UNKEA KATOR REPORT

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Executive Summary

Introduction

The main objective of this project is to carry out a detailed and comprehensive hydrological and geo-physical study of whose main purpose is to locate one suitable site for drilling of a proposed borehole in which to find safe, clean and potable water to serve the purposes of serving workers in UNKEA and the residents in the surroundings. The study took place on the 28th March 2020. It is for this reason that **NSDO Directed** it's geologist to carry out a comprehensive and detailed study of this area. All the area is accessible from Juba .

The study involves running one major HEP or CST including reverse execution ,space being limited, employing ABEM SAS 1000 Terrameter which has the capacity to penetrate and delineate layers underground to up to hundreds of meters using the resistivity mode. The main purpose of employing this mode is to locate anomalous points along the trajectory on which later a VES was conducted. One VES study was executed and concluded that the site selected should be attempted to be drilled.

Terms of Reference

The Hydrogeologist Consultant was commissioned by NSDO to carry out the Hydrological/geo-physical investigations at the identified site in and around the communities to drill one borehole and present a detailed report under the following terms:

a. Compile the available hydrogeological, geological and geophysical of the project area and its environs.

b. Carry out detailed geophysical survey of the proposed borehole sites.

c. Analyze all the above data to assess the groundwater potential of the project area.

d. Select the most suitable locations for the proposed boreholes constructions subject to the results obtained.

e. Compile and submit to the client(UNKEA) comprehensive report which shall include all the relevant details of the above investigations as well as site recommendation.

General Geology

The general geological history of the area can be followed from the Pre-Cambrian era which is represented by the metamorphic rocks of the Mozabican Basement. The regional metamorphism was followed by various cycles of erosion, faulting, graben formation, deposition of continental sediments and by volcanic activity. The structural events played a large role in the formation of the Nile basin, which probably started developing towards its present day form in Oligocene-Miocene times.

The crystalline rocks of the Basement System (Mozabican Belt) occupy the larger part of the area. The Basement System comprises of various types of Precambrian sediments that were transformed by regional metamorphism into gneisses, schists, quartzites and marbles. The Basement System also includes some intrusions. The period between the Precambrian and Tertiary is characterized by repeated uplift and extensive erosion of the Basement System rocks that resulted in the sub-Miocene peneplain. The most recent period is characterized by continuing erosion accompanied by deposition of sediments and formation of residual soils.

Local Geology of study area

The Local geology of the area comprises of weathered granites at a shallow depth. Sedimentary depositions with basement rocks quite shallowly deposited compared to other areas. This is evident from cuttings from the drilling of boreholes drilled around 400 to 500m from other areas in the location. Sediments seem shallower and storage capacity is likely to be unenhanced due to the distance from recharge sources. The area is on an anticline with streams or synclines at a distance of approximately 1.5km on both the north and south directions. The portion of area on which this study was conducted and recommended is after comparison of the data collected from a range of data collection in the neighboring area.

General Hydrogeology

The hydrogeology of an area is normally ultimately dependent upon the parent rock, structural features, sedimentation processes and weathering and the form and frequency of precipitation. The groundwater conditions in the proposed project area have been assessed, taking into account the characteristics of aquifers in the Basement rocks in the area.

Broadly, the hydrogeological setting of the study areas can be classified into sedimentary depositional Systems rocks which are mainly a mixture of mud, sands, clays, grit, pebbles and cobbles, except for the location that has a few laterites. Water flows from the anticlinal structure to the surrounding valleys and streams which are mainly to the South and the North East. A single water point is a pit which was supposed to be a pit latrine dug on the laterites produces water only in the rainy season. Fracturing usually has a positive effect on the yield of boreholes drilled in rocks. A weathered/fissured rock normally has good potential as an aquifer. Groundwater within an area can be expected to occur in the sedimentary system of the Pleistocene Age, The present groundwater resource investigations concentrated on establishing the lithology of different rock formations and their hydraulic characteristics and comparing these with the known geological succession.

Groundwater occurrence is usually controlled by the available recharge and the geological conditions of an area.

Specific Yield ranges of different materials.

Earth Material	Specific yield
Limestone and shale	0.5-50%
Sandstone	5-12%
Clay	1 -10%
Sand and gravel	15-25%

Gravel	15 -30%
sand	10-30%

Climate

The Climate of the study area is wet and humid in the rainy season which in general starts in late March to April and ends around November or December with annual precipitation of about mm and dry and hot in the dry season that is from late December to around March with average temperatures between 23 degrees centigrade.

Rainfall

The main source of water is rainfall over Southern Sudan. The elevated hills and plateaus that form the boundary of the great central plain receives mainly orographic rainfall: precipitation occurs as warm and moisture laden air is forced upward into colder layers of air. However, convectional storms cause most of the rain over the vast plain, as the air near the ground heats up during the day, expands, rises and cools down. As a result, most of these violent but highly localized storms occur in the late afternoons and evenings. Frontal rain is the third form of precipitation: it falls at the boundary of warm, southern air masses, which override colder and denser, northern air (i.e. a "tropical front"). The area experiences prolonged and heavy rainfall between May – November with short rains occurring between November – December, however there are sign of decreasing trend in the rainfall all over south Sudan which might be due to climate change .

Evapotranspiration

Evapotranspiration is the combination of surface evaporation and transpiration from plants. In most environments, this is the single most important loss of water from the hydrological cycle.

Temperature

The annual average temperature at many places in this region like the other equatorial region is estimated to be approximately 28°C, with mean diurnal amplitude of 14°C. The average monthly maximum and minimum temperatures are close to 35°C and 21°C, respectively. The period from January to April is hottest period of the year.

Vegetation

Tropical/ Savana vegetation mostly composed of thorny trees, bushes and shrubs with trees becoming bigger moving to the southern parts of the study area before the population and development of the area with tall elephant grasses approaching the River Nile.

Geophysical Investigation Methods

Investigation of groundwater resources at the project area included the use of geophysical techniques to probe the sub-surface. A variety of methods are available to assist in the assessment of geological sub surface conditions. The main emphasis of the field work undertaken was to determine the thickness and composition of the sub-surface formation and to identify water bearing zones.

This information was principally obtained in the field using Horizontal resistivity profiling/Constant spacing traversing (HRP/CST) and Vertical electrical sounding (VES) using ABEM Terrameter SAS 1000. The VES probes the resistivity layering below the site of measurement and to confirm the existence of deep groundwater

Basic Principle

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. The presence of saline water, clays and conductive materials also reduce the resistivity of the rocks. 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, using the principle of Ohm's Law: The resistance of a material is directly proportional to its length and inversely proportional to its cross-sectional area. 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:

$$R = Rs * L/A \quad \text{(in Ohm)}$$

Where Rs is known as the specific resistivity, characteristic of the material and independent of its shape or size.

With Ohm's Law,

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

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:

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

Horizontal Electrical Profiling (HEP)/Constant Seperation Traversing (CST).

This is carried out to determine the change in electrical properties laterally with constant electrode spacing and is interpreted as a continuous profile. The electrode spacing controls both the profiling depth and resolution of survey.

The observed resistivity values are plotted on a linear graph paper and the graph obtained depicts lateral resistivity variation at constant depth. Geological structures such as faults, fractures, buried stream channels that may conduct groundwater, can be inferred.

Vertical Electrical Sounding (VES)

When carrying out a VES, current is led into the ground by means of two electrodes (current electrodes). Two other electrodes (potential electrodes), situated near the center of the array, measure the potential field generated by the current.

From the observations of the current strength and the potential difference and taking into account the electrode separation, the ground resistivity at different depths can be determined.

During resistivity soundings, the separation between the electrodes is step-wise increased (in what is known as the Schlumberger Array), thus causing the flow of current to penetrate greater depths. By plotting the observed resistivity values against depth on double logarithmic graph paper, the resistivity verses depth is obtained.

This graph can be interpreted with the aid of Master Curves or specialized computer software (RESIX Ix1D) and the actual resistivity layering of the subsoil is obtained. The depths by resistivity values provide the hydro geologist with information on the underlying geological layering and thus interpret the data in terms of the occurrence of groundwater potential.

Geo-physical Unit	Resistivity Range(Ωm)
Top soil	100-2000
Top soli of clayey sands and silts(Cotton soil type) When dry and cracked	20-100 100-1500
Heavy clays(alluvial or intensive clay producing weathering)	2-10
Clays to Clayey sands	10-40
Clayyey saprolite or dry saprock	100-800
Water bearing Coarse saprolite or saprock	50-150
Saturated Zone with saline water	2-10
Fresh Basement rocks	2500-10000

Resistivity Units and Common Resistivity Rangers.

Geophysical Fieldwork and Results

The fieldwork was carried out in and March 2020. one Horizontal Electrical Profiling (HEP/CST) was carried out in the investigated sites at station points of 10 meters separation and a spread of in most case more than a thousand meters depending on the data acquired. These were done in order to determine the presence of lateral inhomogenieties and structural control of groundwater flow. Anomalous locations along the HEP/CST were identified. A total of twelve VESs were carried out at the selected sites within the investigated area however; some were at most times eliminated due to poor data quality. VESs were always conducted at points of interest are marked by clearly labeled pegs pushed into the ground. These are noted by a representative of the Organization and the Community leader of the area.

Analysis of Results

Interpretation of Results

VES interpretation results indicate varying results since all the site locations have unique geologic features but are generally in weathered basement grano-gneisses and adjacent Laterites.

It is therefore recommended that all boreholes be drilled to the maximum depth recommended for the particular site ensuring that most of the aquifer layer is penetrated. Care should be taken in isolating the upper aquifer zones as they may be contaminated. The Hydrogeologist at site can decide an appropriate depth when adequate aquifer layer has been penetrated by the borehole.

Borehole Construction

It is recommended to drill boreholes at the respective locations to the maximum depths in order to optimize the yield. Drilling should continue until the recommended depths are reached. This ensures that sufficient yields are achieved before drilling stops. The maximum drilling depth will of course depend on the hydrogeological conditions encountered. It is recommended to use Mud Drilling due to nature of the soil.

Geological formation samples should be collected every 2 meter intervals, clearly labeled with its appropriate depth, described by a hydrogeologist and reported in Final Borehole Report.

Casings and Screens

The boreholes should be drilled at diameter not less than 6 inches and installed with good quality uPVC casings and screens of not less than 4 inches in diameter with high percentage of effective open surface area (recommended DIN 4925 and slot size of 1mm).

Gravel pack

The use of gravel pack is recommended within the aquifer zone. A 6 inch diameter open hole borehole cased with a 4 inch screen will leave an annular space of 1 inch which should be sufficient. The slot size should be about 1mm. The gravel pack should be an average of 2-4mm. The gravel should be installed well above the depth of the shallow aquifer and at least 3 meters above the uppermost screen. The exact amount of the gravel peck can be determined volumetrically

Sanitary Protection of the Borehole

In order to avoid leaking of dirty water and contamination of aquifer water, section above the gravel pack in the annular space must be sealed off completely with clay. This seal will have to be installed to a thickness of 3 meters.

The remaining annular space should be backfilled with inert material and the top 5 meters grouted with cement to ensure that no water at the well head enters the wellbore and thus prevent contamination.

Well Development

Once the screens, gravel pack and backfills have been installed, the well should be developed in order to remove clays, sand particles and other additives from the borehole walls and alter the physical characteristics of the aquifer around the screens.

Development should be done by use of air preferably, which physically agitates the gravel pack and adjacent aquifer materials.

Unfortunately however, the importance of correct and comprehensive techniques for borehole construction aspect seldom receives the attention it deserves!

Platform Construction

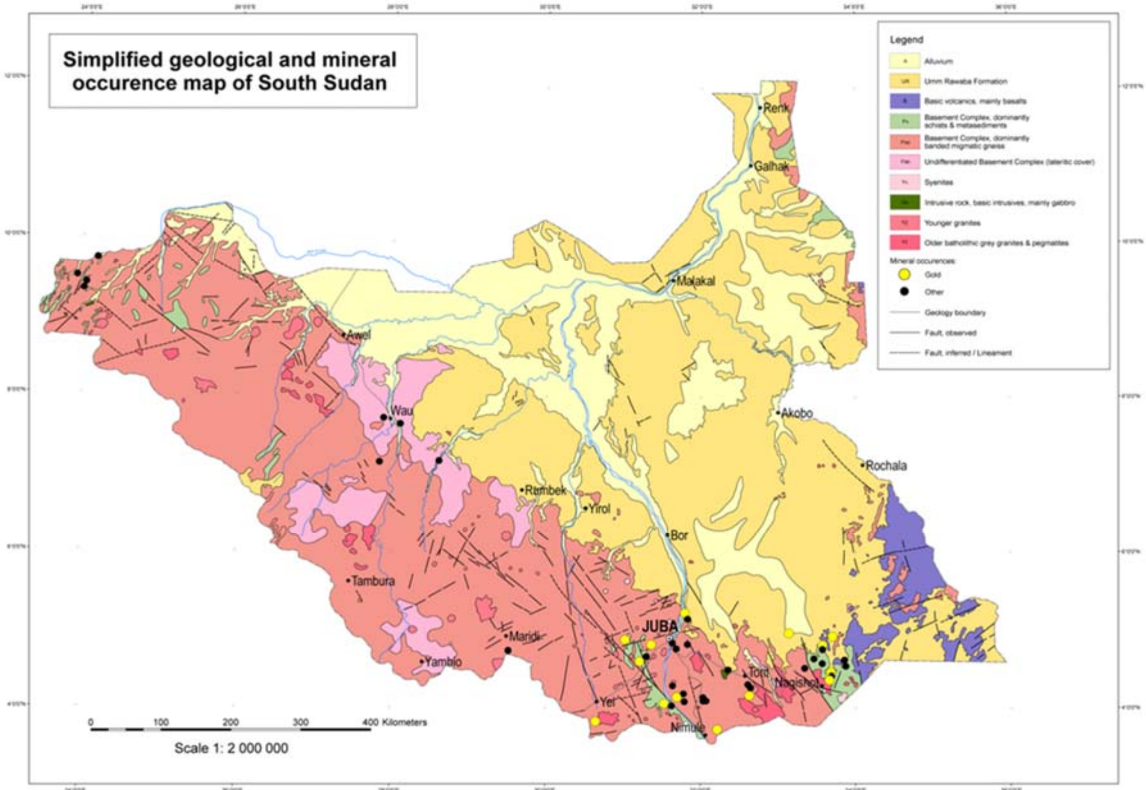
Reference is made to South Sudan Rural Water Supply Manual for technical specifications for platform constructions.

All the above boreholes should be to a maximum depth of 120 mbgl given the geology of the area and the locations of the boreholes unless otherwise decided by the driller or in consultation with the hydro-geologist and only after realizing sufficient quantity of water.

Conclusion.

The recommended and marked VES point should be drilled to a maximum depth of 120 meters

Geological and Mineral and Mineral occurrence map of South Sudan


Simplified geological and mineral occurence map of South Sudan
Legend
Alluvium
Umm Rawaba Formation
Basic volcanics, mainly basalts
Basement Complex, dominantly schists & metasediments
Basement Complex, dominantly banded migmatic gneiss
Undifferentiated Basement Complex (lateritic cover)
Syenites
Intrusive rock, basic intrusives, mainly gabbro
Younger granites
Older batholithic grey granites & pegmatites
Mineral occurences
Gold
Other
Geology boundary
Fault, observed
Fault, inferred / Lineament
Renk
Galhak
Malakal
Awel
Wau
Akobo
Rochala
Rumbek
Yirol
Bor
Tambura
JUBA
Maridi
Yambio
Torit
Nagishot
Yei
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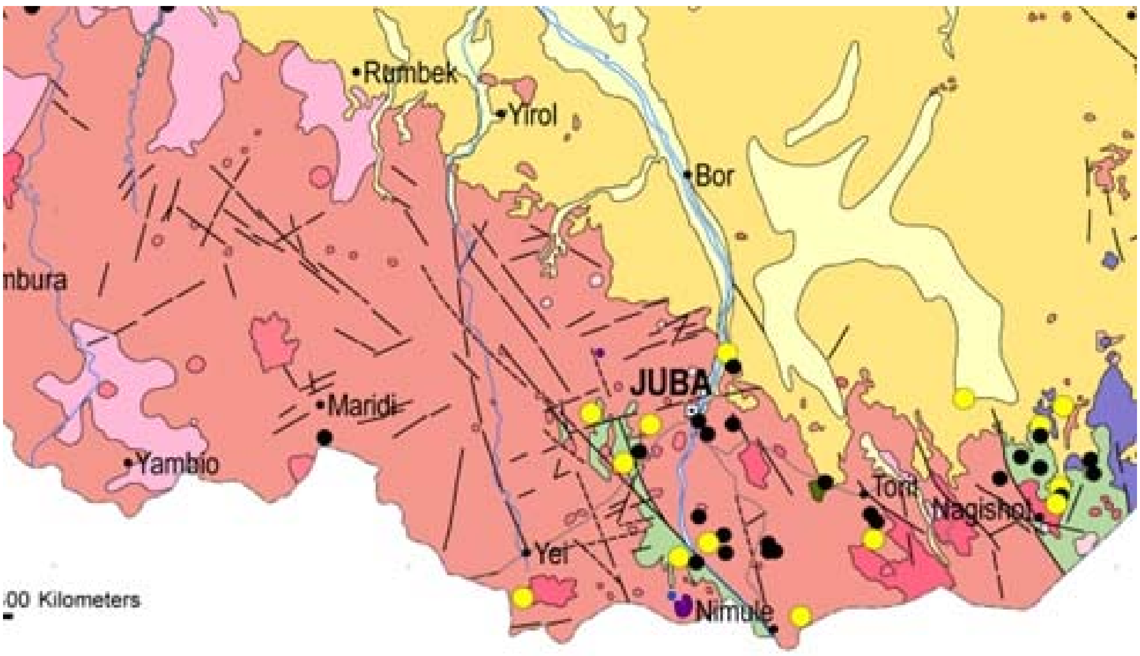
Rumbek
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Torit
Nagishot
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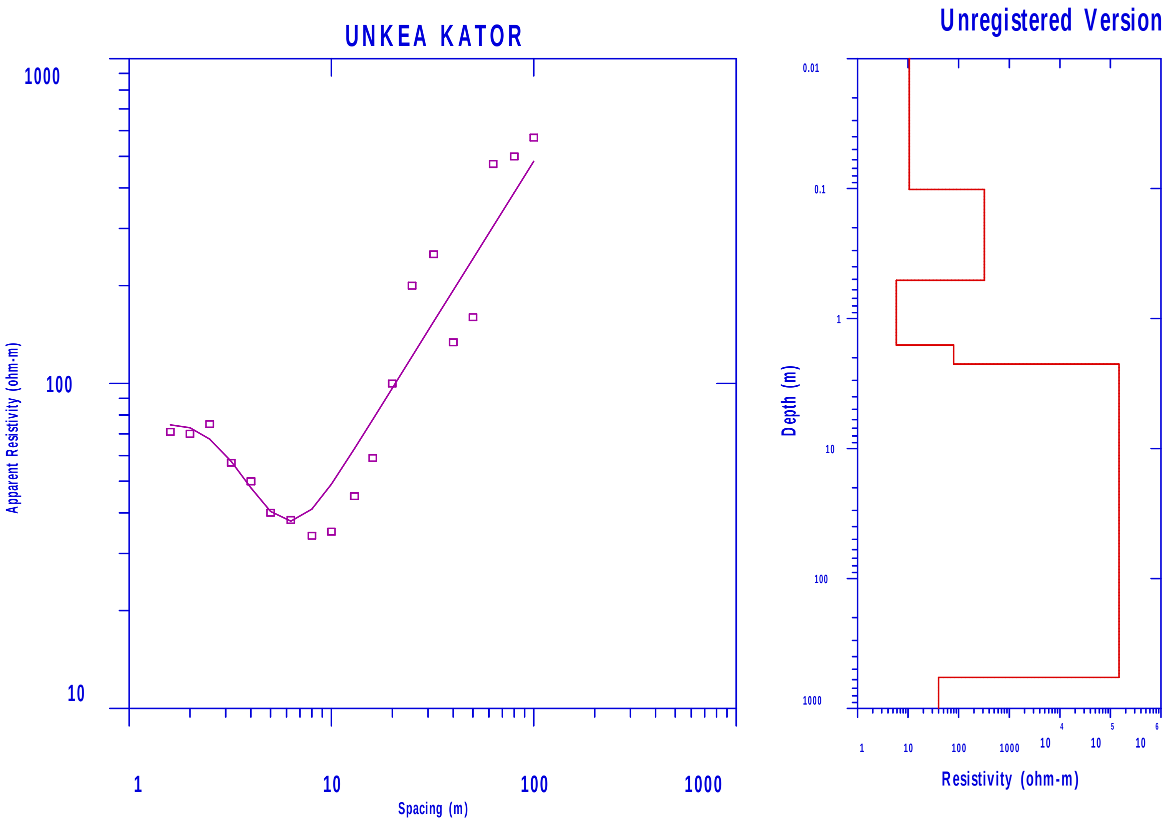
VERTICAL ELECTRICAL SOUNDING RESISTIVITY GRAPH



Abbreviations

- **Ω-Ohm**
- **Ωm-Ohm meter**
- **Mbgl----Metrers below ground level**
- **CST------Constanat Space Traversing**
- **HEP------Horizontal Electrical Profiling**
- **VES------Vertical Electrical Sounding**
- **HRP------Horizontal Resistivity Profiling**
- **SAS-------Signal Averaging System**
- **m---meters**
- **UTM-----Universal Time Mercator**