Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 3 Issue 1, January - 2016

Integrated Resistivity Techniques for Groundwater Potential Evaluation in Matuu, Machakos County, Kenya.

Odero Evance O., K'Orowe Maurice O., Githiri John G. and Munyithya James
Department of Physics
Jomo Kenyatta University of Agriculture and Technology
Nairobi, Nairobi

***Abstract*—In order to evaluate groundwater potential of Matuu-Kilango area an understanding of its subsurface formations and associated geo-electric parameters was critical alongside delineation of faults and fractures which are groundwater conduits. Earlier use of geological reconnaissance report only or none at all in siting boreholes has led to recorded cases of borehole failure in Matuu. Integrated resistivity survey involving Wenner and Schlumberger array techniques was applied over a 25 square kilometre area with an aim of locating groundwater aquifer and the associated characteristic and geometry. Control resistivity measurement was conducted adjacent to existing boreholes to synchronize resistivity results with borehole logging report. Qualitative interpretation involving generation of contour maps for resistivity values from Wenner array was attempted and an anomalous low resistivity zone was observed at the western part of Matuu-Kilango area. Inversion results from vertical electrical soundings were obtained using IPI2Win software giving three to four layered geo-electrical sections having the inferred aquiferous layer in between resistive black top soil and hard gneiss basement. Fractured/faulted zone was identified to the west of Matuu-Kilango area with the inferred aquifer existing at about 100 meters depth having general orientation of South-East to North-West and an average width of 1500 meters. Along the faulted zone were prevalent increasing values of transverse resistance as well as longitudinal conductance calculated from resistivity sounding results, an indication of availability of groundwater resource.**

Keywords—Aquifer; Fractures; Groundwater; Matuu-Kilango; Resistivity

I. INTRODUCTION

The study area (Matuu-Kilango) is located in Yatta District in machakos County, 61.69 Km from Thika town and 110 Km from Nairobi. The area is bounded by latitudes 9879000 and 9874000 and longitudes 335000 and 340000 within zone 37M as shown by the boundary in Fig. 1. The area lies in the Eastern side of Gregory Rift valley and it is largely semi-arid characterized by unreliable rainfall, moreover, given that the area is majorly made up of igneous rock formation its porosity is mainly secondary implying that the possible type of aquifer is fractured aquifer. This study was carried out with a view of determining aquifer characteristics; a key factor in evaluation of groundwater potential and a mitigation measure to curb losses associated with borehole failure due to lack of understanding of the subsurface formations defining aquifer existence.

Matuu-Kilango area has an underlying Precambrian basement crystalline rock system of Mozambique belt segment that have undergone cycle of metamorphism, exposure and erosion, [1]. The surface rocks comprises of metamorphic rocks overlain by Yatta plateau to the south, Yatta plateau formation begun at the start of Miocene period by eruption of Phonolites, [1], this resulted into large part of sub-miocene surface being covered by lava. The geological system of the study area only holds water in a network of fractures and faults within a subsurface formation bounded by an overburden and a bedrock since the metamorphic rocks are non porous and impervious. The rock type is described by meta-intrusive mafic and ultra-mafic rocks that include Diorites, Gabbro, Anorthosite and Picrites, Peridotites where the mafic and ultra-mafic rocks occur in the general Machakos area and its environs, [2], within which the study area is located. Inferred brittle fractures oriented in the North-West and South-East directions are found within the area,

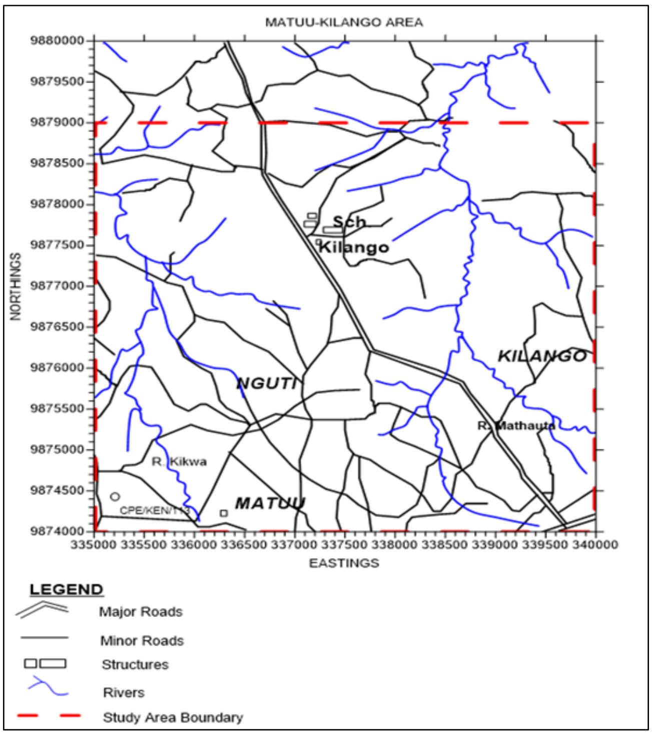

Fig. 1: *Map of the Study Area (Matuu-Kilango)*

moreover, [3], explains that the trends have been postulated to be due to escape of strain in the Mozambique belt rocks as a result of westward rigid craton collision.

Resistivity technique has been applied to groundwater survey in crystalline type of hard rock system and useful results obtained e.g. [4], from a typically hard rock terrain found in the Jangaon sub-watershed, Andhra Pradesh, India, showed linear relationship between transmissivity and formation factor by employing resistivity method.

Investigation of subsurface features associated with groundwater potential in Matuu had been carried out using magnetic and self-potential methods [5], and result obtained delineated inferred fault and fractures to the west of the study area, this information was useful in this study since the type of aquifer investigated here is defined by faulting and fracturing.

II. Material and Method

A. *Resistivity measurement control*

Prior to the commencement of resistivity measurements four deep vertical electrical soundings (VES) were done adjacent to existing boreholes within and close to the study area. The resistivity values were cross-checked with the respective borehole logging records as a control to the overall resistivity measurements.

B. *Resistivity Survey*

Wenner and Schlumberger arrays were applied [6]. Grids were established within which 11 measurement stations were located all within the 25 Km^2 area as shown in Fig. 2. Every station had its northing, easting and elevation measured using handheld Global Positioning System (GPS). Electrical resistivity measurement was done using SARIS Terrameter which was capable of sending current into the subsurface through a pair of conducting electrodes, automatically computing and displaying the apparent resistivity from potential difference created by injected current in the subsurface structure under investigation and data recorded on paper. Horizontal profiling by Wenner array was carried out at the established stations in the area (Fig. 2) with a maintained constant separation of 50m; all profiles were aligned parallel to the inferred river flow direction. VES by Schlumberger array method with half the spacing between current electrodes (AB/2) and potential electrode (MN/2) ranging from 1.5 m to about 200 m and 0.5 m to about 20 m respectively was then conducted within the same grids for vertical investigations. For constant monitoring of resistivity trends logarithmic curves were drawn in situ.

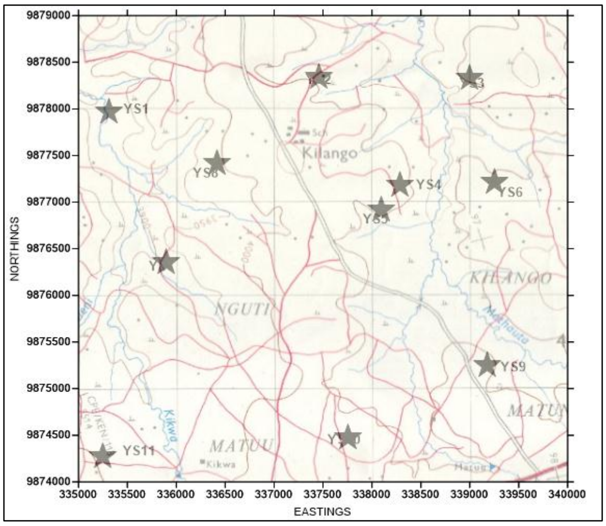

Fig. 2: *Resistivity Stations Overlain on the map of the study area, Star labels shows station positions.*

III. Data Analysis And Discussion

Results from soundings carried out adjacent to existing boreholes were compared with the corresponding borehole logging information and a perfect correlation in terms of number of layers and layer thicknesses was observed for all the four boreholes. Fig. 3 shows a sample case of this comparison.

Apparent resistivity data obtained from Wenner array measurements were subjected to contour plotting using Surfer 10 software with contour interval of 10Ωm (Fig. 4) to qualitatively map the resistivity trends across the subsurface layer lying at approximate depth of 50 m. An anomalous zone to the west of the study area was observed stretching from North West to South Eastern part of the study area.

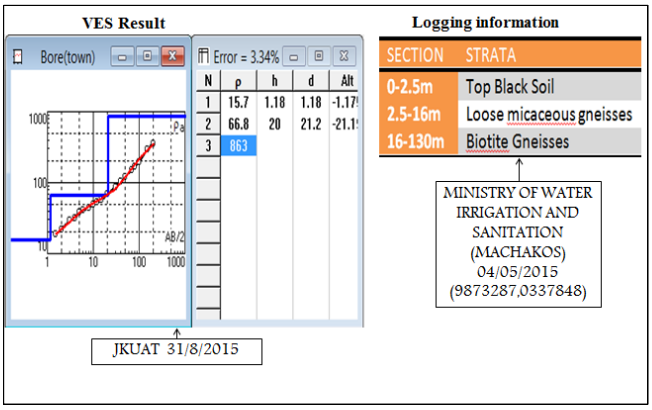

Fig. 3: *Comparision between VES result and borehole logging information*

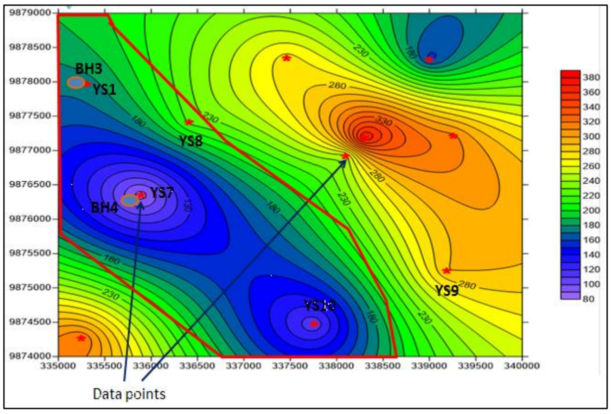

Fig. 4: *Contour plot of apparent resistivity for Wenner array measurement result with a constant separation of 50 m*

VES data from the 11 stations were subjected to digital inversion using IPI2Win software station by station and subsurface formations were mapped together with their corresponding resistivity and thicknesses. Fig. 5 and 6 show the inversion results for soundings YS4 and YS8 respectively among others. Table 1 shows curve types obtained for all the 11 stations and it was evident that the soundings conducted at the western part of the study area had H curve type dominating. This is an indication of an inferred aquifer [6], defined by low resistivity layer bounded by an overburden and resistive basement.

In the investigation of aquifer characteristics transverse resistance (T) and longitudinal conductance (S) were calculated from the inversion result using (1) and (2) for all the vertical electrical soundings over the study area (Table 2). Higher values of the parameter dominated the western zone soundings implying that potential for groundwater is greater at the western part of the study area than it is to the East [7]. Notable trends in the calculated T and S as well as relative thicknesses of the delineated low resistivity layer existed with the western VES results i.e. the values was found to increase towards the North as evident with YS9, YS7, YS8 and YS1 sounding results an indication of increasing borehole yield northwards.

$$S = \sum_{i=1}^{n}\left(\frac{h_i}{\rho_i}\right) = \frac{h_1}{\rho_1} + \frac{h_2}{h_2} + \cdots \frac{h_n}{\rho_n} \qquad (1)$$

$$T = \sum_{i=1}^{n}(h_i\rho_i) = h_1\rho_1 + h_2\rho_2 + \cdots h_n\rho_n \qquad (2)$$

Where h_i, ρ_i is thickness and resistivity of the i^{th} layer of n layered geo-electrical section [8].

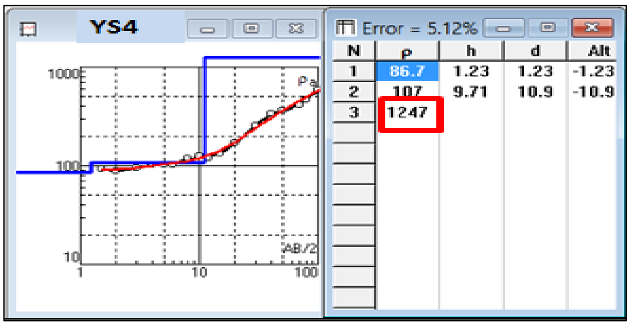

Fig. 5: *Inversion result for YS4 sounding, located at the Eastern side of the study area*

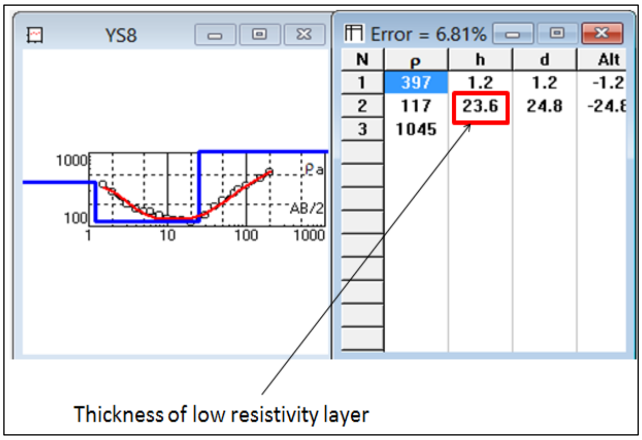

Fig. 6: *Inversion result for YS8 sounding, located at the western side of the study area.*

TABLE I. VES CURVES

VES Station Code	Curve Type analysis	
	Curve nature	***Type***
YS1	$\rho_1 > \rho_2 < \rho_3$	H
YS2	$\rho_1 > \rho_2 < \rho_3$	H
YS3	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	AA
YS4	$\rho_1 < \rho_2 < \rho_3$	A
YS5	$\rho_1 > \rho_2 < \rho_3$	H
YS6	$\rho_1 > \rho_2 < \rho_3$	H
YS7	$\rho_1 > \rho_2 < \rho_3$	H
YS8	$\rho_1 > \rho_2 < \rho_3$	H
YS9	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	KH
YS10	$\rho_1 < \rho_2 < \rho_3$	A
YS11	$\rho_1 < \rho_2 < \rho_3$	A

Curves obtained from analyzed VES over Matuu area.

IV. CONCLUSION

VES correlated well with borehole logs with small variations due to time difference. Wenner plot (r=50m) showed anomalous low resistivity zone (≈130Ωm) stretching from NW to South of study area, indicating the investigated faulted/fractured zone. Results from vertical electrical soundings describes the study area to be of three to four geo-electric subsurface system with generally black top soil, loose/weathered Micaceous gneisses and Biotite gneiss or fresh hard gneiss basement system of which the weathered layer showed characteristics of an aquiferous zone.

Soundings YS9, YS8 and YS1 that existed along the anomalous zone, indicated by analyzed Wenner result, show increasing thickness of low resistivity layer to the north i.e. 11.9m, 23.6m and 74.8m respectively, equally, the calculated values of longitudinal conductance increases to the North i.e. 0.071684, 0.203885 and 0.306062 respectively. The inferred faulted aquifer is approximated to be located at the western part of the study area with average lateral stretch of 1500m and approximate depth of 100m, with its thickness ranging from 10m to about 80m towards the North; an indication of best borehole yields in the North Western part of Matuu-Kilango area. This information forms a knowledge base for sustainable water development in Matuu-Kilango area.

TABLE II. GEO-ELECTRIC PARAMETERS

VES Station Code	Parameters	
	Transverse Resistance (Ωm^2)	***Longitudinal Conductance (mS)***
YS1	11523.12	0.306062
YS2	3275.93	0.088506
YS3	23908.67	0.555043
YS4	1145.611	0.104935
YS5	4023.946	0.097382
YS6	2867.9	0.150078
YS7	880.02	0.434947
YS8	3224.7	0.203885
YS9	2935.598	0.071684
YS10	653.5612	0.586065
YS11	4405.328	0.225382

Calculated geo-electric parameters for aquifer characteristic determination using data from VES over the Matuu study area

ACKNOWLEDGMENT

Special words of gratitude goes to The Society of Exploration Geophysicists Jomo Kenyatta University of Agriculture and Technology Chapter for field work assistance, Department of Physics, Jomo Kenyatta University of Agriculture and Technology for availing survey equipment as well as professional guidance. This work was sponsored by Society of Exploration Geophysicist Foundation.

REFERENCES

[1] E. Mathu, The Mutito faults in the Pan-African Mozambique Belt, Eastern Kenya, In Mason R. (Ed.), Basement Tectonics, Netherlands, Kluwer Academic Publishers, 1992, pp 61-69.

[2] C. Nyamai, E. Mathu, N. Opiyo-Akech and E. Wallbrecher, “A reappraisal of the geology, geochemistry, structures and tectonics of the Mozambique belt in Kenya: East of the Rift System,” African Jouirnal of Science and Technology, Science and Engineering series, 2003, 4(2), pp. 51-71.

[3] P. Mosley, “Geological Evolution of the Late Proterozoic Mozambique Belt of Kenya,” Tectonophys, 1993, 221, pp. 223-250.

[4] M. K’Orowe, M. Nyadawa, V. Sing and R. Rangarajan, “Geo-electrical resistivity and groundwater flow models for characterization of hard rock aquifer system,” Global Advanced Research Journal of Physical and Applied Science, 2012, 1(1): pp 12-31.

[5] E. Odero, M. K’Orowe and J. Githiri, “2D-Euler Deconvolution Technique and Electrical Self-Potential analysis for subsurface structures delineation in Matuu, Machakos County, Kenya,” IOSR Journal of Applied Geology and Geophysics, 2015, 3(6): pp 30-36.

[6] J. Reynolds, An Introduction to Applied and Environmental Geophysics. New York: John Wiley& Sons,1998.

[7] G. Anudu, L. Onuba and L. Ufondu, “Geo-electric sounding for Groundwater Exploration in the Crystalline Basement terrain around Onipe and adjoining areas: South Western Nigeria.” A Journal of Applied Technology in Environmental Sanitation, 2011, 1, pp 38-54.

[8] P. Keary, M. Brooks, I. Hill, An Introduction to Geophysical Exploration, London, Blackwell, 2002.