GEOPHYSICAL AND HYDROGEOLOGICAL INVESTIGATIONS

for

GLOBAL WORSHIP CENTRE
P.O. BOX 491 - 00206
KISERIAN.

in

KIRONITO AREA OF KAJIADO CENTRAL DISTRICT

REPORT NO. GML - 444/10

MAY 2010

SURVEYED & COMPILED BY

J. W. Kariuki
Groundwater Max Ltd

P.O. Box 9419-00300
Nairobi
Mobile: 0733-712764
Email:gwatermax@yahoo.com
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Terms of Reference</td>
<td>1</td>
</tr>
<tr>
<td>3.0 Background Information</td>
<td></td>
</tr>
<tr>
<td>3.1 Geographical Location</td>
<td>2</td>
</tr>
<tr>
<td>3.2 Rainfall and Climate</td>
<td>2</td>
</tr>
<tr>
<td>3.3 Current Land Use</td>
<td>2</td>
</tr>
<tr>
<td>3.4 Approximate Water Demand</td>
<td>2</td>
</tr>
<tr>
<td>4.0 Geology</td>
<td></td>
</tr>
<tr>
<td>4.1 Regional Geology</td>
<td>3</td>
</tr>
<tr>
<td>4.2 Geology of Project Area</td>
<td>3</td>
</tr>
<tr>
<td>4.2.1 Precambrian Basement System Rocks</td>
<td>3</td>
</tr>
<tr>
<td>4.2.2 Recent Deposits</td>
<td>3</td>
</tr>
<tr>
<td>5.0 Water Resources</td>
<td></td>
</tr>
<tr>
<td>5.1 Surface Water Resources</td>
<td>3</td>
</tr>
<tr>
<td>5.2 Groundwater Resources</td>
<td>4</td>
</tr>
<tr>
<td>5.3 Discharge/Recharge Considerations</td>
<td>4</td>
</tr>
<tr>
<td>5.4 Previous Groundwater Development/Hydrogeology</td>
<td>5</td>
</tr>
<tr>
<td>6.0 Groundwater Quality</td>
<td></td>
</tr>
<tr>
<td>The Resistivity Method</td>
<td>8</td>
</tr>
<tr>
<td>6.1 Basic Principles</td>
<td>8</td>
</tr>
<tr>
<td>6.2 Vertical Electrical Soundings</td>
<td>9</td>
</tr>
<tr>
<td>6.3 Fieldwork</td>
<td>9</td>
</tr>
<tr>
<td>6.4 Results and Interpretations</td>
<td>9</td>
</tr>
<tr>
<td>8.0 Conclusions and Recommendations</td>
<td>12</td>
</tr>
<tr>
<td>8.1 Conclusions</td>
<td>12</td>
</tr>
<tr>
<td>8.2 Recommendations</td>
<td>12</td>
</tr>
</tbody>
</table>
1.0 **INTRODUCTION**

**GLOBAL WORSHIP CENTRE** is a Christian registered church ministry with its main centre in Kiserian. Its main activity is preaching the gospel and caring for the disadvantaged in the society. However apart from the evangelization of the gospel, the ministry has also a development arm which is tackling the local communities pressing needs especially in the interior where the issue of water and food is of major concern.

It is in that line that the ministry want to help the **Endonyo Ereko** village community which is located about 46 kilometres south west of Kajiado Town with not only portable water, but also enough to meet their food security concern through subsistence irrigation, training on the need to diversify the reliance on the main economic activities which is livestock keeping and which is hard hit by severe drought.

The local community comprises of 700 people, 200 cows, 3000 donkeys and a nursery school with about 20 children and 1 teacher. The proposed developments include construction of a church and a school.

Presently the local community get their water supply from traditional wells from the river Soree located about 9 kilometres away.

Due to the proposed developments earmarked in the project area, the client is in dire need of reliable, portable and adequate water supply.

Therefore the client has applied to drill a borehole for the local community to meet their anticipated domestic and minor irrigation water requirements which is estimated about 30 cubic metres per day.

It is for this reason that the client commissioned Groundwater Max Ltd to carry out a geophysical and hydrogeological investigation in the project area to find the best possible site for a borehole 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 farm 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.
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.

Compile and submit to the client a comprehensive report which shall include all the details of the above investigations and the consultants recommendations.

3.0 **BACKGROUND INFORMATION**

3.1 **Geographical Location**
The selected borehole site is located in Endonyo Ereko village, Ndopa sublocation, Kironito location, Kajiado central division in Kajiado central District.
The selected site is located on latitudes 01° 48’ 52” South and longitudes 36° 38’ 20” East on approximate elevation of 1520 metres above sea level on Map sheet 161/3.

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 800 millimetres.

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.

3.3 **Current Land Use**
The whole area is under grass, shrubs and scattered acacia trees.

3.4 **Approximate Water Demand**
A water demand of about 30,000 litres of water per day is estimated to be enough for the clients domestic and minor irrigation purposes.

4.0 **GEOLOGY**

4.1 **Regional Geology**
The general area is predominantly Volcanic rocks which have been affected by heavy faulting as part of the great rift valley.

The rocks are mainly Phonolites, Basalt, Laterites and volcanic ash.

4.2 **Geology of Project Area**
The geology of the project area consist of brownish volcanic soil, Lateritic materials overlying a successive matrix of weathering products interrupted by Basaltic and Phonolitic layers.

4.2.1 **Precambrian Basement System Rocks**
The Precambrian rocks of the area are deep rooted being covered by a thick
volcanic layer. However these rocks are exposed towards East where they are part of the Namanga Basement rocks system.

The rocks occur as folded and fractured gneisses and schists with all forms of weathering. When found they are represented by layered fine grained schists 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
Brown volcanic soil with laterites deposits have covered the valleys of the seasonal streams which flow south westwards.

5.0 WATER RESOURCES

5.1 Surface Water Resources
Surface water in the general area is found in the seasonal streams during flooding and also in the seasonal Soree stream which is far and the water is contaminated and polluted.

This calls for quality question and this water is not fit for domestic use only for livestock.

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 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 Ngong forest, Loiyangalani hills and the areas north and north west of the project area.

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.

<table>
<thead>
<tr>
<th>Borehole No:</th>
<th>Distance From site (km)</th>
<th>W.S.L (m)</th>
<th>W.R.L (m)</th>
<th>Tested Depth yield (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 451</td>
<td>11/SSE</td>
<td>135</td>
<td>106</td>
<td>6.84 137</td>
</tr>
<tr>
<td>C 1390</td>
<td>9.0/S</td>
<td>-</td>
<td>-</td>
<td>- 171</td>
</tr>
<tr>
<td>C 3942</td>
<td>8.5/S</td>
<td>107</td>
<td>100</td>
<td>6.42 152</td>
</tr>
</tbody>
</table>

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 area has one of the highest successful groundwater development in the country and some of the deepest aquifers.

5.5.1 Aquifer Transmissivity.

The transmissivity values for the various aquifers are given in the iwater master plan. However it is highly recommended that in order to come up with reasonable, representative and accurate aquifer values, exhaustive ground water modelling research should be carried out.

5.5.2 Hydraulic conductivity.

Hydraulic conductivity $K$ can be estimated by,

$$K = \frac{T}{h}$$

where $h$ is the average aquifer thickness and $T$ is the aquifer Transmissivity.

From the above data of boreholes, the average thickness of the aquifers is about 1 metre and the aquifer transmissivity can be estimated to be 2 square metres per day.
Therefore the hydraulic conductivity is estimated at about 
\((2/1) \text{ M} / \text{day} = 2 \text{ M} / \text{day}\).

5.5.3 **Groundwater flux**

Groundwater flux \(F\) is given by

\[ F = K h l w \]

where \(K\) is the hydraulic conductivity, 
\(H\) is the aquifer thickness, 
\(l\) is the slope and 
\(W\) is the arbitrary distance say 1 kilometre.

Now from the above equation,

\(K = 2 \text{ M} / \text{day}\) 
\(l = 33\text{M/km}\) 
\(H = 1 \text{ M}\) 
\(W = \text{arbitrary distance of 1 kilometre}\).

Using the above values, groundwater flux is thus estimated to be 66 cubic metres/day. 
It should be noted that these values are estimated only as the accuracy of the available data cannot be guaranteed.

6.0 **GROUNDWATER QUALITY**

Groundwater Chemistry from Volcanic rocks varies from place to place due to the chemical constituents of various lavas. Some of the factors which determine the degree of mineralization of groundwater in volcanic 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 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.

<table>
<thead>
<tr>
<th>Quality Variable</th>
<th>Measuring Unit</th>
<th>WHO Guideline</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Mg/l Pt</td>
<td>15TCU</td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>Mg/l CaCO₃</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Ph</td>
<td>PH Units</td>
<td>6.5 – 8.5</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>As µg/l</td>
<td>10</td>
<td>Toxic in excess e.g. bronchial disease</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb µg/l</td>
<td>10</td>
<td>Toxic to animals</td>
</tr>
<tr>
<td>Selenium</td>
<td>Se µg/l</td>
<td>10</td>
<td>Toxic in excess</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al mg/l</td>
<td>0.2</td>
<td>Soluble Al salts exhibit neurotoxicity</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃ mg/l</td>
<td>1.5</td>
<td>Toxic particularly to aquatic organisms</td>
</tr>
<tr>
<td>Boron</td>
<td>Bo mg/l</td>
<td>0.3</td>
<td>Toxic in high concentration to plants</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca mg/l</td>
<td>NS</td>
<td>No standard</td>
</tr>
<tr>
<td>Chloride</td>
<td>Cl mg/l</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Fluoride</td>
<td>Fi mg/l</td>
<td>1.5</td>
<td>Dental and Skeletal fluorosis</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe mg/l</td>
<td>0.3</td>
<td>High concentrations toxic to children</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg mg/l</td>
<td>0.1</td>
<td>May cause diarrhoea in new users</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn mg/l</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Nitrate</td>
<td>NO₃ mg/l</td>
<td>11</td>
<td>Infant blue baby syndrome</td>
</tr>
<tr>
<td>Potassium</td>
<td>K mg/l</td>
<td>NS</td>
<td>No standard</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na mg/l</td>
<td>200</td>
<td>Chronic, long term toxic</td>
</tr>
<tr>
<td>Sulphate</td>
<td>SO₄ mg/l</td>
<td>250</td>
<td>Taste, odours, cathartic effects</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn mg/l</td>
<td>3</td>
<td>Toxic in excess</td>
</tr>
<tr>
<td>Total Coliforms</td>
<td>Per 100ml</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td>Feacal Coliforms</td>
<td>Per 100ml</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td>Sulphide</td>
<td>H₂S µg/l</td>
<td>Undetectable</td>
<td></td>
</tr>
</tbody>
</table>
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 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.

6.1 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 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:

$$ R = \frac{Rs \times L}{A} \text{ (in Ohms)} $$

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

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

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:

$$ R = \frac{A}{L} \times \frac{dV}{I} \text{ (in Ohm)} $$

6.2 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 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.

6.3 Fieldwork
Fieldwork was carried out on May 20, 2010. 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.

6.4 Results and Interpretations
The study show that the sub-surface geological layout in the project area is fairly uniform and comprises several layers (formations). 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, Brown volcanic soil, Lateritic formations, Phonolitic and Basaltic rocks formations.

The expected geological stratigraphy based on the geophysical curve interpretation and existing borehole profiles generally comprise of semi-consolidated, sometimes collapsible formations intercalated with clay.
<table>
<thead>
<tr>
<th>Depth Interval (m)</th>
<th>Apparent Resistivity (ohm-m)</th>
<th>Expected geological formation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the church under tree compound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 – 1.6</td>
<td>60</td>
<td>Brownish volcanic soil</td>
<td>Dry</td>
</tr>
<tr>
<td>1.6 – 6</td>
<td>90</td>
<td>Lateritic volcanics</td>
<td>Dry</td>
</tr>
<tr>
<td>6 – 90</td>
<td>15</td>
<td>Highly weathered volcanics</td>
<td>Moist</td>
</tr>
<tr>
<td>90</td>
<td>200</td>
<td>Fractured Basalt</td>
<td>Wet</td>
</tr>
<tr>
<td>Downwards.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At the Endonyo Ereko stream</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 – 1.6</td>
<td>25</td>
<td>Brownish volcanic soil</td>
<td>Dry</td>
</tr>
<tr>
<td>1.6 – 4</td>
<td>30</td>
<td>Lateritic volcanics</td>
<td>Dry</td>
</tr>
<tr>
<td>4 – 63</td>
<td>90</td>
<td>Fractured basalt</td>
<td>Dry</td>
</tr>
<tr>
<td>63</td>
<td>18</td>
<td>Highly weathered volcanics</td>
<td>Wet</td>
</tr>
<tr>
<td>Downwards.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At dupa stream</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 1.6</td>
<td>35</td>
<td>Brownish volcanic soil</td>
<td>Dry</td>
</tr>
<tr>
<td>1.6 – 9</td>
<td>12</td>
<td>Laterites</td>
<td>Dry</td>
</tr>
<tr>
<td>9 – 100</td>
<td>44</td>
<td>Weathered and fractured volcanics</td>
<td>Wet</td>
</tr>
<tr>
<td>100</td>
<td>120</td>
<td>Compact basalt</td>
<td>Dry</td>
</tr>
<tr>
<td>Downwards.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**VES 4**  
*(Upstream of Ves 3)*

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Depth</th>
<th>Layer Type</th>
<th>Groundwater Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1.6</td>
<td>60</td>
<td>Brownish Soil</td>
<td>Dry</td>
</tr>
<tr>
<td>1.6 - 4</td>
<td>90</td>
<td>Laterites</td>
<td>Dry</td>
</tr>
<tr>
<td>4 – 15</td>
<td>150</td>
<td>Weathered Phonolitic Basalt</td>
<td>Dry</td>
</tr>
<tr>
<td>15 – 51</td>
<td>65</td>
<td>Highly weathered volcanics</td>
<td>Moist</td>
</tr>
<tr>
<td>51 – 100</td>
<td>75</td>
<td>Highly fractured basalt</td>
<td>Wet</td>
</tr>
<tr>
<td>100 – 130</td>
<td>80</td>
<td>Fractured basalt</td>
<td>Wet</td>
</tr>
<tr>
<td>130</td>
<td>110</td>
<td>Compact Basalt</td>
<td>Wet</td>
</tr>
</tbody>
</table>

Downwards.

### 7.0 CONCLUSIONS AND RECOMMENDATIONS

#### 7.1 Conclusions

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

(i) The condition of groundwater occurrence are characterized by the existence of weathered and fractured volcanic rocks.

(ii) That the expected yield from the borehole will be enough to satisfy the clients’ water demand of about 30,000 litres per day.

(iii) That the recharge of the proposed borehole is guaranteed by the source of recharge to the north in the Ngong hills.

(iv) That water from the borehole 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.

#### 7.2 Recommendations

(i) A borehole be drilled at the selected site **VES 4** shown on the topographical map extract to a maximum depth of **150** metres. The site is known to the ministry Bishop.

(ii) That the borehole should be drilled with an 8” diameter, cased with 6” steel casings following the design of a supervising hydrogeologist.
(iii) The borehole should be properly developed, gravel packed and sealed to avoid any contamination from shallow aquifers.

(iv) The borehole 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 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.