MBIRI SCAN CONSULTANTS

HYDROGEOLOGICAL/GEOPHYSICAL SURVEY REPORT

FOR
ONE PRODUCTION BOREHOLE

WITHIN
BARAKA VILLAGE, GATHANJI SUB- LOCATION,
OLJOROROK DIVISION, NYANDARUA COUNTY.

CLIENT: BARAKA PRIMARY SCHOOL,
P.O. BOX 1478-20300,
NYAHURURU.

GROUNDWATER RESOURCES INVESTIGATIONS.

JANUARY, 2024

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SUMMARY

Introduction

This report describes the results of site investigation for a borehole for Baraka Primary School in Baraka village, Gathanji Sub- location, Oljororok Division, in Nyandarua County. The borehole will be used to supply water for domestic use for the school and the surrounding community. This report presents the results of the investigations and the recommendations on the drilling and construction of the borehole at the recommdede site.

Geology

The surveyed site is underlain mainly by volcanic and volcano-sedimentary rocks of Recent to Pleistocene age. The intense tectonic activity associated with the formation of the Great Rift Valley, led to a series of widespread eruptions and lava flows, which occurred from the Upper, Middle and Lower Pleistocene to Quaternary times

Hydrogeology

The area is situated in a zone with medium groundwater potential. The study concludes that on the basis of geophysical, geological and hydrogeological data, the prospects for striking sufficient groundwater for domestic purposes are good.

Ground water in volcanic rocks is limited to fractures and erosional old land surfaces within the volcanic succession. Fresh lavas are generally not water bearing because of their unfractured and impervious character. The water quality is expected to be good

Geophysical Fieldwork

Geophysical investigations were carried out the January, 2024. Vertical electrical sounding and Very Low Frequency – Electromagnetic - Resistivity (VLF-EM-R) method were used during the investigations. The investigations were used to determine the thickness of the underlying layers, their potential as aquifers, and the expected groundwater potential in these formations.

Conclusion

The study concludes that groundwater prospects is good at the investigated site where good groundwater potential is expected within the volcanic succession.

Recommendations

It is recommended that one 8" ϴ borehole be drilled at the location of VLF 1 Point 15 to a maximum depth of 250 metres. The borehole should be installed with 6" ϴ Steel casings and screens. The estimated yield of the borehole is expected to be in the range of 4.54 – 10 m^3/hour, which is sufficient to meet the water demand of the client.

TABLE OF CONTENTS

SUMMARY

LIST OF FIGURES

List of Tables

ABBREVIATIONS (All S.I Units unless indicated otherwise)

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

GLOSSARY OF TERMS

Alluvium General term for detrital material deposited by flowing water.

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

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

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

Development in borehole engineering, this is the general term for procedures applied to repair the damage done to the formation during drilling. Often the borehole walls are partially clogged by an impermeable ―wall cake‖, consisting of fine debris crushed during drilling, and clays from the penetrated formations. Well development removes these clayey cakes, and increases the porosity and permeability of the materials around the intake portion of the well. As a result, a higher sustainable yield can be achieved.

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

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

Grit Coarse sandstone of angular grain

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

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

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

Joint Fractures along which no significant displacement has taken place.

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

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

Permeability The capacity of a porous medium for transmitting fluid.

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

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

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

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

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

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

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

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

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

Tuff Here: hardened volcanic ash.

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

Yield Volume of water discharged from a well.

1. INTRODUCTION

In January, 2024, the Consultant was commissioned by the NG-CDF of Oljoorok Constituency On behalf of Baraka Primary School) to carry out hydrogeological/geophysical site investigations in their School located within Baraka Village, Gathanji Sub- Location, of Nyandarua County.

The address of the Client is:

BARAKA PRIMARY SCHOOL,
P.O. BOX 1478-20300,
NYAHURURU.

The **School** intends to drill the borehole within their parcel of land in order to have a reliable water supply.

The study was carried out as follows:

- ✓ Detailed desk study. This included review of existing information, maps, and reports in the vicinity of the project area, surrounding borehole data analyses etc.
- ✓ Field reconnaissance, geophysical study and consultation with the client. ✓ Hydrogeological study of the project area.
- ✓ Analysis of all gathered information including hydrogeological data, geological logs of surrounding boreholes, groundwater water level in the boreholes and water quality parameters.
- ✓ Data analyses and reporting.

The report describes the hydrogeological investigations and conditions/ groundwater availability within the compound, recommendations and conclusions for the study.

A review on the existing data and collating it with the field data is encompassed in this study.

The recommendations of the drilling procedure will lay emphasis on the construction methodologies that will allow for the development and design of a highly efficient system to meet the client’s requirements. To achieve these objectives, the Consultant proposes to undertake a detailed desk study of the database inventory for boreholes located in the immediate vicinity of the project site, for the purposes of statistical evaluation of the downhole borehole data, and also to define the general aquifer parameters and characteristics.

The results of the project findings are consolidated in this survey report in total conformity to the WRA requirements.

2. BACKGROUND INFORMATION

2.1 Location

The site is situated within Baraka Village, Gathanji Sub Location, of Nyandarua County. It lies within the Survey of Kenya topographic sheets No 105/5). Its defining coordinates in UTM are 37M 020141 & 9998098 Alt 2351 (Fig.2.1)

2.2 Physiography

The site lies at an altitude of about 2351m amsl. The area is drained by the tributaries of River Nyahururu

Fig 2.1: Google map showing the Drainage area

2.3 Climate

Precipitation: The Climate of the project area is generally sub-tropical- in character, with seasonally dry and wet periods. Rainfall is bi-modally distributed March-May and October -December. The most reliable rains are the March-May rains. Year to year variation in total rainfall is marked, but mean annual rainfall is approximately 1100mm.

Temperature: Temperatures vary from season to season and are highest in the months of January to mid-March before the rainy season and lowest between July and August.

2.4 Water Demand

Water from the proposed borehole will be used for domestic purposes within the School. An estimated water demand of 40m³/day is considered adequate.

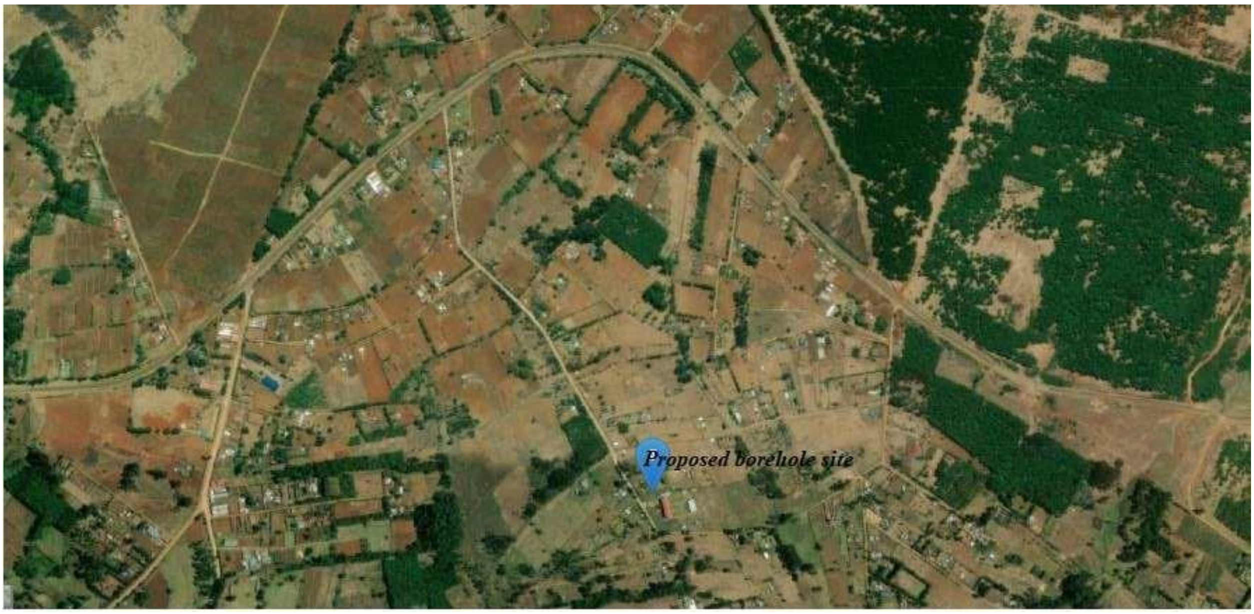


Fig 2.2: Google map showing the study area and environs

Fig 2.3: Pegging of the proposed borehole site.

3. GEOLOGY

3.1 Regional Geology

The surveyed site is underlain mainly by volcanic and volcano-sedimentary rocks of Recent to Pleistocene age. The intense tectonic activity associated with the formation of the Great Rift Valley led to a series of widespread eruptions and lava flows, which occurred from Upper, Middle and Lower Pleistocene to Quaternary times. The thick volcanic sheet is underlain at great depths (probably more than 700 m) by metamorphic rocks of the Basement complex (gneisses and schists) of the Mozambican System. The Tertiary volcanic period lasted approximately 13 million years, and was characterized by cyclic activity: eruptive episodes, marked by the ejection of lava flows, pyroclastic bombs, and ashes, were punctuated by periods of erosion and landmass denudation. During these times of relative quiescence, Old Land Surfaces were formed, which today are important water bearing layers within the volcanic succession.

A short description of the different geological formations underlying the area is given below:

3.1.1 *Ignimbrite*

Ignimbrite is an extrusive rock, belonging to the alkali series of intermediate volcanic rocks. The major mineral component of trachyte is alkali feldspar (e.g. orthoclase), and it generally contains no quartz. Trachyte often displays trachytic texture, where acicular to tabular feldspar phenocrysts align in one direction, suggestive of flow prior to cooling. Trachyte lava is of moderate viscosity and forms thick lava flows and domes.

3.1.2 *Tuffs*

Tuffs are relatively soft, porous rocks that are usually formed by the compaction and cementation of volcanic ash or dust. They are found overlying the basalts and to some extent intercalating with sediments and basalts at the site. It mainly forms the aquifer in this site.

3.1.3 *Pumice and Sediments*

Mainly comprise of volcanic ash and pumice intercalated with sand, gravel and other lacustrine deposits.

3.1.4 *Recent deposits*

Superficial deposits in the area comprise greyish brown loamy soils and murram

4. HYDROGEOLOGY

4.1 Background

The hydrogeology of an area is determined by the nature of the parent rock, structural features, weathering processes and precipitation patterns. Within volcanic rocks, groundwater primarily occurs within fissured zones, fractures, sedimentary beds, lithological contacts and Old Land Surfaces (OLS), which characterize periods of erosion between volcanic eruptions and subsequent lava flows. These are potential aquifers.

The study area is marked by good prospects for sustainable groundwater development. The boreholes drilled in the area and its direct surroundings exclusively draw water from aquifers occurring within the contact zones of the volcanic sequences. Although the primary porosity of these lava flows is generally low, water occurs in fissures and other forms of secondary pore space such as fractures and joints.

4.2 Hydrogeology of the Project Area

Within the phonolite lavas, weathered OLS, pyroclastic layers and bedding planes are often water bearing. However, in most cases such aquifers are only a few metres thick, and individual water bearing zones rarely produce yields in excess of 1-2 m^3/hr. Consequently, it may require several water strikes to obtain a reasonable yield. Higher yields (say >5 m^3/hr) can be achieved from boreholes located in "open" faults and fissure zones. The potential of structurally altered rocks is twofold:

Along faulted or fissured rocks weathering can penetrate much deeper, thus creating sub vertical zones filled with relatively coarse, weathered material. These zones generally have a much higher transmissivity than their surroundings. Recharge occurs over large areas: major faults may extend well beyond the surface catchment, thus intercepting adjacent aquifers or surface sources.

Although faults are often associated with water bearing zones, it should be noted that they may also act as impermeable barrier zones ("closed faults"). In this case the structure acts as a "groundwater dam" and significant storage may build up on its upstream side. Drilling inside such a closed fault system, however, would in most cases be futile.

The main aquifers are composed of tuffs and sediments. There are other minor aquifers struck within the weathered and fractured zones and at the contact zones in the underlying lavas. The lavas are thick and Neoproterozoic rocks are at very deep depths.

4.3 Existing boreholes

A few boreholes have been drilled in the vicinity of the project area. Available records were studied for 4 boreholes within a radius of about 14.5-km from the present site. Results of the data inventory are presented in Table 4.1 while the approximate location of the boreholes has been indicated in Figure 4.1.

Table 4.1 - Boreholes in the Vicinity of the site

Borehole Cnumber	Owner	Distance km	Depth Metres	Water Strike Level (m)	Static Water Level	Yield in M^3/hr	Pumping Water Level
10035	Equator Two	7.8SE	122.8	37.5, 110	29.85	6.6	69.77
9176	Maj. Gen. Wachira	8.0SE	102	60-64	18	4	47
10047	Equator One	6.5 SE	100.6	59.43	31	4.2	89.1
12312	PAUL MBAU	14.5SW	182	44, 132 – 138	24.7	10	61.7

NB: There is an existing borehole about 0.5km from the recommended site, however details of the borehole were not available.

4.3.1 ***Borehole Data Analyses and Aquifer Outline of the Area.***

The available data indicates that various water struck levels occur within drilled depth ranging between **44 m** and **138m** below ground level.

The boreholes in this area have reasonably productive yields of **4 – 10 m^3/hour. The proposed borehole is expected to give a yield within above range.**

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

In order to protect the existing close boreholes especially the shallow ones, it is important to monitor them during the test pumping of the proposed borehole.

4.4 Recharge

The recharge mechanisms (and the rate of replenishment) of the local aquifers has not been fully established. The two major processes are probably direct recharge at surface (not necessarily local) and indirect recharge via faults and/or other aquifers.

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 covers and the state of erosion of the parent rock. Rocks weathering to clayey soils naturally inhibit infiltration and downward percolation. Aquifers may also be recharged laterally if the rock is permeable over a wide area.

4.4.1 *Mean Annual Recharge*

The three recharge mechanisms replenishing the aquifers underlying the study area cannot be separated from one another. Instead they act as integrated parts in a highly-complex and very variable hydrological environment. As a result, the precise location of the mixing zones of the three recharge mechanisms is not possible to pin-point, although it will in any case take the form of transition zones, rather than absolute cut-off zones.

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

1100mm x 5%

Mean Annual Recharge = **55mm**

However, this recharge amount is probably an underestimation due to the possibility of influent recharge from the lake at greater depth.

4.5 Discharge

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

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

4.6 Aquifer Properties

4.6.1 *Calculation of Aquifer Properties*

To calculate the area Aquifer Properties, testing pumping data of borehole **C 12312** was adopted.

In summary, the borehole has a total drilled depth of 182 m, yield of $10m^3$/hr, Water Struck level of 44 – 138 m, Water Rest level of 24.7 m and Pumped Water Level of 61.7 m. 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 37m.

4.6.2 *Estimation Aquifer Transmissivity*

The raw test Pumping Data of the above boreholes in Table 4.1 were not available to assist in calculation of Aquifer Transmissivity using **Jacob's formula (Driscoll 1986):**

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. The derivation of the aquifer properties is based on the data of borehole **C 12312**.

Aquifer Transmissivity (T) is thus estimated as follows:

$T=1.22Q/\Delta S$ Where: $Q =$ Yield per day

$\Delta S =$ Draw down

T = 1.22/240x 37 = **7.91 m/day**

4.6.3 ***Hydraulic Conductivity***

The Hydraulic Conductivity (K) is estimated as follows:

K = T/Aquifer Thickness

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

K = 7.91/7

K = 1.13m/day

4.6.4 ***Specific Capacity***

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

Where: **Q = Discharge (m^3/day) = 240m^3/day**
D = Drawdown (m) = 52.38.
S= 4.719m^2/day

4.6.5 ***Groundwater Flux***

The Groundwater Flux (F) is estimated based on boreholes which more or less share the same aquifers thus **C 12312** & **C 3067**.

F = K.i.h.w Where

K (1.13) - Hydraulic Conductivity
I - (42.3/1000) – Slope
H-(7) Aquifer Thickness
W - (1000) Arbitrary distance

(42.3/1000) x 7 x1000x1.13
= 0.3345m^3/day

4.7 Water Quality

Water quality in the Area is immensely variable, though most groundwater types are alkaline, with high levels of bicarbonate (HCO_3^{-}) as is common for many of Kenya's volcanic groundwater. The principal cation is sodium (Na^+). Electrical conductivity varies from place to place, reflecting a different recharge and discharge mechanism as well as aquifer environments. It also changes in time, though the reason for this is not clear.

The fluoride (F^{-}) concentrations generally exceed maximum admissible levels of 1.5 ppm (parts per million). The spatial distribution of F^- follows no discernible pattern. There may be reason to believe that localized concentrations indicate stagnant groundwater conditions or geothermal activity. W.H.O. and EC guideline concentrations are included for reference in appendix section.

4.8 Impacts of the Proposed Activity to Water Quality, Wetlands or Protected Areas

The Proposed drill site and related works are expected to pose no impact on water quality, either Surface or groundwater resources. There is no any surface water body near the drill site that can be contaminated by waste waters generated during drilling. The entire drilling, borehole construction, pump tests, and completion works will be done under supervision to professional standards. Entry of any foreign material until completion will be avoided to avoid any entry of foreign material into the borehole and only inert materials will be used in construction. The borehole will be properly developed to open up the aquifers and clean the borehole water. Monitoring of electrical conductivity of the water during drilling should be done to detect and seal any aquifer with elevated mineralization.

The site is not located within a wetland or protected land and has no negative impacts on biodiversity.

5.0 GEOPHYSICS

Several geophysical methods are available to assist in the assessment of geological subsurface conditions. The most common methods are resistivity method (also known as the geo-electrical method) and the Horizontal Electrical Profiling method. The latter is used to detect any anomalous conductive zones in the subsurface that might be associated with faulted or fractured zones.

5.1 Basic Principles of the Resistivity Methods

Many geophysical methods are available to assist in the assessment of geological sub surface condition. These utilize such properties such as Electrical, Electro-magnetic, seismic, gravity and seismo-electric, etc. In the present survey **Very Low Frequency – Electromagnetic - Resistivity (VLF-EM-R)** sounding data obtained from the client's plot was used to study the underlying rock conditions capable of groundwater storage and transmission. Resistivity sounding had been carried out by use of a **VLF EM - Resistivity Receiver** by **PQWT S500**.

In the present survey, the main emphasis of the fieldwork undertaken by the consultant was to determine the thickness and composition of the various volcanic rocks, the presence of faults and trace water bearing zones. This information is obtained in the field using resistivity method. Many geophysical techniques are available for ground water investigations and all of which have advantages and disadvantages.

The techniques used for the present survey was the **VLF – Resistivity and Vertical Electrical Sounding**. Other computer software were used in modeling and data analysis and included Excel and Global Mapper programs to zone water quality, flow direction and quantity. Existing borehole logs and resistivity values were used to calibrate the VES data and further enabled better delineation of the potential water bearing formations.

The geophysical surveys were planned with a view to investigate the physical status of the underground formations and targeted the: - Thickness

- Fracturing
- Weathered state of the sub-surface layers.

5.2 Methods

5.2.1 Resistivity Profiles

Resistivity profiles are usually carried in Wenner configuration, i.e. an electrode set-up with a uniform distance between potential and current electrodes (see Fig. 8). The entire array is moved across the area of interest. By doing so, lateral changes in apparent resistivity are measured, which reflect variations in the lithology, the depth of weathering or the water content. So-called "anomalies" may indicate the intersection of a fault (usually a negative anomaly), quartzite band (positive anomaly) or buried riverbed (anomaly depends on nature of surrounding deposits). Usually such lineaments, which may also be observed on aerial photographs, are linked to the occurrence of groundwater.

It must be noted that resistivity differences in a single profile array may largely reflect variations at the surface rather than underground. For this reason, it is usually not sufficient to carry out singlespaced profiles. The depth of penetration increases at greater electrode separations. A series of profiles at variable electrode separations will provide an indication of vertical resistivity trends. Moreover, by repeating the same profile at a different configuration, it will become clear if the observed resistivity patterns are caused by surface phenomena or underground features.

5.2.2 Theory - VLF-R Method

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 hydro geologist with information on the geological layering and thus the occurrence of groundwater.
The VLF method uses electromagnetic waves of very low frequency in terms of radio waves. From the standpoint of geo-electrical methods, these frequencies are considered to be quite high. The sources of such waves are strong radio stations used to maintain communication and emitting waves in the frequency range from 15 to 30 kHz.

The Electromagnetic field is polarized cylindrically around the antenna. By changing the operating frequency, you change the penetration depth. For a small area change, the magnetic field is assumed stable and constant. The relationship between the electric field component and the resistivity can be used to determine high and low resistance characteristics of the geological formation being scanned. As a result of sensor measurements, we obtain three components: **Ex**, **Hy**, and **Hz**.
Horizontal components **Ex** and **Hy** are derived from primary and secondary fields, while the component **Hz** comes from the secondary field only. The apparent resistivity (ϱa [Ωm]) is obtained by calculating the impedance (Z= Ex/Hy) from measured components in electric mode. Where, ϱa [Ωm] is the apparent resistivity; w is the angular frequency, which is equal to $2\pi f$, where f is a frequency of an electromagnetic wave in Hertz; μo = is the magnetic permeability of a vacuum, which is equal to 4π10-7[Vs/Am]; Ex is horizontal component of the electric field, expressed in millivolts per meter [mV/m], Hy is horizontal component of the magnetic field, expressed in microamperes per meter [μA/m].
The section profile is a logarithm of apparent resistivity due to the high variability of this parameter. The zone of reduced resistivity is clearly visible.

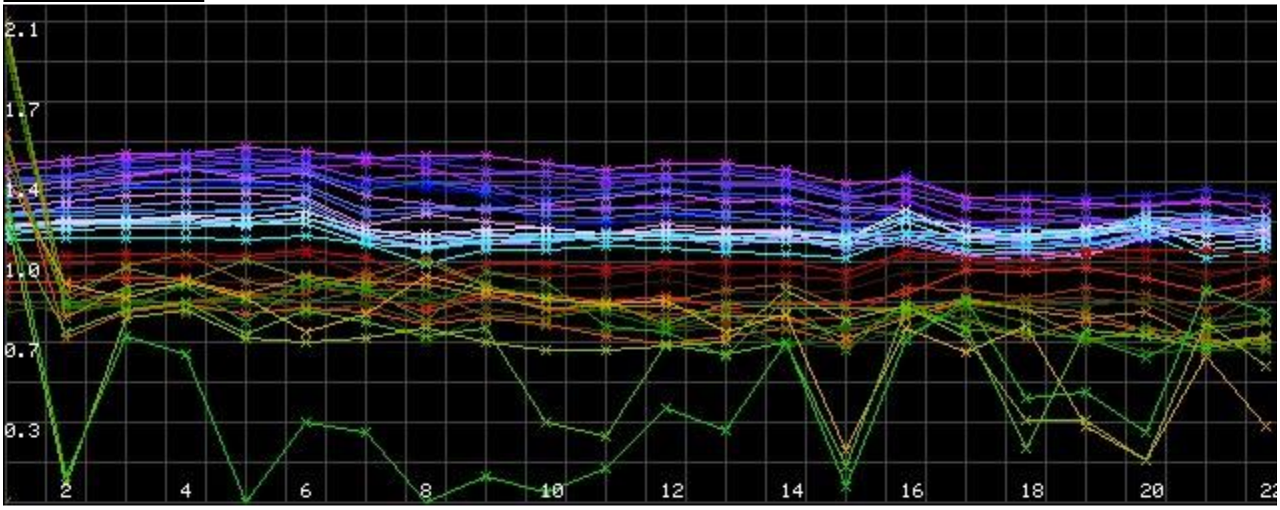
5.3 Fieldwork

Field work was carried out on 21st April 2023. **ONE VES and ONE Very Low Frequency** lines were executed. The aim of the sounding was to determine the prevailing hydro stratigraphy at the site. The results for **VLF** are attached and discussed below.

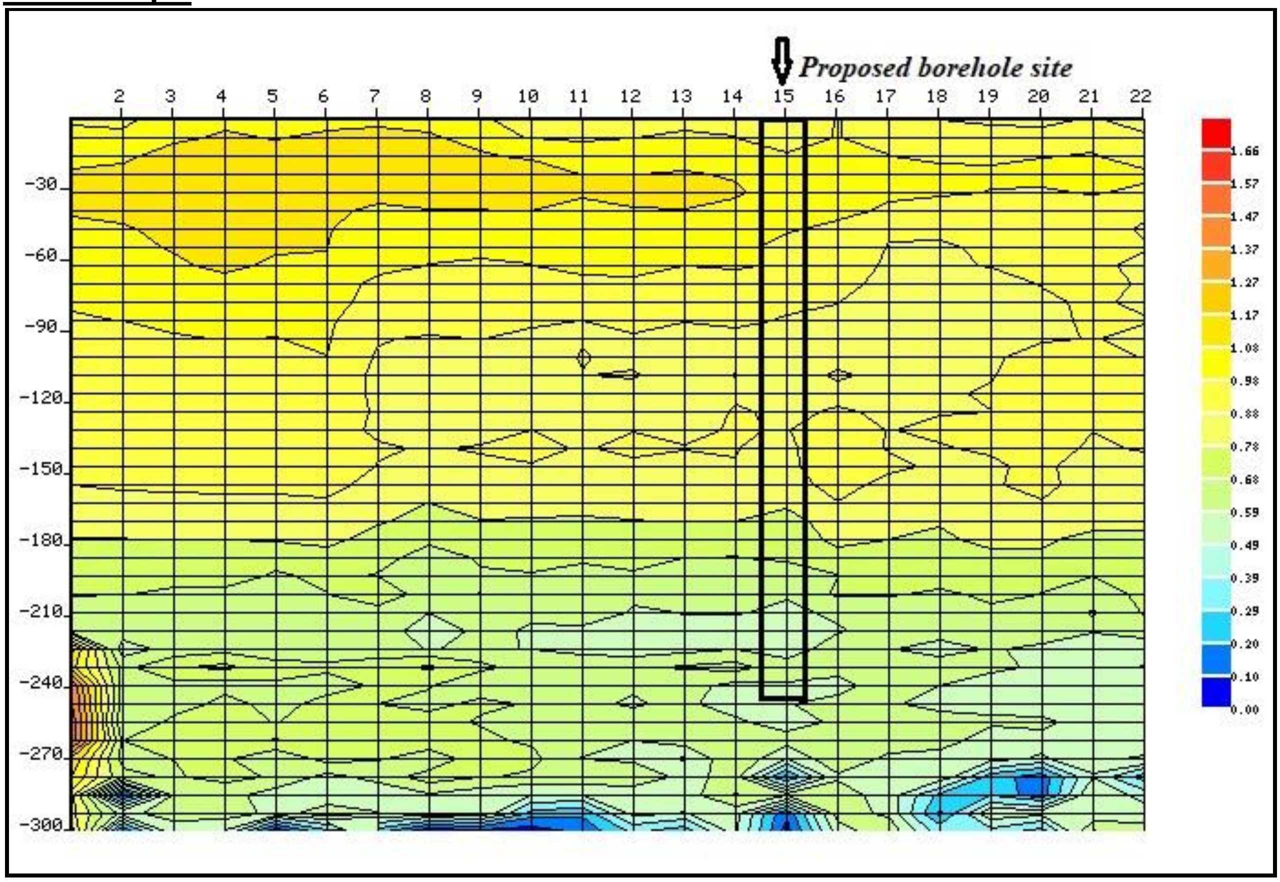
5.3.1 Results

VLF- E-R Method Data

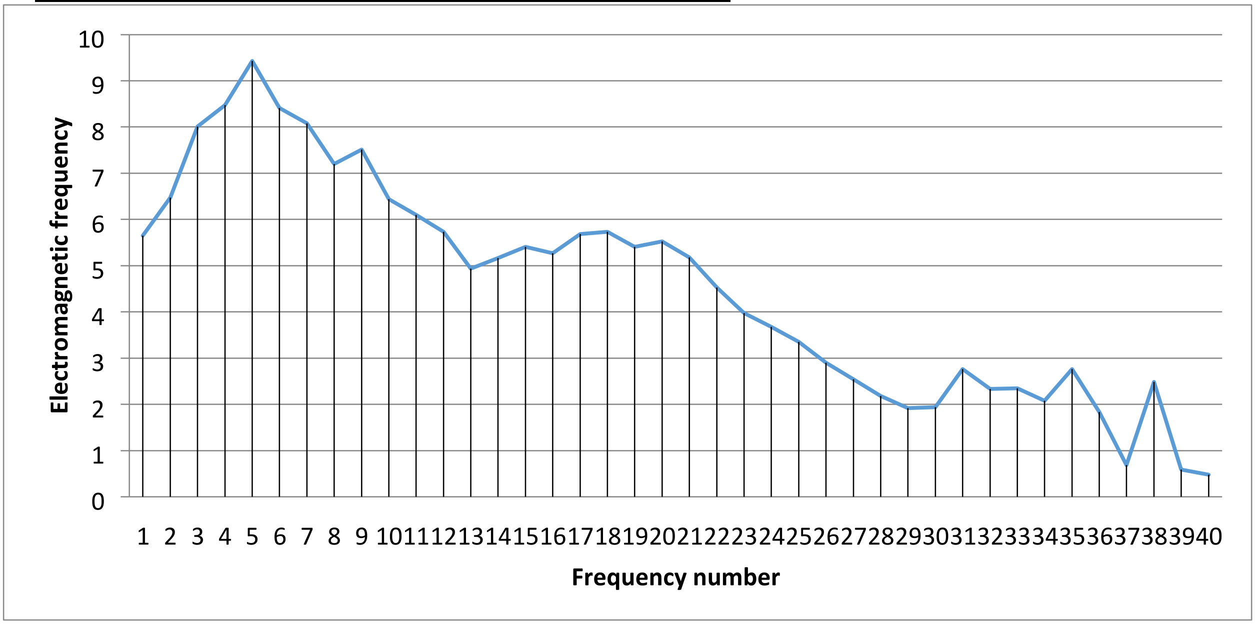
Profile curve 1



Profile Map 1



Interpreted Excel curve of PQWT LINE 1 point 15



HINT: VLF-EM-R; Very Low Frequency – Electromagnetic – Resistivity.

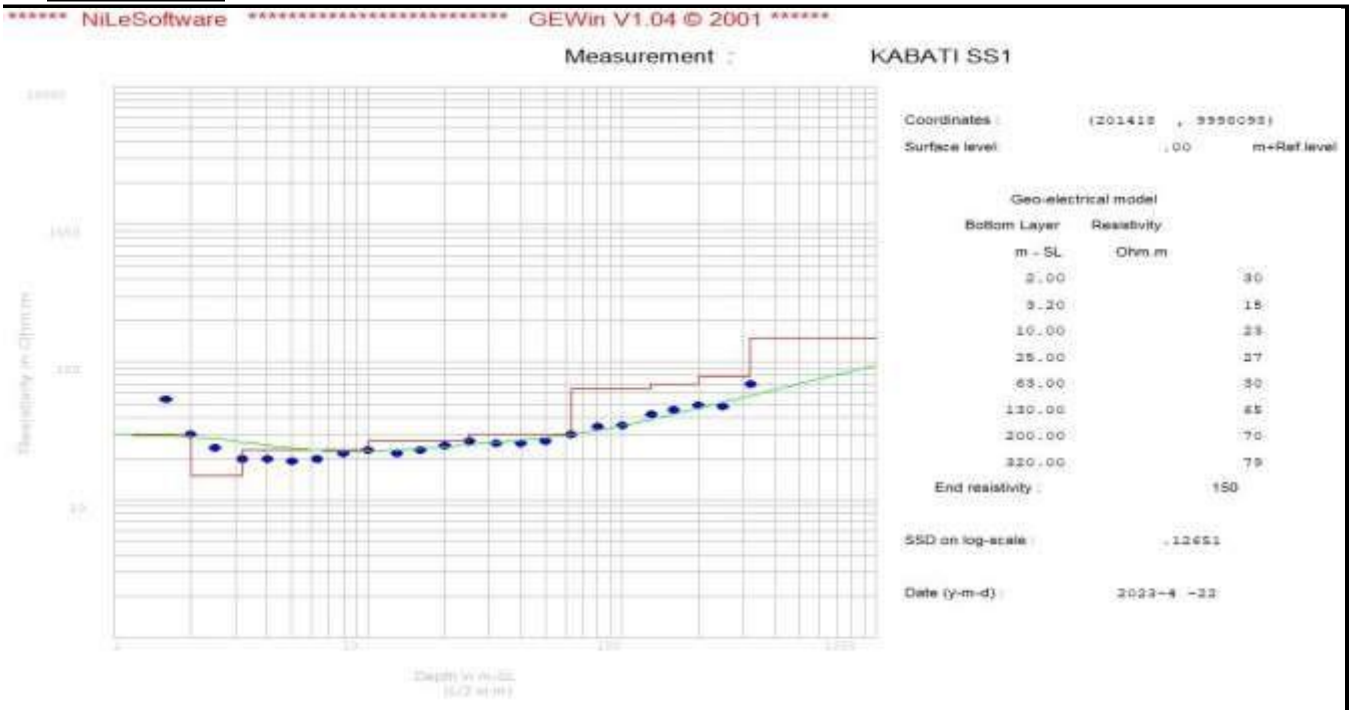
X-axis= Electromagnetic frequency, Hz.

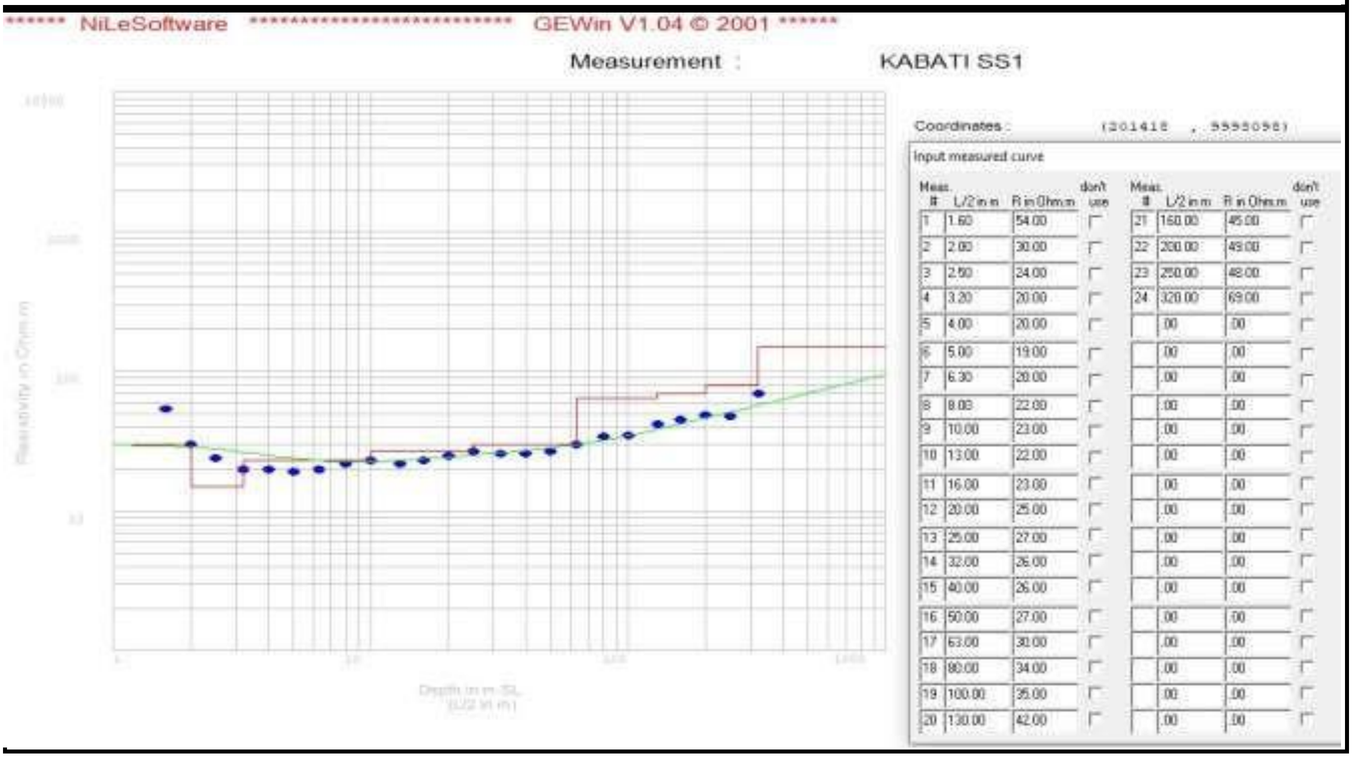
Y-axis= frequency intervals in the sub- surface. The interval between two frequencies recorded is 7.5m.

Recommendation: Recommended to be drilled to a depth of 250m.

NB: This is the point where VES 1 was carried out.

<u>VES 1 DATA</u>





RECOMMENDATION: The site is good and recommended for drilling to a maximum depth of 250m.

VLF 1 data and Geo - electric data interpretation

Depth (m)	**Resistivity**	**Interpretation**
0.0 – 2.0	30.0	Top volcanic Soils
2.0 – 3.2	15.0	Weathered lateritic materials
3.2 – 10.00	23.0	Highly weathered phonolite boulders
10.00 – 25.00	27.0	Weathered phonolite
25.00 – 63.00	30.0	Weathered phonolites
63.00 – 130.00	65.0	Slightly Weathered phonolites
130.00 – 200.0	70.0	Slightly weathered, fractured and decomposed phonolites
200.0 – 320.0	79.0	Slightly weathered to compact phonolites

The study thus recommends that the borehole be drilled at site **VLF 1 Point 15 / VES 1 to a depth of about 250mbgl.**

6.0. CONCLUSIONS AND RECOMMENDATIONS

Based on the program works the following conclusion can be drawn from the comprehensive survey data;

I. That One borehole is to be drilled to a maximum depth of **250m** at the locations of **VLF 1 Point 15 / VES 1;** which is ideal, where there is an optimum groundwater storage manifestation. The site is marked with wooden beacon for the ease of identification and known to **the School Principal.**

II. ii) The borehole will be drilled at the site coordinates **37M 0201418, N 9998098 VLF 1 Point 15 / VES 1.** The highly porous and permeable section of the aquifer system is composed of the Fractured Phonolite and Contact zones between the different formations.

III. The proposed borehole has been identified as a moderate flow system; with slightly modified waters. Though the waters will post high levels of the carbonates > General Hardness, the salinity levels are expected not to be excessive as to limit their usage in domestic application.

IV. The test pumping should be monitored carefully to indicate as much information as possible about the particular water supply aquifers; - in an attempt to confirm the recharge and discharge boundary manifestations.

After the completion of the drilling works, and prior to construction an experienced drilling consultant should carry out the well construction design and supervise the casings and screen installations. It will be the responsibility of the drilling consultant to design the pumping equipment on the basis of the modeled test-pumping data.

i) A monitoring tube should be installed in the drilled intakes to allow regular measurements of the water levels in the drilled borehole.

ii) In case shallow aquifers are encountered it is recommended to seal these off within the upper 20 metres, in order to avoid any risk of surface water ingress and subsequent chemical contamination. Installing a clay or cement seal in the annular space between the borehole wall and the metal casing should achieve the expected sealing tightness.

iii) Screens should only be installed at the deeper aquifers. We emphasize the use of Johnssons borehole screen casings in the intakes constructed to improve the lifespan of the bore. It must however be noted that prohibitive costs of Johnsson screens hamper their widespread use and in place of the same, plasma slotted pipes with enhanced density of slots can be used. For the ultimate and high flow specific borehole outputs from the constructed facilities it may be important to emphasize on Johnson type well screens to boost and maximize the borehole potentials.

iv) The recommendations on well construction cannot be considered complete without the mention of the requirement to test pump the water supply bore to BS 6316 (1992) standard, which is an industrial standard.

v) This standard generates qualitative and quantitative discharge variations over time in response to the abstraction. 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.

vi) The drilling should ideally be carried out with a rotary drill for faster penetration of the fractured fresh lava piles in conventional aerated down hole drilling methodologies.

vii) There is the need to define the Deepest Advisable Pumping water level in the screen deigns during construction. An ultimate scenario without a properly defined DAPWL is the depreciation of the pumping water levels to the screened areas that leads to screen encrustations with the resultant air exposure and water damp.

Table 6.1: Construction Summary

VES No.	**Location (Coordinates)**	**Recommended depth in metres**	**Construction Requirements**	**Anticipated yield (m^3/hr)**
Point 12	**37M 0201418 UTM N9998098 Elev. 2351m**	250	203/153 mm	5-10

7.0 REFERENCES

National Master Water Plan Stage I, Ministry of Water Development

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APPENDICES

APPENDIX 1 - ACCEPTABLE IONIC CONCENTRATION - VARIOUS AUTHORITIES

World Health Organization: European Community:
1983 1971 Int. EC Directive 1980 relating to the
quality Guidelines; Standards; of water intended for human
consumption:

Substance or Characteristic		Guideline Value (GV)		Upper limit (HL), (tentative)		GuideLevel (GL)	Max. Admissible Concentration (MAC)	
Inorganic Constituents of health significance;								
Antimony	Sb						0.01	
Arsenic		As	0.05		0.05			0.05
Cadmium	Cd	0.005		0.01			0.005	
Chromium	Cr	0.05		0.05				
Cyanide		CN	0.10		0.05			0.05
Fluoride		F	1.5		1.7			1.5
Lead	Pb	0.05		0.10			0.05	
Mercury		Hg	0.001		0.001			0.001
Nickel	Ni						0.05	
Nitrates			10 (as N)		45 (as N03)	25 (as NO3)		50 (as NO3)
Selenium	Se			0.01			0.01	

Other Substances			GV:		Highest		Maximum			GV:	
	MAC:										
			Desirable		Permissible						
			Level:		Level:						
Aluminium	Al		0.20						0.05		0.20
Ammonium	NH4								0.05		0.50
Barium		Ba								0.10	
Boron	B								1.0		
Calcium		Ca				75		50		100	
Chloride		Cl		250		200		600		25	
Copper	Cu				0.05				0.10		
Hydrogen											
Sulphide	H2S		ND								ND
Iron	Fe		0.30		0.10		1.0		0.05		0.20
Magnesium	Mg		0.10		30		150		30		50
Manganese	Mn		0.10		0.05		0.50		0.02		0.05

Nitrite NO2 0.10

Potassium K 10 12

Silver Ag 0.01

Sodium Na 200 20

175

Sulphate SO4 400 200 400 25

250

Zinc Zn 5.0 15 0.10

Total Dissolved Solids 1000 500 1500

1500

Total Hardness as CaCO3 500 100 500

Colour oHazen 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 oC 12 25

EC uS/cm 400

Notes ND - Not Detectable IO - Inoffensive

GL - Guide Level UO - Unobjectionable

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

APPENDIX 2: DRILLING TECHNIQUES

Drilling should be carried out with an appropriate tool. A percussion or rotary drilling machine will be suitable, though the latter is considerably faster. Geological rock samples should be collected at 2 metres intervals. Water struck and water rest levels and if possible estimates of the yield of individual aquifers encountered, should also be noted.

1. Well Design

The design of well should ensure that screens are placed against the optimum aquifer zones. The final design should be made by an experienced hydrogeologist.

2. Casing and Screens

The well should be screened with good quality screens considering the depth of the borehole; it is recommended that stainless steel casing and screens of 6‖ diameter be used. Slots should be of maximum 2mm in size.

We strongly advice against the use of torch-lit steel casings for screens. In general, its use will reduce well efficiency (which leads to lower yields) increase pumping costs through greater draw down, increased maintenance's cost, and eventually reduction of the potential effective life of the well.

3. Gravel pack

The use of 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 81/2 diameter borehole screened at 6‖, which should be sufficient. Should the slot size chosen be too large, the well will pump sand, thus damaging the plant and leading to gradual siltation of the well. The grain size of the gravel pack should be an average 2-4mm.

4. Well Construction

Once the design has been agreed, construction can be proceeded. In installing screen and casing, centralizers at 6 metre intervals should be used to ensure centrality within the borehole. This is particularly important to insert the artificial gravel pack all around the screen. If installed gravel packed sections should be sealed off, top and bottom with clay(2m), the remaining annular space should be backfilled with an inert material and the top five metres grouted with cement to ensure that no surface water at the well head can enter the well and thus prevent contamination.

5. 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 addictives from borehole wall. 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 development and cleaning wells.

Wells 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.

6. Well Testing

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

A well test consists of pumping a well from measured start (SWL) at a known or measured yield and recording the rate and pattern by which the water level within the well changes. Once as dynamic water level (DWL) is reached, rate of inflow to the well equals the rate of pumping.

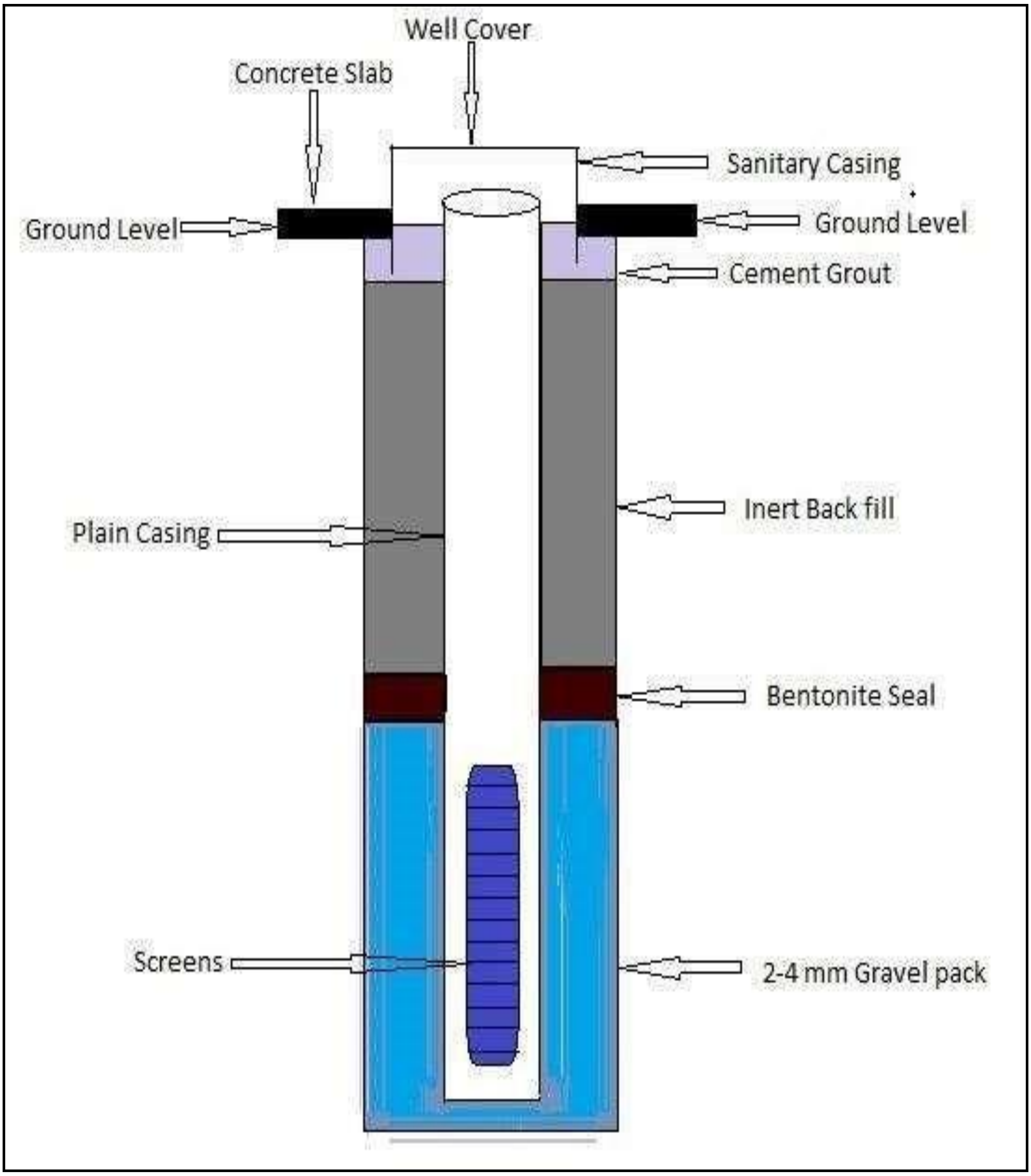
The duration of the test should be 24 hours with a further 24 hours for a recovery test or less depending on the rate of recovery during which the rate discovery to SWL is recorded. The results of the test will enable a hydro geologist to calculate the test recorded. The results of the test pumping rate, the installation depth and the drawdown for a given discharge rate.

It is nowadays-common practice to carry out a so-called step draw down test, in which the yield during testing increases stepwise. Each step is continued until hydraulic equilibrium is reached after which the yield is increased wit 50 to 100% towards the end of the test a water sample of 2 litres should be collected for chemical analysis.

7. Pump Installation

After testing and analysis of the results the pump can be selected and installed. It is important to select the right type of pump, which matches the characteristic of the well. It should have the right capacity to lift the water directly to the storage tank. The pump should never be installed in the slotted section, but at least 2 meters above or below the screened section. The electric submersible pump should be protected with a cut-off switch 2 meters above the pump inlet level.

APPENDIX 3: Schematic Borehole Design



APPENDIX 4: SKETCH MAP OF THE PROPOSED SITE