HYDROGEOLOGICAL SURVEY REPORT

FOR

TORORET PRIMARY SCHOOL
P. O. BOX
KILGORIS

LOCATED ON

THEIR PARCEL OF LAND

IN

TORORET AREA, TORORET SUB-LOCATION, KILGORIS LOCATION, PIRRAR DIVISION, TRANS-MARA WEST SUB-COUNTY, NAROK COUNTY.

Prepared by;

MICAH CHERUIYOT KETER,
Investigating Hydro – Geologist
P. O. Box 50422 – 00100
NAIROBI.
+254-725167711
cheruiyotketera@gmail.com

APRIL 2023

SUMMARY

This report documents on the hydrogeological survey results and findings that was conducted on the parcel of land that belongs to **Tororet Primary School**, on 1st April 2023 with the major aim of drilling a borehole that will be providing sufficient and clean water for domestic use within the school and the community in Tororet Area, Narok County.

On the parcel of land is a public school but lacks reliable water supply for their domestic use hence need reliable and clean water supply.

The area has no piped water system serving the people. The main source of water for the people include seasonal streams that flow during the wet seasons, rain harvesting, pans and development of shallow wells.

It is against this background that our Client decided to develop their own source of clean and reliable water supply mainly for domestic use. They will further distribute a part of the precious resource to the neighboring members.

Therefore, the objective of the survey by using geophysical and hydrogeological methods was to determine the most optimal point with good groundwater potential.

The climate is tropical in Kilgoris. Kilgoris has significant rainfall most months, with a short dry season. In Kilgoris area, the average annual temperature is 20.6 °C. About 1594 mm of precipitation falls annually. The project area is underlain by the rocks of the Greenstone Belt mainly sediments of the Kavirondian System and Granites of the Nyanzian System that have been cut across by volcanic intrusives.

From the climate data, direct recharge is significant around the area though recharge from distant catchments at the elevated areas is equally significant.

One suitable site **VES I (723042.70m E and 9888610m S at an elevation 1740 metres above sea level)** was identified using geophysics where the rocks are deeply weathered and fractured forming a very suitable formation to host an aquifer. The depth of the proposed borehole was recommended to a maximum of **180 metres** below ground level with an estimated yield in excess of **4,000 litres** per hour. The quality of the water is expected to be good with some slight mineralization.

Table 1: Summary of the proposed site

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m^3/hr
36M E723042 9888610m S UTM Elev. 1740 m	**VES I**	**180 meters**	**216mm/153mm**	**4-7**

In addition to the hydro geologic assessment outlined above, a detailed coordinated planning with the Government Authorities [Water Resources Authority} - must be implemented to obtain relevant permits and consent for the project implementation.

Contents

1. INTRODUCTION

1.1. Background Information

Tororet Primary School contracted groundwater consultants to undertake a detailed groundwater assessment on the site that will finally lead to the development of the borehole facility that will serve the facility for daily domestic needs.

The Client is planning for reliable water supply to meet their domestic needs. For any development to take place they will need reliable and clean water supply.

The area has no piped water system serving the people. The main source of water for the people include seasonal streams that flow during the wet seasons, water pans, rain harvesting and development of shallow wells. It is against this background that our Client decided to develop his own source of clean and reliable water supply mainly for domestic use.

Therefore, the objective of the survey by using geophysical and hydrogeological methods was to identify the most optimal point with good groundwater potential.

1.2. Scope of Works

The Scope of works for the execution of the Hydro-geological assessments/ Borehole site investigations within the area, include but not limited to:

i. Undertake comprehensive feasibility study of the groundwater occurrence within the plot. ii. Optimize an ideal –survey location for the proposed borehole project,

iii. Integrate reconnaissance survey data with Geophysical borehole data obtained in the conduct of the surveys and assimilate the borehole data to define the recharge/discharge boundaries for the project site i.e. calibrate the exploration data against known geological settings.

iv. Undertake comprehensive assessments of the existing borehole facilities located in the neighboring areas with a view to quantify the inherent potential; and confirm the actual development of other boreholes subsequent to development of Borehole.

v. Compilation/documentation of all the additional available hydro-geological, geological, geophysical, hydrological data and the subsequent provision of a comprehensive report on the groundwater exploration program for the project area.

The specific Terms of Reference, calls for the need to establish the baseline conditions that control the groundwater dynamics in the general Kilgoris aquifer systems; as a way to quantify and optimize borehole outputs.

The entire study will be contained in a detailed report on the investigations and recommendations. The current study further lays emphasis on the client’s specific water requirements and is geared towards attaining a sustainable domestic water supply component of at least 25.0 m^3/day.

1.3. Project Site Location

The Client's **proposed** borehole project is located in **Tororet Area, Tororet Sub-Location, Kilgoris Location, Pirrar Division, Trans-Mara West Sub-County, Narok County.**

The proposed site is off the Kilgoris-Olchobosei Road. Once at Shartuka Shoping centre, you drive approximately 5.7 kilometres then turn right to join the road that leads to Tororet Primary School. Once on this road, you drive 6km to the site along the road on the left hand side (sketch map appended).

The UTM grid reference for the investigated site is**; 36M 723042m E and 98888610m S at an elevation 1740 metres above sea level** above sea level. The site is located on the topographic map sheet 145/1 of Mara Bridge Area Survey of Kenya.

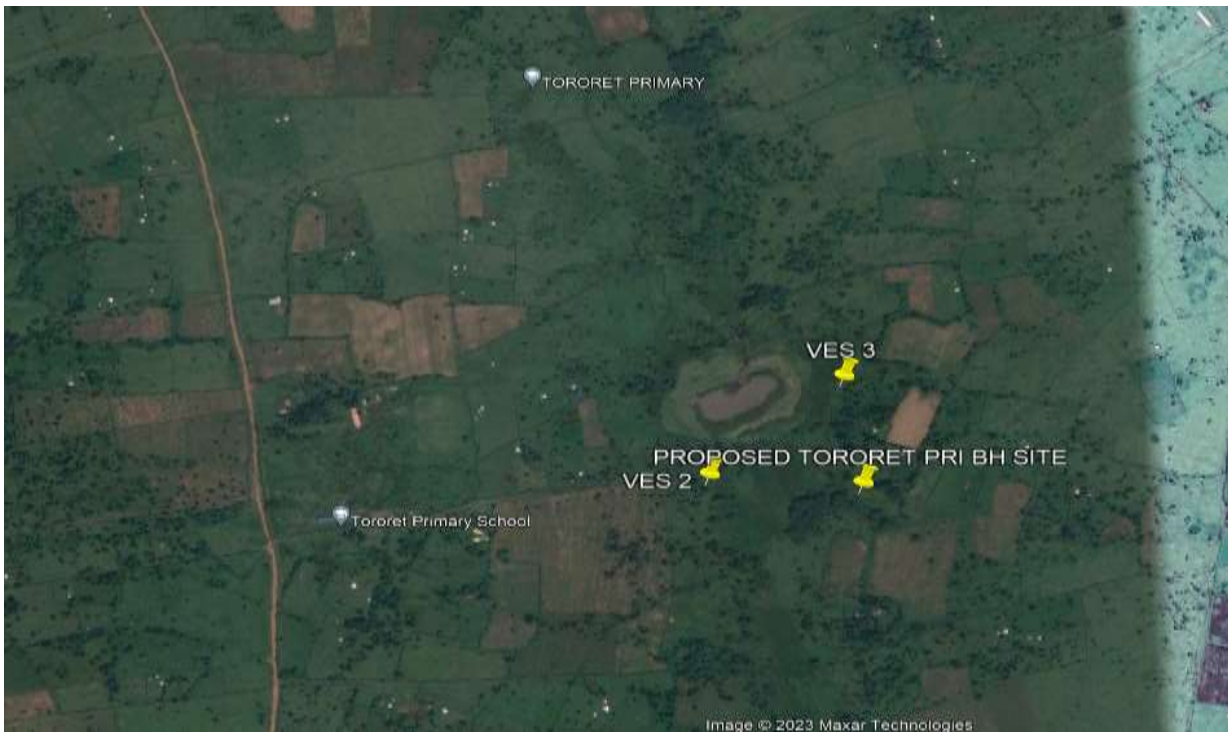


Figure 1.1: Google Earth image showing the location of the site

1.4. Water Supply Situation

Currently the Client and the general public depend on rainfall, shallow wells and river water for domestic use. These sources are constrained by the climatic condition of the area, being dry most parts of the year. The area is characterized by wet river beds that are flowing with water though their levels fluctuates hence cannot be and relied upon.

In the context above, the investigation was to establish the optimum location for a borehole to act as the main source of water for domestic use within his home. Below is a table on the water requirement needs of the client.

Table 1.2: Water requirement needs for the client

Population to be supplied with water	**500**
Expected Rate of water use (m^3/day)	**25**

1.5. Climate, Drainage and Topography

The climate is tropical in Kilgoris. Kilgoris has significant rainfall most months, with a short dry season. In Kilgoris, the average annual temperature is 20.6 °C. About 1594 mm of precipitation falls annually.

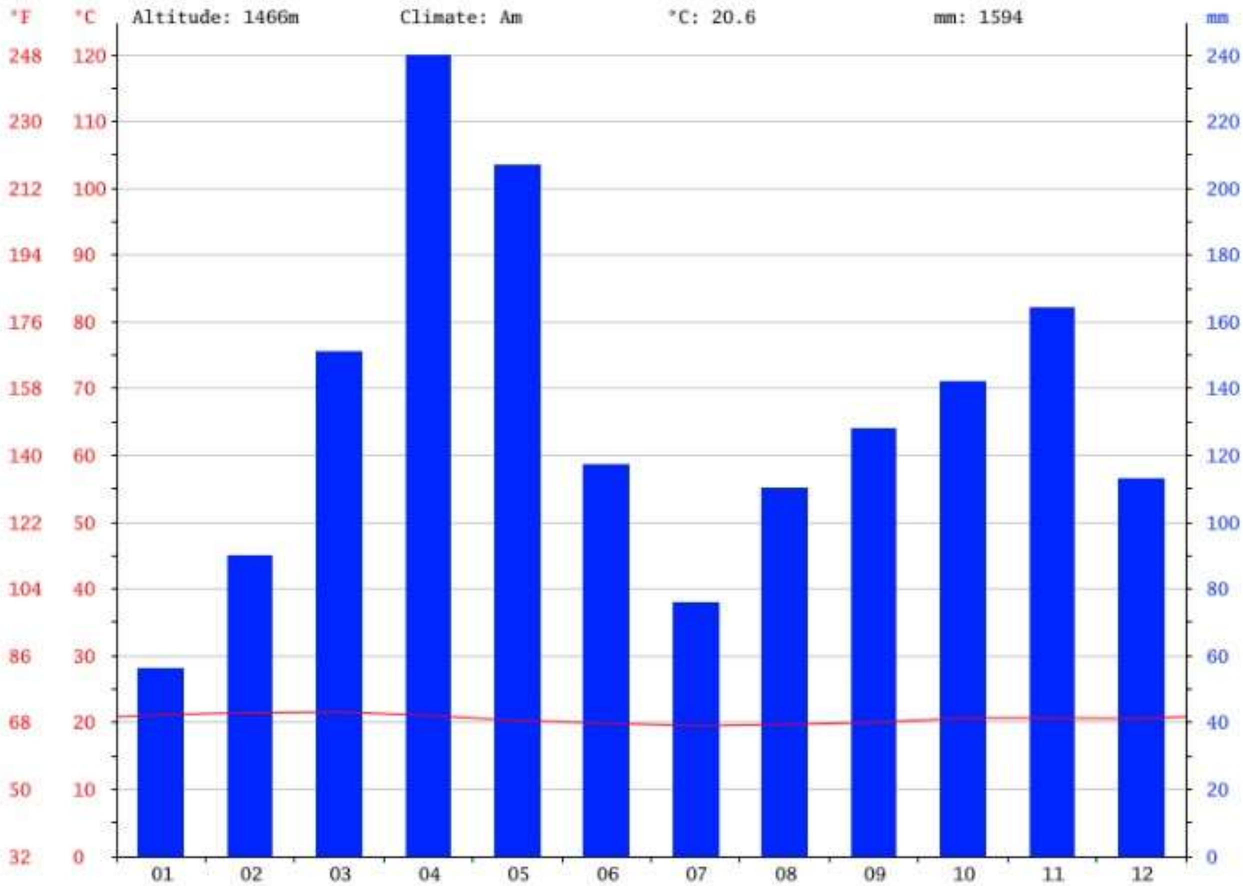


Figure 1.2: Climate Graph of the Project Site

The driest month is January. There is 56 mm of precipitation in January. In April, the precipitation reaches its peak, with an average of 240 mm. With an average of 21.6 °C, March is the warmest month. At 19.5 °C on average, July is the coldest month of the year.

The largest single drainage system in the area is formed by the River Migori to the east.

2. DETAILS OF GEOLOGY

2.1. Regional Geology

The oldest rocks of the study area are of Precambrian age and are represented by the Basement System, the Nyanzian, Kavirondian System and Bukoban System. During considerable lapse of time between the close of deposition of the Bukoban System and the Tertiary folding and faulting took place resulting to eruption of fossiliferous limestone and tuffs. Immense volume of phonolites comprising Kericho plateau was extruded.

2.2. Geology of the Project Area

The rocks which occur in project area and its surrounding area can be divided into the following groups, based on their relative age and lithology;

- Recent deposits,
- The Bukoban System,
- The Nyanzian System.

The main rock units covering the project area are lake sediments underlain by the rocks of the Bukoban and Nyanzian System. A brief discussion on these rocks is as below.

2.2.1. The Bukoban Rock System

Bukoban System rocks overlie those of the Nyanzian, mostly in south western Kenya near Lake Victoria but in Tanzania and Uganda, as well. They include an unmetamorphosed series of Infracambrian (spanning the Precambrian-Phanerozoic boundary) platform sediments - terrestrial and marine sedimentary formations, comprising sandstones, quartzites, shales, red beds, dolomitic limestone, and cherts, etc, along with a sequence of amygdaloidal basalts, and gabbroic to doleritic sills and dykes; several copper occurrences and deposits are associated with these mafic rocks.

2.2.2. The Nyanzian Shield

The Nyanzian and Kavirondian systems forming the Nyanza Craton are the oldest rocks in the country with ages over 2,500 million years. The Nyanzian system is mainly composed of lavas and pyroclastics with minor sediments and banded ironstones.

The Kavirondian, which rests uncomfortably on the Nyanzian, consists of grits, sandstones, greywackes and conglomerates. Both the Nyanzian and Kavirondian systems are isoclinally folded about axes that have an east-westerly trend. Kavirondian, is only slightly younger than Nyanzian but folding in the two systems has similar orientation. Numerous granitic bosses and batholiths have intruded the Nyanzian and Kavirondian. The Kavirondian intrusions were more but the pre-Kavirondian were also widespread and the two systems are discernible.

2.3. Structure

Most faults occur to the south and southeast of the project area. The major fault in this region being the Mfangano fault running Northeast - southwest along the causeway next to Mbita Point. The deposition of Pleistocene sediments in an Aeolian environment depicts bedding and sorting of the sediments.

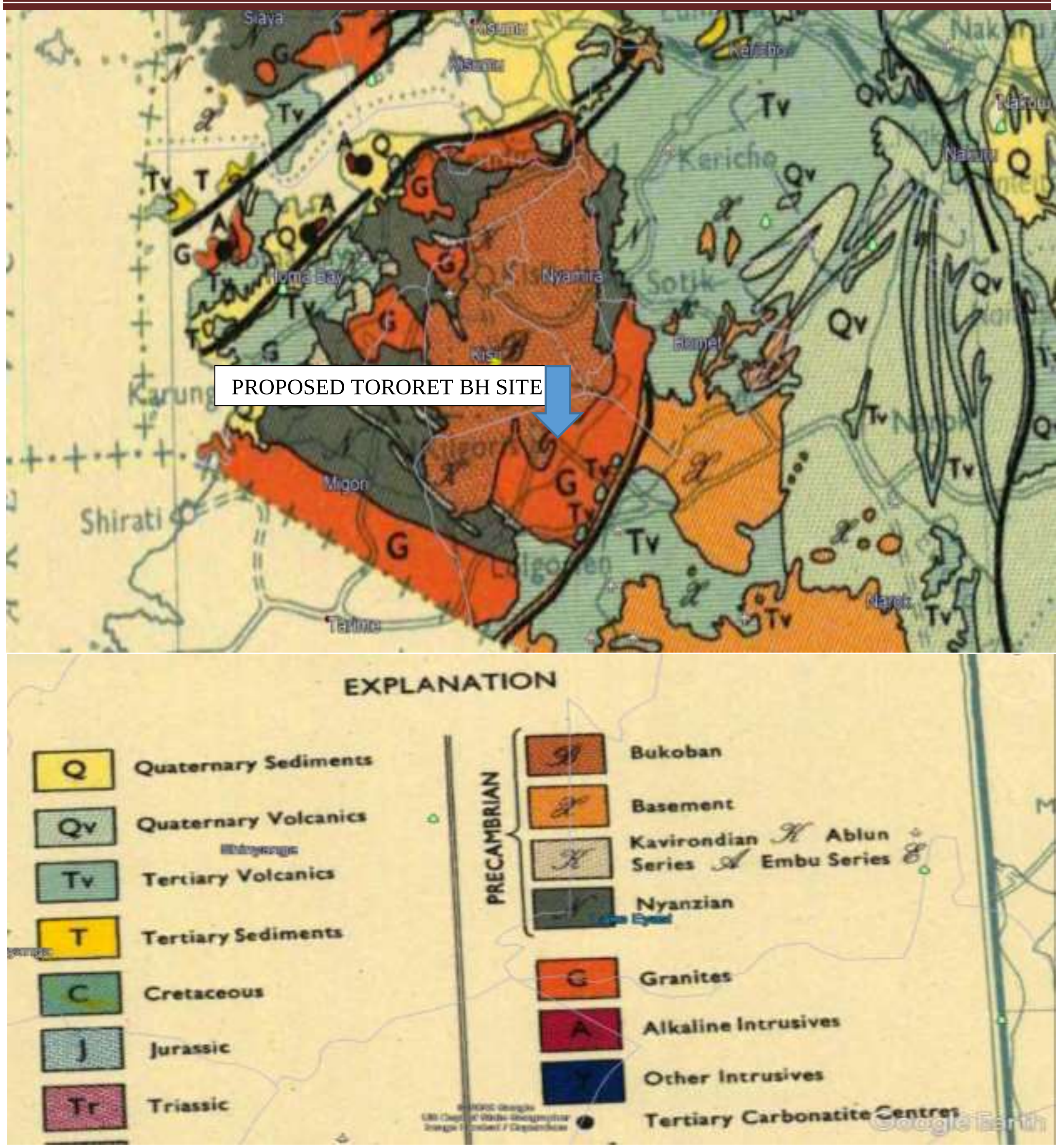


Fig 2.1. Showing geology of the proposed site

3. HYDROGEOLOGY

3.1. Outline of the Hydrogeology

Generally, the area has few boreholes and borehole data hence poses constrain on the calibration of both the geological data and groundwater resources for the type of aquifer characterization.

3.2. Surface Water

The largest single drainage system in the area is formed by the River Kuja and its tributaries. The Kuja flows from the Kisii hills east of Kisii Township down to the lake through the southern half of the area. The river Migori flows east of the project site.

3.3. Groundwater Resources

In our project area where the geological set-up is predominantly archaean Rocks occurence of groundwater is confined to areas of deep weathering, and/or fracture/fault zones.

There are two different types of aquifers encountered in these rocks - those associated with fault and fracture features, the better by far of the two, and those associated with weathered rock, usually encountered beneath the soil cover and overlying compact, or un-weathered rock.

These latter aquifers, located in the regolith, are highly variable in terms of potential yield since the physical transmission of water within the aquifer body itself is dependent upon the total clay fraction present after weathering of the parent rock which itself depends on the chemical constituents of the parent rock and the mechanism of weathering.

Faults and fractures, associated with major movements of the Earth's crust and often accompanied by volcanic activity, lead to the formation of coarser material: this, together with the larger volume of potential storage brought about by the fault, leads to rather better potential yields, especially where a borehole is sited so as to intersect fault features at depth.

3.4. Existing Boreholes

Boreholes are far away within the general project area. We look at the typical data characteristic of the boreholes’ aquifer system; and their rated specific performance.

Table 3.1: Borehole data.

B/H no. c -	Owner	Dis/Bearing from selected site (KM)	T.D (m)	WSL (m)	WRL (m)	PWL (M)	Q (m^3/hr)
3194	-	15.3/WNW	204	61	41	121	1.3
3214	-	15.2/WNW	155	95	46	122	0.18

These boreholes have been drilled to variable depths between 155 metres to 204 metres below ground level. The depths are on average of 179 metres below ground level.

Water struck levels range between 61 metres to 95 metres below ground level. At least a minimum two aquifers have been struck in these boreholes. Water rest levels vary between 41 metres and 46 metres below ground level while their yields vary from 180 to 1300 litres per hour.

The boreholes have variations in drilled depths, water struck levels, water rest levels and yields due to the differences in geological setups, construction design, level of development.

3.5. Aquifer Properties

Borehole Specific Capacities (S) and Transmissivity (T)

Borehole specific capacities have been calculated using the formula S=Q/s (Driscoll, 1986) where Q is the yield during pump test and s is the drawdown that is represented by pumping water level less static water level (PWL–SWL).

Transmistivity is calculated using the formula using the formula T=0.183Q/s. This formula has a limitation because borehole completion data from Ministry of Water and Irrigation gives the summary of pump test. It is ideal if the test pump data is in log scale.

Logan’s formula T=1.22 Q/s is the best for estimating transmistivity.

The area does not have aquifer tests and it is difficult to ascertain specific yields, storage coefficients of existing boreholes in the project area. From Driscoll 1986 the following summary of Specific Yield ranges for earth materials.

TABLE 3.2: SPECIFIC YIELD RANGES OF DIFFERENT MATERIALS

Earth Material	Specific Yield %
Limestone	0.5 – 5%
Shale	
Sandstone	5-15%
Clay	1-10%
Sand and Gravel	15 – 25%
Gravel	15 – 30%
Sand	10-30%

Hydraulic Conductivity and Groundwater Flux

Hydraulic conductivity is a measure of a material's capacity to transmit water. It is defined as a constant of proportionality relating the specific discharge of a porous medium under a unit hydraulic gradient in Darcy's law. The hydraulic conductivity of the proposed borehole can be estimated using the equation below.

K = T/b Where

K is Hydraulic Conductivity

T is Transmissivity and b is

aquifer thickness

Darcy’s formula is used to calculate groundwater flux it is given as Q=T .I. W, where T is the transmissivity of the borehole, I is the gradient and W the width.

In the Ministry of Water and Irrigation data the start of the aquifer is the one recorded and most of the time the thickness is not given. Due to this a lot of assumptions will be made in order to calculate hydraulic conductivity.

3.6. Recharge

Although the rate of recharge in the area cannot be accurately quantified, the mechanism by which recharge occurs can only be postulated. The two possible recharge mechanisms are direct recharge at the surface and indirect recharge via faults or lateral water movement through the homogenous aquifer beds.

Direct recharge at the surface is dependent on the climate, geology, topography and surface cover characterizing the type area. The fore-mentioned factors are closely related and cannot be considered in isolation.

In tropical climates, Basement rocks are altered to sandy soils which are very good materials for percolation of rain water. This is an important aspect in understanding the mechanism of rain infiltration in this region.

Both the topographical and surface vegetation cover aspect determines the flow characteristics of the surface water, i.e. presence of relatively flat areas and dense vegetation cover will retard the rates of flow of the surface water, thus enhancing the infiltration and vice versa.

Indirect recharge is facilitated by the presence of geological structures such as faults. The structures have a substantial effect on the groundwater flow systems at times impeding flow due to hydraulic discontinuities. Faults may facilitate flow by providing channels of high permeability or may be barriers by offsetting zones of high permeability. Higher hydraulic gradients may develop down slope with the resultant effect of the main faults acting as zones of low permeability.

The overall effect of these faults is to channel flow along the axis of the faults, conduits or if they are in filled, they act as barriers to the lateral flow.

3.7. Discharge

The discharge of the area can be considered to be either the artificial component through human activities or the natural component through the drainage systems characterizing the area. Borehole drilling within the area is getting recognition as a reliable source of water; this will lead to the drilling of more boreholes and contribute of the artificial component of discharge.

3.8. Groundwater Quality

Despite having limited exact water quality data, sufficient research has been undertaken elsewhere in the Western Kenya to give an indication of likely quality parameters for Basement groundwater. In inorganic terms groundwater is generally acceptable for human health standpoint.

However, groundwater may contain excess concentration of Aluminium, iron, manganese and hardness that- while not affecting health- raise aesthetic concerns among consumers.

Excess concentrations of what are normally trace elements are attributed to weathering processes over which we have little control.

Excessive concentration of chloride and nitrate are generally attributed to sewage wastes.

In this area waters are likely to be generally more mineralized than in more humid areas of the country simply because of evaporation and concentration.

They are probably calcium/sodium bicarbonates waters with significant concentration of chlorides and sulphates. Waters from the saprolite aquifers are likely to be less mineralized than those from the fractured bedrock aquifer (GRG/DWD/MISR, 1994).

Table Showing Maximum dissolved constituent limits as per WHO/EU standard

Parameter	**WHO/ EU Guideline**
Cations (mg/l)	
Iron	0.2
Manganese	0.5
Calcium	No Guideline
Magnesium	No Guideline
Sodium	200
Potassium	No Guideline
Anions (mg/l)	
Chloride	250
Fluoride	1.5
Nitrate	50
Nitrite	0.50
Sulphate	250
Total Hardness ($CaCO_3$ mg/l)	Desirable: 150-500
Total Alkalinity ($CaCO_3$ mg/l)	No Guideline
Physical Parameters	
PH	Desirable: 6.5-8.5
Colour (Pt mg/l)	Desirable: 15
Turbidity (NTU)	Desirable:< 5
Permanganate Value (O_2 mg/l)	No Guideline
Conductivity (S/cm)	250 microS/cm

4. FIELD EXPLORATION PROGRAM

4.1. Prospecting Methods

4.1.1. Resistivity (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 resistivity than unsaturated and dry rocks.

The higher the porosity of the saturated rock, the lower is 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 the 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:

$$R = \rho * L.A \quad (1)$$

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

$$R = \Delta V / I \quad (2)$$

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

$$\rho = (A/L)\ \Delta\ V/I) \quad (3)$$

4.2. Survey Design

Two categories of field techniques exist for conventional resistivity analysis of the subsurface. These techniques are vertical electric sounding (VES), and Horizontal Electrical Profiling (HEP).

4.2.1. Vertical Electrical Sounding (VES) .

The object of VES is to deduce the variation of resistivity with depth below a given point on the ground surface and to correlate it with the available geological information in order to infer the depths and resistivities of the layers present.

In VES, with wenner configuration, the array spacing "a" is increased by steps, keeping the midpoint fixed (a = 2 , 6, 18, 54…….) .

In VES, with schlumberger, The potential electrodes are moved only occasionally, and current electrode are systematically moved outwards in steps

AB > 5 MN

4.2.2. Horizontal Electrical profiling (HEP)

The object of HEP is to detect lateral variations in the resistivity of the ground, such as lithological changes, near- surface faults.

In the wenner procedurec of HEP, the four electrodes with a definite array spacing "a" is moved as a whole in suitable steps, say 10-20 m. four electrodes are moving after each measurement.

In the schlumberger method of HEP, the current electrodes remain fixed at a relatively large distance, for instance, a few hundred meters, and the potential electrode with a small constant separation (MN) are moved between A and B.

4.3. Field Work

Fieldwork – for this project, the survey was carried out on 1st April, 2023, though the fieldwork was preceded by a reconnaissance site visit partly constituting the desk study for the project site. Three soundings were carried out at the most anomalous zones to a maximum electrode spacing of AB/2 = 250 meters.

The results for the soundings are summarized on tables below;

VES 1

The interpretation of geophysics data is summarized on the table below and the model and curves have been annexed in the appendices.

Table 4.1 –VES 1

DEPTH (in meters)	RESISTIVITY (OHM)	FORMATION	REMARKS
0.0 – 1.6	61	Surfacial Deposits	Dry
1.6 – 6.3	31	Fractured sub-base	Dry
6.3 – 25.0	53	Weathered sub-base	Dry
25.0 – 63.0	116	Highly fractured volcanics	Moist
63.0 – 130.0	161	Deep fractured granites	Moist to Wet
130 -200	215	Slightly weathered granites	Wet
>200	247	Fractured granites	Wet to Dry

The results from the interpretation show variation in the different layers in terms of the rate of weathering and fracturing.

Water is expected to be struck within the fractured and weathered granites at depth of 80m to 100m and second aquifer at 130m to 170m. Groundwater prospect at this site VES 1 is good hence considered and recommended as a drill site for the proposed borehole.

VES 2

The interpretation of geophysics data is summarized on the table below and the model and curves have been annexed in the appendices.

Table 4.2 –VES 2

DEPTH (in meters)	RESISTIVITY (OHM)	FORMATION	REMARKS
0.0 – 1.6	7	Surfacial Deposits	Dry
1.6 – 6.3	6	Weathered sub-base	Dry
6.3 – 32.0	23	Weathered sub-base	Dry
32.0 – 50.0	40	Highly fractured volcanics	Moist
50.0 – 100.0	85	Deep fractured volcanics	Wet
100.0 – 200.0	161	Slightly Fractured volcanics	Wet to dry
>200	197	Compact granites	Dry

The results from the interpretation show variation in the different layers in terms of the rate of weathering and fracturing.

Water is expected to be struck within the fractured granites at depth. Groundwater prospect at this site VES 2 is not good and cannot be considered as a drill site for the proposed borehole.

VES 3

The interpretation of geophysics data is summarized on the table below and the model and curves have been annexed in the appendices.

Table 4.3 –VES 3

DEPTH (in meters)	RESISTIVITY (OHM)	FORMATION	REMARKS
0.0 – 1.6	147	Surfacial Deposits	Dry
1.6 – 6.3	54	Weathered sub-base	Dry
6.3 – 32.0	63	Weathered granites	Dry
32.0 – 63.0	128	Highly fractured granites	Moist
63.0 – 130.0	181	Deep fractured granites	Wet
130.0 – 200.0	231	Fractured granites	Wet to Dry
>200	259	Highly fractured granites	Dry

The results from the interpretation show variation in the different layers in terms of the rate of weathering and fracturing.

Water is expected to be struck within the fractured and weathered granites at depth of 50-100m. Groundwater prospect at this site VES 3 is good though not considered and recommended as the best drill site for the proposed borehole due to only one expected aquifer.

5. IMPACTS OF PROPOSED DRILLING ACTIVITY

Within the project area very few boreholes have been drilled resulting to no effect on groundwater. The borehole will be drilled to the recommended depth

5.1. Impacts of the Local Aquifer Quantity and Quality

The sustainability of the water quantity depends on the level of abstraction and recharge rate. If groundwater is abstracted at a rate greater than its natural replenishment rate, then the project will not be sustainable as there will be dry pumping. Based on the yields of the boreholes, the proposed abstraction of 25 m^3/day on a 10 hour pumping regime is not expected to have any major impact on the aquifers, as there are very few number of boreholes drilled in the area.

The water quality will mainly depend on the host rock, construction design and the age of the water. Overall, the expected impacts resulting from the borehole to the environment and their mitigation measures will be adequately addressed in the EIA study to be conducted.

5.2. Impacts of Existing Boreholes in the Area

It's noteworthy that most of the boreholes examined in this study area are more than a kilometer of the proposed drilled site. Therefore, no negative impacts are expected on the other existing boreholes within the vicinity.

6. RECOMMENDATIONS FOR BOREHOLE DEVELOPMENT

Conclusions

A water supply borehole is to be developed on the proposed project site to a recommended a minimum drill depth of 180 metres below ground level. This depth is considered ideal *Vis* other boreholes falling in close proximity of the site.

Based on the available information on geology and existing boreholes, combined with the hydro geological assessments, the following conclusions can be drawn:-

a) The maximum yield that can be obtained from a borehole which fully penetrates the aquifer formation.

b) The required depth of a fully penetrating hole would be about 180 metres.

The location is shown in the site sketch. Below is a tabulation of the construction summary to be adopted to realize the project objectives: -

Table 5.1: Borehole drilling depth

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield (m^3/hr)
36M E723042 9888610m S UTM Elev. 1740 m	**VES I**	**180 m**	**216mm/153mm**	**5-7**

Recommendations

i. The drilling should ideally be carried out with a Rotary drilling plant rotary in order to attain the recommended drill depth of maximum of 180m below ground level,
ii. A monitoring tube is to be installed in the drilled intake to allow regular measurements of the water levels in the intake wells. This is a requirement for the final pumping equipment installation.
iii. In case shallow aquifers are encountered it is recommended to seal these off within the upper 10 metres, in order to avoid any risk of cone of depression coalescence. The shallower aquifers with the contacts – need to be fully sealed off as part of the safeguard requirements to contamination. The sealing is to be carried through a bentonite – cement seal to prevent any surface contamination within the project area. Screens should only be installed at the deeper aquifers.
iv. The recommendations on well construction cannot be considered complete without the mention of the requirement to test pump the water supply bore to British standards BS 6316 (1992), which is an industry standard. At least 10 hours of the step test at –2-hour interval followed by a CRT test for 30 hours is recommended. Recovery must be carried out to full Static Water Levels.
v. In order to maximize yields in this part of the aquifer systems, the proposed borehole will have to be drilled to the recommended depth, very carefully constructed and developed. This borehole will adopt controlled pumping after development and is thus not likely to interfere with other pumping facilities during and after construction. A limited abstraction capacity of 4.0 m^3/hr is envisaged as the ultimate design yield; which apparently is not excessive.

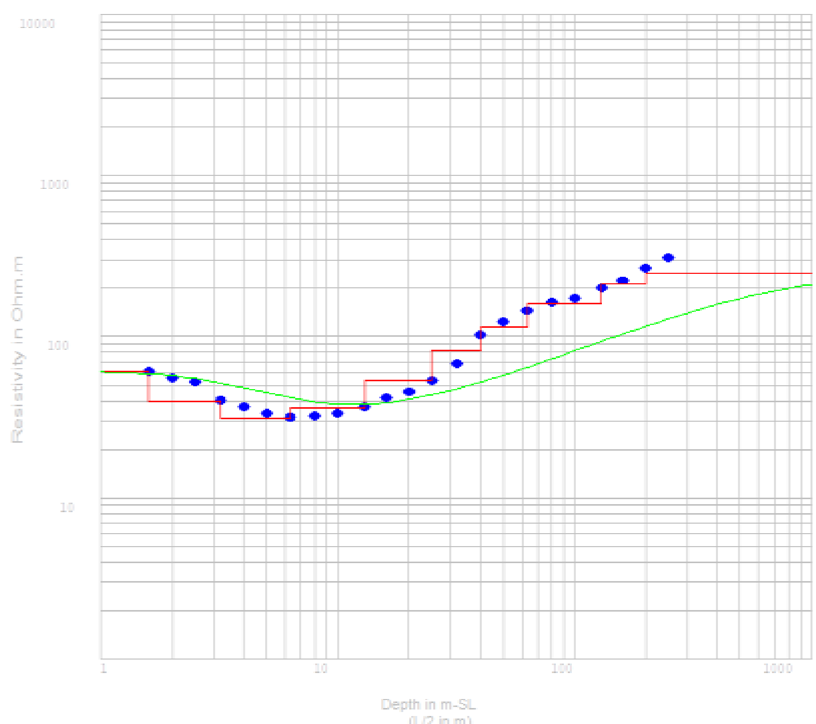
APPENDICES

Appendix 1; VES DATA

VES 1

****** NiLeSoftware *************************** GEWin V1.04 © 2001 ******

Measurement : TORORET 1



Coordinates : (723042 , 9888610)

Surface level: ****** m+Ref.level

Geo-electrical model

Bottom Layer m - SL	Resistivity Ohm.m
1.60	61
3.20	40
6.30	31
13.00	36
25.00	53
40.00	82
63.00	116
130.00	161
200.00	215

End resistivity : 247

SSD on log-scale : 1.14767

Date (y-m-d) : 2023-4 -5

Input measured curve

Meas. #	L/2 in m	R in Ohm.m	don't use	Meas. #	L/2 in m	R in Ohm.m	don't use
1	1.6	61.4		21	130	161	
2	2	55.4		22	160	179.8	
3	2.5	52.2		23	200	215	
4	3.2	40.2		24	250	247.2	
5	4	36.9			.00	.00	
6	5	33.3			.00	.00	
7	6.3	31.9			.00	.00	
8	8	32.5			.00	.00	
9	10	33.5			.00	.00	
10	13	36.9			.00	.00	
11	16	42.2			.00	.00	
12	20	45.6			.00	.00	
13	25	53.4			.00	.00	
14	32	68.2			.00	.00	
15	32	54.9			.00	.00	
16	40	82.6			.00	.00	
17	50	99.8			.00	.00	
18	63	116.9			.00	.00	
19	80	132.5			.00	.00	
20	100	138.6			.00	.00	

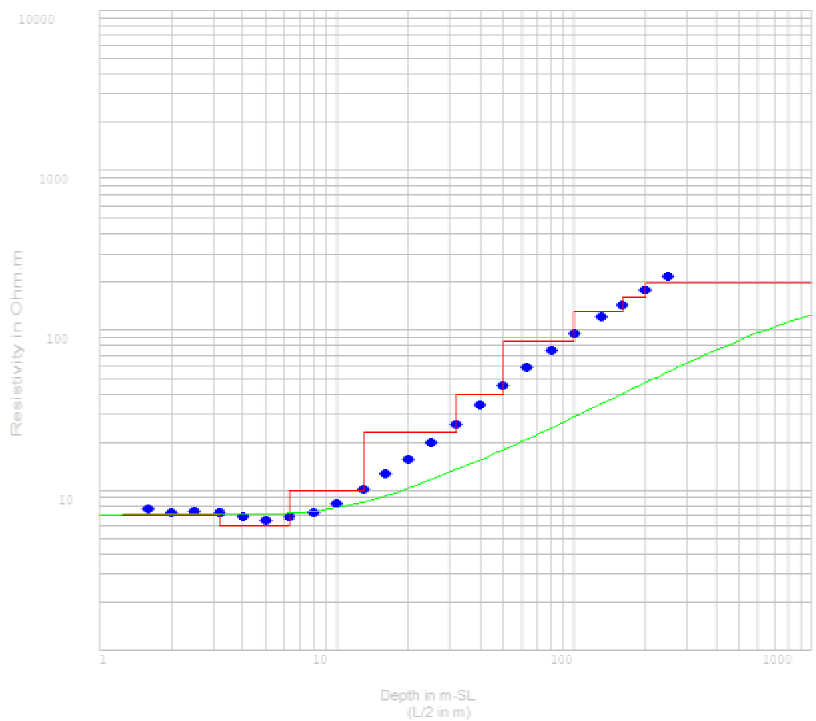
OK
Cancel

i : insert measurement
e : erase measurement
c : clear down

VES 2

****** NiLeSoftware *************************** GEWin V1.04 © 2001 ******

Measurement : TORORET 2 2



Coordinates : (722813 , 9888633)

Surface level: ****** m+Ref.level

Geo-electrical model

Bottom Layer m - SL	Resistivity Ohm.m
1.60	7
3.20	7
6.30	6
13.00	10
32.00	23
50.00	40
100.00	85
160.00	130
200.00	161

End resistivity : 197

SSD on log-scale : 2.47161

Date (y-m-d) : 2023-4 -5

Input measured curve

Meas. #	L/2 in m	R in Ohm.m	don't use	Meas. #	L/2 in m	R in Ohm.m	don't use
1	1.6	7.7		21	130	109.1	
2	2	7.3		22	160	130	
3	2.5	7.38		23	200	161	
4	3.2	7.2		24	250	197.1	
5	4	6.8			.00	.00	
6	5	6.5			.00	.00	
7	6.3	6.8			.00	.00	
8	8	7.2			.00	.00	
9	10	8.2			.00	.00	
10	13	10.2			.00	.00	
11	16	12.7			.00	.00	
12	20	15.7			.00	.00	
13	25	19.7			.00	.00	
14	32	25.6			.00	.00	
15	32	23.1			.00	.00	
16	40	30.6			.00	.00	
17	50	40.7			.00	.00	
18	63	52.6			.00	.00	
19	80	67.7			.00	.00	
20	100	85.5			.00	.00	

OK

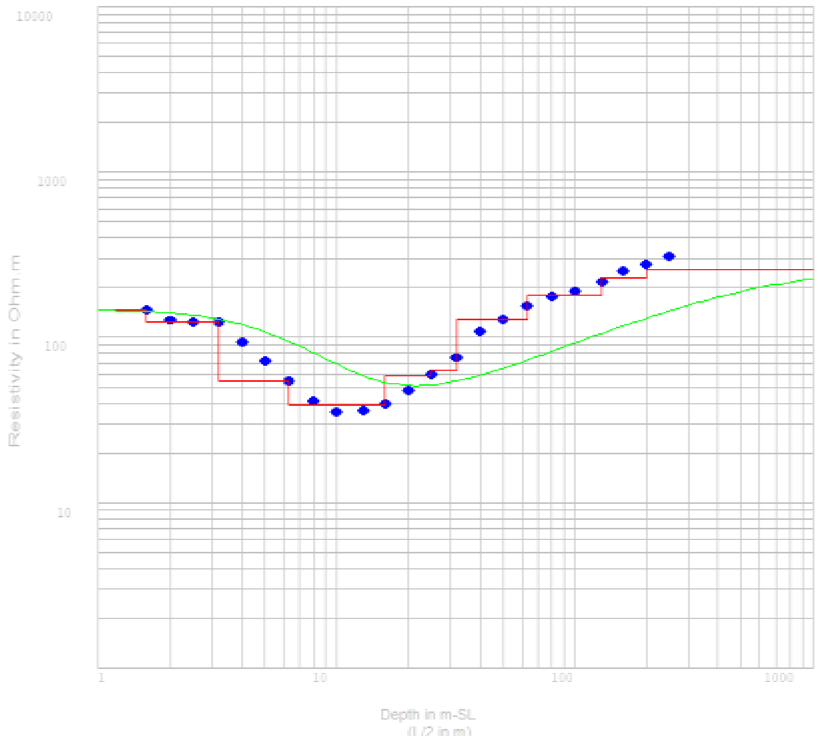
Cancel

i : insert measurement
e : erase measurement
c : clear down

VES 3

****** NiLeSoftware *************************** GEWin V1.04 © 2001 ******

Measurement : TORORET 3



Coordinates : (723020 , 9888808)

Surface level: ****** m+Ref.level

Geo-electrical model

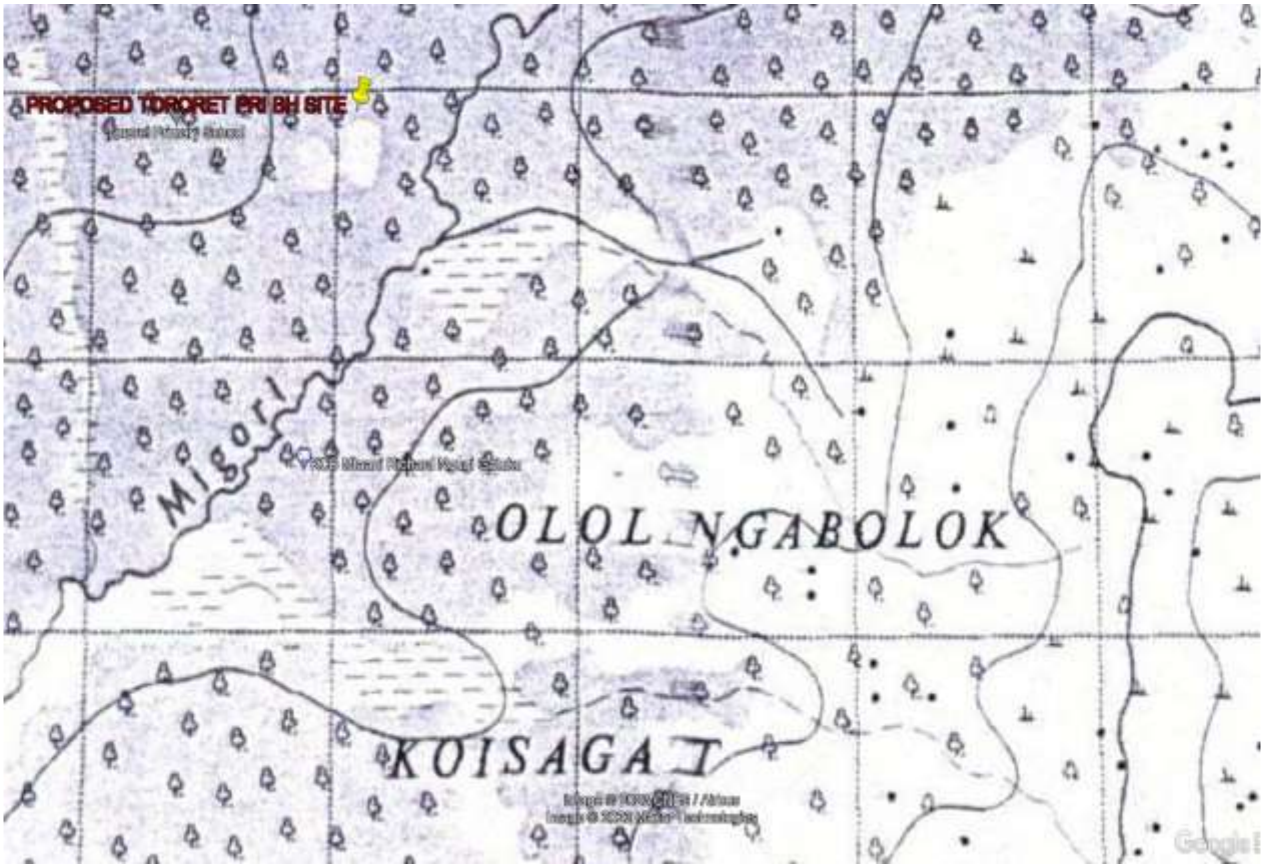
Bottom Layer m - SL	Resistivity Ohm.m
1.60	147
3.20	123
6.30	54
16.00	39
25.00	59
32.00	63
63.00	128
130.00	181
200.00	231

End resistivity : 259

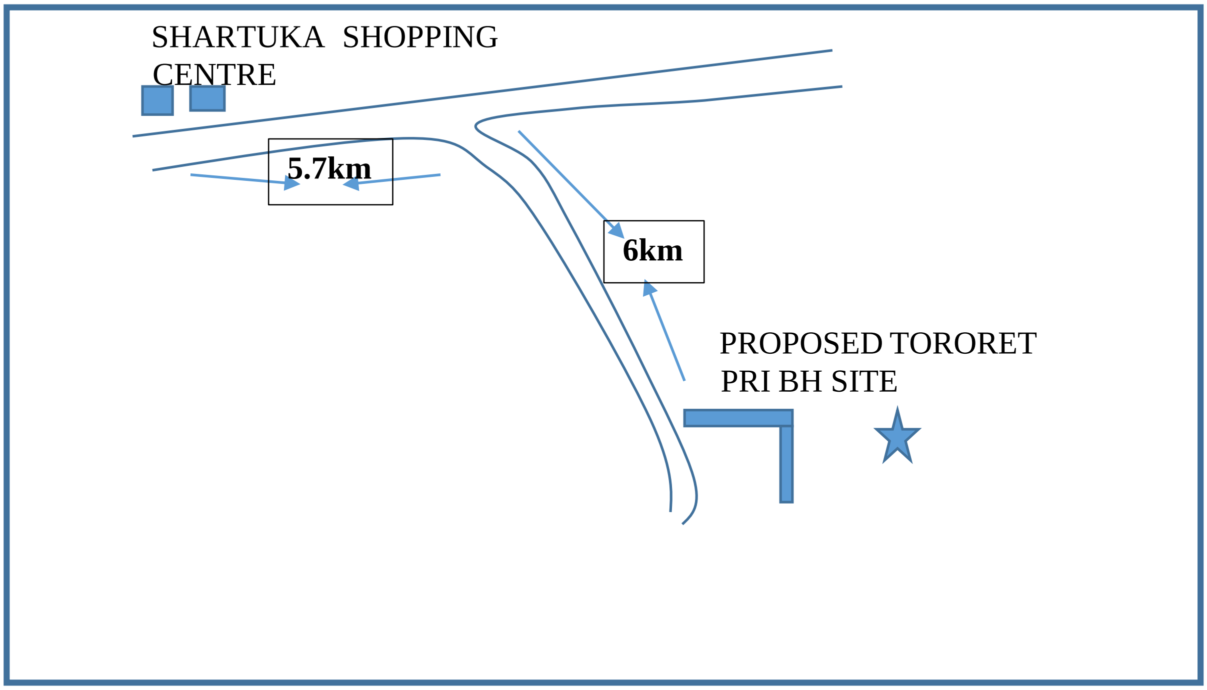
SSD on log-scale : 1.25375

Date (y-m-d) : 2023-4 -5

Appendix 2; Topographical map of the proposed site; 145/1 MARA BRIDGE AREA



Appendix 3; Sketch map of the proposed site



Appendix 4: Drilling Design Drilling Methodology

Drilling should be carried out with an appropriate tool – comprised of a high-powered rotary machine, which is considerably faster. 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.

Well Design

The design of the well should ensure that screens are placed against the optimum aquifer zones. An experienced works drilling consultant/hydrogeologist should make the final design; and should make the main decision on the screen settings.

Casing and Screens

The well should be cased and screened with good quality screens; considering the depth of the borehole it is recommended to use steel casing and screens of 6" diameter. Slots should be maximum 1mm in size. We strongly advise against the use of torch-cut steel well casing as screen. In general, its use will reduce well efficiency (which leads to lower yield), increase pumping costs through greater drawdown, increase maintenance costs, and eventually reduction of the potential effective life of the well.

Gravel Pack

The use of a gravel pack is recommended within the aquifer zone, because the aquifer could contain sands or silts which are finer than the screen slot size. An 8" (203mm) diameter borehole screened at 6" (153mm) 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 the pumping plant and leading to gradual 'siltation' of the well. The grain size of the gravel pack should be an average 2-4mm.

Well Construction

Once the design has been agreed, 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 to insert the artificial gravel pack all around the screen. If installed, gravel packed sections should be sealed off top and bottom with clay (2m).

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

Well Development

Once screen, gravel pack, seals and backfill have been installed, the well should be developed. Development aims at repairing the damage done to the aquifer during the course of drilling by removing clays and other additives from the borehole walls. Secondly, it alters the physical characteristics of the aquifer around the screen and removes fine particles.

We do not advocate the use of over pumping as 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, or the use of the mechanical plunger, 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 is usually justified in longer well-life, greater efficiencies, lower operational and maintenance costs and a more constant yield. Within this frame the pump should be installed at least 2m above the screen, certainly not at the same depth as the screen.

Well Testing

After development and preliminary tests, a long-duration well test should be carried out on all newly-completed wells, because from giving an indication of the quality of drilling, design and development, it also yields information on aquifer parameters which are vital to the hydrogeologist. A well test consist of pumping a well from a measured start level Water Rest Level- (WRL) at a known or measured yield, and simultaneously recording the discharge rate and the resulting draw downs as a function of time. Once a dynamic water level (DWL) is reached, the rate of inflow to the well equals the rate of pumping. Usually the rate of pumping is increased stepwise during the test each time equilibrium has been reached (Step Draw-Down Test). Towards the end of the test a water sample of 2 litres should be collected for chemical analysis. The duration of the test should be 48 hours, followed by a recovery test for a further 24 hours, or alternatively until the initial WRL has been reached (during which the rate of recovery to WRL is recorded). The results of the test will enable the project design consultant to calculate the optimum pumping rate, the installation depth, and the draw-down for a given discharge rate.