HYDROGEOLOGICAL SURVEY REPORT

MAITO AREA, MAITO VILLAGE, KAWONGO SUB-LOCATION, KAWONGO LOCATION, YATTA-KWA VONZA WARD, KITUI RURAL SUB COUNTY KITUI COUNTY

JUNE, 2020

DIXON KIPTANUI Consulting Hydrogeologist WD / WRP / 269
17 JUN 2020
P.O. BOX 1635 - 90100
Tel 0734 904046 0725 201655

Sign……………………………………**Date & Stamp**……………………………………

Surveyed and Compiled by:	**CLIENT:**
DIXON KIPTANUI Registered Hydrogeologist Licence No. ***WD/WRP/269*** P.O BOX 16097-00610 NAIROBI	**MAITO SELF-HELP GROUP** **P.O. BOX 85 - 90200** **KITUI** **Cell: +254 721 913 397** **Email: bernard@sasolfoundation.co.ke** **Report Ref: RYKEP/GWSR/2020/6(002)**

PROJECT SUMMARY SHEET

Client		**MAITO SELF-HELP GROUP** **P.O BOX 85 - 90200** **KITUI**
Project		Borehole at MAITO AREA
L.R. No.		
Locality		KAWONGO
WARD		YATTA-KWA VONZA
SUB COUNTY		KITUI RURAL
Selected Borehole Site	**Map Sheet**	163/2 - KAVISUNI
	Coordinates (GPS)-UTM	37M 0373697 9822246
	Elevation (GPS) (m)	947
Projected Water Demand		**20m^3/day**
Main Purpose of Water Use		Domestic

Acknowledgement

We wish to thank various people /Organization for their valuable contribution to this project. Maito Self-help group for working exhaustedly during data collection; Ministry of Agriculture, water and livestock for its valuable technical support on this project; SASOL foundation for being key player in logistic arrangement and supervision of this project's data collection. Special thanks should be given to Rene and Ineke the projects financier who have supported the project by sourcing funds to carry out the survey.

1.0 General Information

This report summarizes the results of hydrogeological/geophysical study carried out to assess the groundwater potential of the project area located in Maito village, Kawongo Sub Location, Kawongo Location, Yatta-Kwa Vonza Ward of Kitui Rural Sub-County, Kitui County. The project area covers approximately **4.5** acres, and is covered on Topographic Map of **Kavisuni** sheet No. **163/2 (1:50,000).** The farm lies at an altitude of about **947m above sea level (asl).**

1.1 Location

The site lies approximately 47km South West of Kitui town via Kitui-Kiusyani-Kawongo, 54km South West of Kitui town via Kathungi-Kavisuni-Kawongo; 19km South of Kiusyani shopping center and 14km North West of Kavisuni shopping center. The maps (google earth & Topo) indicating the approximate location of the selected borehole drilling site is attached here with.

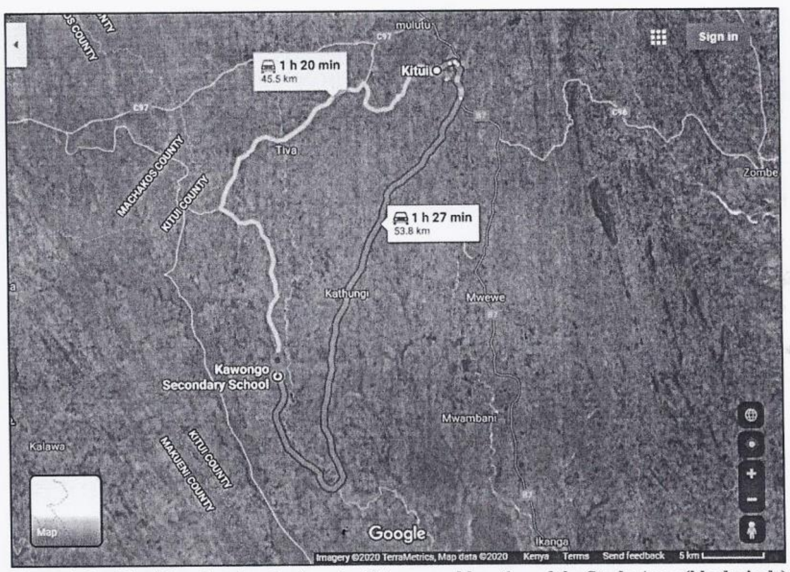


Figure 1 Satellite Map showing the terrain, distance and location of the Study Area (black circle)

2.0 Water Supply and Situation

2.1 Sources of water

The area has a serious water scarcity. The sources of water available to the client include rainwater harvesting, rivers and limited sand dams. The main rivers are Athi and Tiva 10km and 5km W and

E of the study area respectively. The nearby boreholes include Kathome, Kavoo and Nthongoni 6.3km, 12.1km and 8km NNE, SSE and SW respectively. These sources can't meet the availability of sufficient and reliable water sources for human and livestock use thus limiting the economic and social development outcomes for the target population. The objective of this investigation was therefore to establish an optimum location for a borehole which will be near and more reliable.

2.2 Water Demand

It has been estimated that the client requires about 20 cubic meters of water per day. Water from the proposed borehole is to be used for human and livestock purposes.

2.3 Project Justification

Maito Village is located in Kitui County of Kenya. The nearest institutions and social amenities within the area are Maito Primary School, Kawongo Secondary School, Kamanyi Primary and Polytechnic; AIC and VCF churches. The village of over 235 households and over 2800 livestock suffers from a lack of clean water supply and sanitation. The School and the community at large have undergone unheard human miseries due to constant droughts and unreliable rainfalls. Most of the rivers in the area are seasonal, an indication that there is no constant water supply. The village and the schools have undergone a lot of miseries as it has not been able to access enough clean water to the children, women and the larger society. Thus, the community and the children are generally highly vulnerable to health problems since the cleanliness of such waters is not assured.

3.0 Climate, Physiography and Land Use

3.1 Climate

The area receives a mean annual rainfall of about 300mm-400mm. The frequency of the rainfall is unevenly distributed throughout the year and normally falls in two seasons. The first season is expected between March and April while the second is expected between October and December. The actual rate of evapotranspiration is not known. Recharge to the aquifer is expected to be derived from small percentage of the annual rainfall that infiltrates and subsequently percolates into the ground.

3.2 Physiography and Soils

The topography of the area is generally undulating and without hills and ranges. The site is located 2km east and along the foot slopes of Yatta plateau. The top soil comprises lateritic light gray to light brown sandy soils, lateritic soils intercalated with quartzitic pebbles at the drainage channels, though locally, an intercalation of clayey sandy silt and quartzofeldspathic pebbles are observed in the valleys.

3.3 Land Use and Physical Development

The land in this area is mainly used for small scale farming and livestock keeping. The area is also fairly developed with most homes having modern structures. Infrastructure coming up within the area has been hampered by lack of reliable source of water. It is against this background that the client wishes to explore the possibility of sinking a borehole in order to have a convenient source of water.

4.0 Geology and Hydrogeology

4.1 Geology

1. **Local geology**

The subsurface geology of the investigated area comprises of lateritic light gray sandy soils overlying fractured/weathered biotite gneisses below which are the compact granitoid/hornblende gneisses. Under the latter are the crystalline rocks of basement system of rocks tending to massive. Ground water bearing formations are expected to be found within the weathered and fractured zones of the basement rocks.

2. **Structural Geology**

The area has been affected by serious tectonic-metamorphic cycles like folding and faulting in its geological history. According to the geological map covering the area, there are minor and major faults within the vicinity of the project area. The faults and fractures-both micro and macro-could act as excellent conduits for groundwater percolation/transport and subsequent recharge of water to the borehole.

4.2 Hydrogeology and Ground Water Occurrence

1. **Hydrogeology**

The hydrogeology of the area depends on the nature of the rock formation and its degree of secondary permeability factors, their degree of weathering, rate of evapotranspiration and the form and frequency of evapotranspiration. Presence of varying degree of rock tissues plays a big role in groundwater potentiality where secondary rock fissures are, and in absence of these, the rock is massive and barren. An aquifer performs two important functions; storage function and conduit function. The hydrogeology of the project area depends on the nature of the parent rock, geological features, degree of weathering, evapotranspiration rate and frequency of precipitation. Generally, ground water aquifers encountered in the basement rocks are of two types;

i. Faults and Fractures- These are associated with major movement of the earth's crust and often lead to better and potential aquifers with good yields.

ii. Weathered rocks- These are encountered beneath the soil cover, at rock interfaces overlying compact formations as impervious layers. The weathered formation potential depends on porosity of the formation, where clayey nature appears, the yields are minimal.

Water exists in the aquifers under two different physical conditions namely confined and unconfined aquifers. Confined groundwater is isolated from the atmosphere at the point of discharge by impermeable geological formations and is generally subject to pressures higher than the atmospheric pressure. While most aquifers appear at unconfined state and can always be extracted by pumping.

2. Groundwater Occurrence

The occurrence of groundwater depends on geology, rainfall, recharge and weathering. The best aquifers are found when a conjunction occurs of optimum recharge, storage and transmissivity.

5.0 Existing Boreholes and Recharge

Borehole data within a locality is useful in estimating the depth of the proposed borehole, expected water quality and yield.

B/H No	Borehole name	Distance/ Bearing	Total Depth	Water Struck level	Water Rest level	Tested Yield m^3/h	Pumping water level
C-	Kavoo	12.10 km SSE	95.00	-	27.80	48.00	34.50
C-	Nthongoni	7.2km NW	96.00	45.00	06.00	04.00	79.21

Aquifer Properties

5.1 Borehole specific capacities (S) Transmissivity (T) & Specific yield storage Coefficient

The borehole specific capacities have been calculated based on the formula: **S=Q/s** (Driscoll, 1986); Where **Q** is the yield during the pump test and **s** is the draw down i.e. **PWL-WRL.** Transitivity on the other hand is calculated using the formula **T= 0.183 Q/s.** however this formula is applicable where well test data is available in long scale. Logan's formula **T=1.22Q/s** is the best for estimating transmissivity. The area does not have aquifer test and it is difficult to ascertain specific yields, storage coefficients of existing boreholes in the project area. From Driscoll 1986 the following summary of specific yield ranges for earth materials:

Specific capacity = tested yield/(pumping level – water rest level)
Transmissivity = 1.22 x specific capacity x 24hrs

Specific capacities and Transmissivity of existing boreholes

Borehole	Specific capacity(m^2/hr)	Transmissivity(m^2/day)
Kavoo	7.1642	209.7678
Nthongoni	0.0546	1.5998

The Specific capacity ranges from 0.0546 to 7.1642m²/hr while the transmissivity range from 1.5998 to 209.7678m²/day.

5.2 Hydraulic Conductivity (K) and Ground Water Flux

Locations laboratory investigations and isotope methods are very expensive methods and are the best for determining hydraulic conductivity and ground water flux correctly. The results are confined to few locations and they depend on the scale of the investigation method. Rock sample measurements in the laboratory vary from well test results. Ministry of water and irrigation data is also not very reliable.

Hydraulic conductivity is calculated using the formula **K=T/D** where **K** is the hydraulic conductivity, **T** is the transmissivity and **D** is aquifer thickness. **D** is assumed to be 30m. In the ministry of water and irrigation data the start of the aquifer is the one recorded and most of the time, the thickness is not given. Due to this a lot of assumptions will be made in order to calculate the Hydraulic conductivity. Darcy formula is used to calculate ground water flux. It is given as **Q=T.I.W,** where **T** is the transmissivity of the borehole, **I** is the gradient and W is the width. From the above formula **I** is the hydrostatic head. Where **I=0.0375** and the width **(W)** is considered as 1000 meters.

Hydraulic conductivity is calculated using the formula K=T/D
Thus, Ground water flux = Transmissivity x 37.5

Borehole name	Hydraulic conductivity	Ground water flux m^3/day
Kavoo	6.9923	7866.2925
Nthongoni	0.0533	59.9925

The hydraulic conductivity ranges from 0.0533 to 6.9923 m/day and ground water flux ranges from 59.9925 to 7866.2925m³/day.

5.3 Recharge/Discharge Considerations

Given that suitable storage media exist below ground, the mechanisms by which water must reach it also affect aquifer potential. Obviously if no rainfall or river flow is able to percolate to a sandy weathered and fractured basement aquifer due to the presence of an aquifer (impermeable layer) probably clay, the actual potentials are very low. Both basement rocks and volcanic systems suffer the same limitations so far as recharge is concerned. If rainfall is low the volume of water which may eventually percolate to a suitable aquifer is likely to be relatively small and possibly mineralized due to high evaporation rate.

Percolation is dependent on soil structure, vegetation cover and the erosion state of the parent rock. Rocks which weather to clayey soils will naturally inhibit percolation (such as black cotton soil) conversely the sandy soils resulting from the erosion of some basement rocks are eminently suited to deep swift, percolation. Recharge is the term applied to the whole mechanism and includes all the aspects of parent geology, effective rainfall and percolation. Some aquifer systems are recharged by water falling a substantial distance away. Percolation takes place in the higher elevations and this reaches the faults from where it is distributed into permeable aquifers.

5.4 Assessment of Availability of Ground Water

Regarding assessment of available ground water, the following conclusions can be made:

i). Assuming an abstraction of about $20m^3$/day for all the boreholes in the area, then the abstraction per day can be estimated to be about $100m^3$ /day

ii). The available ground water can be calculated as the available through-flow (ground water flux) less the amount of water abstracted per day

5.5 Analysis of Reserve and Ground Water Level Evolution

An adequate estimate of the availability of ground water in storage beneath an area requires determination of the ground water basin boundaries, both vertical and horizontal, and of aquifer dimensions and characteristics. Such an analysis requires careful and accurate determination of the aquifer characteristics, GIS techniques to indicate the extent of the aquifer in question and accurate pump test to determine the capacity of the aquifer(s).

In addition, recharge and discharge must be fairly quantified. It is difficult to accurately determine the storage of ground water in the underlying aquifer. To determine this, it required a very intensive exercise and accurate data that will show the boundaries and its extend both horizontal and vertical. So many techniques are also involved. Ground water lowering was reported after 1950. From the existing bore holes data in ministry of water and irrigation, there is evidence of lowering of water level in the shallow aquifers. This may be an indication that the shallow aquifers are being depleted although a thorough study is required to prove this beyond any reasonable doubts.

6.0 Geophysics

Several geophysical methods are available to assist in the assessment of geological sub surface conditions. In the present survey the resistivity method also known as the (geo electrical method) has been used. **Vertical Electrical Soundings (VES)** are carried out to probe the cautions at such anomalous zones within the sub-surface and to confirm the existence of deep ground water. The techniques are described below.

6.1 Basic principles of the resistivity methods

The electrical properties of the upper parts of the earth's crust are dependent upon the lithology. Porosity and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivities than unsaturated and dry rocks. The higher the porosity of the saturated rocks the lower its Resistivity. The higher the salinity of the saturating fluids, the lower the resistivity. The presence of clays and conductive minerals also reduce the resistivity of the rock.

6.2 Vertical Electrical Soundings (VES)

Vertical Electrical Soundings were carried out to probe the electrical properties and depth to sub surface layered formations below the site of measurement at the most anomalous zones. When carrying out a resistivity sounding electric currents is led to the ground by means of two electrodes and the potential field generated by the current measured. The separation between the electrodes is step – wise increased (in what is known as Schlumberger array) observed resistivity values are plotted in log-log paper and the graph obtained depicts resistivity variation against depth. This graph can be interpreted with aid of a computer and the actual resistivity lying of the sub soil is obtained. The depths and resistivity values provide the hydro geologist with information on the geological layering and thus the occurrence of ground water.

6.3 Electrical Resistivity Method

The method of vertical electrical sounding gives a vertical profile of rocks at given point by probing the changes of the ground resistance with depth by introducing an electric current at known voltage. Introduction of an electric current into the ground creates an electric filed whose potential difference can be measured. Assuming the ground to homogeneous, division of the measured potential difference (**ΔV**) by the current (**I**) will give the resistance of the ground as a conductor. As a property of the ground (rocks) its resistivity is obtained by multiplying the measured resistance with predetermined coefficient (**K**) for various depths of probing. The depths of probing are determined by the separation of the current electrodes. The theoretical expression leading to the computation of the resistivity of the rock as a conducting material is given by the following formula:

$$\rho_a = K * \Delta V / I$$

Where ρ_a - Apparent resistivity in ohm-meters,
ΔV - Potential difference in volts,
I - Current in amperes,
K - Geometric coefficient dependent upon the sounding configuration.

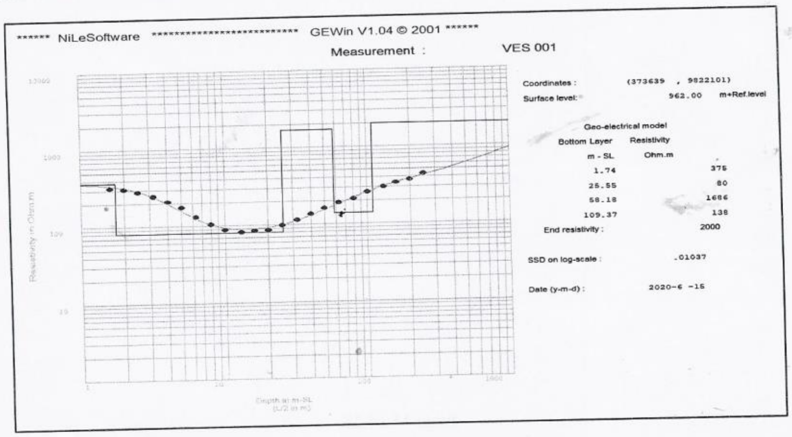
In the present survey, the Schlumberger configuration was applied in the vertical electrical sounding in which the **K** values had been determined a priori for use in the field. That is both the current electrodes and the potential electrodes were moved at predetermined distances from the point being probed. The further the current electrodes were separated the deeper the depth of probing. An intensive geo-electrical profiling was carried out within the selected areas and several points picked and sounded as below. **Three (3)** Vertical Electrical Resistivity sounding designated as **VES 001, VES 002** and **VES 003** were carried out in the farm.

6.4 Interpretation of Field Geophysical Data

6.4.1 Resistivity Data of VES 001/RC-022/2020

AB/2	ρ̇(Ωm)	AB/2	ρ̇(Ωm)
1.6	321	**25**	93
2	312	**32**	108
2.5	284	**32**	102
3.2	246	**40**	122
4	211	**50**	142
5	176	**63**	170
6.3	130	**80**	189
8	105	**80**	166
10	88	**100**	201
13	82	**130**	231
16	85	**160**	263
16	80	**200**	286
20	81	**250**	340

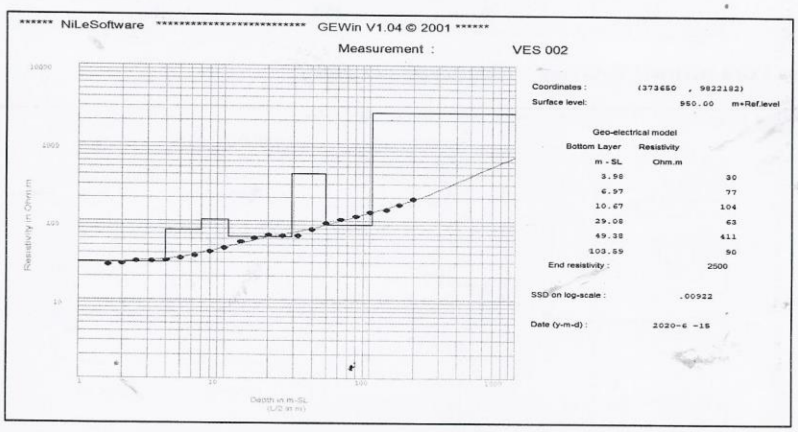
6.4.2 Geo-electrical Modelling of VES 001/RC-022/2020



6.4.3 Resistivity Data of VES 002/RC-023/2020

AB/2	ṗ(Ωm)	AB/2	ṗ(Ωm)
1.6	28	**25**	96
2	29	**32**	96
2.5	31	**32**	94
3.2	31	**40**	113
4	32	**50**	137
5	34	**63**	151
6.3	37	**80**	166
8	41	**80**	184
10	46	**100**	207
13	55	**130**	225
16	61	**160**	258
16	89	**200**	305
20	97	**250**	

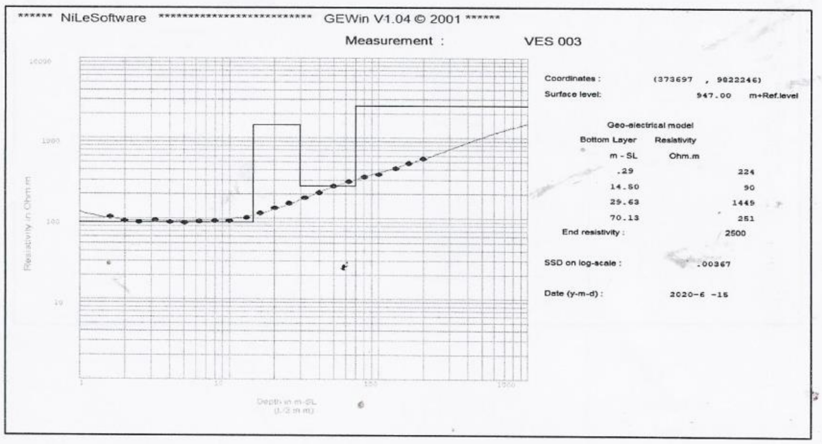
6.4.4 Geo-electrical Modelling of VES 002/RC-023/2020



6.4.5 Resistivity Data of VES 003/RC-024/2020

AB/2	ρ̇(Ωm)	AB/2	ρ̇(Ωm)
1.6	104	**25**	112
2	94	**32**	132
2.5	91	**32**	121
3.2	95	**40**	140
4	90	**50**	168
5	89	**63**	190
6.3	92	**80**	219
8	93	**80**	198
10	94	**100**	212
13	103	**130**	253
16	117	**160**	292
16	85	**200**	335
20	98	**250**	

6.4.6 Geo-electrical Modelling of VES 003/RC-024/2020



6.4.7 Hydrogeological Interpretation of Geophysical Data

Resistivity Curve	Elevation (m)	Depth (m)	Resistivity (Ohm)	Interpretation
RC-022/2020	962	0.00-1.74	375.00	Lateritic red brown sandy soils
		1.74-25.55	80.00	Lateritic/quartzites formation
		25.55-58.18	1686.00	Hard/compact granitoid gneiss
		58.18-109.37	138.00	Fractured biotite/granitoid gneiss
		99999.00	2000.00	Hard/compact granitoid gneiss
RC-023/2020	950	0.00-3.98	30.00	Lateritic light gray sandy soils
		3.98-6.97	77.00	Wet weathered biotite gneiss/schist
		6.97-10.67	104.00	Fairly weathered biotite gneiss
		10.67-29.08	63.00	Weathered biotite gneiss
		29.08-49.38	411.00	Hard biotite gneiss
		49.38-103.59	90.00	Fairly fractured biotite gneiss
		99999.00	2500.00	Hard/compact granitoid gneiss
RC-024/2020	947	0.00-0.29	224.00	Lateritic light gray sandy soils
		0.29-14.50	90.00	Weathered biotite gneiss/schist
		14.50-29.63	1449.00	Compact biotite/granitoid gneiss
		29.63-70.13	251.00	Weathered/fractured granitoid gneiss
		99999.00	2500.00	Hard/compact granitoid/biotite gneiss

7.0 Ground Water Quality

Generally, ground water chemistry from Mozambique Mobile Belt varies from place to place due to the chemical constituents of various rock units. Water from the borehole need be tested in a recognized lab to ascertain if the quality meets the recommended level by WHO. Some of the factors which determine the degree of mineralization of ground water are as follow.

7.1 Evaporation and Transpiration

Direct evaporation by the heat of the sun and preferential up take of certain minerals ions by plants can in certain environments, lead to hardness of water and salinity.

7.2 Dissolution of evaporates

The process of evapotranspiration may in arid conditions lead to the precipitation of salts in the insaturated zone. These salts may then be carried down to the ground water stone during periods of rain; thus, leading to high ion concentrations in space and time.

7.3 Dissolution host rock

Given relatively long residence times and fairly ambient temperatures in ground water systems, progressive salinity or mineralization of ground water can be expected via the solution of various constituents of the host rock. This will vary according to local structures (which may speed the passage of water through an aquifer by means of faults etc.& so limit retention time) local climate and so on. Considering the above factors, the quality of water in our project area is expected to vary from one bore hole to the other but generally the water has a high fluoride exceeding the WHO limit.

8.0 Impacts of Proposed Drilling Activity

In our study area, the rock formations are basement in nature. Basement aquifers are localized, therefore drilling activity within the study area shall have no impact on the aquifers, water quality, and the abstractors and neither shall there be a likelihood of coalescing cones of depression. It shall have no negative implications for other ground water users.

8.1 Impacts on local aquifer's quantity and quality

The sustainability of water quality depends on the level of abstraction and recharge rate. If ground water is abstracted at a rate greater than its natural replenishment rate, then the water table lowers and the project will not be sustainable. Based on the yields of the boreholes in the area, the proposed abstraction of $20m^3$/day based on a 10-hour pumping regime is not expected to have any major impact on the aquifers, as the aquifer is expected to be quite productive. The water quality will mainly depend on the host rock and construction design. Overall, the expected impacts resulting from the borehole to the environment and their mitigation measures will be adequately addressed by the Environmental Impact Assessment Study to be conducted

8.2 Impacts on existing boreholes in the area

It is noteworthy that all the boreholes examined in this study area are more than 1km of the proposed drill site. Therefore, we do not expect any negative impacts on any other existing borehole within the vicinity.

9.0 Conclusions and Recommendations

9.1 Conclusions

Based on the previous hydrogeological studies, geology of the project area, the collected geophysical data and the prevailing hydrogeological conditions, it can be concluded as follows:

1. The region has low to moderate prospects of striking groundwater within the investigated sites of the farm(s).
2. There exist shallow water/perched aquifers (between 1.5m-30m) bgl in the area which can be assumed to depend on local weathering and expected to vary yields on precipitation and ambient temperatures.
3. The main aquifers within 12km radius of the study area are likely to be found between 32m-42m bgl, an observation made from drilled boreholes. Moreover, geophysical data analysis and modelling has identified additional aquifers at 70m bgl and 110m bgl.
4. The entire area has a fairly flat and or undulating topography, a positive factor to recharge during precipitation.
5. Water from this borehole is expected to be of good quality as there are no visible groundwater potential threats and/or contaminants.
6. The estimated yield of the borehole is expected to vary between **2.00**m^3/hr to **5.00**m^3/hr.

9.2 Recommendations

1. That, a borehole is recommended to be drilled at the site **VES 002/RC-023/2020** to a maximum depth of **150** meters or until fresh basement is encountered.
2. The borehole should have a diameter of at least **8″ or 203mm.**
3. It should be lined with appropriate casings and screens of at least **6″ or 152mm**.
4. It should be protected from possible sources of contamination by grouting a certain length of the borehole from the ground surface.
5. The borehole should be properly gravel-packed with **(2-4) mm** gravel pack material to enhance the yield. The gravel pack should be well-rounded to rounded siliceous sands that must be clean and contain no more than 5% non-siliceous material and no organic material.
6. The borehole should be properly developed for **(3-4) hours** to repair, clean and enhance/alter the physical characteristics of the boreholes.
7. Upon completion, the borehole should be fitted with an airline/piezometer and a master meter to facilitate monitoring of static water level and groundwater abstractions respectively.
8. A **two (2) liters** water sample of this water is to be collected in a clean container and be taken to any competent water testing authority for a full chemical, physical and bacteriological analysis.
9. It is a legal requirement, stipulated in the **Water Act (2016)**, that the client applies for a ground water permit from the **Water Resources Authority (WRA)** to sink a borehole. For this purpose, three signed copies of the present report must be submitted to the authority for examination.

10. The recommended site is known to **Bernard Ndunda Muendo** (Contact – 0721913397) and the following group members;

1. Gibson Musau – 0727309176
2. Poeth Ngina – 071088290
3. Mary James – 0715297243
4. Daina Mutisya – 0721654826
5. Kanini Mwanzia – 0704980421
6. Bernice Mutinda – 0725399138
7. Mutinda Kingoto – 0721656588
8. Ndululu Nzioka – 0721627836
9. Taabu Matu – 0707765283
10. Stellah Isaac - 0721896185

====APPENDIX====

1.0 Drilling Methods/ Technique

Drilling should be carried out with an appropriate tool-either percussion or rotary machine. The latter are considerably faster. Geological rock samples should be collected at 2 meters' intervals. Struck and Rest water levels and if possible, estimate of the yield of individual aquifer encountered should also be noted.

2.0 Borehole Design

The design of the well should ensure that screens are placed against the optimum aquifer zones. An experienced works drilling consultant/hydro geologist should make the final design, and should make the main decision on the screen setting.

3.0 Casings and Screens

The well should be cased and screened with good quality screens, considering the depth of the borehole, it is recommended to use steel casing and screens of 153/6" diameter. Slots should be maximum 1mm in size. We do not encourage the use of torch-cut steel well casing as screens. In general, its use will;

a) Reduce well efficiency (which leads to lower yield).
b) Increase pumping costs through greater draw down;
c) Increase maintenance costs and eventually
d) Reduction of the potential effective life of the well.

4.0 Gravel Pack

The use of gravel pack is recommended within the aquifer zones, because the aquifer could contain sands or silts which are finer than the screen slots size. An 8" (203mm) diameter borehole screened at 6" (153mm) will leave an annular space of approximately 1", which should be sufficient. Should the slot size chosen to be too large, the well will pump sand thus damaging the pumping plant and leading to gradual siltation of the well. The grain size of the gravel pack should be having an average of 2-4mm.

5.0 Borehole Construction

Once the design has been agreed, constructions can proceed. In installing screens and casing, centralizers at 6 meters interval should be used to ensure centrality within the borehole. This is particularly important to insert the artificial gravel pack all around the screen. If installed, gravel packed sections should be sealed off top and bottom with clay (2m). The remaining annular space should be backfilled with an insert material and the top five meters grouted with cement to ensure that no surface water at the well head can enter the well and thus prevent contamination.

6.0 Borehole Development

Development aims at;

a) Repairing the damage done to the aquifer during the course of drilling by removing clays and other additives from the borehole walls.

b) Secondly, it alters the physical characteristics of the aquifer around the screen and removes fine particles.

We do not advocate the use of over pumping as means of development since it only increases permeability in zones, which are already permeable. Instead, we would recommend the use of air or water jetting, or the use of the mechanical plunger, which physically agitates the gravel pack and adjacent aquifer material. This is an extremely efficient method of developing and cleaning wells.

Well development is an expensive element in the completion of a well, but is usually justified in longer well life, greater efficiencies, lower operational and maintenance costs and a more constant yield. Within this frame the pump should be installed at least 2m above the screen.

7.0 Borehole Testing

After development and preliminary tests, a long duration well test should be carried out on all newly completed wells. This gives an indication of the quality of drilling, design and development. It also yields information on aquifer parameters which are vital to the hydro geologist. A well test consists of pumping a well from measured start level (water rest level (WRL) at a known or measured yield, and simultaneously recording the discharge rate and the resulting drawdowns as a function of time. Once a dynamic water level (D.W.L) is reached, the rate of flow to the well is equal to the rate of pumping. Towards the end of the test a water sample of 2 liters should be collected for chemical analysis. The duration of the test should be 24 hours; followed by recovery test until the initial W.R.L has been reached (during which the rate of recovery to WRL is recorded. The results of the test will enable the hydro geologist to calculate the following;

a) Optimum pumping rate,
b) Installation depth,
c) Draw down for a given discharge rate.
d) Pump size.

8.0 Water Quality

8.1 Classifications of Ground Water Quality

According to WHO (1984) water for human consumption should have a maximum TDS of 1000mg/1itre, see Table 1.0 below

Table showing WHO Water Quality Classification

TYPE OF WATER	TDS (MG)
Fresh	< 100
Blackish	1,000 – 10,000
Saline	10,000 – 100,000
Brine	>100,000

8.2 A Guideline for Evaluating Water Quality

The guidelines given in Table 2.0 below are used in evaluating the quality of groundwater.

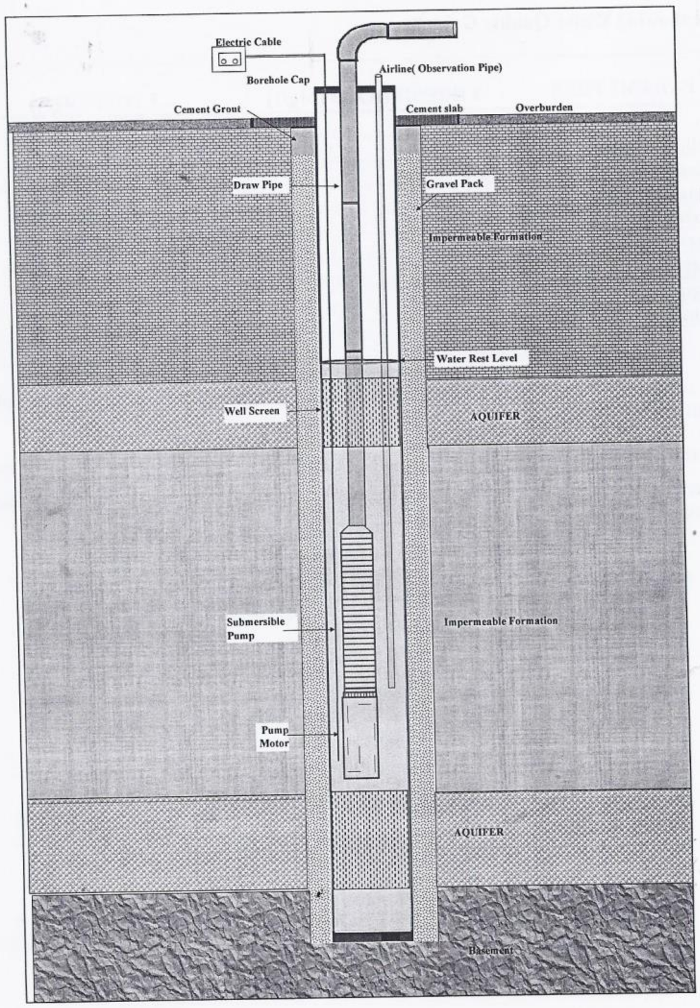
Table showing Water Quality Guidelines

PARAMETERS	THRESH HOLD (Mg/1)	LIMIT (Mg/1)
TDA	2500	5000
Calcium	500	1000
Magnesium	250	500
Sodium	1000	2000
Bicarbonate	500	1500
Chloride	1500	3000
Fluoride	1	6
Nitrate	200	400
Sulphate	500	1000
PH	6.0 – 8.5	5.6 – 9.0

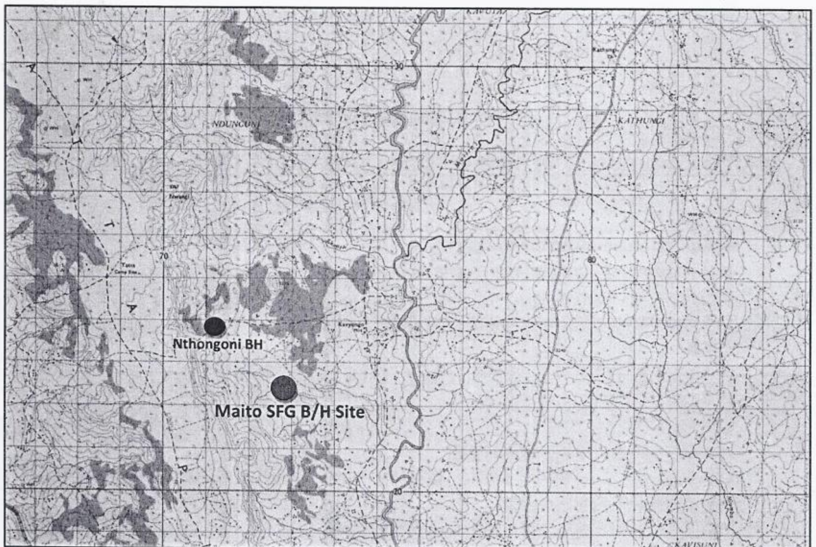
Water from the proposed boreholes should be analyzed to ascertain its chemical, bacteriological suitability before it is made available for domestic use.

9.0 Water Quality Protection

In order to protect the quality of the water, the borehole should be located as far as possible from all sources of danger e.g. septic tanks, pit latrines, polluted water bodies etc.



Schematic design of borehole completion



Section of Topographic Sheet **163/2-IKANGA** showing the location of the borehole **(red circle)**