Fluctuations in Groundwater Level and Corresponding Earth Resistivity Changes

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Abstract

The earth resistivity at a known location was frequently measured, through resistivity sounding. Resistivity of subsurface layers could be influenced by the permeability, porosity, transmissivity, composition etc., where moisture content was the concern of this study. ABEM-Terrameter SAS 1000 instrument was used for surveying and data were interpreted using "IPI2-win" software. A borehole was established to reveal accurate subsurface stratification information and monitor the groundwater level, at the surveying location. Groundwater level was recorded through a datalogger in the borehole, at each 12 hour interval. The precipitation data of the area were obtained from the meteorological department to understand the wet & dry seasonal characteristics. Attempts were made to identify the changes in apperant resistivity data in response to the changing groundwater levels/moisture content and the accuracy of corresponding layer thicknesses, computed through resistivity data.

Keywords: Groundwater exploration, Resistivity surveying, Terrameter SAS1000

1. Introduction

Groundwater level may subjected to fluctuation with the seasonal climate changes. Conversely, extracting excessive amounts of groundwater through bore wells could result rapid drawdown of the groundwater level. Hence, awareness of the seasonal changes and fluctuations of the groundwater table at a particular location/region could assist efficient extraction and optimize the management of water resources. Also, stratergic construction of water extraction wells to cater the water requirements in dry and wet seasons. Aditionally, understanding of the seasonal groundwater table fluctuations could be useful for deep excavations in construction industry.

Significant changes to the subsurface moisture conditions can encounter, if the drawdown largely exceeds the rate of recharge. Corresponding moisture content chages in subsurface could influence electrical conductivity and subsequently the resistivity of the subsurface layers.

Resistivity sounding and profiling procedures can be used to determine apperant resistivity of the subsurface layers. Whereas, both direct and indirect techniques can be used to determine the depth to the groundwater level [1] and the subsurface layer thicknesses.

Comparision of the indirect measurements [2] with the direct readings can be used to validate and assess the accuracy of the indirect measurements.

2. Methodology

This study is conducted to monitor the resistivity changes of subsurface layers at a selected location, within a specified time frame. Depth to the groundwater level was determined through the resistivity survey results. The apperant resistivity readings recorded for each layer was also used to compute the subsurface layer thicknesses and the depth of layer existence. An exploratory borehole was constructed to validate the above subsurface interpretations and to obtain frequent direct measuements on the depth to the water table.

The information gathered from interpretations (groundwater level subsurface layer thickness, depth to each of the layers) were illustrated on tables against the recordings (date/number of records). This enabled the comparision of apparent resistivity readings and corresponding water level changes in response to the dry and wet weather conditions experienced. The above study was facilitated by the rainfall data obtained from the Meteorological Department.

2.1 Site Selection

Following factors were considered during the selection of the site to conduct the resistivity survey.

- Relatively flat terrain with adequate span to extend the electrode arrangements where the distrubances are minimal.
- Ability to construct an exploratory borehole adjacent to the location of surveying.
- Convenient and frequent access to the study site for continuous data recording, thoroughout the period of study.
- Capacity to facilitate the future studies by ensuring the established borehole can be equipped with necessary instruments such as raingagues etc., that could record accurate *in-situ* measurements.

Accordingly, a site within the university premises was chosen as the most appropriate, considering the above requirements and mobilization of equipment as well as convenience of access for borehole construction. Hence, a location adjacent to the scoreboard in the university playground was selected as the study area (Figure 1). The tie-measurements to nearby permanent benchmarks from the base-point of the survey line as well as the borehole, were recorded. The selected location cater for all the above concerns and also have been recommended by a previous study [3] as a location that permits to obtain resistivity readings with minimal interferences.

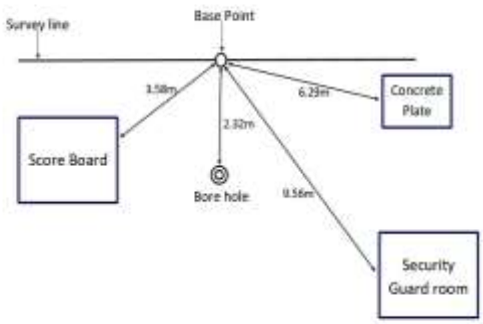

Figure 1 – Arrangement of the survey line and the borehole

2.2 Resistivity Sounding

The surveying line for the study was confirmed after a conducting several profiles in different orientations keeping the base-point of the measuremtns unchanged. Tie measurements and offsets were taken from permanent landmarks and GPS coordinates of the base point was also recorded.

Two steel tapes were laid along the survey line, starting from the base-point in opposite directions. The instrument (Terrameter SAS 1000) was kept near the base-point (under a cover to prevent getting direct sunlight) and it was connected to the battery and electrodes with cables, as prescribed in the user manuel. The resistivity mode of measurements were selected on the Terrameter unit and electrodes (current and potential) were penetrated into the ground at required spacing according to the Schlumberger electrode configuration. Obtained apparent resistivity readings were recorded in the data record sheets.

2.3 Data Interpretation

"IPI2-win" software, which is available for free, was used to interpret resistivity data. 1-D graphs were generated with the axes having apparent resistivity and half of current electrode spacing. Curve fitting on the generated graphs were deployed to determine the layer thicknesses. To accept the interpretations as accurate, the error of obtained curves were maintained to be less than 5% [4]. Accordingly, erroneous data had been removed in order to obtain a smooth field curve along with a suitable master curve.

2.4 Borehole Construction and Observations

To obtain frequent records of the groundwater level an exploratory borehole was established using wash boring/jetting method. The borehole extends upto the bedrock with an approximate depth of 11 m (Figure 2). A pvc casing was installed with provisions to enter/exit the groundwater but not the rainwater from shallow subsurface. "Hobo U20L" water level logger was placed in the borehole to record the groundwater level for every 12 hour interval. Absolute pressure and temperature will be recorded by the data logger [5] as additional information. Depth to water table from the surface was also determined using direct methods.

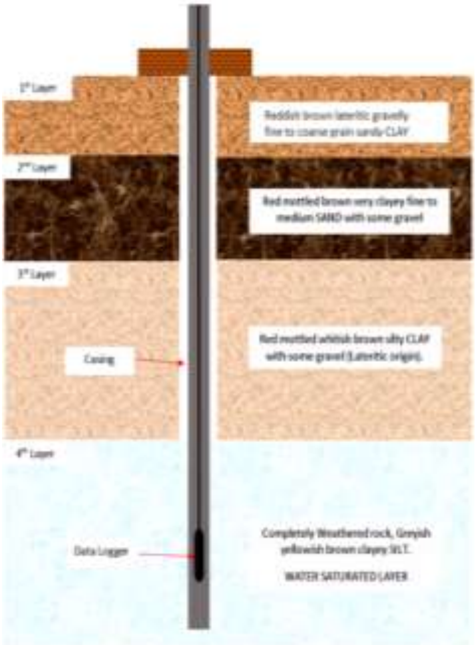

Figure 2 – Stratigraphic cross section of the study site and the exploratory borehole

The pvc casing of the borehole appear above the surface upto a height of 5 inches. An end cap is installed at the top of the casing to eliminate the accumulation of rainwater and gravel. Horizontal openings towards the end cap facilitate the flow of air, inorder to maintain the free movement of water table. The borehole casing above the surface is protected by brickwork and a metal sheet.

The drill log of the borehole revels four distinct layers at the particular location. The completely weatherd layer, which is at the very bottom of the sequence is water saturated. The water table was observed at a depth of ~6.5 m after the borehole construction, allowing the waterlevel to settle. The depth of water table observed in the borehole is inline with the water levels of the domestic dug-wells at the neighbourhood.

3. Results and Discussion

The Table 1 reveals the apparent resistivity values of each layer with respect to the number of records. The first column is the date of measurement whereas, subsequent columns corresponds to layers (L) 1 to 4. The study was conducted from Novermber 2016 to February 2017. Apparent resistivity readings are recorded in Ohm-meters (Ωm).

Apparent resistivity for soils below the water table generally known to be significantly lesser than the soil stratum in vadose zone. Average apparent resistivity values below 100 Ωm considered not only to be saturated but also the presence of saline water [1,6]. According to the records, the resistivity of the 4th layer always appear to be less than 100 Ωm, confirming it is saturated. However, there is no evidence the water to be saline with respect to the available information.

The interpretations of groundwater level through resistivity surveying reveals a maximum depth to water table from the surface as 7.28 m and a minimum value of 5.40 m. This can be the dry periods and rainy days where groundwater level fluctuates in response to the infiltrated surface water by reducing the depth to the water table from the surface. For the considered period of time, the range of fluctuation can be computed as (7.28 – 5.40 m) 1.88 m.

Table 1 – Apparent resistivity of each layer

Date	Apparent resistivity (Ωm)			
	L1	L2	L3	L4
02Nov	201	2599	503	25.60
10Nov	105	4986	331	98.65
15Nov	193	3938	449	38.60
23Nov	161	1210	337	79.52
01Dec	147	2814	551	40.20
06Dec	355	1698	459	92.60
13Dec	274	3147	605	27.50
20Dec	142	5335	444	26.20
27Dec	143	4484	519	24.80
03Jan	121	6966	504	16.60
10Jan	125	2760	555	34.82
16Jan	197	1709	477	24.10
20Jan	225	1362	531	28.80
01Feb	141	1398	558	25.50
08Feb	303	1794	525	46.20
14Feb	177	3564	577	17.60
21Feb	152	3528	531	25.80

Apparent resistivity of the first layer and third layer are increased in dry seasons and decreased with the precipitation due to rainfall. Hence the changes to the resistivity readings in these layers encountered as one would expect inline with the theoretical basis.

However, the apparent resistivity values of the second layer and fourth layer did not changed inline with the first and third layer sequence in response to the rainfall activities.

The second layer and fourth layer indicate some irregularities that finds dificcult to explain in context to the rainfall records obtained from the Meteorological Department.

From the recorded apparent resistivity readings layer thicknesses were computed and the depth values for each of them are given in Table 2. An average layer thickness is obtained from the results to understand the depth to each layer and to compare with the borehole log. The depth variations for each layer at each survey indicates, effect of the subsurface moisture content on the apparent resistivity readings and subsequent thickness calculations. There are three anomalous results* for the bottom most layer on 10,23 Nov and 06 Dec, possibly due to the technical erros during the survey. And those have been excluded from the average thickness calculations.

Table 2 – Depth of the layers determined by each survey

Date	Depth to each layer (m)			
	L1	L2	L3	L4
02Nov	0.274	0.428	5.21	6.52
10Nov	0.238	0.236	4.62	24.45*
15Nov	0.272	0.299	4.89	9.08
23Nov	0.300	1.017	4.42	19.30*
01Dec	0.222	0.218	6.44	5.71
06Dec	0.504	0.535	6.00	22.90*
13Dec	0.331	0.164	6.15	3.31
20Dec	0.191	0.212	6.82	6.25
27Dec	0.197	0.203	5.75	6.53
03Jan	0.166	0.131	5.82	3.90
10Jan	0.248	0.112	6.32	9.78
16Jan	0.334	0.260	6.63	6.69
20Jan	0.380	0.510	6.39	7.24
01Feb	0.300	0.327	5.15	6.24
08Feb	0.329	0.426	5.10	5.77
14Feb	0.229	0.181	5.39	4.60
21Feb	0.204	0.242	5.43	6.53
Ave:	*0.280*	*0.320*	*5.68*	*6.30*

The graph indicate that the groundwater level at the study location reaches its minimum depth (~5 m) by 10th November 2016. This correlates to the heighest rainfall recorded (just below 140 mm) for the region.

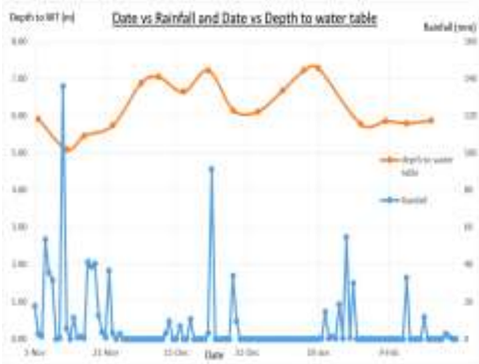

Figure 3 – Groundwater level fluctuations in response to the rainfall

From 23rd November to 6th December, the ground water level has gradually retreated from ~5 to 7 m depth, in response to the dry weather. From 6th to 13th December the depth to water table has decreased, due to small rains and again it has increased due to the absence of rain. 19th December records the second heighest rainfall (~90 mm) for the region, resulting a abrupt decrease in depth to the water table. From 27th December 2016 to 20th January 2017, the depth to the water table has been increased from ~6 m to 7.28 m. From 21st January to 1st February depth has again decreased as a result of considerable rainfall. Throughout the February month it was not recorded a significant rainfall and the water table indicates minimal fluctuations at this locality. In summary, heavy rains has reduced the depth to the water table at a rapid rate, whereas smaller amounts of rainfall has caused gradual changes to the water table depth.

4. Conclusions

The water table at this locality is sensitive to rainfall and fluctuates in response to wet and dry seasons. The corresponding chages in subsurface moisture content has clearly indicated by the recorded resistivity values. The apparent resistivity of layers does not linearly respond to the changing moisture contents.

According to the study, we suggest the following to improve the accuracy of the results.

- Obtain higher resolution of data by increasing the frequency of resistivity surveys.
- Establishment of a rain gauge adjacent to the surveying location/monitoring point.
- Collect data for extensive period of time inorder to compare the groundwater level fluctuations with seasonal climatic changes.
- Radial variations to the line of survey by keeping the base-poinnt unchanged.
- Monitoring parameters that could directly affect the apparent resistivity readings, such as; temperature, salinity of water, permeability, porosity, material composition of subsurface layers.
- Adjusting the current, acquisition delay and time accordingly when expanding the current electrode spacing, instead of using a rigid combination all the time.
- Duplicate the resistivity surveying activities at few other locations where the information on the subsurface stratigraphy is available and waterlevel could be directly monitored/recorded. It should make sure to occupy minimum topographic variations when chosing the resistivity survey line.

Acknowledgement

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