HYDROGEOLOGICAL ASSESSMENT REPORT

FOR

CLIENT;

OLOONTARE PRIMARY SCHOOL, P.O. BOX 428 - 40700, KILGORIS

LOCATION;

OLOONTARE AREA - KEYIAN DIVISION, TRANSMARA WEST DISTRICT, NAROK COUNTY

REPORT NO: SMW/147/2022

Report Compiled By;
S.M. WANJAU (REG.Hydrogeologist)
P.O BOX 37521 – 00100,
NAIROBI
PHONE: 0750 900 921

Date: 3rd January, 2023

SUMMARY

This Report discusses the results of a geophysical site survey for one borehole within Oloontare Village, Oloontare Sub-location, Oloontare Location, Keyian Division of Trans Mara West District, Narok County at Oloontare Primary School's parcel of land. The land is situated at about 32 kilometers from Kilgoris centre within Oloontare area.

The boreholes drilled within the neighborhood of the investigated area have recorded yields ranging between 0.18 – 0.43m^3/hr. The yield of a borehole drilled at the plot is expected to be within the above range, but careful construction and development will lead to maximum borehole productivity, efficiency and long life.

Groundwater occurs within the OLS and highly weathered/ fractured basement rocks.

Recharge of the aquifers is by direct and indirect replenishment.

A suitable site has been located by means of geophysical field measurements to tap water from the main water bearing aquifers within the OLS and highly weathered/ fractured basement rocks.

The proposed borehole should be drilled to a depth of 220 metres below ground level.

The quality and the quantity of groundwater at the proposed site are expected to be good.

The report is accompanied by maps, borehole, geophysical data and curves.

TABLE OF CONTENTS

SUMMARY I
Table of contents.. iii
1. NAME AND DETAILS OF APPLICANT 1
2. BACKGROUND INFORMATION 2
2.1 LOCATION 2
2.2 PHYSIOGRAPHY 2
2.3 CLIMATE 2
2.4 WATER DEMAND 3
3. GEOLOGY 5
3.1 REGIONAL GEOLOGY 5
3.2 GEOLOGY OF THE SURVEY AREA 5
4. HYDROGEOLOGY 7
4.1 BACKGROUND 7
4.2 EXISTING BOREHOLES 7
4.2.1 Borehole Data Analyses and Aquifer Outline of the Area. 7
4.2.2 Impacts to Abstraction Trends and Analyses of Boreholes within 800-m from the Proposed Site 7
4.3 RECHARGE 8
4.3.1 Mean Annual Recharge 8
4.4 DISCHARGE 9
4.5 AQUIFER PROPERTIES 9
4.5.1 Calculation of Aquifer Properties 9
4.5.2 Estimation Aquifer Transmissivity 9
4.5.3 Hydraulic Conductivity 9
4.5.4 Specific Capacity 9
4.5.5 Groundwater Flux 10
4.6 WATER QUALITY 10
4.7 IMPACTS OF THE PROPOSED ACTIVITY TO WATER QUALITY, WETLANDS 10
5. GEOPHYSICAL INVESTIGATION METHODS 11
5.1 RESISTIVITY METHOD 11
5.2 BASIC PRINCIPLES 11
5.3 VERTICAL ELECTRICAL SOUNDINGS (VES) 12
6. FIELDWORK AND RESULTS 13
6.1 RESULTS 13
6.2 SITE IDENTIFICATION 21
7. CONCLUSIONS AND RECOMMENDATIONS 22
8. REFERENCES 23
9. APPENDICES 1

LIST OF FIGURES

FIGURE 2.1: A LOCATION MAP OF THE STUDY AREA...3

LIST OF TABLES

FIGURE 4.1: BOREHOLES IN THE VICINITY OF THE SITE...6

ABBREVIATIONS (All S.I Units unless indicated otherwise)

agl	*above ground level*
amsl	*above mean sea level*
bgl	*below ground level*
E	*East*
EC	*electrical conductivity (μS/cm)*
hr	*hour*
m	*metre*
N	*North*
PWL	*pumped water level*
Q	*discharge (m^3/hr)*
s	*drawdown (m)*
S	*South*
SWL	*static water level*
T	*transmissivity (m^2/day)*
VES	*Vertical Electrical Sounding*
W	*West*
WAB	*Water Apportionment Board*
WSL	*water struck level*
μS/cm	*micro-Siemens per centimetre: Unit for electrical conductivity*
°C	*degrees Celsius: Unit for temperature*
"	*Inch*

GLOSSARY OF TERMS

Alluvium *General term for detrital material deposited by flowing water.*

Aquifer *A geological formation or structure, which stores and transmits water and which is able to supply water to wells, boreholes or springs.*

Colluvium *General term for detrital material deposited by hill slope gravitational processes, with or without water as an agent. Usually of mixed texture.*

Confined aquifer *A formation in which the groundwater is isolated from the atmosphere by impermeable geologic formations. Confined water is generally at greater pressure than atmospheric, and will therefore rise above the struck level in a borehole.*

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.*

Fault *A larger fracture surface along which appreciable displacement has taken place.*

Gradient *The rate of change in total head per unit of distance, which causes flow in the direction of the lowest >head.*

Grit *Coarse sandstone of angular grain*

Hydraulic head *Energy contained in a water mass, produced by elevation, pressure or velocity.*

Hydrogeological *Those factors that deal with subsurface waters and related geological aspects of surface waters.*

Infiltration *Process of water entering the soil through the ground surface.*

Joint *Fractures along which no significant displacement has taken place.*

Lava sheet *Lava flow, in parts very thick, covering a large area.*

Percolation *Process of water seeping through the unsaturated zone, generally from a surface source to the saturated zone.*

Permeability *The capacity of a porous medium for transmitting fluid.*

Phenocrysts *Large, conspicuous crystals in porphyritic rocks (i.e. rocks with visible mineral crystals in a generally fine groundmass).*

Phonolite *Compact and fine textured volcanic rock, belonging to the trachyte-group (together with trachyte ss. and latite). Defined by a high portion of feldspar (40-90%) and feldspatoidic minerals (10-60%: analcite, nepheline, leucite, etc.), and very low to negligible quartz content (0-2%). Incorporated dark coloured minerals (0-40%) most commonly include hornblende, olivine, melanite and acmite. The structure is porphyritic with common phenocrysts of sanidine (orthoclase, or Potassium-feldspar) and nepheline.*

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

Pyroclastic rocks *Group of rocks consisting of volcanic dust, ashes, lapilli and coarse lumps of lava, explosively thrown up in molten condition, and deposited by gravity. Hardened masses of dust, ashes and lapilli are known as tuff, while coarse, consolidated pyroclastic debris is referred to as agglomerate.*

Porosity *The portion of bulk volume in a rock or sediment that is occupied by openings, whether isolated or connected.*

Pumping test *A test that is conducted to determine aquifer and/or well characteristics.*

Recharge *General term applied to the passage of water from surface or subsurface sources (e.g. rivers, rainfall, lateral groundwater flow) to the aquifer zones.*

Static water level *The level of water in a well that is not being affected by pumping (a.k.a. "rest water level")*

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

Tuff *Here: hardened volcanic ash.*

Unconfined *Referring to an aquifer situation whereby the water table is exposed to the atmosphere through openings in the overlying materials (as opposed to >confined conditions).*

Yield *Volume of water discharged from a well.*

1. NAME AND DETAILS OF APPLICANT

Oloontare Primary School *herein referred to as the client and the proprietor of the plot commissioned the present consultants to carry out a hydrogeological and geophysical survey within their parcel of land in Transmara West District.*

The hydrogeological survey was envisaged to determine the best location for drilling the proposed borehole to supply water for domestic use within the plot.

The Client's contact details are as follows:

Oloontare Primary School,
P.O. Box 428 - 40700,
Kilgoris

The objective of the survey was to establish the optimum location of a borehole planned to provide water to our Client for domestic purposes.

The project area is not connected to any public water supply and thus the client relies on water vendors which are expensive and unreliable. Chronic water shortages have driven the client to think of drilling a borehole to act as the main water supply for this plot.

It is against this background that a detailed hydrogeological survey was envisaged to determine groundwater potential within the plot and the possibility of sinking the proposed borehole.

The hydrogeological assessment report gives the details of drilling depth, water quality and estimated yields. It also assists in registration of the borehole with the Water Resources Management Authority of the Ministry of Water and irrigation.

Based on the recommendations of the report, the contractor can project cost estimates for the drilling and construction works.

2. BACKGROUND INFORMATION

2.1 Location

The site is situated within Oloontare Village, Oloontare Sub-location, Oloontare Location, Keyian Division of Trans Mara West District, Narok County. It lies within the 1:50,000 Survey of Kenya topographic sheet for Nyangweso (No. 130/4). Its defining coordinates in UTM are 36M 0683479E and 9890613N (Fig.2.1).

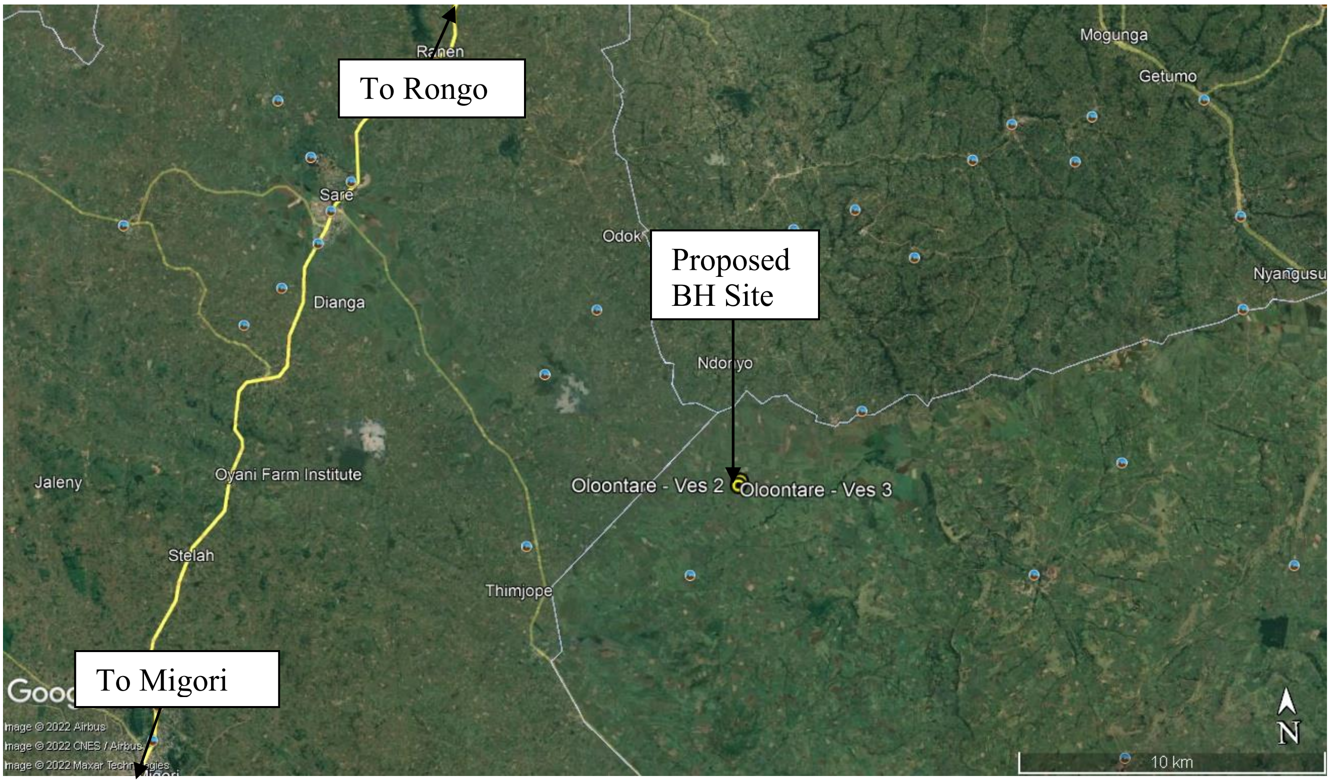


Figure 2-1 - Google Earth Image showing the site location

2.2 Physiography

The plot lies at an altitude of about 1559m.

The general area is formed by a high-lying basement terrain, displayed by steep slopes on either sides and by the remains of a peneplain on the lower ground. The land is located on a flat to gentle sloping region and generally slopes to the south an aspect signified by drainage pattern of streams and rivers. The soils are mainly composed of poorly drained sandy black cotton-type.

2.3 Climate

***Precipitation:** The area is characterized by a semi-arid, warm temperate climate (Sombroek et al, 1982). The mean annual precipitation amounts to 800 mm. There is no a well defined rainy season but the heaviest rainfall is recorded in December-January and again in March-April with the maximum in April.*

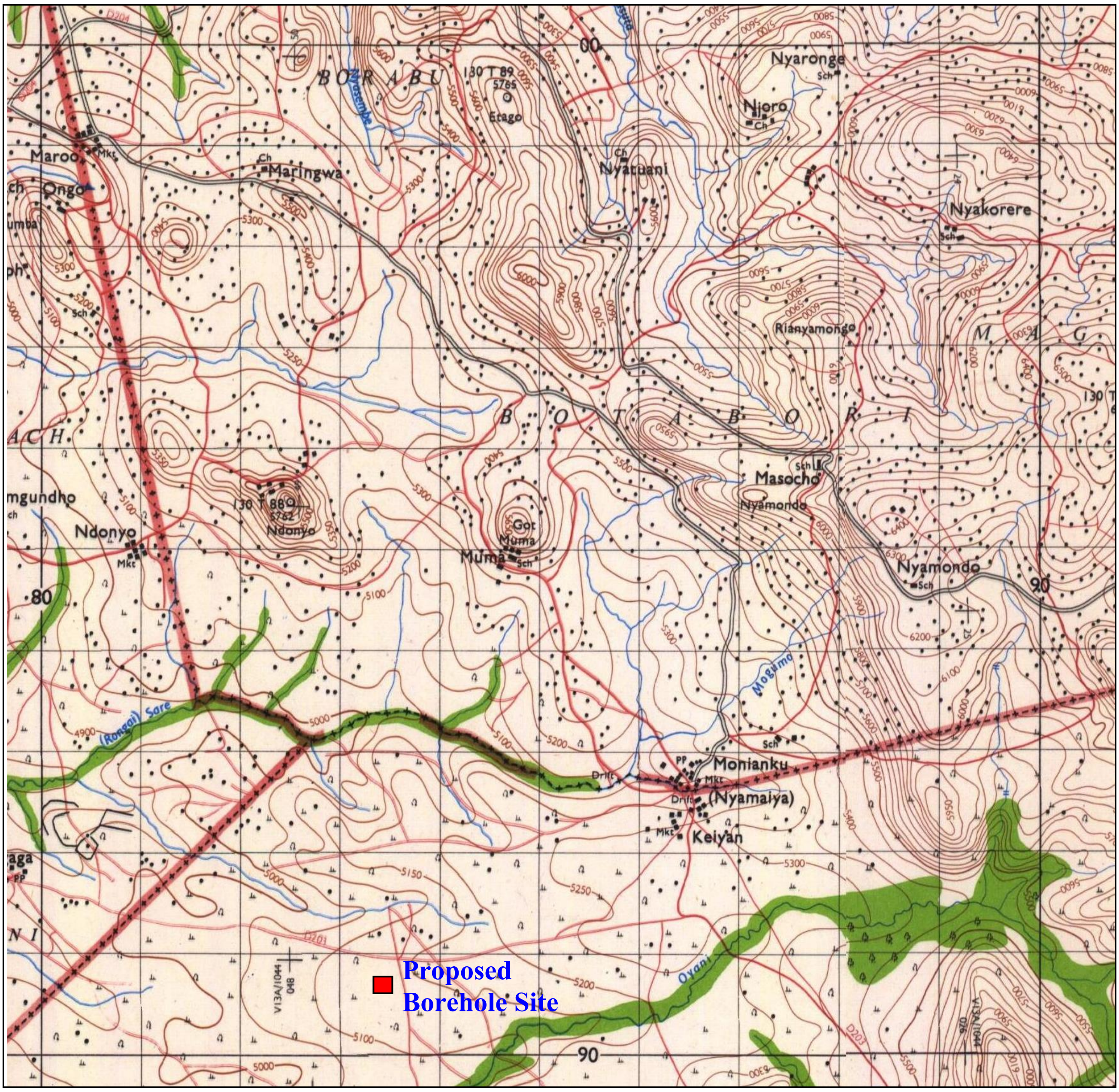
Temperature: *The maximum annual temperature is between 18 and 20 ^oC; with a mean maximum of 24 and 26 ^oC and the mean minimum of 12 - 14 ^oC.*

2.4 Water Demand

Water from the proposed borehole will be used for domestic purposes within the school.

S/No	*Consumer*	*Demand/Day*	*Total Demand*
1.	*200 no. persons*	*100l/day*	*20,000l/day*
Total Demand			*20,000l/day*

Water demand is estimated at $20m^3$/day.



LEGEND

Proposed borehole Site

Surrounding boreholes

Fig 2.1: Map showing the study area and environs, Scale 1:50,000

3. GEOLOGY

3.1 Regional Geology

The area is entirely underlain by Precambrian rocks of the Basement System. Due to its location on the weastern shoulder of the Gregory Rift Valley, the original crystalline rocks of the Mozambican Belt have locally been covered by younger volcanic deposits.

The oldest rocks in the area are formed by various types of gneisses, limestones and quartzites. The original rocks of sedimentary origin were presumably laid down in a geosyncline that covers a large part of East and Central Africa. The lower succession consists of relatively coarse psammitic gneisses, probably produced by rapid deposition in relatively deep water. The upper part, the Loita Series, is mainly pelitic (fine-grained) in character, and numerous limestones and quartzites indicate the calmer environment of a relatively shallow basin. Minor igneous activity is represented by amphibolites, which are thin and concordant.

After their deposition, the sediments were metamorphosed and folded. Metamorphosed granite (an intrusive) was formed during this period. The compression and folding led to the formation of mountain chains, which were intensively eroded at a later stage.

In the area of interest, the oldest of these Tertiary volcanics is the Phonolite which is porphyritic, often vesicular containing rare tuff.

The final event was the formation of Recent soils. In the Basement areas, the soils are usually reddish brown and sandy, but black cotton soils may occur in areas of poor drainage. The Basement System in the Rift Valley yields grey sandy soil. Black cotton soil is formed on most of the volcanic rocks.

3.2 Geology of the Survey Area

The study site gently slopes with little dissection. Outcrops are generally poorly exposed within the studied area but more prevalent on the lower slopes and along the stream channels. Most of the area is covered by black soils.

The outcrops on the western side of the area comprise of biotite-horneblende granites and gneisses. This formation is an intrusive body. Some volcanic outcrops composed of porhyritic often vesicular, phonolites with rare tuff partially cover the intrusive metamorphosed body. At the foot of the escarpment are mylonitized gneisses intercalated by bands of amphibolites a sign of tectonic movements.

These soils are imperfectly drained lateritic clays to dark black cotton soils.

The formations likely to be encountered during drilling are:

- *Recent soils (both elluvial and weathered products: in situ).*
- *Tertiary Sediments and Volcanic (Phonolite and tuffs)*
- *Slightly weathered Biotite-Horneblende granite*
- *Moderately weathered Biotite-Horneblende granite*
- *Fractured/weathered Basement (Quartzo-feldspathic gneiss)*
- *Massive/compact Basement (Biotite-horneblende granite)*

Weathered layers, sediments and Phonolites overlying the basement rocks are all potential aquifers. However, the most important local aquifer occurs in the deeply weathered/fractured rocks of the Basement System.

4. HYDROGEOLOGY

4.1 Background

Kilgoris area and its environs groundwater is found in Basement rock and volcanic deposits. More attention is given to the Basement aquifers owing to the underlying geology (Biotite-horneblende granite) covered by tertiary volcanics;

a. ***In Basement System rocks***

Groundwater can occur in the regolith (the weathered, decomposed and fragmented part of the Basement rock), or in faults and fractures that are interconnected.

b. ***In volcanic rocks***

Groundwater is limited to fractures and erosion levels within the stratified volcanic succession. In the volcanic areas within the region, the best aquifers occur on the boundary of volcanic rocks and the underlying Basement System:

c. ***Sedimentary aquifers***

Consist of erosion debris from volcanic or Basement rocks. Their suitability for aquifer development depends on parent material, thickness and recharge.

4.2 Existing boreholes

Some boreholes have been drilled in the project area. Available records were studied for 4 boreholes within a radius of about 15.5-km from the present site. Results of the data inventory are presented in Table 4.1.

Table 4.1 - Boreholes in the Vicinity of the Site

BH NO.	OWNER	DIRECTION (KM)	TD	WSL	WRL	T.Y	PWL
Ref.	**Oloontare Pri. Sch's Site**						
3214	-	9.6 NE	155	95	46	0.18	122.2
6082	Major Konchella	15.5 NE	82	58	29.6	-	-
10710	St Joseph Hospital	11.8 NE	100	50	16.8	0.43	90.2
Range			**82 – 155.0**	**50 - 95**	**16.8 – 46.0**	**0.18 – 0.43**	**90.2 – 122.2**

4.2.1 Borehole Data Analyses and Aquifer Outline of the Area.

These boreholes abstract water from aquifers between 50 - 95m bgl, and have recorded yields ranging between 01.8 – 0.43m^3/hr. The yield of the present borehole is expected to be within the above range.

4.2.2 Impacts to Abstraction Trends and Analyses of Boreholes within 800-m from the Proposed Site

From the records, there is NO borehole which is located within 1000m radius.

Thus there is no any foreseen interference with the existing boreholes or the groundwater abstraction trends. The boreholes have good yields which is an indication of underlying productive aquifers.

4.3 Recharge

The recharge mechanisms (and the rate of replenishment) of the local aquifers has not been fully established. The two major processes are probably direct recharge at surface (not necessarily local) and indirect recharge via faults and/or other aquifers. However, except for a fault to the east of the area down the escarpment, no other faults have been mapped in the study area.

Direct recharge is obtained through downward percolation of rainfall or river water into aquifer. If the infiltration rate is low due to the presence of an aquiclude (such as clay), the recharge to the aquifer is low. Percolation will depend on the soil structure, vegetation cover and the state of weathering of the parent rock. Rocks weathering to clayey soils naturally inhibit infiltration and downward percolation. Aquifers may also be recharged laterally if the rock is permeable over a wide area.

In the present study area, the principal recharge mechanism is direct infiltration of the rainfall. Rainfall in the region is low to moderate (800 mm). The occurrence of thin layers of clayey soils in the area of study inhibits infiltration of rainwater.

4.3.1 *Mean Annual Recharge*

Although rainfall within the study area is low, regional recharge is of great essence in this area. Much of regional recharge occurs within the eastern flanks of the rift valley followed by base flow within the thick volcanic sheets and faults which characterise the region. ***However, this recharge mechanism is mainly important for the replenishment of (regional) volcanic aquifers and is what has been used to estimate the Mean Annul Recharge.***

At the present location, water also percolates directly into the faults, fractures, local rivers and streams (via fractures) thus deeper and adjacent units are recharged over time.

Mean Annual Recharge has therefore been estimated as follows:

The Recharge is estimated as 5% of the Mean Annual Rainfall of the recharge area

800mm x 5%

Mean Annual Recharge = 40mm

However, this recharge amount is probably estimation due to the possibility of influent local recharge through local rivers and rainwater percolation through faults into the weathered/fractured basement rock system and overlaying OLS.

4.4 Discharge

Discharge from aquifers is either through natural processes as base-flow to streams and springs, or artificial discharge through human activities. However considering the few number of boreholes in the area this is form of discharge is not much pronounced.

The total effective discharge from the aquifers via either of the above means is not known, and should in fact be studied. The main form of discharge is through flow along formations and faults/ interconnected fractures.

4.5 Aquifer Properties

4.5.1 *Calculation of Aquifer Properties*

To calculate the area Aquifer Properties, testing pumping data of borehole C 10710 was adopted.

***In summary**, the borehole has a total drilled depth of 100m, yield of 0.43m^3/hr, Water Struck level of 50m, Water Rest level of 16.8m and Pumped Water Level of 90.2m. The borehole has fairly penetrated the productive upper aquifers and thus will be fair enough to deduce the aquifer properties of the project Area. It had a drawdown of 73.4m.*

4.5.2 *Estimation Aquifer Transmissivity*

Aquifer Transmissivity (T) is estimated as follows:

$$T = 1.22Q/\Delta S \qquad \text{Where: } Q = \text{Yield per day}, \quad \Delta S = \text{Draw down}$$

$$T = 1.22/73.4 \times 10.32 = \mathbf{0.17 m/day}$$

4.5.3 *Hydraulic Conductivity*

The Hydraulic Conductivity (K) is estimated as follows:

$$K = T/\text{Aquifer Thickness}$$

Based on the geological logs of the boreholes in the area, the cumulative aquifer thickness for the purpose of this calculation has been estimated at 7m. Thus,

K = 0.17/7
K = 0.02m/day

4.5.4 *Specific Capacity*

The aquifer Specific Capacity (S) = Q/∆s.

***Where:** Q = Discharge (m^3/day) =10.32m^3/day*
D = Drawdown (m) = 73.4m).
S= 0.14m^2/day

4.5.5 *Groundwater Flux*

*The Groundwater Flux (F) is estimated based on borehole **C- 10710** and **C 6082** which more or less share the same aquifers.*

F = K.i.h.w   Where K- Hydraulic Conductivity = 0.02m/day
i – Slope = 9 /15000
h- Aquifer Thickness =7m
w- Arbitrary distance, 11100m

Thus;

F = 0.02m (9/15000). 7. 11100

F = ***0.93m³/day***

4.6 Water Quality

Water quality strongly reflects aquifer type and geometry, recharge and abstraction periods, and original geology. Practically all types of water, i.e. runoff water, groundwater and even rainwater, contain some dissolved salts and impurities. If certain elements are present in high concentrations, the application of the water for domestic use or any other purpose may be limited.

Groundwater in the study area is actually not known though locals say that water got from the seasonal spring is good for domestic use and for their livestock.

W.H.O. and EC guideline concentrations are included for reference in appendix section.

4.7 Impacts of the Proposed Activity to Water Quality, Wetlands

The Proposed drill site and related works are expected to pose no impact on water quality, either Surface or groundwater resources. There is no any surface water body near the drill site that can be contaminated by waste waters generated during drilling. The entire drilling, borehole construction, pump tests, and completion works will be done under supervision to professional standards. Entry of any foreign material until completion will be avoided to avoid any entry of foreign material into the borehole and only inert materials will be used in construction. The borehole will be properly developed to open up the aquifers and clean the borehole water. Monitoring of ec during drilling will be done to detect and seal any aquifer with elevated mineralization.
The site is not located within a wetland and has no negative impacts on biodiversity.

5. GEOPHYSICAL INVESTIGATION METHODS

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

5.1 Resistivity Method

Vertical electrical soundings (VES) were carried out to probe the condition of the sub-surface and to confirm the existence of deep groundwater. The VES investigates the resistivity layering below the site of measurement. This technique is described below.

5.2 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, and the higher the salinity of the saturating fluids, the lower the resistivity. The presence of clays and conductive minerals also reduces the resistivity of the rock.

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-sectional area A, expressed as:

$$R = Rs * L/A \qquad (Ohm) \qquad (1)$$

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

$$R = dV/I \qquad (Ohm) \qquad (2)$$

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:

$$Rs = (A/L) * (dV/I) \qquad (Ohm.m) \qquad (3)$$

5.3 Vertical Electrical Soundings (VES)

When carrying out a resistivity sounding, current is led 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 electrode separations, the ground resistivity can be determined.

While carrying out the resistivity sounding the separation between the electrodes is step-wise increased (in what is known as a Schlumberger Array), thus causing the flow of current to penetrate greater depths. When plotting the observed resistivity values against depth on double logarithmic paper, a resistivity graph is formed, which depicts the variation of resistivity with depth.

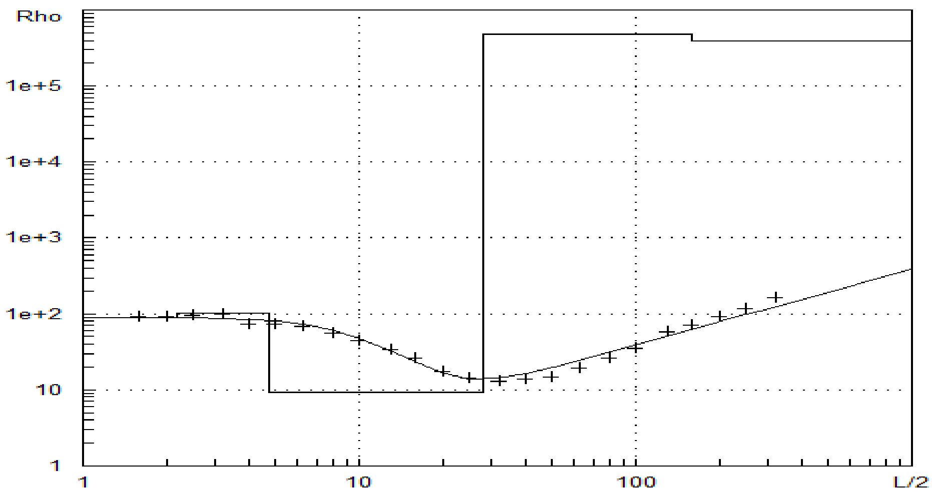
This graph can be interpreted with the aid of a computer, and the actual resistivity layering of the subsoil is obtained. The depths and resistivity values provide the hydrogeologist with information on the geological layering and thus the occurrence of groundwater.

6. FIELDWORK AND RESULTS

Field work was carried out on 20th December, 2022. Three Vertical Electrical Sounding (VES) and one control Ves were executed. The aim of the sounding was to determine the prevailing hydrostratigraphy at the site.

6.1 Results

Control VES (Sikawa) Sounding Curve, Geoelectrical model and Data set.



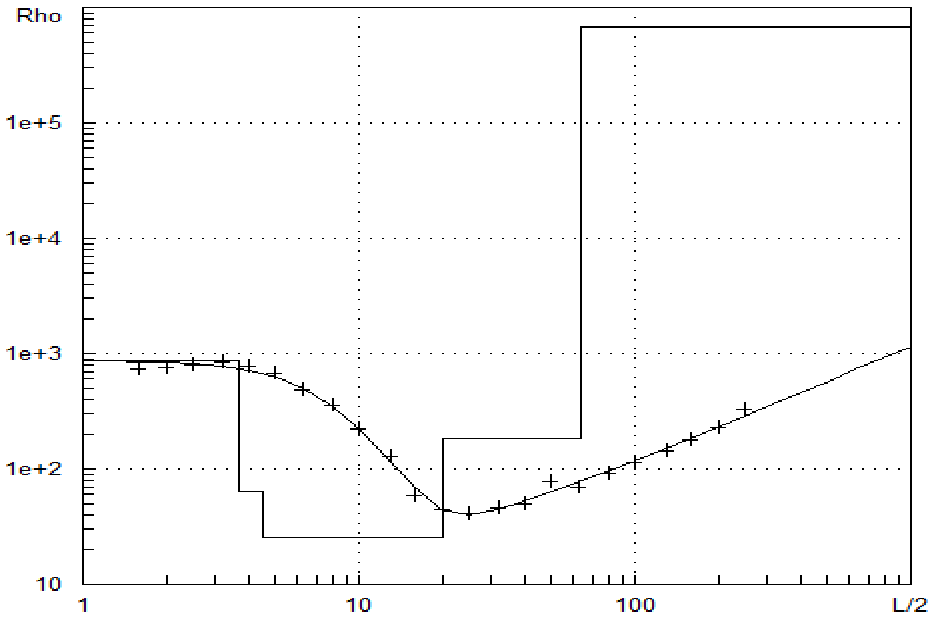
Layer	*Resistivity (Ohm)*	*Thickness (m)*	*Depth (m)*
1	90.50	2.20	2.20
2	98.70	2.50	4.70
3	9.90	23.30	28.00
4	500.60	132.60	160.60
5	500.90		
Station No.	**AB/2**	**MN**	**Resistivity (ohm)**
1	1.6	0.5	92.2
2	2.0	0.5	93.6
3	2.5	0.5	96.2
4	3.2	0.5	97.1
5	4.0	0.5	72.6
6	5.0	0.5	74.1
7	6.3	0.5	68.9
8	8.0	0.5	56.5
9	10	0.5	44.7
10	13	0.5	34.2
11	16	0.5	26.1
12	20	0.5	17.6
13	25	5	14.5
14	32	5	13.1
15	40	5	14.0
16	50	10	14.8
17	63	10	19.3
18	80	10	26.1
19	100	10	35.2
20	130	25	57.2
21	160	25	70.4
22	200	25	92.6
23	250	25	116.3
24	320	25	162.6

Interpretations of Control VES

Depth (m)	***Resistivity (Ohmm)***	***Interpretation***
0.0 – 2.2	*90.50*	*Top sub-surface soils*
2.2 – 4.7	*98.70*	*Weathered sub-surface soils*
4.7 – 28.0	*9.90*	*Highly weathered regolith*
28.0 – 160.6	*500.60*	*Slightly weathered /fractured basement*
Below 160.6	*500.90*	*Slightly weathered to fresh basement*

The results of control VES measurements show that the site is covered at the surface by dry top soils to a depth of about 2.2m and are underlain by weathered sub-surface soils to a depth of 4.7m. These are underlain by highly weathered regolith to a depth of about 28.0m which are then underlain by slightly weathered basement to a depth of 160.6m. Beyond 160.6m is slightly weathered to fresh basement layer with increasing resistivity.

VES 1 Sounding Curve, Geoelectrical model and Data set.



Layer	Resistivity (Ohm)	Thickness (m)	Depth (m)
1	865.20	3.70	3.70
2	63.40	0.80	4.50
3	25.90	15.80	20.30
4	181.30	43.10	63.40
5	900.30		
Station No.	**AB/2**	**MN**	**Resistivity (ohm)**
1	1.6	0.5	740.9
2	2.0	0.5	759.2
3	2.5	0.5	802.7
4	3.2	0.5	856.8
5	4.0	0.5	785.3
6	5.0	0.5	685.3
7	6.3	0.5	488.5
8	8.0	0.5	359.5
9	10	0.5	221.8
10	13	0.5	126.4
11	16	0.5	58.3
12	20	0.5	44.9
13	25	5	41.6
14	32	5	45.4
15	40	5	50.1
16	50	10	78.0
17	63	10	69.9
18	80	10	91.2
19	100	10	114.7
20	130	25	143.6
21	160	25	176.7
22	200	25	231.9
23	250	25	325.0

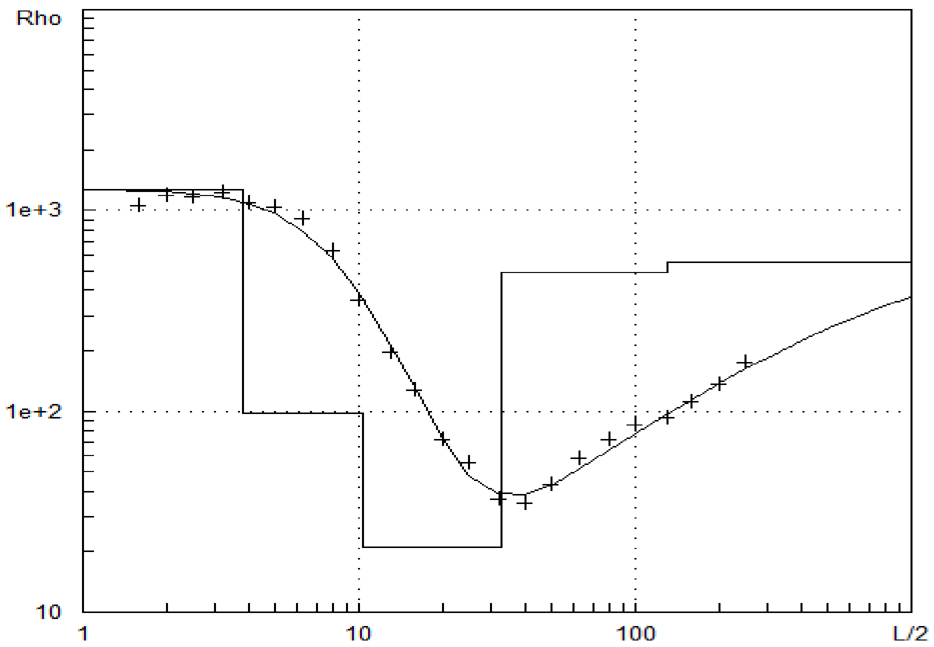
Interpretations of VES 1

Depth (m)	***Resistivity (Ohmm)***	***Interpretation***
0.0 – 3.7	*91.70*	*Top sub-surface soils*
3.7 – 4.5	*36.80*	*Weathered sub-surface soils*
4.5 – 20.3	*450.60*	*Weathered regolith*
20.3 – 63.4	*1900.50*	*Slightly weathered /fractured basement*
Below 63.4	*2900.30*	*Slightly weathered to fresh basement*

The results of VES 1 measurements show that the site is covered at the surface by dry top soils to a depth of about 3.7m and are underlain by weathered sub-surface soils to a depth of 4.5m. These are underlain by weathered regolith to a depth of about 20.3m which are then underlain by slightly weathered basement to a depth of 63.4m. Beyond 63.4m is slightly weathered to fresh basement layer with increasing resistivity.

Drilling is not recommended at this site.

VES 2 Sounding Curve, Geoelectrical model and Data set.



Layer	*Resistivity (Ohm)*	*Thickness (m)*	*Depth (m)*
1	1271.40	3.80	3.80
2	98.00	6.60	10.40
3	21.10	22.20	32.60
4	490.20	97.60	130.20
5	550.30		
Station No.	**AB/2**	**MN**	**Resistivity (ohm)**
1	1.6	0.5	1061.0
2	2.0	0.5	1184.6
3	2.5	0.5	1176.3
4	3.2	0.5	1221.9
5	4.0	0.5	1096.7
6	5.0	0.5	1041.6
7	6.3	0.5	905.5
8	8.0	0.5	627.8
9	10	0.5	359.7
10	13	0.5	196.8
11	16	0.5	127.9
12	20	0.5	72.4
13	25	5	55.5
14	32	5	36.5
15	40	5	34.8
16	50	10	43.2
17	63	10	58.4
18	80	10	72.8
19	100	10	85.1
20	130	25	92.4
21	160	25	111.9
22	200	25	136.8
23	250	25	176.0

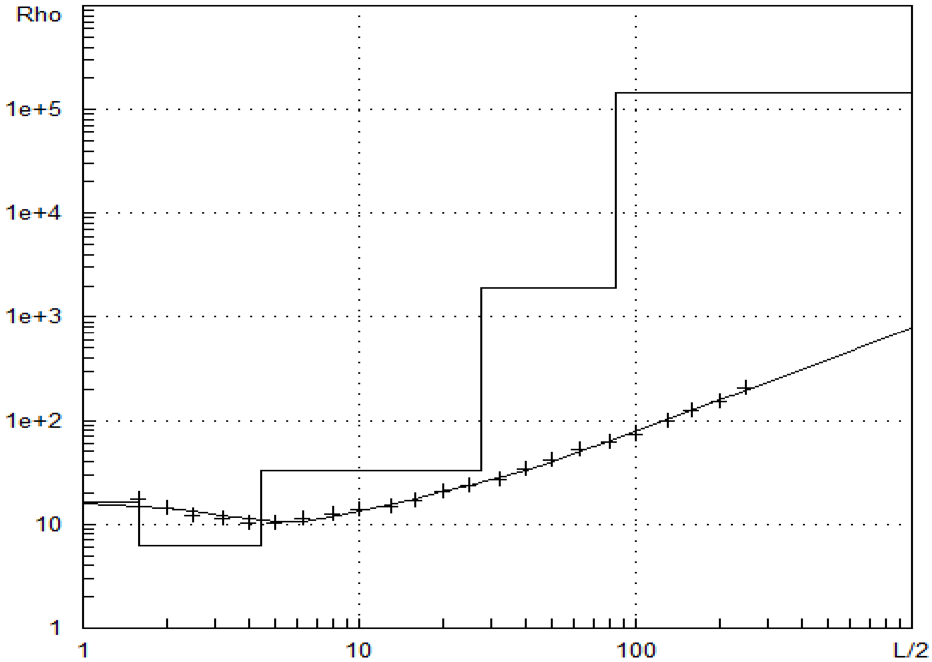
Interpretations of VES 2

Depth (m)	***Resistivity (Ohmm)***	***Interpretation***
0.0 – 3.8	*1271.40*	*Top sub-surface soils*
3.8 – 10.4	*98.00*	*Weathered sub-surface soils*
10.4 – 32.6	*21.10*	*Highly weathered regolith*
32.6 – 130.2	*490.20*	*Slightly weathered /fractured basement*
Below 130.2	*550.30*	*Slightly weathered to fresh basement*

The results of VES 2 measurements show that the site is covered at the surface by dry top soils to a depth of about 3.8m and are underlain by weathered sub-surface soils to a depth of 10.4m. These are underlain by highly weathered regolith to a depth of about 32.6m which are then underlain by slightly weathered basement to a depth of 130.2m. Beyond 130.2m is slightly weathered to fresh basement layer with increasing resistivity.

Drilling is recommended at this site to a depth of about 220m.

VES 3 Sounding Curve, Geoelectrical model and Data set.



Layer	*Resistivity (Ohm)*	*Thickness (m)*	*Depth (m)*
1	16.10	1.60	1.60
2	6.20	2.80	4.40
3	33.40	23.50	27.90
4	200.30	56.70	84.60
5	850.90		
Station No.	**AB/2**	**MN**	**Resistivity (ohm)**
1	1.6	0.5	17.5
2	2.0	0.5	14.1
3	2.5	0.5	12.2
4	3.2	0.5	11.3
5	4.0	0.5	10.3
6	5.0	0.5	10.4
7	6.3	0.5	11.2
8	8.0	0.5	12.7
9	10	0.5	14.0
10	13	0.5	14.7
11	16	0.5	17.0
12	20	0.5	20.8
13	25	5	23.5
14	32	5	26.9
15	40	5	34.0
16	50	10	41.9
17	63	10	52.7
18	80	10	62.3
19	100	10	73.7
20	130	25	98.5
21	160	25	122.6
22	200	25	152.4
23	250	25	208.7

Interpretations of VES 3

Depth (m)	***Resistivity (Ohmm)***	***Interpretation***
0.0 – 1.6	*16.10*	*Top sub-surface soils*
1.6 – 4.4	*6.20*	*Highly weathered sub-surface soils*
4.4 – 27.9	*33.40*	*Weathered regolith*
27.9 – 84.6	*200.30*	*Slightly weathered /fractured basement*
Below 84.6	*850.90*	*Slightly weathered to fresh basement*

The results of VES 3 measurements show that the site is covered at the surface by dry top soils to a depth of about 1.6m and are underlain by highly weathered sub-surface soils to a depth of 4.4m. These are underlain by weathered regolith to a depth of about 27.9m which are then underlain by slightly weathered basement to a depth of 84.6m. Beyond 84.6m is slightly weathered to fresh basement layer with increasing resistivity.

Drilling is recommended at this site to a depth of about 220m.

6.2 Site Identification

The study thus recommends that the borehole be drilled at VES 2 ***to a depth of about 220m bgl or until fresh basement is struck.***

Figure 6-1 - Google Earth Image showing the drilling site

7. CONCLUSIONS AND RECOMMENDATIONS

On the basis of all the information gathered in the field, geological, geophysical and hydrogeological evidence,

*A borehole is recommended to be drilled at the site of **VES- 2 to a <u>depth of about 220m bgl</u>.** This will ensure that the deeper aquifer is fully penetrated.*

The yield of a borehole drilled at the selected site is expected to be within the stated range (0.18-0.43m^3/hr), but careful construction and development will lead to maximum borehole productivity, efficiency and long life.

Water quality is expected to be good for human and livestock consumption.

It is thus recommended that:

- ✓ ***The borehole should be drilled at VES 2 position at a minimum of 8 inch diameter and to a depth of about 220m bgl or until fresh basement is reached**.*
- ✓ *To install the borehole with mild steel casings and gas-slotted screens*
- ✓ *The borehole hydraulic properties and aquifer characteristics should be determined during a 24-hour constant discharge test.*
- ✓ *Samples taken during test pumping must be submitted to a recognized laboratory for full physical, chemical and bacteriological analyses.*
- ✓ *A monitoring tube and master meter should be installed in the borehole to be able to monitor the water level and water consumption respectively.*

With careful implementation of the project by adhering to the study's findings and recommendations and by following the Water Resources Management Authority's Guidelines (found in the Authorization letter to Drill the Borehole), the project will safely meet the client's objectives successfully without any impact to groundwater abstraction trends in the area and surrounding boreholes.

8. REFERENCES

FLETCHER G. DRISCOLL, (1986)
Groundwater And Wells, 2nd Edition

MINES AND GEOLOGICAL DEPARTMENT OF KENYA
Geological map of the Mara River, Degree Sheet No. 50

SOMBROEK, W G, BRAUN, H M H, AND VAN DER POUW, B J A, (1982)
Exploratory Soil Map and Agroclimatic Zone Map of Kenya, 1980, Kenya Soil Survey.

9. APPENDICES

APPENDIX I - Acceptable Ionic Concentration - Various Authorities

		World Health Organization:			European Community:						
		1983		1971 Int.	EC Directive 1980 relating to the quality						
		Guidelines;	Standards;	of water intended for human consumption:							
Substance or		Guideline	Upper limit		GuideLevel	Max. Admissible					
Characteristic	Value (GV)	(HL), (tentative)		(GL)	Concentration (MAC)						
Inorganic Constituents of health significance;											
Antimony Sb							0.01				
Arsenic	As	0.05		0.05				0.05			
Cadmium Cd	0.005		0.01				0.005				
Chromium Cr	0.05		0.05								
Cyanide	CN	0.10		0.05				0.05			
Fluoride	F	1.5		1.7				1.5			
Lead	Pb	0.05		0.10				0.05			
Mercury	Hg	0.001		0.001				0.001			
Nickel	Ni							0.05			
Nitrates		10 (as N)	45 (as NO3)		25 (as NO3)		50 (as NO3)				
Selenium Se			0.01				0.01				
Other Substances		GV:		Highest	Maximum		GV:		MAC:		
			Desirable	Permissible							
			Level:		Level:						
Aluminium Al		0.20						0.05		0.20	
Ammonium	NH4								0.05		0.50
Barium	Ba								0.10		
Boron	B								1.0		
Calcium	Ca				75		50		100		
Chloride	Cl		250		200		600		25		
Copper	Cu				0.05				0.10		
Hydrogen											
Sulphide H2S		ND								ND	
Iron	Fe		0.30		0.10		1.0		0.05		0.20
Magnesium	Mg		0.10		30		150		30		50
Manganese	Mn		0.10		0.05		0.50		0.02		0.05
Nitrite	NO2										0.10
Potassium K								10		12	
Silver	Ag										0.01
Sodium	Na		200						20		175
Sulphate	SO4		400		200		400		25		250
Zinc	Zn				5.0		15		0.10		
Total Dissolved Solids		1000		500		1500				1500	
Total Hardness as CaCO3			500		100		500				
Colour	°Hazen		15		5		50		1		20
Odour			Inoffensive	Unobjectionable					2 or 3 TON		
Taste			Inoffensive	Unobjectionable					2 or 3 TON		
Turbidity (JTU)		5		5		25		0.4		4	
pH			6.5 - 8.5	7.0 - 8.5	6.5 - 9.2	6.5 - 8.5	9.5 (max.)				
Temperature	°C								12		25
EC	uS/cm								400		
Notes	ND - Not Detectable			IO - Inoffensive							
	GL - Guide Level				UO - Unobjectionable						

(Based on Table 6.1, in Twort, Law & Crowley, 1985 - Water Supply, Edward Anorld, London).

APPENDIX II; DRILLING AND DEVELOPMENT PROCEDURES

1. Drilling

Drilling should be carried out with an appropriate tool - either percussion or rotary machines will be suitable, though the latter are considerably faster and higher overheads. Geological rock samples should be collected at 2 metre intervals. Struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered, should also be noted.

2. Well Designs

The design of the well should ensure that screens are placed opposite the optimum aquifer zones. The final design should be left in the hands of an experienced driller or hydro-geologist.

3. Casing and Screens

The well should be cased and screened with appropriate steel casings and screens as per the design given above. In comparatively shallow wells, uPVC casing and screens of 5" or 6" diameter may be adequate. Slots should be 1 mm in size.

4. Gravel Pack

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

5. Well Construction

Once the design has been agreed upon, construction can proceed. In installing screen and casing, centralizers at 6 metre intervals should be used to ensure centrality within the borehole. This is particularly important if an artificial gravel pack is to be installed as it ensures an approximately even annular space. If installed, gravel packed sections should be sealed off top and bottom with clay. It is normal practice nowadays to gravel pack nearly the total length of the borehole but seal off the weathered/topsoil zone at the top.

The remaining annular space should be backfilled with an inert material, and the top five metres grouted with cement to ensure that no surface water at the wellhead can enter the well bore.

6. Well Developments

Once the screen, gravel pack, seals and backfill have been installed, the well should be developed. Development has two broad aims:

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

b) It alters the physical characteristics of the aquifer around the screen and removes fine particles.

We would not advocate the use of over pumping as a 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, 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 it is usually justified in longer well life, greater efficiencies, lower operational and maintenance costs and a more constant yield.*

7. Well Testing

After development and preliminary tests, a long-duration well test should be carried out. Well tests have to be carried out on all newly completed wells, because not only does this give an indication of the success of the drilling, design and development, but it also yields information on aquifer parameters, which are vital to hydrogeologists.

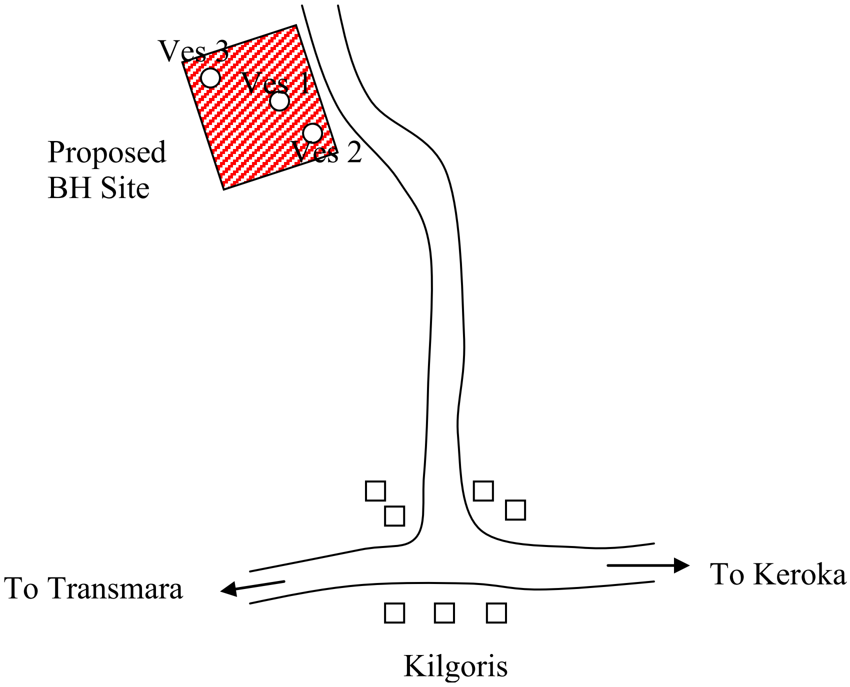
A well test consists of pumping a well from a measured start level (SWL) at a known or measured yield, and recording the rate and pattern by which the water level within the well changes. Once a dynamic water level is reached the rate of inflow to the well equals to the rate of pumping. Towards the end of the test a water sample of at least two litres should be collected for chemical analysis.

The duration of the test should be 24 hours, with a further 24 hours for a recovery test (during which the rate of recovery to SWL is recorded). The results of the test will enable a hydrogeologist to calculate the best pumping rate, the pump installation depth, and the drawdown for a given discharge rate.

8. Well Maintenance

Once the well has been commissioned and a pump installed at the correct depth, the maintenance schedule should be established. Checks on discharge (m3/day), pumping water level (metres below a leveled and immovable bench mark), and static water level (if for any reason the well is not used for a 24-hour period) should be taken as part of a regular, routing process. This will enable the evaluation of all known conditions should reduction in the yield or other problems occur in the future, and recommend the most appropriate action.

Sketch



NOT DRAWN TO SCALE