GEOPHYSICAL AND HYDROGEOLOGICAL INVESTIGATIONS

For

ST.STEPHEN WOMEN GROUP
P.O. BOX 6
WAMBA

In

GOLGOTIM AREA OF SAMBURU EAST DISTRICT

REPORT NO. GML - 729/12

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SURVEYED & COMPILED BY

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Groundwater Resources Investigations and Environmental Management Solutions

Glossary of terms

Aquifer: Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Confined aquifer: An aquifer overlain by a confining bed. The **confining** bed has significantly lower hydraulic conductivity than the aquifer.

Discharge: The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Drawdown: A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of groundwater wells.

Electrical sounding: An earth- resistivity survey made at the same location by putting the Electrodes progressively further apart. It shows the change of apparent resistivity with depth.

Horizontal profiling: A method of making an earth resistivity survey by measuring the apparent resistivity using the same electrode spacing at different grid points around an area.

Hydrologic cycle: The circulation of water from the oceans through the atmosphere to the land and ultimately back to the ocean

Infiltration: The flow of water downward from the land surface into and through the upper soil layers.

Pump test: A test made by pumping a well for a period of time and observing the change in hydraulic head in the aquifer, a pumping test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer, also called aquifer test.

Recovery: The rate at which the water level in a well rises after the pump has been shut down. It is the inverse of drawdown

Runoff: The total amount of water flowing in a stream. It includes overland flow; return flow, interflow and base flow.

Schlumberger array: A particular arrangement of electrodes used to measure surface electrical Resistivity

Development: In borehole engineering, this is the general term for procedures applied to repair the damage done to the formation during drilling. Often the borehole walls are partially clogged by an impermeable “wall cake” consisting of fine debris crushed during drilling and clays from the penetrated formations. Well development removes these clayey cakes, and increases the porosity and permeability of the materials around the intake portion of the well. As a result, a higher sustainable yield can be achieved.

Piezometric level: An imaginary water table, representing the total head in a confined aquifer, And is defined by the level to which water would rise in a well.

Static water level: The level of water in a well that is not being affected by pumping (Also Known as “rest water level”)

Transmissivity: A measure of the capacity of an aquifer to conduct water through its Saturated thickness (m^2/day).

Yield: Volume of water discharge from a well

Abbreviations

WARMA	Water Resources Management Authority
VES	Vertical Electrical Sounding
agl	above ground level
asl	above seal level
bgl	below ground level
EC	Electrical conductivity
hr	hour
m	meter
l	liter
WSL	water struck level
WRL	water rest level
TDS	total dissolved solids
SWL	static water level
Km	kilometers
Ppm	parts per million

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1.0 INTRODUCTION

ST.STEPHEN WOMEN GROUP is located in Golgotim village, Golgotim sublocation, ngilai west location, Wamba Division of Samburu east District.

It is located about 5 kilometers west of Wamba town.

The project village does not have a public water supply and the community has resulted to sand scooping from seasonal river Lengusaka where water is highly polluted and contaminated.

The targeted beneficiaries are the samburu people comprising of 178 households (890 people).

The targeted beneficiaries, the Samburu local community practice a nomadic lifestyle where main economic mainstay is livestock keeping.

The lack of a reliable water supply has adversely affected the development plans of the community and the proposed well will stimulate the same for their benefit.

Consequently therefore the client is in dire need of a well to supply them with reliable, portable and adequate water supply for their domestic needs.

Therefore the client has applied to drill a well to meet their anticipated domestic water requirements which are estimated about 20 cubic meters per day.

It is for this reason that The Samburu project commissioned Groundwater Max Ltd to carry out a geophysical and hydrogeological investigation in the project village to find the best possible site for a 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 borehole 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 selected well site is located in Golgotim village, Ngilai location of Samburu east District.

The selected site is located on latitudes 01° 01' 11''North and longitudes 37° 18' 46"East on approximate elevation of 1265 meters above sea level on map sheet NA-37-9.

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 400 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 dry and wet periods.

However the climate of the general Samburu area has also been affected by the global climatic changes where the rainfalls unexpectedly and in heavy downpour causing havoc. Thereafter the area experiences unexpected severe drought which kills their main economic mainstay of livestock. Temperatures are relatively high sometimes reaching 30 degrees centigrade.

3.3 Current Land Use

The whole area is under grass, bushes and thickets and scattered acacia trees. In the general area, land use is predominantly for livestock keeping mostly goats and camels.

However the area is experiencing sporadic charcoal burning which fortunately the local community is not promoting as their livestock depends on these trees for grazing.

3.4 Approximate Water Demand

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

4.0 GEOLOGY

4.1 Regional Geology

The general area is covered by rocks of the metamorphic system generally a combination of gneisses and schist's. The Basement rocks outcrops where the floods during rains have eroded the thin sandy soil. Erosional resistant hills rises steeply to the sky towards north east of the project village to form the Wamba hills complex which is highly forested and well environmentally conserved.

4.2 Geology of Project Area

The geology of the project area consists of sandy soils, gneisses and schist's. However the rocks are locally weathered and fractured which makes it possible for the enhancement of the water recharge mechanisms.

The seasonal rivers locally found have accumulated sandy deposits which are locally harvested to be used in the construction industry.

4.2.1 Precambrian Basement System Rocks

The Precambrian rocks are predominantly found in the area.
These rocks are locally covered by a very thin layer of top sandy soil which has supported grass cover and other vegetation.

The rocks occur as folded and fractured gneisses and schist's with all forms of weathering and in some cases form very steep hills.

When found they are represented by layered fine grained schist's and coarse grained gneisses that have been invaded by pink quartzo-felspathic pegmatites.
Biotite, hornblende and quartz feldspar gneisses are abundant in the area.

The fractured and weathered zones of these rocks are normally aquiferous.

4.2.2 Recent Deposits

Sandy deposits have covered the depressions which are occupied by seasonal river Ilkisin.

4.2.3 Hydrogeology of the project area

The geology of the area is representative of intense folding, fracturing and cracking. This is evident structurally on the exposed Basement rocks.
These weak zones have become the avenues of water from the recharge areas to the east. Groundwater therefore is mostly found within these weak zones. However the groundwater potential is moderate in the project area.

The sandy deposits which are found in the seasonal rivers help in the water retention thus promoting seepage which enhances the groundwater potential.

5.0 WATER RESOURCES

5.1 Surface Water Resources

Surface water in the general area is found in the seasonal rivers during the rains and flooding.
However this water cannot be used for domestic use only for livestock watering in this area.

This calls for quality question and this water needs continuous water treatment which is not available for the local community.

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 rocks.

If the rocks are not fractured, weathered and impervious, then faults, fissures and cracks make potential aquifers.

Most of the aquifers in the project area are mostly confined.

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 or vesicles).
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 catchment areas located in the north east within Wamba highly forested hills.

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.

The project area mean annual recharge is estimated as 5% of the mean annual rainfall of the area as follows:

Mean annual rainfall = 400 millimeters

Mean annual recharge = 20 millimeters

However this mean recharge amount is not exact as it is affected by intense evaporation levels due to the hot climate of the area and the climatic changes which have rendered the rainfall unreliable and unpredictable.

5.4 Previous Groundwater Development

No well has been drilled in the general project village by other stake holders.

5.4.1 Groundwater availability

The general area does not have boreholes or wells. Consequently the groundwater potential is largely not developed.

The area therefore allows for wells to be drilled strictly for domestic water uses as the area has low to moderate groundwater potential.

5.4.2 Groundwater reserve analysis

The general area has a low population and a nomadic way of life is practiced by the local community.

Also the area does not have boreholes and wells.

Therefore the groundwater potential is largely not known but is expected to be moderate.

5.5 Aquifer properties

Due to inaccurate and insufficient data of the groundwater potential in the project area, it is not possible to compute the exact values of the various aquifers.
However the project area has a low groundwater potential.

5.5.1 Aquifer Transmissivity.

The transmissivity values for the various aquifers are given in the water master plan.

However it is highly recommended that in order to come up with reasonable, representative and accurate aquifer values, exhaustive ground water modeling research should be carried out.

The raw test pumping data of the boreholes in the above project area were not available to assist in calculation of aquifer Transmmissivity using Jacobs's formula.

Consequently therefore the Logan method of approximation is used and is only an approximation as it has an error of about 50%.

Aquifer Transmmissivity (T) is therefore estimated as follows:

$T = 1.22\ Q/\ d$

Where Q is the yield per day and d is the drawdown

5.5.2 Hydraulic conductivity.

Hydraulic conductivity K can be estimated by,
$K = T/h$ where h is the average aquifer thickness and T is the aquifer Transmmissivity.

5.5.3 Groundwater flux

Groundwater flux F is given by
$F = K\ h\ I\ w$ where K is the hydraulic conductivity,
H is the aquifer thickness,

I is the slope and

W is the arbitrary distance say 1 kilometer.

It should be noted that this method of calculation gives estimated values only as the accuracy of the available data cannot be guaranteed.

5.5.4 Specific capacity

The aquifer specific capacity (S) = Q/d

6.0 GROUNDWATER QUALITY

Groundwater Chemistry from Basement rocks varies from place to place due to the chemical constituents of various types of host rocks. Some of the factors which determine the degree of mineralization of groundwater in Basement 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.

6.1 Groundwater quality of the project area

The existing traditionally sand scooped well water has been used for domestic purposes for a long time and the water is reportedly portable.

The lack of an elaborate water supply for the local community has forced the inhabitants to look for other sources of water including sand scooping from the beds of seasonal rivers where water is polluted.

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

The water quality standard varies from country to country and is 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 <u>THE RESISTIVITY METHOD</u>

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 the thickness and composition of the volcanic rocks, the presence of faults and to trace 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, and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivities that 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 I 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

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 August 3, 2012. The field investigations comprised observation of general topography, drainage, geological set up, proximity to other boreholes 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 (VES) measurements were carried out with an ABEM Tarrameter 1000 resistivity instrument.

7.4 Results and Interpretations

The study show that the sub-surface geological layout in the project area is fairly uniform and comprises several layers (formations) depending mainly on the weathering status of the basement rocks which are predominant in the area. Drilling at the proposed drill-site is expected to penetrate the formations including, Sandy soils, weathered Basement, fractured basement, and lastly compact basement grading to fresh basement with increase in depth.

2 Vertical Electrical Soundings were conducted in the project area and their data are interpreted here below.

Depth Interval (m)	**Apparent resistivity (ohm-m)**	**Expected geological formation**	**Remarks**
VES 7			
0 – 1.6	15	Sandy soil	Dry
1.6 – 3	16	Sandy sediments	Dry
3 – 8	40	Weathered Basement	Dry
8 – 32	95	Fractured basement	Wet
32	900	Fresh Basement	Dry
Downwards.			

Depth Interval (m)	Apparent resistivity (ohm-m)	Expected geological formation	Remarks
VES 8			
0 – 1.6	90	Sandy soil	Dry
1.6 – 4	75	Sandy sediments	Dry
4 – 14	15	Weathered Basement	Dry
14 – 40	75	Fractured basement	Wet
40	600	Fresh Basement	Dry

Down wards.

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:-

1. The condition of groundwater occurrence is characterized by the existence of the sandy sediments, weathered and fractured Basement rocks.

2. That the expected yield from the well will be enough to satisfy the local community water demand of about 20,000 liters per day for domestic purposes.

3. That the recharge of the proposed well is guaranteed by the source of recharge to the east of the well selected site

4. That water from the well is expected to be of good quality.

However a water sample from the borehole should be taken to an independent and competent laboratory for physical, chemical and bacteriological analysis.

8.2 Recommendations

(i) A well be drilled at the selected site ***VES 8*** shown on the topographical map extract to a maximum depth of ***70*** meters. The site is known to Mr.Lukas Lekwale, The Samburu project manager.

(ii) That the well should be drilled with a 213 millimeters diameter, cased with 152 millimeters diameter PVC plain and perforated casings following the design of a supervising hydrogeologist.

(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.

(v) That the yield from the well is anticipated to be about 2.0 cubic meters per hour.

NB: *The client should note that before drilling the borehole, 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.*