



P.O BOX 1641-00621,

NAIROBI KENYA.

EMAIL procurement@goodneighbors.ke

CLIENT

TENDER NAME

PROPOSED DRILLING OF ONE (1) BOREHOLE AT KAEKIT VILLAGE IN NADUNG'A, TURKANA NORTH IN TURKANA COUNTY.

TENDER NO:

REF : KGN/OD/PROJECT/CLTS/2025/006

SITE LOCATION

KAEKIT VILLAGE IN, NADUNG'A TURKANA NORTH, TURKANA COUNTY. Coordinates (-2.27999,36.80000)

TENDER NAME

PROPOSED DRILLING OF ONE (1) BOREHOLE AT ILBISSIL TOWNSHIP PRIMARY SCHOOL IN ILBISSIL TOWN, KAJIADO COUNTY.

TENDER NO:

REF : KGN/OD/PROJECT/LEGACY/2025/007

SITE LOCATION

ILBISSIL TOWN, MATAPATO NORTH WARD, KAJIADO COUNTY Coordinates (-2.09789,36.79829)

CLOSING DATE

FRIDAY, 4TH JULY 2025 AT 1600 HOURS

CONTENTS

- **TENDERING PROCEDURES**
- **HYDRO GEOLOGICAL REPORTS (Bissil & Turkana)**

Tendering Procedures

1. **KENYA GOOD NEIGHBORS** invites sealed tenders for Proposed Drilling and Casing of **One (1NO.) Borehole in *Kaakit Village in Nadung'a, located in Turkana North in Turkana County*** and **One (1NO.) at *Ilbissil Primary School in Ilbissil Town, Kajiado County***.
2. Completed tenders must be delivered to the address below on or before **Friday the 4th of July, 2025, 1600 Hrs.** Electronic Tenders shall be sent to email address procurement@goodneighbors.ke

3. Scope of Proposed Tender

- 3.1. The works under consideration shall comprise of **Drilling, Casing and all the ancillary works of Two (2) boreholes.**
- 3.2. The Borehole depth shall be as proposed in the attached Hydrogeological Reports.
- 3.3. The client has already conducted a hydrogeological survey and the reports has been attached.

4. Eligible Tenderers

- 4.1. A Tenderer may be a firm that is a private entity or a joint venture (JV) under an existing agreement with the intent to enter into such an agreement supported by a letter of intent. In the case of a joint venture, all members shall be jointly and severally liable for the execution of the entire Contract in accordance with the Contract terms.
- 4.2. A Tenderer shall not have a conflict of interest. Any tenderer found to have a conflict of interest shall be disqualified. A tenderer may be considered to have a conflict of interest for the purpose of this tendering process, if the tenderer:
 - a) Is a direct relative of any employee of the Client;
 - b) Directly or indirectly controls, is controlled by or is under common control with another tenderer;
 - c) Receives or has received any direct or indirect subsidy from another tenderer;
 - d) Has the same legal representative as another tenderer;
 - e) Any of its affiliates participated as a consultant in the preparation of the design or technical specifications of the goods or works that are the subject of the tender;

- f) Any of its affiliates has been hired (or is proposed to be hired) by the Client as a consultant for Contract implementation;

4.3. A tenderer shall not be involved in corrupt, coercive, obstructive or fraudulent practice. A tenderer that is proven to have been involved in any of these practices shall be automatically disqualified.

4.4. Any Quotations sought by the Client with regard to this project shall be null and void and any contractor who could have quoted is eligible to tender for this works officially with no restrictions or capping on the previously offered quote.

5. Clarification of Tender Documents, Site visit and Pre-tender meeting

5.1. Should the tenderer be in any doubt of the precise meaning of any item and/or figure for any reason whatsoever and should he/she find any page missing, or in duplicate, or indistinct, he must inform the client in writing through email address procurement@goodneighbors.ke, who provided such enquiry shall have arrived Three (3) days prior to the tender closing date [**by 4:00p.m. of Tuesday the 1st of July 2025**], will respond, with copies to all other tenderers if deemed necessary.

5.2. No liability will be admitted nor claim allowed in respect of errors in the Contractor's Tender due to mistakes in the Tender Instructions which should have been rectified in the manner described above.

5.3. Any **Telephone canvassing** from any of the tenderers shall not be allowed and will lead to automatic disqualification.

5.4. **There will be no Joint Pre-Bid Site Visit.** Kenya Good Neighbors however encourages the Tenderers to familiarize themselves with the sites and in case of a need to visit, they shall make their own arrangements with the custodians of the land within which the borehole is located. Kenya Good Neighbors shall not be liable in case of any trespassing by any.

6. Schedule of Required Documents

6.1. The Tenderer shall submit the following documents for the Client to evaluate:

- a. Valid Tax Compliance Certificate.
- b. Valid K.R.A Pin
- c. Valid Certificate of Incorporation/Registration.
- d. CR12 form.

- e. Trade License
- f. Utility Bills (Any of the water, electricity, internet, gas, waste management bills of April and May 2025, under the name of the bidder/ firm)
- g. **Company profile, including a detailed organization structure, Contact, Office Location. Please include the office phone number and email address on the first page of company profile.**
- h. List of Key and relevant Personnel working for the bidder.
 - i. Updated and complete Cvs must be attached.
 - ii. A minimum of Four (4) Personnel will be submitted.
 - iii. Submission of the Bidder Director Cv is mandatory.
 - iv. Submission of the Driller Cv to be engaged on the project is mandatory.
 - v. **Submission of A resume only or tender forms from other procurement applications shall not be accepted.**
- i. Valid Water works licenses.
- j. Work Profile-list of ongoing and previous projects with evidences attached which include Contact Person, Phone Number, email address, L.P. Os, contracts, Practical Completion Certificates etc. Any Documents not authenticated by the previous client shall not be admissible. Award Letters shall be accompanied by Completion Certificates.
- k. Bills of Quantities -
 - i. ***The Tenderer must prepare separate Bills of Quantities for the Two sites.***
 - ii. Tenderer to prepare standard bills of the quantities for the works which should be very detailed in quantities and shall capture but not limited to the following components:
 - Preliminaries
 - Main Works: ***To be based on the recommended depths on the report and casing design be based on the aquifers profile.***
 - Provisional and prime cost Sums

- Borehole Documentation: ***Must include Inspection with a borehole Camera after drilling.***
- All relevant taxes of the land

l. Work Methodology.

m. Programme of works

n. List of owned Equipment with evidence attached

o. Litigation history (sworn affidavit).

p. External Financial audited accounts for the last Two (2) Financial Years (2023 and 2024).

The reports should be authentic and valid audited final reports and accounts which meet all the requirements set by Auditing bodies. External audit reports not signed and stamped by the Auditor and the company Director are not treated as authentic reports.

6.2. For electronic submission the tenderer must name the email subject as follows:

Name of Company- Tender Name i.e “Bidii Contractors- Kaekit Borehole Drilling”.

6.3 **The documents listed in Cl 6.1 shall be submitted as separate files properly named and ZIPPED together.**

7. Amendment to Tender Documents

7.1. At any time prior to the deadline for submission of tenders the employer may, for any reason, whether at his own initiative, or in response to clarification requested by a prospective tenderer, amend the tender documents by the issuance of an “Addendum”. The “Addendum”, the receipt of which must be acknowledged shall be sent in writing. Should the Employer be of the opinion that the issuance of an “Addendum” has created a need to extend the deadline of the submission of tenders, then at his discretion he shall, in writing, grant such an extension.

8. Tender Prices and Discounts

8.1. The tenderers may indicate the allowable percentages of discounts while submitting their bids and their methodology of application. Conditional Discounts Shall not be accepted.

8.2. Only the shortlisted Tenderers will be contacted by the client, should there be need for negotiations on the tender sum.

8.3. Tenderers are reminded that they are required by law to pay all government Taxes arising from or related to the execution of the works. The tenderer must therefore include in their rates all taxes as aforesaid.

8.4. The rates provided by the tenderer shall be inclusive of all the scope of works i.e supply, fixing, delivery, labour, taxes. The Client shall not price any item of work separately than in the tender document.

9. Submission of Tenders

9.1. The Tenderer shall deliver the Tender **in a single sealed envelope** bearing the name and Reference number of the Tender, addressed to the Client.

9.2. Tenders and all Documents in connection therewith, as specified above, shall be delivered at the client's premises which is *along 3rd Sunrise Avenue in Ruiru off Eastern Bypass Between Greenspot Gardens/Brook breeze Apartments and Deliverance Church. Left-hand side After Greenspot Gardens Carpark and of Coordinates (-1.16637,36.96845).*

9.3. The Tenderers shall also submit a softcopy of their bids to the following email address procurement@goodneighbors.ke.

9.4. The deadline for physical (hardcopies) and electronic submissions (softcopies) shall be on **Friday the 4th of July 2025 at 1600 Hrs.**

9.5. For a tenderer to be considered responsive, **it shall be mandatory to submit both hardcopy and softcopy on time.**

10. Responsiveness

10.1. Prior to the detailed evaluation of tenders, the Client will determine whether each tender is substantially responsive to the requirements of tender documents. For the purpose of this clause, a substantially responsive tender is one which conforms to all the terms, conditions and specifications of the tender documents without material deviation or reservation. A material deviation or reservation is one which affects in any substantial way the scope, quality, or performance of the work, or which limits in any substantial way, inconsistent with the tender documents, the Client's rights or the tenderer's obligations under the Contract and the

rectification of which deviation or reservation would affect unfairly the competitive position of other tenderers presenting substantially responsive tenders.

- 10.2. If a tender is not substantially responsive to the requirements of the tender documents, it will be rejected by the Client and may not subsequently be made responsive tenderer despite having corrected or withdrawn the non-conforming deviation or reservation later.

11. Arithmetic Errors

- 11.1. The tender sum shall be absolute and final and shall not be the subject to correction, adjustment or amendment in any way by any person or entity.
- 11.2. Provided that the Tender is substantially responsive, the Client shall handle errors on the following basis:
- a) Any error detected, arising from a miscalculation of unit price, quantity, subtotal, and total bid, if considered a major deviation (more than 20 %) that affects the substance of the tender, shall lead to disqualification of the tender as non-responsive.
 - b) if there is a discrepancy between words and figures, the amount in words shall prevail.

12. TENDER AWARD

- 12.1. Kenya Good Neighbors reserves the right to accept or reject any tender, and to cancel the tendering process and reject all tenders, at any time prior to the award of Contract, without thereby incurring any liability to the affected tenderer or tenderers or any obligation to inform the affected tenderer or tenderers of the grounds for the action.
- 12.2. The Client shall have the exclusive right of Awarding the tenders separately to different Contractors and where it deems fit to One Contractor.

13. CORRUPT AND FRAUDULENT PRACTICES

- 13.1 Kenya Good Neighbors requires that tenderers observe the highest standards of ethics during procurement process and execution of contracts. A tenderer shall sign a declaration that he/she has not and will not be involved in corrupt and fraudulent practices. The declaration shall be submitted together with bidding documents.

13.2 A tenderer shall not be involved in corrupt, coercive, obstructive or fraudulent practice. A tenderer that is proven to have been involved in any of these practices shall be automatically disqualified

13.3 The Client will reject a proposal for award if it determines that the tenderer recommended for award has engaged in corrupt or fraudulent practices in competing for the contract in question.

13.4 The Client offers equal opportunity to the bidders and only awards the tenders based on merit of the bidders. The Client categorically puts across that it does not support offering of any gifts or commission with the intention of securing the award of the tender either to staffs, managers, senior management, Board members, Consultants working or associated with the Client.

14. Advance Payment

14.1 The Client shall not pay monies as an **advance payment** or mobilization fee to the successful tenderer.

14.2 The Payment shall be done to the Contractor upon satisfactory and Approved Completion of the Works. The client shall pay based on the measured works on site.

15. Performance Security

15.1 The successful tenderer shall be required to submit a performance bond of **Ten percent (10%)** of the tender sum before commencement of works.

HYDROGEOLOGICAL SURVEY REPORT

FOR

KAEKIT COMMUNITY BOREHOLE

CARRIED OUT ON COMMUNITY LAND

WITHIN

KEKIT AREA, KAERIS WARD, TURKANA NORTH CONSTITUENCY, TURKANA
SUBCOUNTY, TURKANA COUNTY.

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APRIL 2025

REPORT NO. KGL015/2025

Summary

This report documents on the hydrogeological assessment results and findings that was conducted on community land that is located at Keket Area, Kaeris Ward, Turkana North Constituency, Turkana Subcounty, Turkana County. The hydrogeological Profile survey was done on 22nd April 2025 with a major aim of providing sufficient, clean and palatable water for used for domestic use. The client intends to drill the borehole that can produce a yield of 8 M³.

The oldest rocks in the regional area are of undifferentiated/complex Metamorphic rock basement system. With intrusion by tertiary volcanic rocks. Loose soils are seen resting on top rhyolites that rest on top of olivine basalts which intern overlay undifferentiated/complex Metamorphic rock basement system. Groundwater is expected to occurs within the contact of respective rocks. These is majorly because at these contacts the Old Land Surfaces (OLS) were formed resulting to aquifers. Faults also form good regions where water accumulates.

One suitable point on profile 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	Line with point No & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m ³ /hr
35° 19.609'E 03° 57.391' N +36 758374 437688 Elev. 565m.asl	Line 971 Point 3	Min 120m.bgl Max 150m.bgl	216mm/153mm	5-10 m³ hr

The yield of a borehole drilled at the recommended location is expected to be within or above 5 m³ hr but careful construction and development will lead to maximum borehole productivity, efficiency and long life. **Monitoring of the drilling operation past 110m depth should be done using an EC Meter.** This will be helpful in knowing the electrical conductivity and salt concentration of the deeper aquifer.

It is thus recommended that:

- ✓ The borehole should be drilled at **point 3 of the data to a minimum depth of 120m.bgl. and a maximum depth of 150m.bgl.**
- ✓ The borehole be installed 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.

NOTE:

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.

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ABBREVIATIONS AND GLOSSARY OF TERMS

ABBREVIATIONS (S.I. Units throughout, unless indicated otherwise)

Agl	above ground level
amsl	above mean sea level
bgl	below ground level
E	East
EC	electrical conductivity ($\mu\text{S}/\text{cm}$)
hr	hour
l	Litre
m	metre
N	North
NEMA	National Environment Management Authority
PWL	pumping water level
Q	discharge (m^3/hr)
s	drawdown(m)
S	South
SWL	static water level
T	transmissivity (m^2/day)
W	West
WRA	Water Resources Authority
WSL	water struck level
$\mu\text{S}/\text{cm}$	micro-Siemens per centimetre: Unit for electrical conductivity
$^{\circ}\text{C}$	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 <i>trachyte ss.</i> and <i>latite</i>). 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 <i>tuff</i> , while coarse, consolidated pyroclastic debris is referred to as <i>agglomerate</i> .
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. INTRODUCTION

Good Neighbors Kenya commissioned Kelvin Kimani Burugu to carry out groundwater survey and propose the best site for drilling a borehole. The parcel of land is located in Kaekit area, Kaeris Ward, Turkana North Constituency, Turkana Subcounty, Turkana County.

1.1 Background Information

This report documents on the hydrogeological survey results and findings that were conducted on the site with the major aim of determining the groundwater potential of the site that will lead to the drilling of one productive borehole. The main objective for this survey is to develop a borehole to supply water for Domestic use. The above survey program was envisaged and commissioned by Good Neighbors Kenya.

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.

1.3. Project Site Location

The project site is located in Kaekit area. Access to the site from Lodwar town is 78 Kilometer drive along Lodwar Lokichogio road (A1) then taking a right turn off exit to join a feeder road at Gold Center and making a drive of 67km to Kaeris center. The site is located 15km on feeder road connecting it to Kaeris Center. The site is located on the left-hand side of the road. The coordinates for the investigated site fall on: $35^{\circ} 19.609' E$ $03^{\circ} 57.391' N$ +36 758374 437688 with an Elevation of 565m.asl.



Figure 1.1 Position of proposed borehole site on Goggle earth at a distant aerial view in 3D.



Figure 1.1 Position of proposed borehole site on Goggle earth at a closer aerial view in 3D.

The proposed borehole site is in Kaekit area and the surrounding plots are mainly open fields with for animal keeping. Several small-scale businesses are noticed at Kaeris Center.

1.4 Water Supply Situation.

The area is not yet connected to any water pipeline system. Due to shortages of water by the company, the residents are forced to obtain water from far existing boreholes and water boozers from Lodwar Town.

1.5 Climate

The area's climate is considered local steppe climate. The temperature here averages 29.3 °C, and about 373 mm of precipitation falls annually.

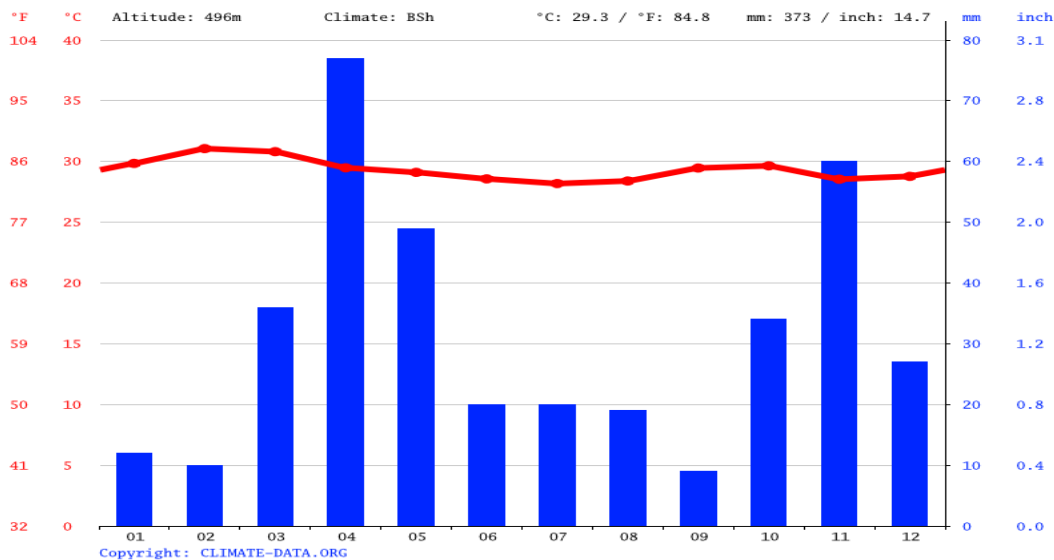


Figure 1.1 Climate Graph of the Area.

The driest month is September, with 9mm rainfall. April receives most precipitation with an average of 77mm. The temperatures are highest on average in February, at around 31.1 °C. July has the lowest average temperature of the year. It is 28.2 °C.

1.6 Drainage.

The site area is drained by River Kaekit to the east and south. The river has a flow direction from east to west and later pours into the seasonal Lotigipi swamp located towards the east and north east. The river used to flow throughout the year, however due to climate changes the river is now regarded as seasonal. The lotigipi swamp normally rests on top of lotigipi aquifer rock formations.

2. GEOLOGY

Ground water presence and consequently the exploration techniques depend to a large extent on the geology of the area. Other factors which influence the ground water occurrence as morphology, topography and pedology are strongly related with the geological setting of the region as well. Without a proper understanding of the geological framework of a ground water system, it is impossible to quantify the resource. The initial stage of the assessment must therefore be the study of the geology. For this purpose, a study has been made of the existing geological maps and reports, supplemented with geological field investigations.

2.1 Introduction. (Regional Geology)

Regionally the oldest rocks in the regional area are of undifferentiated/complex Metamorphic rocks that are overlaid by tertiary volcanic rocks. Loose Sandy soil column overlays the tertiary volcanics.

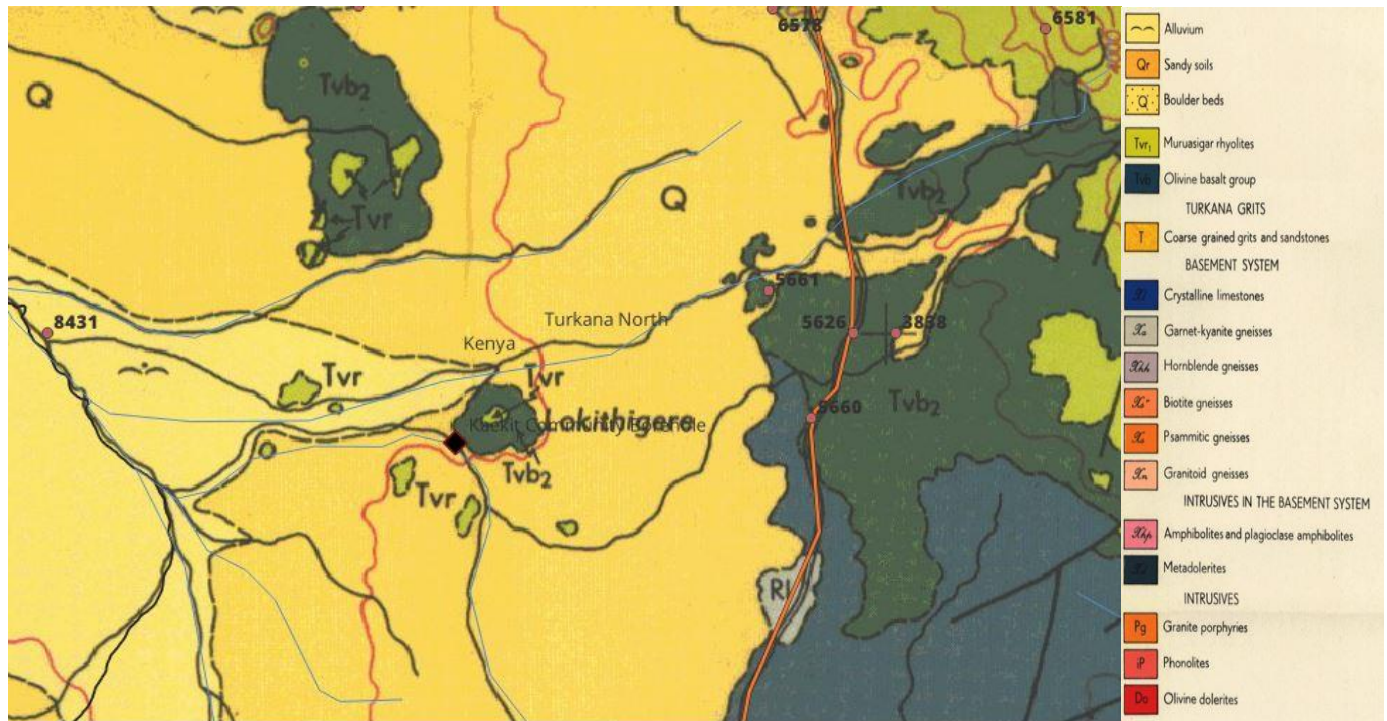


Figure 2.1: Geological map extract from Geology of Northern Turkana Area BY J. Walsh & R.G Godson, 1963.

2.2 Geology of the Project Area

Geology of the project area was narrowed down using the GPS coordinates acquired, therefore making it easy to identify and relate the hydrogeological characteristics of the identified point/site from Geological maps and existing borehole data. Rhyolites overlay olivine basalts which in turn overlay complex metamorphic rocks.

In general, the rocks sequence in age and geological history is as shown below.

4. Very thin column of sandy soil deposits.
3. Rhyolites.
2. Olivine Basalts.
1. Complex and undifferentiated Metamorphic Rocks Systems.

3. HYDROGEOLOGY

This section briefly discusses some of the hydrogeological 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 rocks, groundwater occurs within fissure zones, sediment beds, lithological contacts and old land surfaces (OLS).

3.1 Surface Water Resources

The site area is drained by River Kaekit to the east and south. The river has a flow direction from east to west and later pours into the seasonal Lotigipi swamp located towards the east and north east. The river used to flow throughout the year, however due to climate changes the river is now regarded as seasonal. The Lotigipi swamp normally rests on top of Lotigipi aquifer rock formations.

3.2 Ground Water Resources

Due to far distance from 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 considered being within zones of medium to low groundwater potential whereupon supplies are obtained through a concentration of groundwater recharge from the Southern side of the area.

The metamorphic 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 at the contact zone of the volcanic rocks and at the weathered and fractured zones of these rocks at various depths discussed.

3.3 Existing Boreholes

Exploitation of groundwater within the area is on the rise lately. This is because of unreliable water supply system. There are very few existing boreholes in the area and little information about the boreholes. Several failed hand pumps are also noticed.

Table 3.1: Neighboring Borehole sites from the project site

BH No. C	Owners	Distance (Km)/ Bearing	Depth (M bgl)	WSL (M bgl)	WRL (M bgl)	Yield (M ³ /Hr)	PWL (M bgl)
3838	D.W.D	20.12/ENE	26	-	14	1.38	18
5626	D.OF LODWAR/COMMUN.	18.19/NE	100	-	-	-	-
5660	D.OF LODWAR/COMMUN.	15.71/E	40	-	17	0.78	20
5661	D.OF LODWAR/COMMUN.	15.183/NE	70	-	20	2.64	30
8431	D.OF LODWAR/COMMUN.	18.7/NE	90	-	-	-	-

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

Locations 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. Volcanic systems experience 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 mineralised 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 volcanic 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 Ground Water Quality

Generally, groundwater chemistry from the metamorphic 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 3.2: Maximum dissolved constituent limits as per WHO/EU standard.

Parameters	Unit	WHO/EU Guideline
Iron	mg/l	Max 0.3
Manganese	mg/l	Max 0.1
Calcium	mg/l	Max 100
Magnesium	mg/l	Max 100
Sodium	mg/l	Max 200
Potassium	mg/l	Max 50
Chloride	mg/l	Max 250
Fluoride	mg/l	Max 1.5
Nitrate	mg/l	Max 10
Nitrite	mg/l	Max 0.1
Sulphate	mg/l	Max 450
Total HardnessCaCO ₃	mg/l	Max 500
Total Alkalinity CaCO ₃	mg/l	Max 500
Arsenic	ug/l	Max 10
PH	pH scale	6.5-8.5
Colour	mgPt/l	Max 15
Turbidity	N.T.U	Desirable:<5
Conductivity	uS/cm	Max 2500
Total Dissolved Solids(mg/l)		No Guideline

4. FIELD EXPLORATION PROGRAM

The method and Design of Prospecting for water was carefully selected to ensure that the prospects are well identified.

4.1 Introduction Prospecting Methods

Many different geophysical methods are available to assist in the assessment of geological subsurface conditions. Geophysical exploration is detecting stratigraphic rocks, geological structure and other geological conditions through the study and observation of changes in a variety of geophysical fields. Commonly used geophysical exploration methods include gravity exploration, DC exploration, alternating current survey exploration, magnetic exploration, sonic exploration, seismic exploration, radioactive exploration. In the present survey, the natural electric field method was applied.

This information is obtained in the field using resistivity method:

1. Resistivity Method (Convectional Method) The Vertical Electrical Sounding (VES) and Horizontal Electrical Profiling (HEP)-
Not used.
2. Natural Electric Field Method (Recent Method by PQWT)

The resistivity profiling method is used to trace lateral variation in resistivity to locate fractured and fault zones while, the VES probes the resistivity layering below the site (point) of measurement.

4.2 Basic Principle

4.2.1 Natural Electric Field Method Frequency Selection System (PQWT)

This method is based on the use of existing natural electric field source as a working farm, with resistivity contrasts to probe/detect underground rocks and minerals or underground water. Based on this method the instrument is able to detect subsurface rock ores, ground water, at various depths.

Scientifically based on measuring the natural electric field on the surface of the two selected points (M & N), different frequency electric field component can be recorded. Therefore, according to their different variation of data in the study, further interpretations can be made. Notably abnormal geological features/bodies can well be identified due to abnormal changes in data collected. The working principle of electrical difference of natural earth magnetic field is by using specific frequencies (frequency 0 -170 kHz). Specific frequencies are able to give information on specific Depths.

Because the natural electric field method measures the electrical component of the electromagnetic field of the earth, using specific corresponding frequency as measured within 0-50 meters (or specified distance), the frequency selection method, is always referred to as **natural potential frequency method**. According to this theory and design, instruments working on this principal are referred to as **natural selected frequency electric field instruments**. These instruments can therefore be set with specifications or desired needs.

The instrument (PQWT-TC500) used in conducting the above Hydrogeological survey is able to conduct the following measurement/specifications;

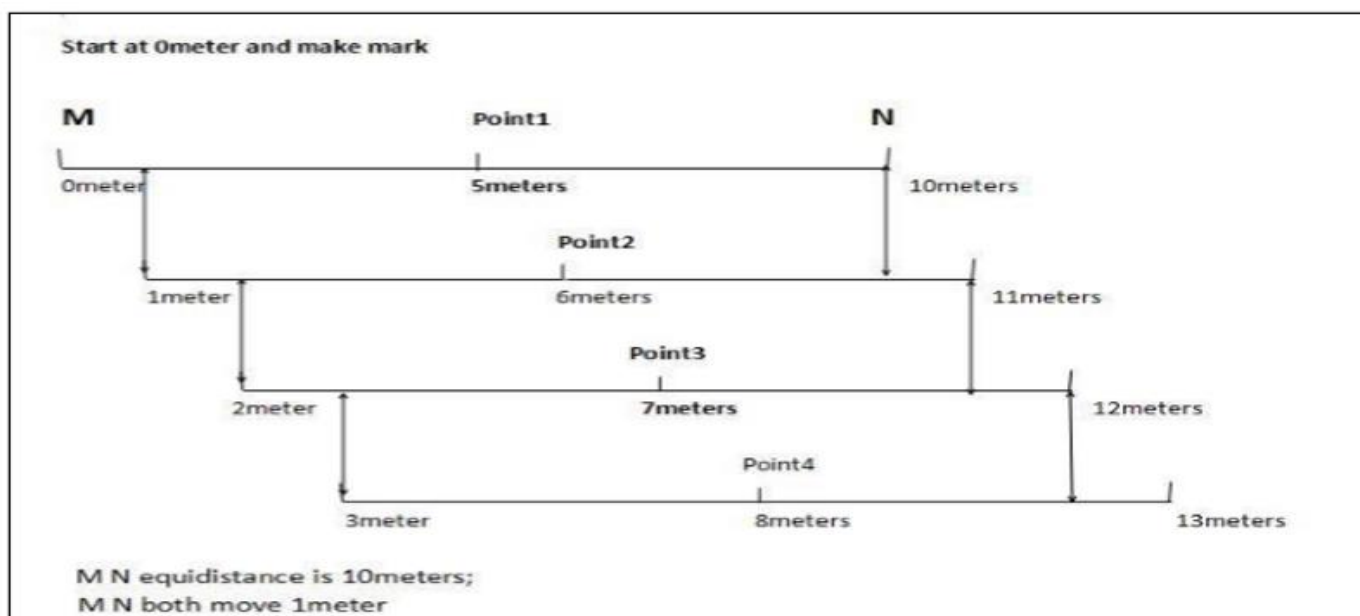
- 1) Single Frequency Measurements.
- 2) Three Frequency Measurements. 170 Hz (shallow), 67 Hz (middle level), 25h Hz (Deep level)
- 3) Band (many) Frequency Measurements-used for Profile Imaging-. 0 to 170 Hz.

NOTE:

- a) The Equipment has a fixed probing Depth of 500 meter and specifications of measuring the above frequencies.
- b) This Survey was done using the Profile Imaging (Band Frequency Measurements).

Methodology

Methodology of measuring Natural electric field is by, placing wired electrodes in a specific direction and location with a 10 meters' interval. The Straight line under investigation should be perpendicular to tectonic lines. A tape Calibrated in Meter is preferred and used to calibrate and mark the points/sites. The first data collection should have one electrode of M at 0 m and the other N at 10m mark on tape. After collecting data on the first point, second data collection point should be done by moving both M & N by a distance of 1meter. Data collection should then take place systematically and successively with reference to meter-marked tape. The MN Electrodes equidistance connection while collecting data is as shown below:



(Note: It is better to measure and tap at 10Meters of M N equidistance, and both M N move 1 meter, because the water detector was designed at 10meters of M N equidistance, and M N both move 1meters. changing the MN equidistance has effect on the depth of measurement)

Figure 4.1: Procedure for Exploration using PQWT instrument.

How to calculate the meters on the ground, according to point in the profile map? Example what meters on the ground at Point 4 in the profile map?

1. M N=10M and both M N move 1meters, point 4 is at 8meters on the ground. (point number +4meters)

4.3. Field Work

Fieldwork was carried out on 22nd April 2025. Observations of the general topography, drainage, geological set up, and distance to neighboring boreholes was also carried out. The geophysical survey started with a general horizontal profile across the client's parcel of land. Using The PQWT-TC underground water detector, a geophysical survey of the site area was carried out as shown in Fig 4.1 Below. The eventual selection of the drilling point also took into consideration the accessibility, geophysical results and proposed infrastructure.

Profile survey

A single profile survey lines was done across the client parcel of land. Line was taken with a specific number of point station taken as displayed below by the profile curve and images.

PROFILE No.	SELECTED POINTS	GRID REFERENCES	UTM 36+
Line 1 (971)	Point 3 on profile (7m on tape)-Best Point.	35° 19.609'E 03° 57.391' N	758374 437688
Line 2 (972)	Point 7 on profile (11m on tape)	35° 19.506'E 03° 57.287' N	758184 437490
Line 3 (973)	Point 5 on profile (9m on tape)	35° 19.446'E 03° 57.268' N	758075 437454
Line 4 (974)	Point 10 on profile (14m on tape)	35° 19.653'E 03° 57.356' N	758456 437619
Line 5 (975)	Point 7 on profile (11m on tape)-Second Best Point.	35° 19.671'E 03° 57.169' N	758493 437273

NOTE: Data collection for profile 1,2,3,4 and 5, had the data collected under the command of the +2 Gain function was adopted due to values noticed when collecting the first two data of each respective profile lines.

4.3.1 Profile Imaging survey-LINE 1

A total of 10 points/stations were taken as displayed below by the profile curve.

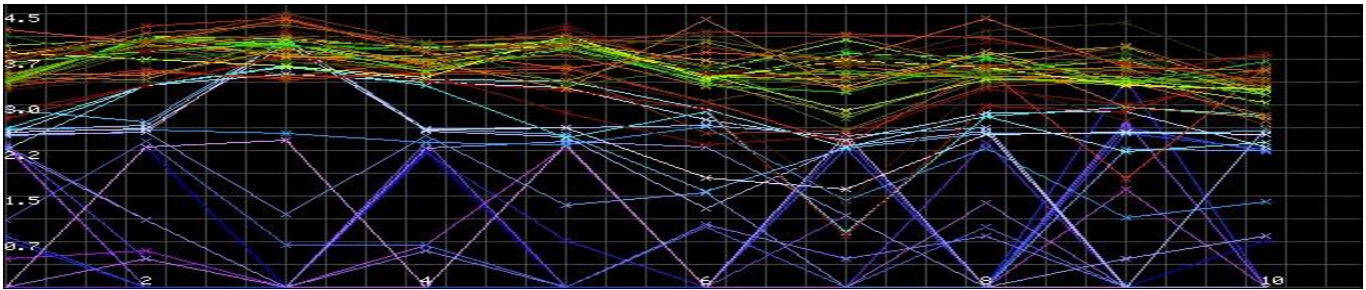


Figure 3.1A. Original and Processed data curves produced on collection after measurement of the 10 points.

Sub-Surface Profile of the project area.

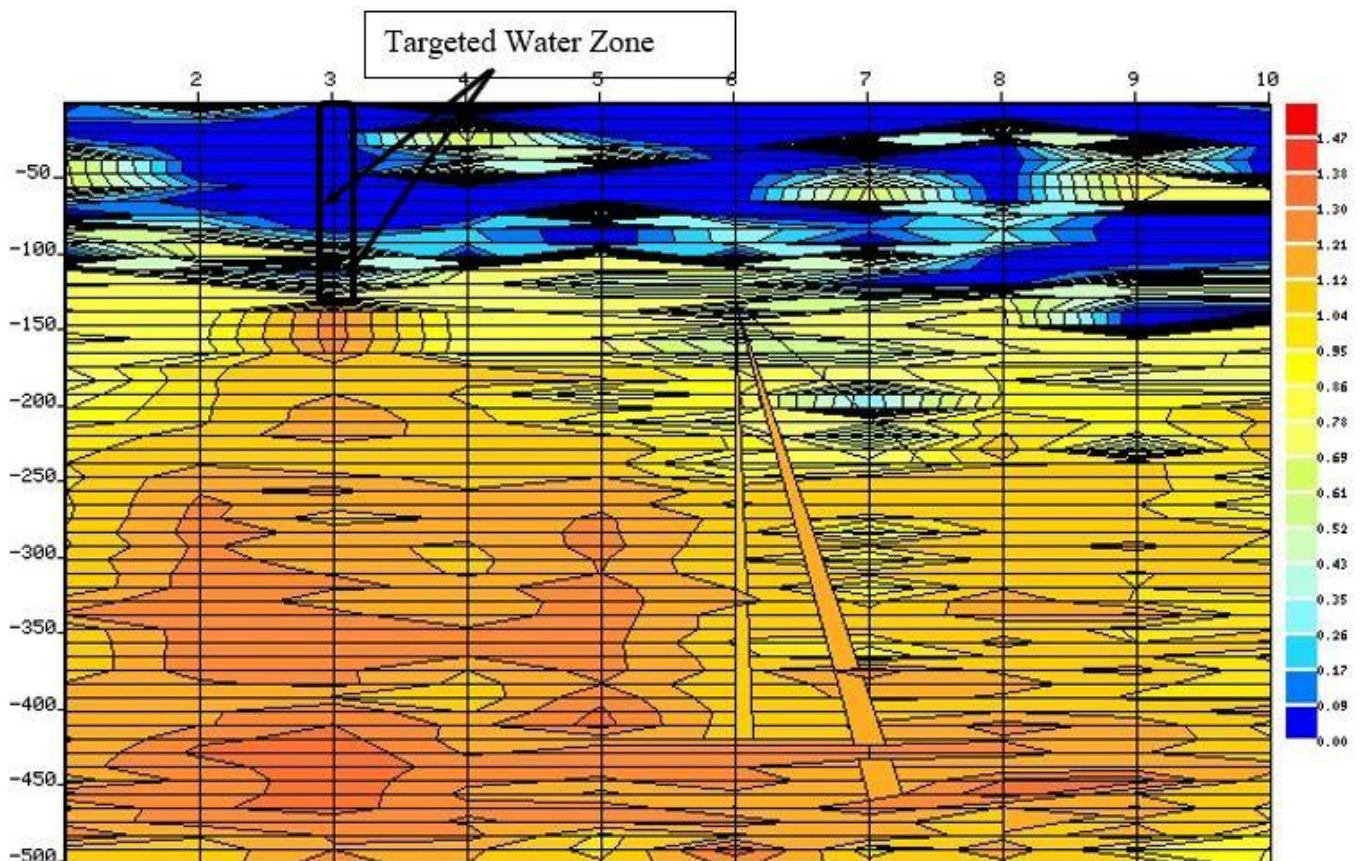


Figure 3.1B. Processed profile image for the surveyed line.

The horizontal profile line survey was done at a constant measurement after every 1m while having a 10-meter interval of the two probing rods. The profile was able to identify a section that has good localized aquifers within the various rocks. River sediments are resting on Tertiary volcanic which intern overlay Metamorphic rocks.

From the processed image, point 3 was selected as the best point for the proposed borehole. Underground water prospects at point 3 are expected are from depth 40m.bgl to 95m.bgl. The second good saturation aquifer is expected from depth 105m.bgl to 145m.bgl. respectively. **Monitoring of the drilling operation past 110m depth should be done using an EC Meter.** This will be helpful in knowing the electrical conductivity and salt concentration of the deeper aquifer. **Point 3 of PROFILE LINE No.1 has been recommended as the best site for drilling of the proposed borehole to a minimum depth of 120m.bgl and maximum depth of 140m.bgl.**

4.3.2 Profile Imaging survey

A total of 9 points/stations were taken as displayed below by the profile curve.

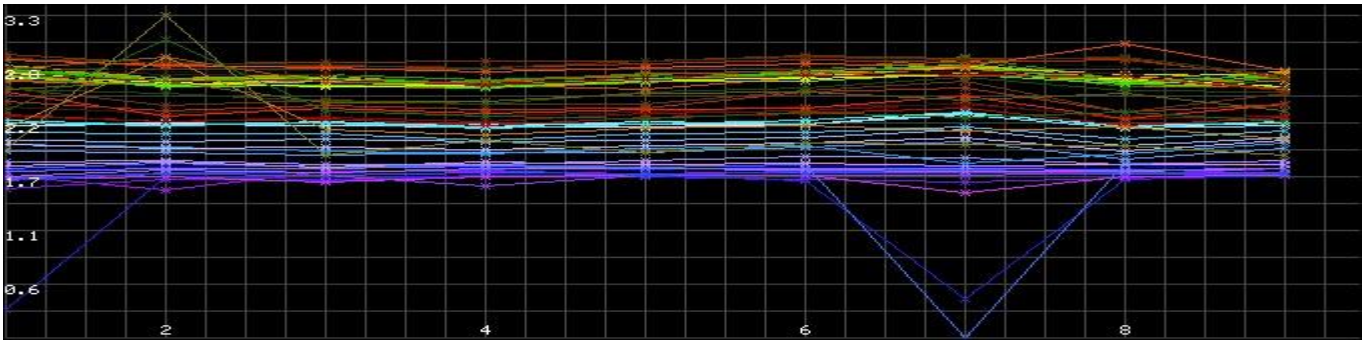


Figure 3.2A. Original and Processed data curves produced on collection after measurement of the 9 points.

Sub-Surface Profile of the project area.

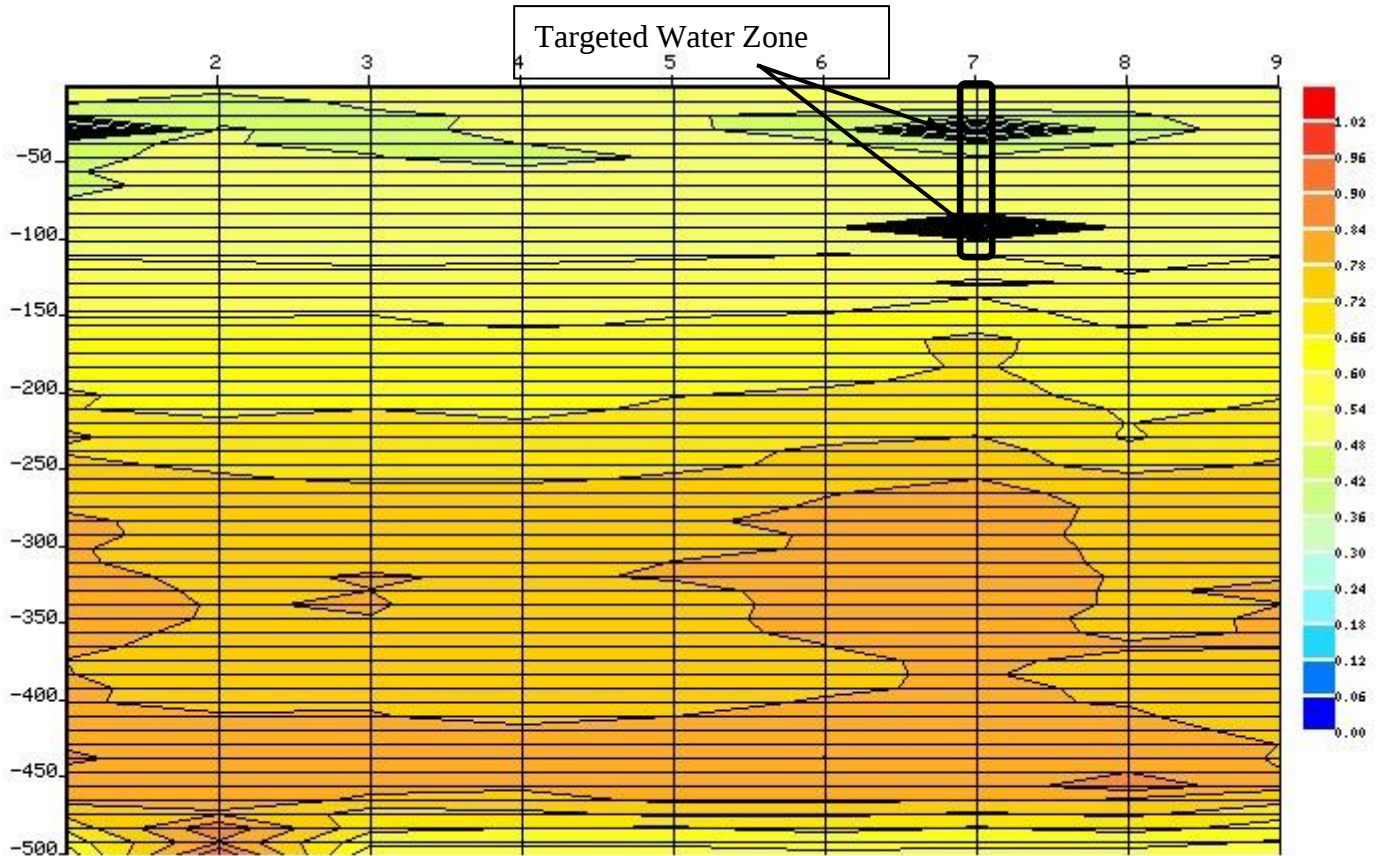


Figure 3.2B. Processed profile image for the surveyed line.

The horizontal profile line survey was done at a constant measurement after every 1m while having a 10-meter interval of the two probing rods. The profile was able to identify a section that has good localized aquifers within the various rocks. River sediments are resting on Tertiary volcanic which in turn overlay Metamorphic rocks.

From the processed image, point 7 was selected as the best point for the proposed borehole. Underground water prospects at point 3 are expected from depth 35m.bgl to 53m.bgl. The second good saturation aquifer is expected from depth 80m.bgl to 100m.bgl. respectively. **Point 7 of PROFILE LINE No.2 has been recommended as the best site for this specific line but was not recommended for drilling.**

4.4.3 Profile Imaging survey-LINE 3

A profile survey was done across the client parcel of land. A total of 11 Point station was taken as displayed below by the profile curve.

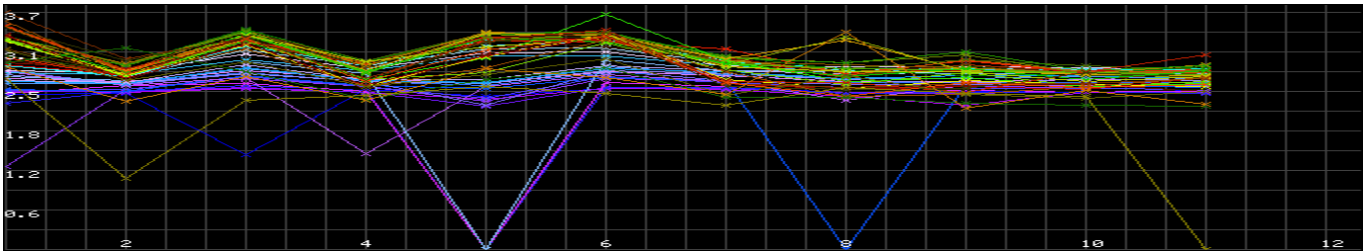


Figure 3.3A. Raw Original and Processed data curves produced on collection after measurement of the 11 points.

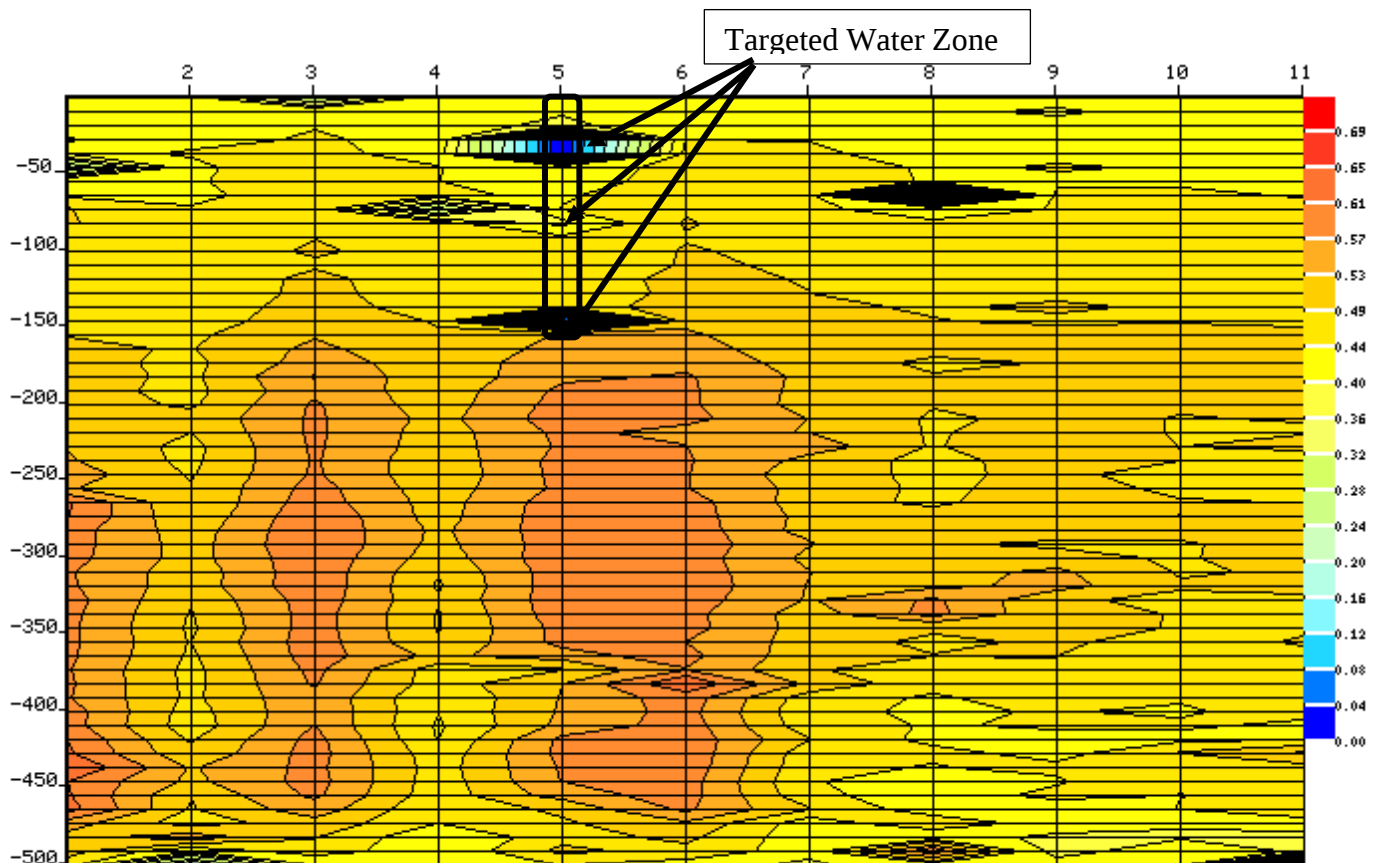


Figure 3.3B. Processed Map for the Surveyed Line

The horizontal profile line survey was done at a constant measurement after every 1m while having a 10-meter interval of the two probing rods. The profile was able to identify a section that has good localized aquifers within the various rocks. River sediments are resting on Tertiary volcanic which intern overlay Metamorphic rocks.

Based on the geophysical data, first aquifer prospects on point 5 is expected at depth 10m to 55m. Fair water saturation is expected from depth 55m to 90m. A deeper aquifer is expected from depth 140m to 160m. **Point 5 of PROFILE LINE No.3 has been recommended as the best site for this specific line but was not recommended for drilling**

4.3.4 Profile Imaging survey-LINE 4

A profile survey was done across the client parcel of land. A total of 12 Point station was taken as displayed below by the profile curve.

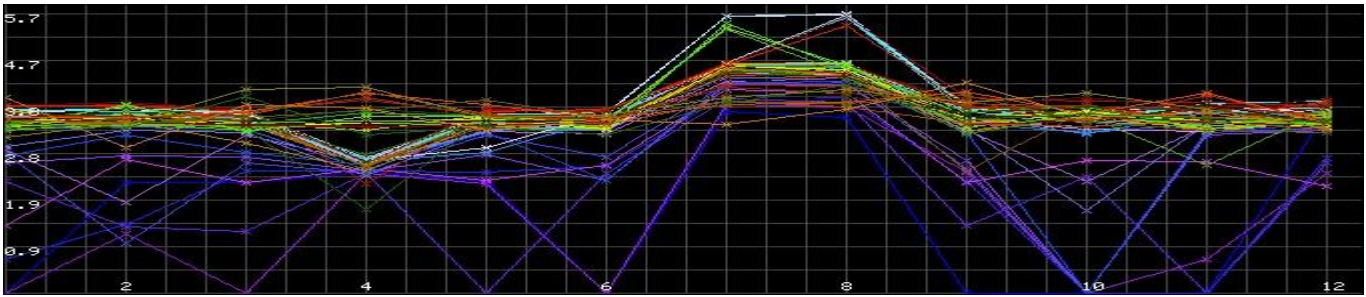


Figure 3.4A; Raw data curve produced on collection after measurement of the 12 points.

Sub-Surface Profile of the project area.

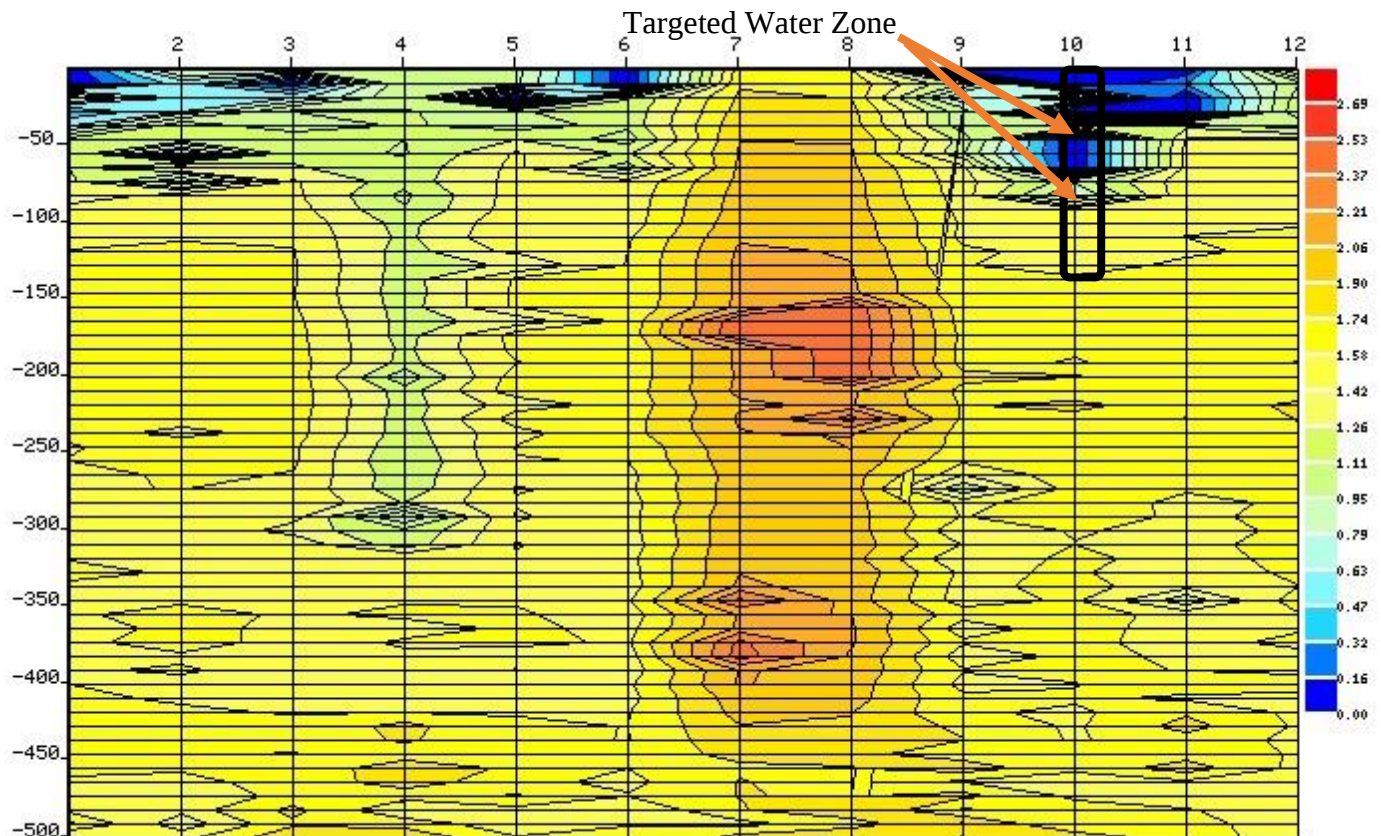


Figure 3.4B; Processed profile for the surveyed line.

The horizontal profile line survey was done at a constant measurement after every 1m while having a 10-meter interval of the two probing rods. The profile was able to identify a section that has good localized aquifers within the various rocks. River sediments are resting on Tertiary volcanic which intern overlay Metamorphic rocks.

Based on these geophysical data, shallow Water prospects at point 10 are expected from depth 5m.bgl to 45m.bgl. The second aquifer is expected from depth 55mghl to 90m.bgl. A zone of low saturation zone is expected from depth 95m.bgl to 220m.bgl. **Point 10 of PROFILE LINE No.4 has been recommended as the best site for this specific line but was not recommended for drilling of the proposed borehole.**

4.3.5 Profile Imaging survey-LINE 5

A profile survey was done across the client parcel of land. A total of 9 Point station was taken as displayed below by the profile curve.

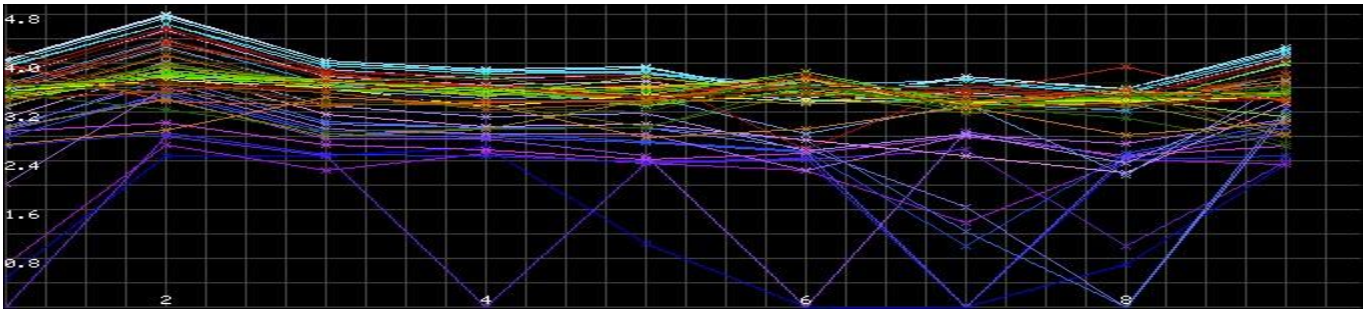


Figure 3.5A; Raw data curve produced on collection after measurement of the 9 points.

Sub-Surface Profile of the project area.

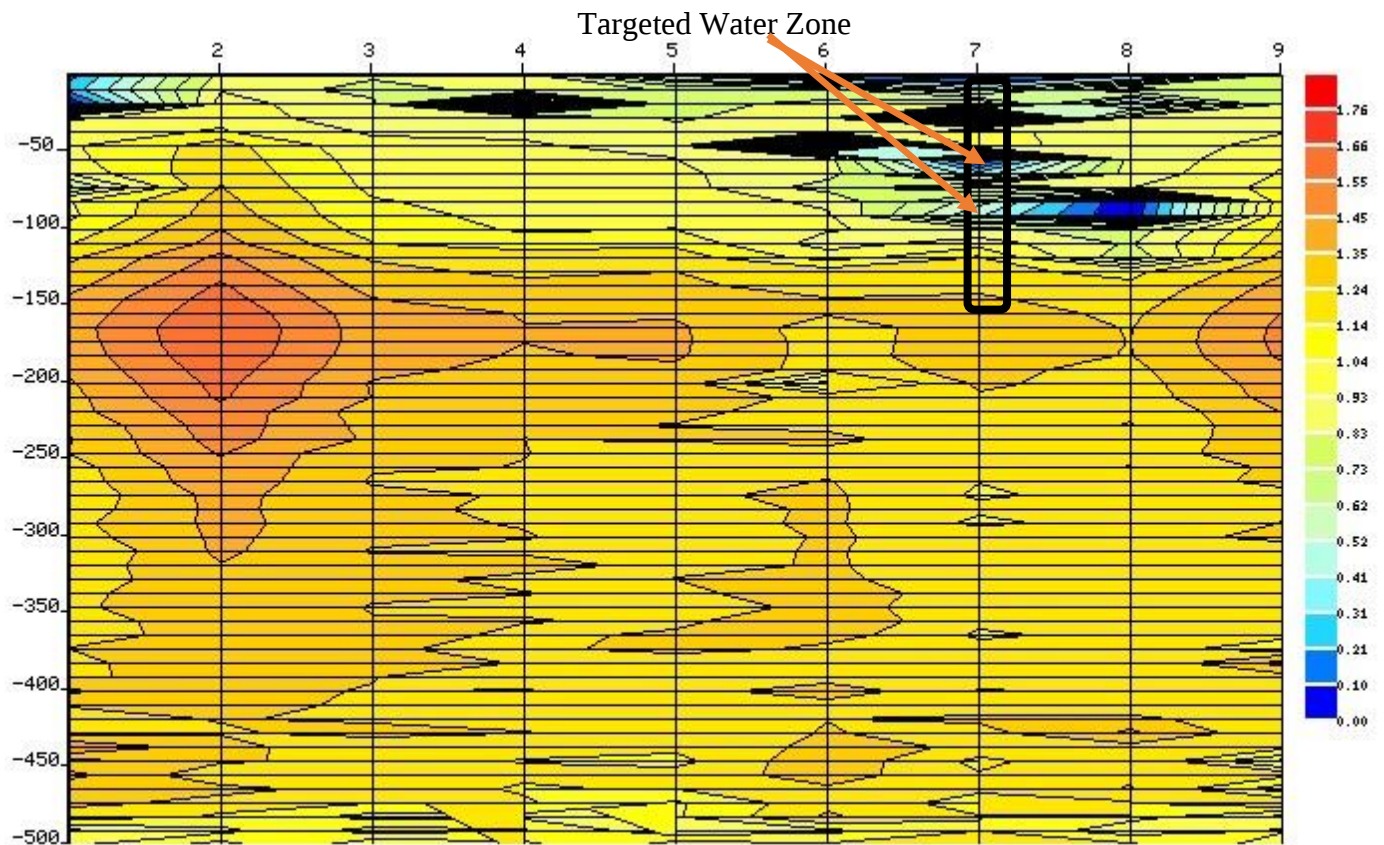


Figure 3.5C; Processed profile for the surveyed line.

The horizontal profile line survey was done at a constant measurement after every 1m while having a 10-meter interval of the two probing rods. The profile was able to identify a section that has good localized aquifers within the various rocks. River sediments are resting on Tertiary volcanic which intern overlay Metamorphic rocks.

Based on these geophysical data point 7 was selected, a shallow aquifer is expected from depth 10m bgl to 40m bgl. A fairly saturated zone is expected from depth 50m to 75m while the deeper aquifer is expected from depth 75m.bgl to 125m.bgl. **Point 7 of PROFILE LINE No.5 has been recommended as the best site for this specific line but was not recommended for drilling of the proposed borehole. It was selected as the SECOND-BEST SITE.**

5. 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.

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 10 meters 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. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

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 formations is likely to be above 5m³/hr.
- b. It is recommended that a borehole be **drilled to a minimum depth of 120m.bgl. and max depth of 150m.bgl.**

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

Site coordinates	Line with point No & ranking in Yield Potential	Recommended depth in meters	Construction Requirements.	Anticipated Yield m ³ /hr
35° 19.609'E 03° 57.391' N +36 758374 437688 Elev. 565m.asl	Line 971 Point 3	Min 120m.bgl Max 150m.bgl	216mm/153mm	5-10 m³ hr

6.2 Recommendations

1. The drilling should ideally be carried out with a Rotary drilling plant rotary in order to attain the minimum depth of 120m.bgl and maximum recommended drill depth of 150 m below ground level unless enough water has been struck or the formation is complicated to continue drilling.
2. 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.
3. In case shallow aquifers are encountered it is recommended to seal these off within the upper 10 meters, in order to avoid any risk of cone of depression coalescence and contamination by surface water.
4. 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.
5. 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

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-meter 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 consists 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 liters 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.

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METEORIC WATER LIMITED

HYDROGEOLOGICAL SURVEY REPORT

FOR

ONE PRODUCTION BOREHOLE

ON

PLOT NO: BISIL/

WITHIN

ILBISIL TRADING CENTRE, ILBISIL SUB LOCATION, ILBISIL LOCATION, KAJIADO COUNTY

CLIENT: ILBISIL TOWNSHIP PRIMARY SCHOOL-BISIL

P.O. Box 414-01100

KAJIADO

PROJECT: DOMESTIC WATER SUPPLY

May 2025

A. LESLIE DULLO

M.GSK, M.GRB, REG HYDROGEOLOGIST

EXECUTIVE SUMMARY**Introduction**

This report describes the results of hydrogeological and geophysical borehole site investigations on **Ilbisil Township Primary School's** parcel of land located in Ilbisil Trading Centre, Ilbisil sub location, Ilbisil location, Kajiado County. The aim of the investigations was to locate a suitable borehole drilling site within their parcel of land. To accomplish this, detailed hydrogeological and geophysical investigations were executed.

The study focused on availability of fresh groundwater in sufficient quantity for domestic and general use in the institution.

Climate

The climate is semi arid, being dry for most of the year. Rainfall is bi modal (March May and October December). Mean annual rainfall is approximately 530 mm.

Temperatures are highest in the months January to March; Annual mean daily minimum and maximum temperatures are 13 to 26° C (TAMS, 1980).

Potential evaporation is between 1,800 and 2,000 mm per year and these losses are exacerbated by frequent high winds in the area.

Geology

The surface geology exclusively comprises of **undifferentiated banded gneisses, schists and granulites** of Archean age which are underlain by crystalline limestones and quartzites.

Hydrogeology

The major water bearing formations in the area are as follows:

- Weathered Basement rocks
- Fractured Basement rocks

Geophysical Fieldwork

Geophysical measurements were used to determine the thickness of the underlying layers, their potential as aquifers, and the expected quality of groundwater in these formations. Two Vertical Electrical Soundings were executed at the site. The soundings were carried out to an electrode separation of 320m & 250m respectively, in an attempt to unveil the hydrostratigraphy of the area.

Conclusions

The study concludes that, on the basis of hydrogeological evidence, groundwater prospects in the study area are low to medium as a result of existence of the metamorphic formation underlying the site. From records of neighboring boreholes, the expected yield is envisaged to range between **1.128m³/hour and 13.5m³/hour and a mean value of 4.39m³/hour which is good.**

Recommendations for Drilling

In view of the geophysical results and hydrogeological nature of Ilbisil area, **it is recommended that a borehole (8inch in diameter) be drilled at VES 1 of this site to a maximum depth of 270m bgl or until sufficient yield is struck.** It is imperative to note that **the yield increases with progressive depth as deeper lying aquifers** are penetrated. A summary of all the investigations done and the recommended drilling site are given below: -

Recommended Drilling Location for the Investigated Sites

No. of VES (es) Done	Recommended VES	Min Depth (m)	Max Depth (m)	Groundwater Prospects
2	1	-	270	Good

Borehole site investigation**Ilbisil Township Primary School. Ilbisil location, Kajiado County.**

The VES sites were pegged using wooden pegs with the respective VES numbers clearly written during the field investigations. The VES coordinates were obtained using Global Positioning System (GPS) and were shown to the client's representative.

Monitoring

Regular monitoring should be instituted and maintained in the boreholes in order to keep track of groundwater levels. A monitoring tube should be installed in the borehole to be able to monitor the water level in the well.

Borehole Construction

Recommendations are given for borehole construction and completion methods. The importance of correct and comprehensive techniques in this particular aspect cannot be over-emphasized.

Drilling Permits

A drilling permit must be applied from the Water Resources Management Authority Regional office in Kibwezi under the Ministry of Water and Irrigation.

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GLOSSARY OF TERMS:

Abstraction	Means removal of water from any water source, either permanently or temporarily.
Airline	Means the tube installed in a borehole or well for the purposes of measuring water level.
Alien species	Means any exotic non-indigenous life forms originating from outside a given ecological location.
Alteration	Means any physical change in the depth, diameter, casing, screen or any other structural change in an existing borehole, or any consequent change in the Permit yield as a result of an approved variation.
Analysis	Means the testing or examination of any matter, substance or process for the process for the purpose of determining its composition or qualities or its effects (weather physical, chemical or biological) on any segment of water or examination thereof.
Aquifer	A geological formation or structure which transmits water and which may supply water to wells, boreholes or springs.
Arbitration	Means to decide between parties in a dispute or conflict of water source, use and availability;
Artificial Ground Water Recharge	Means the intentional augmentation of ground water resources by directly improving the infiltration of water to a target aquifer through the construction of suitable recharge structures.
Authority	Means the Water Resources Management Authority established under Section 7 of the Act,
Confined	Confined aquifers are those in which the piezometric level is higher (i.e., at a greater elevation relative to sea level) than the elevation at which the aquifer was encountered.
Intercalated	Interbedded - a lava flow may occur between layers of sediment, or vice-versa.
Old Land Surface	Old Land Surfaces (OLS's) is the term given to ancient erosion surfaces now covered by younger surface material. In hydrogeology, OLS's frequently make good aquifers, especially where the erosion debris left behind is coarse in nature.
Phenocrysts	The larger crystals in porphyritic rocks. In >comendites, these are usually crystals of the minerals quartz, alkali-feldspar, aegirite, and riebeckite.
Porphyritic	A rock containing large crystals (>phenocrysts) in a finer groundmass.
Recharge	The general term indicating the process of transport of water from surface sources (i.e., from rivers or rainfall) to groundwater storage.
Unconformity	The representation in physical geology (i.e., in the rock record) of a break in the ordered succession of rocks.
Volcanics	Here used as a general term describing geological material of volcanic origin.

1. INTRODUCTION

1.1 Introduction

Meteoric Water Limited was commissioned to carry out a hydrogeological survey by **Kenya Good Neighbors** on behalf of **Ilbisil Township Primary School** of **P.O Box 414-01100, Kajiado** on the school's parcel of land. The land, **PLOT NO: BISIL/**, is situated in Ilbisil Trading Centre, Ilbisil sub location, Ilbisil location, Kajiado County.

The Client requires detailed information on the availability of groundwater to be used for domestic and general use in the institution. The required amount of water is estimated to be approximately 20m³/day.

The objective of the present study is to assess the availability of groundwater, to recommend a drill-site and to comment on aspects of depth to potential aquifers, aquifer availability and type, possible yields and water quality. For this purpose, all the available hydrogeological information of the area has been analyzed, and a geophysical survey has been carried out.

1.2 Background

The objective of the investigations was to assess the availability of groundwater and to advice on the viability of drilling boreholes or other water supply alternatives. The investigations involved hydrogeological, geophysical field investigations and a detailed desk study in which the available relevant geological and hydrogeological data were collected, analyzed, collated and evaluated within the context of Client's requirements. The data sources consulted were mainly in four categories:

- a) Published Master Plans, Geological and Hydrogeological Reports and Maps, etc.
- b) Ministry of and Water and Irrigation (MoWI) Borehole Completion Records, usually a valuable source of data.
- c) Various technical reports of the Rural Domestic Water Supply and Sanitation Programme, BKH Consulting Engineers.

1.3 The Objectives of the Study

The purpose of the hydrogeological/geophysical survey is to assess suitability of the proposed site for groundwater development, taking into account the prospects for sustainable supply, water quality and quantity parameters, and economic viability.

1.4 Approach

The study is carried out the in the following steps

- Desk review of the existing hydrogeological, hydrological and other relevant data of the area.
- Ground geophysical surveys at the site, using geo-electrical profiling and vertical electrical sounding methods.
- Assessment of the prospects of groundwater development in the selected site, and the feasibility of drilling a borehole.
- Selection of the most suitable location for borehole drilling, taking into account the prospects of sustainable abstraction, water quality parameters and social aspects.
- Determine the required drilling depth, expected yield and water quality. Recommend on the expected chances of success, drilling specifications and designs, testing requirements, and completion details.

2. BACKGROUND INFORMATION

2.1 Location

The site is located in Ilbisil Trading Centre, Ilbisil sub location, Ilbisil location, Kajiado County, approximately 0.73km east of Bisil Town, 1.15km NE of Kuju's Lounge & Restaurant and 0.68km off Namanga Road (view sketch on page 3 below). It also lies within the Survey of Kenya topographic sheets for **Ilbisil** (No. 172/2) as shown on Fig 1 below. Its defining coordinates are **37M 0255132 UTM 9768110 or S02° 5'47.09" and E036°47'54.65"**.

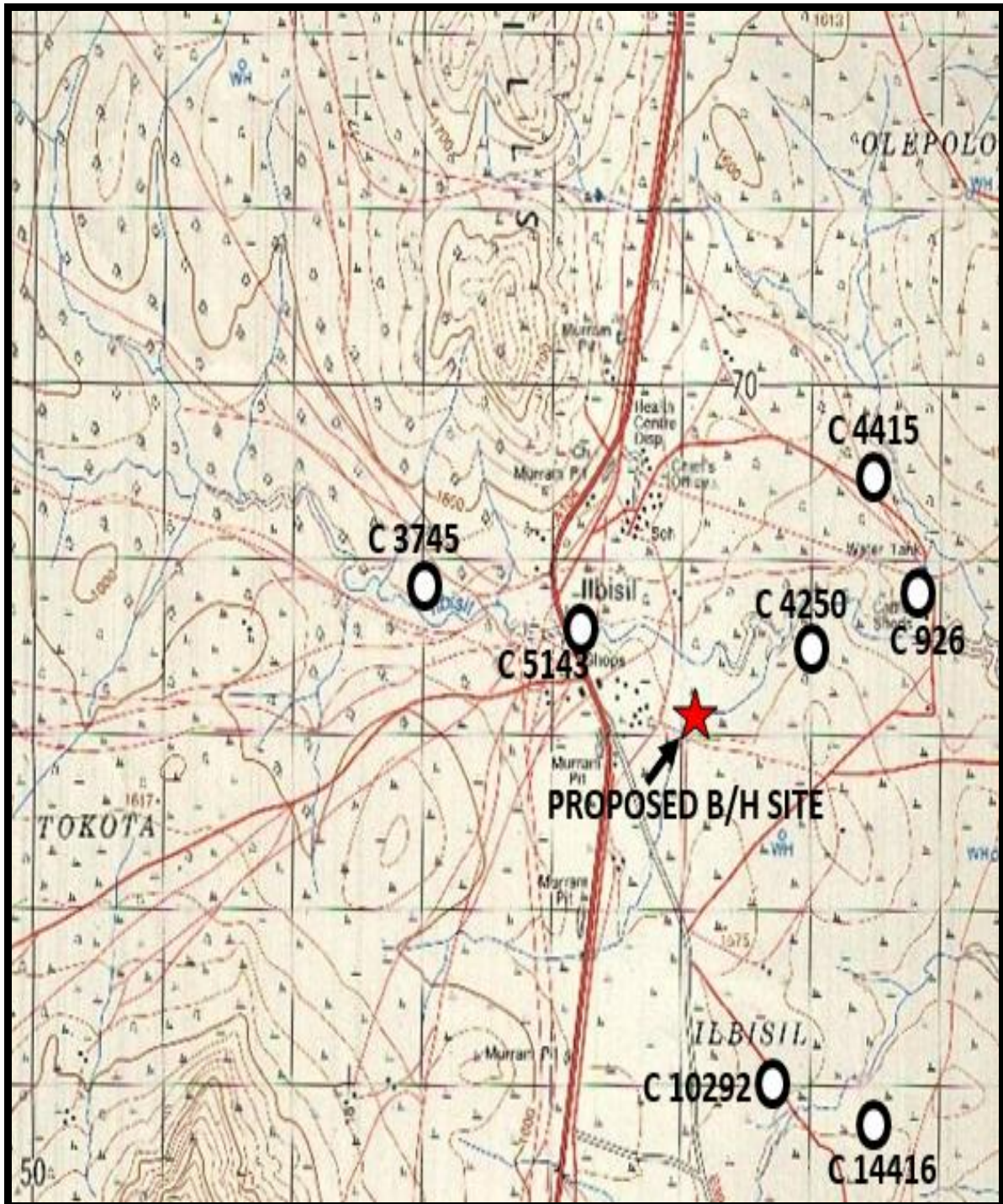


Figure 1: Topographic Map of the Investigated Area

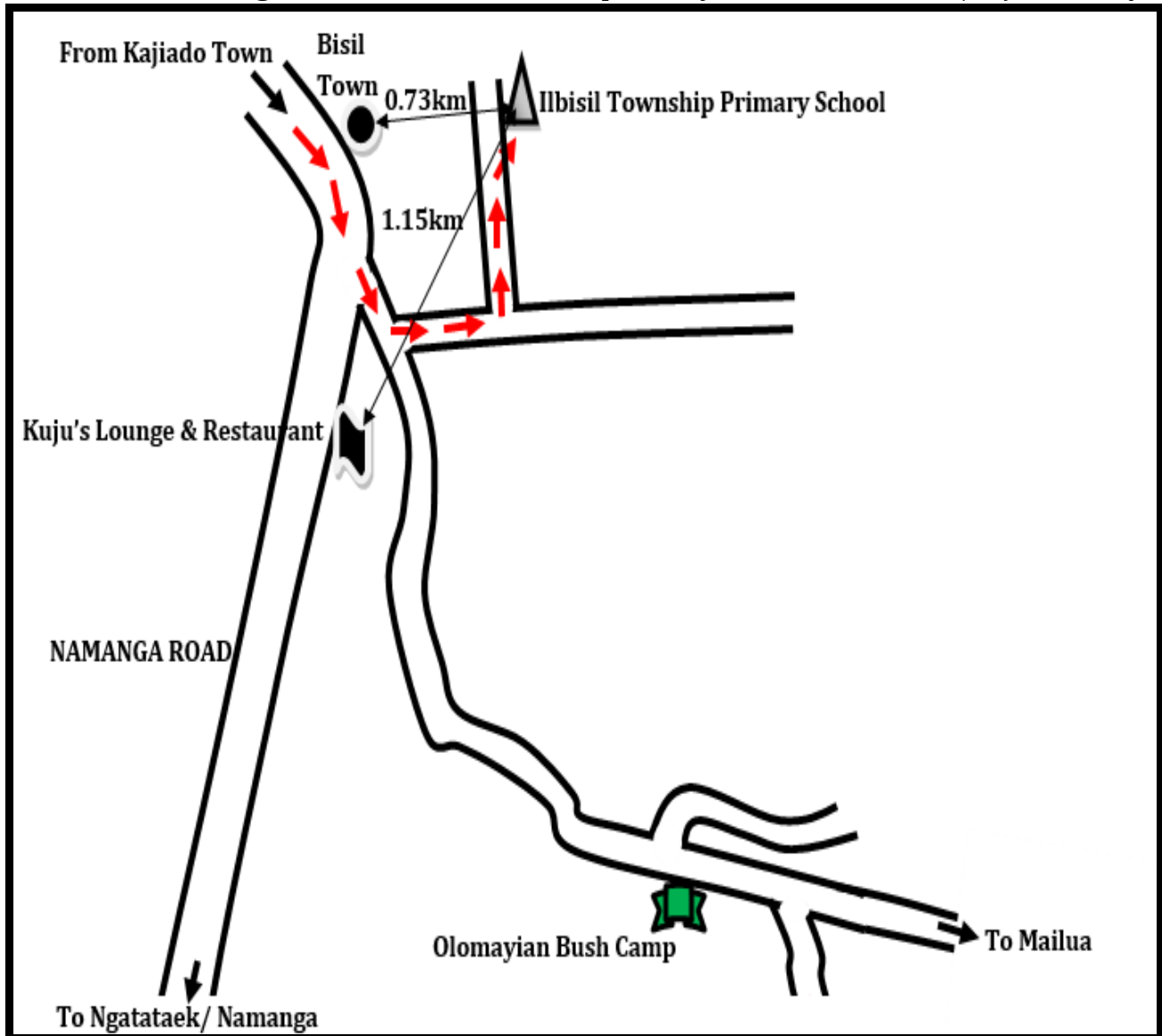


Figure 2: Sketch Map of the Investigated Area

2.2 Accessibility

Accessibility from the loose, weathered road from the Namanga road junction to the site is good during dry spells but can be difficult during rainy seasons.

2.3 Physiography

The site lies at an altitude of about 1535m amsl on the foot of Maparasha hills.

2.4 Climate

The climate is semi arid, being dry for most of the year. Rainfall is bi modal (March May and October December). Mean annual rainfall is approximately 530 mm.

Temperatures are highest in the months January to March; Annual mean daily minimum and maximum temperatures are 13 to 26° C (TAMS, 1980).

Potential evaporation is between 1,800 and 2,000 mm per year and these losses are exacerbated by frequent high winds in the area.

2.5 Water Supply and Demand

Currently the client purchases water from privately owned neighboring boreholes. The aforementioned source is however inadequate and unreliable due to frequent rationing thus the need for a production borehole. The estimated daily demand is about **20m³/day**.

Table 1: Water Demand

Consumer	Consumer Classification	Population/ Area	Consumption rate (litres per person per day)	Litres/day
Farm House	Medium Class house	6	150	900
Workers' Quarter	Low Class housing	4	75	300
Dairy Cattle		4	50	200
Goats		30	5	150
Subsistence farming	3 hours daily of water pumping	1.0 ha	1.5/l/s/ha	16,200
TOTAL WATER DEMAND				17750

Table 2: Population Density Estimates

Residential	Number of Persons
Single family unit	3-5
Multiple family units	10-30
Apartments	50-100
Commercial areas	15-20
Industrial	20-100

Table 3: Residential Water Consumption

Home Use	Daily water demand per person in litres	Total consumption in litres
400 people	50	20000

NOTE:

The proposed borehole will serve approximately 120 people thus the **domestic water demand** is estimated to be **400 x 50 = 20m³/day**.

3. GEOLOGY

3.1 Regional Geology

Surface rocks in the project area exclusively comprise of **undifferentiated banded gneisses, schists and granulites** of Archean age which are underlain by Crystalline limestones and quartzites as illustrated in the geological map below.

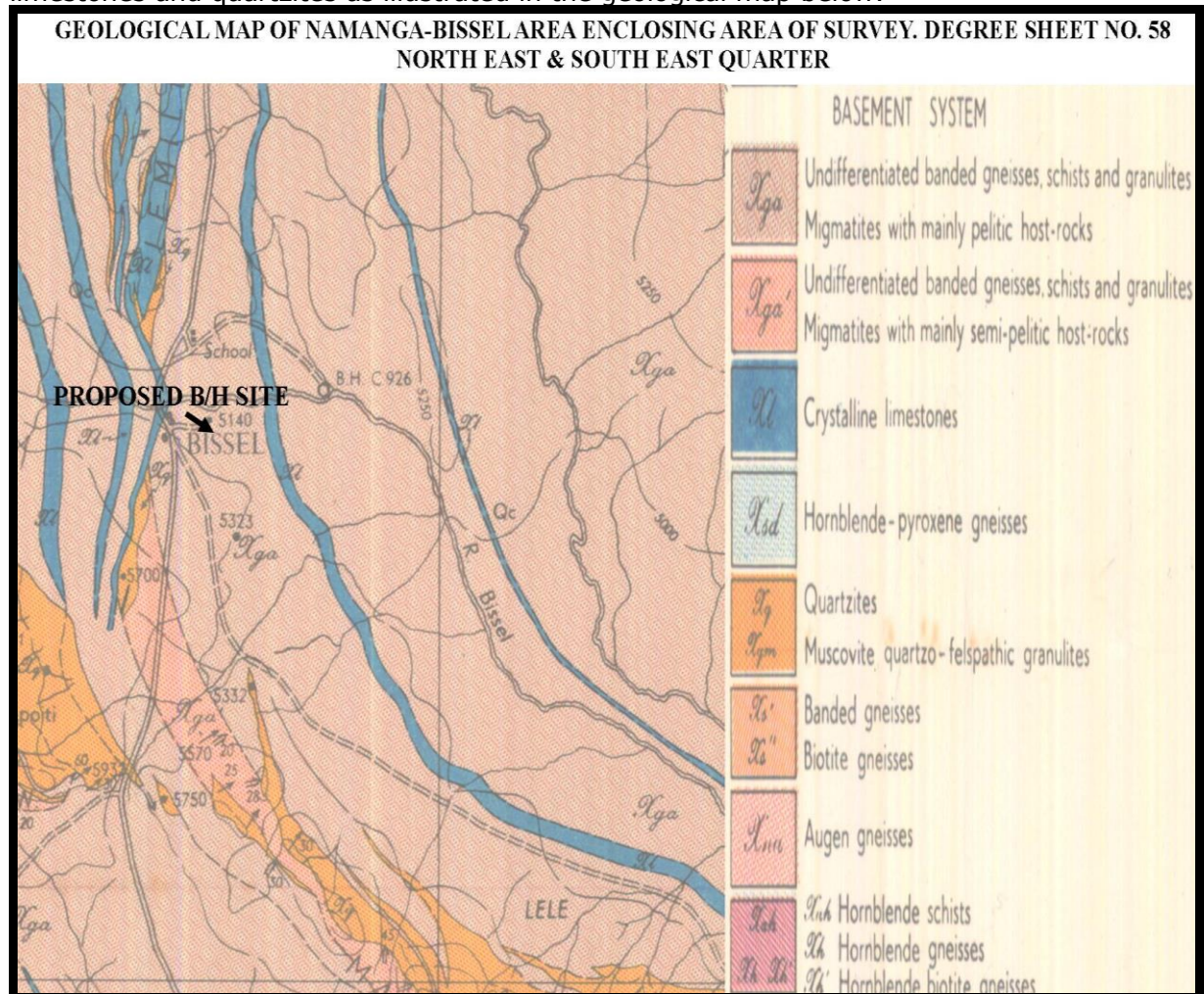


Figure 3: Geological Map of Surveyed area

A short description of the different volcanic units is given below in order of geological age (youngest to oldest rocks).

3.1.1 Pleistocene and Recent sediments

Superficial deposits in the area comprise red sandy soils and silts. These form a thin cover at the study site.

3.1.2 Basement System Rocks

Rocks of the Basement System are exposed and outcrops are confined to the inselbergs and the few dry river valleys and gullies. They include types derived from the metamorphism and granitization of originally calcareous, pelitic, psammitic, and carbonaceous sediments. Broadly speaking the area is characterized by a high grade of metamorphism and variable though rarely. These are represented in the study area by **Banded gneisses**, Quartzites, Biotite gneisses and Augen gneisses of Archean age.

4. HYDROGEOLOGY

The hydrogeology of an area is determined by the nature of the parent rock, structural features, weathering processes and precipitation patterns. Within metamorphic rocks, groundwater primarily occurs within weathered zones, fissure zones, fractures zones and sedimentary beds.

4.1 Regional Hydrogeology

The prevailing geological and climatological conditions in Ilbisil area, favours groundwater occurrence in:

- Weathered basement rocks
- fractured zones in the basement rocks, and
- sediments interbedded between undifferentiated basement rocks,

The regional groundwater system in this area is locally recharged by infiltration of rainwater into open fault and fissure zones acting as groundwater conduits in the neighboring hills. Potential aquifers thus occur within the **fractured basement system rocks**.

4.2 Boreholes in the Immediate Vicinity of the Area

A number of boreholes have been drilled in the project area. Available records were studied for 8 documented boreholes within a radius of about 8km from the present site. Results of the data inventory are presented in Table 4 while the approximate location of the boreholes has been indicated in Figure 1 above.

Table 4: Boreholes in the Vicinity of the Site

A	B	C	D	E	F	G	H
BH No.	Owner	Location (X km dir)	Depth (m bgl)	WSL (m bgl)	WRL (m bgl)	Q (m ³ /hr)	PWL (m)
C-	Ilbisil Township Primary School's Site						
926	-	1.9 ENE	122	89	21	2.9	-
3745	-	2.3 WNW	137	12.2	5.8	4.9	-
4250	-	1.1 ENE	179	DRY			
4415	-	1.8 NE	137	27, 96	27	13.5	-
5143	-	1.1 NW	-		-	-	-
10292	Pat Neylan	2.1 SSE	70	32.05	22.88	1.128	67.70
14416	Sarah Jane Neylan	2.6 SSE	150	36	22.03	2.1	126.77
	Martin Moshisho	8 SE	188			1.8	
			70-188	12.2-96	5.8-27	1.128-13.5	67.7-126.77

Description of columns

- A Owner
- B Ministry of Water Resources Identification Number (lowest numbers represent oldest holes)
- C Distance in km and bearing from selected BH site
- D Total drilled depth in meters below ground level (m bgl)
- E Water Struck Level 1, 2 and 3, depth at which the aquifer was encountered, in meters below ground level (m bgl)
- F Water Rest Level, depth of piezometric surface, or water table, in meters below ground level (m bgl)
- G Tested yield in m³/hr
- H Pumped Water Level

4.2.1 Borehole Data Analyses

The available data indicates that various water struck levels occur within drilled depth ranging between **12.2m** and **96m bgl**.

- i. The first intercalated aquifer is found between **12.2m** and **36m bgl** in the lake bed.
- ii. The second main aquifer is found between **89m** to **96m and beyond** and to a penetration depth of up to **200m**. **This zone is within the lower fractured basement system rocks.**

The surrounding boreholes have been tested at yields ranging between **1.128m³/hour** and **13.5m³/hour** and a mean value of **4.39m³/hour** which is good. The proposed borehole is expected to give yields 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 **NONE** of the 8 analyzed boreholes is located within 800m radius. In regards to this borehole and considering that the upper aquifers in this region are quite vulnerable to depletion, only deeper aquifers should be abstracted **to avoid any interference in abstraction trends of the nearby boreholes** and chiefly, to maximize on yields.

4.3 Recharge

The recharge mechanisms (and the rate of replenishment) of the local aquifers have 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.

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 erosion of the parent rock. Rocks weathering to clayey soils naturally inhibits 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 zones are the highlands within the eastern flanks of the rift valley. These areas probably receive higher rainfall than the investigated site. As a result, the aquifers identified are indirectly recharged by underground drainage of water falling some distance from their present locations.

4.3.1 Mean Annual Recharge

Rainfall within the study area is average (530 mm) and regional recharge is of great essence in this area. Much of regional recharge occurs within the faults of Ilemelepo hills couple of metres to the west.

Mean Annual Recharge has therefore been estimated as follows:

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

$$530\text{mm} \times 5\%$$

$$\text{Mean Annual Recharge} = 26.5\text{mm}$$

However, this recharge amount is probably estimation as there is strong possibility of influent regional recharge through faults.

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 numbers of boreholes in the area this is form of discharge is not much pronounced.

Borehole site investigation

Ilbisil Township Primary School. Ilbisil location, Kajiado County.

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 Problems Associated With Calculation of Aquifer Properties

Very little information is available concerning the aquifer characteristics in this area. It is not possible for example to determine if proper pump test were carried out on the existing borehole since some data of the analyzed borehole are missing.

Thus, in absence of proper pump test data, the **Logan method of approximation** has been employed (Logan, 1965). This method however has errors of 50% or more and is thus used for estimation purpose only. *To calculate the area Aquifer Properties, test pumping data of nearest borehole C- 14416 (Sarah Jane Neylan) was adopted.*

In summary, the borehole has a total drilled depth of 150m, yield of 2.1m³/hr, Water Struck level of 36m, Water Rest level of 22.03m and Pumped Water Level of 126.77m, 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 104.74m.

4.5.2 Estimation Aquifer Transmissivity

Aquifer Transmissivity (T) is estimated as follows:

$$T = 1.22Q/\Delta S \quad \text{Where: } Q = \text{Yield per day} \\ \Delta S = \text{Draw down} \\ T = 1.22/104.74 \times 50.4 = \mathbf{0.59m^2/day}$$

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 5m. Thus,

$$\mathbf{K = 0.59/5} \\ \mathbf{K = 0.12m/day}$$

4.5.4 Specific Capacity

The aquifer Specific Capacity (S) = $Q/\Delta s$.

$$\text{Where: } \mathbf{Q = Discharge (m^3/day) = 50.4m^3/day} \\ \mathbf{\Delta s = Drawdown (m) = 104.74m} \\ \mathbf{S = 0.48m^2/day}$$

Table 5: Specific Capacity of other Surrounding boreholes

Borehole C No.	Yield (m3/day)	Drawdown (m)	Specific Capacity(m ² /day)
10292	27.07	44.82	0.6

4.5.5 Groundwater Flux

The Groundwater Flux (F) is estimated based on borehole **C-14416** which more or less shares the same aquifers.

$$F = K.i.h.w \quad \text{Where K- Hydraulic Conductivity} = 0.28m/day \\ i - \text{Slope} = 36/3740 \\ h - \text{Aquifer Thickness} = 5m$$

Thus;

$$F = 0.12m (36/3740) \cdot 5 \cdot 1300$$

$$F = 7.35m^3/day$$

4.6 Water Quality Considerations

When deposition occurs in a land-locked basin under conditions of semi-aridity, evaporation of the connate water occurs with the consequent precipitation of mineral salts, mainly carbonates, chlorides, and sulphates. These are disseminated throughout the succession with varying degrees of concentration and, being partly soluble, are readily re-dissolved by meteoric groundwater; hence the water derived from these beds is liable to be saline.

Groundwater may be classified based on salinity as shown in Table 3 below.

Table 6: Groundwater Classification Based on Salinity

Category	TDS (ppm)	EC ($\mu S/cm$)
Fresh water	0-1,500	0-2,000
Brackish water	1,500-10,000	2,000-15,000
Saline water	10,000-100,000	15,000-150,000
Brine	>100,000	> 150,000

TDS : Total Dissolved Solids (in parts per million = mg per liter)
EC : Electrical Conductivity in micro-Siemens per cm

Table 7: Salinity Limits for Groundwater Use

EC ($\mu S/cm$)	TDS (ppm)	Use/Limitation
< 2,000	< 1,500	Potable water
> 2,000	> 1,500	Unsuitable for domestic purposes
2,000-3,000	1,500-2,000	Generally too salty to drink but still fit for livestock
> 3,000	> 2,000	Generally unfit for dairy cattle and young cattle
> 7,000	> 4,500	Unfit for grazing cattle and sheep

4.7 Groundwater Movement

Groundwater will always flow towards the area with the lowest piezometric head. For this area, this base level is ultimately found south east of the investigated site.

With respect to the potential for faults to create aquifers and to recharge the aquifers, it is very important to establish whether the faults occurring in the rocks are groundwater barriers or preferential flow paths. The pervious faults have a larger secondary porosity. This macro porosity accounts for a greater mobility of the groundwater. The water stays in contact with the rock for a relatively short period; hence, mineralization stays low. Mobility in the (primary) micropores, on the contrary, is low. The groundwater in these pores will be highly mineralized by dissolved salts.

4.8 Rainfall, Percolation and Recharge

Assuming that suitable storage media exist below the ground, aquifer potential is also affected by the mechanisms of percolation of rainfall or river water down to the aquifer. If the infiltration capacity is low due to the presence of an aquiclude like clay, the recharge to the aquifer is low.

Percolation will depend on the soil structure, vegetation cover and the permeability of the rocks. Clayey formations naturally inhibit percolation. Aquifers may also be recharged laterally if the rock is permeable over a wide area.

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

It is sometimes referred to as DC resistivity technique. This method measures the earth's resistivity by driving a direct current (DC) signal into the ground and measuring the resulting potentials (voltages) created in the earth. From that data the electrical properties of the earth (the geoelectric section) can be derived and thereby the geologic properties inferred. The diagram below illustrates the basic electrical array for that measurement.

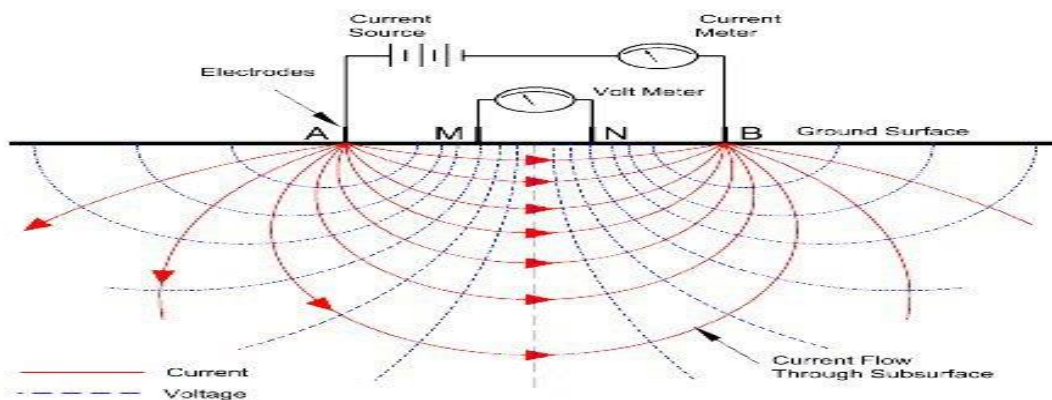


Figure 4: Schematic Diagram of DC Resistivity Method

The figure above is a schematic diagram showing the basic principle of DC resistivity measurements. Two short metallic stakes/current electrodes (AB) are driven about 1 foot into the earth to apply the current to the ground. Two additional potential electrodes (MN) are used to measure the earth voltage (or electrical potential) generated by the current. Depth of investigation is a function of the distance of current electrodes.

In this method an electric current is passed into the ground and the potential difference measured to get the Resistivity of the underlying layers.

There are many Resistivity arrays used in the field. The one used in this survey was the horizontal resistivity profile and vertical electrical sounding (VES).

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 water. It is imperative to note that:

- 1 Saturated rocks have lower resistivities than unsaturated and dry rocks.
- 2 The higher the porosity of the saturated rock, the lower its resistivity.
- 3 The higher the salinity of the saturating fluids, the lower resistivity of the host media.
- 4 Clays and conductive minerals also reduce 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:

$$R = R_s * L/A \quad (\text{Ohm}) \quad (1)$$

Borehole site investigation

Ilbisil Township Primary School. Ilbisil location, Kajiado County.

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

$$R = dV/I \quad (\text{Ohm}) \quad (2)$$

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:

$$R_s = (A/L) * (dV/I) \quad (\text{Ohm.m}) \quad (3)$$

5.1.1 Horizontal Electrical Profile (HEP)

In horizontal Electrical Profile, lateral changes in resistivity are measured at a given depth depending on the values of AB and MN where AB is the distance between the current electrodes and MN is the distance between the potential electrodes. The direction in which a profile is taken is always across the fault line. The profile would therefore detect these regions and a VES would be done at the appropriate areas to confirm the presence of water. Apparent resistivities are different from the actual resistivities of the profile because of changes in the electric current that result from its pathway through various earth materials. Therefore, the apparent resistivities often require inversion modeling to convert the raw data to actual resistivities.

5.1.2 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 comprising of two Vertical Electrical Soundings (VES) was carried out on 21st May 2025. The aim of the soundings was to determine the prevailing hydrostratigraphy at the site.

6.1 Results**VES 1 Geo-electric Layers, Sounding curve and Interpretations**

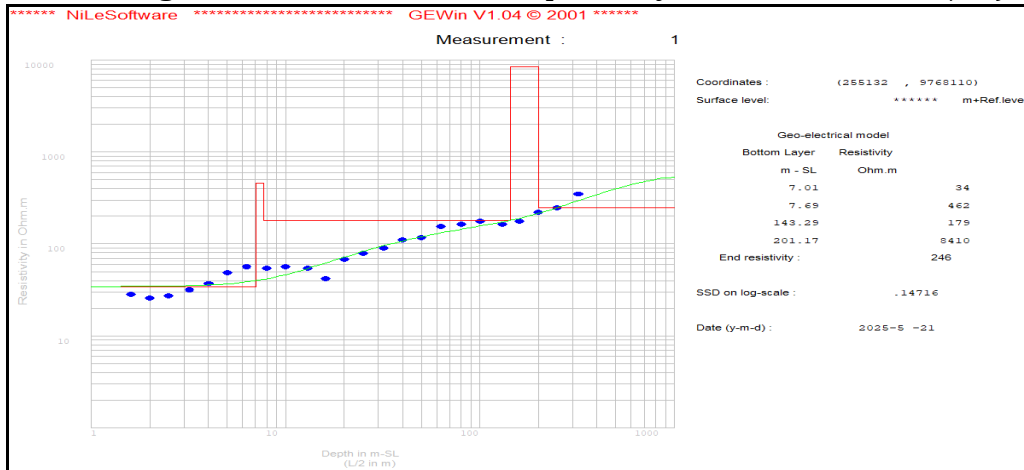
The results of **VES 1** measurements that the site is covered at the surface by dry superficial soils to a depth of about 7.01m. These are underlain by a layer of decomposed regolith to a depth of about 7.69m. A low resistivity layer (179Ω-m) is present below the latter, which is interpreted to represent fractured and fissured basement system rocks to a depth of 143.29m. It is envisaged to host the **first sustainable aquifer**. It is further underlain by a layer of compacted basement system rocks to a depth of 201.17m. This layer is ultimately underlain by a fractured layer of basement system rocks beyond depths of 201.17m believed to host **key aquifers of interest that become sustainable with progressive depths.**

Groundwater Potential at **VES 1** is **good** and hence **IT IS RECOMMENDED THAT AN 8INCH IN DIAMETER BOREHOLE BE AIR DRILLED AT VES 1 TO A MAXIMUM DEPTH OF 270M BGL or until sufficient yield is struck.**

Depth (m)	App Resistivity (Ohm-m)	Interpretation and description	Water bearing?
0.0 – 7.01	34	Dry superficial soils	No
7.01 – 7.69	462	Decomposed regolith	No
7.69 – 143.29	179	Fractured and fissured basement system rocks	Fair to Good
143.29 – 201.17	8410	Compacted basement system rocks	No
> 201.17	246	Fractured basement system rocks	Good

Borehole site investigation

Ilbisil Township Primary School. Ilbisil location, Kajiado County.



Layer no	Apparent Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	34	7.01	7.01
2	462	0.68	7.69
3	179	135.60	143.29
4	8410	57.88	201.17
5	246		

DATA SET	VES 1	37M 0255132 UTM 9768110	1535 METRES	
Number	AB/2	MN/2	APPARENT RESISTIVITY	INDUCED POLARIZATION
1	1.6	0.5	17.09	0.90
2	2	0.5	15.55	0.64
3	2.5	0.5	16.42	1.35
4	3.2	0.5	19.16	0.75
5	4	0.5	22.27	1.88
6	5	0.5	29.09	1.36
7	6.3	0.5	34.04	2.76
8	8	0.5	32.49	3.98
9	10	0.5	33.90	2.37
10	13	0.5	32.84	4.48
11	16	0.5	25.19	3.59
12	20	0.5	41.06	2.60
13	25	0.5	47.49	7.11
14	32	0.5	54.29	-11.1
15	32	10	75.62	3.21
16	40	10	92.29	7.85
17	50	10	98.74	0.24
18	63	10	129.28	6.72
19	80	10	137.89	4.00
20	80	25	165.03	1.63
21	100	25	177.71	5.24
22	130	25	164.63	-8.91
23	160	25	177.48	-24.5
24	200	25	222.19	-8.40
25	250	25	246.67	15.1
26	320	25	349.41	-1.25

VES 2 Geo-electric Layers, Sounding curve and Interpretations

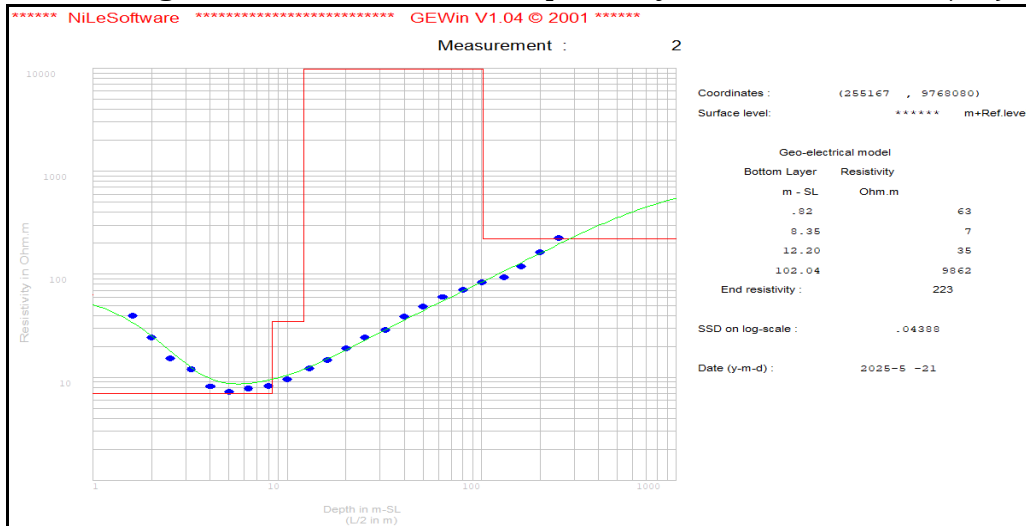
The results of **VES 2** measurements that the site is covered at the surface by dry superficial soils to a depth of about 0.82m. These are underlain by a layer of decomposed regolith to a depth of about 8.35m. A relatively low resistivity layer (35Ω-m) is present below the latter, which is interpreted to represent weathered basement system rocks to a depth of 12.2m (surface **water**). It is further underlain by a layer of compacted basement system rocks to a depth of 102.04m. This layer is ultimately underlain by a fractured layer of basement system rocks beyond depths of 102.04m believed to host **low yielding aquifers that become sustainable and more productive with progressive depths.**

Groundwater Potential at **VES 2** is **fair**.

Depth (m)	App Resistivity (Ohm-m)	Interpretation and description	Water bearing?
0.0 – 0.82	63	Dry superficial soils	No
0.82 – 8.35	7	Decomposed regolith	No
8.35 – 12.20	35	Weathered basement system rocks	Fair
12.20 – 102.04	9862	Compacted basement system rocks	No
> 102.04	223	Fractured basement system rocks	Fair

Borehole site investigation

Ilbisil Township Primary School. Ilbisil location, Kajiado County.



Layer no	Apparent Resistivity (Ω-m)	Thickness (m)	Depth (m)
1	63	0.82	0.82
2	7	7.53	8.35
3	35	3.85	12.20
4	9862	89.84	102.04
5	223		

DATA SET	VES 2	37M 0255167 UTM 9768080	1546 METRES	
Number	AB/2	MN/2	APPARENT RESISTIVITY	INDUCED POLARIZATION
1	1.6	0.5	37.89	0.51
2	2	0.5	23.21	0.64
3	2.5	0.5	14.66	1.02
4	3.2	0.5	11.57	1.67
5	4	0.5	7.82	2.28
6	5	0.5	6.92	2.35
7	6.3	0.5	7.47	3.37
8	8	0.5	7.91	9.42
9	10	0.5	9.23	2.08
10	13	0.5	11.64	-1.41
11	16	0.5	14.05	8.39
12	20	0.5	18.22	23.7
13	25	0.5	23.43	38.0
14	32	0.5	27.76	-70.7
15	32	10	25.03	-0.21
16	40	10	33.46	5.03
17	50	10	41.73	5.49
18	63	10	52.06	8.83
19	80	10	61.41	5.96
20	80	25	71.23	4.05
21	100	25	83.62	2.39
22	130	25	93.35	7.30
23	160	25	118.99	7.35
24	200	25	163.32	7.75
25	250	25	223.93	2.97

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Based on the available information and the geophysical investigations it is concluded that the investigated area is located in an area with low to medium groundwater prospect due to characteristic metamorphic rocks. **Although the interpreted results indicate a shallow aquifer of colluviums material at a depth of 20m, 50 & 85m-110m bgl the yields would most likely be unsustainable for abstraction.** Thus, the **deeper aquifers in the basement system rocks** have to be penetrated.

The recommended point is well known to the client.

7.2 Recommendations

7.2.1 Drilling

In view of the above it is recommended that:

- An 8" borehole should be drilled to **a maximum depth of 270m bgl or until sufficient yield is struck.**
- The most suitable location for the borehole is at **VES 1.**
- From the records **NONE** of the 8 analyzed boreholes is located within 800m radius. However, considering that the upper aquifers in this region are quite vulnerable to depletion, only deeper aquifers should be abstracted **to avoid any interference in abstraction trends of the nearby undocumented boreholes** and also to have high yields.
- The borehole should be cased using machine made mild steel screen casings.
- Test pumping should be done for 24 consecutive hours to aid in determining the safe pumping yield and appropriate pump size.
- A piezometer should be installed in the borehole to enable monitoring of the water level.
- A master meter should be installed to record the amount of water abstracted from the borehole.
- A water sample should be collected at the end of the test pumping to be taken to a competent lab for a complete water quality test.

Additional recommendations on the construction and completion of a borehole are given in Appendix 1.

If fluoride concentrations are above 1.5 ppm, it is not recommended to use the borehole as a permanent source for drinking water. Children especially are susceptible to fluorosis if they depend on drinking water with high fluoride concentrations (see Appendix 2).

A monitoring tube and a master meter should be installed in the borehole in order to monitor the water level in the borehole.

8. REFERENCES

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Appendix 1: Drilling

Drilling Technique

Drilling should be carried out with an appropriate tool - either percussion or rotary machines will be suitable, though the latter are considerably faster. However, due to unstable sub ground condition mud drilling is the most suitable method. 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. The final design should be made by an experienced hydrogeologist.

Casing and Screens

The well should be cased and screened with good quality material. Owing to the shallow depth of the boreholes, it is recommended to use uPVC casings and screens of high open surface area.

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" 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 the pumping plant, and leading to gradual 'siltation' of the well. The slot size should be in the order of 1.5 mm. The grain size of the gravel pack should be an average 2 - 4 mm.

Well Construction

Once the design has been agreed, construction can proceed. In installing screen and casing, centralizers at 6 metres intervals should be used to ensure centrality within the borehole. This is particularly important for correct insertion of artificial gravel pack all around the screen. After installation, gravel packed sections should be sealed off top and bottom with clay (2 m).

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 well head can enter the well bore and cause contamination.

Well Development

Once screen, 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 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, 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 2 m 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. Well tests have to be carried out on all newly-completed wells, because apart 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 consists 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 drawdown 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 step wise during the test. The results of the test will enable a hydrogeologist to calculate the optimum pumping rate, the pump installation depth, and the drawdown for a given discharge rate.

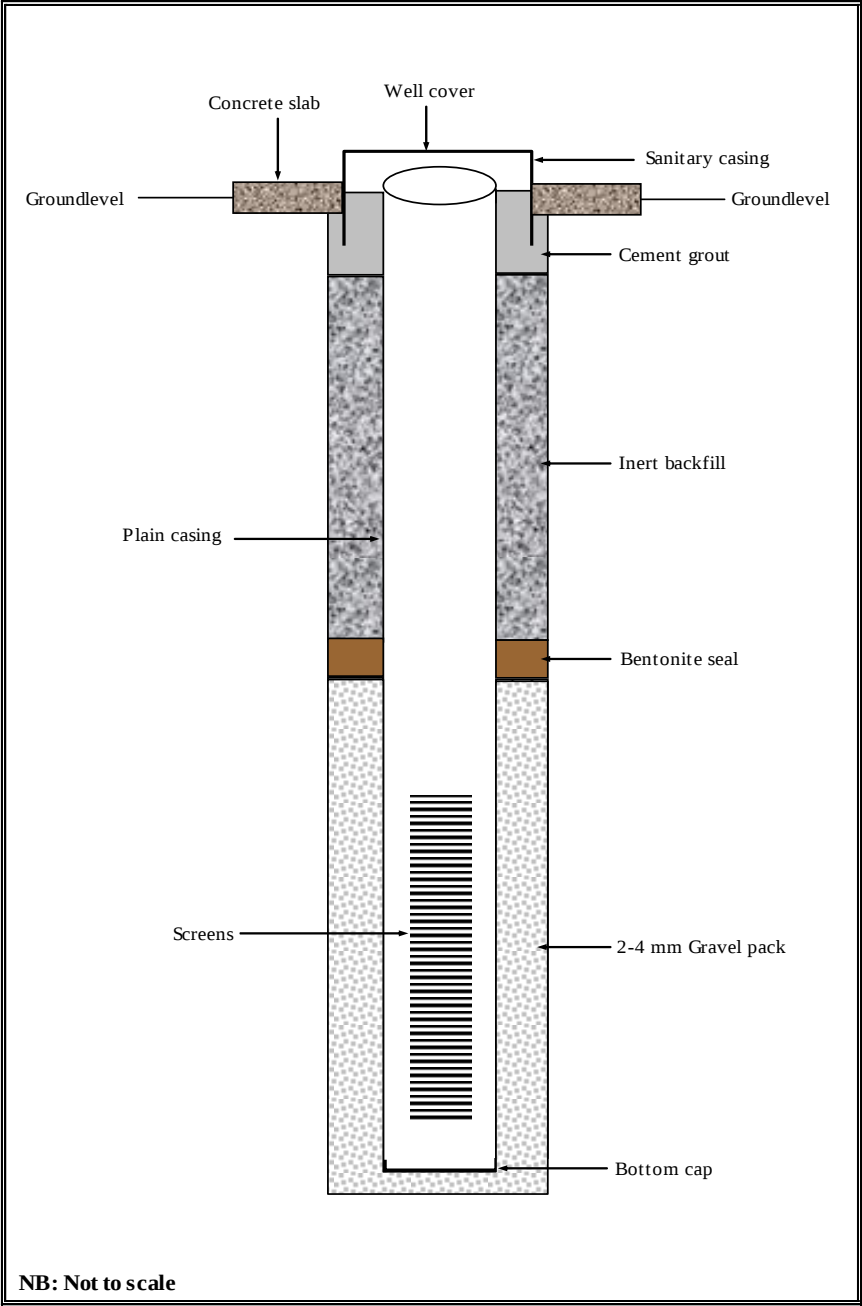


Figure 5: Schematic Design for Borehole Completion

Borehole site investigation **Ilibisil Township Primary School. Ilibisil location, Kajiado County.**
Appendix 2:- Acceptable Ionic Concentration – Various Authorities

World Health Organization: Guidelines;		European Community: 1983 Standards; of water intended for human consumption:		1971 Int.	EC Directive 1980 relating to the quality	
Substance or Characteristic	Value	Guideline	Upper limit	Guide Level	Max. Admissible	
<u>Inorganic Constituents of health significance:</u>						
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 NO ₃)	25 (as NO ₃)		50 (as NO ₃)	
Selenium Se			0.01		0.01	
Other Substances		GV: Desirable Level:	Highest Permissible Level:	Maximum	GV:	MAC:
Aluminum, Al		0.20			0.05	0.20
AmmoniumNH ₄					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, H ₂ S		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, NO ₂						0.10
Potassium, K					10	12
Silver, Ag					0.01	
Sodium, Na		200			20	175
Sulphate, SO ₄		400	200	400	25	250
Zinc, Zn		5.0	15	0.10		
T D S		1000	500	1500		1500
Total Hardness as CaCO ₃		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).

(Source: Endemic Fluorosis in Developing Countries, 1991, J.E. Frenken, editor, TNO Institute for Preventive Health Care, The Netherlands)

Introduction

Fluoride is an essential constituent of the human body where it concentrates mainly in bones and teeth. A deficiency as well as an excess of fluorine may have negative effects on someone's health. Excessive intake of fluorine may lead to Fluorosis, a disease associated with dental and skeletal deterioration.

Especially for drinking water purposes these high concentrations form a limitation. In this appendix the aspects of fluoride in groundwater e.g, the source of fluoride, the health hazard of high fluoride concentrations and fluoride removal methods, will be discussed briefly.

Sources of Fluoride

Fluoride (F^-) is an ion of the chemical element fluorine (F). The elemental form does not occur in nature due to the electro-negativity and high chemical reactivity.

The geochemical behavior of fluoride is similar to that of the hydroxyl ion (OH^-).

Fluorine bearing minerals are found in igneous, sedimentary and metamorphic rock. Especially in contact metamorphic rocks high concentrations are found. The main fluorine bearing minerals are listed in the Table below.

Fluorine bearing minerals

Group	Examples
Silicates	Amphiboles, Micas
Halides	Fluorite, Villiaumite
Phosphates	Apatite
Others	Aragonite

The most important mineral containing fluorine is fluorite (CaF_2). Furthermore volcanic gases may contain fluorine; examples are HF , SiF_4 and H_2SiF_6 .

Other sources of fluorine are related to pollution caused by agricultural and industrial activity (use of phosphatic fertilizers, processing of phosphatic raw materials).

Furthermore, fluoride concentrations in water are determined by weathering processes (CO_2 pressure, hydrothermal activity), evaporation and calcium concentration. At low calcium concentrations (in environments with high alkalinity and when calcite limits calcium concentrations) fluoride can not be equilibrated by fluorite solubility and can reach very high concentrations.

In volcanic areas without hydrothermal activity the fluoride concentrations are mainly determined by the weathering of amphiboles or volcanic glass. Both are important constituents of phonolites. Volcanic tuffs on an average have a higher content of soluble volcanic glass than phonolites.

Health hazard of fluoride

The prevalence and severity of dental and skeletal fluorosis is depending on many factors but the most important risk indicator will be fluoridated drinking water. Results of several investigations show that especially children are susceptible to fluorosis if they depend on (drinking) water with high fluoride concentrations. The results indicate that mild dental fluorosis can occur when concentrations of 0.4 ppm are considered. More serious problems occur at fluoride concentrations of 2.1 ppm (100 % prevalence

Borehole site investigation

Iibisil Township Primary School. Iibisil location, Kajiado County.

of dental fluorosis in age group 10 - 15 years) and 3.6 ppm (skeletal changes in 11 - 15 years old). Above 10 ppm skeletal deformities may occur in children.

The World Health Organization uses the guideline limit of 1.5 ppm fluoride. This limit is based on the assumption that people consume only 2 liters of water per day. This assumption seems to be rather low since people, especially in countries with hot climates, consume more than 2 liters per day. The recommended WHO concentration limits together with the possible effects are listed in the Table below.

Fluoride contents in drinking water and possible effects (WHO)

Concentration fluoride ppm	Possible effects
0.5 - 1.5	Fluoride in water has no adverse effects, incidence of caries decreases
> 1.5	Mottling of teeth may occur to an objectionable degree e.g. dental fluorosis incidence of caries decreases
3.0 - 6.0	Association with skeletal fluorosis
> 10.0	crippling skeletal fluorosis

Results of investigations in tropical areas suggest a maximum recommended level of 0.6 ppm more appropriate for tropical regions. Above this value mottling of teeth may occur.

Some countries however use higher permissible or maximum recommended levels, simply because of the absence of water with lower concentrations. The maximum permissible level in Tanzania is 8 ppm, while the Kenyan maximum permissible level is set at 1.5 ppm.

Removal of fluoride from groundwater

Especially during the last decade several methods have been developed to remove or reduce the fluoride concentration in drinking water. However, most of the methods are rather complicated and expensive and are still in the laboratory or experimental stage. The methods are mainly based on:

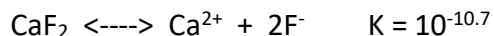
- Precipitation (use of lime, alum, sulphate, gypsum, etc)
- Adsorption / ion exchange (use of bones, charcoal, clays, etc)
- Osmosis
- Electrochemically stimulated coagulation
- Electrodialysis

Although the methods are still in the laboratory phase, the application potential for the bone char, gypsum / fluorite and clay method are rather good. These methods are simple and the raw materials are often available at the site. The methods can be applied at household and community level.

The *gypsum / fluorite* method can reduce the fluoride concentrations to 4 ppm only. More advanced steps are necessary to reduce the concentrations below 1.5 ppm. The basic principle of the method is the dissolution of gypsum in drinking water with high fluoride concentrations. Fluoride concentrations will be reduced due to the precipitation of fluorite according the following reaction:



Fluorite will precipitate as soon as the water is saturated with fluorite. The equilibrium constant for fluorite:



The water is saturated as soon as:

$$SI = \log ([Ca] * [F]^2 / K) ^3 1$$

Bone media has been used successfully to remove fluoride. Reductions of the fluoride concentration to less than 1.0 mg/lit are reported.

The principle of the method is based on the fact that the bone media is reacting with fluoride in a similar way as bones and teeth of the human body. The fluoride is immobilized in the filter medium through the process of ion exchange.

The equipment used in laboratory and field tests is rather simple. The defluoridator unit consists of a container and a filter. The filter has a bottom layer of 300gr crushed charcoal for adsorption of color and odor. The middle layer consists of 1000gr bone media. At the top 200gr of pebbles are used to prevent the middle layer of floating. The bone media can be either granulated bone media or bone char. In both cases the material has to be pretreated carefully to optimize the results. For the granulated bone media, the bones selected have to be clean, non porous and crushed into chippings of 1 to 2 mm. For the bone char the bones have to be activated by heating to a temperature of 600°C. For both methods it is advised to treat the bone media with sodium hydroxide before it is used.

The time over which the filtering material remains active depends on the amount of water which has been treated and the initial fluoride content. In experiments in Argentine (contact time necessary to allow fluoride to chemically combine with granulated bone media amounted to 0.5 hours) the filter had to be replaced every 3 months at a production of 20 l/day and an initial concentration of 10 ppm.

Different *types of clay* have been used in laboratories to reduce the fluoride contents. Kaolinite, serpentine, china clay and clay pot are used as natural adsorbents. Reductions from 10 ppm to 1.5 ppm and lower are reported.

For this methods Ph, temperature and/or salt content should be maintained at a level predetermined through laboratory experiments.

Conclusions and recommendations

High fluoride concentrations in drinking water may cause dental and / or skeletal fluorosis. The maximum recommended levels differ per country, the recommended WHO limit is 1.5 ppm. In fact, the maximum advisable level depends on factors such as diet, climate and age.

Nevertheless, it can be concluded that especially children are susceptible to fluorosis. Therefore, it is recommended not to use borehole water with fluoride concentrations exceeding 0.5 ppm as drinking water for children. The recommended maximum level for adults is 1.0 ppm. These levels only have to be considered when the borehole water is used as a permanent source for drinking water.

The equipment for the removal of fluoride from drinking water is not yet available for domestic purposes but future prospect is good.