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# GEOPHYSICAL AND HYDROGEOLOGICAL INVESTIGATIONS

*For*

NAIBOISHO WOMEN GROUP  
P.O. BOX 1  
WAMBA

*In*

NALKAPUR VILLAGE, SEROLIPI AREA OF SAMBURU EAST DISTRICT

REPORT NO. GML - 585/11

JULY 2011

Groundwater Max Ltd.  
P.O. Box 9419-00300,  
Nairobi  
Date: 01/02/2011

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Groundwater Resources Investigations and Environmental Management Solutions

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## 1.0 INTRODUCTION

**NAIBOISHO WOMEN GROUP** is located in Nalkapur village, Serolipi sub location in Serolipi location of Waso Division, in Samburu East District. The local community comprises of about 10 manyattas each having average of 10 households averaging about 5 people in each household, thus totaling about 500 people.

The community also has Lengaya nursery school having 40 children and 1 teacher.

The main activities of the self help group is looking for a reliable water supply, merry go round, planting trees and other self help activities.

Presently the local community gets their water supply from sand scooping from seasonal river Serolipi.

However this water supply is neither reliable nor permanent and is also polluted and the community has to travel long distances to 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 Nalkapur village in Serolipi sub location of Serolipi location of Waso Division of Samburu East District.

The selected well site is on latitudes 01° 07' 41" South and longitudes 37° 35' 09" East on approximate elevation of 740 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 is under grass, scattered shrubs and acacia trees.

Livestock keeping especially goats is the economic mainstay of the local community. However the livestock is seriously affected by drought and most of them die leaving the local community highly vulnerable

#### 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 Erosional 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.

**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 during floods in the seasonal streams which are part of the Ewaso Nyiro river drainage system.

**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 Transmissivity 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 infants 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 <sub>3</sub>	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 <sub>3</sub>	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 <sub>3</sub>	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 <sub>4</sub>	Mg/l	250	Taste, odors, cathartic effects
Zinc	Zn	Mg/l	3	Toxic in excess
Total Coliforms	Per	100ml	Nil	
Faecal Coliforms	Per	100ml	Nil	
Sulphide	H <sub>2</sub> S	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 whether 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:-

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

Where  $R_s$  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 22, 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 Terrameter 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). Underlying 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	1100	Sandy soil	Dry
1.6 – 5	800	Sandy sediments	Dry
5- 32	70	Weathered Basement	Moist
32 – 40	110	Fractured Basement	Wet
40 – 80	150	Fractured Basement	Wet
80 Downwards	300	Compact Basement	Dry

**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 2 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 the acting serolipi sublocatioal assistant chief.
- (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.***



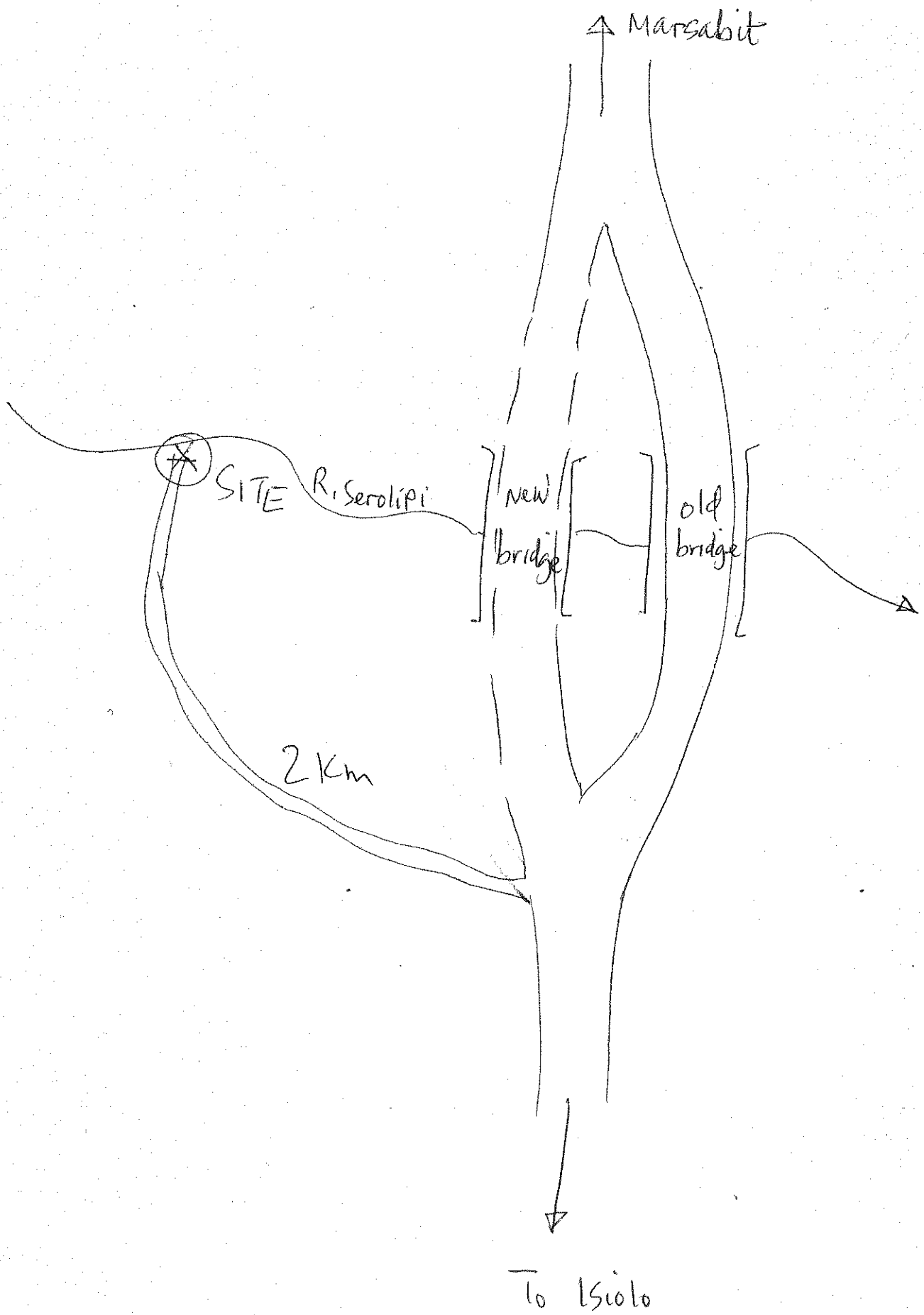
37°

15'

30'

45'

38°



NOT To Scale



## Water Resources Management Authority

### **BOREHOLE COMPLETION RECORD**

(To be submitted in triplicate)

(Rule 76,77)

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

PARTICULARS OF APPLICANT			DETAILS		
1. Full name of applicant(s) (In Block Letters)			NAIBOISHO 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	1	
6. Village(s)/Ward(s)	NALKAPUR		7. Town	WAMBA	
8. Sub-location(s)	SEREOLUPI		9. Post Code	20603	
10. Location(s)	SEREOLUPI		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: - <b>Drilled</b> ; Driven; Bored; Jetted; Other			DRILLED		
Borehole Construction (also see sketch page 3)					
Drilling started (date)	5/10/2011	Drilling completed (date)	14/10/2011	All work completed (date)	25/10/2011
Total Depth: Reported (m)	65	Measured (m)	65	Final (back-filled) Depth (m)	65
Hole Diameter (mm)	203	From (m)	0	To (m)	6
Hole Diameter (mm)	152	From (m)	6	To (m)	65
Hole Diameter (mm)		From (m)		To (m)	



Permanent Casing									
Plain									
Type	upvc	Diam (mm)	114	Length (m)	26	From (m)	0	To (m)	26
Type	upvc	Diam (mm)	114	Length (m)	6	From (m)	29	To (m)	35
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
<b>Slotted or Perforated:</b>									
<b>Size and Description of Openings</b>									
Type	upvc	Diam (mm)	114	Length (m)	3	From (m)	26	To (m)	29
Type	upvc	Diam (mm)	114	Length (m)	9	From (m)	35	To (m)	44
Type	upvc	Diam (mm)	114	Length (m)	9	From (m)	50	To (m)	59
<b>Type and Make</b>									
Diameter (mm)		Length (m)		set from (m)		To (m)			
<b>Gravel Pack</b>									
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				
<b>Open Hole</b>									
Diam (mm)		From (m)	-	To (m)	-				
<b>Aquifer</b>									
1 <sup>st</sup> Water Struck at (m)	16	Water Rest Level (m)	5.5						
2 <sup>nd</sup> Water Struck at (m)	33	Water Rest Level (m)	5.5						
Thin Aquifer Struck at (m)	33	Water Rest Level (m)	5.5						
Water bearing material	weathered Basement	From (m)	6	To (m)	50				
Other Aquifers, Remarks, etc (also see log on page3)									
Yield: SWL (m)	5.5	PWL (m below surface)		Discharge (litres per minute)	35				
After pumping (hours)									
Recovered to SWL in (minutes)									
Expected production discharge (litres per hour)									
With pump set at (m below surface)									



*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)		
^fter pumping continuously for (hours)		
ime 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)	18:50	On (date)	26/10/2011
Sediment	none	Taste	slightly saline	Odour	none
Colour	clear	Temperature (0c)		Spec. Conductivity (µS/cm)	1896

*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	





