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HYDROGEOLOGICAL SURVEY REPORT

FOR

OUR LADY OF ASSUMPTION CATHOLIC MISSION

KAMPI YA JUU

BOX 688, ISIOLO.

COMPILED BY:

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SUMMARY

This report summarizes and describes the results of groundwater potential surveys carried out on a piece of land located 4 Kilometres within Kampi ya Juu, Southwest of Isiolo Town, Eastern Province of Kenya. Father Munene, who is in-charge of the Parish, intends to put up a water supply in order to enhance development. Other developments include: - a church and some few classrooms. Future developments will include a dispensary, among others.

The water demand is estimated to be about 40 cubic metres per day for domestic purposes. The current water sources are from Isiolo Water Company whose water supply hardly reaches the consummers. Alternative water source is the Isiolo River which is located 3 kilometres away. No other feasible alternative sources of water exist within the vicinity of the project area except ground water.

Due to lack of reliable water supply, Fr. Munene has sought professional advice on the possibility for exploration of alternative and reliable water sources. The objective of the water investigations was to establish the optimum location for drilling of one borehole to provide water for domestic purposes.

This report therefore outlines the hydrogeological studies carried out on the site so as to arrive at the right conclusions and recommendations. The report is based on the site visits, the findings and analysis of available hydrogeological, geological and geophysical data from the project area.

The report concludes that the area is of high groundwater potential. Available data of boreholes near the surveyed area indicate moderate but varying borehole yields. Underlying the area, are the grey clayey soils, the calcrete (Kunker limestone), Basalts, and the deeply seated Metamorphic Rocks, in that stratigraphic order.

The main water-bearing zone is encountered within the intervolcanic zones and the weathered zones between the volcanic and the Metamorphics. The borehole yields range from 5 to over 15.00 m^3 per hour (**50-150 m^3 /Day**). Sufficient groundwater will be struck from the proposed borehole, thus meeting the Centre's water needs. The groundwater quality is expected to be better for most purposes.

During the drilling exercise, there will be need to carry out water quality analysis for information and record purpose. The report recommends that a borehole should be drilled at the selected site to a **maximum depth of 80 metres.**

The drilling site is pegged on the ground and also marked on the map extract.

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1.0 INTRODUCTION

This report summarizes and describes the results of groundwater potential surveys carried out on a piece of land located 4 Kilometres within Kampi ya Juu, Southwest of Isiolo Town, Eastern Province of Kenya. Father Munene, who is in-charge of the Parish, intends to put up a water supply in order to enhance development. Other developments include: - a church and some few classrooms. Future developments will include a dispensary, among others. The land covers about 2 acres.

The water demand is estimated to be about 40 cubic metres per day for domestic purposes. The current water sources are from Isiolo Water Company whose water supply hardly reaches the consummers. Alternative water source is the Isiolo River which is located 3 kilometres away. No other feasible alternative sources of water exist within the vicinity of the project area except ground water.

In order to achieve this objective, Fr. Munene commissioned a consulting hydrogeologist to carry out the relevant hydrogeological survey within the plot. The objective of this study is to assess the availability of groundwater, comment on aspects of depth to potential aquifers, possible yields and water quality in addition to recommending a drill site for the proposed borehole.

2.0 TERMS OF REFERENCE

The consultant was commissioned to carry out a hydrogeological survey of the project area and subsequently present a hydrogeological report under the following terms:

- Compile all the available hydrogeological, geological, geophysical and hydrological data for the project area.
- Analyse all the above data in order to assess the ground water potential of the project area.
- Select the most suitable borehole site within the project area subject to the results in i-ii above, accessibility, and the requirements of the Water Act.

3.0 BACKGROUND INFORMATION

3.1 Geographical Location, Topography and Cover Type

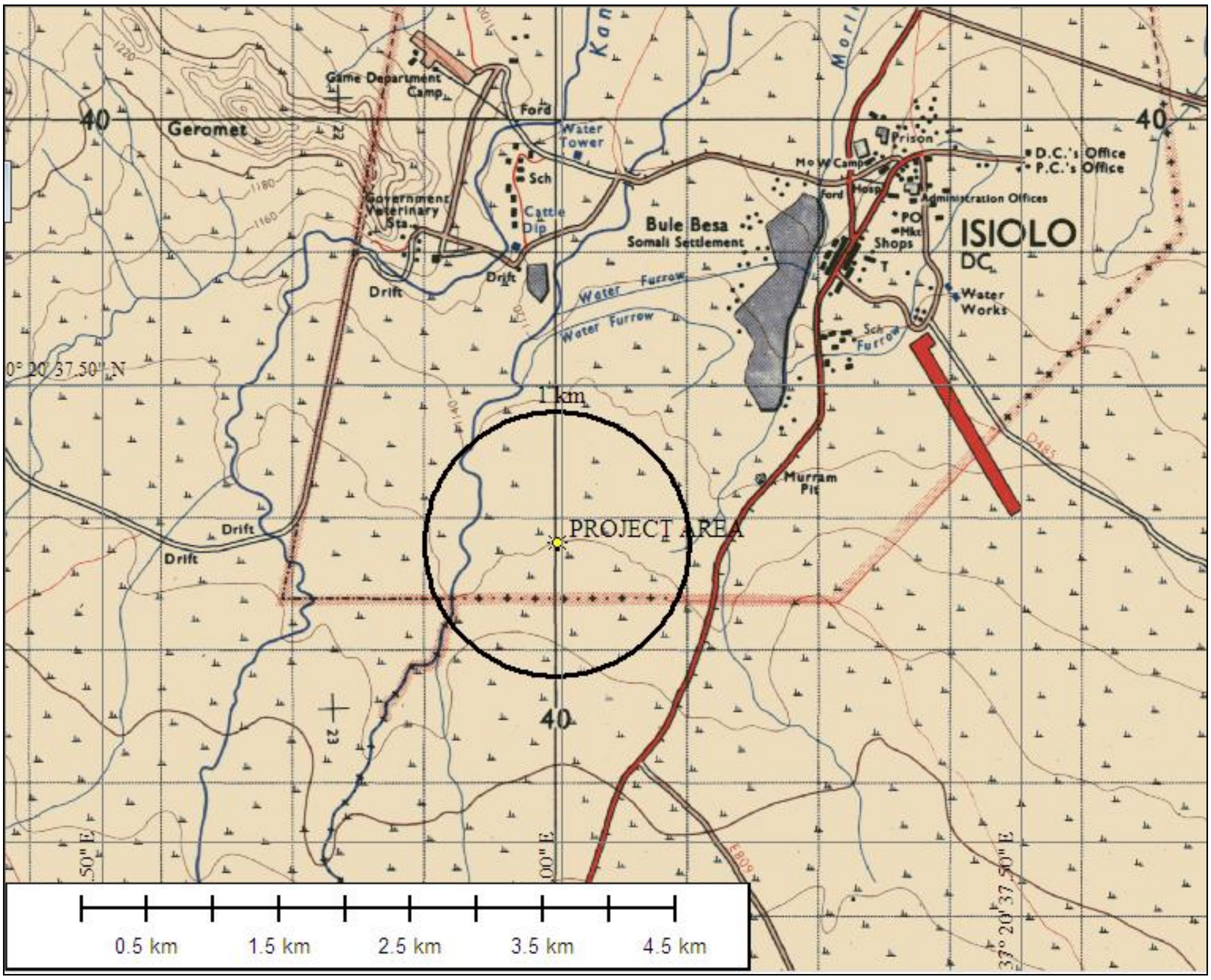
Our Lady of Assumption Catholic Mission is located about 4 kilometres to the Southwest of Isiolo Town. The plot slope to the north, while the southern side, which is raised offers a good panoramic view of the surrounding features. The plot is being developed and currently there are a church, classrooms/nursery and a residential house. There is Nanyuki-Isiolo or Maru-Isiolo all weather road located 2 kilometre to the east.

The topography of the area is varied, reflecting closely the details of the underlying geology. Most of the land surrounding the project site is undeveloped. Where a moderate thickness of soil cover has accumulated, are extensive groves of

Euphorbia trees. Number of these trees also flourishes in the highly calcareous soils and limestone-rubble overlying the lacustrine sediment.

The project is at an elevation of 1175metres above mean sea level. Generally, the land slopes to the north. There are depressions located to the far west and act as the main drainage system.

LOCATION : E 37.30961895^0
N 0.33446446^0
ELEVATION : 1158METRES amsl
MAP SHEET : 108/1



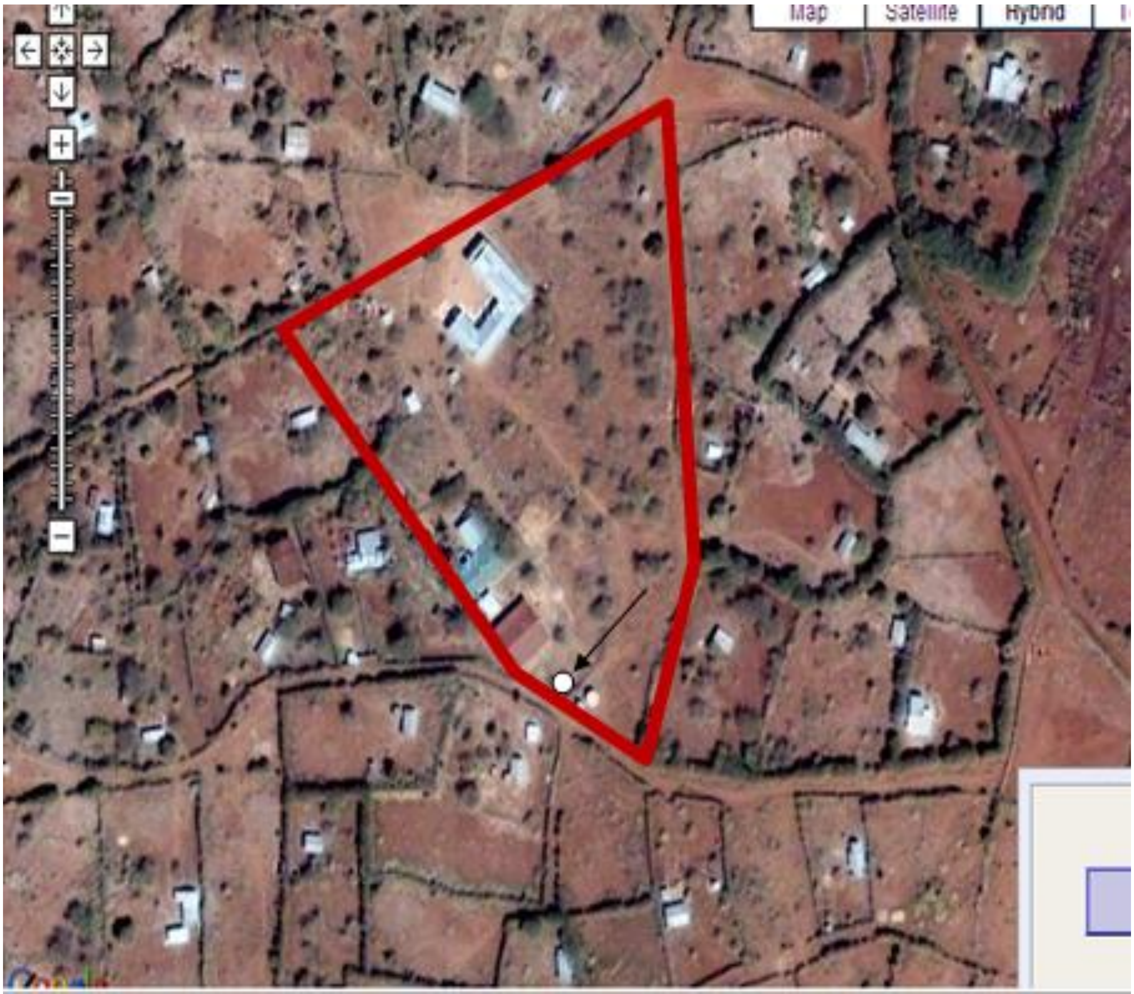
TOPOMAP OF THE PROJECT AREA.

3.2 Climate and Rainfall

The climate is hot and dry and the area often subjected to strong easterly winds. The rainfall is slight and variable, concentrated into two short rainy seasons, one in April and another in November. Rainfall is highly localized, often occurring as abrupt torrential storms sweeping across the countryside from the east. Mean annual rainfall amounts to about 500mm, while the temperatures averages about 29^{o}C
.

3.3 Current Land Use and Potential

Generally, in this semi-arid region, water supply is all-important, dictating the distribution of settlement. The Isiolo River located 3kilometres away is the life-line of the entire area and this has led to inadequate water supply for various uses. The community keep goats, sheep, cattle, chicken, while donkeys are used for carrying loads and water.



SATELLITE IMAGERY OF THE PROJECT AREA.

3.4 Approximate Demand

The proposed borehole is expected to meet the Centre's water needs. It is therefore estimated that about 40 cubic metres per day is adequate to meet the domestic water demand.

4.0 WATER RESOURCES

4.1 Surface Water Resources

There is no surface water resource in the vicinity of the project area. However, during the rainy seasons, the valleys do collect water that seeps underground while the rest is drain by a nearby seasonal stream that flows in a northwards direction. Isiolo River is located over 3 kilometres away.

4.2 Groundwater Resources

The most reliable source of water in the area is groundwater. It is however undeveloped due to low groundwater potential sites and/or due the required capital to drill a borehole.

The volcanic rocks, which comprise the solid geology of the area, are not in themselves particularly permeable. However, groundwater does occur in fractured zones and weathered layers commonly referred to as "old land surfaces" (erosion layers formed between successive lava flows or fracture zones and are usually water bearing). Most of the volcanics have been eroded over time and replaced by lacustrine sediments.

Boreholes drilled close to the survey area are successful. The average depth of these boreholes is about 100with. The aquifer is adequately replenished/recharged from local precipitation of 1800mm per annum through lineaments and from the Mount Kenya located to the far South. The water potential of the area is generally considered as high.

5.0 GEOLOGY

5.1 Regional geology

The geology of the project area comprises of a succession of clayey soils and gravels of quaternary age, lavas and pyroclastics rocks of Cenozoic age, while the underlying Archaen Basement system comprises the Pre-Cambrian Schist and Gneisses of the old Mozambiquan system of Rocks.

The deposition of the Cenozoic formations was accompanied by phases of volcanic activity and crustal movement. Doming, linear warping, faulting and erosion of the Sub-Miocene surface also accompanied the extrusion of the lava.

The Cenozoic lavas have all been affected by tilt such that only those to the south of the study area show their original depositional dip. The basalts flows have been eroded with time to expose the Formation below, which covers most of the study area.

The Basement System, forming the floor of the volcanics represents an old land surface of Pre-Cambrian. Schist and Gneisses are exposed to the far west and north of the present area with considerable relief.

5.2 Local Geology

The area is characterized by shallow or absent overburden, with exposures of the underlying rocks that comprises of the Kunkar Limestone and Basalts in various thicknesses. The geological succession underlying the project area consists of the Cenozoic volcanics, which in geo-chronological order, consists of the following formations: Clayey soils/kunkar Limestones, Basalts, Pyroclastics, Sediments and Basement Rock.

The younger, Pleistocene basalts overlie the metamorphic within the study area. These basalts originate from Mount Kenya and the Nyambeni hills, a multi-centre volcanic ridge southeast of Isiolo.

However, along the road, fairly fresh compact basalt is overlain by weathered limestones and basalts, and itself overlies older lava flows and the Basement system

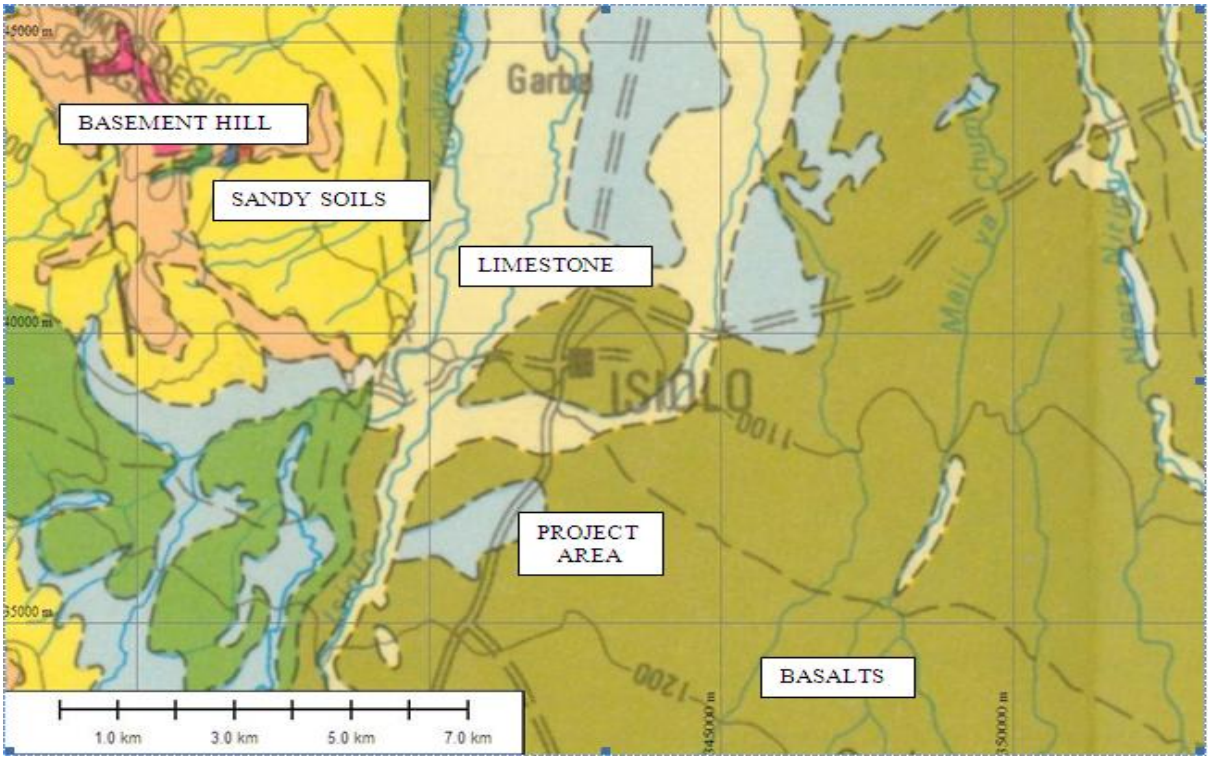
The basalts are covered by younger limestone deposits that are partially a lacustrine deposit and partially a precipitate of evaporating groundwater from the lavas (kunkar limestone). Pleistocene and Recent Alluvial deposits are found everywhere in and along the few rivers and laggas.

The Lower Nyambeni basalts are porphyritic and often markedly vesicular, Olivine bearing types and leaving very fluid and mobile at the time of eruption, spread out widely over the comparatively flat surface of the end-Tertiary peneplain.

The various flows of the Upper Nyambeni volcanic rock show an appreciate variation in composition and texture for, in addition to basalts and prophyritic olivine basalts, there are phonolites, porphyritic phonolites and tephrites present.

The presence of the inselbergs as the Basement outcrops, suggest the relative proximity of the underlying Basement in the area.

The Basement System forms the floor upon which all the remaining rocks of the area rest, consisting of quartzo-felspathic gneisses containing varying proportions of biotite.



GEOLOGICAL MAP OF THE PROJECT AREA.

6.0 GEOPHYSICS

6.1 Resistivity Method

Many geophysical methods area available to assist in the assessment of geological sub surface condition. These utilize such properties such as Electrical, Electro-magnetic, and Plastic etc. In the present survey the resistivity sounding data obtained from a neighbouring plot was used to study the underlying rock connections capable of groundwater storage. Resistivity sounding had been carried out by use of an ABEM 300C Terrameter.

In the present survey, the main emphasis of the fieldwork undertaken by the consultants 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.

6.2 Theory

Geophysical prospects is often involves in the assessment of groundwater resources. Its appeal is in fact that geophysical data acquired at even above the Earth's surface contain information about the sub surface. This physical information may be disclosed and interpreted in a hydro geological context and benefit a groundwater investigation. One of the main contrasting subsurface physical properties is the electric receptivity. They range from less than 10hm-m for some mineral bearing rocks and saltwater fitted sediments to more than 10000 Ohm-m for unweathered intrusive rocks (granite, gabbro and rock salt).

Effective interpretation of geophysical data is by no means a simple task. Due to its very nature, inversion of surface geophysical data into a model that represents the subsurface spatial variation of the involved physical property is mostly not exclusive. All subsurface models that fit into the data measured at the Earth's surface are equivalent. Geophysical data, geologic data groundwater data, and petrophysical data, experience and insight into the hydrogeology of the project area are necessary in interpretation.

The voltage drop across an infinitesimally thin shell of material of thickness ‘dr’ around the source follows from the application of the Ohm’s Law to the shell. The current through the shell is ‘I’, whereas its resistivity R_{shell} is given by:

$$R_{shell} = \rho.\partial r/4.Л.r^2$$

Thus

$$dv = I.\rho.\partial r/4.Л.r^2$$

$$V = I.\rho.\partial r/4.Л.r$$

This formula describes quantitatively the electric potential around a point source of current in an infinitely extended, homogeneous and isotropic material of resistivity.

The current injected and collected through electrodes ‘A’ and ‘B’ (point sources) respectively, is distributed three-dimensionally in the Earth. With a direct current, the resulting subsurface current distribution is entirely controlled by the sub surface resistivity structure. The relation between subsurface resistivity structure and subsurface current distribution is unique.

A subsurface distribution of direct current sets up a subsurface distribution of dielectric voltages. Current and Voltages are interconnected through Ohm’s law. There is also a unique relation between the subsurface resistivity structure and the subsurface distribution of electric voltages. The potential distribution at the Earth’s surface depends uniquely on the subsurface resistivity structure. This means that in principle all information on the subsurface resistivity structure is contained in the electric potentials at the Earth’s surface. Thus measuring electric potentials at the ground surface in response to passage of a controlled electric through the Earth constitutes a way to obtain information on the subsurface.

In practice and in theory, it is convenient to combine current and potential differences with the geometry of the electrode configuration in a formula that defines a so-called apparent resistivity,

Thus: -

$$\mathbf{K} = \pi.\,[(AB/2)^2-(MN/2)^2]/(MN).$$

$$\boldsymbol{\rho}_a = K.\partial v/I$$

Whereas **K** is the geometric constant of the configuration used.

6.3 Geophysical Methods Applied

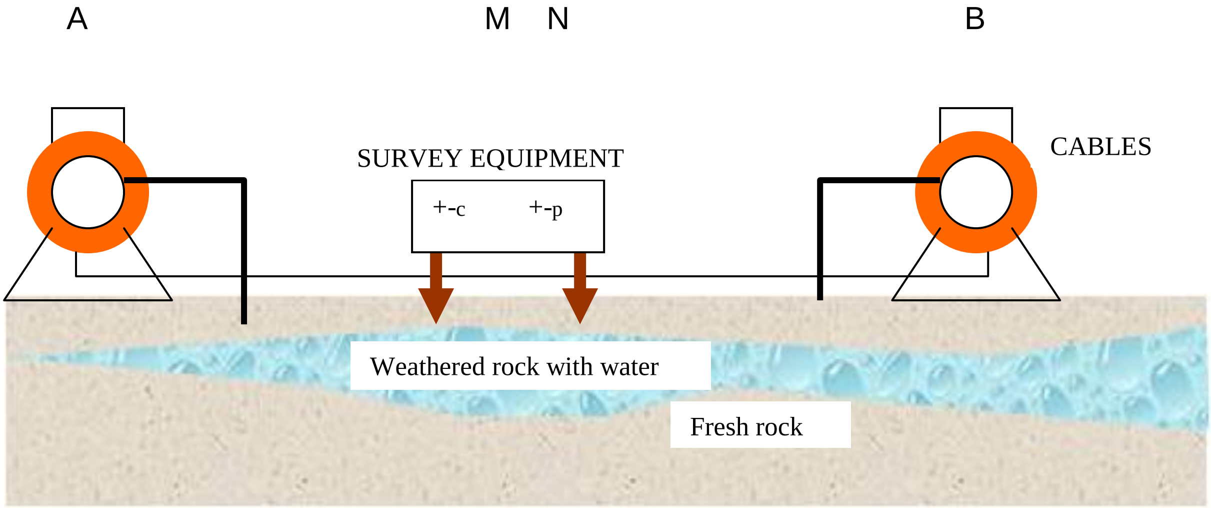
Many geophysical techniques are available for ground water investigations and all of which have advantages and disadvantages. The techniques used for the present survey was the Vertical Electric Soundings (VES). Computer software were used in modelling and data analysis and included VES software, Excel and Global Mapper programs.

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.

Field layout is as shown below.



6.4 FIELDWORK

Fieldwork was carried out on 31st January, 2009. The field visit comprised observation of the general topography, drainage, geological set up and geophysical survey.

The eventual selection of the drilling site was based on groundwater potential; accessibility and future development plans as proposed by the developer. One site was targeted for detailed geophysical surveys.

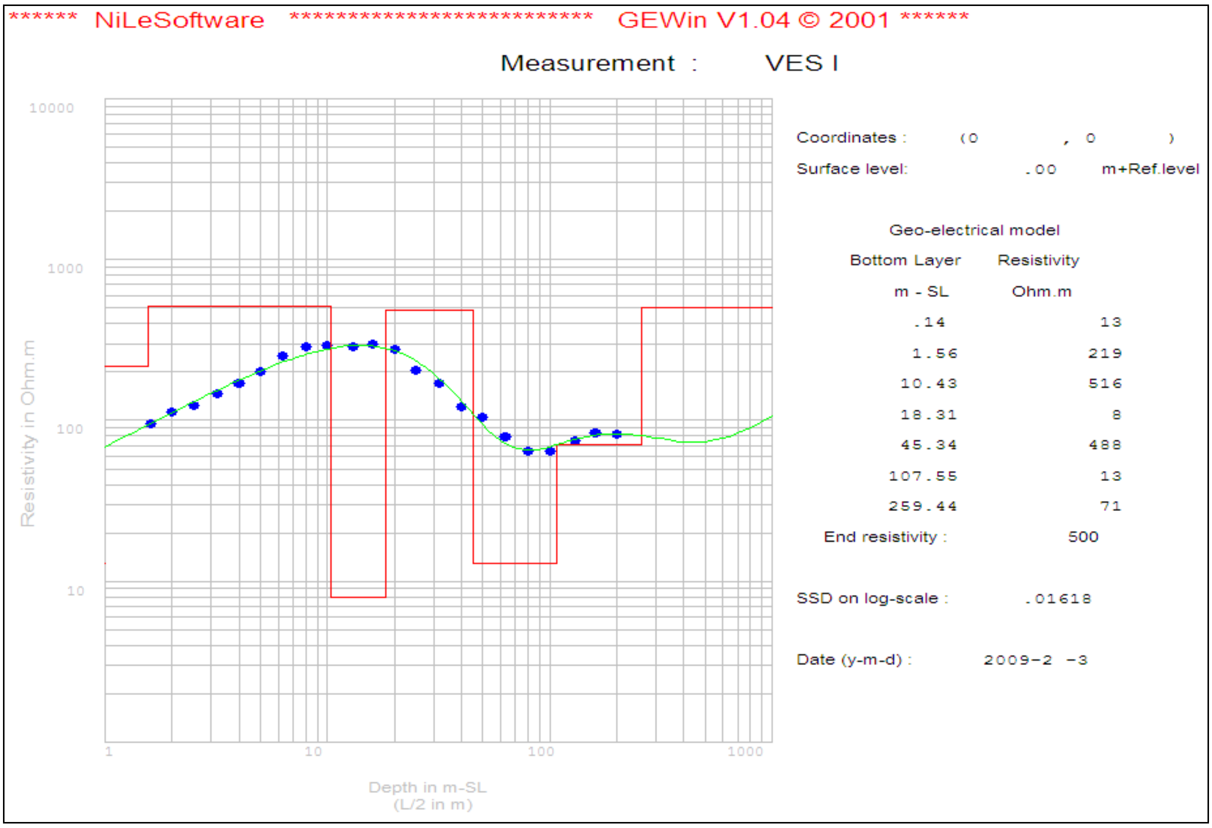
6.5 Results

The study shows thick layers of water bearing zones of weathered and fractured rocks, which extend from 100 metres and beyond. The underlying geology as derived from a correlation approach, where stratigraphy on already completed boreholes in the near vicinity of the site has been used, comprise of various formations as described below.

From the results of the geophysics it is evident that part of the strata is fairly weathered and fractured. Presence of clayey layers is also expected within the "Old Land Surface" between the difference rock strata.

6.5.1 Geophysical data interpretation.

	Thickness (m)	**Resistivity (Ohm-m)**	**EXPECTED LITHOLOGY**
1	**0-0.14**	**13**	**DRY CLAYEY SOILS**
2	**0.14-1.56**	**219**	**FRACTURED BASALT**
3	**1.56-10.43**	**516**	**FRESH BASALT**
4	**10.43-18.31**	**8**	**HIGHLY WEATHERED BASALT/PYROCLASTICS.**
5	**18.31-45.34**	**488**	**FRESH BASALT**
6	**45.34-107.55**	**13**	**FRACTURED BASALT /PYROCLASTICS**
7	**107.55-259.44**	**71**	**HIGHLY WEATHERED BASALT**
8	**>259.44**	**500**	**FRESH GRANITOID GNEISS**



Modeled field data

6.0 HYDROGEOLOGY

6.1. Introduction

The hydrogeology of an area is determined by the nature of the parent rock, structural features, weathering processes and precipitation patterns. Lava flows rarely possess significant primary porespace; instead, groundwater occurs within secondary features, such as fissure zones, fractures, sedimentary beds, lithological contacts and Old Land Surfaces (OLS).

The weathered zones or "Old Land Surfaces" (OLS) characterize periods of erosion between volcanic eruptions and subsequent lava flows. These potential aquifers comprise soils, weathered rocks and water-lain material of volcanic origin. The thickness of the OLS is variable, but the water-producing zones, which are usually sandy or gravelly, rarely exceed a few meters.

Unlike lava flows, pyroclastic deposits and especially volcanic sediments are generally porous: the cavities between the mineral grains are usually open and interconnected. Consequently, they can contain and transmit water.

6.1 Groundwater Occurrence.

Based on the available data of the drilling boreholes and the resistivity values of the fore mentioned geoeletrical units, groundwater occurs in different types of lithological composition and is present under confined or unconfined conditions. There aquifers are discussed as follows: -

6.1.1 Shallow Groundwater confined to the alluvial deposits

During periods of flood, water percolates down into the sandy riverbeds of the lagas. Additional recharge of these bodies may take place by lateral flow from the alluvial deposits along the river. This seepage is usually indicated by the occurrence of secondary limestone along the edges of the alluvial deposits.

The community depends on Isiolo River to the west and occasionally from the Isiolo Water Company..

A problem occurring where calcrete is formed is that a large quantity of the water evaporates, causing an increased salinity of the remaining water. Water with a high salinity can be found in these riverbed deposits where the groundwater becomes stagnant or where it is forced to rise to shallower depths by a natural subsurface dam.

Further, due to leaching from the volcanic material through which the water flows and the slightly elevated temperature observed in some of their flowing for long distances at shall depth under a lava plain devoid of vegetation cover.

6.1.2 Groundwater in the Weathered Basement

The Basement System, if deeply weathered, may contain water in sufficient amounts. This is not always the case, however, as feldspathic rocks usually weather to clays, which form thick, impermeable layers that obstruct re-charge and limit the potential for abstraction.

The coarse sands of the riverbed along Ewaso Nyiro River course Archers' Post form considerable water reservoirs during the wet season. Many lagas in these areas have also been reported to have a perennial sub-surface flow. This means that during the greater part of the year water can be found in the riverbed deposits.

6.1.3 Groundwater in the fractured Basement

Groundwater in basement areas may also occur in fractured zones in the basement rocks such as faults or joint systems. These fracture systems may store groundwater in reasonable quantities and enhance the sub-surface recharge.

6.1.4 Groundwater in Volcanic Rocks

The volcanics in Isiolo District are of a type that are usually well fractured and which show large, interconnected cavities. This enables the rocks to store and gradually discharge large quantities of groundwater. At the edges of the lavas, springs seepage zones occur.

Generally, several boreholes have been drilled close to the study area and are high yielding and the quality of the water is good.

6.2 Recharge/discharge consideration

Groundwater normally occurs in pores and interstices of various rock formations depending on the geological conditions, the physiography of the area, the permeability and porosity of the rock formations, the degree and depth of weathering, fracturing of the rock formation and the tectonic historical conditions of the area.

The local recharge to the underlying aquifers is facilitated by the occurrence of permeable zones, in which free groundwater is also present.

The overlying strata confine the basaltic layers. Aquifers in this area may be thick and are mainly located within the weathered intervolcanic zones and the Pyroclastics. The recharge may be derived from the higher areas to the south and also by vertical percolation of rainwater, thus contributing significantly to the total yield.

The groundwater prospects for this area (and indeed for most of the surveyed area) are fairly good with moderate yields being obtained from boreholes drilled to relatively shallow depths of up to 100 metres.

The recharge mechanisms of the confined aquifers of the surveyed area and its surroundings are by either direct recharge at the surface (at up-dipping exposures) or indirect recharge via faults and/or other aquifers.

The volcanic aquifers underlying the study site are most likely recharged indirectly through lateral groundwater flow. In addition, recharge is likely to occur indirectly from the Highlands of nearby hilly areas. The presence of faults/synclines in the area would provide optimum conditions for this transmission.

The movement of groundwater within the aquifers follow gravity; as a result water travels from the west and percolates through successive formations towards the east. Some of the rainwater is conducted through local faults. This mechanism is particularly important for recharge to shallow aquifers of the Escarpment, which through fracture systems subsequently replenish the deep aquifers. The latter provide the most reliable groundwater supplies in the area.

The main area of recharge is most likely formed by the complex of faults within the internal drainage system. Rainfall on the southern flank of the Mt Kenya is relatively high (from 965 to 1,800 mm/year). At these locations water percolates directly into the faults and cracks within the Pleistocene Basaltic formation through which deeper and adjacent units are recharged over time. The amount of recharge and groundwater is known to be significant considering that some boreholes are high yielding. This presumably recharges a portion of the formation and the aquifer underlying the Client’s plot.

6.2.2. Discharge

Discharge from aquifers is either through natural processes as groundwater base flow to streams and springs or artificial discharge through human activities. The total effective discharge from the underlying aquifers via the above means is not known.

6.3. Hydrogeology of the Project Area

The site is located in a hydrogeological zone that is characterized by moderate to high groundwater potential. Recharge is to a large extent received from the south. The main aquifer is struck within the weathered intervolcanic zones.

Local boreholes with depths between 33 and 120 m are commonly marked by yields between 5 and 15 m^3/hr. The maximum reported tested yield in the area is 10m^3/hr.

6.4. Existing Boreholes

Several boreholes have been drilled in the past and were successful with boreholes yields as high (> 6m^3/hr).

Table 1 below gives data for boreholes drilled in the vicinity of the project site.

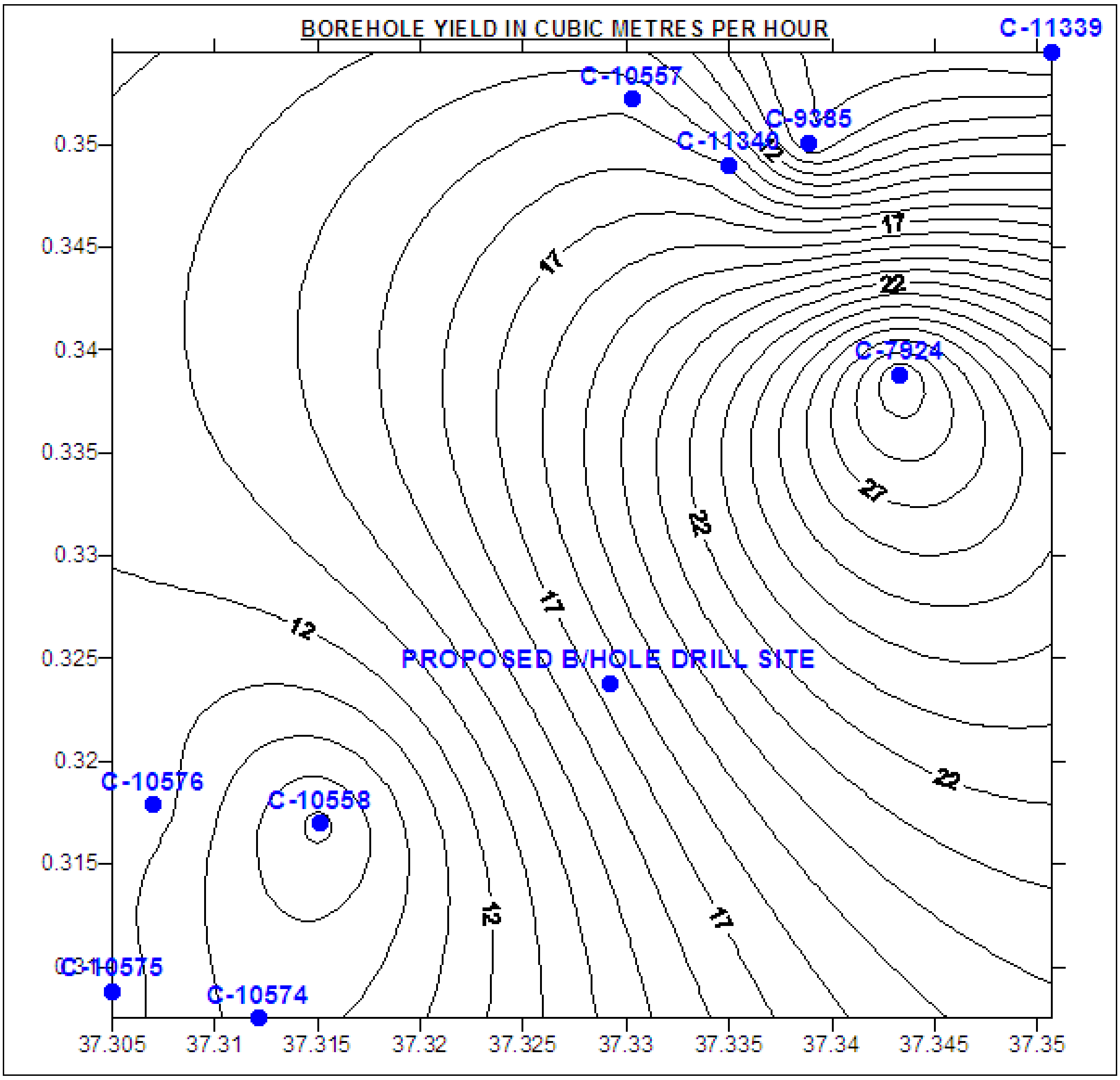
C-Number	Eastings	Northings	Total Depth	WSL_1	WSL_2	WSL_3	WRL	TY(m^3/hr)
RTC	313722	39576	70	33			25	10
C-7924	0.3383	37.597	184	32	58	112	18	30
c-9385			102	33	55		26	9
C-10557	314288	39134	40	11	25		8	14.7
C-10558	312271	34936	101	42.5		94	31.4	7.66
C-10574	311656	33682	104	45.1			15.7	9.6
C-10575	310943	33395	79.8	38.7			13.4	11.5
C-10576	311353	34035	102	35.3	60.8		21.9	11.5
C-11339	315911	38068	91			89	25	8
C-11340	314689	38617	45	30			15	15

The above data indicate that there are few potential aquifers underlying the project area.

The first aquifer is expected between 5 to 100metres below the surface. The borehole tested discharge rates (yield) close to the project site ranges between 5 and over 15m3/hr. The above boreholes have a depth range of between 33m and 120m below ground level.

The variability in tested yields is caused by differences in total drilling depth, hydrogeological site conditions (especially the thickness and depth of the aquifer material), the quality of well design and completion, and the pumping equipment available during testing. It should be noted that the tested yield of a borehole is usually the maximum discharge sustained during a 12 or 24-hour constant discharge test.

The envisaged depth of the borehole is 100 metres. In order to account for possible lowering of the water level (due to depletion and overlapping cones of depression), it may be necessary to drill deeper. However, it must be realized that despite their depth, these holes are relatively moderately yielding.



6.4.1 Hydrogeology of Investigated Area:

- The area is situated in a zone with moderate, but variable groundwater potential. The study concludes that on the basis of the geological evidence, the prospects for medium scale groundwater abstractions are fair.

- A thin layer of volcanic and the sediments underlie the surveyed site, which are both important formations. The geological records indicate that Basement gneisses are expected at depths of over 130m below surface.

- The natural recharge pattern in most of the project area is dominated by groundwater inflow from the far south. Recharge probably largely occurs indirectly by means of groundwater inflow from the surrounding hills and faults/lineaments.

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- The main aquifer is found within the weathered zone, at depths between 40 and 100 metres below ground level.

7.0 GROUNDWATER QUALITY

Practically all types of water, (runoff water, groundwater and even rainwater), contain some dissolved salts and impurities. If certain elements are present in high concentrations, the application of the water for domestic use or any other purpose may be restricted.

The groundwater quality in the surveyed area of fair. The water quality at the investigated site is expected to be better since water from the aquifer is less mineralized, and thus of somewhat better quality.

The quality of ground water in the area is expected to be good; however it is advisable that a sample of water obtained from the proposed borehole be submitted to competent institution for full chemical, physical and bacteriological analysis before use.

Table 2

Below provides the World Health Organization (WHO) guidelines.

QUALITY/ VARIABLE	MEASURING UNIT	WHO GUIDE LINE	COMMENTS
Colour	Mg/l PT	15 TCU	
Hardness	Mg/l $CaCO_3$	500	
pH	pH Units	6.5 - 8.5	
Turbidity	NTU	5	
Arsenic	As mg/l	10	Toxic in excess e.g. bronchial diseases
Lead	Pb mg/l	10	Toxic to animals
Selenium	Se mg/l	10	Toxic in excess
Aluminum Al	mg/l	0.2	Soluble Al salts exhibit neurotoxicity
Ammonia	NH_3 mg/l	1.5	Toxic particularly to aquatic organisms.
Boron	Bo mg/l	0.3	Toxic in high Concentration to plants.
Calcium	Ca mg/l	NS	No Standard
Chloride	Cl mg/l	250	
Fluoride	Fl mg/l	1.5	Dental and skeletal fluorosis
Iron Fe	mg/l	0.3	High concentrations toxic to children.
Magnesium	Mg mg/l	0.1	May cause diarrhoea in new users.
Manganese	Mn mg/l	0.1	
Nitrate	NO_3 mg/l	11	Infant blue baby Syndrome
Potassium	K mg/l	NS	No Standard
Sodium	Na mg/l	200	Chronic, long term toxic Effects.
Sulphate	SO_4 mg/l	250	Taste, odours, cathartic
Zinc	Zn mg/l	3	Toxic in excess
Total Coliforms	per m/L	100	Nil
Faecal Coliforms.	per m/l	100	Nil
Sulphide	H_2S mg/l		Undetectable

8.0 CONCLUSIONS AND RECOMMENDATIONS

From a Hydrogeological point of view and based on the foregoing study, the following conclusions have been made: -

- The hydrogeological conditions within the surveyed area are favourable for the drilling of the proposed boreholes.

- From available records, no aquifers have been struck within the thin overburden overlying the project area. The main aquifer(s) is however, expected to be struck within the weathered contact zones between the lava flow/sediments and the Basement. See chapter on hydrogeology.

- Though a sort of a regional aquifer exists within the intervolcanic flow that underlies the area, records indicate that borehole yields vary. The differences in the yield are attributed to the underlying geological strata and other recharge parameters as well as the type and capacity of the pump used to carry out the test pumping. The final borehole design and construction is a very common source of borehole failure. Proper borehole construction plays a very vital role in the productivity and lifespan of a borehole.

- The few boreholes drilled in the vicinity of the proposed borehole site are between 33 and 120metres deep. The consumption from nearby boreholes is very low since it is used for domestic water supply. This borehole is currently broken down.

- The water requirement from the proposed borehole is 40cubic metres per day to be used basically for domestic purposes.

The following recommendations are proposed: -

- That a borehole should be drilled at the selected site and as shown on the map extract to a maximum depth of **80metres.** **Dr**illing may be discontinued if aquifers with adequate water supply are encountered at shallower depths. The drilling site is pegged on the ground.

- That aquifer(s) struck at less than 5 metres below ground level should be sealed off completely with neat cement grout and/or bentonite.

- The borehole should be fitted with a water master meter to monitor groundwater abstraction and an airline for monitoring of the water levels.

- A qualified hydro geologist should supervise the drilling, construction and test pumping of the proposed borehole.

ADDENDUM I

DRILLING AND DEVELOPMENT PROCEDURES

1. Drilling

Drilling should be carried out with an appropriate tool - either percussion or rotary machines will be suitable, though the latter are considerably faster and higher overheads. Geological rock samples should be collected at 2 metre intervals. Struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered, should also be noted.

2. Well Designs

The design of the well should ensure that screens are placed opposite the optimum aquifer zones. The final design should be left in the hands of an experienced driller or hydrogeologist.

3. Casing and Screens

The well should be cased and screened with appropriate steel casings and screens as per the design given above. In comparatively shallow wells, uPVC casing and screens of 5" or 6" diameter may be adequate. Slots should be 1 mm in size.

4. Gravel Pack

The use of a gravel pack is recommended within the aquifer zone, because the aquifer could contain sands or silts that 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 pumping plant, and leading to gradual `siltation' of the well. The grain size of the gravel pack should be an average 2 - 4 mm.

5. Well Construction

Once the design has been agreed upon, construction can proceed. In installing screen and casing, centralizers at 6 metre intervals should be used to ensure centrality within the borehole. This is particularly important if an artificial gravel pack is to be installed as it ensures an approximately even annular space. If installed, gravel packed sections should be sealed off top and bottom with clay. It is normal practice nowadays to gravel pack nearly the total length of the borehole but seal off the weathered/topsoil zone at the top.

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 wellhead can enter the well bore.

6. Well Developments

Once the screen, gravel pack, seals and backfill have been installed, the well should be developed. Development has two broad aims:

a) It repairs the damage done to the aquifer during the course of drilling by removing clays and other additives from the borehole walls, and

b) It alters the physical characteristics of the aquifer around the screen and removes fine particles.

We would 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, 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 it is usually justified in longer well life, greater efficiencies, lower operational and maintenance costs and a more constant yield.

7. 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 hydrogeologists.

A well test consists of pumping a well from a measured start level (SWL) at a known or measured yield, and recording the rate and pattern by which the water level within the well changes. Once a dynamic water level is reached the rate of inflow to the well equals to the rate of pumping. Towards the end of the test a water sample of at least two litres should be collected for chemical analysis.

The duration of the test should be 24 hours, with a further 24 hours for a recovery test (during which the rate of recovery to SWL is recorded). The results of the test will enable a hydrogeologist to calculate the best pumping rate, the pump installation depth, and the drawdown for a given discharge rate.

8. Well Maintenance

Once the well has been commissioned and a pump installed at the correct depth, the maintenance schedule should be established. Checks on discharge (m3/day), pumping water level (metres below a leveled and immovable bench mark), and static water level (if for any reason the well is not used for a 24-hour period) should be taken as part of a regular, routing process. This will enable the evaluation of all known conditions should reduction in the yield or other problems occur in the future, and recommend the most appropriate action.