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EFFECTIVE BOREHOLE DESIGN IN DIFFICULT CRYSTALLINE ROCK TERRAIN; A CASE STUDY OF THE ABAKALIKI PYROCLASTIC ROCKS.

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ABSTRACT

The Ebonyi State Police Headquarters, Abakaliki is within the area underlain by the pyroclastic rocks that are generally known to have low prospect for groundwater. Yet, a borehole with sustainable yield was required to supply part of the increased population of the barracks through a newly constructed 40,000 litres capacity overhead tank Modified borehole design and yield enhancement procedure along with pre- drilling electrical resistivity survey were used to achieve sustained yield of 1500 litres per hour from a motorized borehole.

KEYWORDS: Pyroclastic rocks, borehole design, sustainable yield.

INTRODUCTION

Most crystalline rocks are naturally poor as aquiter due to lack of the essential hydraulic characteristics required for the storage and transmission of ground water.

The hydraulic capabilities of these rocks however improved through various tectonic events and prolonged weathering process leading to accumulation of decomposed layer. Petrology of the bedrock and geomorphic factors also have influence on the thickness, textural and hydraulic characteristics of the regolith The fine grained mafic rocks terrain are generally known to exhibit poor groundwater potential due to low frequency of fractures and poor hydraulic conductivities of their regoliths (Offodile, 1983).

In such terain despite elaborate expiration programme, yields from wells are small and dry or seasonal holes are common.

However, reports have shown (Driscol, 1989) that yield from wells in such terrain may be increased with improved well design method and yield enhancement procedures along with adequate pre-drilling geophysical investigation.

The Abakaliki pyroclastics comprising mainly of basaltic rocks is a typical example of difficult crystalline rock terrain with low prospect for groundwater. Due to the low yield from boreholes and -dug wells in the area, uses of motorized pumps are uncommon.

At the Ebonyi state police Headquaters, in the heart of Abakaliki town, motorized borehole with sustainable yield was required to feed a newly constructed 40,000 capacity overhead tank to supply part of the increased population of the barracks.

This paper reports geophysical investigation for groundwater in the barracks and the yield enhancement procedures adopted to achieve sustainable yield from a motorized borehole.

GEOLOGICAL SETTING

The Southern Benue Trough in the Cretaceous period is straigraphically represented by sediments of three main marine depositional cycles: Albian – Cenomanian; Turonian – Santonian ; and Campano – Maastrichtain (Rayment, 1965; Ofoegbu, 1985).

The first marine inundation of the trough is generally believed to have occurred in mid – Albian times. Sediments of the Asu River Group and Abakaliki shales were deposited during this transgressive phase. They are mostly shales with localized development of sandstones and carbonates. The Cenomanian deformational episode terminated this cycle and restricted marine sedimentation to the Calabar area where sediments of the Odukpani formation were deposited (Nwachukwu, 1972; Ofoegbu et al, 1987).

Igenous rocks occur in place within the trough, in both the lower upper cretaceous sections of the sequences. The Abakaliki pyroclastic rocks happen to be one of them. The basaltic pyroclastic rocks were first reported in the Abakaliki area of the Southern Benue Trough by Okezie (1965). The volcaniclastic outcrops are distant from one another, areally restricted and poorly exposed.

The Abakaliki pyroclastics are light to dark grey lapilli tuffs and capillistones of basaltic composition (Olade, 1978; Hoque, 1981, 1984). They consist of a compact chaotic mixture of unsorted angular to sub – angular lithic fragments (shale , mudstone , siltstone and and limestone) and amygdaloidal scoria and pumice set in a lightly altered basaltic ground mass.

These pyroclastics trend northeast – south west and are surrounded by the Abakaliki shales of mid Albian Age (Fig.2). The 1905 – 1909 mineral survey of southern Nigeria report assigned a mid albian age to the pyroclastic rocks of Abakaliki, while Uxuakpunwa (1974) and Hoque (1981) have suggested Aptian and late Santonian ages respectively.

LOCATION AND DESCRIPTION

The study area is located in the Abakaliki Police Headquarters' is within the central part of Abakaliki town, situated directly opposite the state's Government House. It falls within the geographical co-ordinates of

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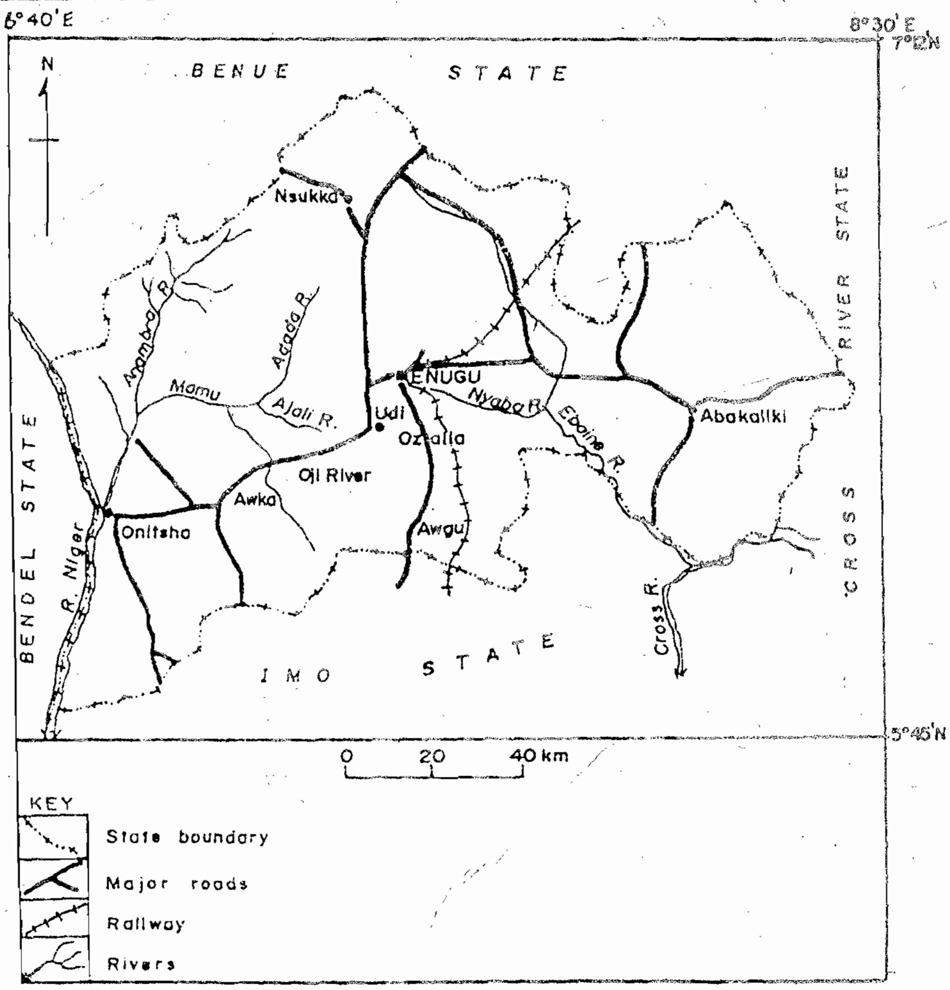


Fig. 1: Map of Southeastern - Nigeria

Latitude 6^0 15' – 6^0 30'N and Longitude 8^0 – 8^0 10' E (Fig. 1)

The area is within the rain forest region with rainy season occurring from April to October. The mean annual rainfall values range from 1500mm – 1830mm (Inyang, 1975; Ezeigbo 1987). The rainfall is characterized by a high surface run – off and very low infiltration rates. The surface run – offs feed the surrounding seasonal streams and also in some cases stagnant water ponds, which the local populace depend upon for their domestic and agricultural needs.

Most surface water in Ebonyi state are bacteriological contaminated as revealed by the available bacteriological data of between 1980-1985 (Ezeigbo, 1987). Edungbola (1985) categorized the Abakaliki area as highly endemic to guinea-worm infection and recommended that to effectively dissuade the local population of these area from using stagnant water from ponds, large pipe borne water scheme should be established.

Ground water within the Abakaliki area is generally free from bacteriological contamination with low concentration of major ions such as chlorines, sulphates, nitrates, and total dissolve solids, all within recommended limits (Ezeigbo, 1987).

During the season, the static water level drops and by virtue of the thinness of the aquifer thickness, most of the boreholes are rendered dry holes. Thus, the need to develop an effective borehole design and yield enhancement procedures.

FIELD MEASUREMENT

Pre-drilling geophysical investigation involving the electrical resistivity method was made with the aid of an **ABEM SAS** 300 digital Terrameter.

The vertical electrical sounding (VES) technique using the Schlumberger electrode configuration **(4 VES)** with total current electrode separation of between 260m and 300m was employed. (Fig 3) The vertical electrical sounding results are presented as geo-electrical sections. The VES data was interpreted quantitatively by the partial curve matching and computer iteration techniques.

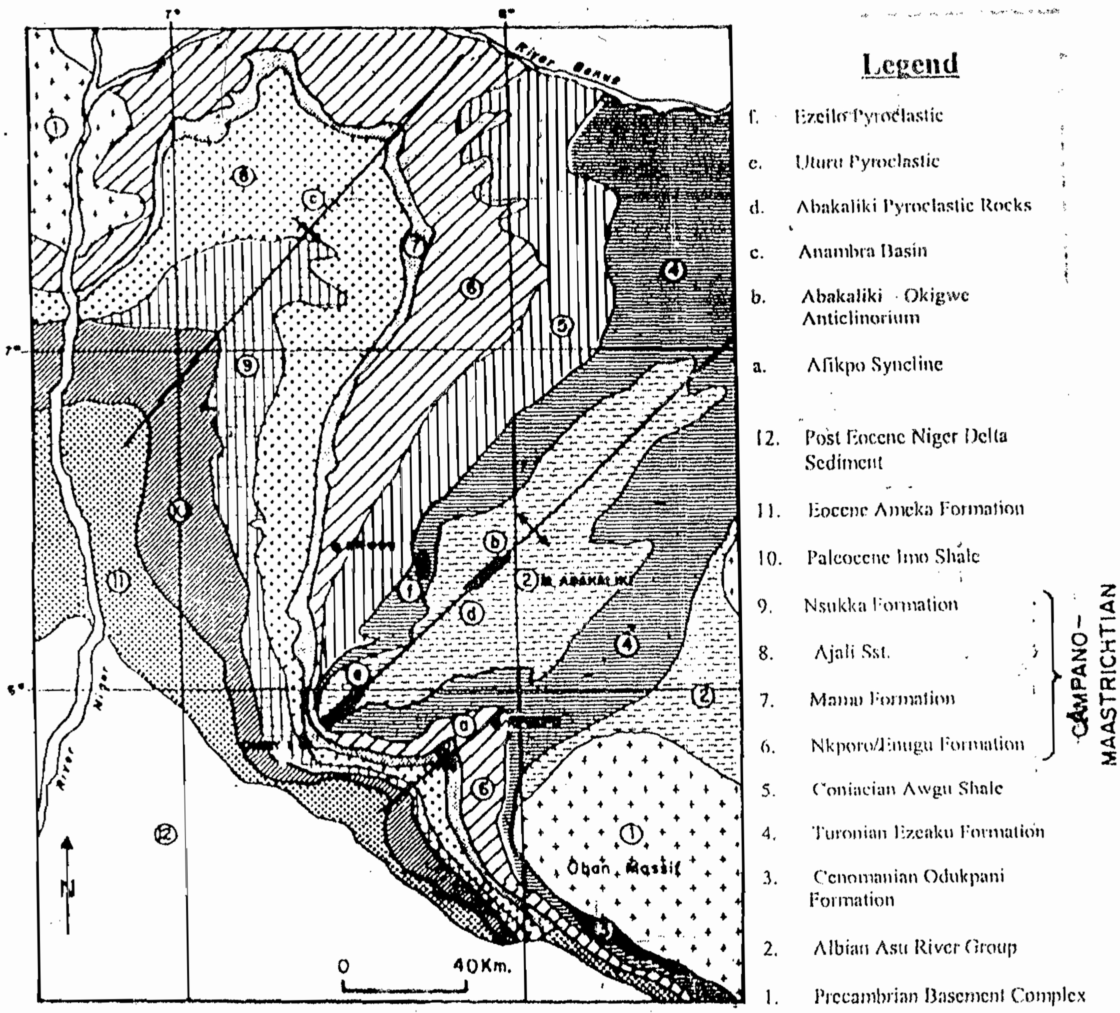


Fig. 2: Geologic Map of Southern Benue Trough showing pyroclastic rocks at Ezillo and Abakaliki (After Ofoegbu and Amajor 1987)

RESULTS AND DISCUSSION

Interpretation of Geophysical data

The depth sounding curves are the QHK, HKA and the HK types. (Fig. 4) The interpretations of results of the sounding curves are presented as geo- electric section (Fig. 5). Five geo- electric layers were differentiated from ground surface to depth of about 50m (Table II).

The first layer is the topsoil composed of clayey sand or sandy clay.
Resistivity values of the layer ranges from 140 ohm-m to 650 ohm-m. The layer has thickness of about 1m.

The second layer is the lateritized zone occurring as clayey laterite soil and latertic hard crust. The soil portion has resistivity values of between 50 0hm-m and 195 ohm; whereas the hard crust has resistivity value of 400 ohm-m to 595 ohm.m . Thickness of the layer ranges from 3m to 6.5m

The third layer is the decomposed bedrock, which is made up of clayey portion with resistivity values of 15 ohm-.m to 30 ohm-m beneath VES 4 and 2 respectively. The layer is however, composed of sandy clay, which is regarded as the first aquifer, beneath VES 1 with resistivity value of 270 ohm-m. The layer thickness varies from 6m beneath VES 4 to 20m beneath VES 2

The partially weathered bedrock regarded, as the second aquifer unit in the area is the fourth layer. Resistivity value of the layer ranges from 84 ohm-m beneath VES 2 to 150 ohm-m beneath VES 1. The layer, which was not detected beneath VES 4, has thickness that varies from 3m beneath VES 2 to 6m beneath VES 1.

The last layer delineated in the area is the fresh bedrock with resistivity value of 3800 ohm-m to infinity. Depth to the fresh bedrock ranges from 16m beneath VES 4 to 33m beneath VES 1. (Table 1)

The low groundwater potential of the site is portrayed by the clayey nature of substantial portion of

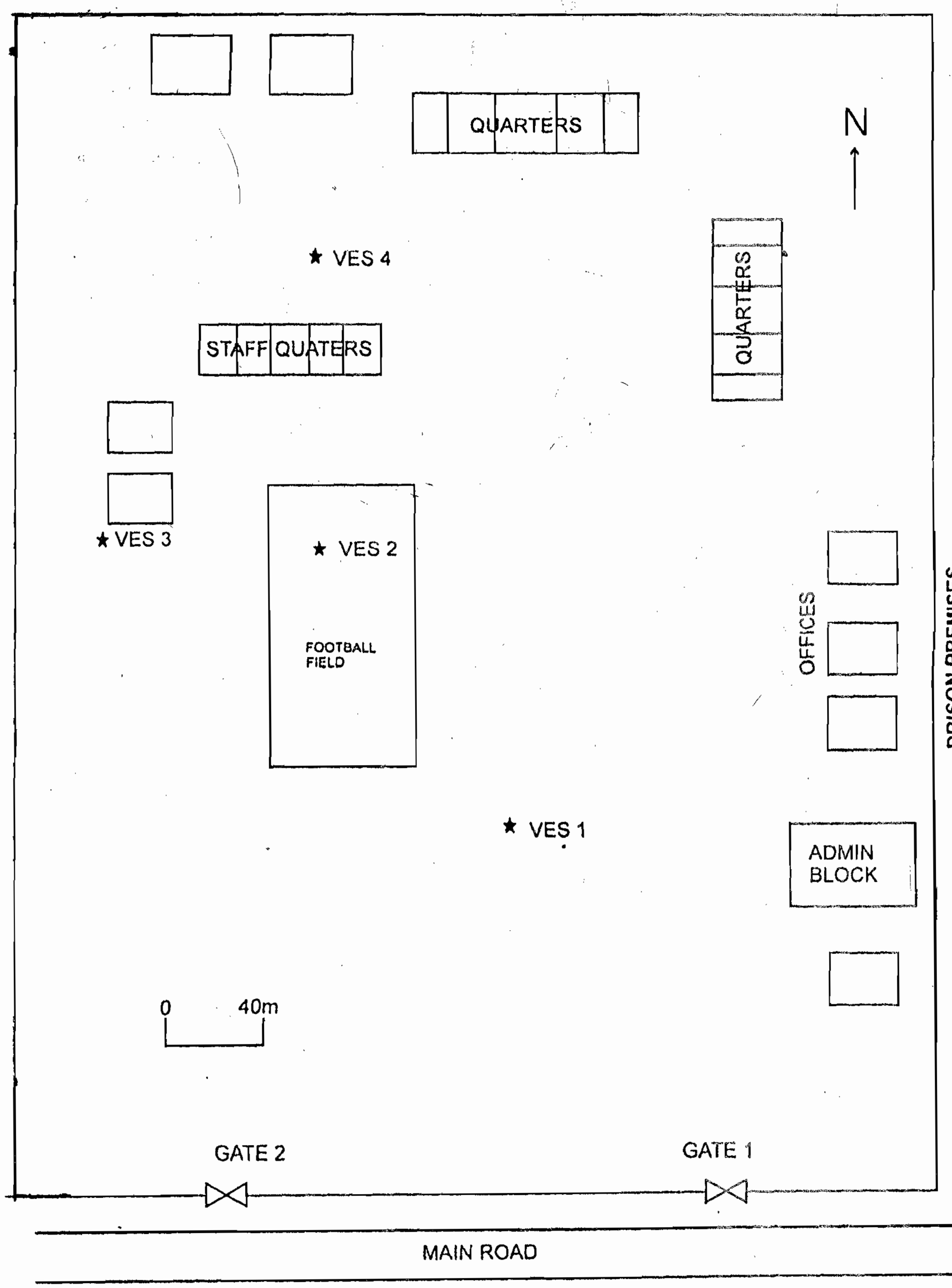


Fig. 3: Schematic sketch of the site showing the ves locations

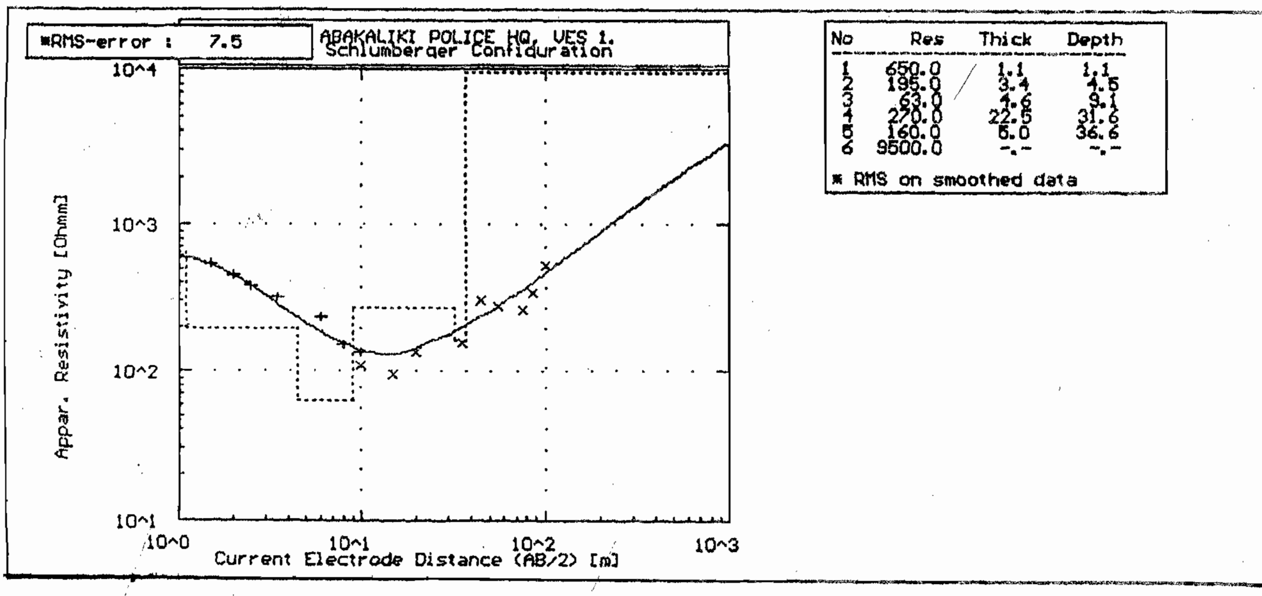
the weather layer and the low thickness (6m) recorded for the partially weathered layer as well as absence of fractures within the bedrock. In addition, the occurrence of the pyroclatics within shale deposits indicates low recharge rate of the regolith aquifer from rainfall. However, VES 1 was chosen for the borehole drilling due to the relatively sandy nature of the weathered layer and appreciable thickness of the partially weathered bedrock at this location.

Borehole Design

The poor hydraulic property of the site is however, expected to produce large draw down resulting is dewatering of the aquifer on installation of motorized

TABLE 1: Summary of results of depth sounding interpretation

Layers	Resistivity Values (ohm-m)	Description	Thickness (m)
1st	230 – 650	Topsoil composed of sandy clay or clayey sand	1.1 – 1.3
2nd	50 – 95 400-595	Laterite soil Lateritic hard crust	2.1 – 7.3 1.0 – 1.8
3rd	15 – 30 270	Clayey weathered layer Sandy clay weathered layer	6 – 18 20
4th	84 – 150	Partially weathered bedrock	3 -6
5th	3,800 – infinity	Fresh bedrock	



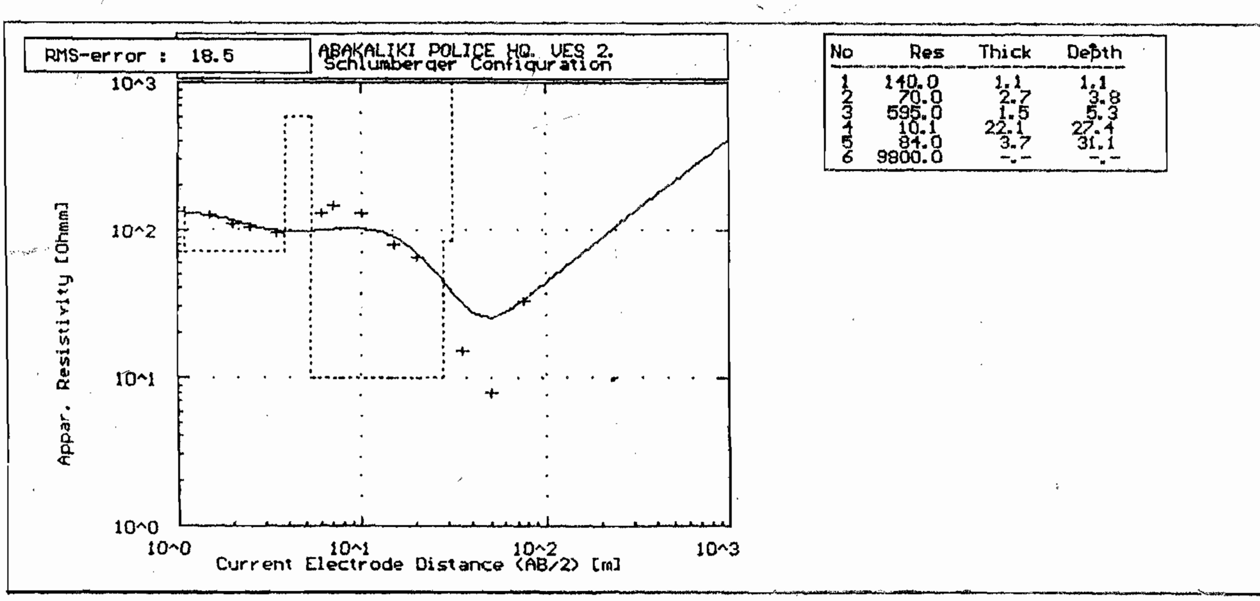


Fig. 4: Schlumberger depth sounding curves beneath VES 1 and VES 2

TABLE 2

Bore-hole Completion Data

Borehole depth:	55m
Drilling method:	Hydraulic rotary method and air system with down the-hole method.
Types of casing screen:	uPVC
Diameter of casing:	145mm
Screen type:	Continuous Slot
Screen length:	24m
Gravel pack materials:	*Riverbed gravel fairly well sorted*
Type of pump:	Groundfos Sp-3a –12 model (0.75kw)

TABLE 3

Borehole Lithologic Logging

Depth	Lithologic desrciption
0 – 3m	lateritic soils with traces of iron stones
3m - 6m	yellowish brown clay
6m – 16m	light brown clayey sand
16m – 23m	greyish coarse sediment(weathered bed rock)
23m – 29m	greyish partially weathered rock fragments
29m – 31m	fragments of bed rock partially weathered
31m – 55m	fresh fragments of bedrock.

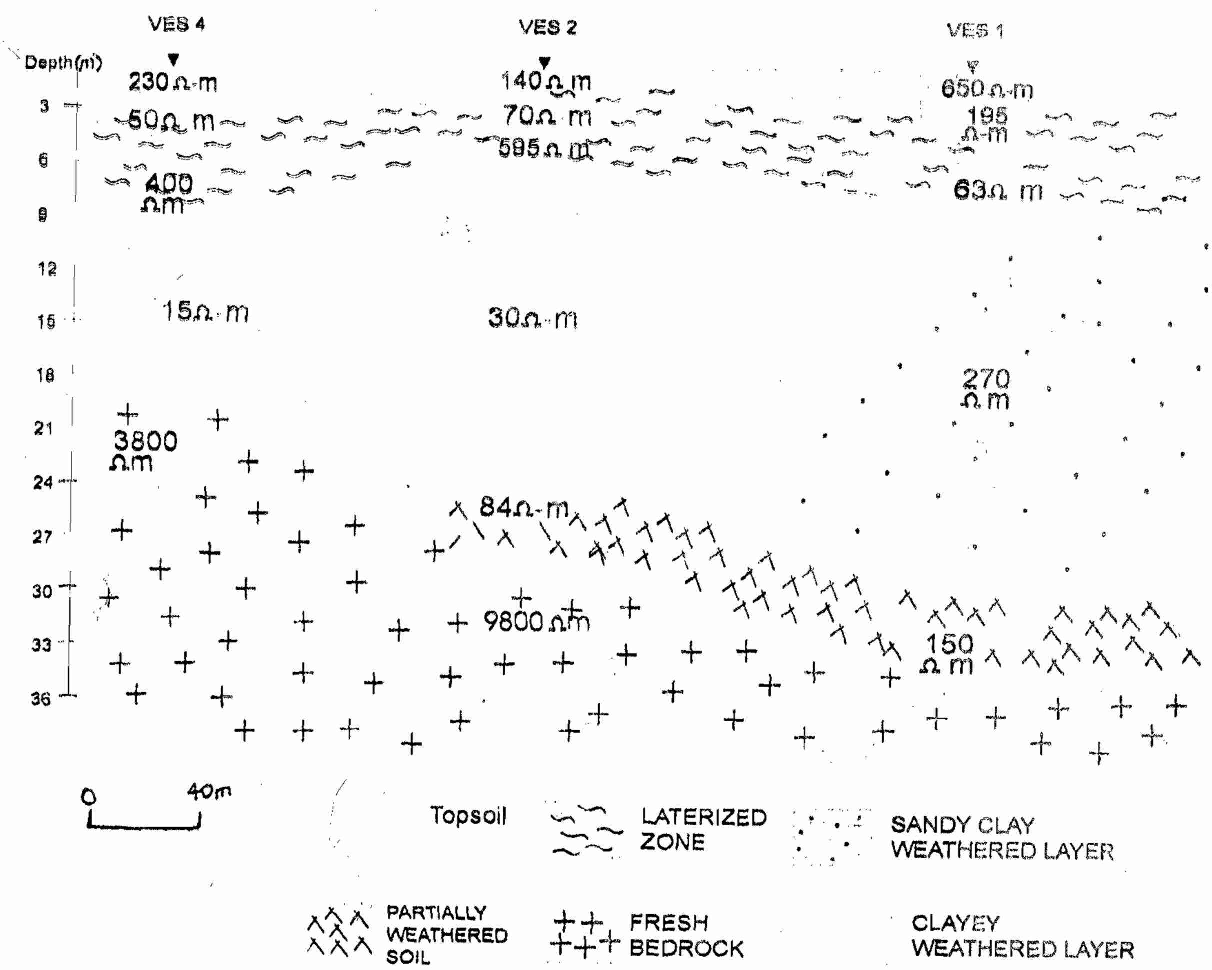


Fig. 5: Geo - electric section relating VES 1, 2, & 4

submersible pump.

Consequently, the conventional design method of terminating crystalline rock boreholes a few meters into the fresh bedrock was not adopted. A modified design method of drilling the borehole to substantial depth within the fresh bedrock was adopted in order to accommodate the envisaged large drawdown and thereby achieve sustainable yield from motorized pump.

The borehole was drilled to 58m depth in two stages. The first stage involved drilling of 200mm diameter hole within the weathered layer to depth of about 33m using direct rotary method with tri-cone/rock-roller bit. The second stage involved drilling of 165mm diameter hole within the percially weathered layer and the fresh bed-rock with air drilling system using down –hole hammer bit. The 25m-drilled depth within the fresh bedrock was designed to serve as reservoir. The Borehole completion data is given in Table II

Other yield enhancement procedures adopted involved setting of the screen sections within the partially weathered bedrock and the fresh bedrock so as to maximize the specific capacity of the borehole. Moreover, the entire borehole section was hydraulically connected by means of gravel pack materials to further enhance the borehole yield (fig 6).

Good correlation was recovered for the borehole lithologic Logging (Table III) and the geo-electric section.

On installation of a low rating (0.75 kw) submersible pump at depth of 55m, a sustained yield of approximately 1,500 litres per hour was recorded. The dynamic water level after six hours of a single stage pumping was 44m. Specific capacity of the borehole calculated as 0.047m^3 /hr/m portray the low ground-water potential of the area.

The borehole was completed and commissioned in 1998. Monitoring of the borehole was carried out periodically over a period of one and half years by the contracting firm. With the exception of minor electrical faults, the yield was sustained throughout the entire period with minor fluctuations (50-100 litres per hr) in the yield, which coincides with the peaks of dry and raining seasons

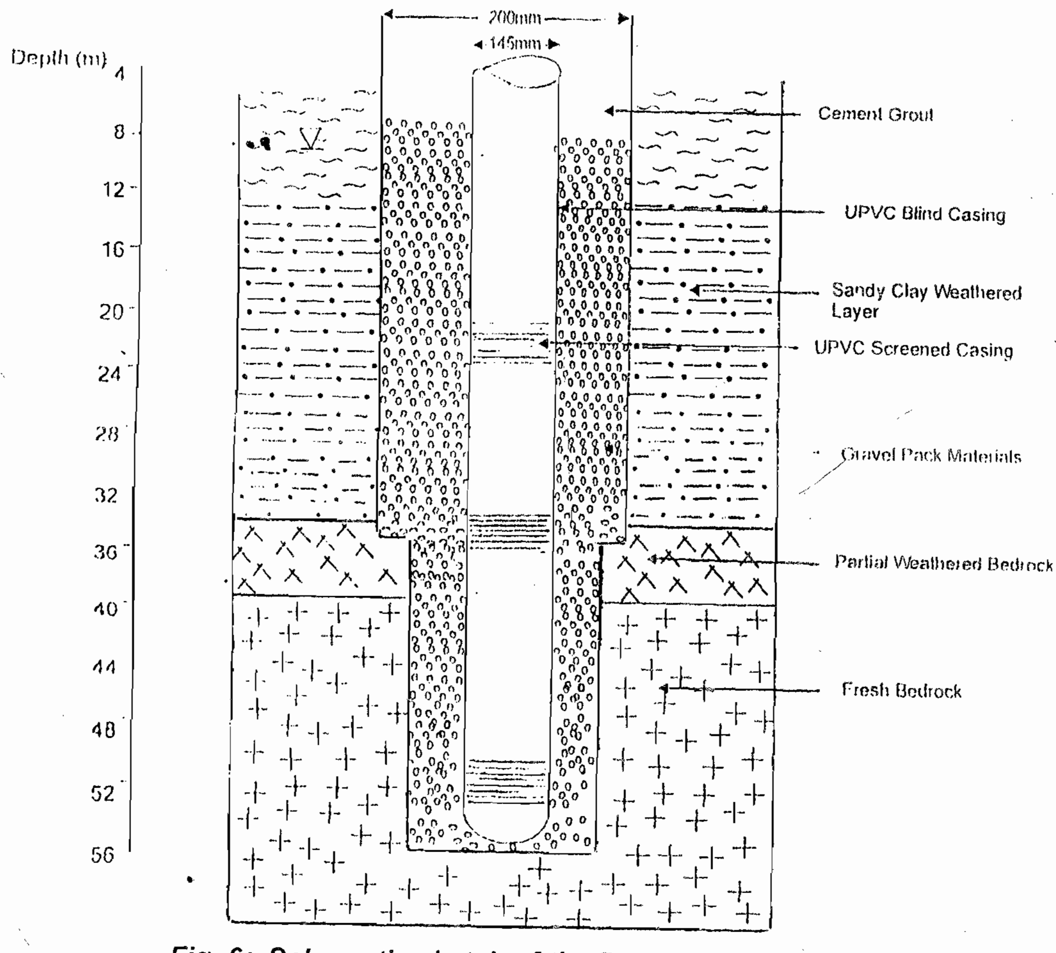


Fig. 6: Schematic sketch of the Borehole Design

CONCLUSION

The electrical resistivity survey of the site indicates occurrence of predominantly clayey decomposed layer with thin layer of partiarly-decomposed horizon to confirm the poor groundwater prospect of the terrain.

A modified borehole design was used to achieve sustainable yield from motorized borehole to supply an existing overhead tank. This may probably have been impossible with conventional borehole design.

Results of the study suggest that various modification of borehole design may be used to achieve improved yield from boreholes in difficult terrain.

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