HYDROGEOLOGICAL SURVEY REPORT

FOR

OLOMONIRA PRIMARY SCHOOL
P.O. BOX 591,
NAROK

LOCATED ON

ON THEIR PARCEL OF LAND

IN

OLOMONIRA SUB-LOCATION, NARASHA LOCATION, NAROK SOUTH SUB-COUNTY, NAROK COUNTY.

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Summary

This report documents on the hydrogeological survey results and findings that was conducted on the parcel of land that belongs to Olomonira Primary School, on 25th February 2023 with the major aim of providing sufficient and clean water for domestic use within the school in Olomonira area of Narok County.

The area is mostly for grazing of animals owing to suitability of the land. The main constrain is that the area doesn't have a water supply system. The area mainly depends on roof catchment, small earth dams, seasonal rivers and few privately owned boreholes. The main objective for this survey is to develop a borehole water source supply for the client in view of no water supply by any water service providers. The above survey program was envisaged and commissioned by project site owner.

About 25 m^3 borehole water is required per day. The area's climate is classified as warm and temperate. The warm seasons are much rainier than the cold seasons. The temperature here averages 20.8 °C. The average annual rainfall is 619 mm.

The subsurface geology of the project area is composed of greyey loamy soils, underlain by the Mau volcanics. Aquifers where water is expected is located at the contact zones between the volcanic rocks and the weathered and fractured zones of the volcanic rocks at depth. Recharge of these aquifers is either directly through percolation of rain water or at distant locations within catchment areas.

Geophysical survey was conducted on site that enabled the selection of a suitable point to drill the proposed borehole.

Below is a tabulation of the construction summary to be adopted to realize the project objectives:

One suitable site has been located by means of geophysical field measurements, where the rock is found to be deeply weathered and fractured to greater depths. Below is a tabulation of the construction summary to be adopted to realize the project objectives:

Summary of the proposed site

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m^3/hr
36 M E 785311 UTM 9855462 S Elev. 1863m	**VES 2**	**250m**	**216mm/153mm**	**5-10**

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.

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1.0 INTRODUCTION

1.1. Background Information

Olomonira Primary School commissioned groundwater consultants to carry out groundwater survey on their parcel of land located in Olomonira area, Narok County. Hence this report documents on the hydrogeological survey results and findings that was conducted on the client's site with the major aim of determining the groundwater potential of the area that will lead to the drilling of one productive borehole.

The site has been developed with a school facility and close to $25m^3$/day of water is required for any further development to take place. The area is not connected to any water supply system and the fact that pastoralists are the most occupants, they travel long distances in search of water.

Hence, the main objective for this survey is to develop a borehole water source supply for the client in view of the inadequate water supply in the area. The above survey program was envisaged and commissioned by the project site owner. About $25m^3$ borehole water is required per day.

1**.2. Scope of Works**

The Scope of works for the execution of the Hydro-geological assessments/Borehole site investigations within the premise, 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 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 m3/day.

1.3. Project Site Location

The project site is located in Narasha area off Kaplong-Narok –Mai Maihu road, Narok County. Access to the site from Narok Town is through the exit to join the Sekenani road that connects to Maasai Mara at Maasai Mara Junction. Once on this road you drive 42.2 kilometers then join a right turn-off exit 9km to the project site as directed by the site sketch attached (sketch map annexed in the appendices).

The GPS coordinates for the investigated site falls on – **336 M E785311 UTM 9855462 S Elevation 1863m** above the ground level.

Figure 1.1 Google Earth image showing the location of the proposed borehole site.

The proposed borehole site is in Narasha area and the surrounding plots are mainly open fields occupied by nomadic pastoralists.

1.4. Water Supply Situation

The area residents depend on roof catchments and limited community borehole which are far and unreliable. Other water supply sources being exploited are rainwater, seasonal streams, earth dams, pans and local water supply. All these water sources are limited as their supply highly depends on the ever-changing weather pattern and growing population. In the context above, the investigation was to establish the optimum location of a borehole to act as a source of water supplement for the client's domestic use.

Due to shortages of water in the area and its environs there are few boreholes that have been drilled mainly for domestic uses by private individuals. Perennial drought in the area is responsible for seasonal rivers that remain dry most part of the year. Approximate water demand is 25,000 litres per day to be abstracted from the proposed borehole for a population of approximately 250 people.

1.5. Climate, Drainage and Topography

This area has a tropical climate. In the cold months, there is much less rainfall than in warm months. The average temperature is 20.8 °C. In a year, the average rainfall is 619 mm.

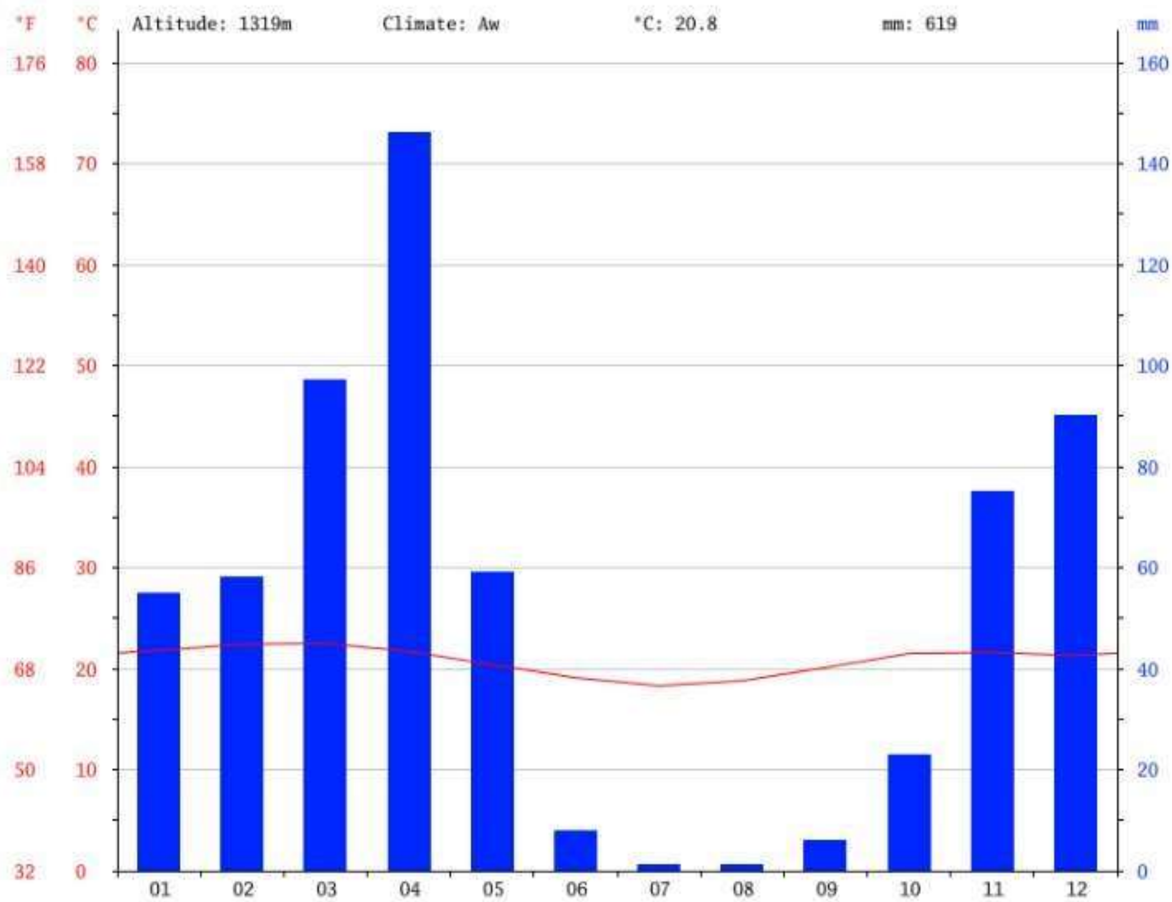


Figure1.2: Climate Graph of the Area

The least amount of rainfall occurs in July. The average in this month is 1 mm. Most precipitation falls in April, with an average of 146 mm. The temperatures are highest on average in March, at around 22.5 °C. In July, the average temperature is 18.3 °C. It is the lowest average temperature of the whole year.

1.6. Drainage

The area is drained by Uaso Ngiro River and its tributaries to the east. These rivers are seasonal and have water only during and immediately after the rain seasons otherwise they are dry most part of the year.

2.0 DETAILS OF GEOLOGY

2.1. Regional Geology

Volcanic rocks and associated sediments deposited during the formation of the Rift Valley dominate the regional geology of the area. This is well described in ‘Geology of The Narok Area’ (J. B. Wright, 1959).

2.2. Mau Lavas

The Mau Lavas comprise two units of the Miocene age: Phonolite and Ankaratrite.

a. Mau Phonolite

The maximum thickness of the phonolite in the Mau area cannot be estimated with accuracy since the flows are largely obscured by overlying pyroclastics. The main outcrops are found along valley floors west of Amala and Cheptuich rivers. Mau Phonolite is only a few hundred feet thick in the Mara River area (Williams, 1964b) Occurrences are also encountered in the Engito and Sigindirr streams.

b. Ankaratrite

The Ankaratrite is of rare occurrence in the area, with only a few outcrops of hard volcanic rocks on the high grounds. These underlie the Mau phonolite (Saggerson; 1966)

2.3. Mau Tuffs

Exposures of consolidated pyroclastic rocks, provisionally assigned to the Pliocene, are confined to more or less continous sections along the lower parts of all deeper valleys that dissect the Mau range. Small total thicknesses of the Mau tuffs are spread over an area of many hundreds of square miles cusing an overall dip (of about 80-90feet per mile) to the SSW, corresponding to with that of streams dissecting the area, (see Figure 3.1) This distribution of individual thin members in the succession is attributed to the conclusion that most, if not all of the pyroclastic rocks are ash-flow tuffs. The Mau tuffs are sub-divided as follows:

- Upper welded Tuffs
- Ndorroboni Agglomerates and Chapaltarakwa Lapilli-Tuffs
- Lower Welded Tuffs

2.4. Mau Ashes

The Mau ashes are dominantly unconsolidated,non-eutaxitic, ash-fall types which differ markedly from the ash-flow types of the Mau tuffs below. They are of the Pleistocene age, although there is no conclusive but due t6o their stratigraphic position above the Mau Tuffs. Their high degree of erosion and deep weathering make a recent age unlikely.

The Mau Ashes are lithologically and stratigraphically sub-divided into two:

- Ashes
- Basal Lapilli-Tuffs and Agglomerates

2.5. Alluvial and Superficial deposits

Superficial deposits in the area comprise of brown and greyish-brown loams derived from volcanic ashes, though black clayey soils are well represented. Pale grey calcareous beds in the extreme south-west may have been derived from calcareous beds in the ash sequence.

2.6. Structural Geology

Structural features such as faults in the rocks often optimize storage, transmissivity and recharge, particularly when they occur adjacent to, or within, surface drainage systems. Several NNW-trending faults in the Mau Narok district clearly represent a continuation of the system of the Rift valley boundary faults.

Faulting will have the highest impact on hard and massive rock types; elastic formations such as tuffs and weakly consolidated deposits will bend (fold) rather than break (fault). As a result, they tend to suppress the radius of influence and the magnitude of the damage caused by tectonic events. In relatively plastic rocks, the porosity will not increase in the area affected by the fault. Fractures and joints, thus giving rise to increased (secondary) porosity, on the other hand, will break hard layers such as lavas.

3.0 HYDROGEOLOGY

This section briefly discusses some of the hydro geological characteristics of the aquifers and boreholes within project site and its surroundings. The hydrogeology of the area is determined by the nature of the parent rock, structural features, weathering processes and precipitation patterns. Within volcanic rocks, groundwater occurs within fissure zones, sediment beds, lithological contacts and old land surfaces (OLS).

3.1 Surface Water Resources

The project site is located in an area that is drained by surface water resources that are dry for the most parts of the year. There is a moderately elevated and some hills that lies to the south of the site, there are few streams. The streams flow in a south-east direction.

These river systems are marked by dry river valleys as part of their seasonal flows. The floor of the river valleys is characterized by black cotton soils that have been transported from the volcanic terrains.

3.2. Groundwater Resources

In the absence of the nearby surface water sources and the unreliable rainfall patterns, groundwater thus suffices as the practical and feasible option for the sustainable & construction of a groundwater supply at the client's land.

The area is consider being within zones of medium to low groundwater potential whereupon supplies are obtained through a concentration of groundwater recharge from the North-western side of the flow.

The basement system rocks are marked by a significant secondary permeability. The occurrence of the weathered formation renders the sequence highly susceptible to considerable recharge. Groundwater will thus occur in the weathered/fractured basement.

3.3. Existing Boreholes

Exploitation of groundwater within the area is on the rise. This is because of unreliable water supply systems within the vast Narok County. Data regarding a few boreholes drilled are tabulated while their locations are on Figure 3.1.

Table 3.1: Neighboring Borehole sites from the project site

BH NO. C-	NAME	Distance/ Bearing	TD(m)	WSL(m)	WRL(M)	Q(m3/hr)	PWL(m)
4800	Muguga High school	15Km/NW	180	132	103	5.4	128.4
4132	-	28Km/E	196	183	172	-	-
NEW BH	-	2.5KM/N	250	-	-	-	-
New BH	Mathew Ndemo	10km/E	220	-	-	5	-

3.4. Aquifer Properties

Aquifer characteristics: Transmissivities (T) and specific yield / storage coefficients

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).

Transmissivity is calculated using the formula T=0.183Q/s. This formula has a limitation because borehole completion data from Ministry of Water and Irrigation Services 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 transmissivity.

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.

Hydraulic conductivity (K) and Groundwater Flux

Location's laboratory investigations and Isotope methods are very expensive methods and are the best for determining hydraulic conductivity and groundwater flux correctly. The results are confined to few locations, and they depend on the scale of the investigation method. Rock sample measurements in laboratory vary from well test results. Ministry of Water and Irrigation Services data is also not very reliable.

Hydraulic conductivity is calculated using the formula k=T/D where k is the hydraulic conductivity, T is the transmissivity and D is aquifer thickness. In the Ministry of Water and Irrigation Services data the start of the aquifer is the one recorded and most of the time the thickness is not given.

3.5. Recharge

Given that suitable storage media exist below ground, the mechanisms by which water must reach it also affect aquifer potential. Obviously, if no rainfall or river flow is able to percolate to a sandy weathered and fractured Basement aquifer due to the presence of an aquitard (impermeable layer) probably clay, the actual potential is very low.

Both Basement Rocks and Volcanic systems suffer the same limitations so far as recharge is concerned: if rainfall is low the volume of water which may eventually percolate to a suitable aquifer is likely to be relatively small, and possibly mineralized due to high evaporation rate.

Percolation is dependent on soil structure, vegetation covers and the erosion state of the parent rock. Rocks which weather to clayey soils will naturally inhibit percolation (such as black cotton soils); conversely, the sandy soils resulting from the erosion of some Basement rocks are eminently suited to deep, swift percolation.

Recharge is the term applied to the whole mechanism, and includes all the aspects of parent geology, effective rainfall and percolation. Some aquifer systems are recharged by water falling a substantial distance away. Percolation takes place at the high grounds to the northwest area of the project plot and this reaches the faults from where it is distributed into permeable aquifers.

3.6. Groundwater Quality

Generally, groundwater chemistry from the volcanic terrain varies from place to place due to mode of recharge and how long water has interacted with rocks. Water quality from the proposed borehole is expected to meet the WHO standards but with some slight modification due to the increased amounts of minerals.

Consumption by humans of waters with concentrations somewhat above the standard limits is not necessarily harmful. Still, the best possible quality should be targeted, and the identified sources should have chemical properties within and/ or to the WHO norms. Appropriate technological solutions must be considered in areas where adverse types of water are likely to have hazardous effects on man and livestock. However, for toxic substances, a maximum permissible concentration limit has been established. The constituents for which these standards have been set (e.g. heavy metals, pesticides, bacteria) all have a significant health hazard potential at concentrations above the specified limits. Hence, the specified limits should not be exceeded in public water supplies.

Table 3.1: 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 CaCO3 (mg/l)	Desirable:150-500
Total Alkalinity CaCO3 (mg/l)	No Guideline
Physical Parameters	
PH	Desirable:6.5-8.5
Colour(Pt mg/l)	Desirable:15
Turbidity(NTU)	Desirable:<5
Conductivity(S/cm)	250microS/cm
Total Dissolved Solids(mg/l)	No Guideline

4.0 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:

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

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

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

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:

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

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 fault.

In the wenner procedure 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

A detailed exploration program was carried out on the 25th February 2023, and it entailed both reconnaissance and hydro geological and geophysical surveys. Two VESs were carried out at the most anomalous zones sited by HEP.

4.3.1. Interpretation of Field Curves

Interpreted results of the vertical electrical sounding with the inferred geological layering– are shown in tables 4.1 while the resistivity curve is as presented in the annexes.

Table 4.1 – VES 1

Depth (In Meters)	Resistivity (Ohm)	Formation
0.0 – 8.0	36	Lateritic surficial deposits
8.0 – 16.0	20	Weathered phonolites
16.0 – 32.0	9	Fracture/weathered phonolites
32.0 – 80.0	11	Weathered phonolites
80.0 – 130.0	27	Fractured phonolites
130.0 – 200.0	27	Fractured/weathered phonolites
>200	52	Weathered phonolites

VES 2

Depth (In Meters)	Resistivity (Ohm)	Formation
0.0 – 1.6	26	Lateritic surficial deposits
1.6 – 16.0	5	Weathered phonolites
16.0 – 32.0	11	Fracture/weathered phonolites
32.0 – 80.0	9	Weathered phonolites
80.0 – 130.0	10	Fractured phonolites
130.0 – 160.0	10	Fractured/weathered phonolites
>160	37	Weathered phonolites

Evaluation of the VES data

The VES Sounding: VES depicts some heterogeneous strata. The above interpreted results show top loamy soils underlain by fractured volcanics, weathered and tuffs to a depth of about 200 metres below ground level and beyond. The site VES 2 has good groundwater potential and has been recommended for drilling the proposed borehole.

5.0 IMPACTS OF PROPOSED DRILLING ACTIVITY

The area is characterized by a low density of boreholes as can be referenced from the table of neighboring boreholes in section 3. The boreholes are generally moderately yielding and the proposed borehole will not have any significant effect to the aquifer if drilled. Water abstraction from the borehole will have to be controlled.

The proposed borehole water will be used mainly for domestic applications. For this kind of abstraction, the effects to aquifer will be quite minimal as the aquifer is ample with an excellent recharge owing to its large recharge area and huge storage capacity.

Pumping this facility will unlikely cause any adverse effects to cone of depression hence there shall be no hydraulic interference to other boreholes in the neighborhood of the proposed site.

Groundwater contamination will be controlled by construction input where use of bentonite clay seal is proposed together with an 8” surface casing of at least 5m long. A 1x1x1 m slab must be constructed around the protruding 6” casing to limit surface water intrusion. Any water struck above 20 metres must be sealed off during construction for fear of pathogens from pit latrines.

Water discharged during drilling process will however be discharged into a soak pit. Waste water has also one advantage as it can be reused during drilling in case need for water arises during drilling process.

The proposed borehole should be installed with the following devices to allow routine measurements of groundwater abstraction and water levels: -

i. Water master meter for monitoring groundwater abstraction.

ii. Airline for monitoring water table fluctuation.

However, all conditions given by Water Resources Management Authority should be adhered to and they include pumping 60% of the tested yield for a period of 10 hours a day.

6.0 CONCLUSIONS AND RECOMMENDATIONS FOR BOREHOLE DEVELOPMENT

Conclusions

Based on the discussions in the previous chapters on hydrogeology, geophysics and existing boreholes, it has been concluded that a water supply borehole is to be developed on the proposed project site to a recommended maximum depth of 250 m below ground level. This depth is considered ideal considering the thickness of the aquifer that will be penetrated.

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 formation is likely to be above 7 m^3/hr.

b) The required depth of a fully penetrating hole would be at least 250 metres maximum.

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 6.1: Borehole Construction Recommendations

Site coordinates	VES No. & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m^3/hr
36 M E 785311 UTM 9855462 S Elev. 1863m	**VES 2**	**250**	**216mm/153mm**	**5-10**

Recommendations

i. The drilling should ideally be carried out with a Rotary drilling plant rotary in order to attain the maximum recommended drill depth of 250 m below ground level unless enough water has been struck or the formation is complicated to continue drilling.
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 20 metres, in order to avoid any risk of cone of depression coalescence and contamination by surface water.
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 10hours 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.

APPENDICES

Appendix I Showing VES data and VES Graphs

VES 1

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	36		21	130	27.2	
2	2.0	36.3		22	160	31.6	
3	2.5	35.2		23	200	27.7	
4	3.2	36.4		24	250	52.4	
5	4.0	38.4			.00	.00	
6	5.0	33.2			.00	.00	
7	6.3	30.3			.00	.00	
8	8.0	25.8			.00	.00	
9	10	21.1			.00	.00	
10	13	18.7			.00	.00	
11	16	20.2			.00	.00	
12	20	11.6			.00	.00	
13	25	6.6			.00	.00	
14	32	8.4			.00	.00	
15	32	7.2			.00	.00	
16	40	6.4			.00	.00	
17	50	7.4			.00	.00	
18	63	9.7			.00	.00	
19	80	11.8			.00	.00	
20	100	18.0			.00	.00	

OK

Cancel

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

VES 2

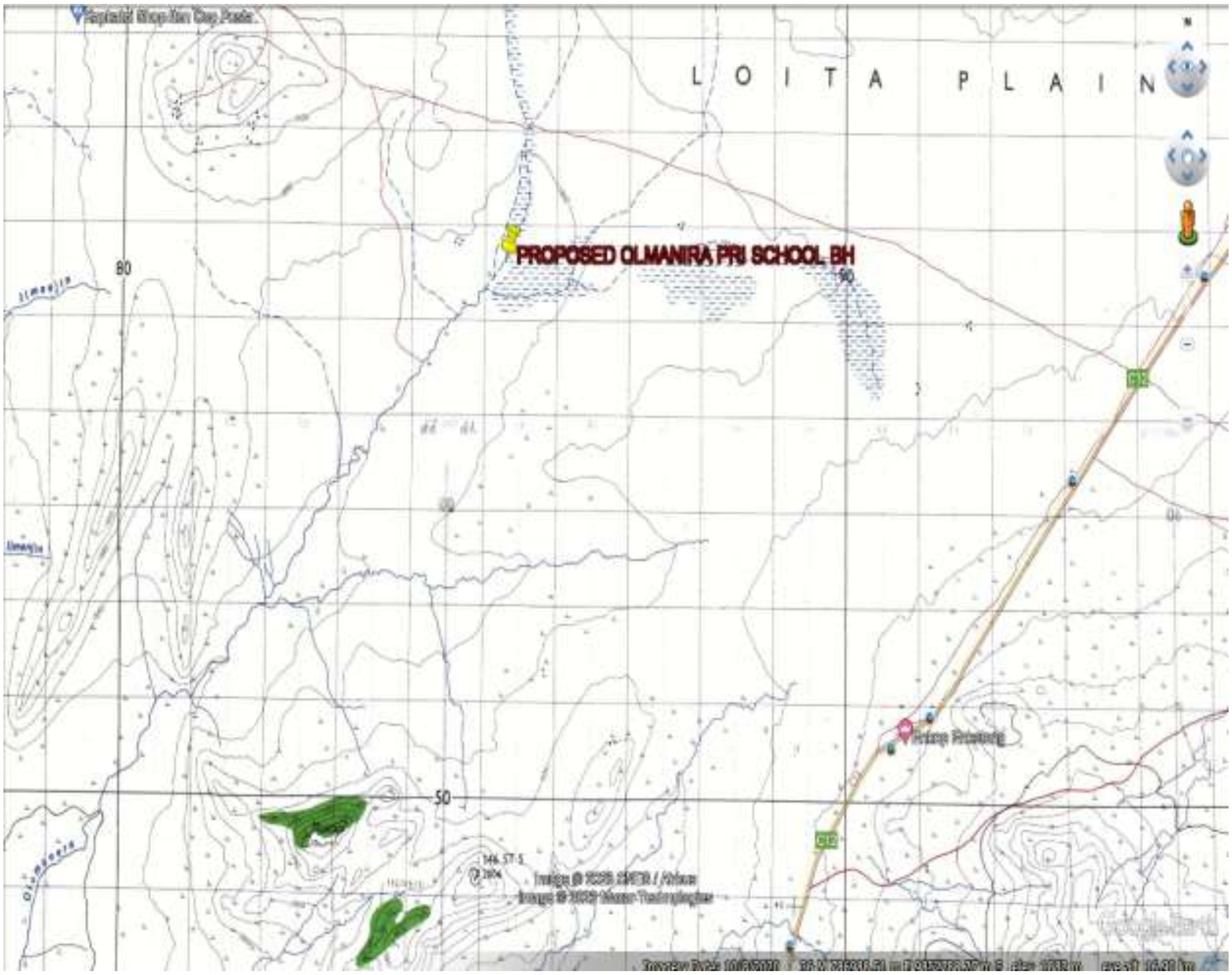
Input measured curve

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	26.612		21	130	10.32	
2	2	14.490		22	160	10.987	
3	2.5	3.8494		23	200	37.78	
4	3.2	7.28			.00	.00	
5	4	6.715			.00	.00	
6	5	7.633			.00	.00	
7	6.3	7.080			.00	.00	
8	8	6.8591			.00	.00	
9	10	6.509			.00	.00	
10	13	5.7824			.00	.00	
11	16	5.188			.00	.00	
12	20	6.2959			.00	.00	
13	25	6.5747			.00	.00	
14	32	11.785			.00	.00	
15	32	7.2353			.00	.00	
16	40	7.22			.00	.00	
17	50	7.49			.00	.00	
18	63	8.5			.00	.00	
19	80	9.69			.00	.00	
20	100	12.7			.00	.00	

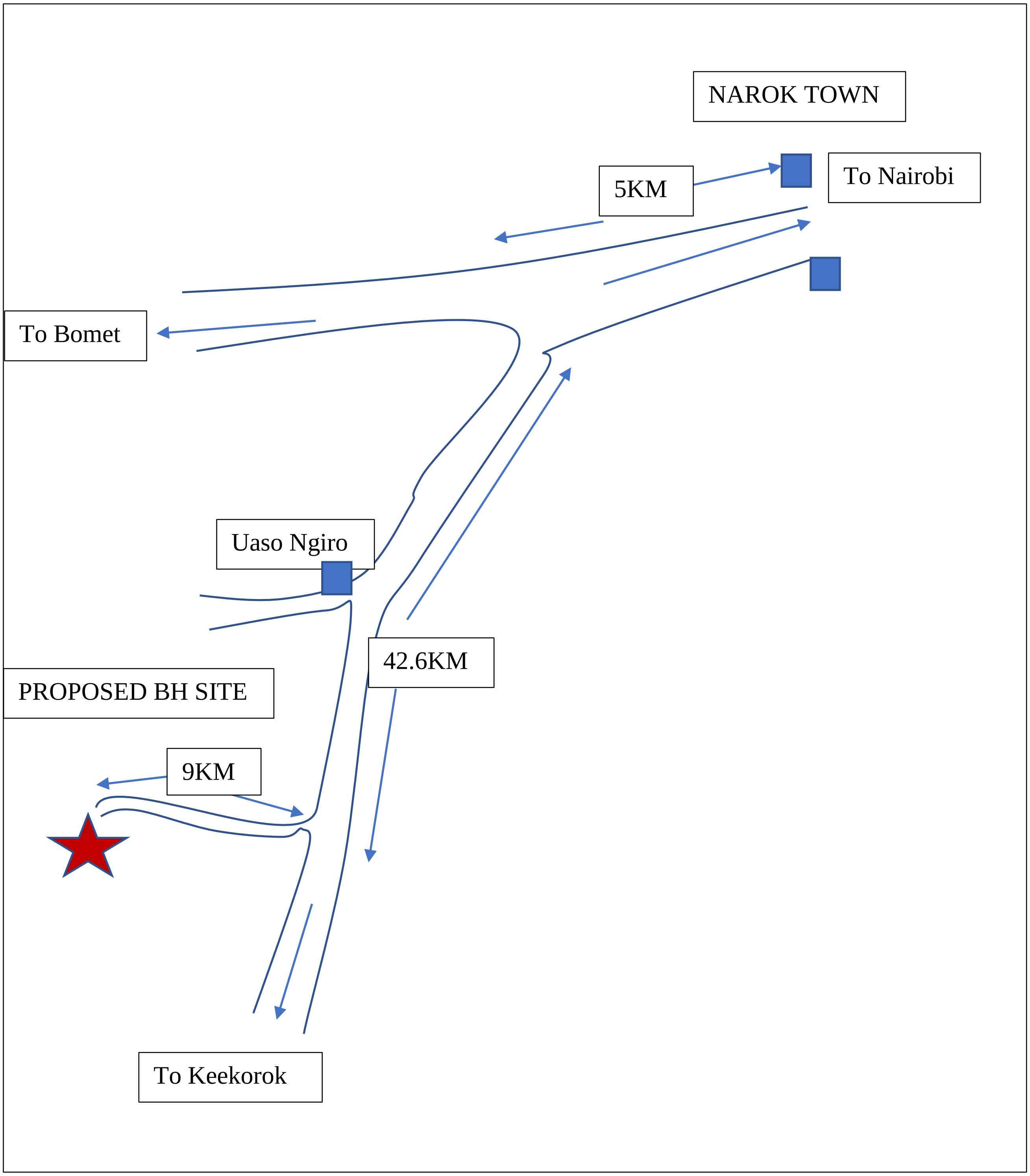
OK
Cancel

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

Appendix II Showing Topographical Map of the Proposed Site



Appendix III; Sketch map of the location of the proposed site



Appendix IV; 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 drawdowns 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.