GEOLOGICAL HYDRO-GEOLGICAL ENGINEERING CONSULTANCY

Groundwater prospection & Investigations, Drilling Techniques & Supervision, Geotechnical Site Investigations and Civil Engineering

Abdulnassir Rd, Kilifi Corner (Opp. National Oil)
IITACK Computer College
Mobile: 0722 757 753/0735 776 649
P.O. Box 40925, Mombasa – Kenya

Our Ref: GC/20/31 13th November, 2020
Your Ref: ……………………………

HYDROGEOLOGICAL SURVEY REPORT

CLIENT:
BARAKAJEMBE COMMUNITY BOREHOLE

P.O. ADU

GEOLOCATION SITE:
BARAKAJEBE - ADU AREA
KILIFI COUNTY
S 02°49´57.6"; E 039°56'39.4”

MAN'GON'GO OCHARO
REG .GEOLOGIST/HYDROGEOLOGIST .
Website: www.geoconsult.co

ABSTRACT

This groundwater report describes the hydrogeological and geological conditions existing within the proposed Barakajembe community borehole site area and its environs located at Barakajembe - Adu area within Kilifi County.

This survey has been carried out in view of determining the groundwater prospects and potentiality within the Barakajembe primary school and its environs.

The climatic conditions of the area, as per the available data from the Meteorological Department, can be summarized as semi humid fairly to very hot in some seasons especially December to March with mean annual temperature ranging between 24° to 30ºC.
The average annual evaporation is 2200mm whilst the mean annual precipitation is approximated at 1100mm.

A comprehensive geophysical works carried out at the site and of the available data and the extrapolation of known geological conditions of the area have enabled a fairly accurate picture of the groundwater potentiality and the underlying rocks of the surveyed area to be concluded.

One (1) Geophysical Surveys measurements have been carried out at the site, to investigate the geohydrological and subsurface geological condition.

In view of the above and the geophysical interpretation results it is observed and concluded that there are chances of striking groundwater within the surveyed areas.

It should be noted that **the quality and quantity of the recommended borehole cannot be determined at this stage of the investigation until drilling is complete and the above parameters determined.**

Recommendation is therefore made for the client to drill a borehole to the maximum depth of 230 meters on marked site
The importance, correct, professional and comprehensive technique in this particular field is of paramount importance and should be given the attention it deserves.

GEOLOGY

The detailed Geological Report of the Adu areas and their environs is discussed in the reports by: L.A. Williams (1953/1956).

The surveyed area is part of the Coastal belt whereby a series of three, more less parallel zones or plains, each slightly dissected by denudation which rise in steps one above the other towards the interior. Trending from East to West the zones are distinct.

1. The Coast plain, which is occupied by Pleistocene deposits.
2. The foot plateau, which is practically coincident with Jurassic outcrops.
3. The Coast Range, formed essentially of the Upper Duruma Sandstone, owing its eminence to resistant bands of grit that occur within it.
4. The Nyika, being the area covered by the Duruma Sandstones series and gneisses West of it covering the greater part of the Tsavo west and East on the Galana areas.

The surveyed area falls under the Coast Plain formed of the Pleistocene deposits.

Geologically the area is underlain by the calcareous sandstone and fine grained calcareous conglomorates of tertiary age which are in turn overlain by the radish brown windblown sands of the Pleistocene age.

a. Groundwater

In groundwater, the porosity of a rock is an important parameter in regard to its potentiality as a water bearing zone. In sedimentary rocks the porosity differs with the morphology and texture of the rock material. Sandstone which is compacted possesses low to poor porosities while unconsolidated rock materials such as sands, corals have high porosity which increases the recharge, therefore make good aquifers. In the surveyed area, the stratigraphic sequence is composed of Cretaceous age formations as mentioned above. The permeability of these formations will largely depend on the size of the cavity or pore space. Thus, the larger the pore the higher the permeability and vice versa. Sand formations normally make excellent aquifer material due to their morphology and the higher rate of permeability and transmissivity rates that they possess.

b. Recharge

Recharge of any geological setup is depended largely on the precipitation of the area. The recharge for this area is derived from local precipitation of about 1100mm annually.

The mechanism of the recharge into the aquifer zones is through vertical and lateral infiltration processes.

The recharge of any borehole is determined after drilling is complete and during test pumping this parameter is calculated.

The procedure is when the pumping is ongoing the drawdown increases and the cone of depression expands.

This concept makes it possible to calculate the transmissivity from the time/drawn data using following equation:

$$\boldsymbol{T = \frac{264Q}{\Delta S}}$$

Whereas ***T***= coefficient of transmissivity in lpd/m

Q= pumping rate in lpm

Δ***S***= slope of the time drawdown/graph

c. Aquifer Transmissivity

The aquifer transmissivity is calculated from pump rate and slope of the time-drawn graph using the following relationship developed from the following equation:

T = 264Q where T is the coefficient of the transmissivity lpd/d, Q being the pumping rate in lpm while Δs is the slope of the time-drawn graph expressed as the change in drawdown between any two times on the log scale.

d. Borehole Specific Capacities.

The specific capacity of a borehole is the relationship of the drawdown to yield. Well operating under confined conditions shows that the yield is directly proportional to the drawdown expressed as H-h as long as the drawdown does not exceed the distance from the static potentiometric surface to the top of the aquifer (water table). If the drawdown exceeds this amount then the proportionality does not hold true.

In case where a well/borehole has been sunk through an unconfined aquifer the part of the formation within the cone of depression is dewatered during pumping. This exercise affects the ratio of the drawdown to yield. This means that the specific capacity reduces with increasing drawdown.

e. Storage Coefficient

The coefficient of storage is also readily calculated from the Time-Drawdown graph by using the zero-drawdown intercept of the straight line, as one of the terms:

$$S = \frac{0.3Tt_o}{r^2}$$

Where S is the storage coefficient, T is the coefficient of transmissivity in lpd/m, 't_o' being the intercept of the straight line at zero drawdown in days while 'r' is the distance in meters from the pumping well to observational well.

f. Hydraulic Conductivity

Hydraulic conductivity is the capacity of a porous rock material to transmit water, which in hydrogeology is expressed in the following equation:

$$K = \frac{k\mu}{\rho g}$$

Where K is the hydraulic conductivity, μ is the dynamic viscosity ρ is the fluid density while g is the acceleration of the gravity.

Hydraulic conductivity is controlled by the size and shape of the pore space; effectiveness of the interconnection between pores and physical properties of the fluid. Where the pores are small the flow is constrained while when the pores are large enough the higher the flow.

g. Groundwater Influx

Groundwater influx is the process that water flow within the underground medium. Darcy (1856) recognized that the flow of water through the ground is analogous to the pipe-flow, and from the experiment conducted it was found that the rate of flow through a column of saturated sand is proportional to the difference to hydraulic head at the ends of the column and inversely proportional to the length of the column by using the following Darcy's Law:

$$V\delta f = \frac{K(h^1 - h^2)}{L}$$

Where $V\delta f$ is the Darcy Flux (specific discharge); $h^1 - h^2$ is the difference in hydraulic head while L is the distance along the flow path between points h^1 and h^2 and K is the hydraulic conductivity. This formula assumes that discharge occurs throughout the cross-section area.

h. Assessment of the Groundwater systems

In the assessment of the groundwater system of this surveyed area there are no existing drilled recorded boreholes which would have served as a basis for the assessment of the groundwater characteristics to be determined. The closest borehole is approximately 6 kilometer away at Adu Catholic Church.

The stratigraphy, as observed from the geological map of the area, indicates that the groundwater is struck within the Pleistocene sediments composed of the Magarini sands of the quaternary age.

The observation is in agreement with the resistivity sounding analysis.

From the analysis, there's a high likelihood of water being struck within the weathered strata of corals and the sands

Water Quality

Microbiological quality of groundwater.

1. Pathogens and pathways.

Water can transport many different pathogenic micro-organisms. These which concern us occur in the feaces of humans and some animals. Infections result when someone who is susceptible consumes contaminated water.

Generally these pathogens exist as viruses, bacteria, protozoa, and helminthes. The bacteria and protozoa are the most common pathogens found in groundwater.

VIRUSES	BACTERIA	PROTOZOA
Coxsackievirus	Escherichia coli	Crypostoridium parvum
Echovirus	Salmonella spp	Giardia lambilia
Norovirus or Norwalk	Shigella spp	Campylobacter jejuni
Rotavirus	Yersinia spp	-
Enteric adenovirus	Legionella spp	-
Calicivirus	Vibrio cholera	-

Table 1: List of the common pathogens in groundwater.

CATEGORY	TOTAL DISOLVED SOLIDS (TDS) mg/l
Fresh water	0-1000
Brackish water	1000-10,000
Saline water	10,000-100,000
Brine water	More than (>) 100,000

Table 2: Simple groundwater classification based on Total Dissolved Solid (TDS).

In discussion of the Water Quality within the Coastal Region, the area would be sectioned into two major portions, namely the **Coastal strip with close proximity to the sea** and **further hinterland**.

The general water quality with close a proximity to the sea (Coastal) is brackish due to the closeness to the sea and the geological formation of the area which is composed of the Pleistocene deposits of the coral breccias and solid corals (limestone) rich in calcium carbonate minerals.

The other factor that contributes to the groundwater in this section to be brackish is the low and high tide oscillation phenomenon, since the area is close to the sea during high tide the water in the borehole rises due to the high tide while during low tide the water rest revel in the borehole drops.

In some section of this coastal area there exists the Gyben Herzberg relation (fresh water- salt water interface) where the lesser brackish water is above the brackish/saline water.

The hinterland section have high mineralized(Saline) groundwater due to the desiccation which occurred when the sandstone (Duruma sandstone) were being deposited and when mineral salts, mainly carbonates, chloride and sulphates were being precipitated and in turn these salts disseminated throughout the succession with varying degrees of concentrations and since they were partly soluble they were readily dissolved by groundwater, hence the groundwater drawn and derived from these beds and deposits is saline.

GEOPHYSICS

Tabulated below are the results of the geoelectrical sounding carried out at the site to a maximum depth of 160 meters to determine the subsurface geology.

V.E.S .No	DEPTH(M)	RESISTIVITY(ohm-m)	GEOLOGICAL CONDITION.
GC/20/31	0 –2.20	1339	Top dry sands
	2.20-250	110	Coral breccia/clay
	250- ∞	∞	Pliocene corals/clay

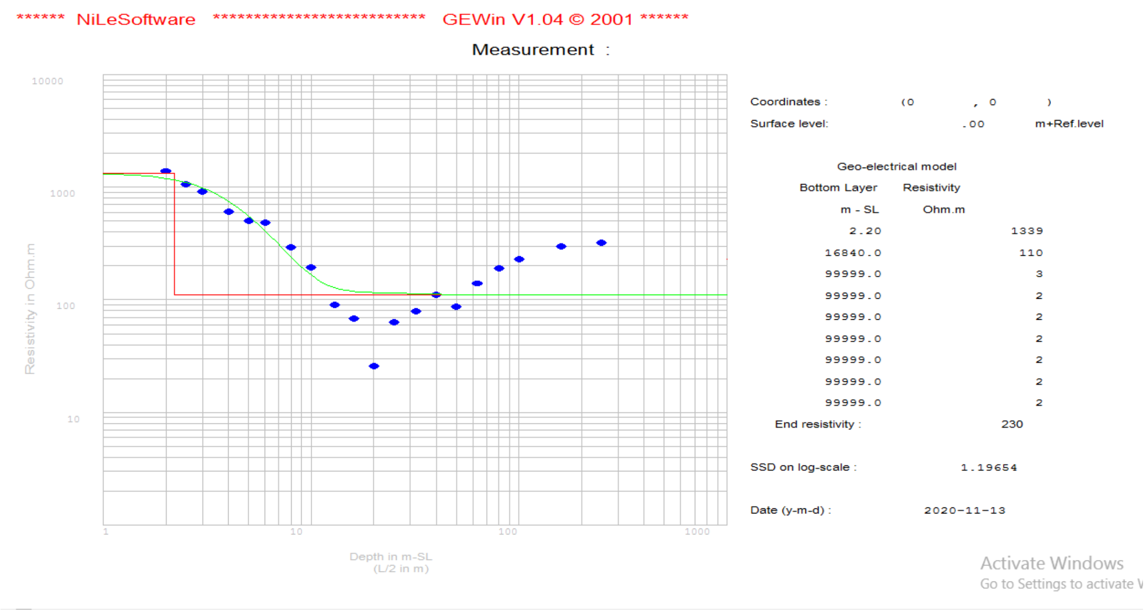


Figure 2 Computer interpretive geoelectrical soundings.

The above sounding was carried out using the **Geotron Resistivity Meter Model G-41 of Geotron Systems (Pty) Ltd** (see picture below) applying the ***Schlumberger Method***, probing to the maximum depth of 100 meters. See the plate below:

Plate 1: Geotron Resistivity Meter (Model G-41).

There are other several electrode arrays used in geophysical groundwater prospection but the *Schlumberger* is most suitable for probing at greater depth especially when the groundwater is deep seated. The other methods of arrays are *Wenner, Partitioning, Azimuthal, Parallel, Perpendicular, Radial, Equatorial and Axial or Polar*. The *Wenner* is usually used for geophysical profiling to locate anomalies especially in basement consolidated formations.

Below are the commonly used Geo-electrical Arrays:

WENNER ELECTRODE ARRAY

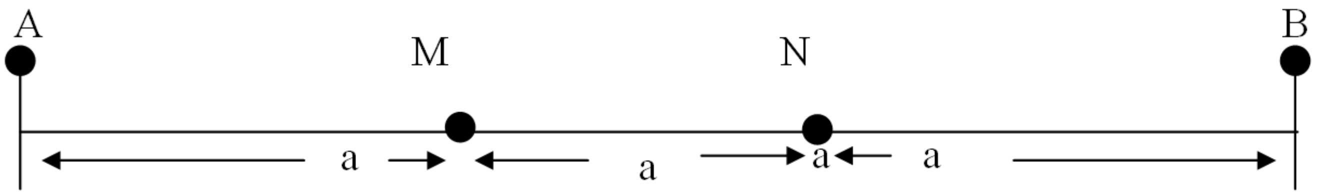


Figure 2: The Wenner Electrode array.

SCHLUMBERGER ELECTRODE ARRAY

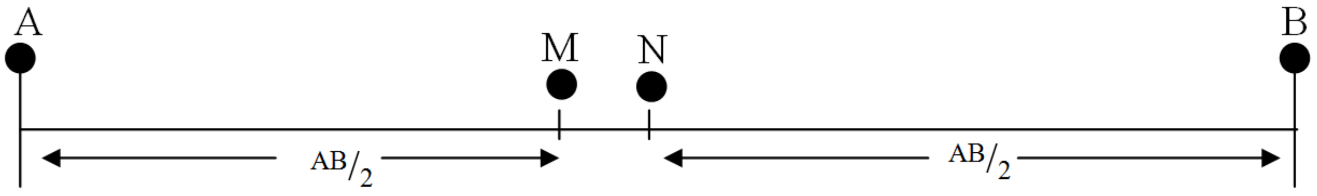


Figure 3: The Schlumberger Electrode array.

BOREHOLES

A borehole is relatively a small diameter (6,8,10 inch) hole vertically drilled into the ground. These boreholes are usually used in urban and rural water supply projects.

Boreholes have several advantages, namely:

- They are quick to construct, if the right equipment is available;
- They can be drilled deep, and this can aid in tapping deep seated, sustainable groundwater.
- They can be drilled in hard basement and granitic rocks.
- Effective filtration seals can be installed to aid filtration of the highest order.
- However, it should be cautioned that borehole drilling is an expensive groundwater works which requires specializes drilling rigs. The machinery are expensive to maintain and run.

A borehole is required to be lined up with casings and screens to avoid caving and sediment particles entering into the borehole.

At the aquifer zone (saturated zone) the borehole is lined with perforated casings (screens), while the non-saturated zones are cased with plain casings. The bottom of the hole should be capped to avoid any siltation into the borehole. See details on drilling techniques.

CONCLUSION AND RECOMMENDATIONS

Recommendation is made for the client to drill a borehole at the marked site to a maximum depth of 230 meters.

Drilling should be carried out according to the following procedures:

APPENDICES

APPENDIX I: DRILLING TECHNIQUES

Drilling should be carried out with an appropriated drilling machine, a **Rotary machine.**

The borehole should be drilled with an 8 inch diameter bit (203mm).

Geological rock formation samples should be collected at every 2-meter intervals.

Struck water levels and static water levels should be monitored and recorded keenly.

On completion of drilling the borehole should be cased and screened with 6 inch diameter (152 mm) casings and class “D”, uPVC screens.

APPENDIX II: BOREHOLE/WELL DESIGN AND CONSTRUCTION

The borehole/well should be designed in a way that ensures screens cover the optimum aquifer zones. The well should be cased and screened with good quality standardizes P.V.C. casings and screens. The gravel pack is recommended and should fill the annular space within the aquifer zones to avoid silt blocking the screens. Screen clogging would result in low yields due to siltation in the absence of the gravel pack.

In well construction, the centralizers of the screens and casings should be used at every 6-meter interval to ensure centrality within the borehole. so it would be easier to install the gravel park all around the screens. The remaining annular space should be backfilled with an inert material and the top 5 meters grouted with cement to ensure that no surface water at well head can enter the well/borehole, so as to prevent surface pollution.

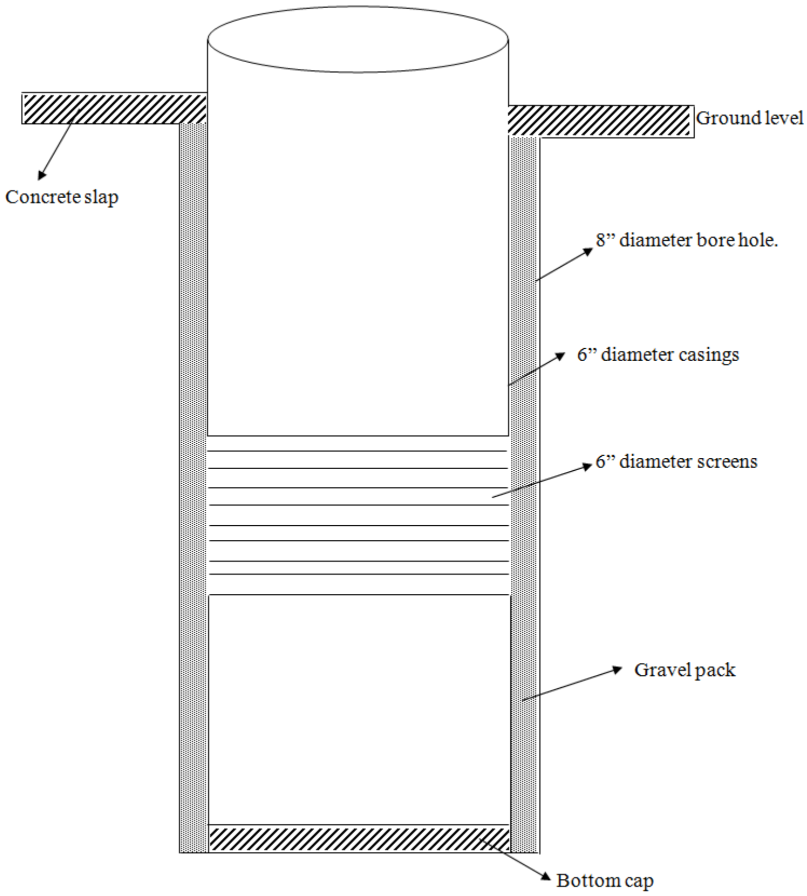


Figure 4: Borehole design and construction.

BOREHOLE / WELL DEVELOPMENT AND YIELD TEST

After the well design and construction the borehole should be developed well without over pumping. Development aims at repairing or reconditioning of the aquifer which may have been damaged during drilling. It also alters and improves the physical characteristics of aquifer around the screens and removes fine particles.

Thereafter, a long-duration yield testing (Pump Testing) should be carried out to determine the following main, critical, parameters:

1. **aquifer transmissivity,*****
2. **drawdown and recharge rates** (measured gradual as pump testing in progress by electrical dipper
3. **Static water level** (measured by electrical dipper)
4. **Pumping water level** (measured by electrical dipper)
5. **Borehole yield** (discharge (Q) per (lpm).
6. **Specific capacity** (borehole yield expressed per unit drawdown (lpm/m)

7. Residual drawdown (During water level recovery, the distance between the water level and initial static water level)

Aquifer transmissivity.

There are three (3) methods used to determine transmissiviy

- Using dated collected during test pumping
- Analyzing the hydraulic properties of aquifer material
- Calculations based on laboratory tests.

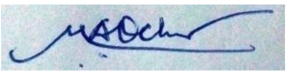
1. The first is based on observing the continues drawdown of the borehole water during pump testing.
2. The second method is to determine hydraulic conductivities of the rock materials (rock samples) from the borehole especially from the aquifer zone. The estimation of the grain size of the cuttings or rock samples from exploratory boreholes/wells. Transmissivity for the individual layer is determined by the multiplication of the strata thickness.
3. The third method need a special laboratory to test field samples using an apparatus with constant-head permeater while the hydraulic conductivity is found by measuring the area of samples and rate of flow and hydraulic gradient.

The borehole water should undergo the chemical and bacteriological analysis by a qualified Chemist, before it is put any use.

All the above works must be carried and conducted with the close supervision of a qualified experienced hydro geologist who will certify the completion of the works as per the required standard

REFERENCES

1. Adelana M.A.Segun, MacDonald M Alan. **Applied Groundwater Studies in Africa;** Internationa Association of Hydrogeologist publication, 2008
2. Caswell and Thompson 1953& 1956; **Geological Reports of Mombasa-Kwale and Kilifi Mazeras.**
3. Bwocharo A. Man'gon'go. **Hydrogeological Investigation using Geoelectrical methods in Uasin Gishu and Yatta Plateus of Kenya**. M.Sc Thesis Unpublished, Brussels 1991.
4. MacDonal,Alan,Davis Jeff,Calow Rodgers.Chilton John. **Developing Groundwater; a guide for Rural Water Supply**. International Association Of Hydrogeologist Publications, 2005.ITDG publication.
5. Owor Michael,Taylor Richard,Mukwanya Christine and Tindimugaya Clallist. **Groundwater/surface water interaction on deep weathered surface of low relief; Evidence from Lake Victoria and Kyoga, Uganda**. Hydrogeology Journal Vol. 19 number. 7 November 2011.
6. Zezza Fulvio, Di Sipio Eloisa ; **Present and Future challenges of Urban systems effected by seawater intrusion; A case of Venice Italy** ; Hydrogeology Journal Vol. 19 number. 7 November 2011.



M.A.OCHARO

REG. GEOLOGIST/ HYDROGEOLOGISTS