APPLICATION OF ELECTRICAL RESISTIVITY METHOD TO INVESTIGATE GROUNDWATER POTENTIAL IN LAKE CHALA WATERSHED

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ABSTRACT

A geo-electrical investigation was carried out in Lake Chala Watershed in Kenya to determine the groundwater potential of the area. The Vertical Electrical Sounding using schlumberger configuration with a maximum current electrode spread varying from 250 - 320m and potential electrode spread of 25m was utilized to provide information of the aquifers and subsurface lithology. A total number of 50 VES were carried out. The data obtained were interpreted by computer iteration process. Interpreted results revealed four to six distinct subsurface layers which comprised of top soil (clay, sandy clay soil intercalated with silt, sand and gravel), highly weathered ryholite, and moderately weathered basalt volcanic ash, highly weathered fractured basalt, weathered basalt, slightly fractured dry and fresh basalt and basalt basement rock layers. The results showed that the auriferous layer was composed of highly weathered fractured basalt, moderately weathered basalt & volcanic ash and weathered basalt geological material. The layer had a resistivity range of 40 to 200 and a thickness range of 1.38 to 91m. The results showed that lake chala watershed have high groundwater potential which can be exploited as an alternative source of water in the area.

KEYWORDS: Aquifer, Geological Layers, Groundwater, Resistivity, Vertical Electrical Sounding, Watershed

INTRODUCTION

Water is an important natural resource that is vital for existence of all forms of life. It is a vital resource for agricultural development, energy generation; municipal and commercial needs livestock development, industrial growth, wildlife and recreational activities (Zacchaeus, et al., 2009). Despite its importance, water is a scarce resource, yet an essential component for human survival. This scarcity is linked to climate change, high population growth, demand that exceeds available water resources and unsustainable use of the resource.

These challenges put water resources under increasing stress and reduce freshwater availability (Molle, 2000).

A study by (IUCN, 2003) shows that Lake chala watershed which is located in Taveta district is facing water stress, the river's flow has decreased dramatically in recent years, and water demand is expected to double by 2015. The situation is worsened by high population growth with a high growth rate that is estimated at 1.8% per annum. The Population of Taveta District was 53,038 in 1999 and 65,448 in 2013. By the year 2015 this population is expected to increase to 67,968 (KFS, 2008). Increasing population requires water for domestic use, food production and industrial use. Population growth increase lead to an over-exploitation of water resources and increase the demand and competition for water among land users, industry and ecosystems. The water demand in the whole of the Taveta district was estimated at 8844 m3 per day in 2005 and was projected at 12,521 m3 per day by the year 2015 (Taita Taveta district water plan 1995, cited in musyoiki 2003. There is therefore the need to provide alternative sources of water in order to sustain the growing population reduce water shortage experienced in the area as well as help in reducing overexploitation and degradation of the available water resources in Lake Chala watershed.

Groundwater is one of the alternative sources of water that can be explored to help reduce water shortage and reduce over exploitation of available water sources in Lake Chala Watershed. Ground water is an essential hidden and replenish able resource. Its distribution and occurrence varies according to the local and regional geology, hydrogeological as well as the nature of human activities (Yusuf Ismail et al., 2012). Groundwater is characterized by parameters such as permeability, porosity, transmissivity and conductivity. These parameters can be determined by electrical resistivity method (Alile, et al., 2012). Electrical resistivity method has proven to be very effective in groundwater exploration and investigations because; it provides a good contrast between resistivity of water bearing zones and water-devoid zones, structural and lithological information of the sub-surface (thickness of aquifer overlying resistive bedrock, the quality of groundwater whether water is saline, fresh, contaminated with toxic waste or brackish, strata thickness, depth to bedrock, hydrogeological units, aquifer hydraulic properties, fault zones and types of subsurface materials (Sabet, 1975 and Ratnakumari, et al., 2012,).

MATERIALS AND METHODOLOGY

Lake Chala watershed lies on Kenyan Tanzania border on the southern slopes of Mt Kilimanjaro in Taita Taveta district between 740, m.a.s.l and 4000 m.a.s.l. figure 1. The watershed experiences an annual rainfall of between 500– 4000 mm. The geological units of the watershed are mainly volcanic pyroclastic, volcanic alluvium deposits, fractured and weathered basalts. The Lake Chala Watershed vegetation cover is composed of forest, bush land and scrubland.

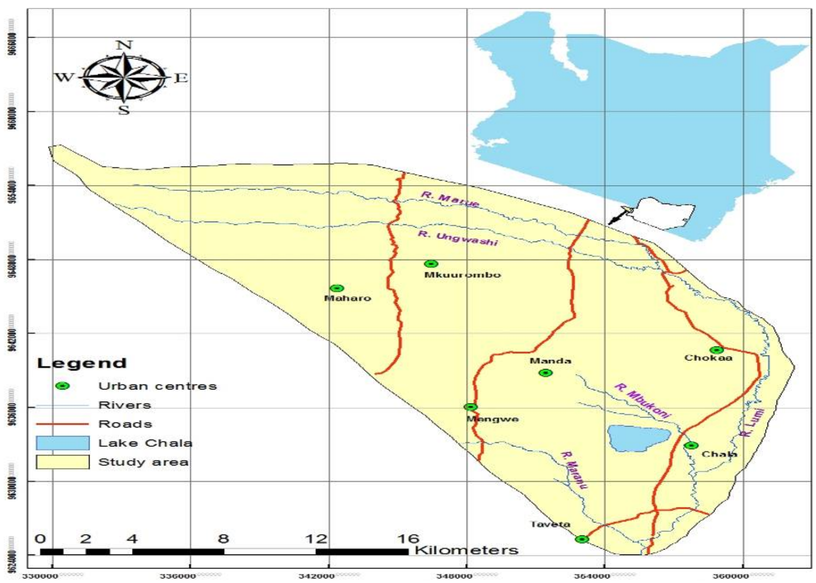

Figure 1. Lake Chala Watershed Location Map

The field procedure involved geo electrical investigation by the application of vertical electrical sounding method (VES) using Schlumbergher array configuration. A total of 50 Vertical electrical soundings (VES) were conducted around the Lake Chala. The VESs were concentrated within a 10 by 10 kilometer area (approximately 5 kilometer radius) around the lake figure 1. They were conducted along five horizontal profiles with each having approximately 6 VESs. The distance between the VESs and profile was approximately1 to 2 kilometer. The distribution between the VES and profiles varied because of the topography and vegetation. The Schlumberger electrode configuration employed for the survey was carried out with measurements beginning with current electrode spacing (AB/2) of 250 to 320 and varying potential electrode spacing (MN/2) of 0.5m to 25m. The corrected apparent resistivity data was plotted against current electrode distance for all VESs using IP12win+IP software to generate sub-surface layers, layer thickness, resistivity of the layers and depth to bedrock which was then interpreted to give water bearing layers(aquifers).

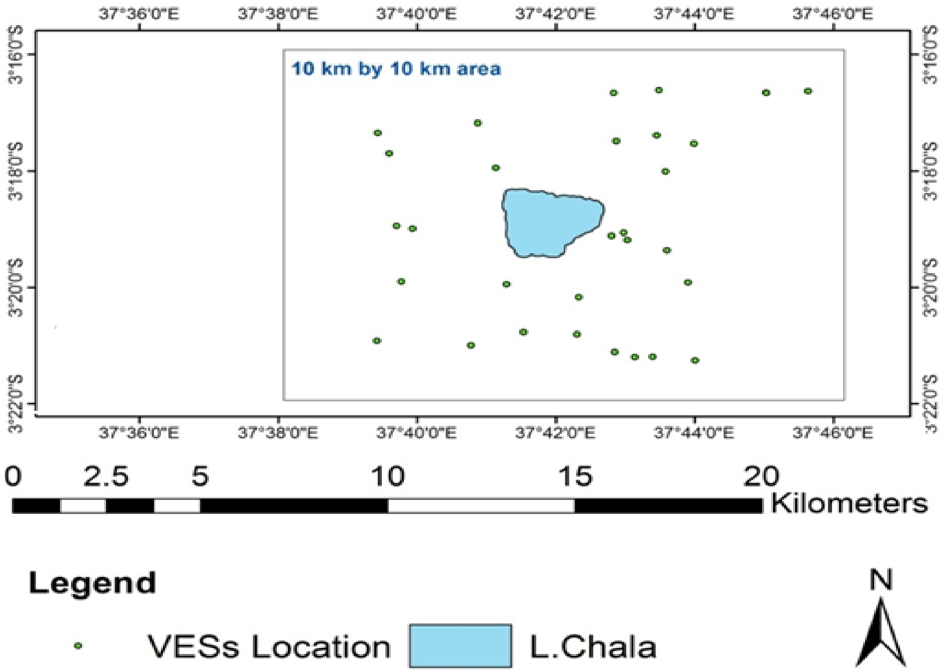

Figure2. Vertical Electrical Soundings Location

RESULTS AND DISCUSSION

The interpreted results of vertical electrical sounding indicate that the subsurface layers of the study area consist of four (4) to six (6) different lithological units as indicated in table 1. The resistivity and thickness of the first layers (topsoil) varied from 1.14 to 696 Ωm and from 0.8-7.92m respectively while the second layers showed a resistivity range of 0.35 to 4083 and a thickness of 0.19 to 26.1 m. The third layers had a resistivity range of 7.59 to 7942 Ωm and a thickness range of between 1.38 to 104 m. Fourth layers resistivity ranges from 3.46 to 5511 Ωm and the thickness range from 1.27 to 177m, the fifth layers had a resistivity range of 4.03 to 4934 and a thickness range of 7.9 to 215 m and the sixth layers had a resistivity of 3.54 to 4769 Ωm as shown in table 1.

Layers with resistivity range of 1 Ωm to 40 Ωm were composed of clay and sandy clay soil intercalated with silt, sand and gravel. These layers served as a site for evapotranspiration and percolation of water to groundwater sources. The layers were generally unreliable for groundwater accumulation in all the VES stations. Layers with resistivity range of 40 Ωm to 200 Ωm were found to have very high water bearing capacity.

The layer was found to be a high water bearing layer because the highly weathered ryholite, moderately weathered basalt and volcanic ash have high porosity levels. These layers were considered to contain the aquiferous layer of the study area. Layers of resistivity range of between 200 Ωm to 500 Ωm were categorized as low groundwater bearing layers. These layers were formed of highly weathered fractured basalt which was low saturated with water in some areas and dry in other areas. Layers with resistivity range of 500 Ωm to 1000 Ωm were considered as dry to slightly water bearing. They were made up of weathered basalts. Geological layers with resistivity of between 1000 Ωm to 5000 Ωm were considered as dry layers. These layers were made of slightly fractured dry and fresh basalts. Layers with resistivity greater than 5000 Ωm were considered as very dry without groundwater bearing capacity. These layers were formed of compact basalts basement rocks. The layers resistivity, thickness, and depth are shown in table 1.

Table 1. Resistivity of Geological Materials

Resistivity (Ώ.m)	Materials	Water bearing
1-40	Clay and sandy clay soil intercalated with silt, sand and gravel	Occasionally water bearing
40-200	Highly weathered ryholite, moderately weathered basalt and volcanic ash	Water bearing (high yielding aquifer)
200-500	Highly weathered fractured basalt	Less saturated and water bearing (low yielding aquifer)
500-1000	Weathered basalt	Dry to slightly water bearing
1000- 5000	Highly weathered ryholite, moderately weathered basalt and volcanic ash	Dry
5000	Basalt basement rock	Very dry.

Based on the interpretation of the resistivity of the geo-electrical layers, 41 VES(es) namely; VES 1, 3, 4 , 5 , 6 ,7, 8 , 9, 10, 11,12,13, 14, 16, 17,18, 19, 20, 22, 23, 24, 26, 28, 29, 30, 31, 35, 36, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 48, 49, and 50 were found to have highest water yielding aquiferous layers as shown in table 2. The aquiferous layer in all the above mentioned VES (es) was found from the second layer in some areas to the sixth layer in other areas respectively. The aquiferous layers on the above mentioned VES (es) had a groundwater resistivity of about 40 to 200 and a thickness range of 1.38 to 91 m. the aquiferous layer comprised of highly weathered ryholite, moderately weathered basalt and volcanic ash. A study carried out by (Alker, et al., (2008) showed that groundwater within the study area occurs in areas with volcanic alluvium deposits composed of sand clay & gravel, with calcerous deposits with some lava and pyroclastic volcanic rocks, as well as fractured and weathered basalts. The aquifer in the lake chala watershed area was therefore defined by the highly weathered fractured basalt, moderately weathered basalt & volcanic ash and weathered basalt which are in agreement with (Alker, et al., (2008)

Table 2. Summary of the Resistivity Survey

VES NO.	Layers	Apparent resistivity	Thickness (m)	Depth (m)	Geological interpretation
1.	1	44.1	1.94	1.94	Clay and sandy clay soil intercalated with silt, sand and gravel
	2	141	3.8	5.74	Highly weathered fractured basalt
	3	5785	3.32	9.06	Basalt basement rock
	4	107	39.4	48.50	Highly weathered fractured basalt
	5	23.2	93.8	142	Clay and sandy clay soil intercalated with silt, sand and gravel
	6	2280	∞	∞	Basalt basement rock
2.	1	58.5	0.97	0.97	Moderately weathered basalt and volcanic ash
	2	3.79	0.99	1.97	Clay and sandy clay soil intercalated with silt, sand and gravel
	3	18	2.86	4.83	Clay and sandy clay soil intercalated with silt, sand and gravel
	4	3.46	7.10	11.90	Clay and sandy clay soil intercalated with silt, sand and gravel
	5	10.2	74.3	86.2	Clay and sandy clay soil intercalated with silt, sand and gravel
	6	812	∞	∞	Slightly fractured dry and fresh basalt
3	1	162	0.89	0.89	Highly weathered fractured basalt
	2	2380	0.58	1.48	Basalt basement rock
	3	509	30.7	32.2	Slightly fractured dry and fresh basalt
	4	59.10	50.90	83.10	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	5	149	∞	∞	Highly weathered fractured basalt
4	1	696	3.22	3.22	Slightly fractured dry and fresh basalt
	2	41.9	3.11	6.33	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	3	5606	9.59	15.9	Basalt basement rock
	4	28.70	13.10	29	Clay and sandy clay soil intercalated with silt, sand and gravel
	5	1089	40	69.1	Basalt basement rock
	6	2709	∞	∞	Basalt basement rock
5	1	5.77	1.04	1.04	Clay and sandy clay soil intercalated with silt, sand and gravel
	2	2611	0.57	1.61	Basalt basement rock
	3	14	4.64	6.25	Clay and sandy clay soil intercalated with silt, sand and gravel
	4	753	15.60	21.90	Slightly fractured dry and fresh basalt
	5	63.9	42.9	64.7	Highly weathered ryholite, moderately

					weathered basalt and volcanic ash
	6	388	∞	∞	Weathered basalt
6	1	36.4	1.33	1.33	Clay and sandy clay soil intercalated with silt, sand and gravel
	2	9.57	28.2	29.5	Clay and sandy clay soil intercalated with silt, sand and gravel
	3	1098	103	133	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	4	42.60	9.19	142	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	5	4.59	∞	∞	Clay and sandy clay soil intercalated with silt, sand and gravel
7	1	47.6	3.52	3.52	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	2	10.6	3.45	6.97	Clay and sandy clay soil intercalated with silt, sand and gravel
	3	18.4	30.3	27.2	Clay and sandy clay soil intercalated with silt, sand and gravel
	4	581	49	76.20	Weathered basalt
	5	169	∞	∞	Highly weathered ryholite, moderately weathered basalt and volcanic ash
8	1	381	1.38	1.38	Highly weathered fractured basalt
	2	6.51	0.5	1.88	Clay and sandy clay soil intercalated with silt, sand and gravel
	3	77.1	35.5	37.4	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	4	2056	45.80	83.20	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	5	8.53	∞	∞	Clay and sandy clay soil intercalated with silt, sand and gravel
9	1	55.9	0.91	0.91	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	2	1287	2.02	2.94	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	3	265	29.8	32.7	Highly weathered fractured basalt
	4	120	14.80	47.50	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	5	685	∞	∞	Weathered basalt
10	1	166	5.35	5.35	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	2	19.3	4.54	9.89	Clay and sandy clay soil intercalated with silt, sand and gravel
	3	125	1.38	11.3	Highly weathered ryholite, moderately weathered basalt and volcanic ash
	4	550	22	33.30	Weathered basalt
	5	277	∞	∞	Highly weathered fractured basalt

CONCLUSION

The geo-electrical method of investigation adopted by this study has helped in the identification of the aquiferous units and has provided an understanding of aquifer dimensions which have enabled in the locating of aquiferous layers to show groundwater potential in Lake Chala Watershed. The results of geo-electric investigation carried out in Lake Chala Watershed revealed that the area is composed of 4 to 6 geo-electrical layers. The results also showed that the aquiferous layer was composed of highly weathered fractured basalt, moderately weathered basalt & volcanic ash and weathered basalt geological material. The layer had a resistivity range of 40 to 200 and a thickness range of 1.38 to 91m. The results showed that lake chala watershed have high groundwater potential which can be exploited as an alternative source of water in the area. This is because the aquiferous layer dominates the largest part of the watershed and also the layer is very thick (1.38-91m) thus creating large area for groundwater accumulation.

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