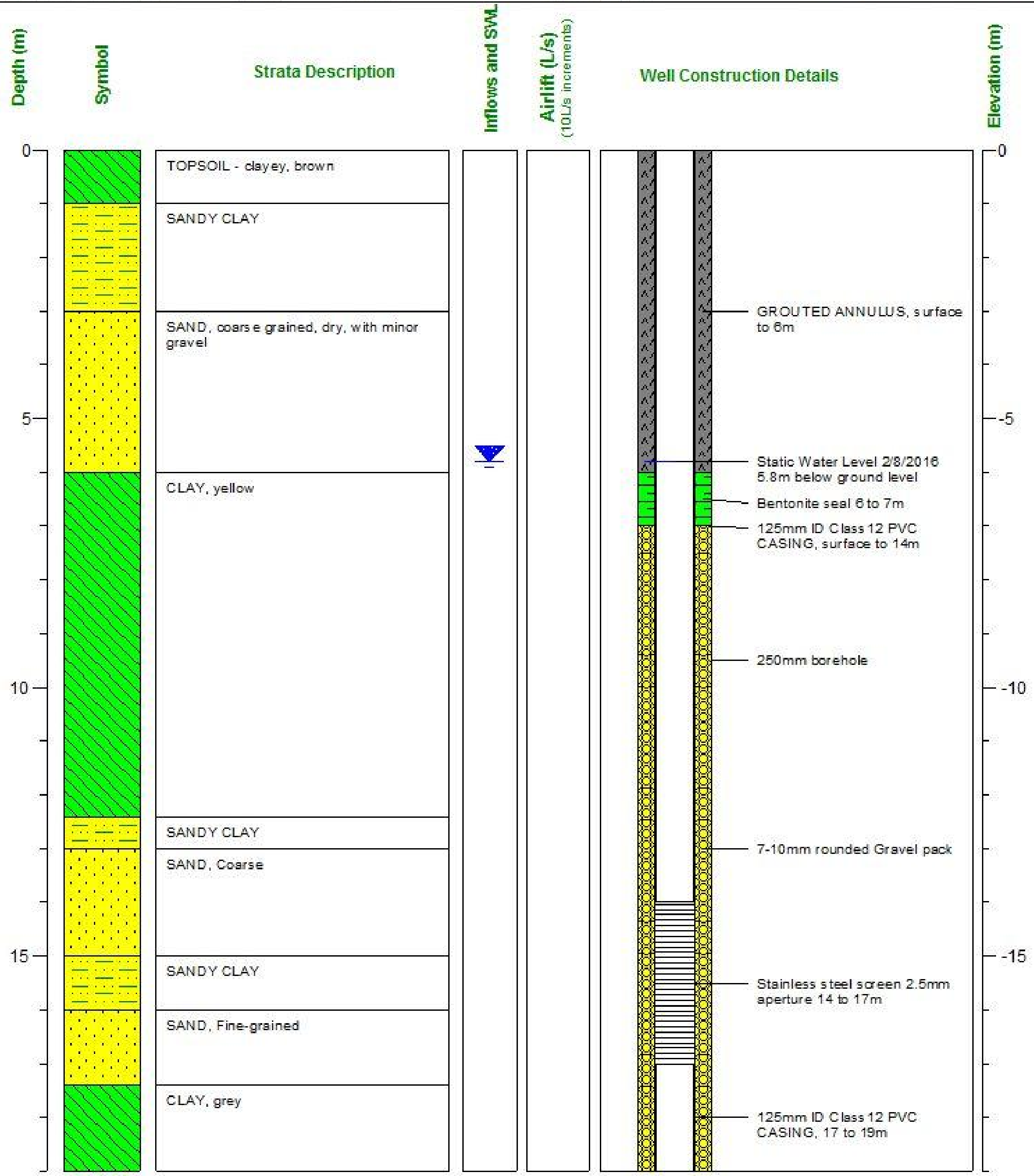
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile No 4 | **Client: Flinders Shire Council**

Location: !5 Mile Reserve | **Date Drilled:** 2/8/2016 | **Project No:** 265
Easting: 195841 | **Northing:** 7699447 | **Elevation (m):**
Method: Mud Rotary | **Driller:** Drillex | **Drilling Rig:**



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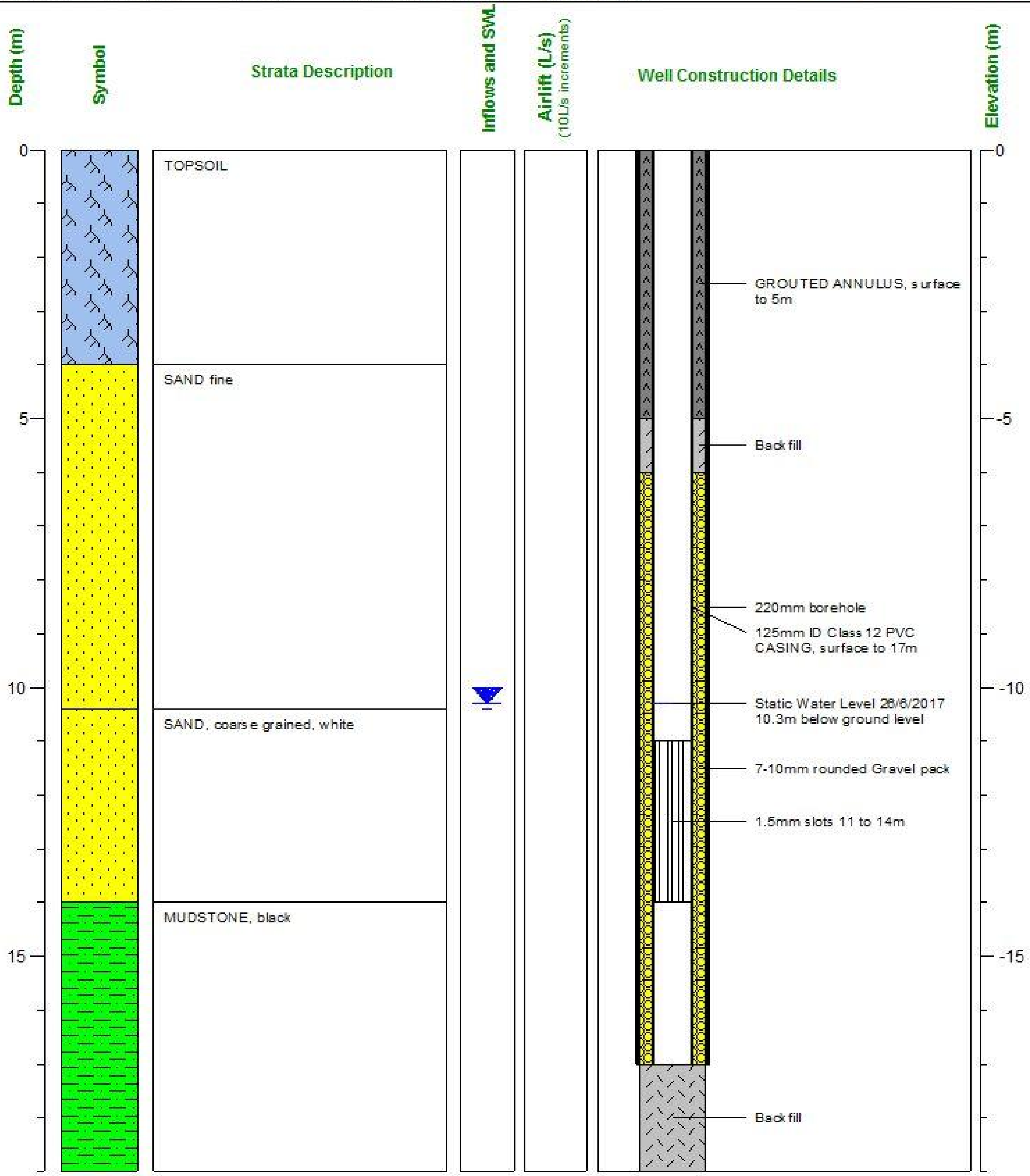
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile OB1 | **Client: Flinders Shire Council**

Location:	!5 Mile Reserve	**Date Drilled:**	**26/6/2017**	**Project No:**	265
Easting:	195655	**Northing:**	7698513	**Elevation (m):**	
Method:	Cable Tool	**Driller:**	Ayr Boring Company	**Drilling Rig:**	



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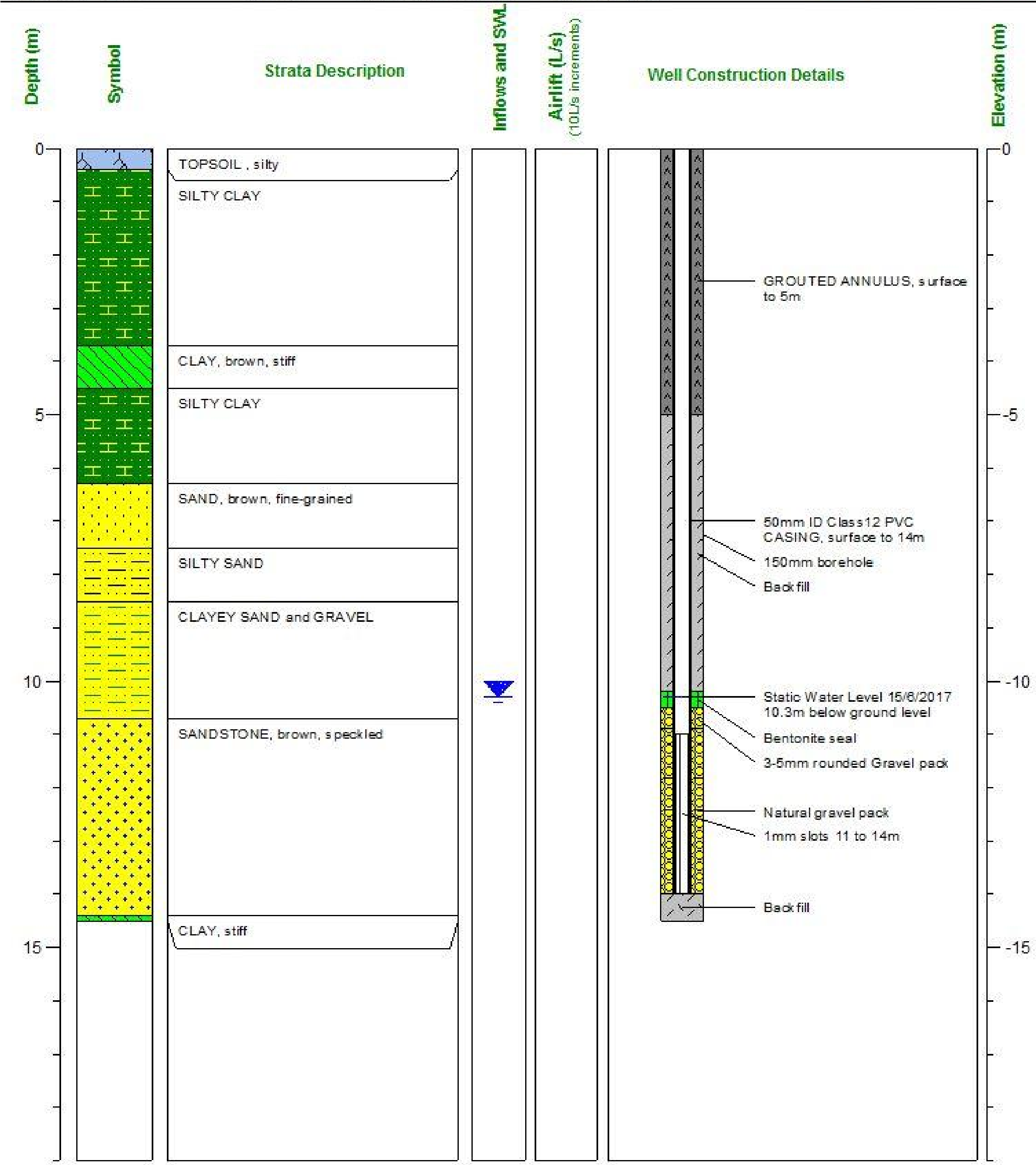
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile OB2 | **Client: Flinders Shire Council**

Location: !5 Mile Reserve | **Date Drilled:** 15/6/2017 | **Project No:** 265
Easting: 195858 | **Northing:** 7698455 | **Elevation (m):**
Method: Auger | **Driller:** Ayr Boring Company | **Drilling Rig:**



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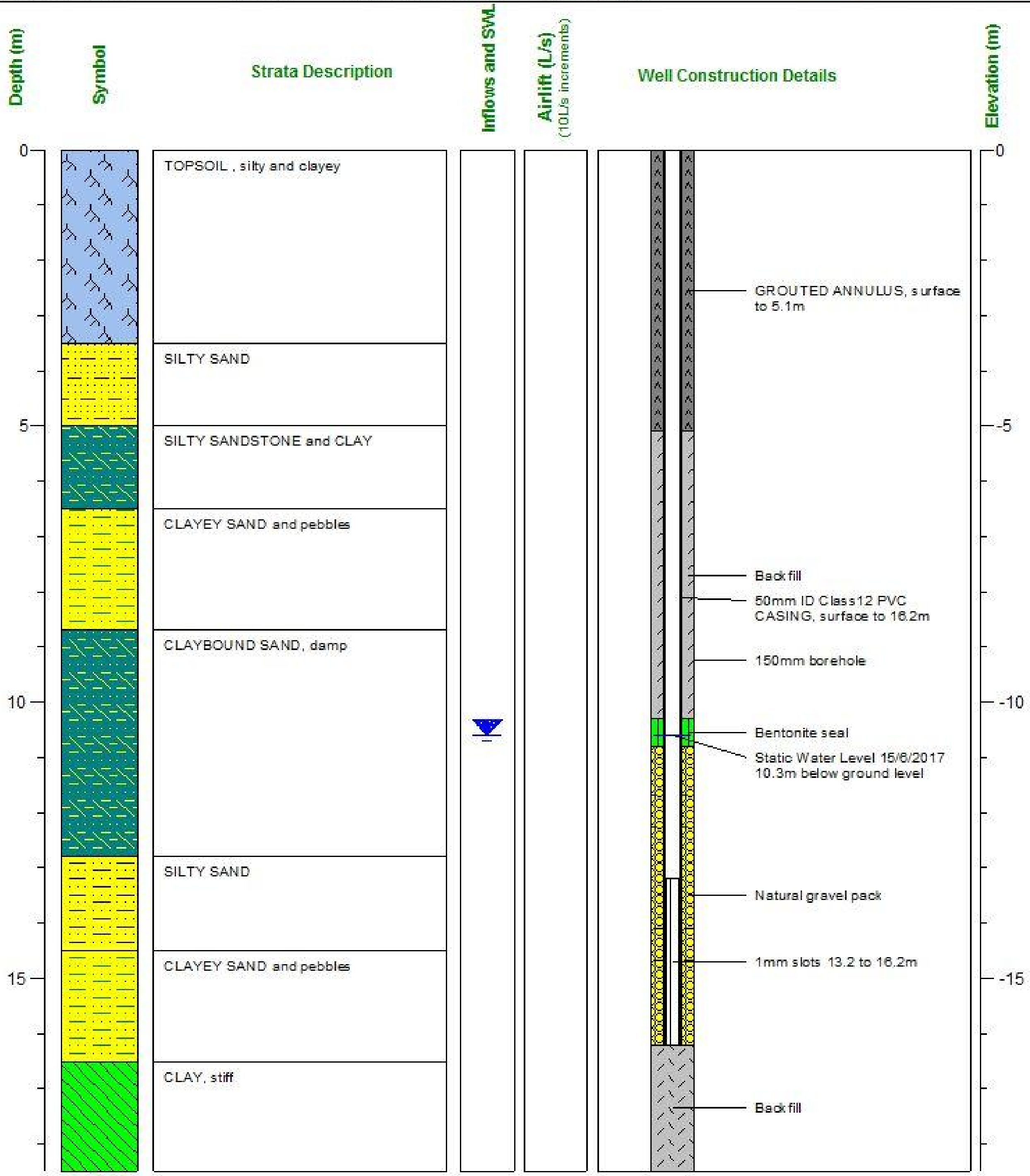
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile OB3 **Client: Flinders Shire Council**

Location: !5 Mile Reserve **Date Drilled: 6/7/2017** **Project No:** 265
Easting: 195702 **Northing:** 7698616 **Elevation (m):**
Method: Auger **Driller:** Ayr Boring Company **Drilling Rig:**



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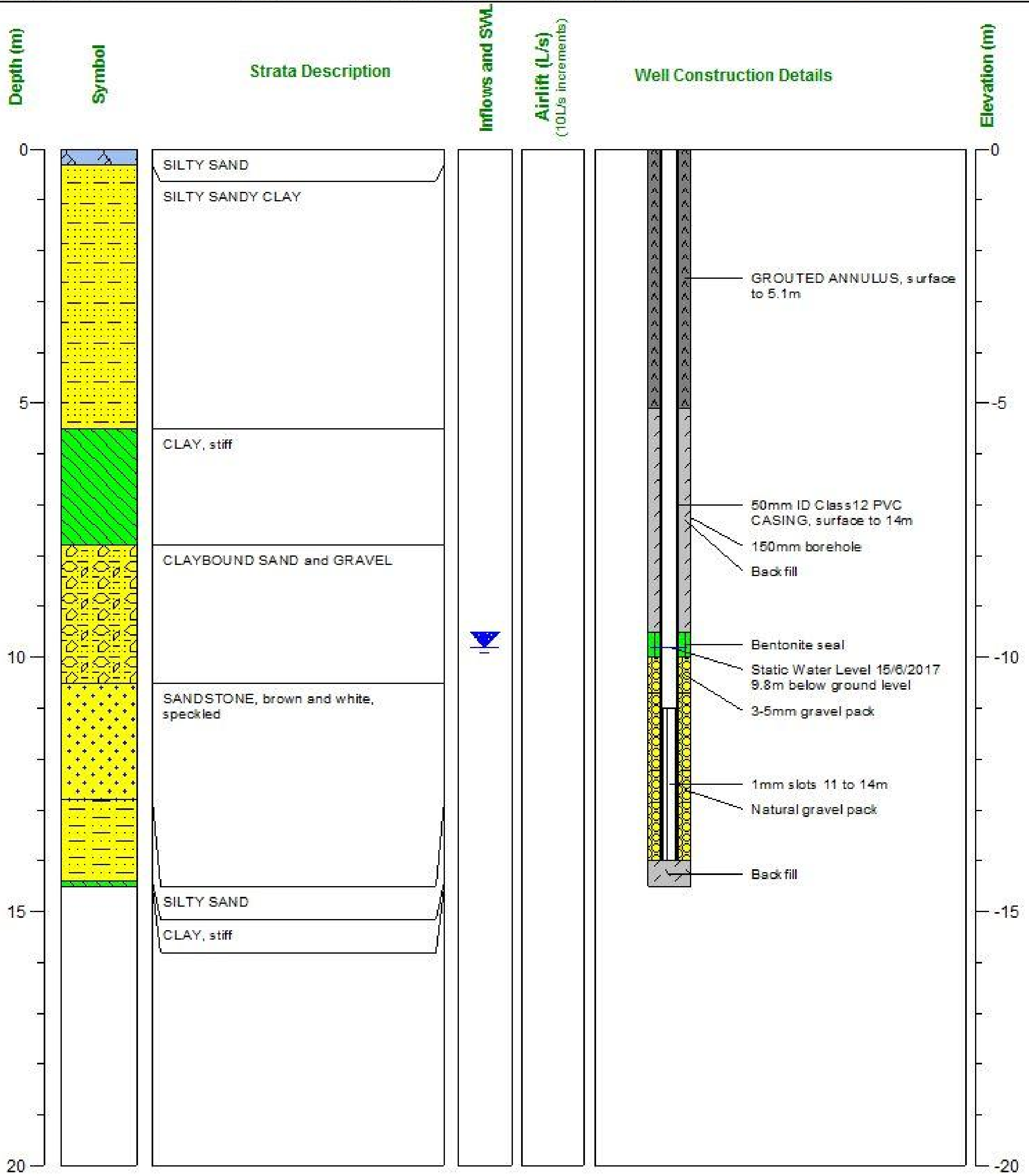
Flinders Hire Council 15 Mile Project
Strata description compiled by driller

Borehole No: 15 Mile TH4/MB5 **Client: Flinders Shire Council**

Location:	15 Mile Reserve	**Date Drilled:**	**15/6/17**	**Project No:**	265
Easting:	195711	**Northing:**	7698606	**Elevation (m):**	
Method:	Auger	**Driller:**	Ayr Boring Company	**Drilling Rig:**	



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Flinders Hire Council 15 Mile Project
Strata description compiled by driller

APPENDIX 2: DERIVATION OF AQUIFER HYDRAULIC PARAMETERS

The hydraulic parameters of the aquifer were assessed using the Theis, 1935[2] or Neuman, 1975 methods. The hydraulic parameters that were derived are:

- Specific Yield (Sy): usable pore volume, also known as the drainable porosity, is a ratio, less than or equal to the effective porosity, indicating the volumetric fraction of the bulk aquifer volume that a given aquifer will yield when all the water is allowed to drain out of it under the forces of gravity.

- Storativity or Storage Coefficient (S): the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer.

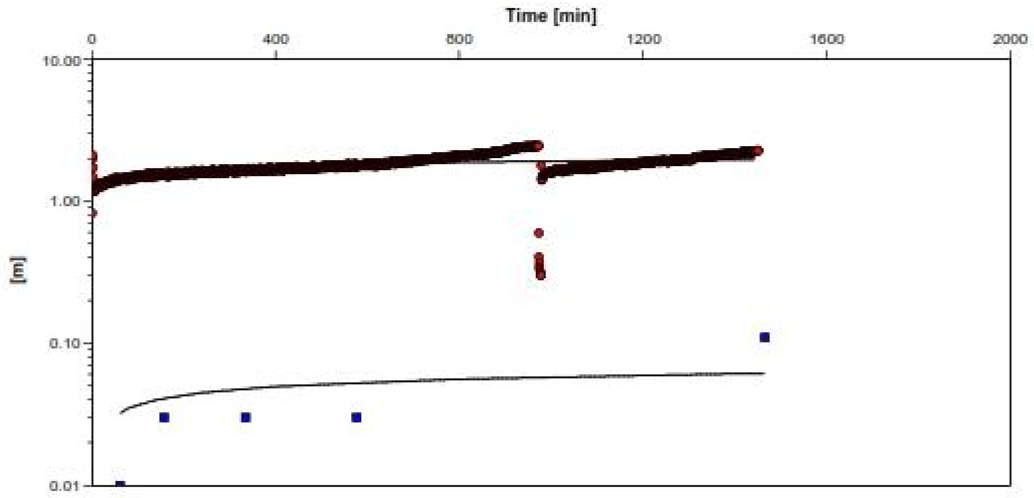
- Transmissivity (T): the relative ease with which an aquifer transmits groundwater.

The graphical analytical solutions for the pumping tests are shown below.

[2] Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Rob Lait and Associates Pty Ltd **PO Box 788** **Innisfail,** **Queensland 4860**	**Pumping Test Analysis Report** Project: 15 Mile Number: 265 Client: Flinders Shire

Location: Hughenden	Pumping Test: 15 Mile No 1 pumping test 2	Pumping Well: 15Mile#1
Test Conducted by: R Lait		Test Date: 14/06/2017
Analysis Performed by: R Lait	Neumann Analysis	Analysis Date: 18/06/2017
Aquifer Thickness: 1.80 m	Discharge Rate: 12.5 [l/s]	



Calculation using Neuman

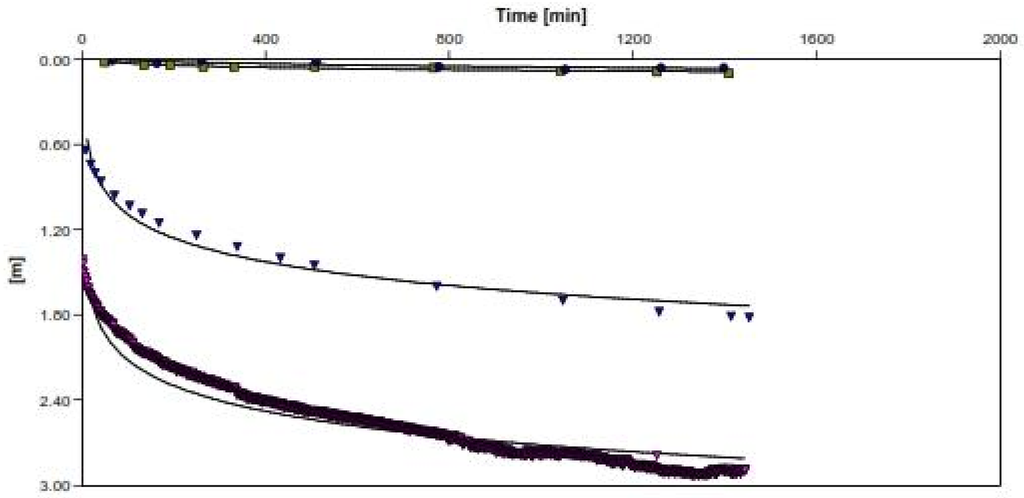
Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific Yield	Ratio K(v)/K(h)	Ratio Sy/S	Radial Distance to PW [m]
15Mile#1	6.29×10^{2}	3.50×10^{2}	5.00×10^{-1}	3.41×10^{-2}	1.00×10^{1}	0.13
91500046	9.45×10^{3}	5.25×10^{3}	5.00×10^{-1}	1.00×10^{-2}	1.00×10^{2}	7.21
Average	5.04×10^{3}	2.80×10^{3}	5.00×10^{-1}	2.21×10^{-2}	5.50×10^{1}	

Rob Lait and Associates Pty Ltd
PO Box 788
Innisfail,
Queensland 4860

Pumping Test Analysis Report

Project: 15 Mile
Number: 265
Client: Flinders Shire

Location: Hughenden	Pumping Test: 15 Mile No 2	Pumping Well: 15Mile#2
Test Conducted by: R Lait		Test Date: 31/07/2017
Analysis Performed by: R Lait	Theis	Analysis Date: 8/08/2017
Aquifer Thickness: 6.00 m	Discharge Rate: 22.5 [l/s]	



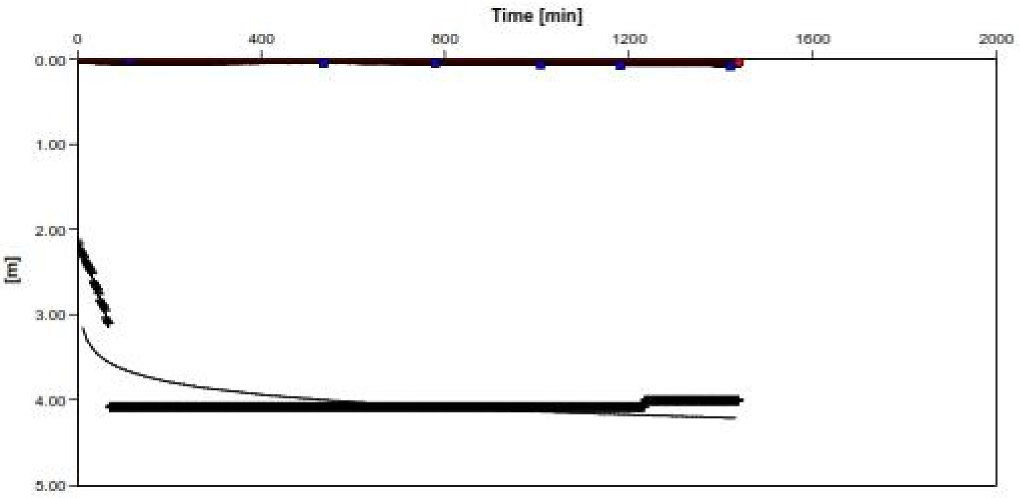
Calculation using Theis

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Storage coefficient	Radial Distance to PW [m]	
15Mile#2	5.95×10^{2}	9.92×10^{1}	9.90×10^{-1}	0.16	
OB1	6.27×10^{3}	1.05×10^{3}	4.70×10^{-2}	92.66	
OB2	5.10×10^{3}	8.49×10^{2}	1.05×10^{-1}	116.07	
TH4	6.42×10^{2}	1.07×10^{2}	1.34×10^{-1}	2.63	
Average	3.15×10^{3}	5.25×10^{2}	3.19×10^{-1}		

Rob Lait and Associates Pty Ltd
PO Box 788
Innisfail,
Queensland 4860

Pumping Test Analysis Report
Project: 15 Mile
Number: 265
Client: Flinders Shire

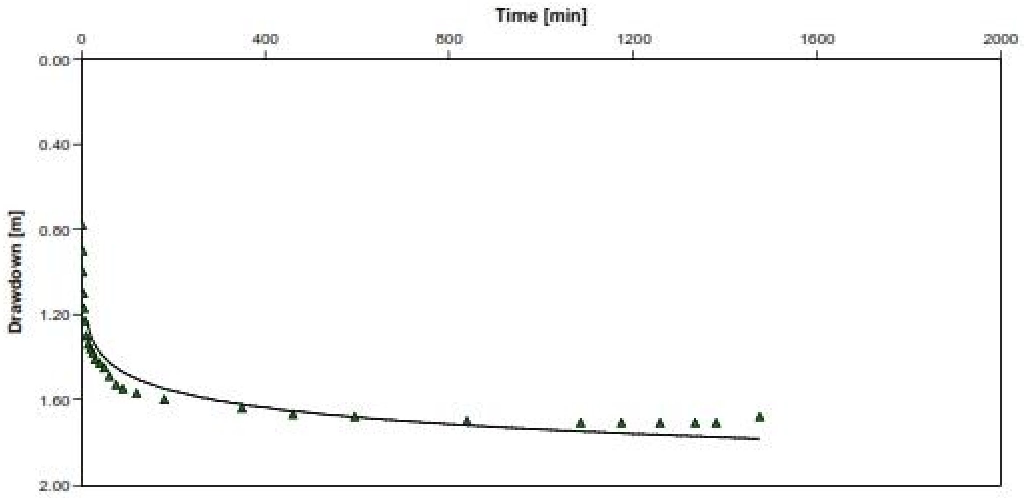
Location: Hughenden	Pumping Test: 15 Mile No 3	Pumping Well: 15Mile#3
Test Conducted by: R Lait		Test Date: 1/08/2017
Analysis Performed by: R lait	Theis	Analysis Date: 9/08/2017
Aquifer Thickness: 7.00 m	Discharge: variable, average rate 22.188 [l/s]	



Calculation using Theis

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Storage coefficient	Radial Distance to PW [m]	
15Mile#3	7.11×10^{2}	1.02×10^{2}	1.73×10^{-4}	0.16	
15Mile#1	3.09×10^{4}	4.42×10^{3}	1.13×10^{-1}	157.81	
91500046	3.39×10^{3}	4.85×10^{2}	6.32×10^{-2}	153.57	
Average	1.17×10^{4}	1.67×10^{3}	5.69×10^{-2}		

Rob Lait and Associates Pty Ltd PO Box 788 Innisfail, Queensland 4860	**Pumping Test Analysis Report** Project: 15 Mile Number: 265 Client: Flinders Shire	
Location: Hughenden	Pumping Test: 15-Mile No 4	Pumping Well: 15Mile#4
Test Conducted by: R Lait		Test Date: 13/06/2017
Analysis Performed by: R Lait	Neuman Analysis	Analysis Date: 18/06/2017
Aquifer Thickness: 4.40 m	Discharge Rate: 5.56 [l/s]	



Calculation using Neuman

Observation Well	Transmissivity [m²/d]	Hydraulic Conductivity [m/d]	Specific Yield	Ratio K(v)/K(h)	Ratio Sy/S	Radial Distance to PW [m]
15Mile#4	3.41×10^{2}	7.75×10^{1}	1.51×10^{-1}	5.02×10^{-3}	1.06×10^{1}	0.08

The table below summarises the T and S values of the aquifer from the four pumping tests.

TABLE 2: CALCULATED T AND S VALUES		
Bore_ID	***T (m3/day/m)***	***S (dimensionless)***
15 Mile No 1	5140	0.25
15 Mile No 2	3150	0.32
16 Mile No 3	11700	0.05
16 Mile No 4	314	0.15
Averages	5076	0.19

APPENDIX 3: ASSESSMENT OF VOLUME IN STORAGE

The volume of groundwater in storage in the aquifer was assessed using the following relationship:

Total volume in storage = A b S

Where:

A = area of aquifer
b = saturated thickness of the aquifer
S = average storativity

The area of the high permeability aquifer is 70.4ha. The area of the lower permeability aquifer is 101.6ha.

The saturated thickness averaged from all bores within the high permeability aquifer is 5m. The saturated thickness within the lower permeability aquifer is assumed to be 2.5m.

The storativity of the high permeability aquifer is 0.19. The storativity of the lower permeability aquifer is assumed to be 0.1.

The table below shows the calculated volumes of groundwater in storage in the aquifer.

Aquifer Segment	**Area**	**S**	**Av saturated thickness**	**Volume in storage**	
	m^2	*dimensionless*	*m*	*m^3*	*ML*
Lower permeability	1016060	0.1	2.5	254015	254.015
Higher permaebility	703940	0.19	5	668743	668.743
				Total	922.758
				Useable	738.2064