Deliverable No. 5: Project K5/2338/1

Progress Report 4: River reaches 2nd year quantifications & development of transmission loss parameters

Quantification of transmission processes along the Letaba River for improved delivery of environmental water requirements (Ecological Reserve)

Raubenheimer, R [1], ES Riddell [2,3], JM Nel [1], A Swemmer [4],

With inputs from R Minnaar[1]

1 GCS Consulting, Pretoria
2 Centre for Water Resources Research, University of KwaZulu-Natal
3 Conservation Management, South African National Parks
4 SAEON Ndlovu Node, Phalaborwa

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1. Introduction

This deliverable report stems from the non-solicited Water Research Commission (WRC) research project K5/2338 titled:

Quantification of transmission processes along the Letaba River for improved delivery of environmental water requirements (Ecological Reserve)

This report covers progress to date in terms of river reaches SW-GW connectivity determination at the Letaba River Transmission Losses study site (Figure 1-1).

This report presents data collected since the submission of previous deliverable 3 (July 2015), and includes:

- Summary information related to the completion of the groundwater borehole piezometric network.
- Initial hydrometric interpretation of groundwater data
- Updated conceptualisation of hydrogeological process interaction between the Letaba River and the surrounding aquifer, and;
- Preliminary estimation of transmission loss parameters based on early hydraulic characteristic data

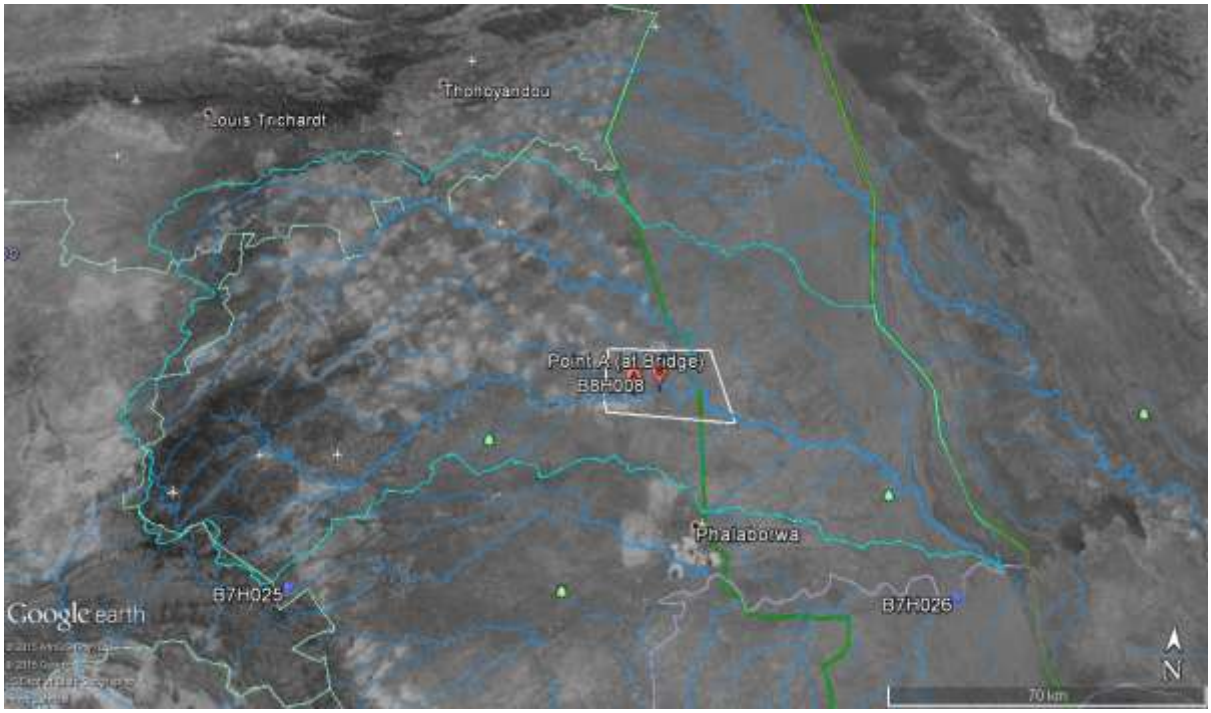


Figure 1-1 The location of the Transmission Losses study site within the Letaba River catchment

2. Borehole Drilling Report and Initial Hydraulic Characterisation

The drilling of the piezometric borehole network by the Department of Water & Sanitation Limpopo Drilling Division at the Letaba Transmission Losses study site commenced in June 2015 with the first borehole complete on 4 June 2015. The drilling campaign focused initially on the western side of the project area within the farms, before moving east to the protected areas. In total 29 boreholes were drilled by the time drilling ceased in December 2015. The network comprises paired piezometric boreholes drilled into shallow weathered material and deep fractured hard rock, as depicted in Figure 2-1 and detailed in Table 2-1. This campaign used the guidance of the geophysics campaigns discussed in previous deliverables in order to identify suitable drilling sites within and adjacent to the riparian zone. Furthermore, two boreholes were drilled either side of the dolerite dyke, within the main river channel close to the Letaba Ranch gauging weir (B8H008), in order to characterise the longitudinal hydraulic gradient across this geological structure. The nomenclature used for these boreholes follows Letaba Farms (LF), Letaba Reserves (LR), Letaba River Water (in channel, LRW) followed by a number (e.g. 001), where two numerals are used implies the borehole was drilled away from the riparian zone (e.g. 0031). The reader is referred to Appendix I for initial fluid logging information on the boreholes and Appendix II for the full drilling report. Note also that these boreholes are manual dip-read once a week and that 15 have been equipped with Solinst^{TM} Level-loggers for continuous hourly monitoring. It is anticipated that during 2016 further boreholes may be required at a greater distance to the north and south of the river in order to characterise the regional groundwater interactions.

Figure 2-1: Groundwater peizometric monitoring network at the Letaba river Transmission Losses study site as of February 2016.

Table 2-1: Letaba river Transmission Losses study site borehole drilling information

	Site Name	Site Description	Latitude	Longitude	Altitude (m)	Depth (m)	Solid Casing Depth (m)	Casing height (m)	Date completed	Initial Water Level (m)	Strike (m)	Blow Out yield (l/s)	EC (uS/cm)
Farms	LF002A	Mabunda/Baloi	-23.674299259	31.005508751	332.816	60	6	0.51	08/10/2015	11.51	11	1	
	LF002 B	Mabunda/Baloi	-23.674297937	31.005498881	332.966	15	6	0.58	10/09/2015	11.78	11	0.4	864
	LF0021	Mabunda/Baloi in river	-23.674764519	31.004662622	329.940	24	6	0.63	01/11/2015	8.26			
	LF003 A	Maliesa's Farm	-23.669515034	31.016633354	332.840	72	36	0.7	25/05/2015	10.97	15	0.3	1740
	LF003 B	Maliesa's Farm	-23.669519698	31.016568496	328.683	20	14	0.8	01/06/2015	10.76	12	<0.5	1446
	LF003C	Maliesa's Farm	-23.669494574	31.016672592	333.985			Dry					
	LF0031 A	Maliesa's Farm	-23.667002914	31.016215720	333.183	60	24	0.22	25/05/2015	12.95	21	3	1518
	LF0031 B	Maliesa's Farm	-23.667069700	31.016260718	335.904	20	6	0.255	26/06/2015	12.68	19	1	2535
	LF004 A	Abram's Farm	-23.677412130	31.005063317	337.243	72	24	0.43	22/10/2015	13.385	25	0.5	3413
	LF004 B	Abram's Farm	-23.677413088	31.005053265	338.883	15	10	0.46	23/10/2015	13.39	12	0.5	3996.00
	LF005 A	Bongele,s Farm	-23.671245070	31.017841574	328.391	72	30	0.29	04/06/2015	12.33	32	0.5	2800
	LF005 B	Bongele,s Farm	-23.671308501	31.017884338	330.151	42	6	0.305	09/06/2015	12.15	13	<0.5	3354
	LF005 C	Bongele,s Farm	-23.671222963	31.017831282	332.179	18	6	0.345	14/07/2015	10.97	13	0.5	3074
	LF0051 A	Bongele,s Farm	-23.673002919	31.018831950	328.978	54	36	0.54	11/06/2015	14.29	25/40	1.5	1446
	LF0051 B	Bongele,s Farm	-23.673047435	31.018857310	327.363	30	6	0.36	25/06/2015	14.26	16	1	1393
reserves	LR001 A	Mthimkhulu	-23.661769123	31.046823055	328.039	60	30	0.46	03/09/2015	10.35	10	0.5	5600 - 7000
	LR001 B	Mthimkhulu	-23.661764275	31.046805745	330.826	12	6	0.355	08/09/2015	11.93	10		>10 000
	LR0011 A	Mthimkhulu	-23.662934730	31.045922747	324.700	72	24	0.3	14/09/2015	10.3	10	0.1	>10 200
	LR0011 B	Mthimkhulu	-23.662913645	31.045961774	331.089	10	6	0.315	15/09/2015	10.15	10		11 100
	LR002 A	Mthimkhulu	-23.666323042	31.040506466	330.907	42	24	0.43	28/09/2015	10.59	25	0.5	2478.00
	LR002 B	Mthimkhulu	-23.666330049	31.040511463	329.536	10	6	DRY	01/10/2015				
	LR003	Mthimkhulu. Tercias BH	-23.661232653	31.047126602	326.855	10	4	0.355	26/09/2015	Initially dry	0	0	5595
	LR004 A	Letaba Ranch	-23.669463099	31.042411630	327.109	54	30	0.57	02/12/2015				
	LR004 B	Letaba Ranch	-23.669447874	31.042414074	326.388	24	0	0.505	03/12/2015				
	LR005 A	Letaba Ranch	-23.662268314	31.049551881	327.444	60	42	0.265	09/07/2015	8.95	25/38/50	5.7	1740
	LR005 B	Letaba Ranch	-23.662269810	31.049502905	328.971	24	6	0.56	13/07/2015	8.94	19	1.8	1580
	LRW001	Mthimkhulu in river	-23.659273246	31.048663193	316.063	12	0	0.35	26/11/2015	1.23	5	0.2	
	LRW002	Mthimkhulu in river	-23.659964290	31.048604409	317.902	6	0	0.52	30/11/2015	1	4	0.2	
	LR006	Mthimkhulu Near camp				75	0		24/11/2015				

2.1. Slug test data

The Slug Test analysis was conducted between 4 and 5 February 2016 and represents an initial estimate of the hydraulic parameters in the borehole hydrometric network at the study site. Due to limited accuracy and multiple factors influencing these tests, the results provided here should be considered a rough estimate of the hydraulic characteristics of the borehole network. Over the next two months more comprehensive slug tests and pump drawdown tests will be conducted to provide better estimates.

For these initial tests the following methodology was used:

Slug length:	1.55m
Slug radius:	0.055m
Slug volume:	0.015m^3
Volume of 1.55m casing:	0.033m^3
Difference in volume:	0.018m^3

Using the following equation:

$L=V/(\pi r^2)$ Where: L is length (m), V is volume (m^3) and r is radius (m)

Thus length of displacement:	0.861m
Pullback = 95% recovery	
Thus pullback:	4.31cm

The recovery of the water level after the slug was inserted was timed on a stopwatch. If the borehole did not recover within 3 minutes a reading was taken at 1min intervals. The data was then plotted using FC – EXCEL software developed by IGS (using the Bouwer & Rice 1976 method) to calculate the hydraulic conductivity of each borehole and is depicted in Table 2-2.

The hydraulic conductivity (K) and transmissivity (T) was calculated from the data obtained from the slug tests. The transmissivity being directly proportional to the hydraulic conductivity. Fourteen of the boreholes display a transmissivity of between 1m^2/day and 4m^2/day this is typical and in range of aquifers found in crystalline rocks such as granites and gneisses, thus the K and T values correspond with the geology.

Boreholes LR002A and LF005B displays the lowest K and T values which was expected because of their low yields. Four boreholes stand out LR005A/B and LR004 A/B with relatively high K and T values especially LR005A and LR005B. This can be the result of a high yielding fracture in boreholes LR005A/B. LR005A/B and LR004 A/B are both located on the southern bank with similar geology that might explain the similar high K and T values. Surprisingly LRW001 and

LRW002 displays relatively low K and T values even though they were drilled within the river bed.

Table 2-2: Initial Slug Test Data for Piezometric network

Borehole nr.	Static Water Level (m)	Date	Time	Seconds to recover	Estimated yield L/s	K (m/d)	D(m)	T (m^2/d)
LR005A	9.43	02/04/2016	08:21	4.68	11	0.40	50.57	20.2
LR005B	9.75	02/04/2016	08:40	144	1	1.09	14.25	15.6
LR004B	11.07	02/04/2016	09:18		0.37	0.61	12.93	7.8
LF004A	13.46	02/04/2016	11:57		0.26	0.09	48	4.1
LR001A	10.4	02/05/2016	10:40		0.22	0.12	30	3.6
LF003A	11.78	02/05/2016	09:18	50	1.6	0.10	36	3.5
LF0051B	14.83	02/04/2016	10:05		0.24	0.23	15.17	3.4
LF0031A	13.62	02/05/2016	08:40	4.11	12.51	0.27	12	3.2
LR0011A	10.22	02/05/2016	11:08		0	0.06	48	2.9
LF005A	12.88	02/04/2016	10:31		0.2	0.07	42	2.9
LF0051A	14.85	02/04/2016	09:39	145	0.66	0.06	39.15	2.5
LF003B	11.79	02/05/2016	09:30	12.49	5	0.29	8.21	2.4
LRW002	1.01	02/05/2016	10:12	264	0.41	0.42	4.99	2.1
LRW001	1.4	02/05/2016	09:58		0.16	0.18	10.6	1.9
LF0021	8.4	02/04/2016	12:55		0.15	0.10	15.6	1.6
LF004B	13.36	02/04/2016	12:14	27	2.65	0.88	1.64	1.4
LR004A	11.12	02/04/2016	09:01		0.09	0.03	42.88	1.1
LF002A	11.7	02/04/2016	13:12		0.11	0.08	12.3	1.0
LF0031B	13.33	02/05/2016	09:00		0.1	0.12	6.68	0.8
LR002A	10.72	02/05/2016	11:31		0.04	0.02	18	0.4
LF005B	12.66	02/04/2016	10:46		0.04	0.01	29.34	0.4
LR003	11.42	02/05/2016	06:28		0	0.00	0	0.0
LF002B	Could not	02/04/2016	13:27	Problems with borehole. Casing not properly installed.				
LR001B	Water column to shallow for slug test.							
LR0011B	Water column to shallow for slug test.							

3. Initial Hydrometric Interpretation

This section gives a brief overview of the observed groundwater hydrodynamics to date from the groundwater piezometric network. Figure 3-1 displays the rainfall observed since the completion of the first borehole. This was collected from Davis automated weather stations installed within the study area. The 2015-16 hydrological year has been characterised as a very low rainfall year, with only 20.8 mm (Mahale) to 45.6 mm (Mthimkulu) received since 1 October 2015.

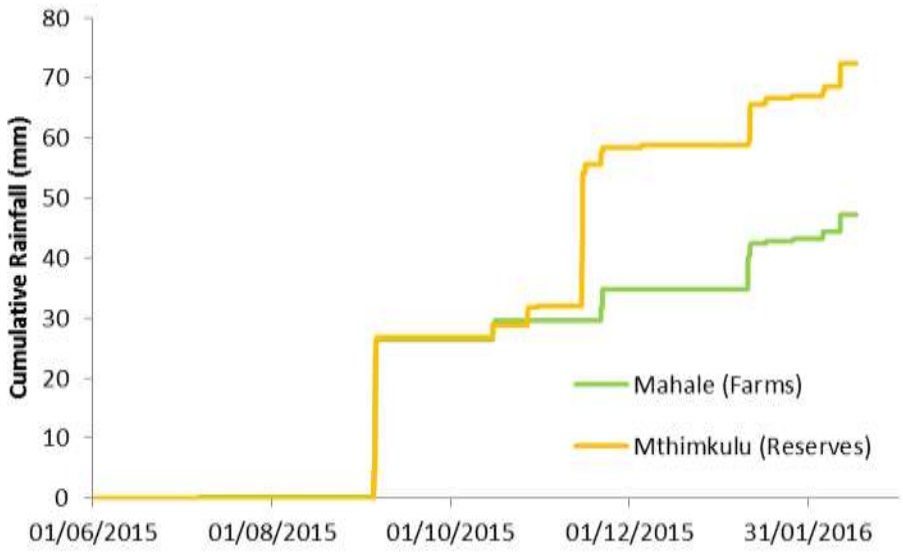


Figure 3-1 Cumulative rainfall since June 2015 at the Letaba Transmission Loss study site

3.1. Groundwater Hydrodynamics - Farms

Boreholes LF002A/B are located within the farm area of the study location. LF0021 is located just west of LF002 within a suspected paleo-floodplain. The manual water levels (Figure 3-2) depict a relatively steady decline over the summer season during which very little to no recharge occurred. The greatest drop in hydraulic head between these 3 boreholes where found in LF0021 with a drop of 0.14m. LF002A and LF002B decreased by 0.086m and 0.1m respectively and indicating a greater drop in hydraulic head in the shallower borehole. LF0021 displays a higher water level than LR002A/B however they all decline at a similar rate indicating that the aquifer connectivity in this vicinity.

Boreholes LF004A/B are located just south of LR002A/B and LR0021 on the southern bank of the Letaba River (Figure 3-3 **Water level responses at LF004**). The deeper borehole LF002A displays a steady but much greater decrease of 0.19m over the season compared with LR002B which only decreases by 0.08m. Important to note is that there is a lower density in vegetation around LR004A/B than compared to LR002A/B. This is because the surface is used for agriculture and most of the trees and vegetation where removed. This could result in lower levels of transpiration from the vegetation and a higher water level in the shallow aquifer.

LF0031A/B and LF003A/B are located on the northern bank of the Letaba River within an agricultural area. LF0031A/B is located uphill from LF003A/B which is drilled closest to the river. The largest decrease in water levels over the season in all boreholes at the study location was found between these four boreholes. LF003A and LF003B displayed the most decrease with 1.07m and 0.78m respectively. LF0031A/B also displayed a decrease of 0.39m and 0.38m, this is still relatively high compared to the other borehole on-site. The high losses in these boreholes indicate similar aquifer properties with the groundwater flowing from LF0031 to LF003. The losses of the shallow boreholes are lower than the deeper boreholes indicating that the decrease is more regionally related. Note however that the large decrease is also partially because these boreholes have been monitored for much longer when compared to the other borehole.

LF005A/B and LF005A/B/C is located on the southern bank of the Letaba River opposite LF003A/B. These boreholes display the longest range of data as they were drilled first. A steady decline is observed in all the boreholes with an average decrease of 0.15m indicative of them sharing the same aquifer. A definitive hydraulic gradient is observed from LF005C to LF005B. When taking LF003 and LF0031 into consideration it is apparent that the groundwater flow direction is from north to south in this transect. LF005 and LF0051 shows a small decrease in water levels when compared to LF003/31 indicating that the river might be contributing by flow losses to the groundwater aquifer in the southern bank.

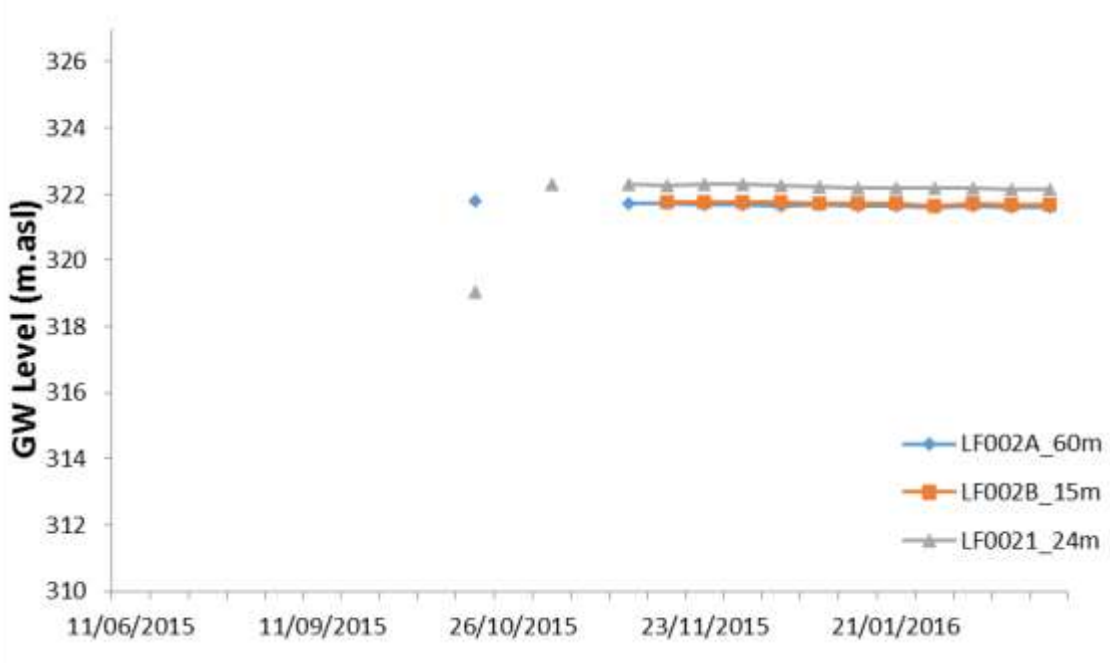


Figure 3-2 Water level responses at LF002

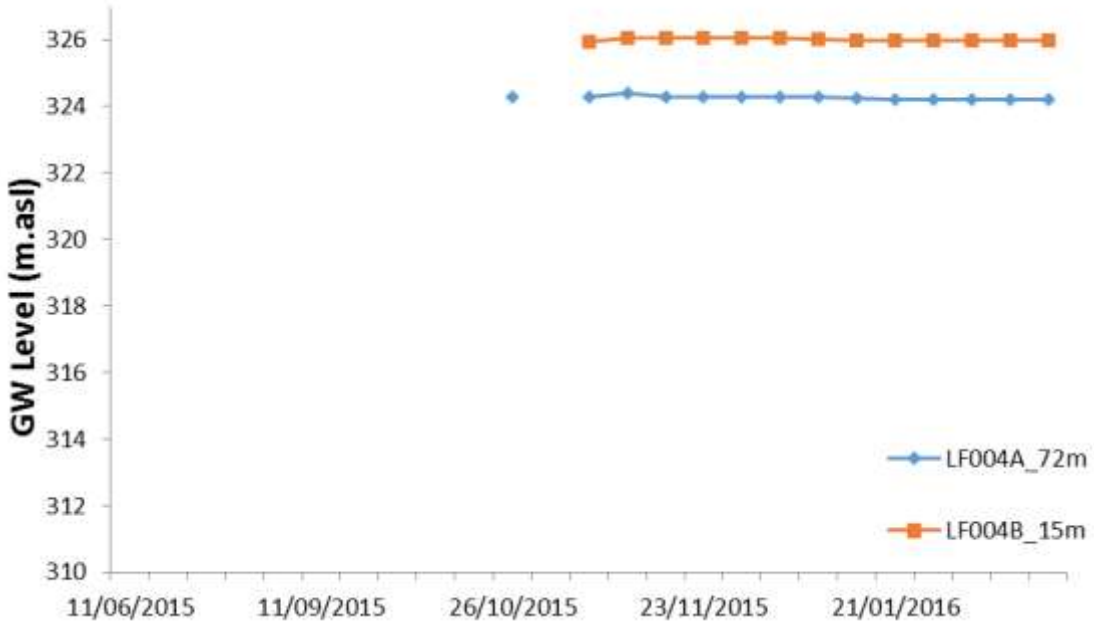


Figure 3-3 Water level responses at LF004

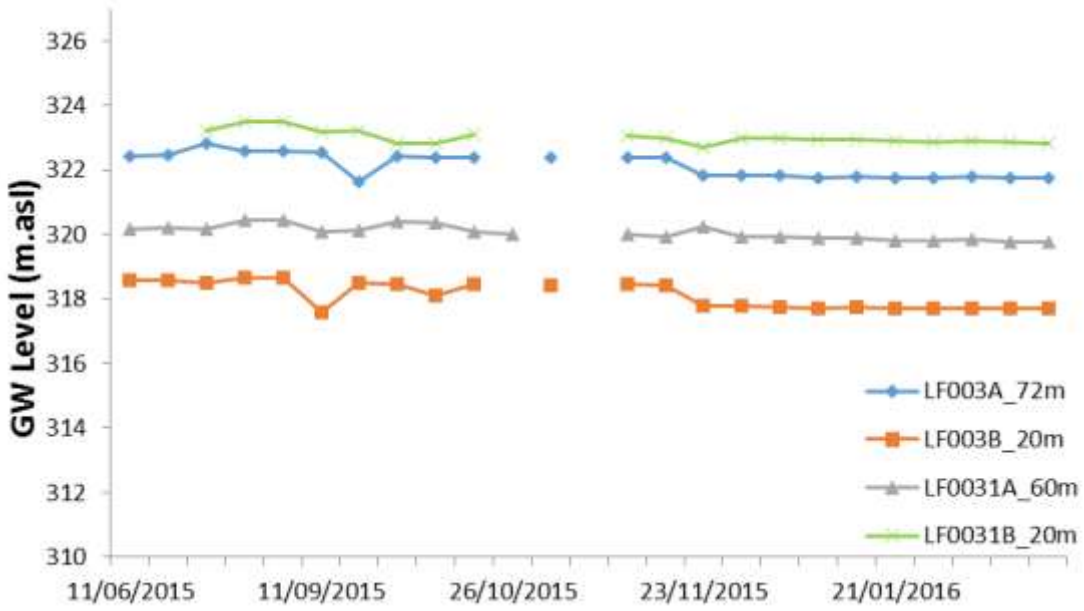


Figure 3-4 Water level responses at LF003 and LF0031

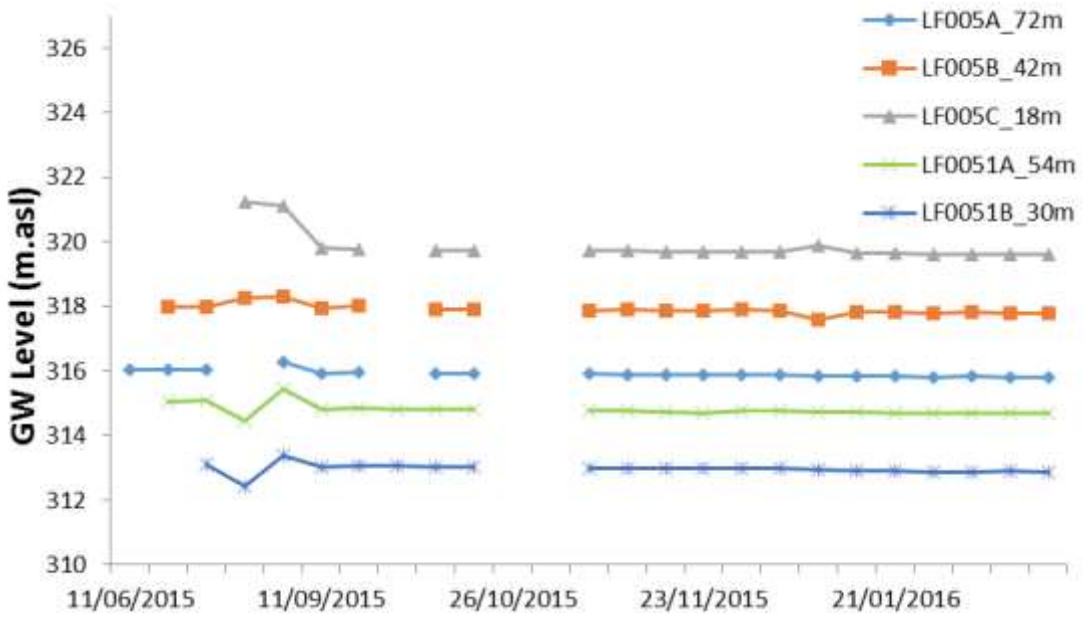


Figure 3-5 Water level responses at LF005 and LF0051

3.2. Groundwater Hydrodynamics – Protected Areas

LR001A/B, LR0011A/B and LR003 are located on the northern bank of the Letaba River in the Mthimkhulu game reserve. LR0011A was drilled to the south of LR001A/B on the other side of a dolerite dyke which may then separate the aquifer. All of the boreholes display a steady decrease over the season with an average of 0.18m except for LR001B which showed minimal fluctuation and decreasing by only 0.02m. This might be an indication that the shallow aquifer is separated by the dolerite dyke. LR003 displays a low water level and decreased the most, which may be due to the fact that a water strike was never obtained in this borehole and was initially dry thus, it is more subject to the effects of riparian vegetation transpiration.

LR005A and LR005B are located in the Letaba Ranch on the southern side of the Letaba River opposite LR001A/B. Both boreholes display a steady decrease in water level with LR005B showing a greater decrease of 0.55m from a possible combination of vegetation transpiration and increased drainage toward the river.

LRW001 and LRW002 are located within the riverbed between the two game reserves and on opposite sides of a dolerite dyke with LRW001 to the north and LRW002 to the south. Both are relatively stable showing a much higher decrease in LRW001 which has a much lower water level. This was expected as the river flows from north to south in this section and is intersected by the dolerite dyke forming a possible subsurface dam in the river channel on the southern side at the location of LRW002.

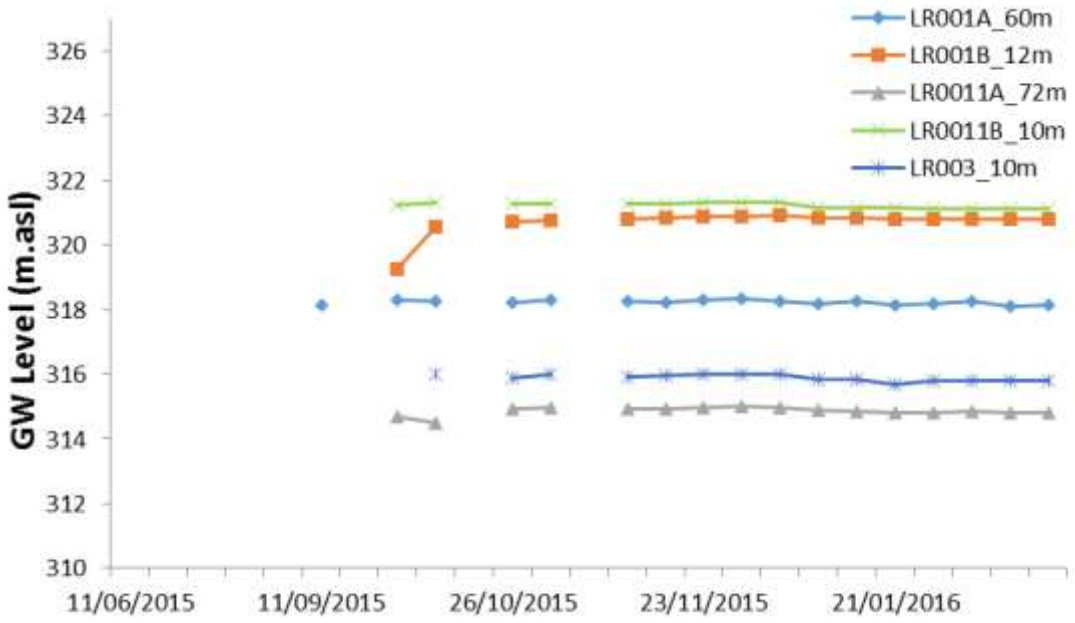


Figure 3-6 Water level responses at LR001, LR0011 and LR003

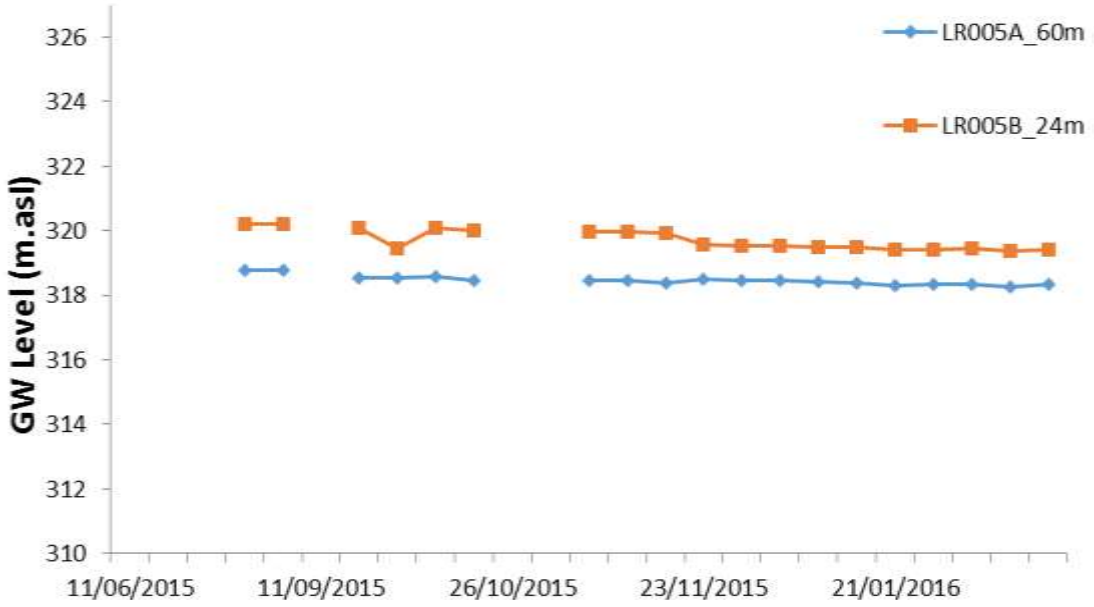


Figure 3-7 Water level responses at LR005

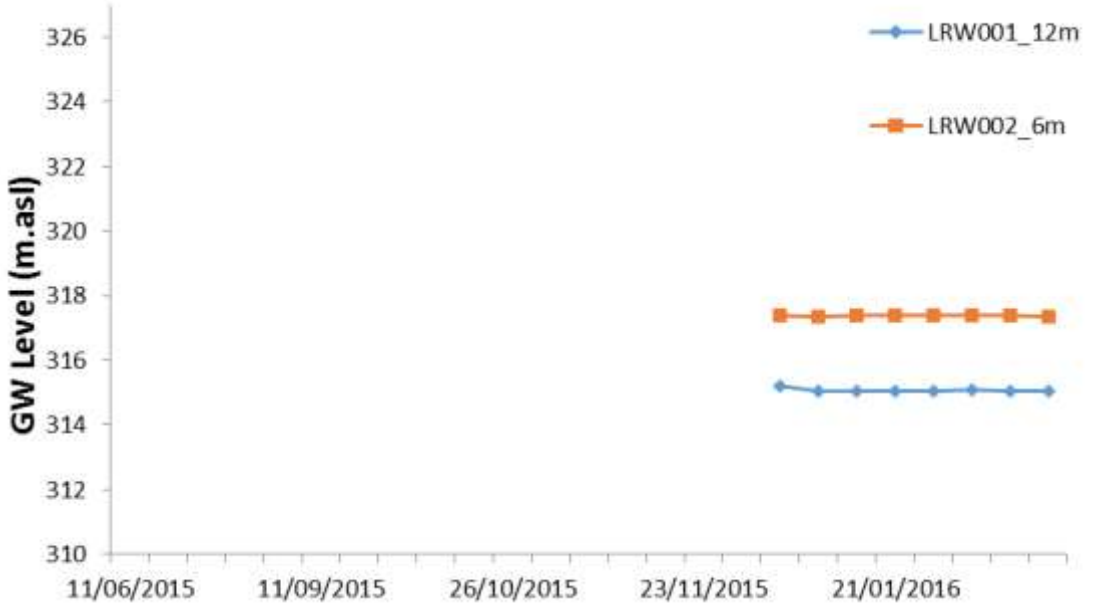


Figure 3-8 Water level responses at LRW001

3.3. Groundwater Hydraulic Gradients

The following section plots the water levels as observed on 15 February 2016 in cross-section relating to the position of the river. Included are the initial values for K and T in order to build a preliminary interpretation of *potential* losses or gains to the Letaba river from the surrounding aquifer(s).

Commencing with Figure 3-9 for the most upstream transect, the hydraulic gradient shows potential groundwater flow from south (LF004) to north (LF002). The T values show that there is a higher flow from the southern bank to the river especially from the deep hard rock aquifer. After intersecting with the river the T values display a slight loss to the river but, a greater loss to the riparian zone as indicated by LF0021. The shallow boreholes show a much larger decrease to the north possibly from river drainage to the aquifer and possible losses to riparian vegetation transpiration.

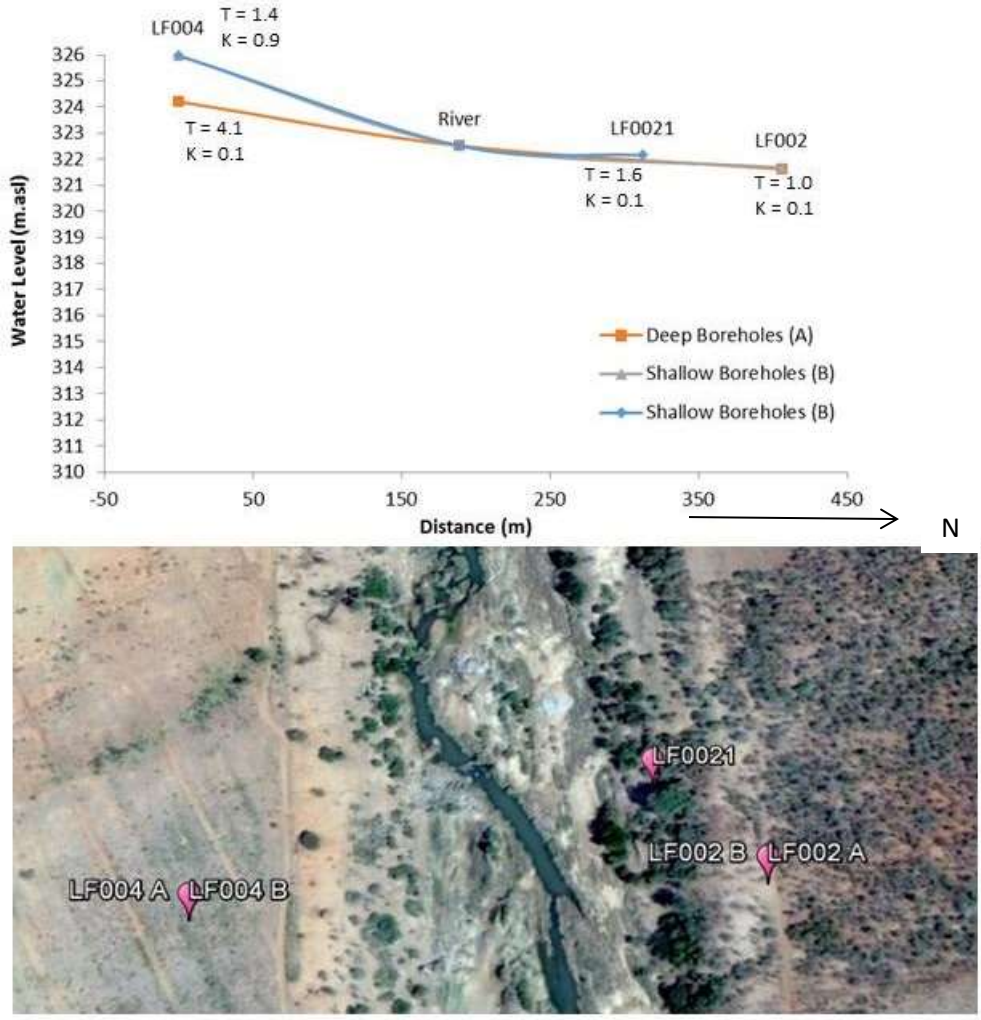


Figure 3-9 Cross-section plot of transect LF004 to LF002, February 2016

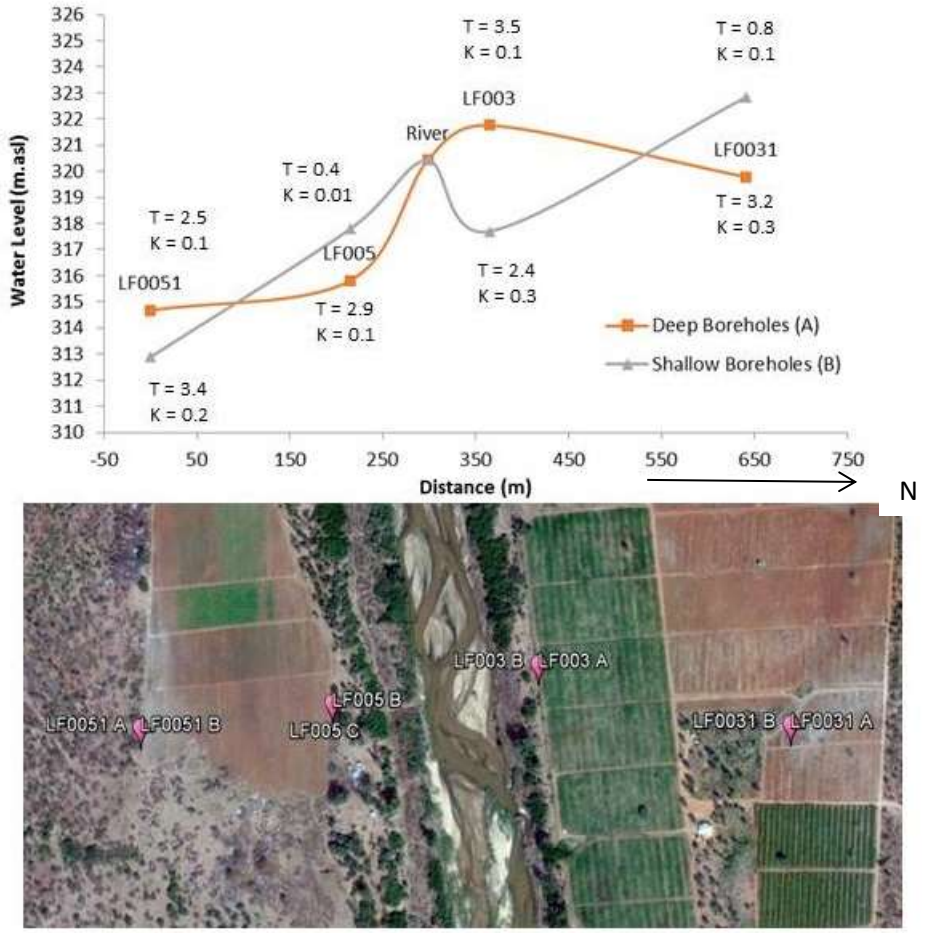


Figure 3-10 Cross-section plot of transect LF0051 to LF0031, February 2016

Figure 3-10 indicates that the hydraulic gradient is from north (LF0031) to south (LF0051). There is a definitive loss to the aquifer from the river on the southern bank in the weathered and hard rock indicated by a high hydraulic gradient and high T values. LF003 seems to be an anomaly and might be disconnected from the regional aquifer as it indicates high flow from the T values and because of its high hydraulic head it can flow in both north and south directions. A possible explanation could be the water still flows from north to south but, because there is an increase in the hard rock elevation as seen in the geophysics (see deliverable 3) it "pinches" the water at LF003 increasing flow and "pushing" the groundwater over the elevated hard rock.

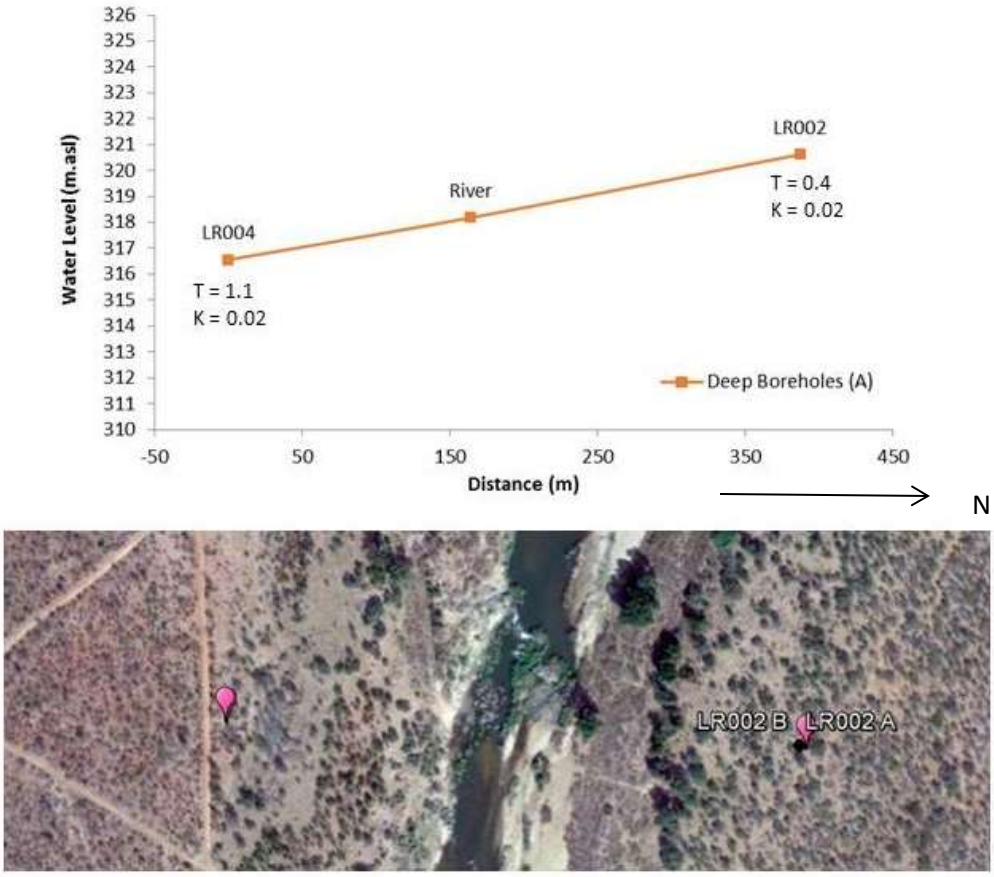


Figure 3-11 Cross-section plot of transect LR004 to LR002, February 2016

In **Figure 3-11** it appears that the groundwater flows from the northern bank to the southern bank. The deep hard rock aquifer does not appear to be largely affected by the intersection of the river. The T value of LR002 display a small gain to the river from the surrounding aquifer while the T value of LR004 shows a potentially large gain to the aquifer from river losses.

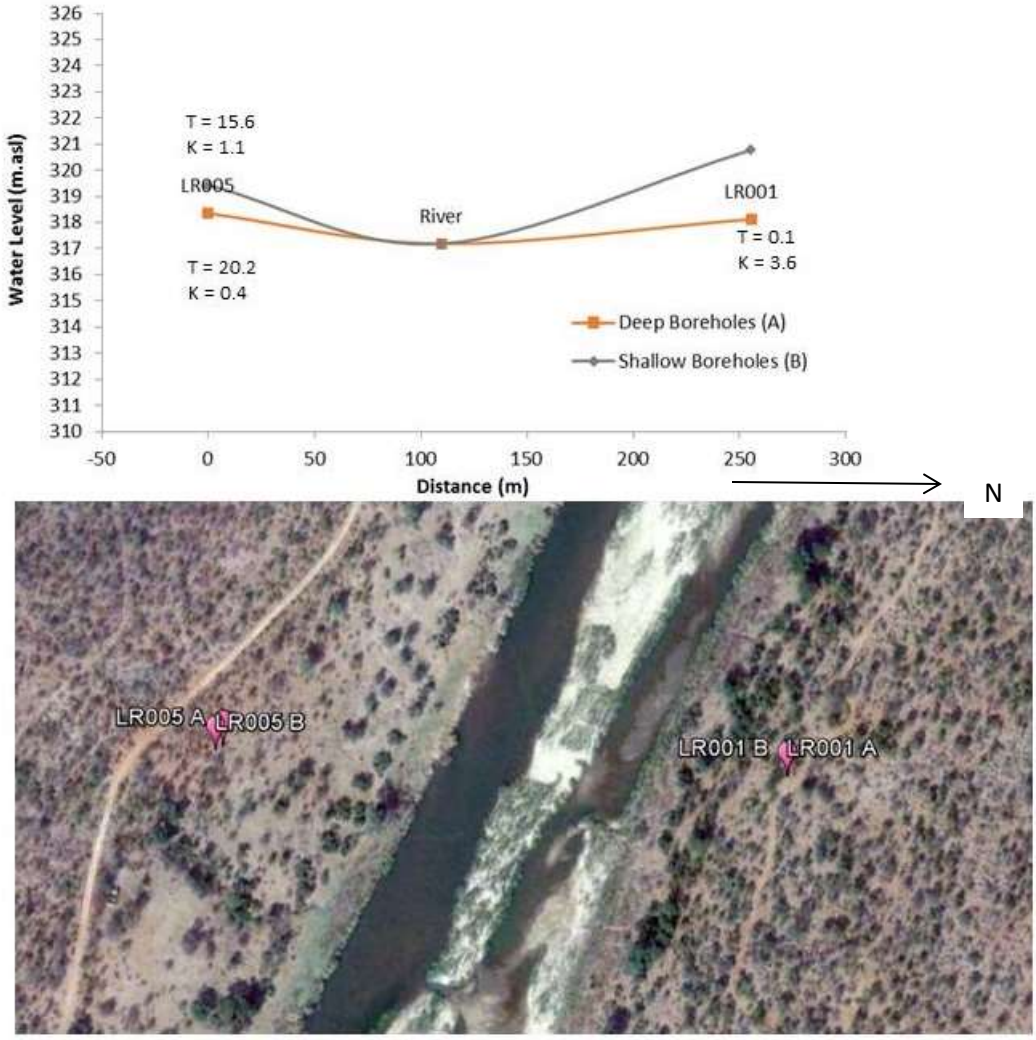


Figure 3-12 Cross-section plot of transect LR005 to LR001, February 2016

In **Figure 3-12** both the deep hard rock aquifer and the shallow weathered aquifer display a large potential contribution from the groundwater to the river from both the south and north. It is likely that the shallow weathered aquifer contributes much more than the hard rock aquifer although this will be impacted by riparian vegetation transpiration. Through flow of the aquifer is not displayed in this transect as in all the other transects although, as there is a dolerite dyke running through the river between these two borehole positions in a North – East and South West direction. It is therefore possible that this dyke might be separating two contributing aquifers.

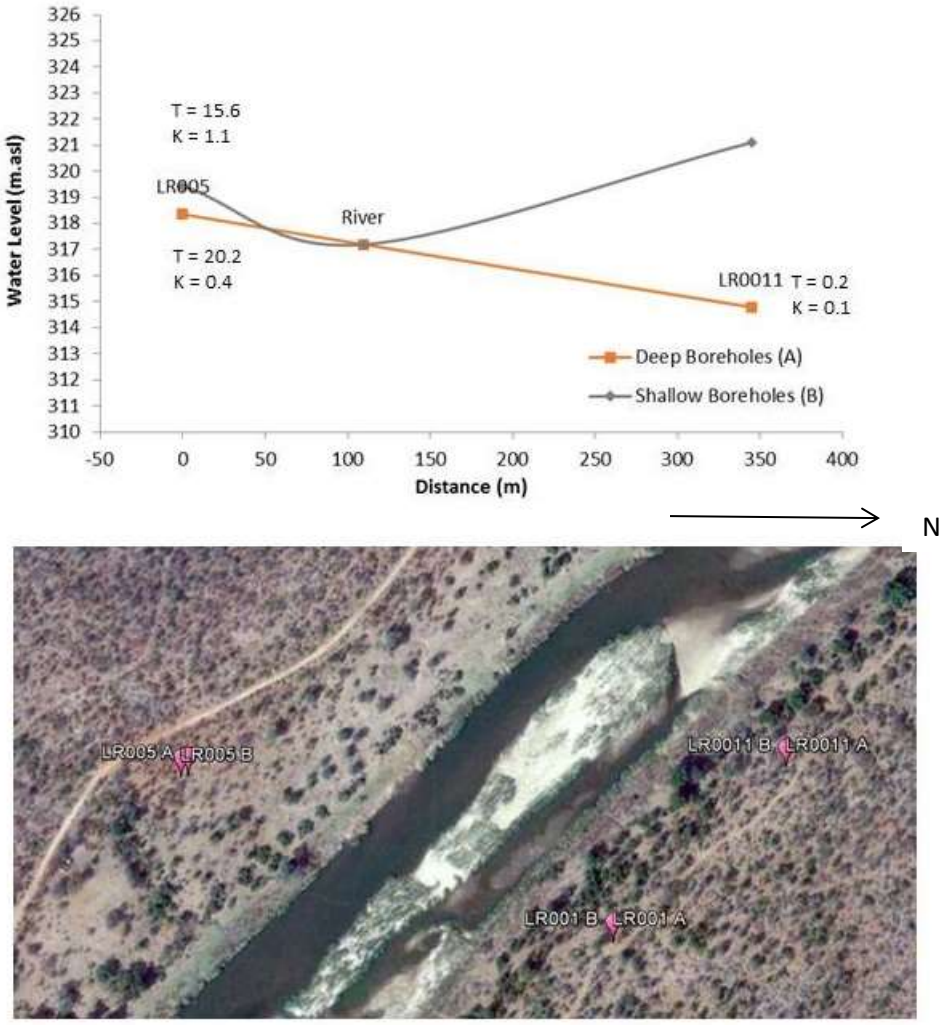


Figure 3-13 Cross-section plot of transect LR005 to LR0011, February 2016

The hydraulic gradients in **Figure 3-13** suggest a through flow of the deep hard rock aquifer with a large contribution from the southern bank to the river depicted by the T values. This through flow is similar to the other transects and might indicate that the dolerite dyke does in fact separate the aquifer from LR001. The shallow weathered aquifer from the northern bank does not show a large loss to the river drainage (but this still requires hydraulic data characterisation), this can also been seen in the manual water levels where only small fluctuations occurred in the water level during the season.

4. Initial Transmission Loss Estimation

Following the initial groundwater hydraulic characteristic data presented previously a first order transmission loss estimate can be made for the section of river assessed in the study. It must be cautioned however that this is preliminary and will be followed with more detailed parameterisation during the remainder of the study.

In accordance with the 4 geohydrological transects described an estimate was made of the approximate river reach lengths represented by the surrounding aquifers, as depicted in Figure 4-1, which divides the river between Mahale and Letaba Ranch into 4 representative river reaches upon which the interaction between the river and the aquifer can be estimated in terms of either gains or losses from the water course. These river reaches will be surveyed in detail over the next few months in order to accurately quantify representative river reaches.

Figure 4-1 Assumed river reaches between Mahale and Letaba Ranch weirs associated with geohydrological transects (green represents farming areas and yellow the protected areas).

Transmission losses along a river can be estimated using the following equation:

$$Q = TiL \quad (4.1)$$

Where Q is discharge (m^3), T is transmissivity, i is the hydraulic gradient between the river and the surrounding aquifer (dimensionless), L is the length of river reach (m)

This equation was applied to each river reach distinguishing between hydraulic parameters for deep and shallow boreholes and applied to the hydraulic gradients determined for the study site on 15 February 2016, as depicted Table 4-1.

It is interesting to note that based on Table 4-1 there appears to be a net loss from the river to the surrounding aquifer in the transects representing the farming areas, and this is potentially greater into the shallow weathered zone (-187 m^3/day), whilst further downstream in the protected areas there is a potential flow gain from the surrounding aquifer especially in the deep hard rock zone (198 m^3/day).

It is therefore important to take this into context of the prevailing hydrology for the day in which the upstream Mahale weir was discharging only through low flow outlets with an estimated flow of between 0.4-0.5 m^3/sec or 34560 to 43200 m^3/day. Hydro-census information for river abstractions (surface water only) between these two weirs (see deliverable 3) allows for an estimate of total daily abstractions of 52 m^3/day.

Table 4-1 Preliminary Transmission Loss parameters determined for the Letaba river study site for 15 February 2016 (yellow highlighted data is where data was absent and values assumed from adjacent boreholes)

		River Section	Assumed River Section Length (m)	*T* m/day	*i*	Q - actual m^3/day
Deep BH data (A)	**Farms**	LF002	2200	1	-0.0041	-9.02
		LF004	2200	4.1	0.0089	80.28
		LF003	2180	3.5	0.0201	153.36
		LF005	2180	2.9	-0.0552	-348.97
					Total	**-124.35**
	Reserves	LR002	1580	0.4	0.0109	6.89
		LR004	1580	1.1	-0.0099	-17.21
		LR001	880	3.6	0.0064	20.28
		LR005	880	20.2	0.0106	188.43
					Total	**198.38**
Shallow BH data (B)	**Farms**	LF0021	2200	1.576	-0.0029	-10.05
		LF004	2200	1.44	0.0183	57.97
		LF003	2180	2.373	-0.0408	-211.06
		LF005	2180	0.352	-0.0315	-24.17
					Total	**-187.32**
	Reserves	LR002	1580	0.4	-0.001	-0.63
		LR004	1580	7.823	-0.0147	-181.70
		LR001	880	3.6	0.0246	77.93
		LR005	880	15.561	0.0204	279.35
					Total	**174.95**

5. Updated conceptual model: groundwater-surface water interaction

The previous sections have detailed the initial hydrometric results from the piezometric borehole network. Based on this and the first fluid logging results from the boreholes (Appendix I) as well as the two longitudinal hydrochemical profiles of the entire river reach (**Figure 5-1**) it is possible to present an updated conceptual model for the study site. This being from the groundwater-surface interactions perspective.

Figure 5-1 compares the survey of November 2014 which can be considered representative of the dry season, but following a wet cycle climatically. With the October 2015 survey also in the dry season it does follow a significantly below average rainfall year. This figure reveals two interesting aspects. The first being the apparently lower EC in the November 2014 survey, with a clear increase in EC in the river reach represented by the LF003-LF005 transect in the farming area, which then returns to a lower EC further downstream. This contrasts with the higher EC throughout in October 2015 with no EC elevation at the LF003-LF005 transect. Two factors may explain this: low flows in the Letaba river were significantly lower in the latter period (<0.5 m^3 at Letaba Ranch) compared to the former (˜1.0 m^3 at Letaba Ranch) and therefore subject to greater concentration of salts from natural processes as well as anthropogenic activities; whilst the 2014-15 being a low rainfall year may have prevented a significant hydraulic gradient from the weathered zone and disturbed landscapes of the farming region on the northern bank of the river (LF003-LF0031). This is of course speculative as we have no groundwater observations to verify for this period, but certainly an aspect to consider in long term monitoring of the site.

The second aspect is the observed increase in pH seen in both surveys in the vicinity of the LF003-LF005 transect. Appendix I shows that the shallow borehole of LF003B shows a marked increase in pH at 10m deep with an increase in EC also, supporting a shallow weathered zone inflow to river through unconsolidated material on the northern bank. Meanwhile, LF005 shows a pH increase up to 30m suggesting that these groundwater accruals from the northern bank may also translate to river losses into the aquifer on the southern bank of the river. Furthermore the boreholes LF0051 further to the south also show a steady increase in pH with depth beyond 10m. This therefore supports the interpretations of the hydraulic gradient as depicted in Figure 3-10.

Meanwhile other aspects to consider from the fluid logging are the low EC readings for LF002 suggesting continuous connection to river surface water, and therefore implying losses to the northern bank in the most upstream part of the study. Moreover, LF004 on the southern side of the river shows increasing EC to a depth of 30m with corresponding increase in temperature with depth, suggesting sustained groundwater contributions from elsewhere in the landscape.

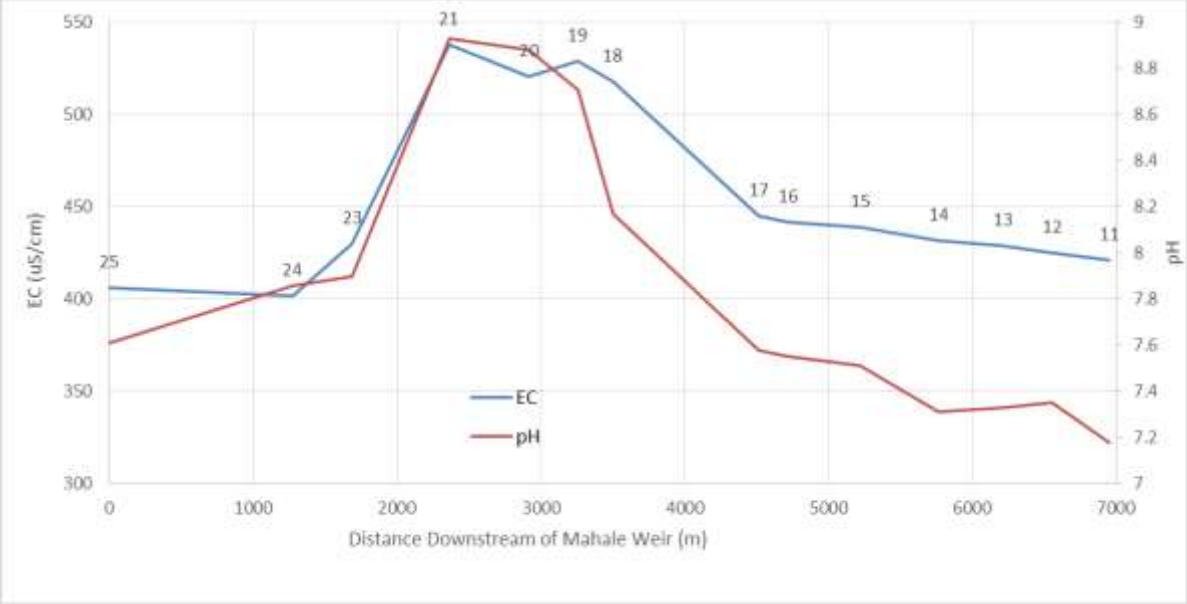
When examining the data for the lower end of the system in the protected areas, we see that at LR002 on the northern bank there is an apparent decrease in temperature with depth, whilst at the same time an increase in EC and a rapid increase in the pH up to 10m. Whether this is

related to river flow or contributions from the aquifer needs to be explored. Remembering that the hydraulic gradients at this point suggest potential contributions of groundwater to river from the northern bank. The complicated geological features in the form of dykes in this vicinity will need to be examined further, utilising stable isotopes to assess connectivity.

At the lowest end of the study site the fluid logs suggest that there is a sustained groundwater contribution from the northerly directions into the river channel, as suggested by decreasing temperature and stable EC with depth at LR001. With similar observations in the boreholes at LR005 also supports sustained groundwater contributions to surface flow in the river from a southerly direction.

The initial interpretations outlined allows for an updated conceptualisation for the study site as revealed in Figure 5-2. In summary therefore one expects moving forward in this study to see greater evidence for groundwater accruals to the river from the south in the eastern farming area, with some losses from the river channel on the northern bank. Whilst moving west but still within the farms, the river may appear to intersect the regional groundwater flow path, and it is expected that paleo-floodplain alluvium is the conduit for an unconfined aquifer in this region. Moving downstream one sees significant inflows from the regional aquifer on both sides of the river.


S1
S2
LR0011 A
LF005 A
S5
LF002 A
S6
LF0031 A
S4
S7
S11
S10
LF003 A
LF005 A
S8
LF0051 A
S9
LF004 A
Google earth


550
500
450
400
350
300
EC (uS/cm)
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
7.2
7
pH
0
1000
2000
3000
4000
5000
6000
7000
Distance Downstream of Mahale Weir (m)
EC
pH
25
24
23
21
20
19
18
17
16
15
14
13
12
11

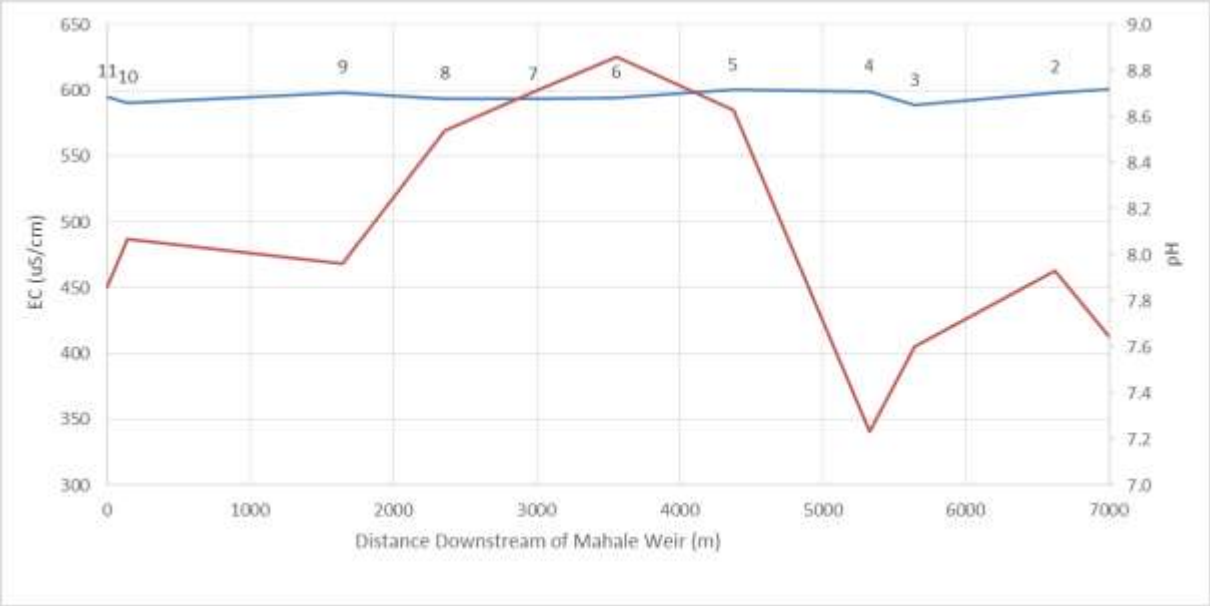


Figure 5-1Results of longitudinal hydro-chemical snap-shot survey of the Letaba river between Mahale and Letaba Ranch on 24 November 2014 (above) using parameters measured in in-situ and 27 October 2015 by the MOSA Mobile Laboratory (below).

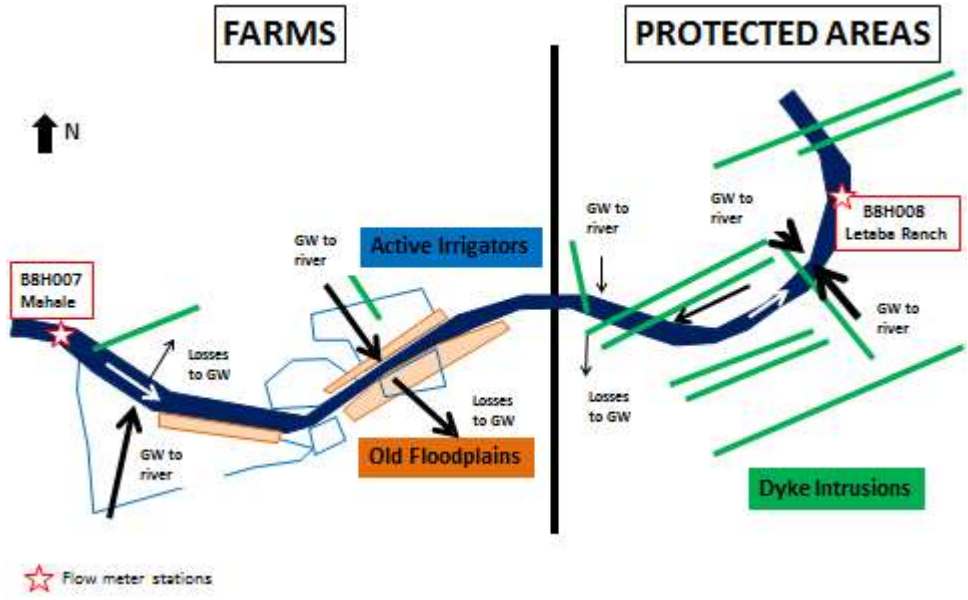


Figure 5-2 Updated geohydrological conceptual model of the study site

6. Workplan

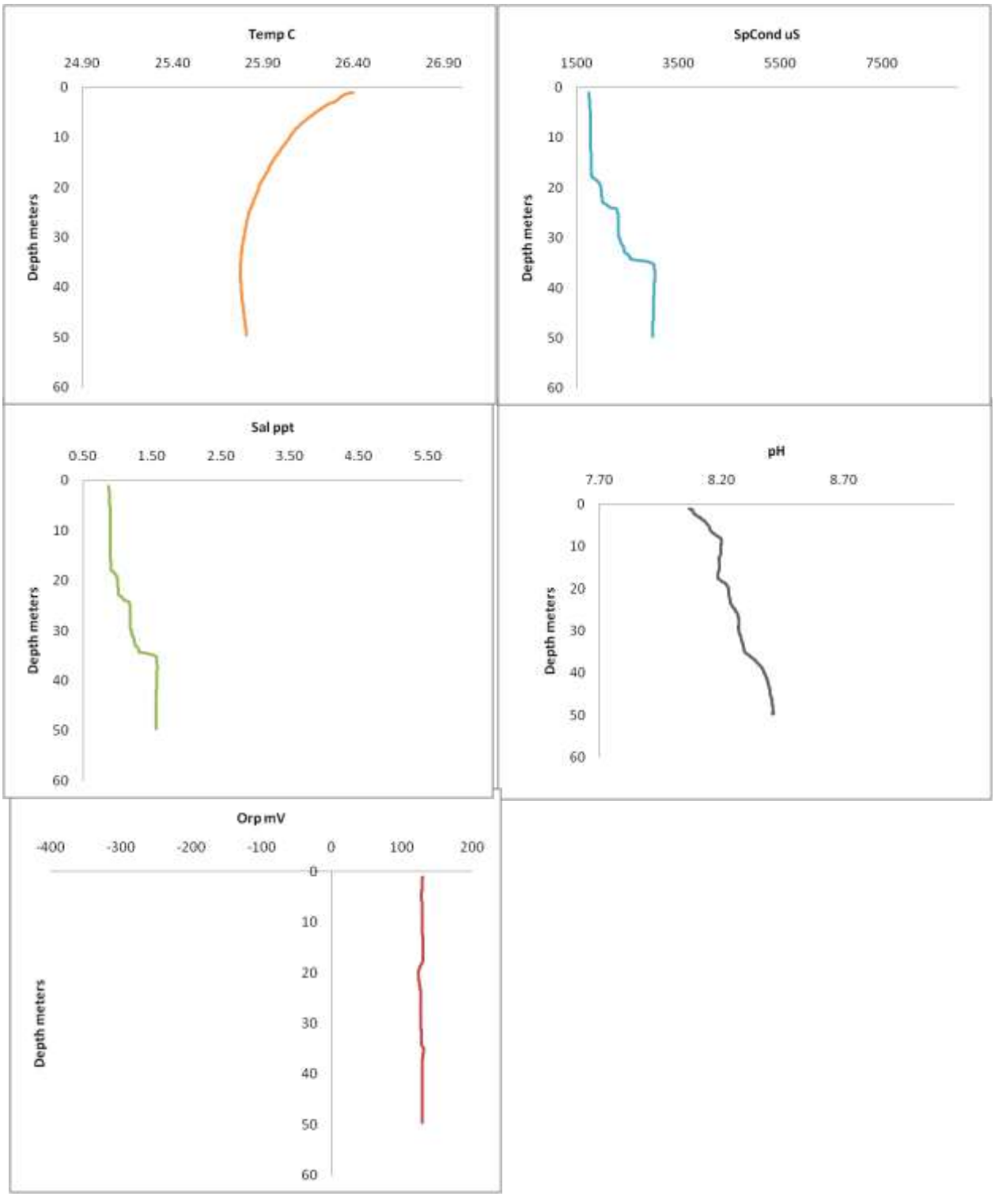
The focus of the work schedule for the next few months will be the following:

- A longitudinal river walk will take place to delineate with greater surety the discrete river reaches, based on geological and hydro-chemical and geomorphological indicators.
- Pump tests will continue in order to fully characterise the hydraulics of the aquifer with a focus on step and drawdown tests, as well as a more comprehensive slug test assessment using data loggers.
- Hydrochemistry will continue to be collected including longitudinal river reach profiling as well as repeated fluid logging of the boreholes.
- Stable Isotope samples will be collected during borehole pump tests and end members determined in relation the river surface samples.

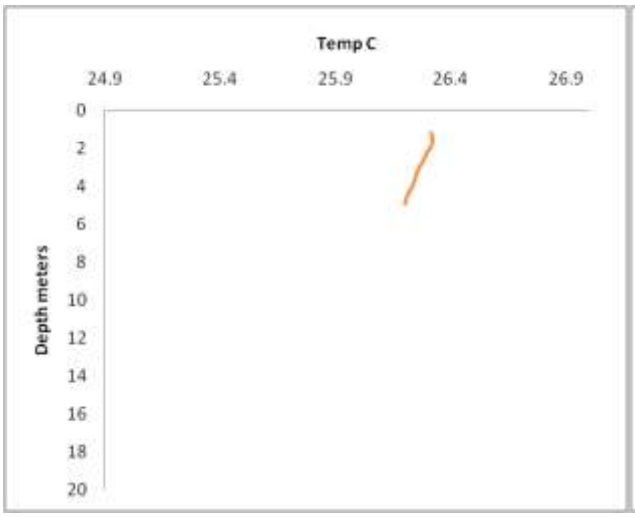
Appendix I Fluid Logging

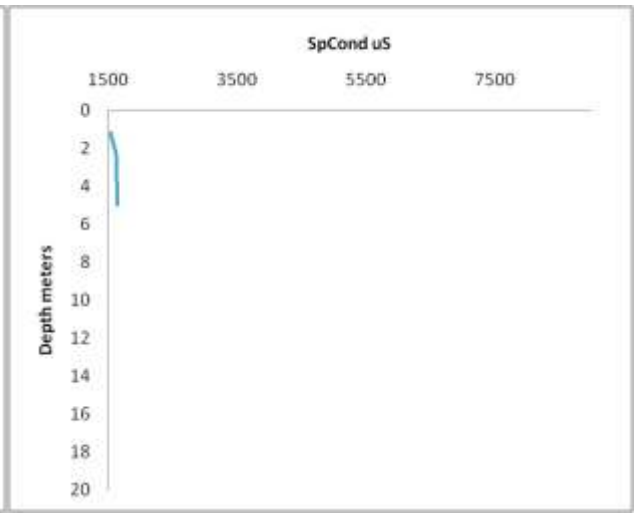
The following section highlights main observations during fluid logging of the drilled boreholes at the Letaba study site using a YSI 600 XLM multi-parameter probe (for locations see Figure 2-1).

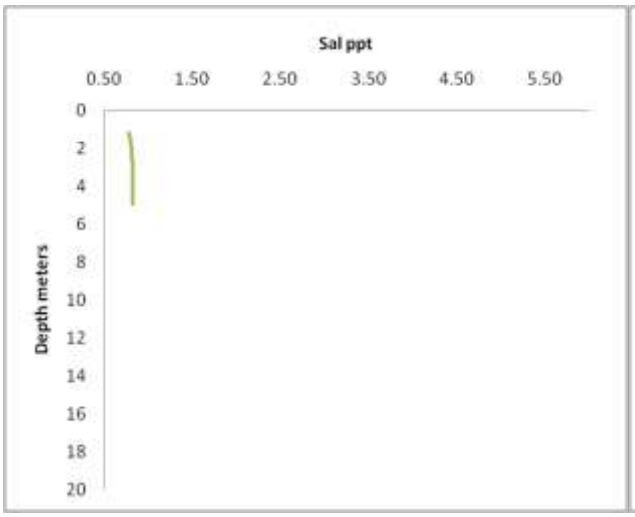
LF002A - The temperature here decreases with depth until it reaches 35m, where it starts to increase again. This is a result of the inflow of water through a possible fracture that decreases the temperature above and below the fracture, thus the closer the water in the borehole is to the fracture the colder the water will be. This phenomenon can be seen in most of the boreholes that where tested. The salinity and conductivity confirms the temperature phenomenon showing a sudden increase as soon as the fracture is passed at around 35m and also at 22m. Most of the boreholes show an increase in salinity and conductivity to the bottom of the borehole. This is due to the fact that the bottom contains lots of dissolved solids from debris falling from the sides of the borehole to the bottom. The possible fractures at 22m and 35m are also confirmed by the ORP (Oxidation-Reduction Potential) that indicates changes at these depths. The pH also indicates a quick rise in alkalinity as soon as it passes the 22m and 35m, indicative of inflow of increasingly alkaline ground water at those depths.

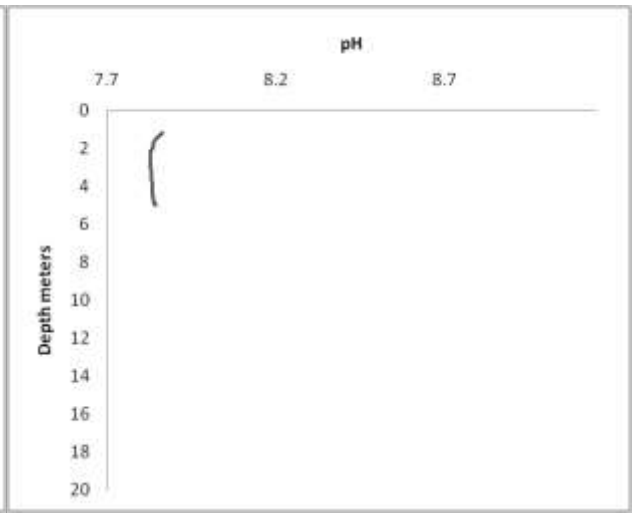

Temp C
24.90
25.40
25.90
26.40
26.90
Depth meters
0
10
20
30
40
50
60
SpCond uS
1500
3500
5500
7500
Depth meters
Sal ppt
0.50
1.50
2.50
3.50
4.50
5.50
Depth meters
pH
7.70
8.20
8.70
Depth meters
Orp mV
-400
-300
-200
-100
0
100
200
Depth meters

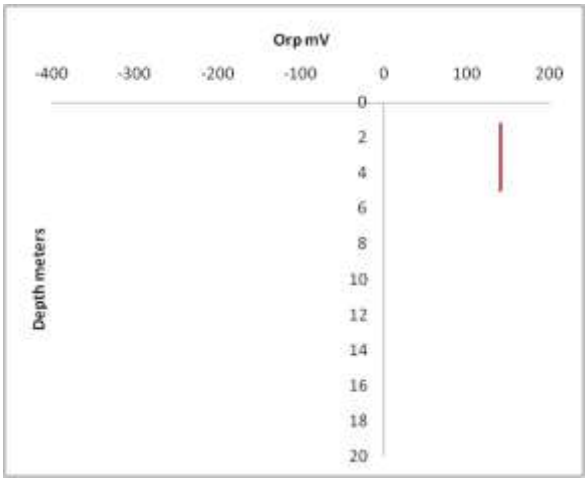
LF002B - The temperature shows the start of the decline to the fracture as seen in LF002A with both at 26.22 °C at 4.72m. The rest of the parameters do not display any obvious signs of fractures.



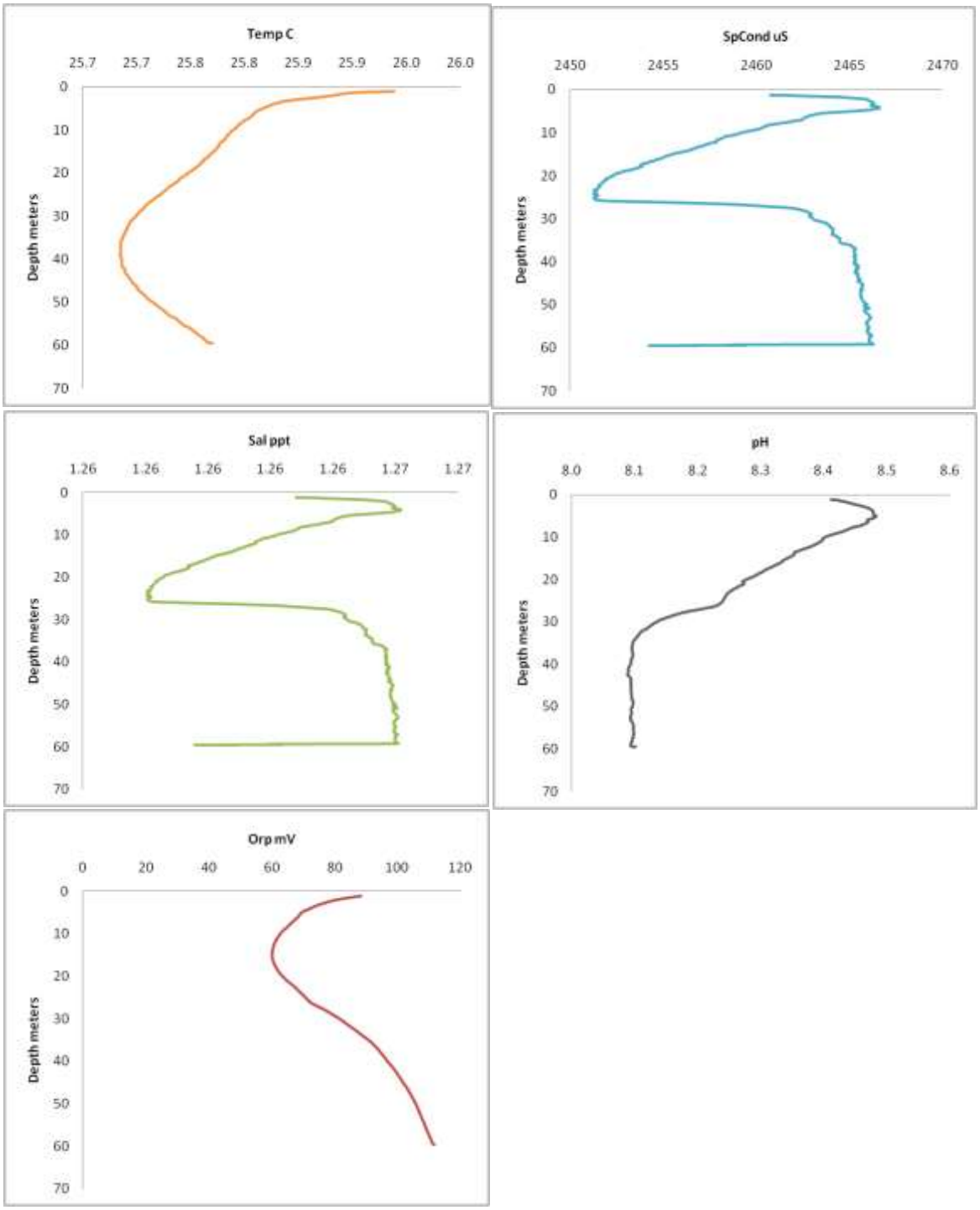




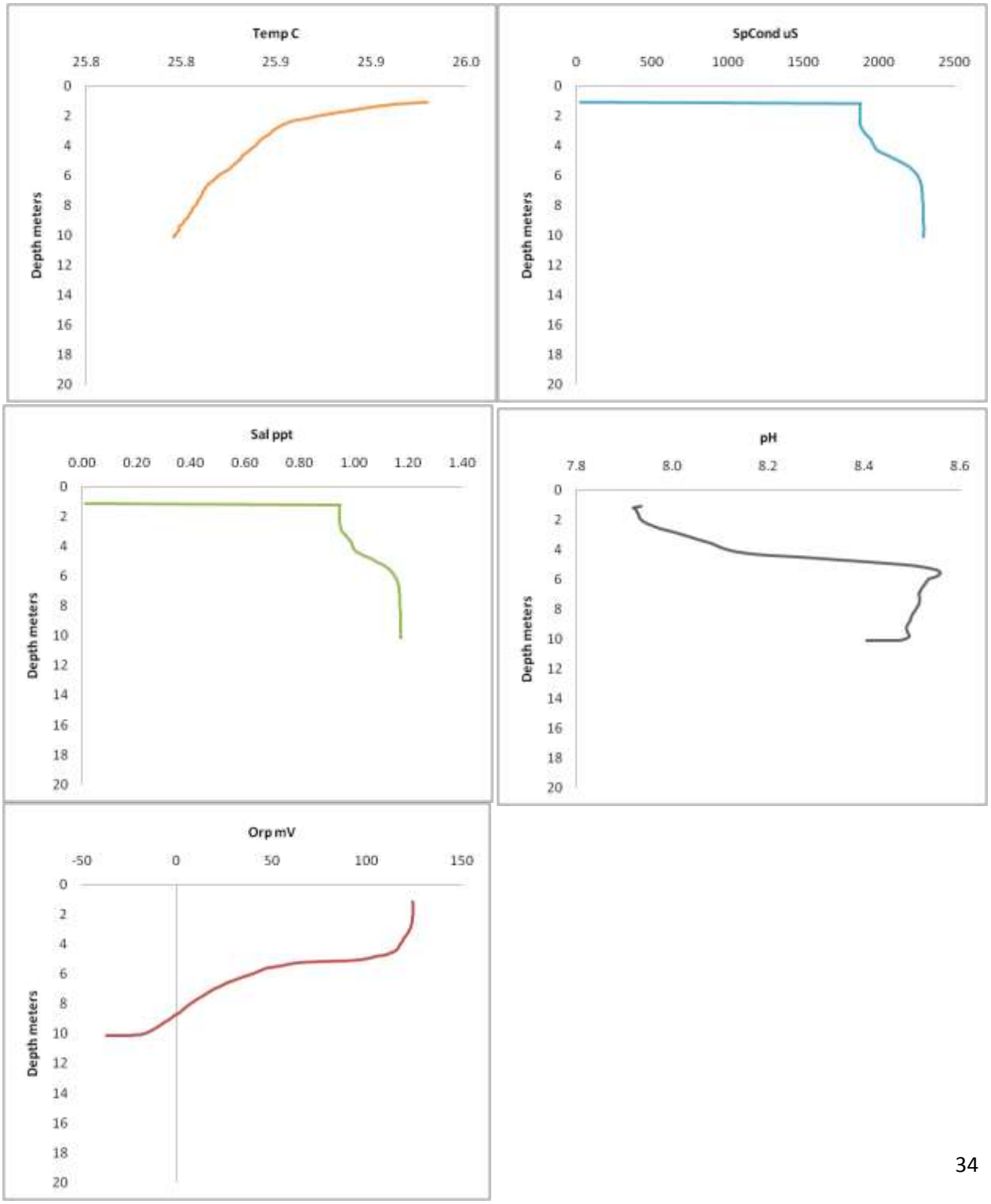




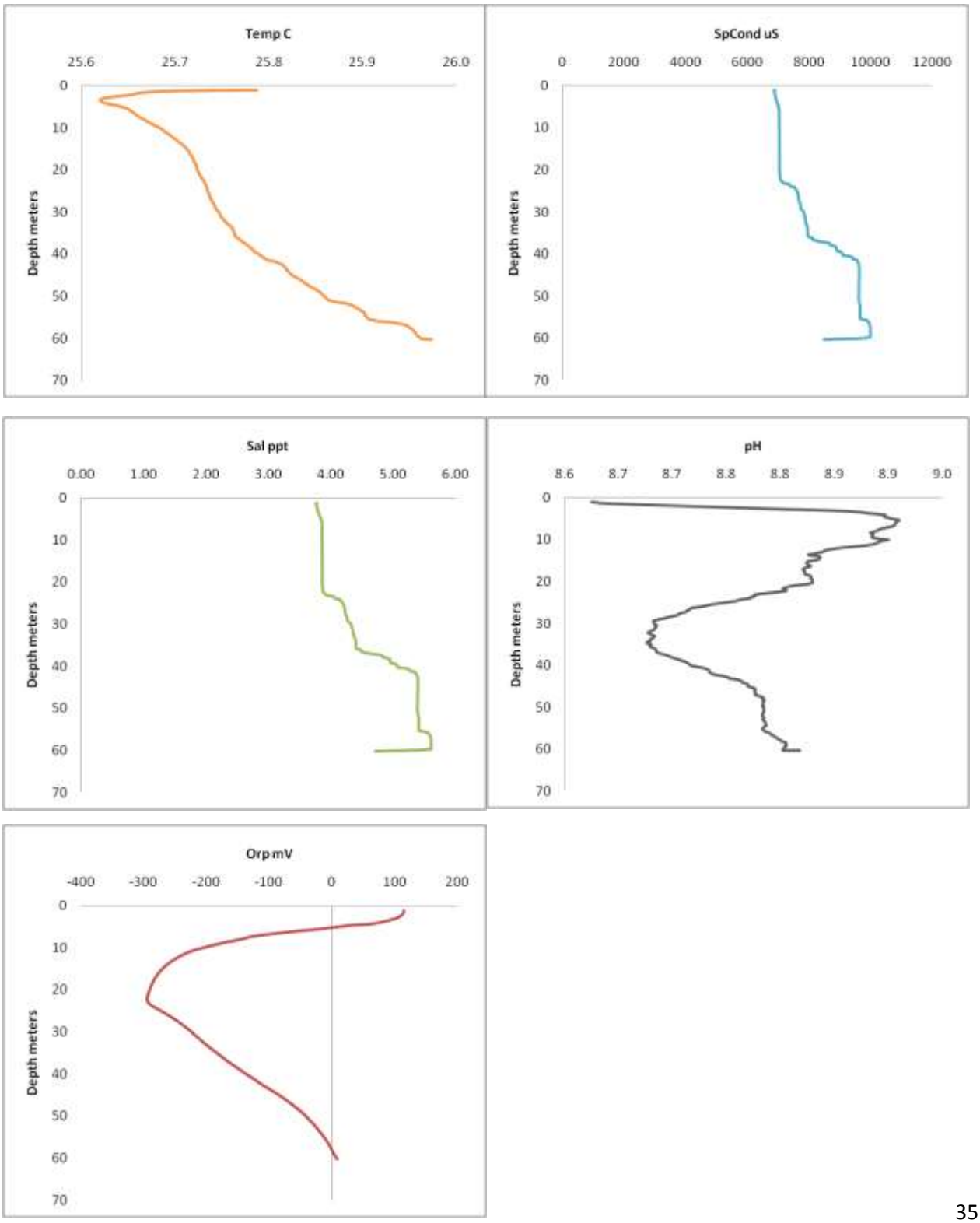
LF003A - The parameters at this location show two anomalies. The first is a rapid drop in temperature to about 5m after which there is a temperature decrease at a slower rate to the second anomaly located around 24m. The conductivity and salinity displays a similar trend with a quick increase to about 5m deep after which there is a sudden drop. This indicates the sudden inflow of groundwater through a fracture. This drop continues steadily to 21m where it stabilizes for 4m after which it drops quickly as it should to the bottom of the borehole that is high in dissolved solids. The stabilizing and quick drop of these parameters indicates a fracture at around 24m. The pH confirms the findings of the other parameters with a sudden decrease in pH at 5m after which it also continues to decrease to around 24m. From 24m to 32m it decreases slower and ultimately stabilizes. This decreasing of pH indicates the inflow of a slightly more acidic groundwater from the surrounding aquifer.



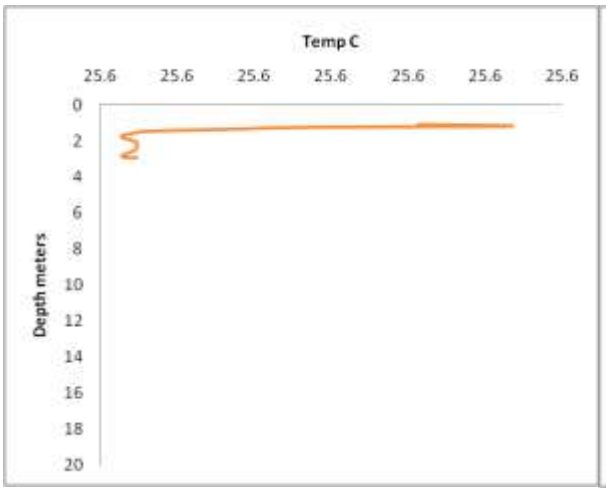
LF003B - The temperature decreases slowly with depth and shows a similar trend as LF003A, although the conductivity and salinity does not. The salinity and conductivity increases slowly until it stabilizes to the bottom of the borehole, showing no obvious fractures of inflow. The pH follows a similar trend and stabilizes to the bottom of the borehole suggesting high dissolved solids.

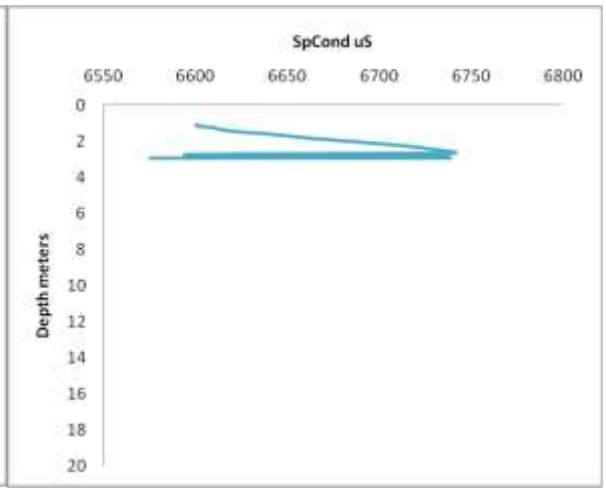


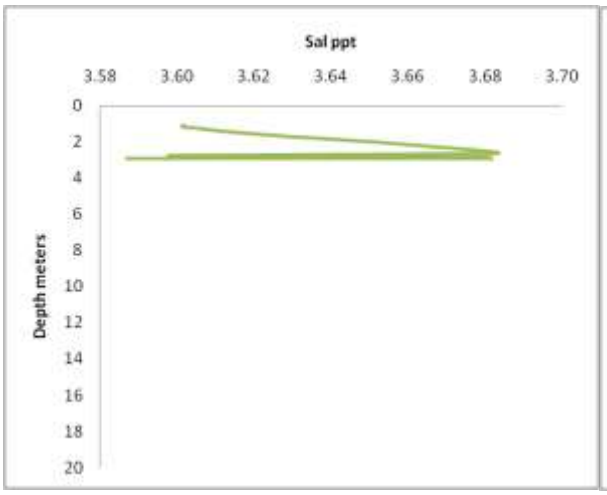
LF004A - The temperature does not follow the typical decrease and increase of the other boreholes. It only displays a steady decrease with no obvious anomalies. The conductivity and salinity in contrast show two anomalies with a sudden increase in these parameters at 20m and 33m respectively. The pH confirms this with a typical decrease at these two depths indicating at an inflow of a slightly more acidic groundwater.

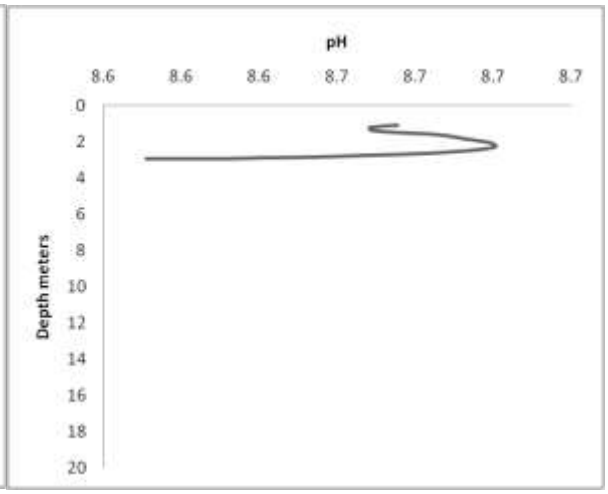


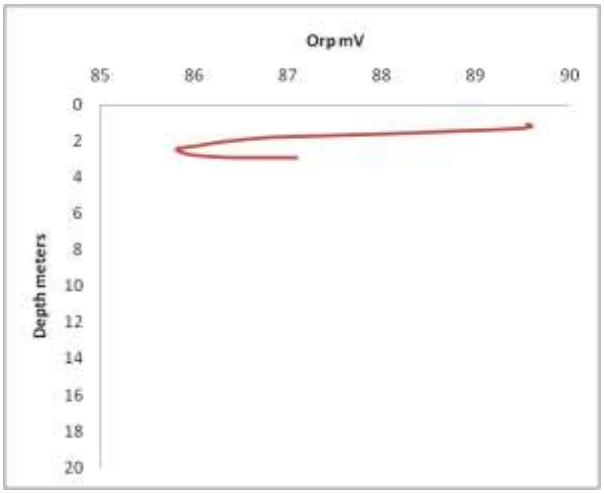
LF004B - All the parameters indicate an anomaly at 2.7m. The temperature indicates a small decrease almost at the bottom of the borehole. The conductivity and salinity also displays a sharp decreasing spike at 2.7m that is indicative of a groundwater inflow through a fracture. The pH and ORP confirms this with the pH indicating a sharp decrease from the inflow of a slightly more acidic groundwater.



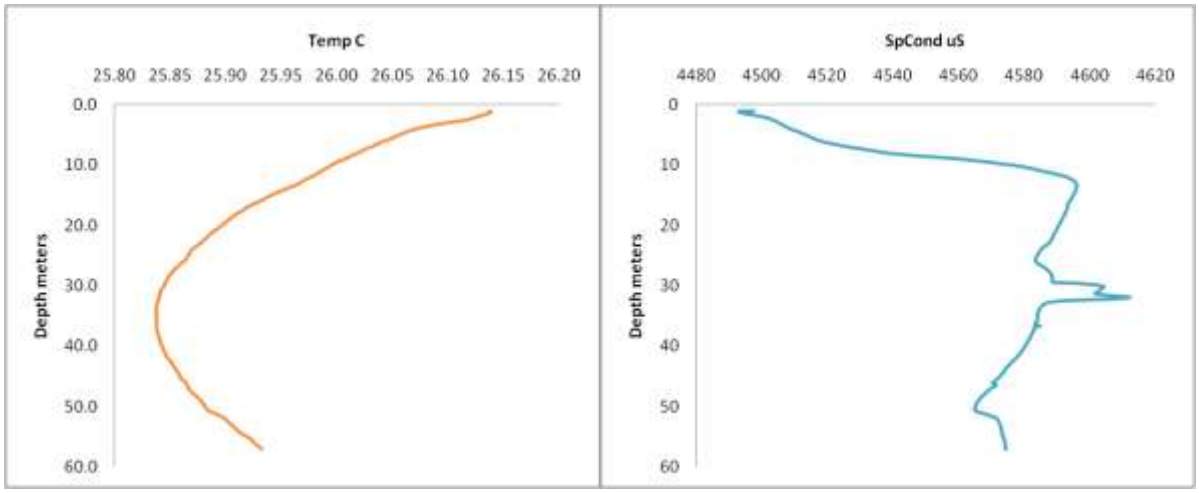


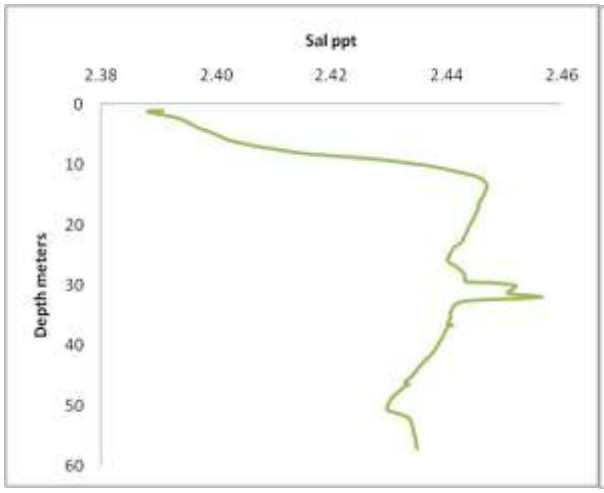


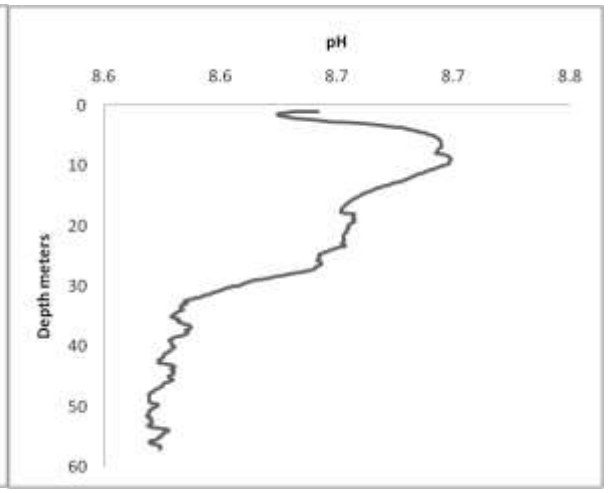


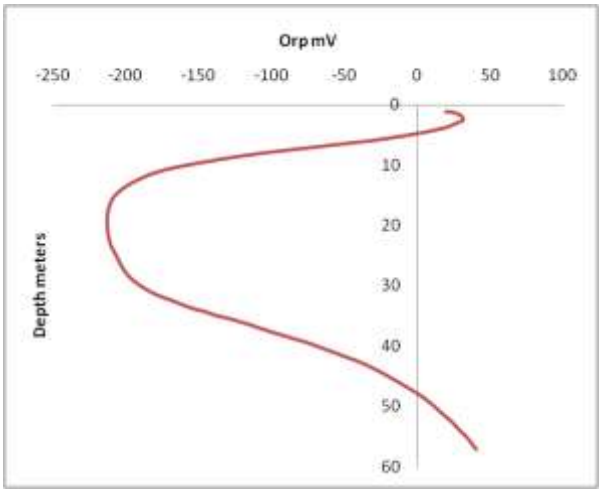


LF005A - The temperature show the typical decrease to the fracture or inflow with the subsequent increase at 32m. The conductivity and salinity shows a definitive fracture at 30m and 32m respectively where there is a positive spike in value that is indicative of the inflow of groundwater with high conductivity and salinity values. The pH confirms this with a steady decrease to 33m and stabilizing after the fractures.

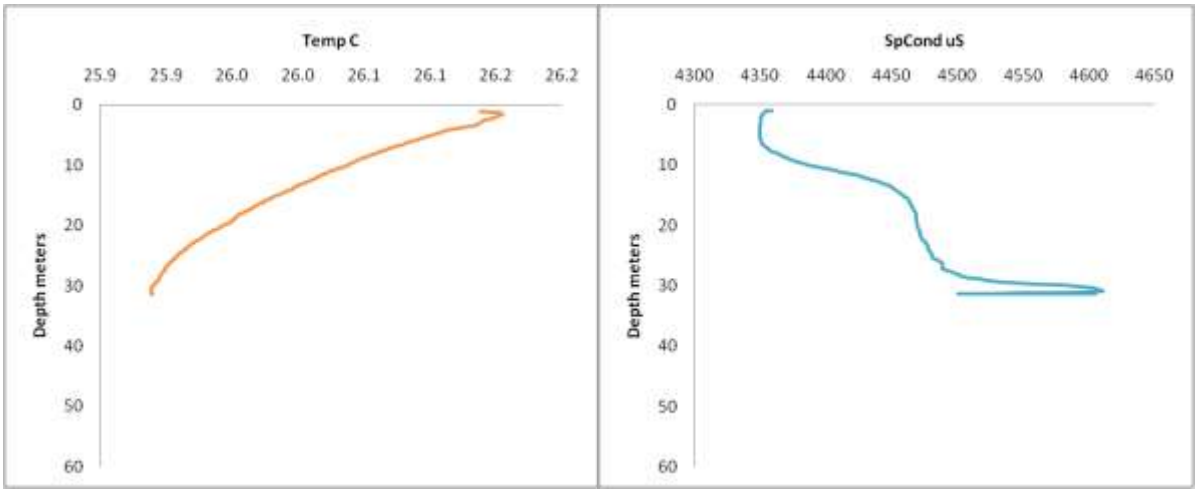


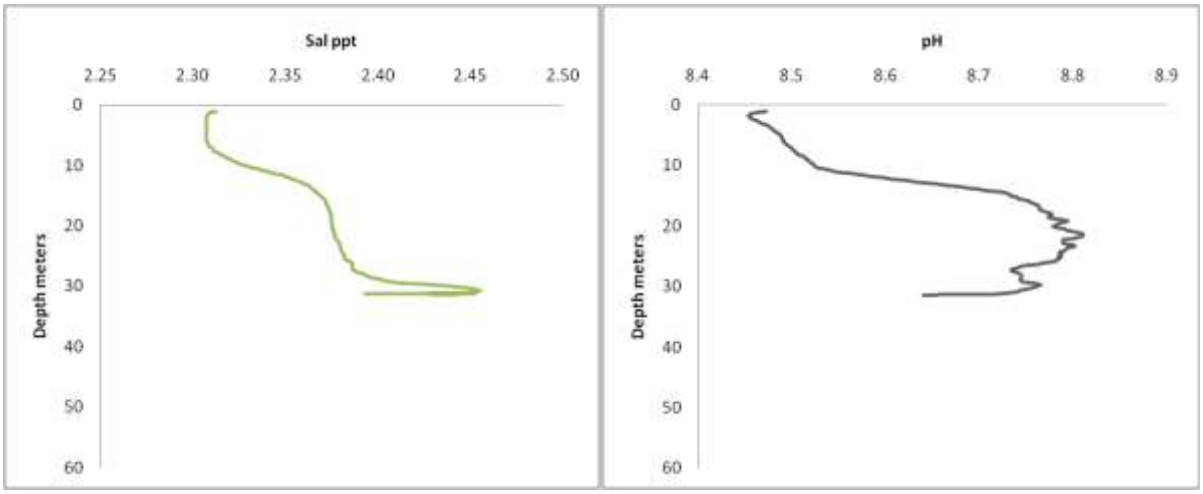


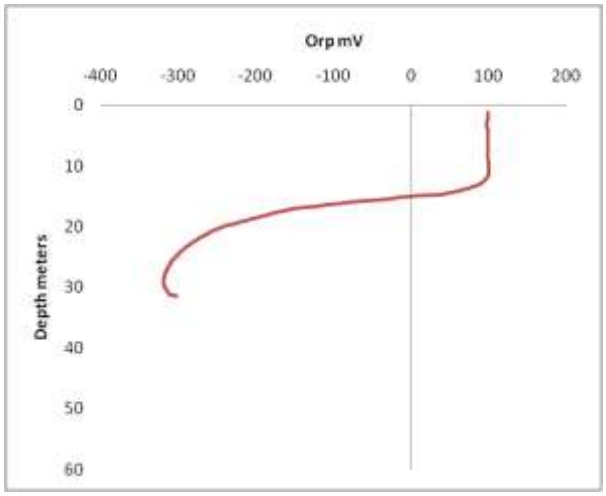




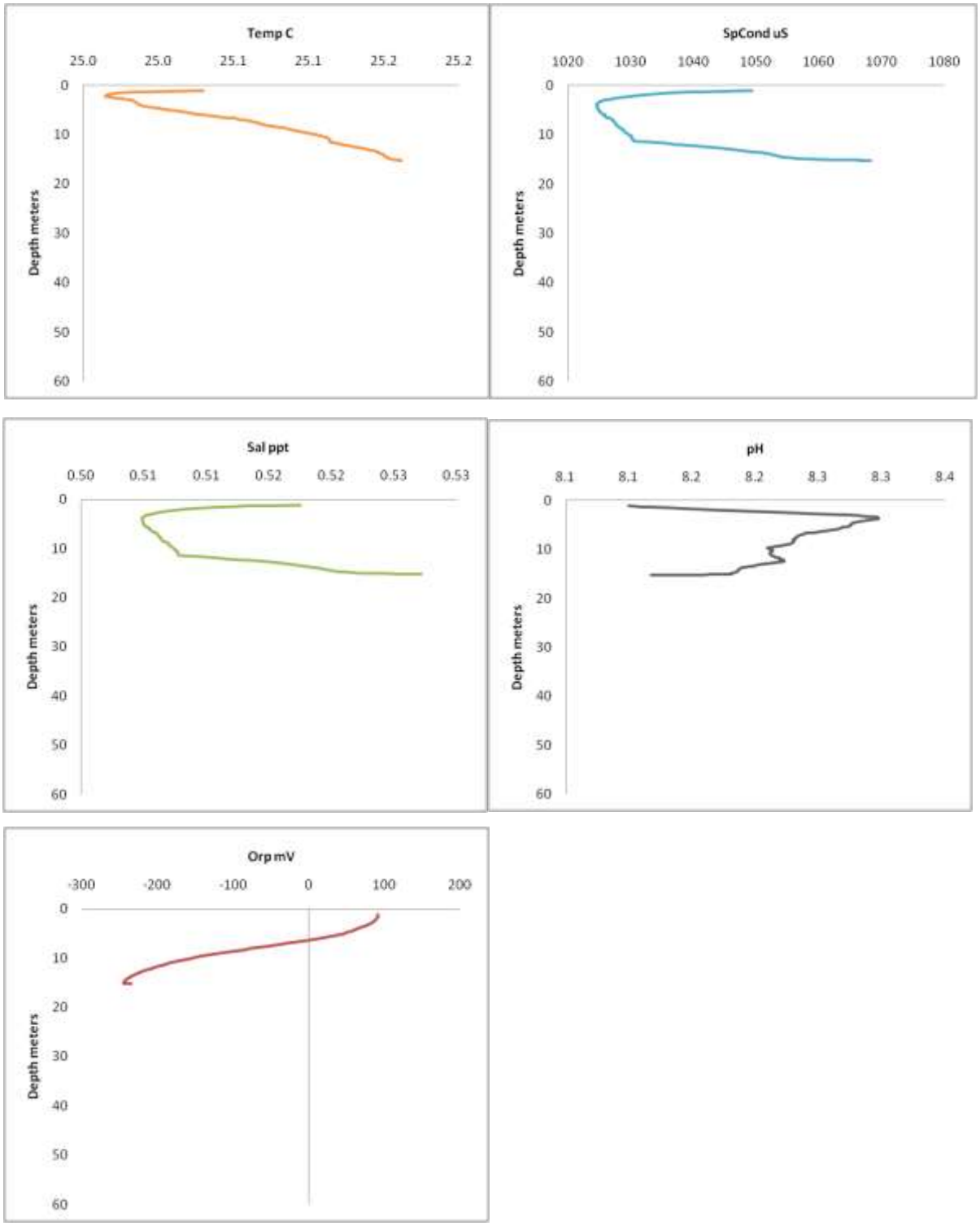
LF005B - The temperature shows a similar trend to the deeper borehole LF005A and decreases to 31m where the inflow of water is. The conductivity and salinity parameters show the exact same spike at 30m thus, they both intersect the same fracture at 30m containing a groundwater that's high in conductivity and salinity. Again the pH confirms this with a sudden decrease as the slightly more acidic groundwater enters through the fracture.



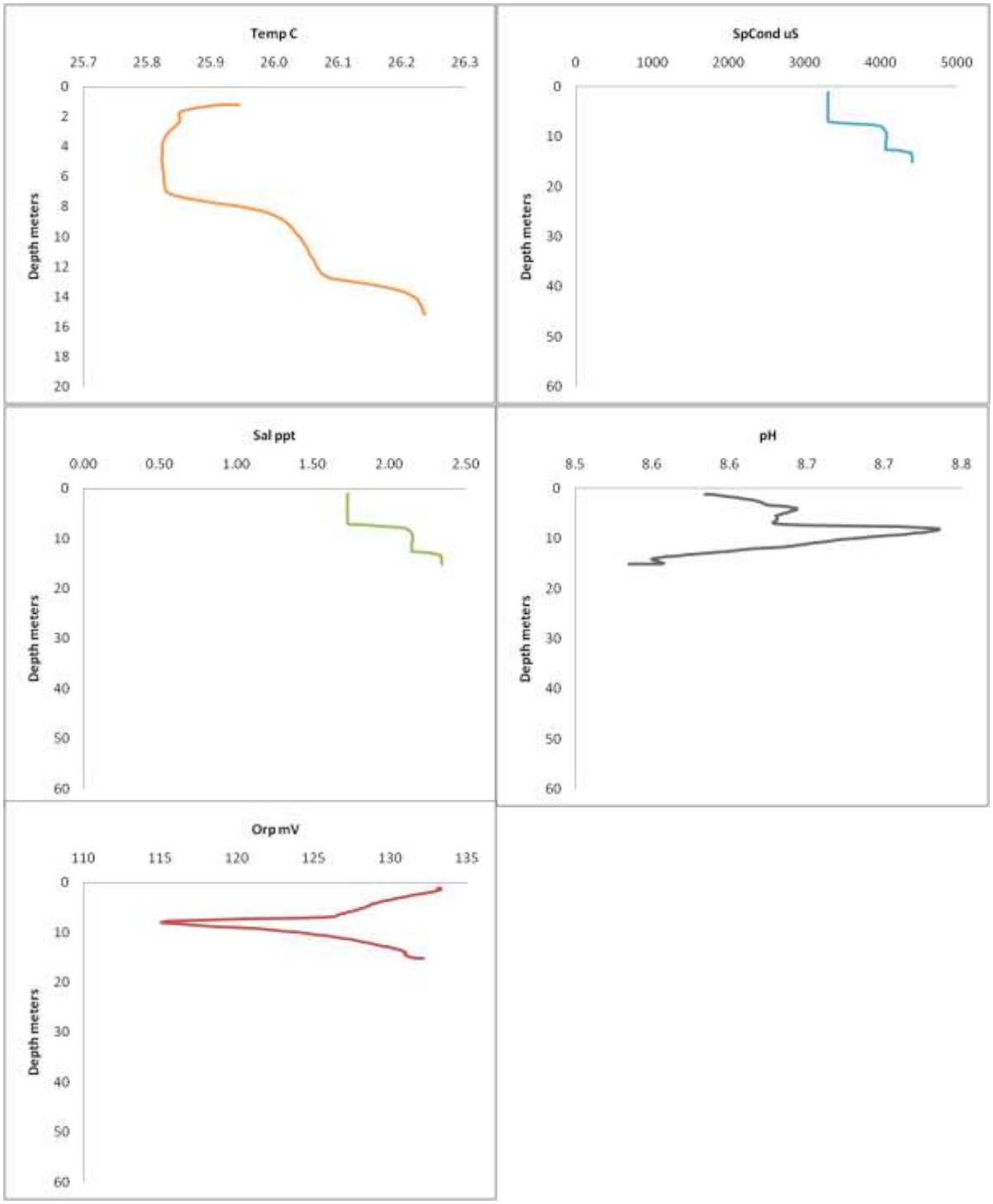




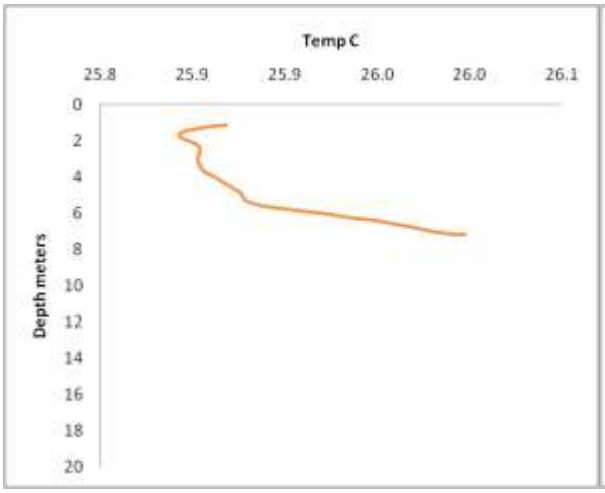
LF0021 - The temperature does not display the typical decrease and subsequent increase after a fracture that is seen in the other boreholes. Although the conductivity and salinity shows a sharp increase at 11.3m. However this can also be from the dissolved solids at the bottom of the borehole. The pH suggests otherwise displaying a decrease from around 11.3m indicating on the inflow of slightly acidic groundwater.

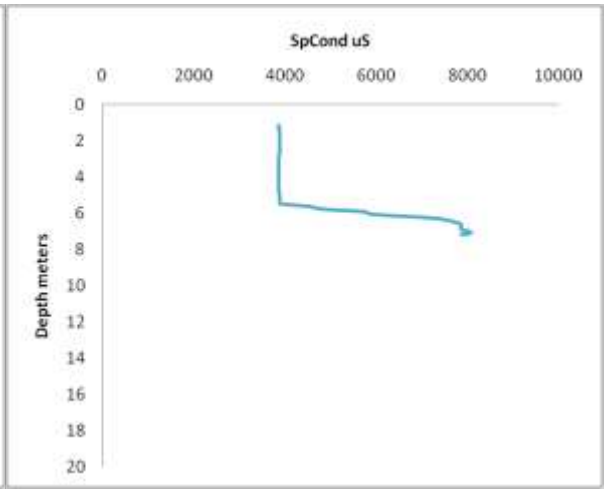


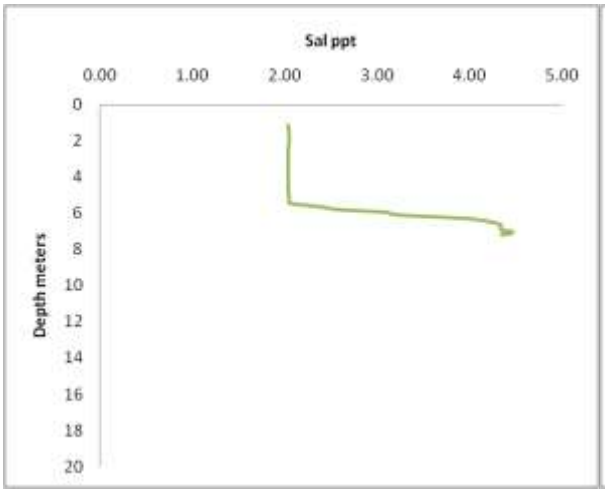
LF0031A - The temperature show the typical decreasing and subsequent increasing, although there are two definitive anomalies at 8.6m and 14m where the increase is slowed. The conductivity displays the same trend where the normal increase to the bottom of the borehole is temporarily stabilized before continuing the trend. The final confirmation is from the pH and Orp that displays a drop in pH at 8.6m and 14m respectively and an increase of the Orp values at the exact same depths. The result is two fractures at 8.6m and 14m respectively as show by the parameters.

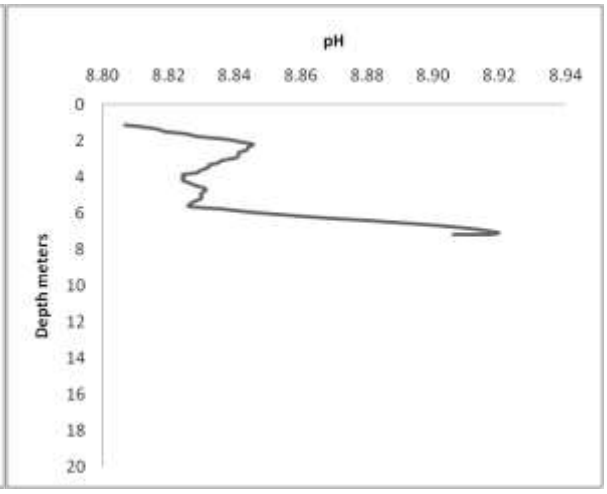


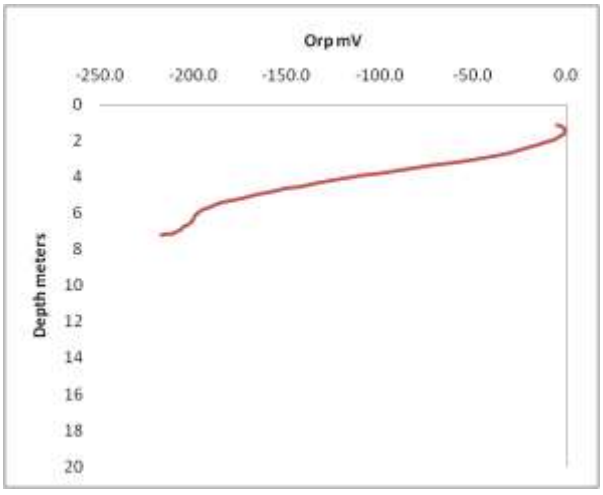
LF0031B - displays the same trend as the deeper borehole LF0031A but, it only intersects the first fracture and does so at an earlier depth of 7.2m indicating the angle of the fracture.



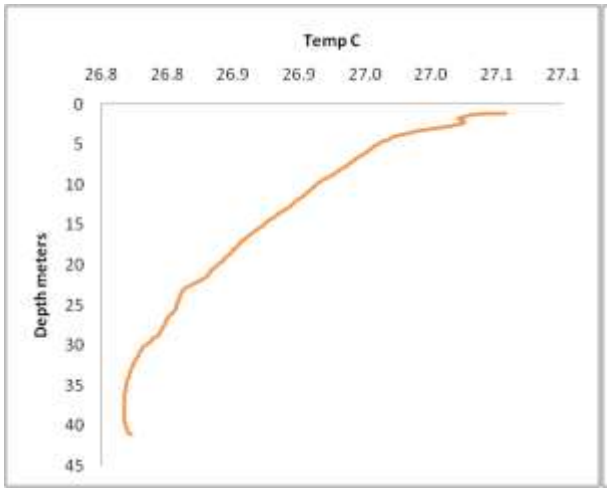


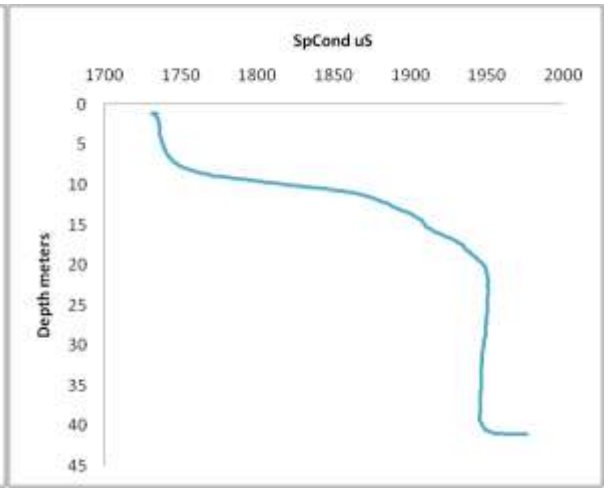


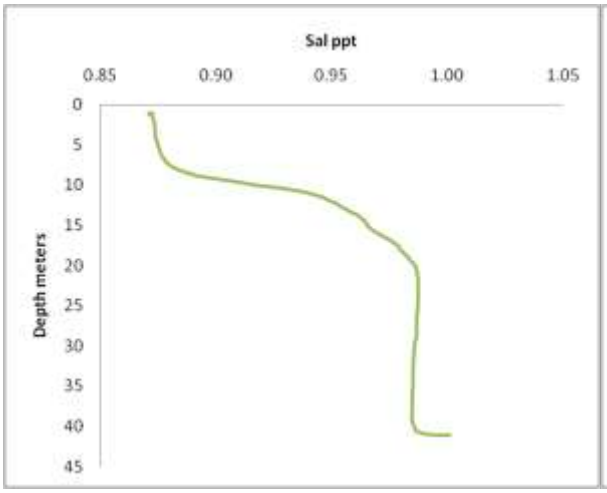


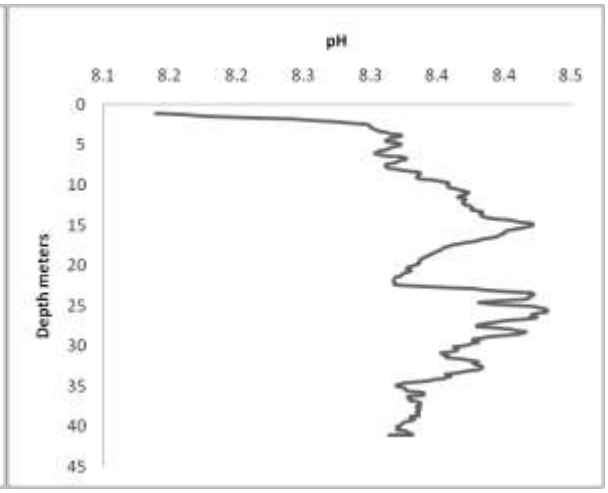


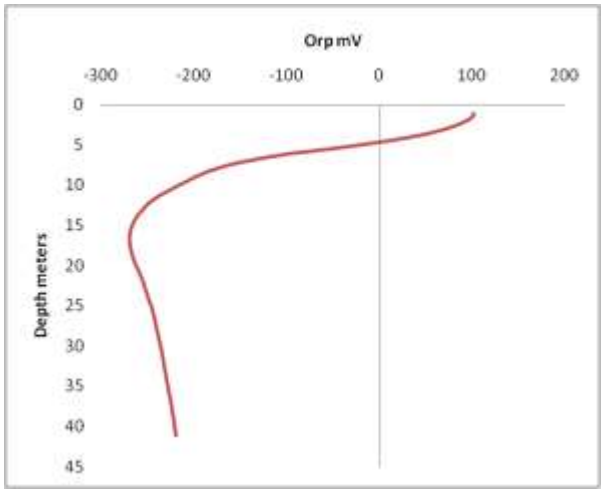
LF0051A - The temperatures show the typical decrease as seen in the other borehole with a small anomaly at 22m. The conductivity and salinity displays a steady increase with no anomalies and stabilizes after 22m. The pH decreases until it reaches 22m where there is a rapid increase again. This confirms the fracture at 22m with a slightly acidic inflow.



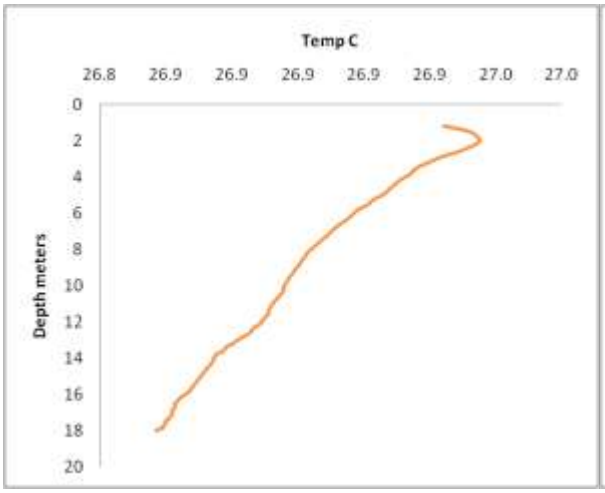


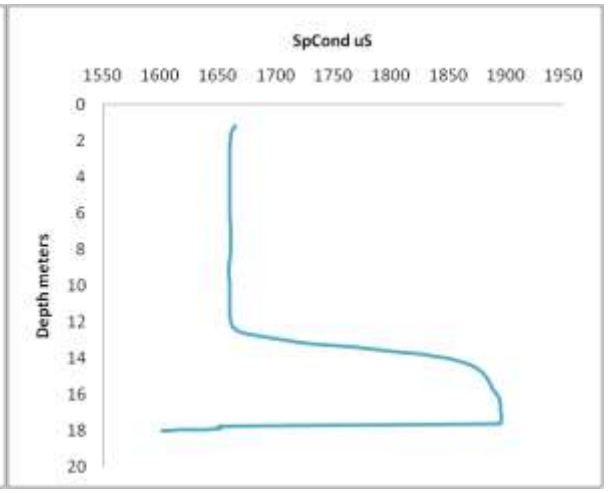


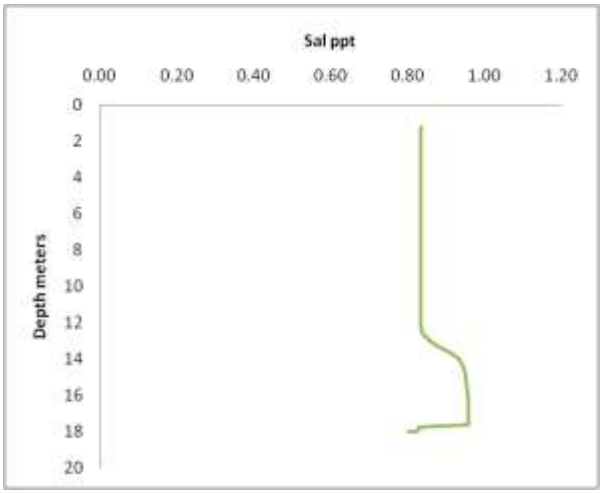


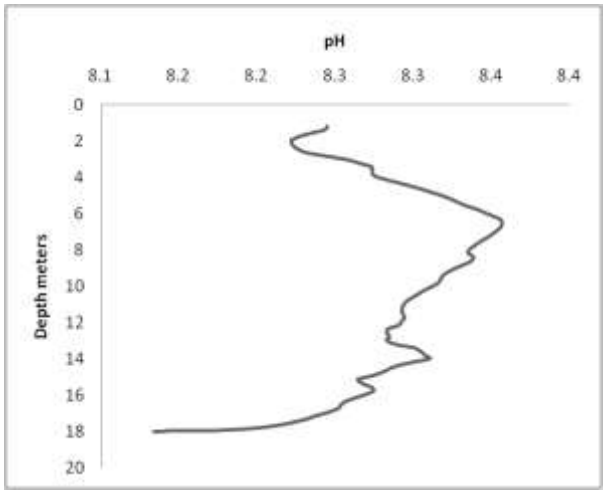


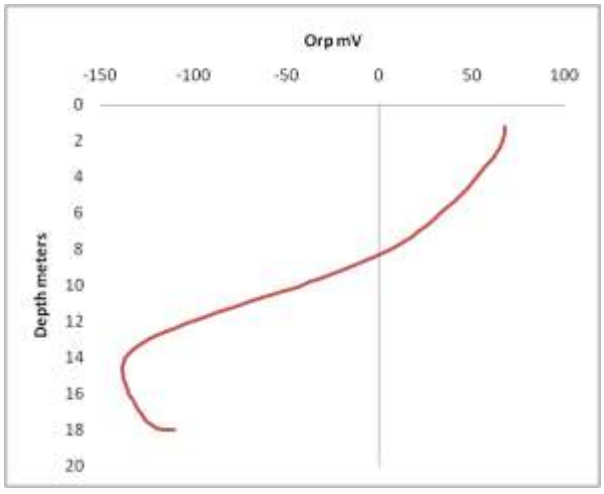
LF0051B - The temperature displays a similar pattern as LF0051A with a normal decreasing trend. The conductivity and salinity display a normal increase to 17.6m where there is a large drop in values indicating on a definitive fracture although, this fracture is not seen in the deeper borehole. The pH and ORP confirms this with a decrease and increase respectively.



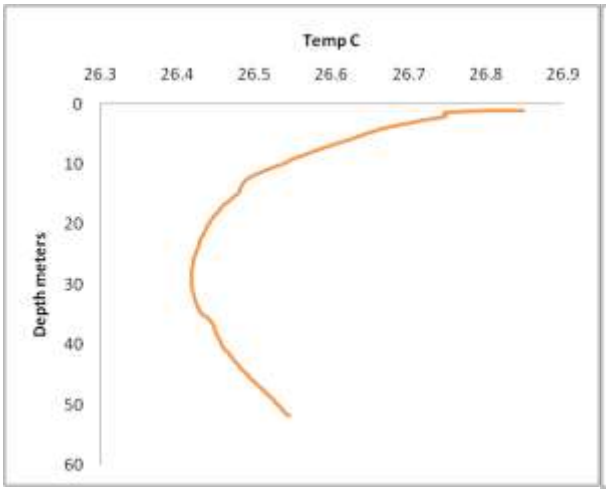


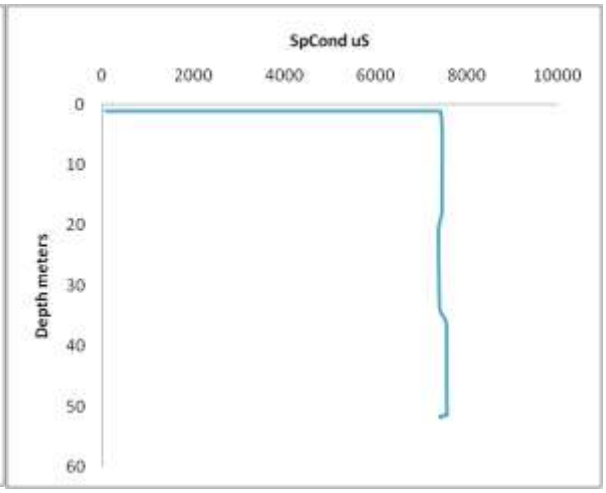


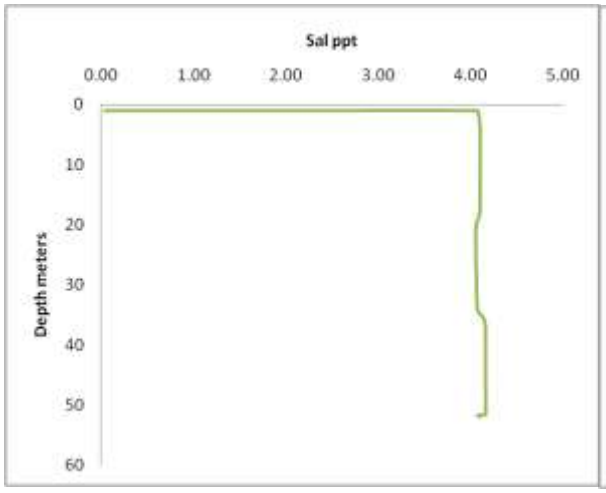


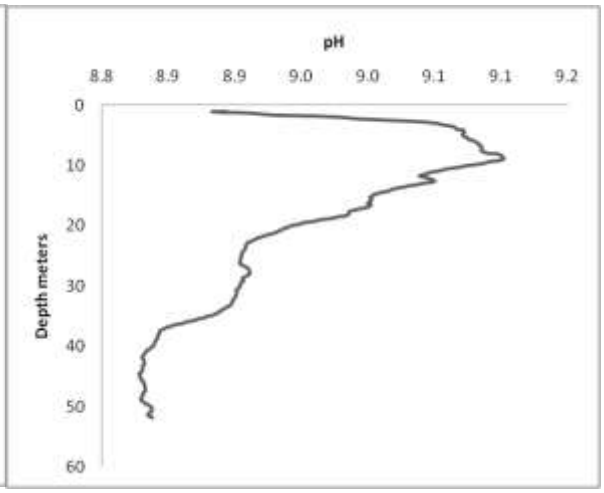


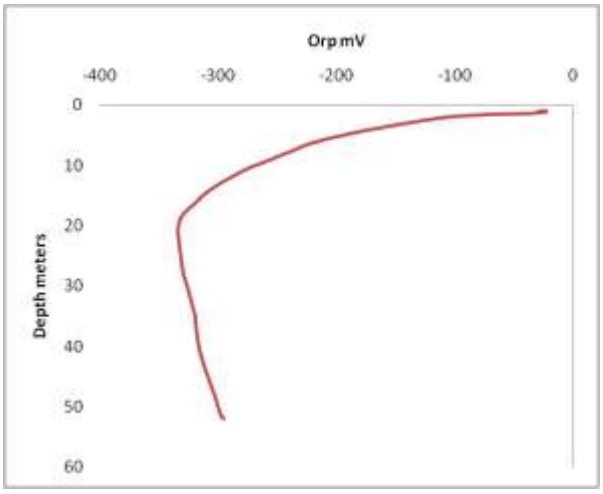
LR001A – This hole shows very little activity. There is however a two anomalies shown by the temperature at 12m and 35m respectively from the normal decreasing - increasing trend. The conductivity and salinity also show a very small decrease from 15m to 35m. The pH confirms the fractures at 12m and 35m with a sharp decrease indicating on the inflow of a slightly acidic groundwater.



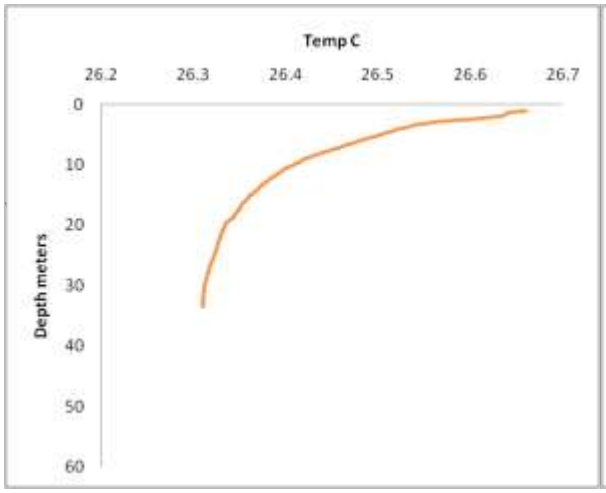


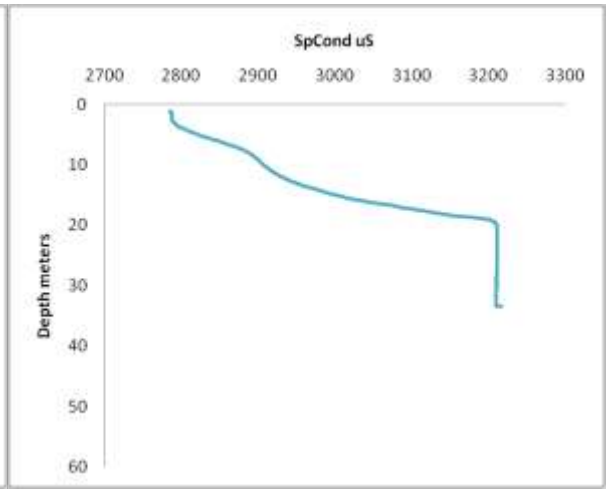


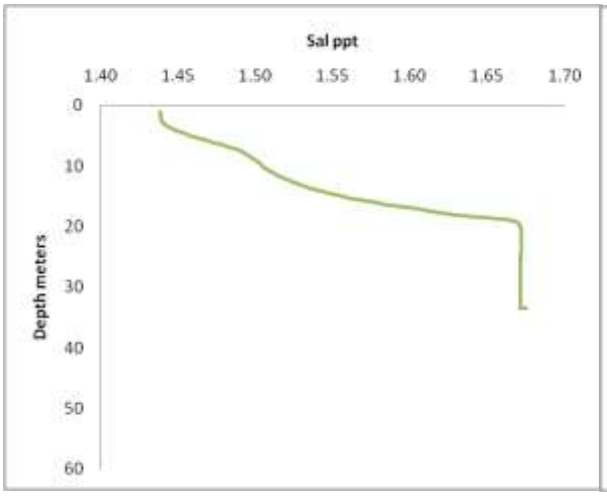


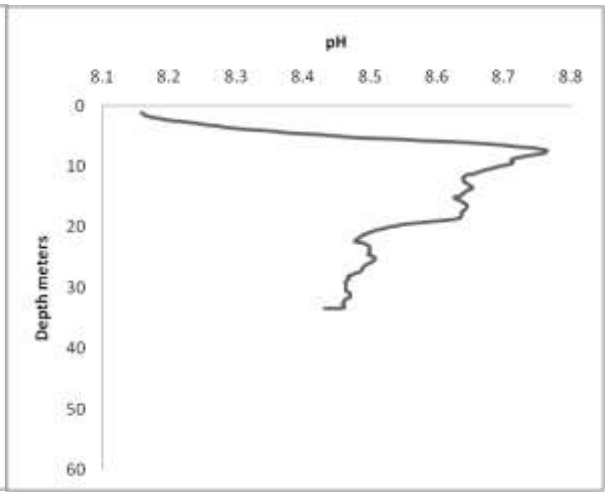


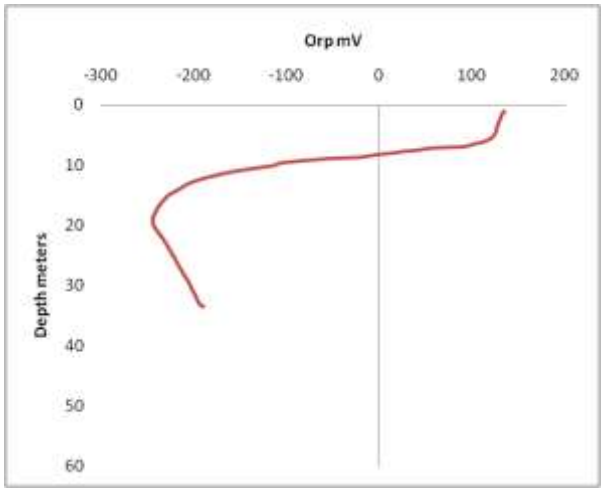
LR002A - The temperature follows the normal decreasing trend with no obvious anomalies. The conductivity and salinity also follows the normal trend until it reaches 20m and stabilizes. The pH and ORP show a possible small fracture at 20m with a decrease and increase respectively thus, confirming a small fracture at 20m.



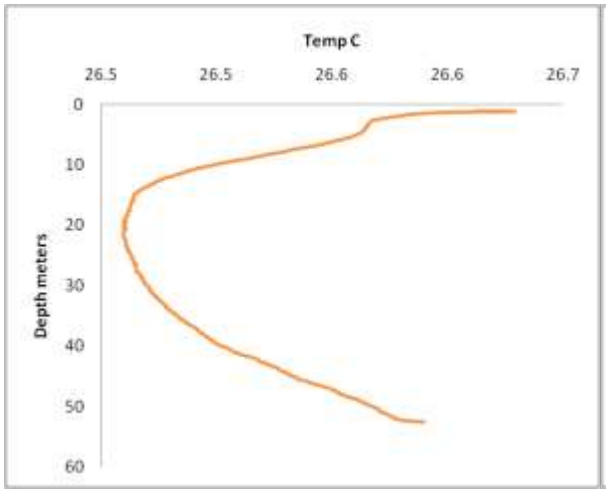


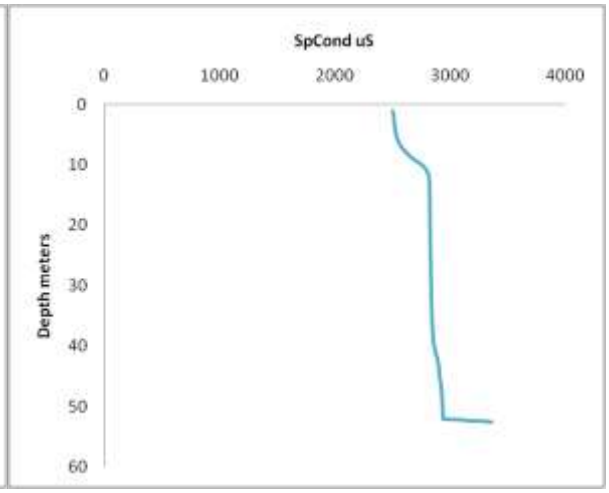


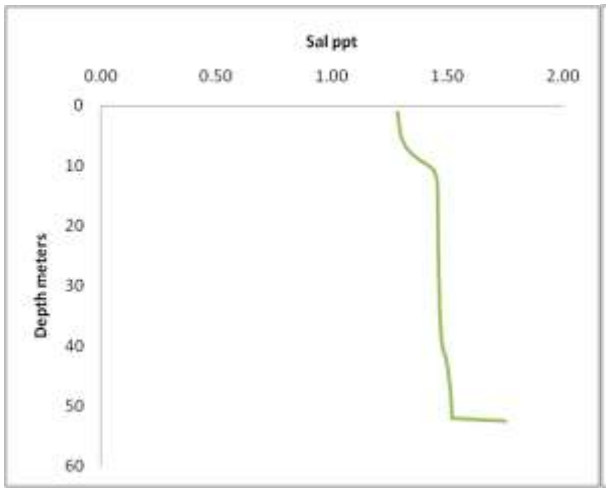


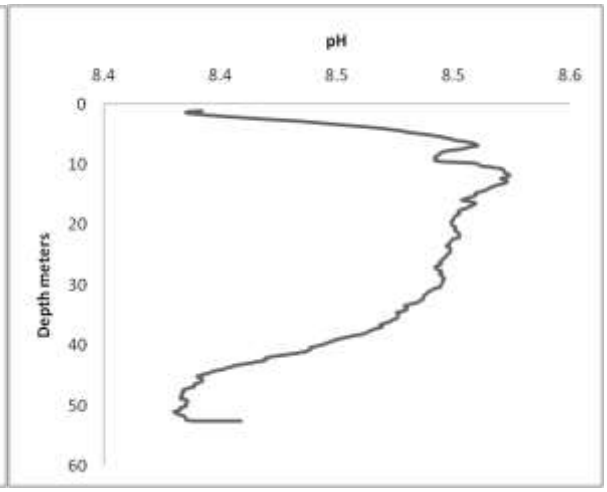


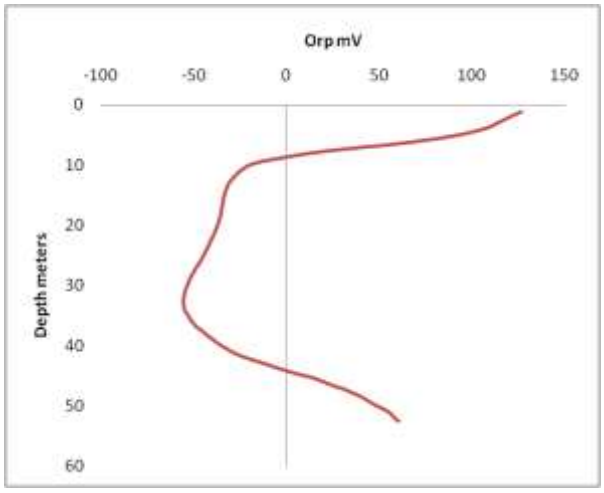
LR005A - The temperature shows the normal decrease - increase trend with most of the water flowing between 10m and 20m. The conductivity and salinity shows surprisingly very little changes. The pH on the other hand confirms a fracture at 10m with a decrease from the inflow of the slightly more acidic groundwater.



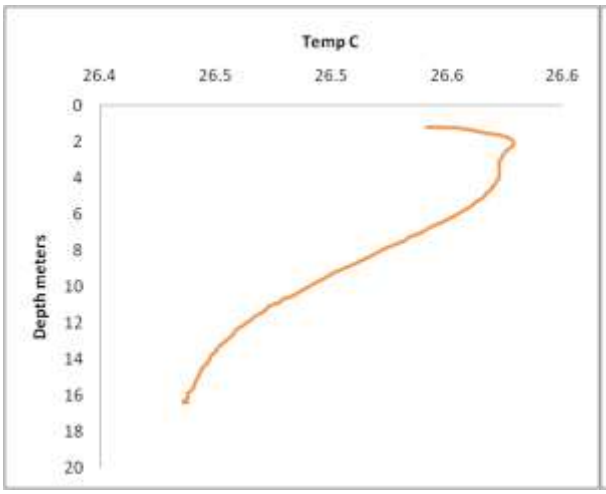


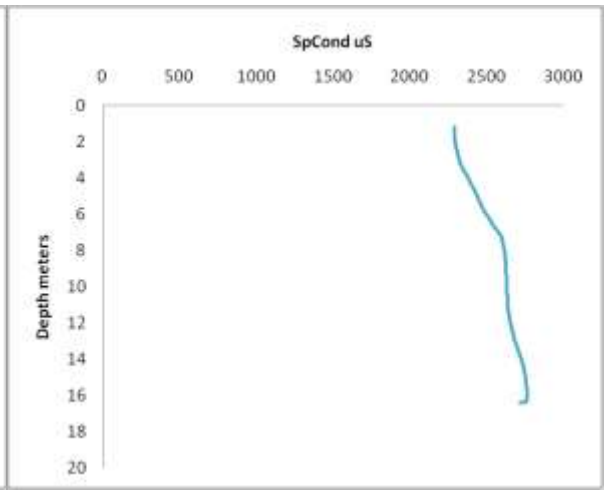


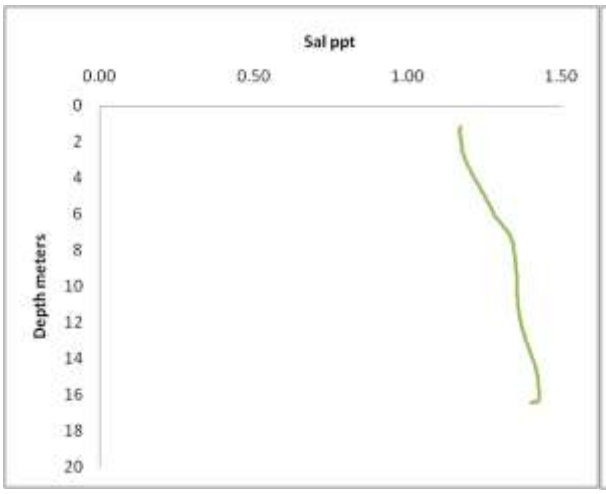


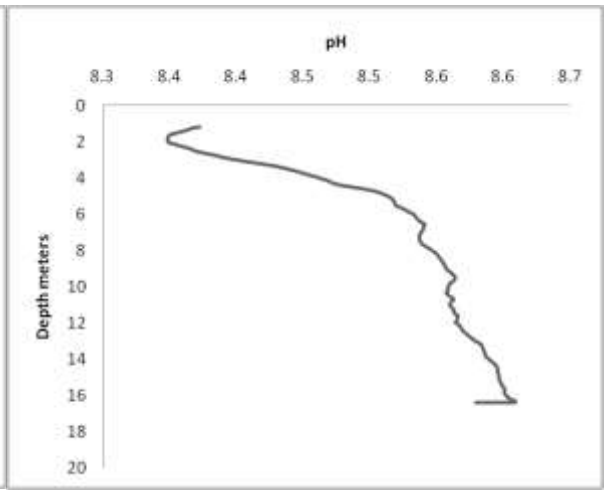


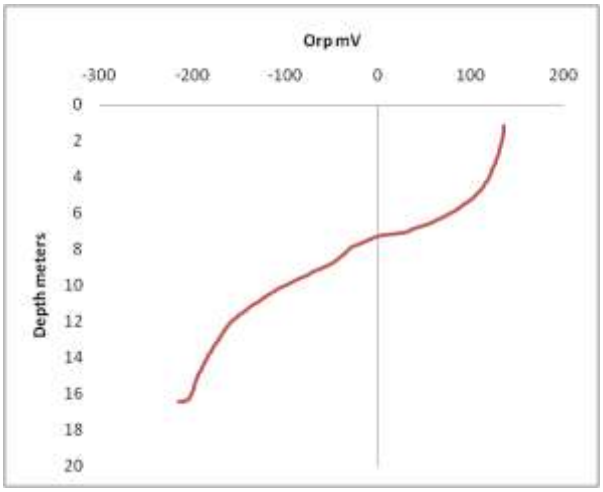
LR005B - this follows the decrease trend similar to LR005A but, the rest of the parameters display no obvious signs of a fracture.



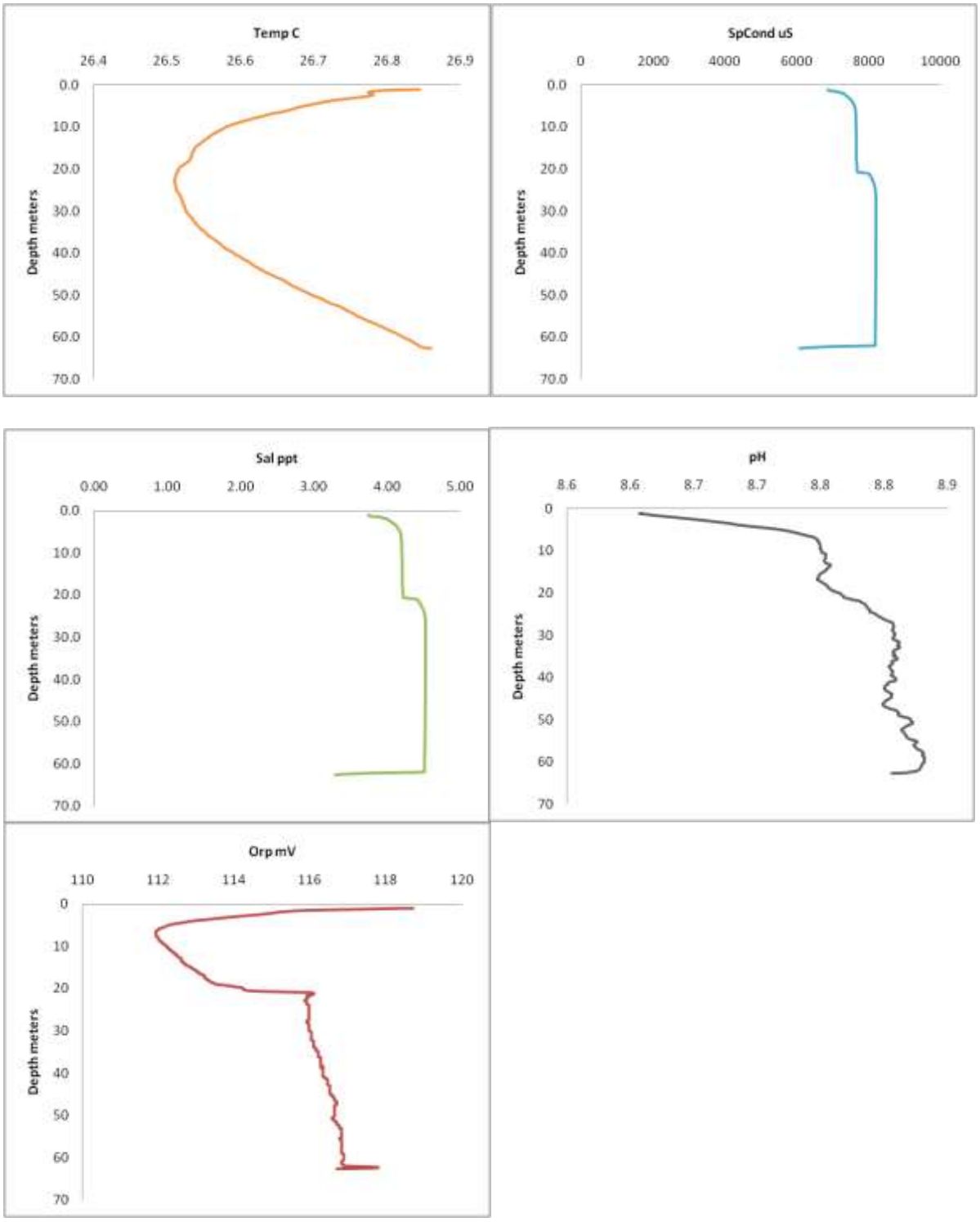




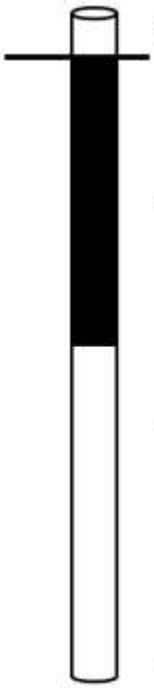




LR0011A - The temperature decreases to 20m and increase again to the bottom of the borehole thus, indicating a possible fracture at this point. None of the other parameters can confirm this although the ORP stabilizes 20m from the bottom of the borehole.



Appendix II Borehole Drilling Report



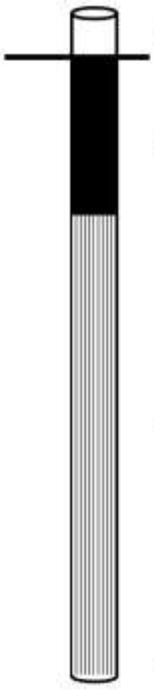
BOREHOLE NAME: LF005A

Date Completed:	04/06/2015
Date Corrected:	21/07/2015
GPS Co-ordinates:	S 23.671245070° E 31.017841574°
Site:	Bongele's Farm
Borehole Depth:	72m
Water Strike:	32m
Estimated Yield:	0.5 l/s (measured)

Date	Observed Water Levels (m)
11/06/2015	12.33
15/06/2015	12.33
10/07/2015	12.34
15/07/2015	12.35

Date	EC	Temp
15/07/2015	2800 uS/cm	26.1 °C

NOTES: Initial solid casing depth was too shallow, thus was re-cased to 30m (21/07/2015). Found iron-stained calcrete (chalk) at 12-18m during the casing repair.



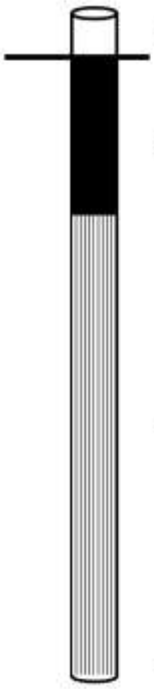
BOREHOLE NAME: LF005B

Date Completed:	09/06/2015
GPS Co-ordinates:	S 23.671308501° E 31.017884338 °
Site:	Bongele's Farm
Borehole Depth:	42m
Water Strike:	13m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
11/06/2015	18.34 (recovering)
15/06/2015	12.15
10/07/2015	12.12
21/07/2015	12.21(repair to nearby borehole)

Date	EC	Temp
10/07/2015	2963 uS/cm	26.1 °C
21/07/2015	3354 uS/cm	26.2 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 18m borehole was drilled alongside LF005A and LF005B (21/07/2015).



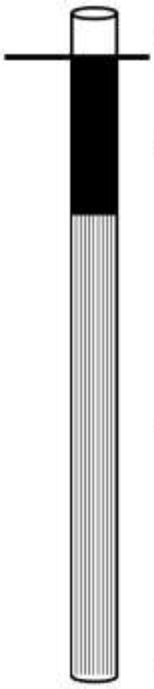
BOREHOLE NAME: LF005C

Date Completed:	14/07/2015
GPS Co-ordinates:	S 23.671222963° E 31.017831282°
Site:	Bongele's Farm
Borehole Depth:	18 m
Water Strike:	13m
Estimated Yield:	0.5 l/s

Date	Observed Water Levels (m)
21/07/2015	11.3 (recovering)
31/08/2015	11.41
11/09/2015	12.7
17/09/2015	12.75

Date	EC	Temp
21/07/2015	3074uS/cm	24.90 °C
31/08/2015	2219uS/cm	25.10 °C

NOTES: This borehole is drilled within the unconsolidated material.



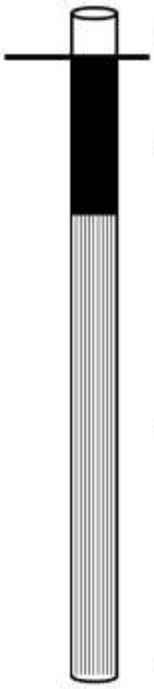
BOREHOLE NAME: LF002A

Date Completed:	10/8/2015
GPS Co-ordinates:	S 23.674299259 E 31.005508751
Site:	Mabunda/Baloi
Borehole Depth:	60m
Water Strike:	11m
Estimated Yield:	1l/s

Date	Observed Water Levels (m)
22/10/2015	11.51(recovering)
09/11/2015	11.61
16/11/2015	11.62
23/11/2015	11.63

Date	EC	Temp
22/10/2015	862 uS/cm 26.1 °C	27.20 °C
09/11/2015	1143 uS/cm	27.00 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 15m borehole was drilled alongside LF005A and LF005B (10/09/2015).



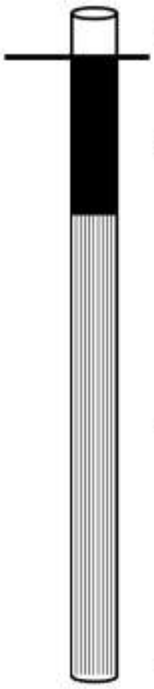
BOREHOLE NAME: LF002B

Date Completed:	10/9/2015
GPS Co-ordinates:	S 23.674297937 ° E 31.005498881 °
Site:	Mabunda/Baloi
Borehole Depth:	15m
Water Strike:	11m
Estimated Yield:	0.4 l/s

Date	Observed Water Levels (m)
16/11/2015	11.78
23/11/2015	11.77
30/11/2015	11.77
07/12/2015	11.75

Date	EC	Temp
16/11/2015	864uS/cm	26.9 °C
21/07/2015	820 uS/cm	26.2 °C

NOTES: This borehole was first drilled to a depth of 10m and contained no water. It was then redrilled to 15m to obtain the groundwater table on 10/11/2015.



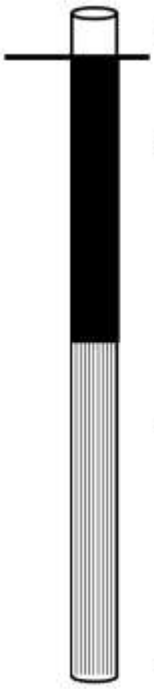
BOREHOLE NAME: LF0021

Date Completed:	11/1/2015
GPS Co-ordinates:	S 23.674764519 ° E 31.004662622 °
Site:	Mabunda/Baloi in river
Borehole Depth:	24m
Water Strike:	9m
Estimated Yield:	0.2 l/s

Date	Observed Water Levels (m)
22/10/2015	11.51 (recovering)
02/11/2015	8.26
09/11/2015	8.28
16/11/2015	8.29

Date	EC	Temp
22/10/2015	862uS/cm	27.2 °C
02/11/2015	783uS/cm	25.6°C

NOTES: This borehole was drilled 20 from the river bedrock within the unconsolidated material.



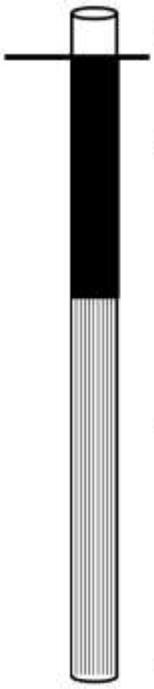
BOREHOLE NAME: LF003A

Date Completed:	09/06/2015
GPS Co-ordinates:	S 23.669515034 ° E 31.016633354 °
Site:	Maliesa's Farm
Borehole Depth:	72m
Water Strike:	15m
Estimated Yield:	0.3 l/s

Date	Observed Water Levels (m)
11/06/2015	11.1(recovering)
6/15/2015	11.09
7/10/2015	10.71
21/07/2015	10.95

Date	EC	Temp
21/07/2015	1740uS/cm	26.1 °C
31/08/2015	1476 uS/cm	26 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 20m borehole was drilled alongside LF003A (01/06/2015).



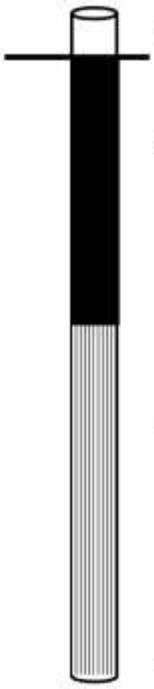
BOREHOLE NAME: LF003B

Date Completed:	01/06/2015
GPS Co-ordinates:	S 23.669519698 ° E 31.016568496 °
Site:	Maliesa's Farm
Borehole Depth:	20m
Water Strike:	12m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
01/06/2015	10.76 (recovering)
11/06/2015	10.91
6/15/2015	10.9
7/10/2015	11

Date	EC	Temp
7/10/2015	1614 uS/cm	26 °C
21/07/2015	1446 uS/cm	26.2 °C

NOTES: This borehole is drilled within the unconsolidated material.



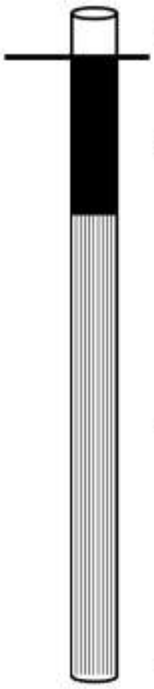
BOREHOLE NAME: LF0031A

Date Completed:	25/05/2015
GPS Co-ordinates:	S 23.667002914 ° E 31.016215720 °
Site:	Maliesa's Farm
Borehole Depth:	60m
Water Strike:	21m
Estimated Yield:	3l/s

Date	Observed Water Levels (m)
25/05/2015	12.95(recovering)
11/06/2015	13.22
6/15/2015	13.18
7/10/2015	13.23

Date	EC	Temp
11/6/2015	1518 uS/cm	26.1 °C
7/10/2015	1589 uS/cm	26.0°C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 20m borehole was drilled alongside LF0031A (26/06/2015).



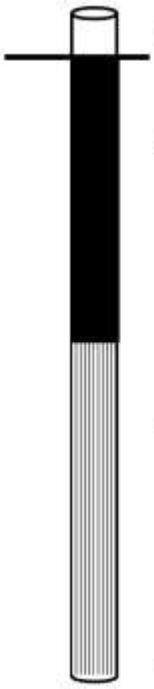
BOREHOLE NAME: LF0031B

Date Completed:	26/06/2015
GPS Co-ordinates:	S 23.667069700 ° E 31.016260718 °
Site:	Maliesa's Farm
Borehole Depth:	20m
Water Strike:	19m
Estimated Yield:	1 l/s

Date	Observed Water Levels (m)
27/06/2015	12.68 (recovering)
10/07/2015	12.94
21/07/2015	12.68
31/08/2015	12.68

Date	EC	Temp
7/10/2015	2897 uS/cm	26.1 °C
21/07/2015	2535 uS/cm	26.21°C

NOTES: This borehole is drilled within the unconsolidated material.



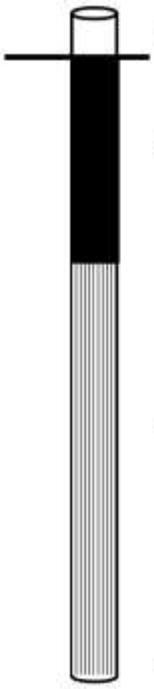
BOREHOLE NAME: LF004A

Date Completed:	22/10/2015
GPS Co-ordinates:	S 23.677412130 ° E 31.005063317 °
Site:	Abram's Farm
Borehole Depth:	72m
Water Strike:	25m
Estimated Yield:	0.5l/s

Date	Observed Water Levels (m)
26/10/2015	13.385 (recovering)
03/11/2015	13.4
09/11/2015	13.28
16/11/2015	13.38

Date	EC	Temp
26/10/2015	3413 uS/cm	26.1 °C
16/11/2015	2833 uS/cm	26.2 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 18m borehole was drilled alongside LF004A (23/10/2015).



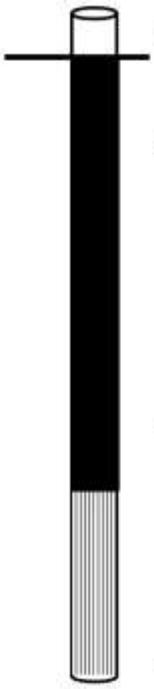
BOREHOLE NAME: LF004B

Date Completed:	23/10/2015
GPS Co-ordinates:	S 23.677413088 ° E 23.677413088 °
Site:	Abram's Farm
Borehole Depth:	15m
Water Strike:	12m
Estimated Yield:	0.5 l/s

Date	Observed Water Levels (m)
03/11/2015	13.39 (recovering)
9/11/2015	13.29
16/11/2015	13.29
23/11/2015	13.30

Date	EC	Temp
03/11/2015	3996 uS/cm	26.1 °C
9/11/2015	3449.00 uS/cm	26.1 °C

NOTES: This borehole is drilled within the unconsolidated material.



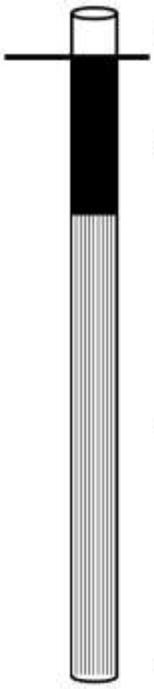
BOREHOLE NAME: LF0051A

Date Completed:	11/06/2015
GPS Co-ordinates:	S 23.673002919° E 31.018831950°
Site:	Bongele's Farm
Borehole Depth:	54 m
Water Strike:	25/40 m
Estimated Yield:	s1.5 l/s

Date	Observed Water Levels (m)
6/15/2015	14.49 (recovering)
7/10/2015	14.42
21/07/2015	15.05
31/08/2015	14.06

Date	EC	Temp
6/15/2015	315.03 uS/cm	27.20 °C
7/10/2015	315.10 uS/cm	27.10 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 30m borehole was drilled alongside LF0051A (25/06/2015).



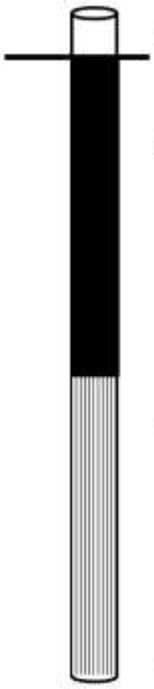
BOREHOLE NAME: LF0051B

Date Completed:	25/06/2015
GPS Co-ordinates:	S 23.673047435 ° E 31.018857310 °
Site:	Bongele's Farm
Borehole Depth:	30 m
Water Strike:	16m
Estimated Yield:	1l/s

Date	Observed Water Levels (m)
7/10/2015	14.605 (recovering)
21/07/2015	15.31
31/08/2015	14.32
11/9/2015	14.69

Date	EC	Temp
21/07/2015	1393 uS/cm	26.1 °C
31/08/2015	1443.uS/cm	26.2 °C

NOTES: This borehole is drilled within the unconsolidated material.



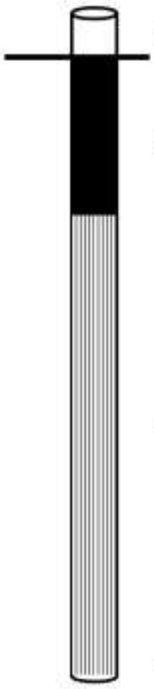
BOREHOLE NAME: LR001A

Date Completed:	03/09/2015
GPS Co-ordinates:	S 23.661769123 ° E 31.046823055 °
Site:	Mthimkhulu
Borehole Depth:	60 m
Water Strike:	13m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
11/9/2015	10.35(recovering)
02/10/2015	10.19
14/10/2015	10.22
26/10/2015	10.28

Date	EC	Temp
14/10/2015	5600 uS/cm	27.5 °C
22/10/2015	4752 uS/cm	27.4 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 12m borehole was drilled alongside LF001A (08/09/2015).



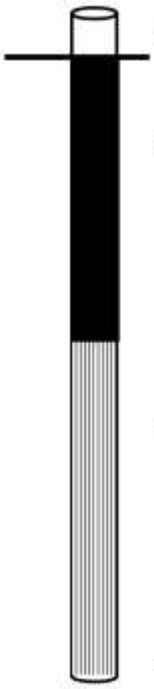
BOREHOLE NAME: LR001B

Date Completed:	08/09/2015
GPS Co-ordinates:	S 23.661764275 ° E 31.046805745 °
Site:	Mthimkhulu
Borehole Depth:	12 m
Water Strike:	10 m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
2/10/2015	11.93 (recovering)
14/10/2015	10.63
26/10/2015	10.47
02/11/2015	10.43

Date	EC	Temp
26/10/2015	6437uS/cm	27.2 °C
2/11/2015	3533uS/cm	27.2 °C

NOTES: This borehole is drilled within the unconsolidated material.



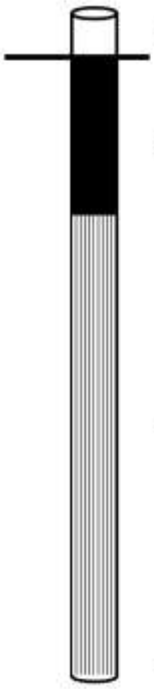
BOREHOLE NAME: LR0011A

Date Completed:	14/09/2015
GPS Co-ordinates:	S 23.662934730° E 31.045922747 °
Site:	Mthimkhulu
Borehole Depth:	72m
Water Strike:	10m
Estimated Yield:	0.1 l/s

Date	Observed Water Levels (m)
2/10/2015	10.3 (recovering)
14/10/2015	10.5
22/10/2015	10.07
26/10/2015	10.03

Date	EC	Temp
26/10/2015	6437 uS/cm	27.2 °C
2/11/2015	5470 uS/cm	27.5 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 12m borehole was drilled alongside LF0011A (15/09/2015).



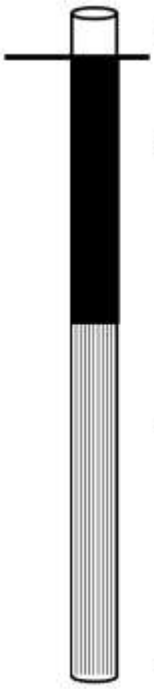
BOREHOLE NAME: LR0011B

Date Completed:	15/09/2015
GPS Co-ordinates:	S 23.662913645 ° E 31.045961774 °
Site:	Mthimkhulu
Borehole Depth:	12m
Water Strike:	10m
Estimated Yield:	< 0.1 l/s

Date	Observed Water Levels (m)
2/10/2015	10.15 (recovering)
14/10/2015	10.08
26/10/2015	10.11
2/11/2015	10.14

Date	EC	Temp
26/10/2015	3920 uS/cm	27.2 °C
2/11/2015	6678 uS/cm	27.2 °C

NOTES: This borehole is drilled within the unconsolidated material.



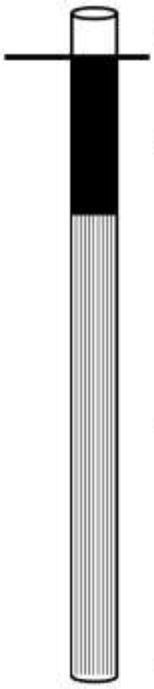
BOREHOLE NAME: LR002A

Date Completed:	28/09/2015
GPS Co-ordinates:	S 23.666323042° E 31.040506466°
Site:	Mthimkhulu
Borehole Depth:	42m
Water Strike:	25m
Estimated Yield:	0.5 l/s

Date	Observed Water Levels (m)
14/10/2015	10.59
26/10/2015	10.59
2/11/2015	10.57
09/11/2015	10.57

Date	EC	Temp
14/10/2015	2478 uS/cm	27.2 °C
26/10/2015	1869 uS/cm	27.2 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 10m borehole was drilled alongside LF002A (01/10/2015).



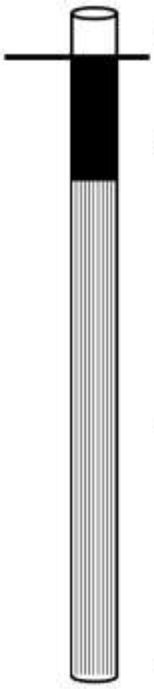
BOREHOLE NAME: LR002B

Date Completed:	01/10/2015
GPS Co-ordinates:	S 23.666330049 ° E 31.040511463 °
Site:	Mthimkhulu
Borehole Depth:	10m
Water Strike:	Initially dry
Estimated Yield:	-

Initially dry

Initially dry

NOTES: This borehole was drilled to a depth of 10m although no water strike was obtained.



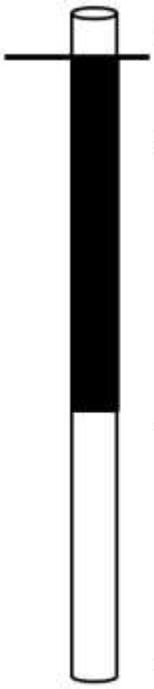
BOREHOLE NAME: LR003

Date Completed:	26/09/2015
GPS Co-ordinates:	S 23.661232653° E 31.047126602°
Site:	Mthimkhulu. Tercias BH
Borehole Depth:	10m
Water Strike:	Initially dry
Estimated Yield:	-

Date	Observed Water Levels (m)
26/09/2015	Initially dry
14/10/2015	11.22
26/10/2015	11.34
2/11/2015	11.23

Date	EC	Temp
26/10/2015	6248 uS/cm	27.1 °C
2/11/2015	5720 uS/cm	27.4 °C

NOTES: This borehole was drilled to a depth of 10m although no water strike was obtained.



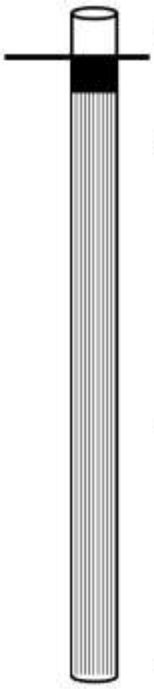
BOREHOLE NAME: LR004A

Date Completed:	02/12/2015
GPS Co-ordinates:	S 23.669463099° E 31.042411630°
Site:	Letaba Ranch
Borehole Depth:	54m
Water Strike:	13m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
07/12/2015	13.38 (recovering)
7/1/2016	11.06
14/01/2016	11.06
21/01/2016	11.13

Date	EC	Temp
07/12/2015	2568uS/cm	26.5 °C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 24m borehole was drilled alongside LF004A (21/07/2015).



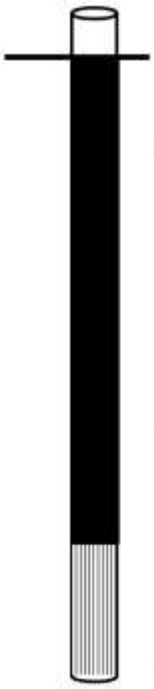
BOREHOLE NAME: LR004B

Date Completed:	03/12/2015
GPS Co-ordinates:	S 23.669447874 ° E 31.042414074 °
Site:	Letaba Ranch
Borehole Depth:	24m
Water Strike:	13m
Estimated Yield:	< 0.5 l/s

Date	Observed Water Levels (m)
07/12/2015	13.30 (recovering)
07/1/2016	11.02
14/01/2016	11.02
21/01/2016	11.07

Date	EC	Temp
07/12/2015	2883 uS/cm	26.2 °C

NOTES: This borehole is drilled within the unconsolidated material.



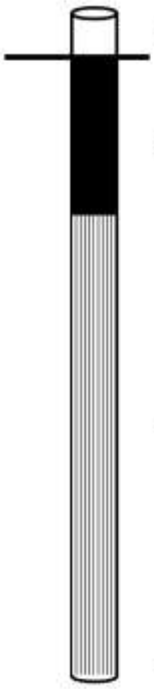
BOREHOLE NAME: LR005A

Date Completed:	09/07/2015
GPS Co-ordinates:	S 23.662268314° E 31.049551881 °
Site:	Letaba Ranch
Borehole Depth:	60m
Water Strike:	25/38/50
Estimated Yield:	5.7 l/s

Date	Observed Water Levels (m)
21/07/2015	8.95 (recovering)
31/08/2015	8.945
17/09/2015	9.18
2/10/2015	9.18

Date	EC	Temp
21/07/2015	1740uS/cm	27.1°C
31/08/2015	1403uS/cm	26.9°C

NOTES: This borehole is too deep and drilled beyond the unconsolidated material, therefore a shallower 24m borehole was drilled alongside LR005A (13/07/2015).



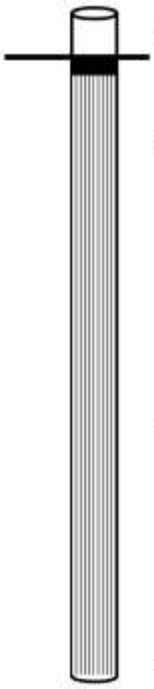
BOREHOLE NAME: LR005B

Date Completed:	13/07/2015
GPS Co-ordinates:	S 23.662269810° E 31.049502905°
Site:	Letaba Ranch
Borehole Depth:	24m
Water Strike:	19m
Estimated Yield:	1.8 l/s

Date	Observed Water Levels (m)
21/07/2015	8.94 (recovering)
31/08/2015	8.95
17/09/2015	9.06
02/10/2015	9.7

Date	EC	Temp
21/07/2015	1580 uS/cm	27.1 °C
31/08/2015	1396 uS/cm	26.6 °C

NOTES: This borehole is drilled within the unconsolidated material.

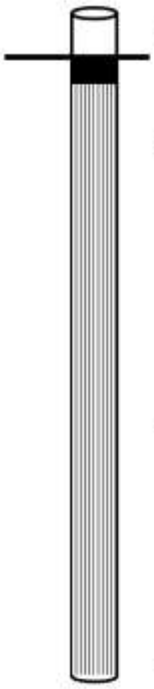


BOREHOLE NAME: LRW001

Date Completed:	26/11/2015
GPS Co-ordinates:	S 23.659273246° E 31.048663193°
Site:	Mthimkhulu in river
Borehole Depth:	12m
Water Strike:	8m
Estimated Yield:	< 0.2 l/s

Date	Observed Water Levels (m)
7/12/2015	1.23 (recovering)
07/1/2016	1.39
14/01/2016	1.39
21/01/2016	1.38

NOTES: This borehole was drilled within the river to obtain the water lever of the river and for monitoring purposes.



BOREHOLE NAME: LRW002

Date Completed:	30/11/2015
GPS Co-ordinates:	S 23.659964290° E 31.048604409°
Site:	Mthimkhulu in river
Borehole Depth:	6m
Water Strike:	5m
Estimated Yield:	< 0.2 l/s

Date	Observed Water Levels (m)
7/12/2015	1 (recovering)
07/1/2016	1.06
14/01/2016	1.02
21/01/2016	1.01

NOTES: This borehole was drilled within the river to obtain the water lever of the river and for monitoring purposes.

Appendix III Pictures of Borehole Drilling

Figure III.1 Drilling river borehole (LRW002) in river bed close to Letaba Ranch gauge

Figure III.2 example of the percussion drill during water strike