HYDROGEOLOGICAL ASSESSMENT REPORT

Namanjalala African Devine Church,

(L.R 312)

Namanjala Location, Kwanza District

Trans Nzoia County

****

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Report No. 31/2012

EXECUTIVE SUMMARY

Introduction

This report presents the results of the Hydrogeological and Geophysical Investigation for 1 No. Site in Namanjalala Location, of Trans-Nzoia district, the study was implemented by Earths Scope Geo-Hydro Services.

Geology

The study area comprises of rocks of the Pre-Cambrian basement system, the Tertiary lavas-Mt. Elgon volcanics and the Recent lateritic and the black cotton soils. The Basement System rocks in the study area consists mainly quartzites and schists derived from argillaceous and arenaceous sediments which have been transformed by metamorphism and recrystallization into quartz and feldspar-rich rocks with much muscovite, biotite, and hornblende minerals.

Road sections in the neighbourhood of Kitale show irregular bedded layers of coarse pebbles, coarse sands, fine sands and sills. These Pleistocene, sediments form part of old river terraces deposited during the period of glaciations of Mount Elgon when abundant water from the melting glaciers not only incised deep gorges through the volcanic rocks but, on reaching the flat Kitale Plains, spread out into broad torrential rivers, of which the limits are shown by the outcrop of black cotton soil.

Hydrogeology

Data obtained from the boreholes drilled in the area reveal that groundwater can be obtained at depths as shallow as 18 to greater depths, the principle water bearing horizon lies at the junction of the Elgon volcanics with the underlying basement rock, where a considerable amount of weathering of the later took place prior to the deposition of the volcanic rocks, producing a permeable water-bearing horizon. This horizon increases in depth towards Mount Elgon. Other water bearing horizons can be expected within the volcanics themselves, where almost horizontal and suitable associations of rocks yield conditions satisfactory for ground water storage.

Geophysics

Geophysical fieldwork was executed on 26th September 2012. Electrical resistivity method was employed for the geophysical investigations. Vertical Electrical Sounding (VES) was used to determine the horizontal and lithological changes in terms of electrical resistivity with depth. In total (1) VES were carried out.

Water Balance

Summarizing the annual averages of the conservative estimated components of water balance on the long term for the study area is calculated as tabulated below:

Hydrologic Parameter	Estimated Value
Catchment Area	$6x10^6m^2$
Aquifer extent	$l.5xl0^6m^2$
Aquifer thickness	40m
Storage Coefficient	1.2×10^{-4}
Specific yield	10%
Precipitation	1100mm
Recharge	6.6×10^5 m^3/year
Proposed abstraction	$1.08 \times l0^4$ m^3/year

From the water balance it is clear that the proposed abstraction is negligible compared to the other components of the aquifer hydrological cycles.

Conclusions

- On the basis of geological and hydrogeological evidence, the study concludes the hydrogeological conditions are the same all over the plot
- At the point where the shallow well is being dug (VES 1), water strike is expected at depth from 15 to 25 m bgl.
- Higher yields are expected with greater depths from the water strike level, however the water levels are expected to fluctuate with seasons.
- The aquifers in the study area are adequately replenished from an underground storage reservoir that is several orders larger than the imposed abstraction, thereby ensuring a reliable long-term water supply.
- Groundwater quality in the area is good for human consumption. However the fluoride concentration may be above the maximum recommended level of 1.5 ppm by the WHO guide level

Recommendations for Drilling

- It is also recommended to dig a telescoped well at the location of VES 1 with 3 m diameter from 0-20 m bgl and then reduce to 2.5 m diameter from 25 m bgl and finally reduce to 2m diameter
- Hand digging is limited to waist, therefore once the water is struck dewatering is recommended to optimize aquifer penetration. This will ensure sufficient yield of the well is achieved.
- Wellhead protection with concrete slab to avoid contamination
- As a better option an 8” borehole be drilled at the location of VES 1 to a depth minimum depth of **60 m** and a maximum depth of **70m bgl**
- The recommended point is known to M/s. Bedina Muhonja (0710626860), and Joseph Pamba the Chemase (0712314551).

Shallow Groundwater Abstraction

Before digging or drilling commences, a drilling permit has to be obtained from the Water Resources Management Authority, Lake Victoria North Catchment Area regional Office in Kitale, Trans Nzoia County under the Ministry of Water and Irrigation.

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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 (mS/cm)
h	head
hr	hour
K	hydraulic conductivity (m/day)
I	litre
m	metre
N	North
PWL	pumped water level
Q	discharge
sQ/s	specific capacity (discharge – drawdown ratio; in m. cu/hr/m)
Cu	cubic
Sq	square
S	drawdown (m)
S	South
Sec	second
SWL	static water level
T	transmissivity (m.sq/day)
VES	Vertical Electrical Sounding
W	West
WSL	water struck level
mS/cm	micro-Siemens per centimetre: Unit for electrical conductivity
°C	degrees Celsius: Unit for temperature
Wm	Ohm-m: Unit for apparent resistivity
ra	Apparent resistivity

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 process, with or without water as an agent. Usually of mixed texture.

Conductivity: Transmissivity per unit length (m/day)

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

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 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 lowest > head.

Heterogeneous: Not uniform in structure or composition.

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

Hydrogeological: Those factors that deal with sub-surface 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.

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

Perched aquifer: Unconfined groundwater separated from an underlying main aquifer by an unsaturated zone. Downward percolation hindered by an impermeable layer.

Peneplain: A level surface, which has lost nearly all its relief by passing through a complete cycle of erosion (also used in a wider sense to describe a flat erosional surface in general)

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

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

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 of sub-surface sources (e.g. rivers, rainfall, lateral groundwater flow) to the aquifer zones.

Saprolite: Weathered residual rock in place.

Static water level: The level of water in a well that is not being affected by pumping. (Also known as ‘rest water level’)

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

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

1.1 Background

Earths Scope Geo- Hydro Services, was commissioned by African Devine Church Boyani HQ to carry out a hydrogeological at Namanjalala African Devine Church in their WATSAN Program in Namanjalala area of Kwanza District, Tranzoia County.fieldwork was carried out from 26^{h} September 2012.

The Client requires detailed information on prospects of drilling production boreholes. The objective of the present study is to assess the availability of groundwater, to recommend borehole drilling sites and comment on aspects of depth to potential aquifers, aquifer availability and type, possible yields and water quality. For this purpose all available hydrogeological information of the areas have been analyzed, and a geophysical surveys done.

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 the Client's requirements. The data sources consulted were mainly in four categories:

a) Published Master Plans.
b) Geological and Hydrogeological Reports and Maps.
c) Ministry of Water and Irrigation Borehole Completion records.
d) Technical reports of the area by various organizations.

1.2 Scope of the Works

The scope of works includes:

(i) Site visits to familiarize with the project areas. Identify any issues that might hinder the implementation of works in any of the areas and report to the Head of Groundwater Investigation in the Ministry.
(ii) To obtain, study and synthesize background information including the geology, hydrogeology and existing borehole data, for the purpose of improving the quality of assessment and preparing comprehensive hydrogeological reports,
(iii) To carry out hydrogeological evaluation and geophysical investigations in the selected sites in order to determine potential for groundwater and appropriateness of drilling boreholes at the sites.
(iv) To prepare hydrogeological survey reports in conformity with the provisions of the rules and procedure outlined by the Water Resources Management Authority, including the following:
- Site Name, Location and GPS readings
- Geology and hydrogeology
- Present sources and status of the existing water supply
- Existing borehole data information.
- Geophysical data and analysis
- Conclusions and recommendations, including the groundwater potential of the investigated sites, name and location of the site recommended for drilling,

recommended maximum drilling depth in metres and appropriate drilling method

1.3 Reporting Requirements

The format of writing the Hydrogeological Investigations Report, as described out in the Second Schedule of the Water Resources Management Rules, 2007. Such a report must consider the following (verbatim): -

1. Name and details of applicant
2. Location and description of proposed Activity
3. Details of climate
4. Details of geology and hydrogeology
5. Details of neighbouring boreholes, including location, distance from proposed borehole or boreholes, number and construction details, age, current status and use, current abstraction and use.
6. Description and details (including raw and processed data) of prospecting methods adopted, e.g. remote sensing, geophysics, geological and or hydrogeological cross sections. Hydrogeological characteristics and analysis, to include but not necessarily be limited to, the following:
    a. Aquifer transmissivity
    b. Borehole specific capacities
    c. Storage coefficient and or specific yield
    d. Hydraulic conductivity
    e. Groundwater flux
    f. Estimated mean annual recharge, and sensitivity to external factors
7. Assessment of water quality and potential infringement of National standards
8. Assessment of availability of groundwater
9. Analysis of the reserve
10. Impact of proposed activity on aquifer, water quality, other abstractors, including likelihood of coalescing cones of depression and implications for other groundwater users in any potentially impacted areas
11. Recommendations for borehole development, to include but not limited to, the following:
    a. Locations of recommended borehole(s) expressed as a coordinate(s) and indicated on a sketch map
    b. Recommendations regarding borehole or well density and minimum spacing in the project area
    c. Recommended depth and maximum diameter
    d. Recommended construction characteristics, e.g. wire-wound screen, grouting depth
    e. Anticipated yield
12. Any other relevant information (e.g. need to monitor neighbouring boreholes during tests).

This report is written so as to cover each of the above, insofar as data limitations allow. The report also includes maps, diagrams, tables and appendices as appropriate.
The addresses: -

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2. DESCRIPTION OF THE PROJECT AREA

2.1 Location and Administration

The project area is located within the Lake Victoria North drainage basin. The study area lies administratively in Namanjala Location, Kwanza Division in Kwanza District of Trans Nzoia County, coordinates 36N0721465/UTM 0118990

2.2 Geomophology and Drainage

The area can be divided into three natural divisions in each of which the relief, climate, vegetation, and human activity are more or less uniform —

(1) The West Suk Lowlands
(2) The Kitale Plain
(3) Mount Elgon.

The West Suk Lowlands, which form part of the mid-Tertiary peneplain (Dixey, 1948), are separated from the Kitale Plains by a formidable escarpment ranging in height from 460 to nearly 650 meters. This escarpment is higher in the east, where the Kitale Plains rise gradually towards the Cherangani Hills, against which the escarpment abuts. In the west, towards Mount Elgon, the escarpment is less conspicuous, though still approximately 300 meters high, but it appears to die out under the mountain.

The Kitale plain, which forms part of the pre-Miocene peneplain of the Trans-Nzoia district (Dixey, 1948), has a slight southerly tilt, with the principal drainage system flowing towards Lake Victoria. The maximum elevation appears to lie along an east-west line corresponding to latitude I^0 10' N. which forms a watershed between the Nyanza drainage area and that of the Lake Turkana area. North of this line, the Kitale plain dips gently northwards to the Trans-Nzoia escarpment. In the northern part of the Plain the north-flowing streams have been incised into the Basement rocks to a considerable depth, giving rise to steep-sided V-shaped valleys with many prominent interlocking spurs. On the southern side of the watershed the drainage is mainly easterly, but to the east of Kitale it flows in a south-easterly direction. Ultimately it runs in a southerly direction just before joining the River Nzoia which flows westwards into Lake Victoria.

The principal river of the Kitale Plain is the Koitoboss which rises at the foot of Koitoboss Peak. All streams between Endebess Bluff and the Chepchoina River are tributary, to it. The southern watershed separating the Koitoboss tributaries from those of the Rongai River runs in an east-west direction roughly parallel to the Endebess road.

2.3 Climate of the study area

The diurnal range of temperature is considerable. During the wet season the night temperatures of 19^0C is common, rising to 25.6°C during the hottest part of the day. The difference between the maximum and the minimum temperature in the dry season is even, greater, temperatures as low as 15.8°C and as high as 27.9°C having been recorded, giving a range of 12°C. The principal climatic difference between the Kitale plains and the West

Suk Lowlands lies in the relative humidity which is greater over the Kitale area than over the lowlands, and is due to the difference in altitude between these two levels.
As would be expected, (There is more rainfall in the foothill zone of Mount Elgon, with an average of 1270mm. at the Elgon Sawmills; the minimum recorded being 1016mm. and the maximum 1549mm.

LEGEND

Investigated Area

Principal Roads

Other Roads

Kitale town

Rivers and a dam

Figure 1 : General Location Map of the Area

3. GEOLOGY

3.1 Summary of Geology

The study area comprises of rocks of the Pre-Cambrian basement system, the Tertiary lavas-Mt. Elgon volcanics and the Recent lateritic and the black cotton soils. The Basement System rocks in the study area consists mainly quartzite and schists derived from argillaceous and arenaceous sediments which have been transformed by metamorphism and recrystallization into quartz and feldspar-rich rocks with much muscovite, biotite, and hornblende minerals.

The Tertiary Lavas-Mount Elgon is formed of a great mass of agglomerate, breccia and tuff with intercalated bands of lava, the whole having been ejected from a vent during Tertiary times. The boulders of lava in the agglomerate, like the lava flows themselves, are composed of nephelinites that contain much made material such as olivine, augite, magnetite, ilmenite and perovskite. Surrounding the caldera produced round the vent are lavas and breccias of phonolitic-nephelinites in which aegirine-augite and orthoclase appear. The floor of the caldera, lying over 300 meters below the caldera rim, is composed of volcanic ash, the last eruptive material ejected from the volcano.

3.2 Detailed Geology

3.2.1 Basement System

Basement System rocks in the study area consists of metamorphic rock-types which originated solely by the effect of pressure, and consequent rise in temperature. In the study area they mainly include quartzite and schists derived from argillaceous and arenaceous sediments which have been transformed by metamorphism and recrystallization into quartz and feldspar-rich rocks with much muscovite, biotite, and hornblende minerals.

3.2.1.1 Pelitic Schists and Gneisses

These rocks are predominant in the area and include the Muscovite-quartzite, mica schist and the hornblende schist. Biotite-schists are closely associated with the asbestos deposits in some areas forming an outer rim to the zoned bodies. Muscovite-schists containing about 60 percent muscovite and 40 percent kaolinized feldspar and quartz are also fairly mapped in the region, the schists occur within the metamorphic succession, but show considerable distortion. Inclusions within the muscovite include rutile, zircon and apatite. Chlorite-schists are noticeably absent from the area as a whole but have been mapped sparsely developed only in close contact with the zoned asbestos bodies of which they form part, talc-schists in the area are also a product of the metasomatism of the ultramafic igneous intrusions.

The hornblende schists, in the area, are fine grained, dense, glistening black rocks which outcrop only over narrow widths, suggesting dyke-like forms.

3.2.1.2 Metamorphosed Semi-Pelitic Sediments

These are gneisses which were formed by the metamorphism of sandy shales and argillaceous sandstones and are represented in the area by biotite gneisses, feldspar-porphyroblast gneisses and the banded microcline augen gneisses.

3.2.2 Kavirondian System (Graywackes Grits and Philites)

The sedimentary Kavirondian System of the present area lies with strong angular unconformity on the upturned edges of the folded Nyanzian rocks. This unconformable relation is well demonstrated by the strong discrepancies in dip and strike between the two systems. The System is unfossiliferous and its age is not definitely known, but is probably Pre-Cambrian. Conglomerates, grits and mudstones are the main members of the series, with pebbly grits and sandy mudstones making up a subordinate part of the sequence. Various suggestions have been made regarding the order of deposition of the sediments. Combe (1927) interpreted the succession as: -

a) Upper Division of shales and phyllites with interbedded argillaceous sandstones.
b) Middle Division of felspathic sandstones, quartzites and grits, grading into arkoses.
c) Lower Division of shales and phyllites.

Combe considered that the conglomerates did not lie in a definite horizon but occurred at various levels in thick 'lenses up to three miles in length, grading laterally into felspathic quartzites.

Kitchen (1937) suggested a somewhat different succession: -

a) Upper Division of felspathic grits with pebble bands.
b) Middle Division of slates and mudstones.
c) Lower Division of felspathic grits and conglomerates.

Pulfrey (1945), suggested that as no constant datum horizons had been found, no useful attempt could be made to split up the series into sub-divisions, and with this view the writer is inclined to agree, though the evidence just south of Kakamega does rather suggest a basal section which is predominantly conglomeratic, with minor grit bands, followed by an alternating series of grits and mudstones. In the grits of the latter series pebble bands are rare in the present area and only occasionally, do they become distinctly conglomeratic, though here they contain flattened pebbles of mudstone and cannot therefore belong to a basal conglomerate group

3.2.3 The Tertiary Mt Elgon Volcanics

The classification and succession of the Elgon volcanic series as proposed by Odman (1930) is reproduced bellow.

Volcanic Succession of Mount Elgon

	Dominant Lavas	**Pyroclastics**	**Dyke-rocks**
Series of Gortex-Riva	Phonolite	Agglomerate Tuff	
Series of the Caldera	Phonolitic-nepheline-Basalt	Agglomerate Tuff	
Series of the Caldera-rim	Phonolitic-Nephelinites	Agglomerate Tuff	Bergalite
Basaltic Stage	Melilite-nepheline	Agglomerate	Melilite-nepheline

	Basalt Melilite-basalt Nepheline-basalt	Tuff Ash	Basalt Melilite-basalt Nepheline-basalt
Nephelinitic stage	Nephelinite	Agglomerate Tuff	

This succession is based on the rocks found on Elgon not only in Kenya but also in Uganda. The nephelinitic stage is more evidence on the western side of the mountain, there being no representatives on the eastern side. The use of the term "basalt" for nephelinites which by definition are feldspar-free is unfortunate; the usual connotation of the word is a basic rock containing plagioclase feldspar. In this report rocks that would have been named nepheline-basalt by Odman are called olivine-nephelinites. It appears that most of the nephelinites exposed on the eastern side of the mountain are of relatively late occurrence, the earlier phases being represented by coarse agglomerates and volcanic breccias.

The study area falls in what is referred in the geological report as the Lower Pyroclastics Series and Lake Beds, and thus will be described in details bellow.

3.2.3.1 The Lower Pyroclastics Series

The contact between the pyroclastics rocks of Mount Elgon and the Basement System rocks runs approximately north-south across the Kitale Plains and crosses the Kitale-Endebess road about 10 kilometres from Kitale. North of this road there is no sharply defined morphological feature separating the pyroclastics rocks from the Basement System rocks and only a change in soil type, from the reddish-brown volcanic soil to lighter coloured sandy Basement soils, is visible.

The coarse grey tuff, which is about 1 meter thick grades into a 6 meters bed of very fine-grained volcanic tuff and siltstone. The tuff is buff-coloured and closely jointed, whilst the siltstone, which represents a volcanic mud precipitated by the torrential rain that accompanied the first violent outburst from the original vent, shows closely-spaced horizontal jointing and colour banding. At the top of the siltstone the tuff becomes coarser and passes into an incoherent ash containing many shiny black crystals of pyroxene and many fragments of lapilli. Zeolites and carbonate are abundant secondary products in these ashes, which pass upwards into volcanic breccia and agglomerate.

Apart from these tuff deposits, the rest of the lower volcanic series covering the Kitale plain consists principally of breccia and agglomerate. Most of the boulders of lava in the agglomerate show a considerable degree of secondary alteration and weathering whilst the breccias are greatly altered so that it is difficult to distinguish between the original blocks of lava and the matrix. The breccias are extensively quarried for use as building stone; they present not only a picturesque appearance due to their mottled red, green and grey colour, but the absence of hard and compact boulders of lava makes their quarrying and trimming a relatively easy process.

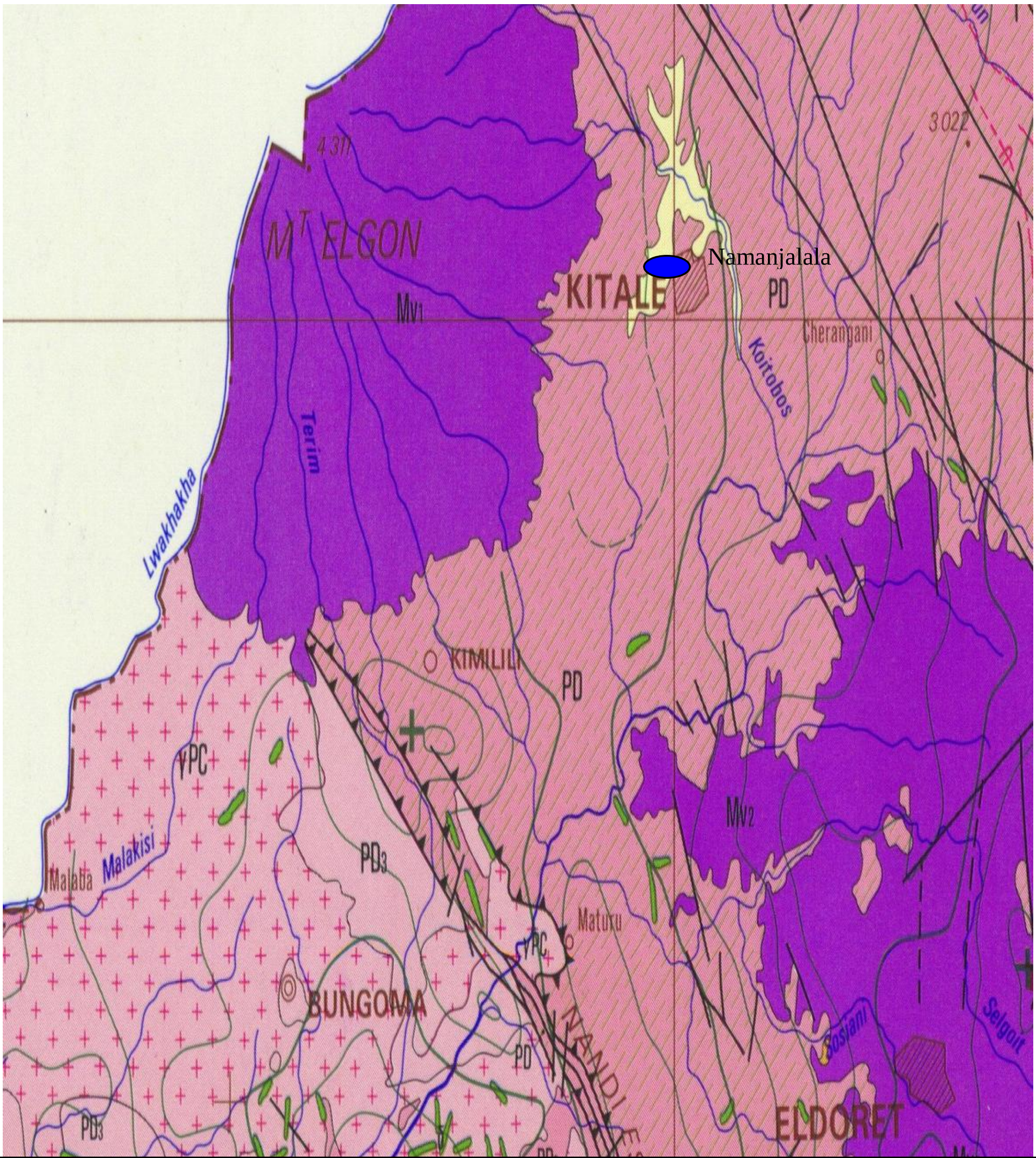
3.2.3.2 Age of the Elgon Volcanic Series

The Elgon volcanic rocks rest in the present area upon a westerly tilted old land surface, regarded as Pre-Miocene in age (Dixey, 1948) and reaching a height of approximately 1850 meters near Kitale, but falling off in height towards Endebess, where it attains only 1700 meters and is covered by 140 meters of volcanic rock. To the south and south-west of Mount Elgon the volcanics rest upon progressively lower levels including the widespread sub-Miocene peneplain. There is no other evidence for the age of the volcanism on the east side of Mount Elgon.

3.2.4 Pleistocene to Recent Deposits

Road sections in the neighbourhood of Kitale show irregular bedded layers of coarse pebbles, coarse sands, fine sands and sills. These Pleistocene, sediments form part of old river terraces deposited during the period of glaciations of Mount Elgon when abundant water from the melting glaciers not only incised deep gorges through the volcanic rocks but, on reaching the flat Kitale Plains, spread out into broad torrential rivers, of which the limits are shown by the outcrop of black cotton soil.Within the Kitale township on the central Elgon road a pit approximately 2 meters deep shows 1 meter of reddish brown soil at the base, containing irregularly sorted and angular quartz pebbles, followed upwards by a 20 to 25 cm, layer of small quartz pebbles covered by a 10 cm. layer of red soils.

Soils vary in type, corresponding largely with the underlying bedrock, though there is a modification in certain portions of the area due to the disintegration of the laterite caps. Buff or light brown sandy soils are produced by the breakdown of Kavirondian grits and bright red clayey soils by the mudstones. Where, however, there is close interbanding of the grits and mudstones the grit type soils are obscured by the mudstone disintegration products. The granites give rise to coarse light brown, sandy, soils more subject to soil erosion than the more clayey varieties mentioned above, while the diorites, syeno-diorites and syenites, having a greater proportion of mafic minerals, give darker red brown, more clayey, types. This also applies to areas in the granite rich hi basic xenoliths



Legend

Elgon Volcanics

Metasediments

Alluviums

Rivers

Investigated Area

Figure 2 : General Location Map of the Area

4. HYDROGEOLOGY

Data obtained from the boreholes drilled in the area reveal that groundwater can be obtained at depths as shallow as 18 to greater depths, the principle water bearing horizon lies at the junction of the Elgon volcanics with the underlying basement rock, where a considerable amount of weathering of the later took place prior to the deposition of the volcanic rocks, producing a permeable water-bearing horizon. This horizon increases in depth towards Mount Elgon. Other water bearing horizons can be expected within the volcanics themselves, where almost horizontal and suitable associations of rocks yield conditions satisfactory for ground water storage.

4.1 Aquifer Characteristics in Trans-Nzoia District

The aquifers in this area occur in the basement system of rocks at the contact between the weathered and the fresh basement rocks. From the borehole data collected in this area, the following parameters have been determined.

4.1.1 Specific Capacity

This is a crude indication of the efficiency of the borehole as an engineered structure, and is calculated by dividing the discharge rate (as m^3/day) by the total drawdown. High specific capacities generally indicate high transmissivities, low specific capacities the opposite

The specific capacity (yield-drawdown ratio) of the boreholes in the study area ranges from 1.125 to 123.3. The variation is partly determined by the depth of the borehole. The specific capacity of the surveyed borehole is expected to be high and to decrees gradually at increasing abstraction rates. The specific capacity of some boreholes in the Kitale has been calculated and is presented in the table below.

Table 1:- Borehole specific capacities

Bh No.		Yield (m^3/h)	Total Drawdown	Specific Capacity (m^3/day/m)
C-12693	Bakoko horticulture	2.8	4.0	16.8
C-12708	Wa muini ACK	2.4	5.5	10.47
-	KARI	3.6	64.9	1.33
	Joseph Leting	2.0		
	Kuza farm	0.8		
	Capt. Lebo	1.2		
	Bakhita	1.5		

4.1.2 Transmissivities

This is the rate of flow of water under a unit hydraulic gradient through a cross-section of unit width across the entire saturated section of an aquifer. Strictly speaking, transmissivity should be determined from the analysis of a well test, but the figures given below have been determined from past studies as reported in the national water master plan (1992) using Logan's method. Logan (1964) developed a relationship between specific capacity and transmissivity, 1.22 x Q/s, based on a reworking of Thiem's seminal steady-state groundwater flow equation (Thiem 1906).

4.1.3 Aquifer Parameters within the Trans-Nzoia Municipality

The transmissivity values for the Kenya Agricultural Research Institute (KARI) within the Municipality area in Trans-Nzoia district was calculated using the lagans formulae as follows. The product of (K) and thickness (D) is defined as the transmissivity (T) of an aquifer system (KD=T). This property can be derived from the commonly applied Jacobs formula (Driscoll 1986):

$$\mathbf{T=1.22Q/\Delta s}$$

Where: Δs = increase in drawdown over 1 log cycle of time. According to the data of the borehole named above, **Δs=24.14** m/log cycle and the average yield Q =3.6 m^3/hr.

$$\text{Thus } T = 1.22*3.6*24/24.14$$
$$=4.366\ m^2/\text{day}.$$

This value of T and an aquifer thickness of 24 m, K = 0.1819 m/day.

4.1.4 The Storage Coefficient

The storage coefficient of an aquifer is the volume of water released from or taken up per unit surface area per unit change in head. It is dimensionless. Empirical values of the storage coefficient cannot be determined from test data collected from pervious drilling programmes in the Kitale area, as aquifer test data is not available. In an aquifer test, a borehole is pumped at a known discharge rate and water levels in one or more neighbouring observation boreholes, and the shape and type of drawdown curve in the observation borehole(s) is used to calculate the storage coefficient.

4.1.5 Groundwater Quality

Groundwater quality in the study area is usually good for human consumption. The analysis reports of the boreholes in the study area have shown that all the parameters are in good concentrations for domestic use.

Table 2: Groundwater Classification Based on Salinity

Category	TDS (ppm)	EC (µS/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 microSiemens per cm

Table 3: Salinity Limits for Groundwater Use

EC	*TDS(ppm)*	*Use/Limitation*
<2000	*<1500*	*Potable*
>2000	*>1500*	*Unsuitable for Domestic Purposes*
2000-3000	*1500-2000*	*Generally too salty to drink but still fit for livestock*
>3000	*>2000*	*Generally unfit for dairy cattle and young calves*
>7000	*>4500*	*Unfit for grazing cattle and sheep*

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 geoelectrical method) has been used.

5.1 Resistivity Method

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

5.2 Basic Principles

The electrical properties of rocks in the upper part of the earth's crust are dependent upon the lithology, porosity, and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivities than unsaturated and dry rocks. The higher the porosity of the saturated rock, the lower its resistivity, and the higher the salinity of the saturating fluids, the lower the resistivity. The presence of clays and conductive minerals also reduces the resistivity of the rock.

The resistivity of earth materials can be studied by measuring the electrical potential distribution produced at the earth's surface by an electric current that is passed through the earth.

The resistance R of a certain material is directly proportional to its length L and cross-sectional area A, expressed as:

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

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

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

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

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

5.3 Vertical Electrical Soundings (VES)

When carrying out a resistivity sounding, current is led into the ground by means of two electrodes. With two other electrodes, situated near the centre of the array, the potential field generated by the current is measured. From the observations of the current strength and the potential difference, and taking into account the electrode separations, the ground resistivity can be determined.

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

This graph can be interpreted with the aid of a computer program 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.

FIELDWORK AND RESULTS

5.4 Namanjalala African Devine Church Farm

5.4.1 Location

Namanjalala African Devine Churchs farm is located about 20 kilometres away from Kitale town on the Kitale-Kapenguria road, Kwanza Division of Kwanza District.

The investigated site is defined by Latitude 36N 0731112 and Longitude 0123110 at an elevation of 1942 m asl. The VES location for the investigated site is presented in the VES and site location map.

5.4.2 Physiography and Drainage

The area has a gentle slope south-eastward towards the Sabwani river which is a tributary of the Nzoia River that originates from the Mount Elgon forest. The regional Physiography however is that of the Kitale plain, which forms part of the pre-Miocene peneplain of the Trans-Nzoia County and the Cherangany hills

5.4.3 Soil Cover, and Vegetation

The soil cover is reddish brown to grey in colour. This soil is a weathering product of the basement system of rocks that underlies the entire area. These soils support a large scale farming of maize and coffee and other natural and planted trees.

5.4.4 Water Demand and Existing Water Supply

The client needs about 10m3/day for domestic. Currently the client gets water from a shallow well in the compound though not well protected.

5.4.4.1 Recharge

The main source of recharge to the basement aquifers in the Namanjalala area is the rainfall that percolates deep underground to recharge the shallow aquifers..

5.4.5 Geophysical Fieldwork and Results

5.4.5.1 Field Work

The fieldwork was carried out on26th of September 2012. To determine the subsurface conditions and their suitability for groundwater storage and identify a suitable borehole site, one vertical electrical resistivity sounding was carried out. The sounding was carried out to a maximum AB/2 = 130 m using TSP resistivity meter and employing Schlumberger array configuration.

Table 4: GPS Co-ordinates of the VES Location

VES NO.	CO-ORDINATES		UTM		ALTITUDE
	Longitudes	Latitudes	Latitudes	Latitudes	
1	E 034^{0} 59’24.6”	N 01^{0} 04’ 13.6”	0721466	118990	1842m

5.4.5.2 Interpretation Results

The interpretation result of the VES is tabulated in the following table.

The results of interpretation of the resistivity soundings data are presented in the following sections. In addition, this section briefly describes the results of the measurements and also presents plots of the interpretation graphs for the resistivity soundings.

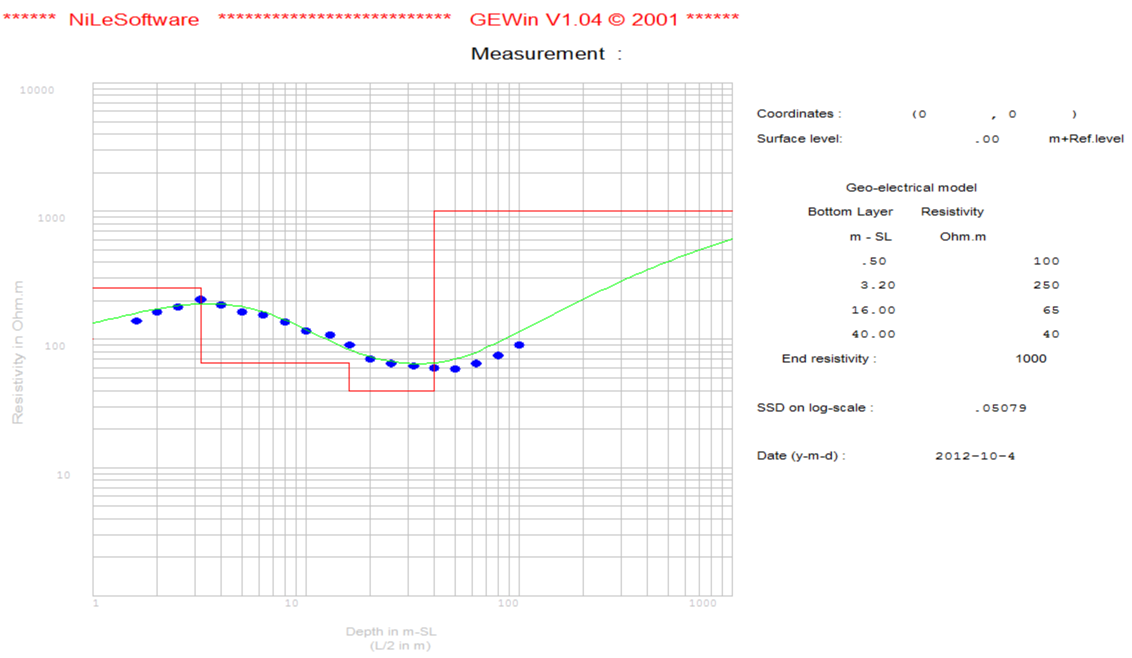


Figure 3:- Interpretation Graph for Namanjalala African Devine Church VES 1

Table 5: Interpretation of Results for the Survey

VES 1	Resistivity (Ohm-m)	Depth (m bgl)	Geological Interpretation	Hydrogeological Significance
LAYER 1	100	0 – 0.5	Top superficial layer	Dry
LAYER 2	250	0.5 – 3.2	Top Superficial Layer	Dry
LAYER 4	65	53.2-16	weathered basement rocks	Aquiferoust
LAYER 5	40	16-40	Highly Weathered	Aquiferious
LAYER 5	1000	>40	Fresh Basement	Dry

6. Conclusions and Recommendations

6.1 Conclusions

- On the basis of geological and hydrogeological evidence, the study concludes the hydrogeological conditions are the same all over the plot
- At the point where the shallow well is being dug (VES 1), water strike is expected at depth from 15 to 25 m bgl.
- Higher yields are expected with greater depths from the water strike level, however the water levels are expected to fluctuate with seasons.
- The aquifers in the study area are adequately replenished from an underground storage reservoir that is several orders larger than the imposed abstraction, thereby ensuring a reliable long-term water supply.
- Groundwater quality in the area is good for human consumption. However the fluoride concentration may be above the maximum recommended level of 1.5 ppm by the WHO guide level

6.2 Recommendations for Drilling

- It is also recommended to dig a telescoped well at the location of VES 1 with 3 m diameter from 0-20 m bgl and then reduce to 2.5 m diameter from 25-30 m bgl
- Hand digging is limited to waist, therefore once the water is struck dewatering is recommended to optimize aquifer penetration. This will ensure sufficient yield of the well is achieved.
- Wellhead protection with concrete slab to avoid contamination

Although water struck levels are expected at depths shallower than 60 m, it is important to understand that the cumulative yield of the well/borehole will increase with depth as deeper aquifers are penetrated.

- Geological rock samples should be collected at 2 meter intervals. Struck and Rest water levels and if possible, estimates of the yield of individual aquifers encountered, should also be recorded.
- A piezometer should be installed in the borehole to enable monitoring of the water level.
- 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 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

The proposed drilling site is known to the client Mr. Namanjalala African Devine Church the client

7. REFERENCES

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GIBSON, A.B. 1950. Geology of the Broderick Falls Area, Ministry of Environment and Natural Resources, Mines & Geol Dept., Kenya, Report No. 26

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Appendix 1: Drilling and Construction

Drilling Technique

Drilling should be carried out with an appropriate tool preferably a rotary drilling machine.

Geological rock samples should be collected at 2 meter 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 hydrogeologist should make the final design.

Casing and Screens

The well should be cased and screened with good quality material. Owing to the depth of the borehole, it is recommended to use steel 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 meter 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 meters grouted with cement to ensure that no surface water at the wellhead 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.

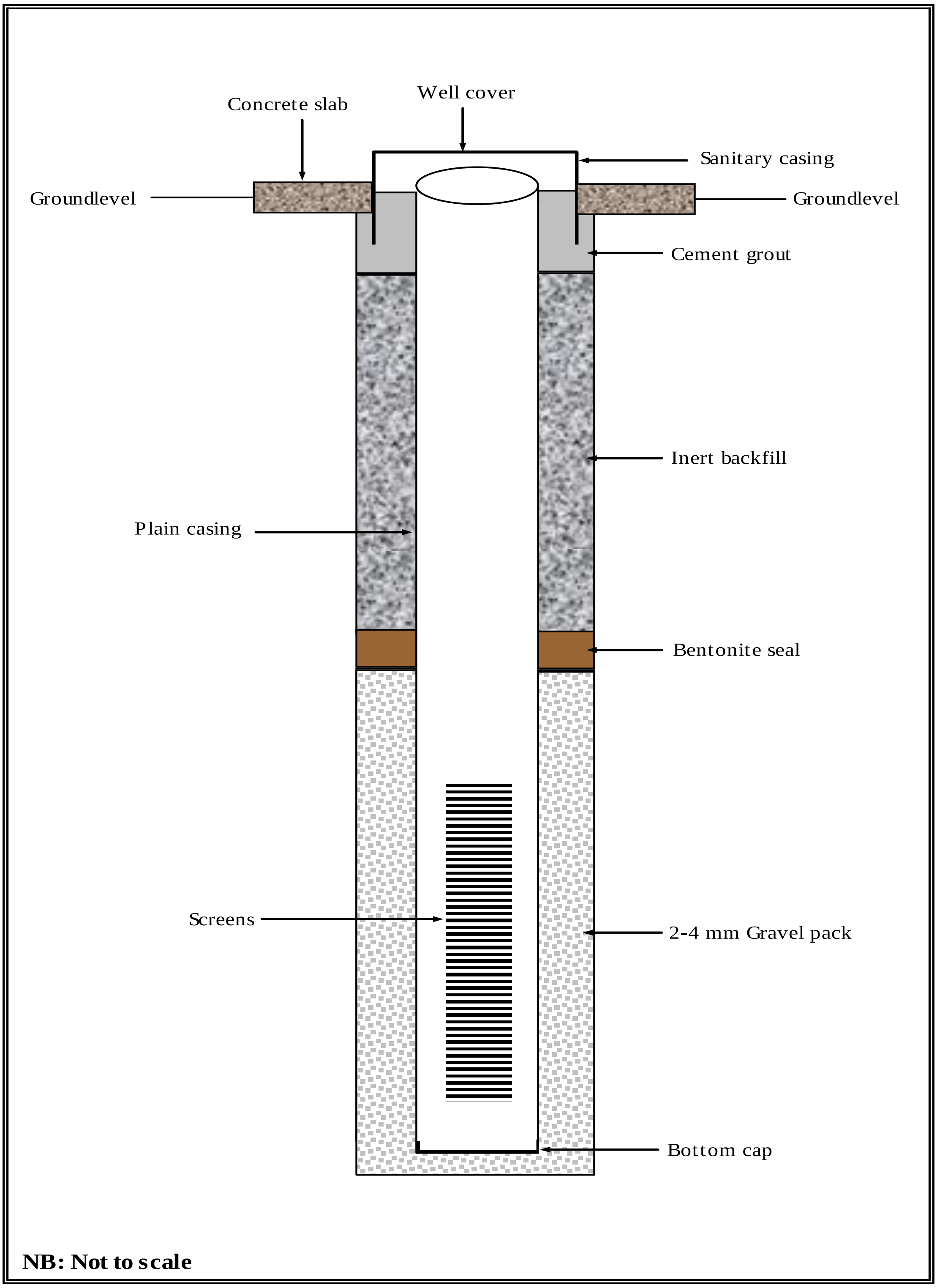
Well development is an expensive element in the completion of a well, but is usually justified in longer well-life, greater efficiencies, lower operational and maintenance costs and a more constant yield. Within this frame the pump should be installed at least 2 m above the screen, certainly not at the 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 stepwise during the test each time equilibrium has been reached (Step Drawdown 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 24 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 a hydrogeologist to calculate the optimum pumping rate, the pump installation depth, and the drawdown for a given discharge rate.



Schematic Design for Borehole Completion