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Assessment of Groundwater Potential of Parts of Owerri, Southeastern Nigeria

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Abstract
The Aquifer characteristics around Owerri, Southeastern Nigeria were evaluated using geophysical survey, borehole logs, sieve analysis and pumping test. The area lies on the Benin Formation of Southeastern Nigeria which is composed of loosely consolidated sands, sandstones and gravels with minor intercalations of clays. The study is an initial step towards providing information needed to develop techniques to protect the groundwater system in the area. The geophysical survey and borehole logs show that the area is sand dominated. The borehole logs and sieve analysis results indicate: coarse grained sand to medium grained sand to fine grained sand to gravel to (silt & clay). Pumping test results give transmissivity ranging from 1008.3m^2/day to 1551.0m^2/day. The storativity varies from 3.04 to 4.32. The hydraulic conductivity is of the order of 0.06cm/sec to 0.49cm/sec. The findings indicate that the area has high groundwater potentials.

Keywords:
Assessment, Aquifer characterization, Geophysical survey, Borehole logs, Sieve analysis, pumping test, Owerri and Benin Formation.

Introduction

Water is the elixir of life, without it, life is not possible. Deny man food and his body can sustain life for days, but deny him water and death must come within hours. Only if he is denied air will death come faster (Johnson, 1975). This research work focuses on the characterization of the aquifers around Owerri area using hydraulic parameters such as transmissivity, storativity and hydraulic conductivity in addition to sieve analysis and geophysical survey. The need for aquifer characterization arises from the need to have base information for groundwater management. The population increase in Nigeria and consequent pollution are good reasons for this study.

Study Area Description.

The study area is Owerri (Southeastern Nigeria). It Lies between Latitudes 5°20'N to 5°40'N and longitudes 6°50'E to 7°10'E (Fig.1) covering an area of 129.6m^2 It is a low lying terrain with a good road network. The area is drained by three main rivers (Otamiri, Oramiriukwa and Nworie). The rivers flow in the north-south direction except Njaba River which flows from west to east to join Oramiriukwa River (Fig.1).

General Geology of the Area.

Stratigraphic succession of rocks in the study area consists of Nsukka formation, Imo-Shale, Ameki formation, Ogwashi-Asaba formation and Benin formation (Hazel, 1971) as shown in Table1. The coastal plain sand belonging to the Benin formation extends to a considerable depth in the area and is favourable for ground water development. The formation consists predominantly of very thick coastal sand, sandstone, clays and sandy clays occur in lenses. North of Owerri towards Orlu and Okigwe, the thickness of Benin formation decreases drastically and starts to overlap the Ogwashi-Asaba formation which is mainly clayey sand with lignite seams (Fig.1). The Ameki formation which is mainly sandstone unconformably underlies the Ogwashi Asaba. The Imo Shale unconformably underlies the Ameki formation while the Nsukka formation underlies all the formations (Uma and Egboka, 1984; Short and Stauble, 1967). Groundwater occurs abundantly in the coastal plain sands (Benin formation) and the static water level (SWL) ranges from 8-65meters depending on the location and the time of the year. The Benin formation also overlies the petroleum bearing Agbada and Akata formations in the south (Niger Delta) area (Table 2). It is a good aquifer with an average annual replenishment of about 2.5 billion cubic meters per year (Onyegocha, 1980). In most areas, the sandy components forms more than 90% of the sequence of the layers therefore permeability, transmissivity and storage coefficient are very high. Inspite of these favourable conditions for groundwater accumulation, cases of borehole failures abound in Owerri area. This is part of what led to the present study.

Climate and Physiography of the Area.

The study area lies within the tropical rainforest belt of Nigeria and the climate has distinct wet (March-October) and dry (November-February) seasons. The average annual rainfall is approximately 2,250mm. The humidity is generally high throughout the year and the rates of evapotrauspiration far exceed that of precipitation during the dry seasons (Uma and Egboka, 1986). The topography is characterized by gently undulating lowlands and plains.

Study Objective

The main objective of this study was to analyze available data: predrilling geophysical survey, drilled borehole logs, pumping tests and sieve analysis carried out in the area and to use it in assessing the occurrence of groundwater and potential of the area. The study also provided information to be used for optimum development and proper management of groundwater resources of the area and Niger Delta in general.

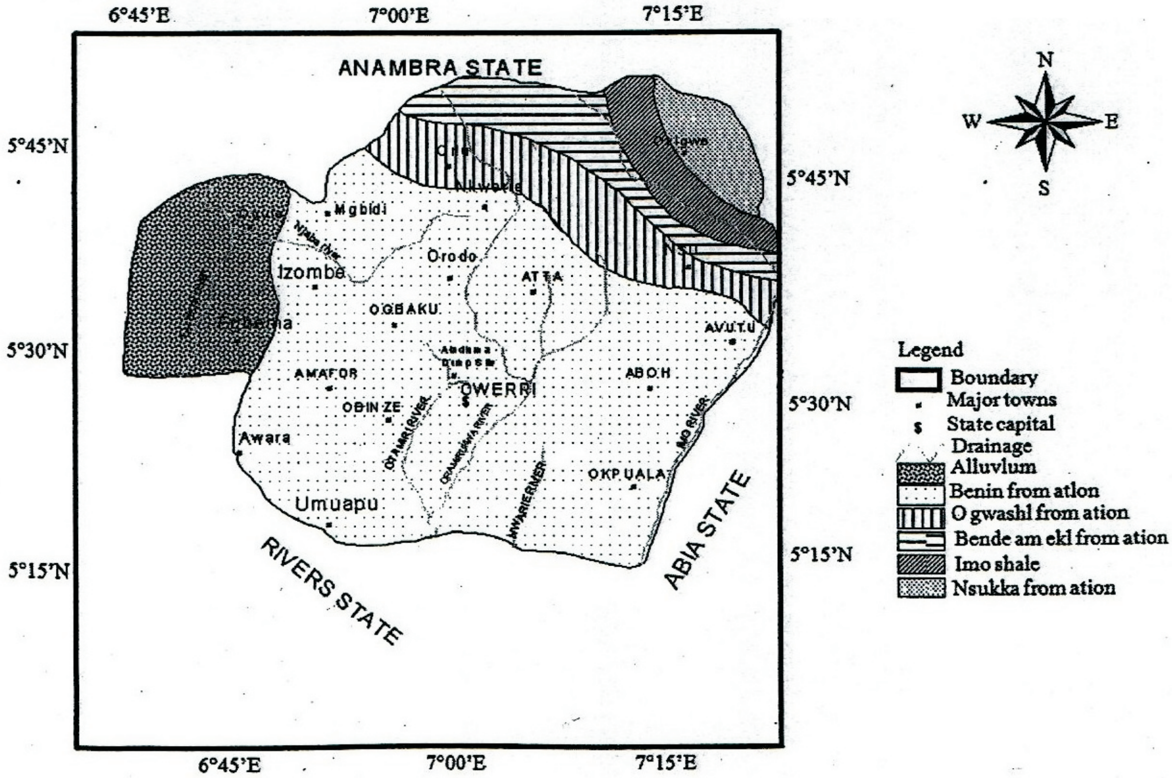

Fig. 1: Geology Map of Owerri Area

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Materials and Methods

To determine the groundwater potential of an area, the potential aquifers have to be identified and their hydrogeological features have to be considered. These hydrogeological data were obtained from 5 predrilling geophysical survey, 18 drilled borehole logs, 5 pumping tests and 15 sieve analyses data as shown in Fig.2.

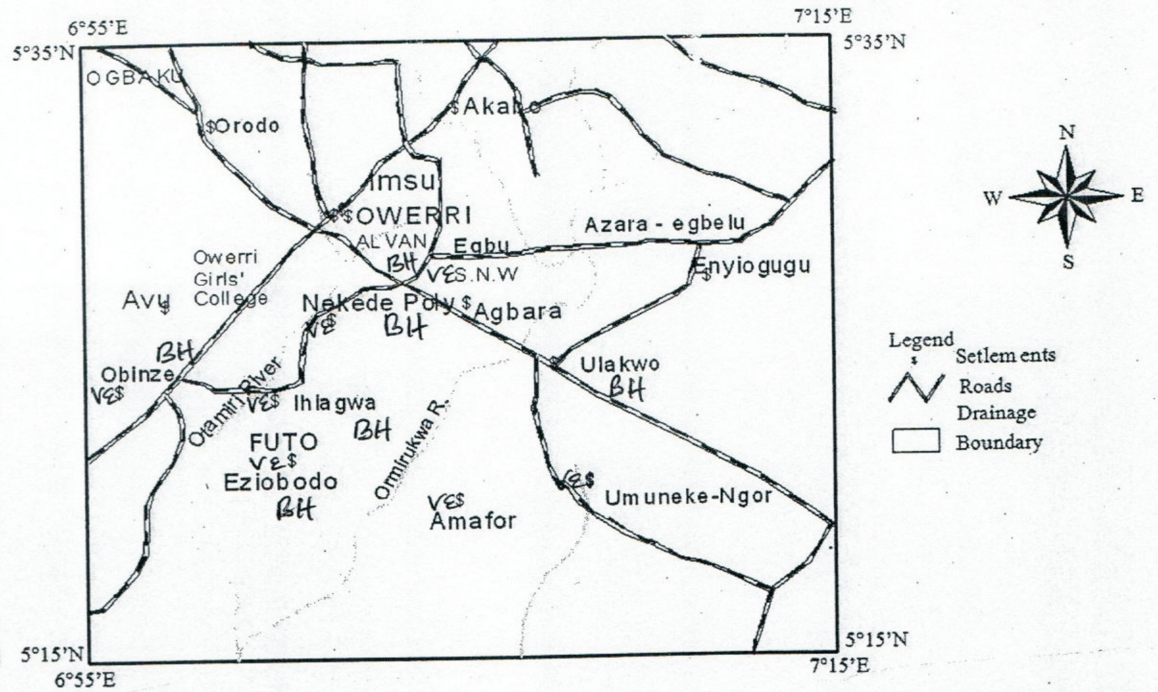

Fig. 2: Map of the Study area showing the VES, Pumping Test and Bore-hole Locations

Geophysical Survey

Predrilling geophysical investigation was carried out in 5 locations (Fig.2). Resistivity method, using the Vertical Electrical Sounding (VES) Schlumberger array technique was used. The survey provides information about the nature of the subsurface geology and the viability of the drilling project at a chosen site. The lithostratigraphic information obtained through geophysical survey compliments geological mapping and lithologs obtained from borehole drilling in the determination of dominant rock type in the area. The geoelectric sections obtained revealed that the area is dominated by Sandy Formation with minor clay intercalation (Fig.3).

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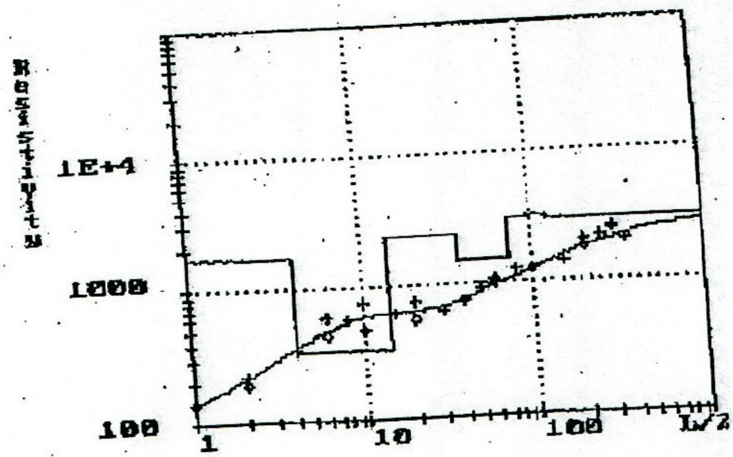

Fig. 3: Computer Modelled Curve for Owerre-Nkworji

Stratalogs

The results of the stratalogs prepared from the litho-samples collected from 18 drilled borehole locations in the area shows that the area is sand dominated (Fig.4). Medium to coarse grained sand occupies over 85% of the entire stratalogs, which conforms with the geophysical survey results (Fig.4)

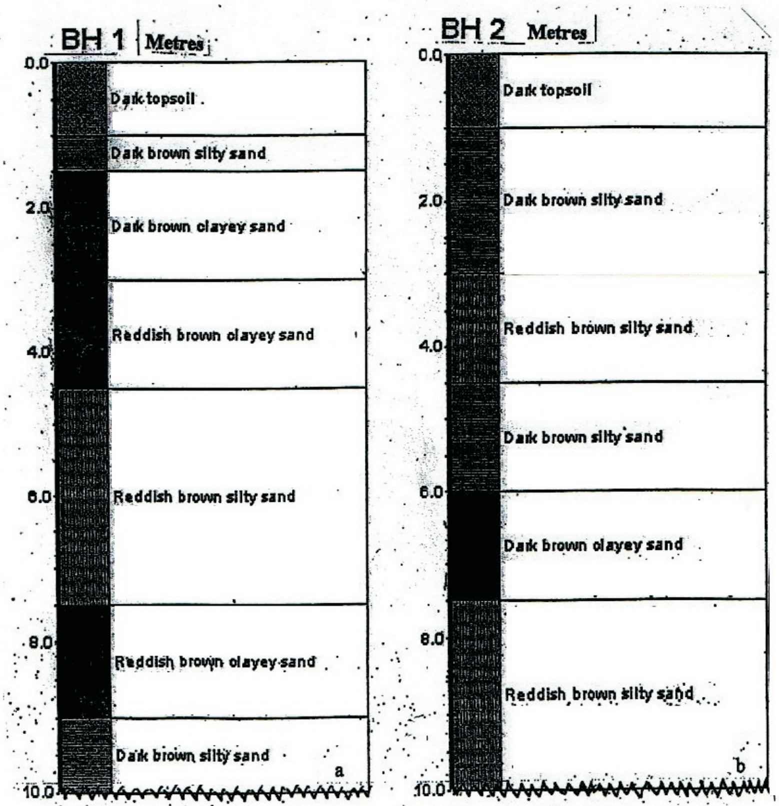

Fig. 4: Stratalog of Owerre-Nkworji

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Pumping Tests

Pumping tests were carried out in 5 locations to obtain information about the yield and drawdown of the wells. It is these data that were used to determine the specific capacity or the discharge-drawdown ratio of the well. It is the discharge value that was finally used to determine the transmissivity and storativity of the aquifers in the area which provided a picture of the groundwater potential of Owerri. The aquifer transmissivity and storativity were calculated from the pumping test data using Theis formula and Cooper-Jacob formula respectively.

The modified Jacob straight line method of Theis (1935) was used to calculate the aquifer transmissivity:

$$\mathbf{T = \frac{264Q}{4\ S}}$$

Where: **T** = Transmissivity (m^2/day)
Q = Pumping rate (m^3/day);
s = Slope/ log cycle

The values of Q were determined in the field as pumping was in progress while the values of s were determined from the slope along drawdown

1. **Emeabian Borehole**

Q = 6000 lit/hr = 6000/ (60 x 60) = 1.67 lit/sec.

= 1.67 x 60 x 60 x 24/1000 = 144.3m^3 /day

Δs = 72.25 – 70.00 = 2.25 (from the graph).

$$T = \frac{264Q}{4\ s}$$

= 264 x 144.3 / 4 x 3.142 x 2.25
= 1347.2 m^2/day.

Cooper-Jacob's method (1946) was used to determine the aquifer storativity. The equation is given as:

$$\mathbf{S = \frac{2.25KDt}{r^2}}$$

where: **S** = Storativity (dimensionless); **r** = radius of the well (mm); **t** = time (Sec),
KD = Hydraulic conductivity X Aquifer thickness =Transmissivity (m^2/day)

1. **Emeabian Borehole**

S = 2.25 KDt/r^2
KD = T = 1347.2 m^2/day
t = 7 sec
r = 76 mm
S = 2.25 x 1347.2 x 7/ (76 x 76)
= 3.67

The drawdown and recovery graph of Emeabian Borehole is shown in fig. 5

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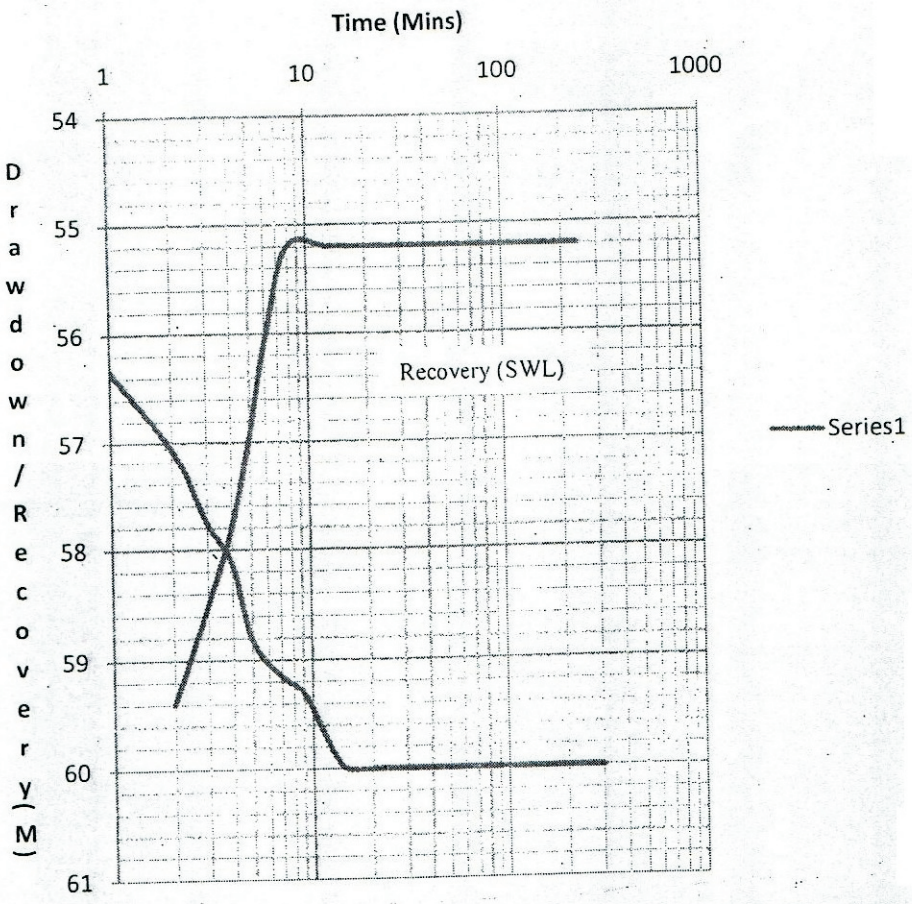

Fig. 5: Drawdown and Recovery graph for Emeabian Borehole

Sieve Analysis

Sieve analysis was carried out on 15 borehole litho-samples. 85% of the grain size distribution curves falls within the sandy region in the order of: coarse sand > medium sand > fine sand > (silt & clay) > gravel (Fig.6). Hydraulic conductivity (K) of the area was calculated from the grain size distribution curve using Hazen formula.

The Hazen's formula is given as:

$$\mathbf{K = c|d_{10}|^2}$$

Where: **K** = hydraulic conductivity (cm/sec)

$\mathbf{d_{10}}$= the effective grain size (cm)

C = a coefficient factor

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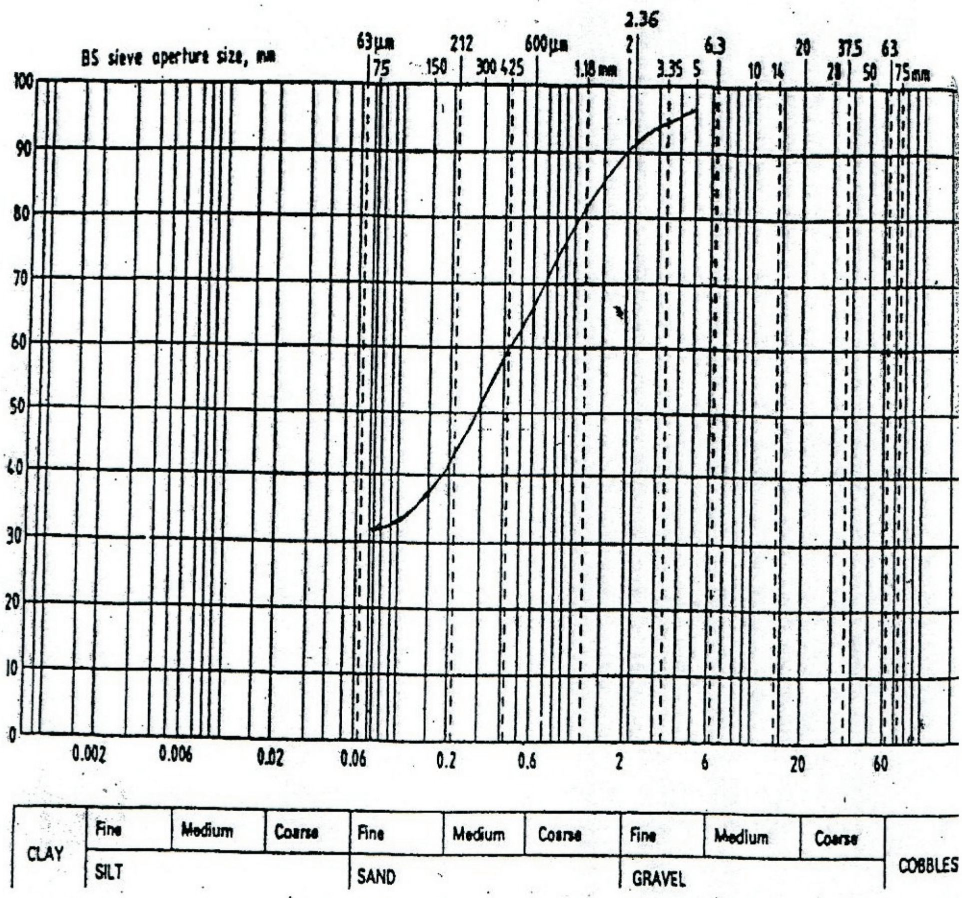

Fig. 6: Particle Size Distribution Curve for Owerre-Nkworji

Discussion of Results

Rocks having similar hydrogeologic properties such as specific yield, transmissivity, storativity etc are called hydrostratigraphic unit. Based on the constituent materials, the formation can be named as sandstone aquifer (sand being the constituent material). The need for borehole to augment water supply from surface water makes it imperative to have a good knowledge of the aquifer potentials from which groundwater is sourced. The study of groundwater potentials in different parts of Nigeria has revealed that most boreholes are wrongly located due to inadequate predrilling geophysical and hydrogeological studies (Olashinde, 2003).

The results of the predrilling geophysical survey and the sieve analysis indicate that the area is predominantly sandy formation. The transmissivity value ranges from 1008.3m²/day to 1551.0m²/day while that of storativity vary from 3.04 to 4.32. The hydraulic conductivity is of the order of 0.06cm/sec to 0.49cm/sec. In view of the findings, the aquifers in the area are of high groundwater potentials.

Conclusion and Recommendation

The area has a good groundwater potential as revealed by the transmissivity, storativity and hydraulic conductivity values determined using Thiems formula, Cooper-Jacob formula and Hazen formula respectively. The unsaturated zone materials are mainly sandy and gravelly facies with high permeability rates. The highly permeable overburden and shallow water table are indications that contaminant would migrate easily into the groundwater. The permeability and porosity of the aquifer materials enhance both vertical and horizontal movement of contaminant into the groundwater system. Groundwater quality management through education of the public on health implication of poor groundwater management and the enforcement of necessary laws that would help protect the groundwater system is advocated.

The high values of transmissivity, storativity and hydraulic conductivity are good indicators of aquifer potentials with high groundwater potential, however, proper geophysical and hydrogeological study would have enhanced greater productivity and provide more information that can be used for optimum development and proper management of groundwater resources in the area.

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