(10)

GEOPHYSICAL AND HYDROGEOLOGICAL INVESTIGATIONS

For

MUTONYOK WOMEN GROUP
P.O. BOX 518
ISIOLO

In

SUPALEK (LORUBAE) VILLAGE, WASO AREA OF SAMBURU EAST DISTRICT

REPORT NO. GML - 588/11

JULY 2011

Groundwater Max Ltd.
P. O. Box 9419-00300,
Nairobi
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Groundwater Resources Investigations and Environmental Management Solutions

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1.0 INTRODUCTION

MUTONYOK WOMEN GROUP *is* located in Supalek(Lorubae) village, Archers Post sub location in Waso location of Waso Division in Samburu East District.

The local community comprises of about 1000 people.

The main activities of the self help group are promotion of tourism activities, planting trees and other self help activities.

Presently the local community gets their water supply from the highly polluted and contaminated river Ewaso Nyiro.

This river whose water is always colored and contaminated is also infested with deadly crocodiles which have eaten children and goats.

This has left the community to rely on other areas to fetch water which sometimes is not fit for human consumption.

Therefore the local community is in dire need of clean and portable water.

The group therefore has applied for 20 cubic metres of water per day for domestic purposes from the proposed well.

It is in this regard that ***The Samburu Project*** commissioned Groundwater Max Ltd to carry out a geophysical and hydrogeological survey in the project area to find the best site for a possible well development.

2.0 TERMS OF REFERENCE

The consultants were required by the client to carry out a hydrogeological survey of the project area and subsequently present a hydrogeological report under the following terms:-

(i) Compile all the available hydrogeological, geological, geophysical and hydrological data of the area and its environs.

(ii) Carry out fieldwork involving a resistivity geophysical survey of the project area subject to site conditions.

(iii) Analyze all the above data to assess groundwater potential of the project area.

(iv) Select the most suitable well site within the project area subject to the result in i – iii above, accessibility, and the requirements of the water Act.

(v) Compile and submit to the client a comprehensive report which shall include all the details of the above investigations and the consultant's recommendations.

3.0 BACKGROUND INFORMATION

3.1 Geographical Location

The group is located within Supalek (Lorubae) village in Archers post sub location of Waso location of Waso Division of Samburu East District.

The selected well site is on latitudes 00° 37' 51" South and longitudes 37° 39' 17" East on approximate elevation of 843 meters above sea level.

3.2 Rainfall and Climate

The area displays two main rainy seasons lasting from March to May and mid October to mid December. Mean annual rainfall is about 500 millimeters.

Temperatures are highest in the months of January to mid March before the rainy season and lowest in the month of July to August.

The climate is arid and semi arid in character with seasonal dry and wet periods.

3.3 Current Land Use

The present land use is for grazing where the land under grass, scattered shrubs and acacia trees.

Livestock keeping especially goats is the economic mainstay of the local community.

3.4 Approximate Water Demand

A water demand of about 20,000 liters of water per day is estimated to be enough for the local community domestic purposes.

4.0 GEOLOGY

4.1 Regional Geology

The regional geology is predominantly Basement where within the seasonal valleys you get sandy deposits.
However these drainage systems are separated by Eros ional resistant hills.

Under the sandy sediments are the metamorphic rocks represented in the project area by gneisses and schist's.

4.2 Geology of Project Area

The geology of the project area consists of the sandy sediments which are weathering products from basement rocks. Exposure of gneisses and schist's are seen in the gullies. The sandy sediments are locally used in the construction industry.

5.0 WATER RESOURCES

5.1 Surface Water Resources

Surface water in the general area is only found in the constructed pans and dams which dry up during dry periods.
Surface water is also found in the Ewaso Nyiro River.

5.2 Groundwater Resources

Groundwater occurrence depends mainly on the varied rock conditions, physiographic nature of the study area, the permeability and porosity of the rock formations and the weathering and fracturing of the host rocks.

Most of the aquifers in the project area are confined.

The area has scanty groundwater information as the attempts made in drilling of boreholes and wells have been minimal. However groundwater is locally sand scooped in some dry river beds.

5.3 Discharge/Recharge considerations.

Storage, porosity and permeability form the most important factors in groundwater discharge and recharge.

The suitability of a host rock material as aquifers will depend very much on weathering formation characteristics (cracks, joints).

The mechanism of groundwater recharge and rate of replenishment will depend on soil structure, vegetation cover and the erosion state of the parent rock.

The primary recharge source of the aquifers in the project area is lateral inflow from the catchments areas of water storage.

Secondary replenishment of the aquifers is partly through infiltration and percolation of the annual precipitation through open fissures to the aquifers zones after evapo-transpiration deductions.

Weathered and fractured zones as well as buried valleys, fault zones and open joints are preferred media for groundwater movement.

5.4 Previous Groundwater Development/Hydrogeology.

No previous well or borehole have been drilled in similar geological conditions in the general project area.

5.5 Aquifer Properties

Due to unavailability of boreholes close to the vicinity of the project area, it is difficult to compute Transmmissivity and other aquifer properties of the area.

6.0 GROUNDWATER QUALITY

Groundwater Chemistry from Metamorphic rocks varies from place to place due to the chemical constituents of various gneisses. Some of the factors which determine the degree of mineralization of groundwater in metamorphic rocks are as follows.

(i) **Evaporation and Transpiration**
Direct evaporation by the heat of the sun and preferential uptake of certain mineral ions by plants can lead to hardness of groundwater and increase in salination.

(ii) **Dissolution of Evaporites**
The process of evapotranspiration may in arid and semi arid conditions lead to the precipitation of salts in the unsaturated zones. These salts may then be carried down to the groundwater store during periods of rain, thus leading to high concentrations in space and time.

(iii) **Dissolution of host rock**
With long contact periods and high temperatures in groundwater systems, progressive salinity or mineralization of groundwater can be expected through the solution of various constituents of the host rock.

This will vary according to the local geological structures which may speed the passage of water through an aquifer by means of faults etc and so limit retention time and also local climate.

Considering the above factors the quality of water in our project area is expected to vary from one borehole to the other but generally boreholes which are not very deep have low fluoride content than very deep ones.

It is advisable a sample of water obtained from the completed borehole be submitted for physical, chemical and bacteriological analysis before it is made available for use.

The water quality standards vary from country to country and are determined by the intended use of water. Drinking water standards are based on the toxicity of certain elements such as lead, Arsenic, Nickel or Selenium, while Nitrate levels are set by the tolerance levels of instants as it causes conditions known as blue baby syndrome at levels exceeding 10mg/l.

Table 2 below provides the world organization (WHO) guidelines.

Quality Variable	Measuring Unit		WHO Guideline	Comments
Colour	Mg/l	Pt	15TCU	
Hardness	Mg/l	$CaCO_3$	500	
Ph	PH	Units	6.5 – 8.5	
Turbidity	NTU		5	
Arsenic	As	µg/l	10	Toxic in excess e.g. bronchial disease
Lead	Pb	µg/l	10	Toxic to animals
Selenium	Se	µg/l	10	Toxic in excess
Aluminum	Al	Mg/l	0.2	Soluble Al salts exhibit neurotoxicity
Ammonia	NH_3	Mg/l	1.5	Toxic particularly to aquatic organisms
Boron	Bo	Mg/l	0.3	Toxic in high concentration to plants
Calcium	Ca	Mg/l	NS	No standard
Chloride	Cl	Mg/l	250	
Fluoride	Fl	Mg/l	1.5	Dental and Skeletal fluorosis
Iron	Fe	Mg/l	0.3	High concentrations toxic to children
Magnesium	Mg	Mg/l	0.1	May cause diarrhea in new users
Manganese	Mn	Mg/l	0.1	
Nitrate	NO_3	Mg/l	11	Infant blue baby syndrome
Potassium	K	Mg/l	NS	No standard
Sodium	Na	Mg/l	200	Chronic, long term toxic
Sulphate	SO_4	Mg/l	250	Taste, odors, cathartic effects
Zinc	Zn	Mg/l	3	Toxic in excess
Total Coliforms	Per	100ml	Nil	
Feacal Coliforms	Per	100ml	Nil	
Sulphide	H_2S	µg/l	Undetectable	

7.0 THE RESISTIVITY METHOD

The chapter will first briefly present the basic theoretical elements of the resistivity method, after which the application of this method to the project area is discussed.

A great variety of geophysical methods are available to assist in the assessment of geological subsurface conditions. In the present survey, the resistivity method (also known as the geo-electrical method) has been used.

The main emphasis of the fieldwork was to determine wherether there are fractured and weathered zones within the Basement rocks for any water bearing zones. This information is obtained in the field using resistivity method: mainly Vertical Electrical Sounding (VES).

The resistivity profiling method is used to trace lateral variation in resistivity to locate fractured and fault zones while, the VES probes the resistivity layering below the site of measurement. These are described below.

7.1 Basic Principles

The electrical properties of rocks in the upper part of the earth's crust are dependent upon the lithology, porosity, 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 rock, the lower its resistivity. The presence of clays and conductive minerals also reduce the resistivity of the rocks. The resistivity of earth materials can be studied by measuring the electrical potential distribution produced at the earth's surface by an electric current that is passed through the earth.

The resistance R of a certain material is directly proportional to its length L and cross-section area A, expressed as:-

$$R = Rs * L/A \text{ (in Ohms)}$$

Where Rs is known as the specific resistivity, characteristic of the material and independent of its shape or size. With Ohm's Law.

$$R = dV/I \text{ (in Ohm)}$$

Where dV is the potential difference across the resistor and is the electric current through the resistor, the specific resistivity may be determined by:-

$$R = (A/L) * (dV/I) \text{ (in Ohm)}$$

7.2 Vertical Electrical Soundings (VES)

When carrying out a resistivity sounding, current is let into the ground by means of two electrodes. With two other electrodes, situated near the centre of the array, the potential field generated by the current is measured.

From the observations of the current strength and the potential difference, and taking into account the electrodes separations, the ground resistivity can be determined.

While carrying out a resistivity sound the separation between the electrodes is stepwise increased (in what is known as a Schlumberger Array), thus causing the flow of current to penetrate greater depths. By plotting the observed of resistivity values against depth on double logarithmic paper, a graph of resistivity Vs depth is obtained.

This graph can be interpreted with the aid of a computer, and the actual resistivity layering of the subsoil is obtained. The depths by resistivity values provide the hydrogeologist with information on the geological layering and thus the occurrence of groundwater.

7.3 Fieldwork

Fieldwork was carried out on July 20, 2011. The field investigations comprised observation of general topography, drainage, geological set up, and carrying out geophysical investigations.

The eventual selection of the drill site was based on accessibility, existing infrastructure, geophysical results and proximity to the existing boreholes. The Vertical Electrical Sounding measurements were carried out with an ABEM Tarrameter 1000 resistivity instrument.

7.4 Results and Interpretations

The study shows that the sub-surface geological layout in the project area is not uniform and comprises several layers (formations). Underlaying the area, are medium resistivity layers suggesting a low clayey component in the formations. Drilling at the proposed drill-site is expected to penetrate the formations including, sandy soils and gravel, weathered Basement, Fractured basement and Fresh Basement.

The expected geological stratigraphy based on the geophysical curve interpretation comprise of semi-consolidated, sometimes collapsible sandy formations intercalated with clay.

One Vertical Electrical Sounding (VES) was conducted within the project area.

The field data and the graph of the VES is presented in the appendix.

The geo-electrical interpretation is summarized in the table below.

VES 1

Depth Interval (m)	Apparent Resistivity (ohm-m)	Expected Geological Formation	Remarks
0-1.6	6	Sandy soil	Dry
1.6 –3.2	7	Sandy sediments	Dry
3.2- 16	18	Fractured Basement	Moist
16 – 50	60	Fractured Basement	Wet
50 Downwards	500	Fresh Basement	Dry

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

From the desk study, field observations and subsequent geophysical data and interpretations, the following conclusions were made:-

(i) The condition of groundwater occurrence is characterized by the existence of sandy sediments, weathered basement and fractured Basement.

(ii) That the expected yield from the well estimated about 1.0 cubic meters per hour will be enough to satisfy the community water demand of about 20,000 liters per day.

(iii) That after the completion of the drilling operations the well should be equipped with a hand pump.

(iv) That water from the well is expected to be of acceptable quality.

However it is advisable that a water sample from the well should be taken for physical, chemical and bacteriological analysis before the water is put into use in a competent and independent laboratory.

8.2 Recommendations

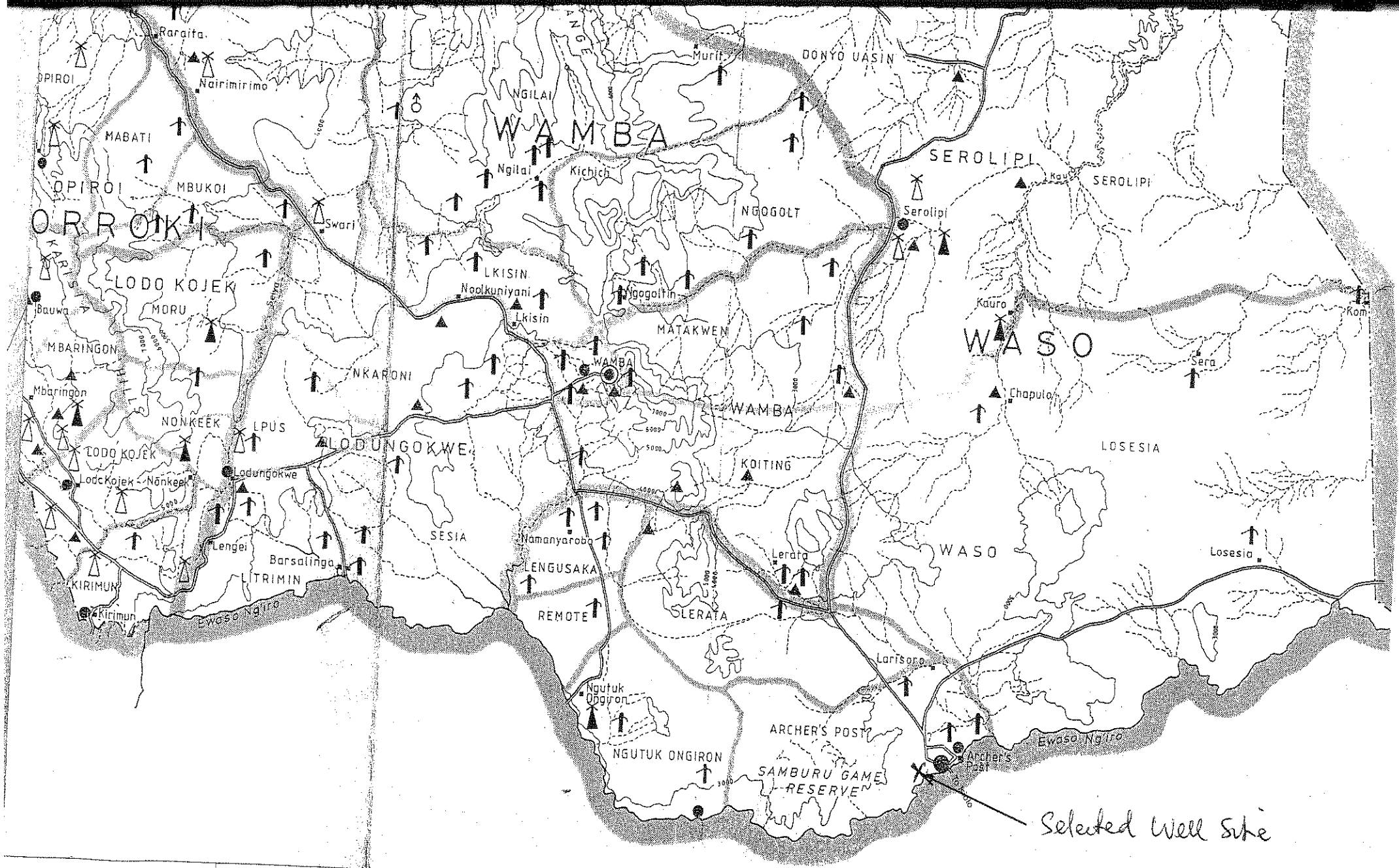
(i) A well be drilled at the location ***VES 1*** shown on the topographical map sheet extract to a maximum depth of ***70*** metres. The site is known to Lukas Lekwale of the Samburu project.

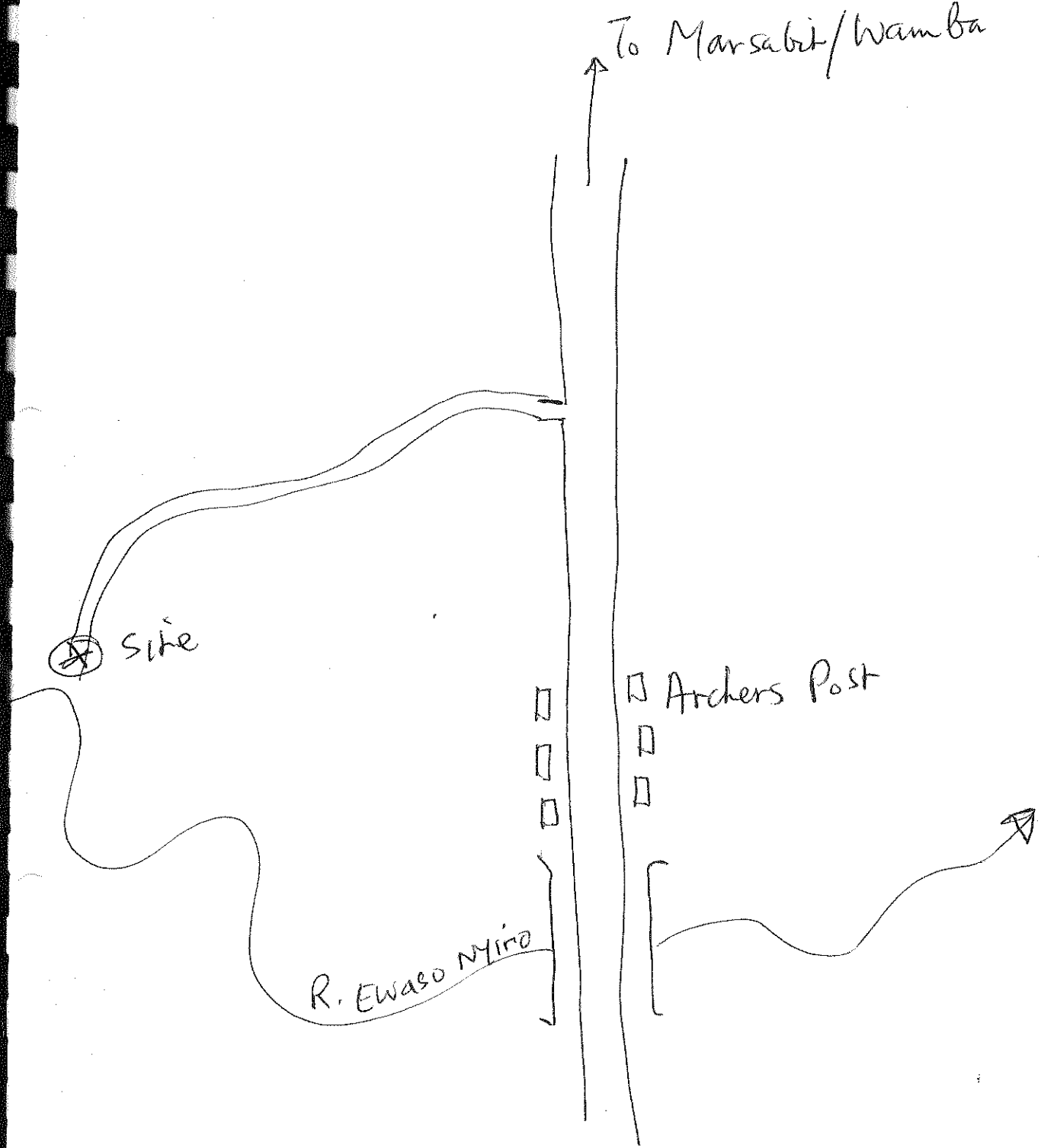
(ii) That the well should be drilled with a standard diameter, and cased as appropriate.

(iii) The well should be properly developed, gravel packed and sealed to avoid any contamination from shallow aquifers.

(iv) The well should then be fitted with a water master meter and an airline for measuring groundwater abstraction and monitoring water levels respectively.

NB: The client should note that before drilling the well, an authorization to drill should be obtained from the Water Resources Management Authority and subsequently a groundwater abstraction permit should be obtained after drilling the borehole from the same organization.


Raraita
Nairimirimo
OPIROI
MABATI
OPIROI
MBUKOI
ORROKI
Swari
LODO KOJEK
MORU
Bauwa
MBARINGON
Mbaringon
NONKEEK
LPUS
LODO KOJEK
LodKojek
Nonkeek
Lodungokwe
LODUNGOKWE
Lengei
Barsalinga
KIRIMUN
Kirimun
LTRIMIN
Ewaso Ngiro
SESIA
NKARONI
Ngilai
WAMBA
Kichich
NGILAI
Murit
DONYO UASIN
LKISIN
Nooikuniyani
Lkisin
Ngogoltin
NGOGOLT
MATAKWEN
WAMBA
WAMBA
Namanyaroba
LENGUSAKA
REMOTE
KOITING
Lerata
LERATA
Ngutuk Ongiron
NGUTUK ONGIRON
ARCHER'S POST
SAMBURU GAME RESERVE
Larisoro
Archer's Post
Ewaso Ngiro
Serolipi
SEROLIPI
Kauro
SEROLIPI
WASO
Kauro
Kom
Sera
Chapulo
LOSESIA
WASO
Losesia
Selected Well Site
37°
15'
30'
45'
38°



NOT TO SCALE

The Chief Executive Officer,
Water Resources Management
Authority,
P.O. Box 45250 – 00100
NAIROBI

Form: WRMA 009 A
Catchment: _____
WRMA ID: _
File: _____

Water Resources Management Authority

BOREHOLE COMPLETION RECORD

(To be submitted in triplicate) *(Rule 76,77*

Borehole No:.....
Borehole Name: MUTONYOK WOMEN GROUP .....
Formation: BASEMENT .....

PARTICULARS OF APPLICANT		**DETAILS**	
1. Full name of applicant(s) (In Block Letters)		**MUTONYOK WOMEN GROUP**	
2. Category of Applicant - Individual, Group [Association, Society], Company, Institution		**GROUP**	
3. ID Number of Applicant (Individual) or Certificate of Incorporation or Registration for Groups or Companies		**Certificate of registration from social service department.**	
Physical Address where water is to be used (see sketch)		**Contact Address of Applicant**	
4. L/R Number(s)		5. Box Number	**518**
6. Village(s)/Ward(s)	**SUPALEK(LORUBAE)**	7. Town	**ISIOLO**
8. Sub-location(s)	**ARCHER'S POST**	9. Post Code	**60300**
10. Location(s)	**WASO**	11. Telephone Contact (Landline)	
12. Division(s)	**WASO**	**13. Telephone Contact (Mobile)**	
14. District(s)	**SAMBURU EAST**	**15. Email Contact**	
PARTICULARS OF CONTRACTOR			
16. Box Number	**38937**	**22. License Number**	**DB400/164**
17. Town	**NAIROBI**	**23. Gazetted On**	**02/03/2001**
18. Post Code	**00623**	24. Drilling Supervisor	**DUNCAN MULEI**
19. Telephone Contact (Landline)	**8067380**	25. Type and Make of Drill Rig	**PRD**
20. Telephone Contact (Mobile)	**0722708222**		
21. Email Contact	**info@passafricadrilling.co.ke**		
INTENDED USE OF WATER			
Public W.S.; Irrigation.; Industries, Domestic; Stock, other		**DOMESTIC**	
PARTICULARS OF BOREHOLE			
Type of Borehole: - **Drilled**; Driven; Bored; Jetted; Other		**DRILLED**	
Borehole Construction (also *see* sketch page 3)			

Drilling started (date)	**21/10/2011**	Drilling completed (date)	**23/10/2011**	All work completed (date)	**2/11/2011**
Total Depth: Reported (m)	**65**	Measured (m)	**65**	Final (back-filled) Depth (m)	**65**
Hole Diameter (mm)	**203**	From (m)	**0**	To (m)	**1**
Hole Diameter (mm)	**152**	From (m)	**1**	To (m)	**65**
Hole Diameter (mm)		From (m)		To (m)	

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Permanent Casing									
Plain									
Type	**upvc**	Diam (mm)	**114**	Length (m)	**23**	From (m)	**0**	To (m)	**23**
Type	upvc	Diam (mm)	114	Length (m)	9	From (m)	29	To (m)	38
Type	**upvc**	Diam (mm)	**114**	Length (m)	**6**	From (m)	**44**	To (m)	**50**
Type	upvc	Diam (mm)	114	length (m)	6	From (m)	59	To (m)	65
Slotted or Perforated:									
Size and Description of Openings									
Type	**upvc**	Diam (mm)	**114**	Length (m)	**6**	From (m)	**23**	To (m)	**29**
Type	**upvc**	Diam (mm)	**114**	Length (m)	**3**	From (m)	**35**	To (m)	**38**
Type	**upvc**	Diam (mm)	**114**	Length (m)	**6**	From (m)	**41**	To (m)	**47**
Type and Make									

Diameter (mm)		Length (m)		set from (m)		To (m)	

Gravel Pack					
Size of grains (mm)	**2 - 4**	Roundness (good, fair, poor)	**good**	Volume inserted in annular Space (m3)	**1.44**
		From (m)	**0**	To (m)	**65**
Open Hole					
Diam (mm)		From (m)	-	To (m)	-

Aquifer			
1st Water Struck at (m)	**6**	Water Rest Level (m)	3.9
2nd Water Struck at (m)	**24**	Water Rest Level (m)	3.9
Main Aquifer Struck at (m)	**24**	Water Rest Level (m)	3.9

Water bearing material	**weathered & Fractued basement**	From (m)	**1**	**To (m)**	**65**
Other Aquifers, Remarks, etc (also *see* log on page3)					

***Yield*: SWL (m)**	**3.9**	PWL (m below surface)		Discharge (litres per minute)	**60**
After pumping (hours)			Recovered to SWL in (minutes)		
Expected production discharge (litres per hour)			With pump set at (m below surface)		

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Authority,
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File: _____

Pumping Test Record in Summary (Detailed test records on attached sheets): (all depth measurements to be in metres below ground surface)		
	Test No. 1	**Test No. 2**
Date of Test (day, month, year)		
Depth of Borehole at time of test (m)		
Water Entry (perforations or screen setting at time of test)	From (m)4	From (m)
	To (m)	To (m)
Static Water (SWL) before test (m)		
Type of Pump (Bailer) used		
Depth of Pump intake (m)		
Discharge (in litres per minute)		
Pumping Water Level (PWL m)		
After pumping continuously for (hours)		
Time of Recovery to Original SWL (minutes)		
Rate of Recovery-WL after 5 minutes (m)		
Rate of Recovery-WL after 20 minutes (m)		
Rate of Recovery-WL after 60 minutes (m)		
Rate of Recovery-WL after 180 minutes (m)		

(Additional pumping tests to be mentioned in REMARKS and included with file).
Government representative witnessing the test.....

Quality of Water					
Sample (Yes/No)	**yes**	Collected at (hour)	**10:20**	On (date)	**22/10/2011**
Sediment	none	Taste	tasteless	Odour	none
Colour	**clear**	Temperature (0c)		Spec. Conductivity (µS/cm)	**1275**

Remarks: (drilling difficulties, gravel-pack details, all pertinent information about the drilling and completion of the hole)	

Drilling Supervisor		*Drilling Contractor*	
Signature		Signature	
Name	**Duncan Mulei**	Name	**Pass Africa Ltd**
Date	2-12-2011	Date	

The Chief Executive Officer,
Water Resources Management
Authority,
P.O. Box 45250 – 00100
NAIROBI

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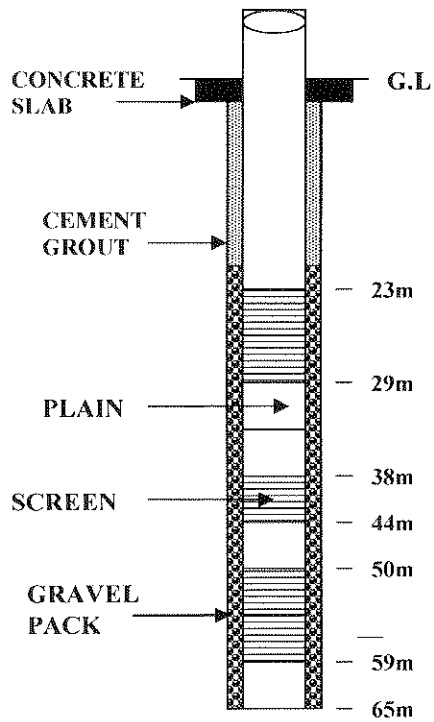
Catchment: _____
WRMA ID: _
File: _____

Borehole No.....

1. *Driller's Log.*
Construction:

From (m.)	To (m.)	Drilling Rate (m. /hr.)	Description of Formation Penetrated
			Please see the attached site log sheet.
0	6	14.7	weathered gneisses
6	14	15.3	fractured gneisses
14	24	7.6	weathered basement
24	65	11.2	fractured basement

12. *Sketch of Borehole*



Total depth

(Sketch to include: - depth and changes of hole diameter; casing positions, manner of casing (of different diam.) connections, and casing connection to screen; depths of screens or slotted casing lengths; how casing is closed at bottom; formation caving zones; and any other pertinent information).