Evaluation of Aquifer Characteristics in Southern Part of Imo State, Southeastern Nigeria

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Abstract
The hydrogeological characteristics and groundwater potential of parts of Imo State, Southeastern Nigeria were evaluated via bacteriological analysis, chemical analysis, pumping test data, borehole logs, geophysical survey and sieve analysis. Transmissivity value ranges from 88.0m^2/day to 135.0m^2/day. The hydraulic conductivity varies from 0.05cm/sec to 0.50cm/sec. The geophysical survey and borehole logs confirmed that the area is sand dominated. The sieve analysis results indicate: coarse grained sand > medium grained sand > fine grained sand > gravel > (silt & clay). The borehole logs give a good lithostratigraphic profile of the subsurface rocks in the area. The aquifer system in the study area is mainly unconfined. The study revealed low concentrations of cations and anions which are attributed to the paucity of soluble materials in the bed-rock of the formation and the overlying soil. The microbial analysis of the water samples indicate high value of "total coliform" when compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) maximum permissible limits for drinking water. The pH value varies from 4.5 to 6.8 with a mean value of 5.5. These findings indicate that the area has good groundwater potentials and high aquifer recharge.

Keywords: ***Hydrogeology, Water Resources, Geophysical Survey, Strata-logs, Sieve Analysis, Transmissivity, Hydraulic Head, Static Water Level and Benin Formation.***

Introduction

This paper gives a detailed appraisal of the aquifer system and hydrogeology of the southern part of Imo State with the aim of calculating the groundwater reserves and recharge. The transmissivity and hydraulic conductivity of the aquifer system in the area were determined using Theis formula and Hazen formula respectively. The study also provided information to be used for optimum development, utilization and proper management strategies of water resources in the area and Niger Delta in general. This present study is a pioneer attempt in this direction and the population increase in Imo State with its associated pollution tendencies are good reasons for this study.

Study Area Description.

The study area is Owerri, the capital city of Imo State (Eastern Heartland). It Lies between Latitudes 5°12'N to 5°47'N and longitudes 6°45'E to 7°15'E (Figure.1). It is a low lying terrain with a good road network. The area is drained by Otamiri, Oramiriukwa, Njaba, Nworie and Imo Rivers. The rivers flow in the north-south direction except Njaba River which flows from west to east to join Oramiriukwa River (Figure.1).

Geology of the Area

The undulating plains and valleys are underlain by thick sandy horizons belonging to the Benin Formation of Miocene to Recent age. The formation is made up of friable sands with minor intercalations of clay. The sands are mostly coarse-grained, pebbly, poorly sorted and contain pods and lenses of fine-grained sands while the clays occur as streak and discontinous lenses. The Benin Formation is in part cross-stratified with the forset beds alternating between coarse and fine-grained sands.

Petrographic study on several thin sections (Onyeagocha, 1980) shows that quartz makes up more than 95% of all grains but Asseez (1976), Avbovbo (1978) and Ezeigbo (1989) indicated greater percentage of other skeletal materials including feldspar. The general thickness of Benin Formation is variable and ranges from less than 200m at the north-eastern limit to about 2000m at the depocenter (Avbovbo, 1978). Within the study area, the average thickness of the formation is about 800m (Onyeagocha, 1980). 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 is characterized by gentle undulating ridges and low lands. Springs are few and confined to the valley of the Imo River. The area has two distinct seasons: a dry season which lasts from November to March, and a rainy season which lasts from April to October. The dry season is often punctuated by a few scattered rains especially in February and March. Rainfall is brought by the moist Equatorial Maritime Air Mass from the Gulf of Guinea with prevailing winds from the south-west. The average annual rainfall is about 2500mm (Uma, 1989). The humidity is generally high throughout the year and the rates of evapo-transpiration far exceed that of precipitation during the dry seasons (Uma and Egboka, 1986).

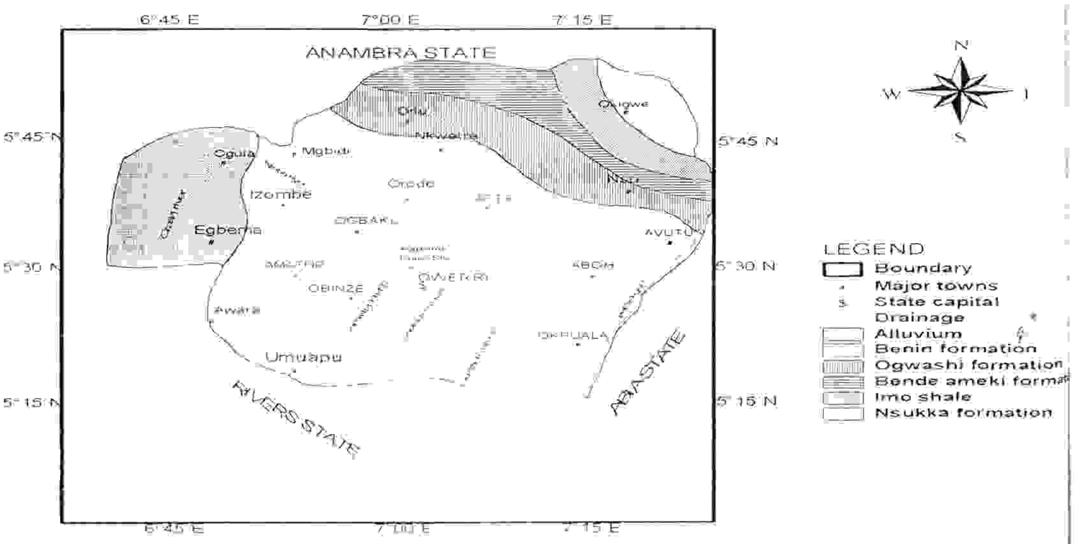


Fig.1. Geology Map of Imo State

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 6 pre-drilling geophysical survey, 18 drilled borehole logs, 5 pumping tests and 14 sieve analysis as shown in Figure 2.

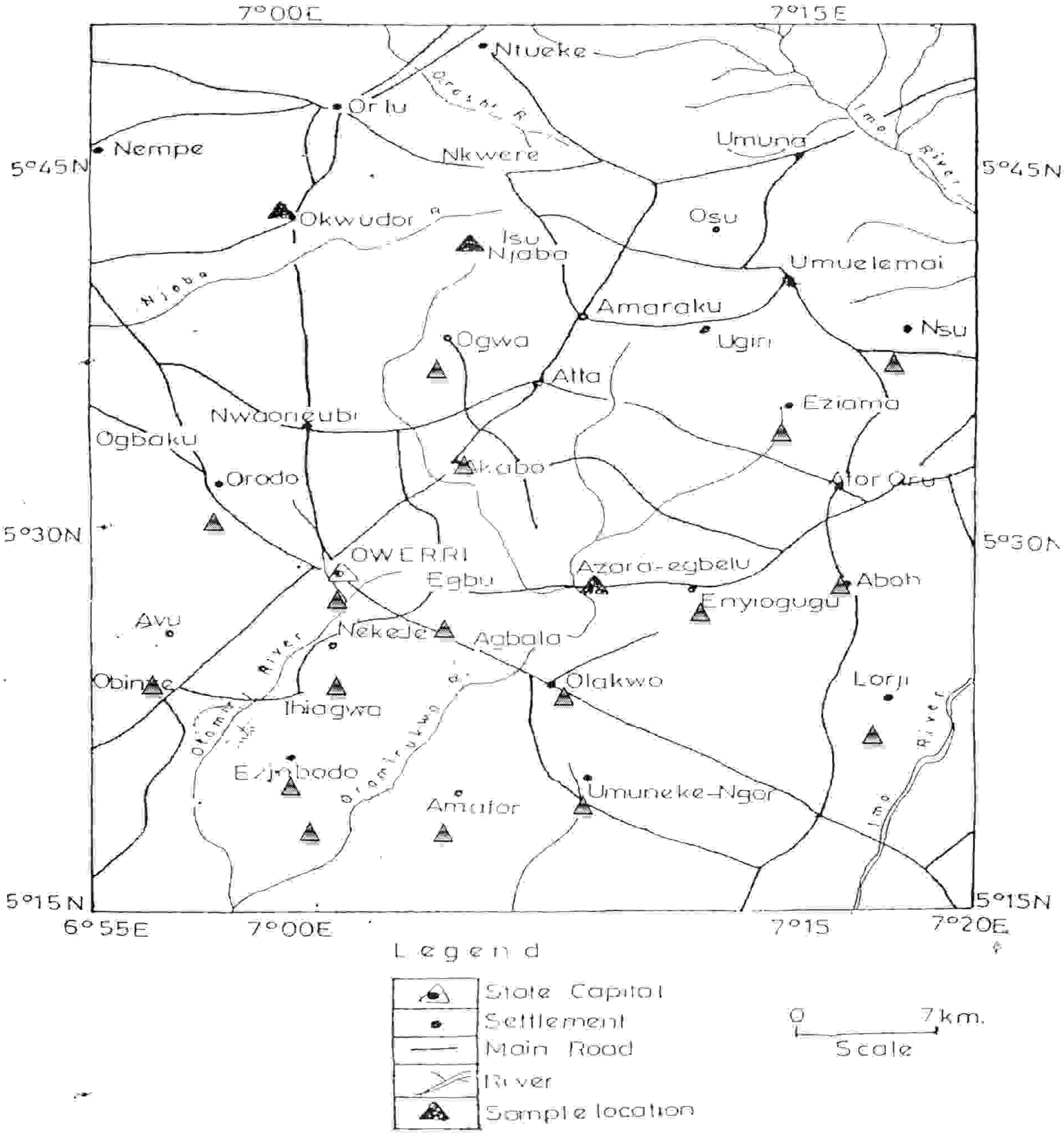


Fig. 2. Map of the Study area showing the Sample locations.

Geophysical Survey

Pre-drilling geophysical investigation was carried out in 6 locations (Figure 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 (Figure 3).

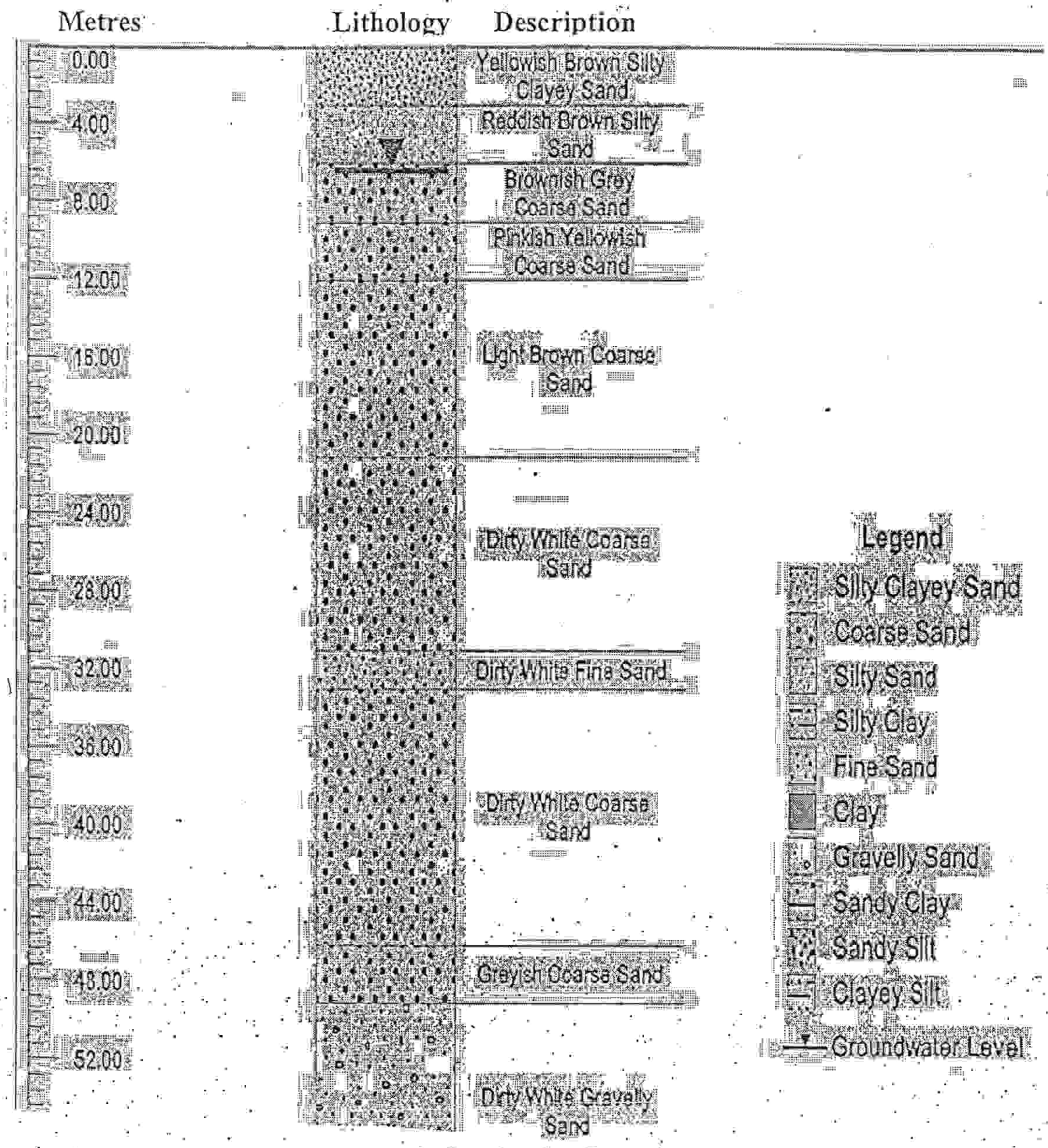


Fig. 3. A typical Geoelectric Section for Owerri.

Borehole-logs

The borehole-logs from the area show that the area is dominated by sandy formation (Figure 4). Medium to coarse grained sand occupies about 75% of the entire logs. which conforms to the geoelectric section shown in figure 3.

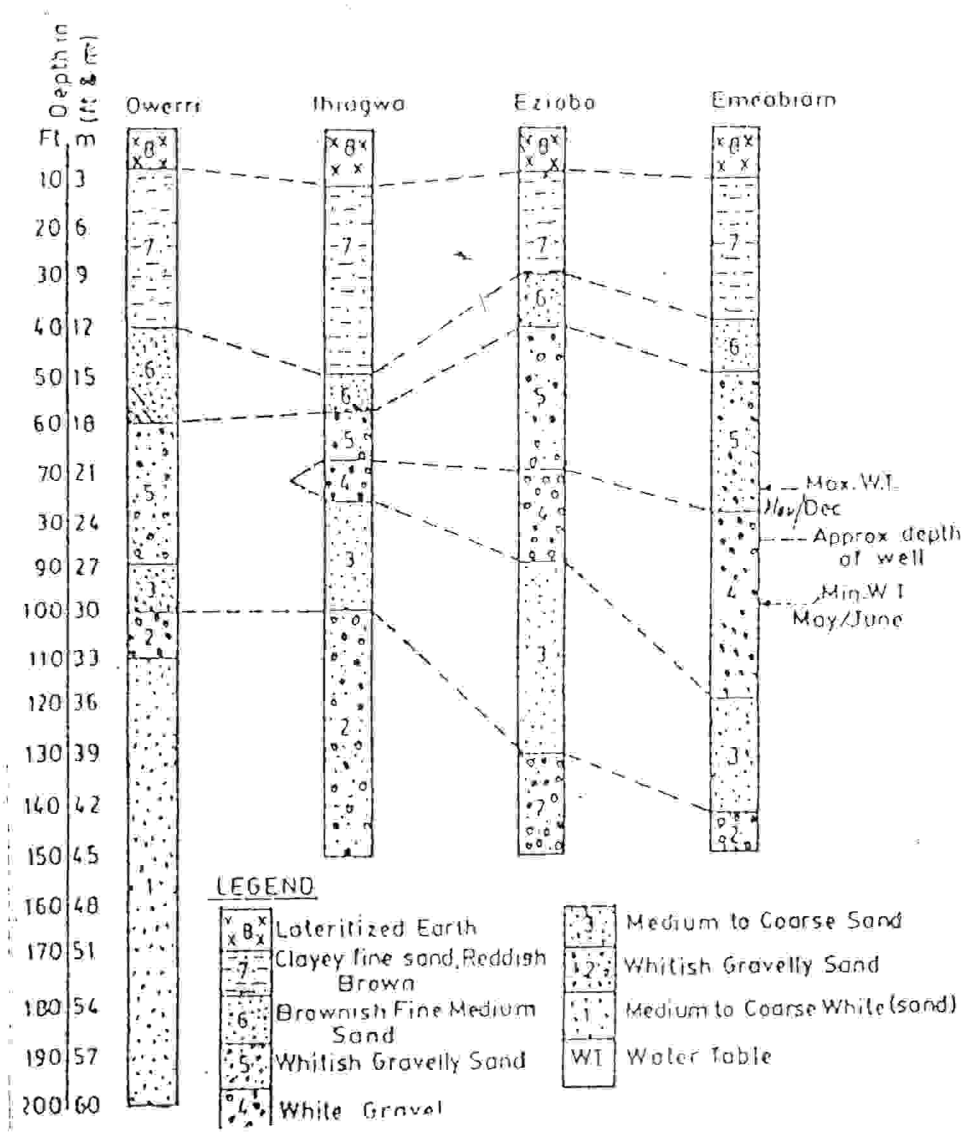


Fig.4.Strata log Correlation along the N-S axis of the Study Area

Static Water Level (SWL) and Hydraulic Head Distribution.

Static water level measurements were made in 18 boreholes using electric well sounder. Hydraulic head was determined from two dimensional network of piezometers installed along the banks of Otamiri river. They were installed by hand augering to a depth of about 60cm below the water table. It was constructed from 1-inch diameter PVC pipe whose bottom was sealed with a PVC stopcork. The static water level, hydraulic head, hydraulic gradient, topographic and drainage maps were used to construct the ground water flow map for the area (figure 5). The static water level of the 18 drilled boreholes and their corresponding hydraulic head are summarized in Table 5.

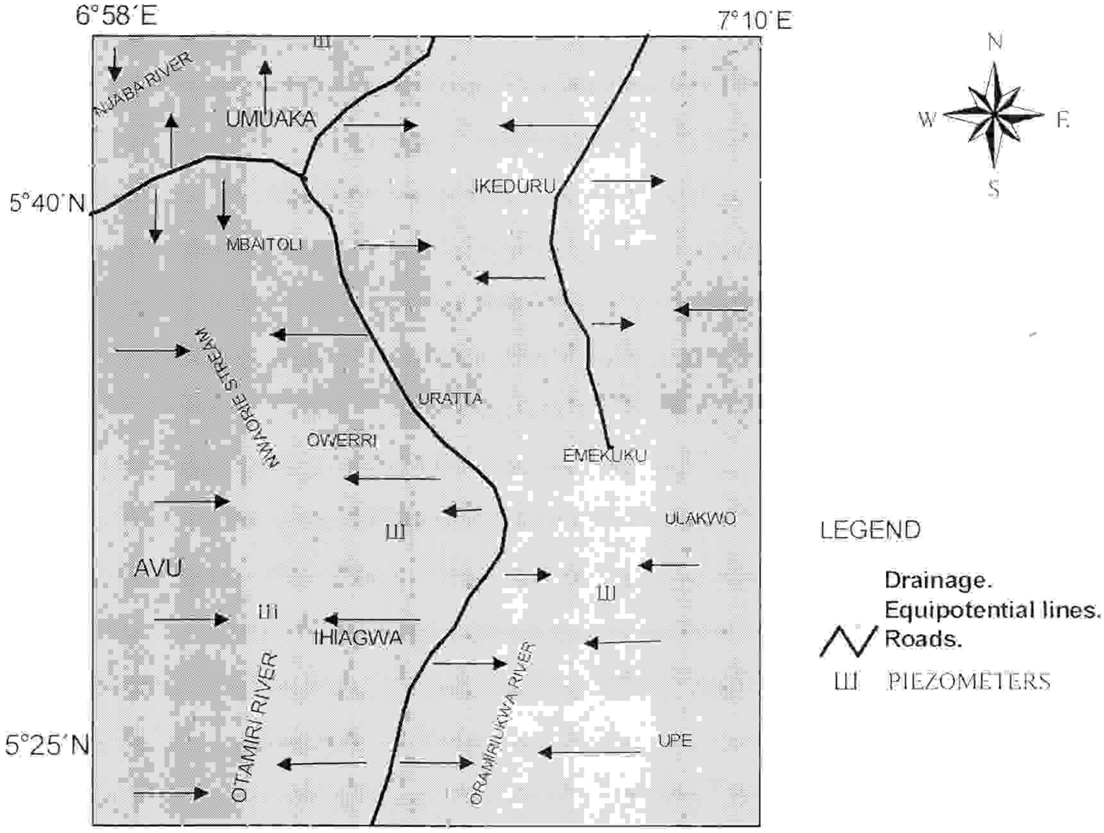


Fig.5. Groundwater Flow Map of the Study Area.

Pumping Tests

Pumping tests were carried out in few locations to obtain information about the yield, drawdown and recovery rates of the wells. It is these data that were used to determine the specific capacity or the discharge-drawdown ratio of the wells. The discharge value was finally used to determine the transmissivity of the aquifers in the area which provided a picture of the groundwater potential of the study area. The aquifer transmissivity was calculated from the pumping test data using Theis formula stated below:

$$T = \frac{2.30Q}{4\pi\Delta S}$$

Where: **T** = Transmissivity (m^2/day)

Q = Pumping rate (m^3/day);
Δs = Slope/ log cycle

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

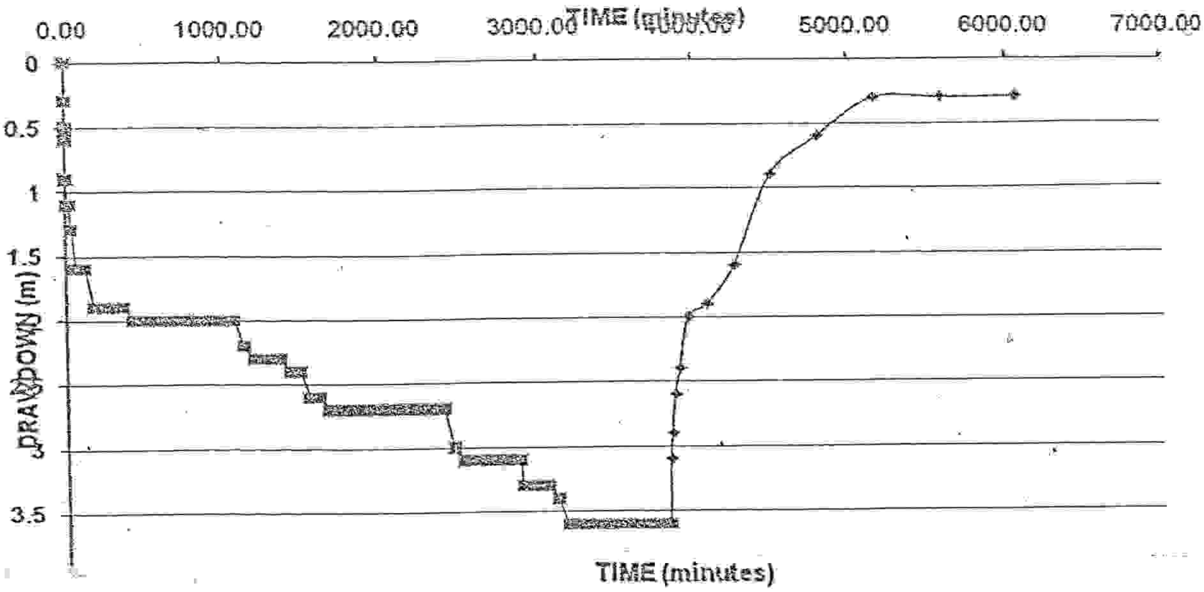
$\Delta s = 0.29$ (from the graph).

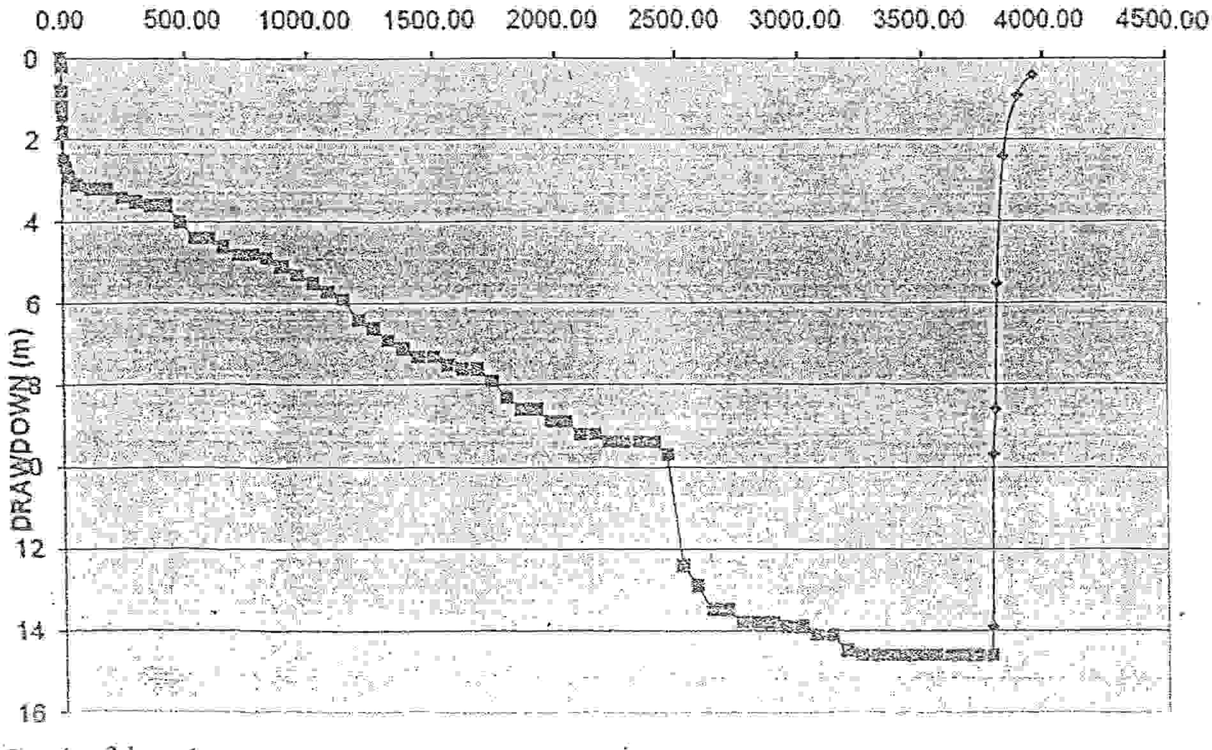
$$T = \frac{2.30Q}{4\pi\Delta s} = \frac{2.30 \times 144.3}{4 \times 3.142 \times 0.29} = 91.0\ m^2/day.$$

Eziobo 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





Graph of drawdown versus recovery

Sieve analysis was conducted on 14 borehole litho-samples. 85% of the grain size distribution curves indicates sandy region in the order of: coarse sand > medium sand > fine sand > (silt & clay) > gravel (Figure 7). Hazen formula was used to determine the Hydraulic conductivity (K).

The Hazen's formula is given as:

$$K = c[d_{10}]^2$$

Where: K = hydraulic conductivity (cm/sec)

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

C = a coefficient factor

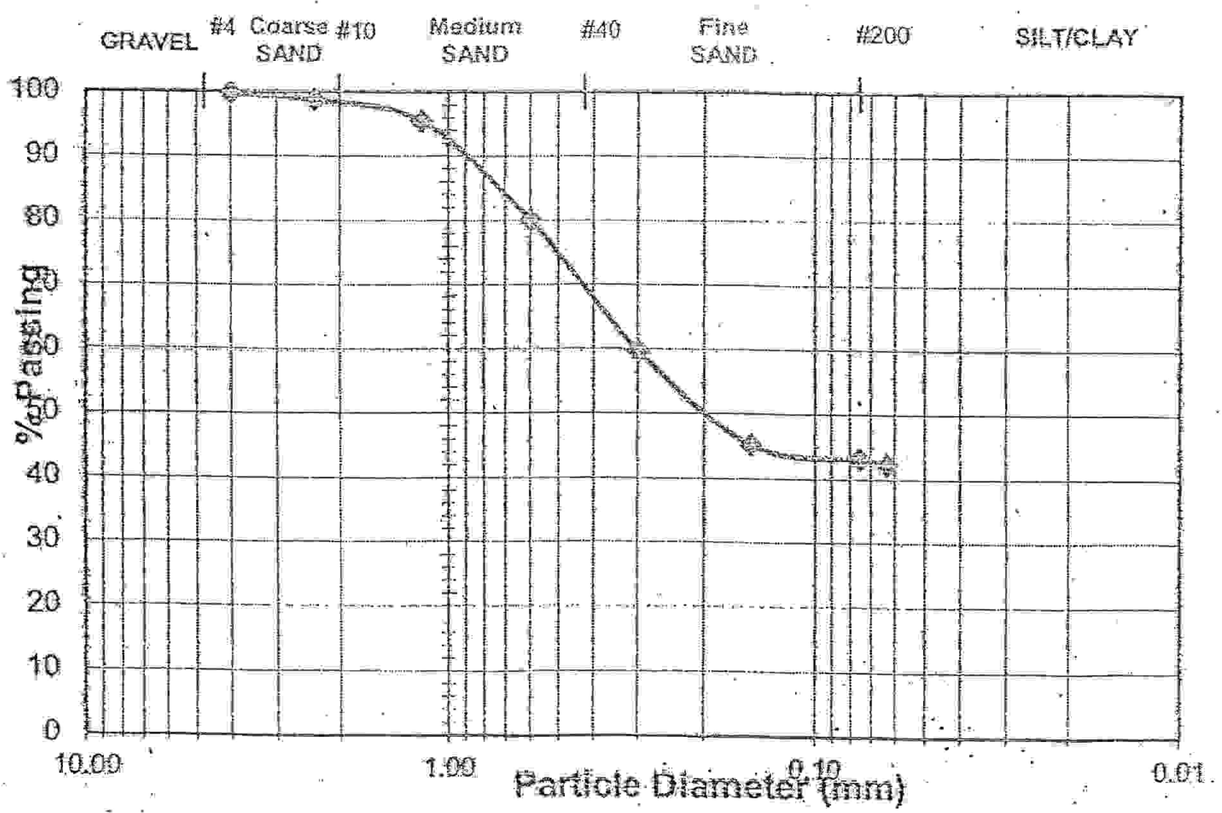
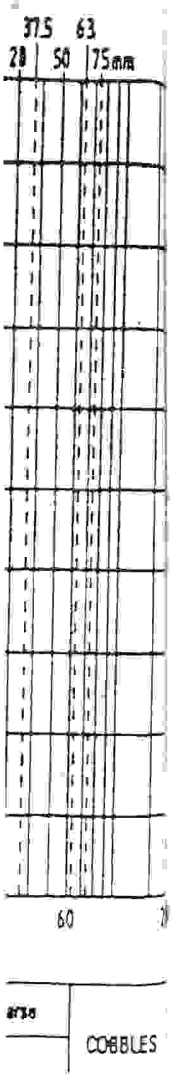


Fig7. A Typical Particle Size Distribution Curve for Owerri Area

as:

nductivity

size (cm)



Bacteriological and Chemical Analyses of Water samples.

The most common and widespread health risk associated with groundwater contamination is microbial contamination. Microbial contamination of major urban system has the potential to cause large outbreak of water borne disease. The microbial analysis of the water samples reveals high concentration of "total coliform" which is attributed to anthropogenic interference while chemical analysis of the water samples from the same area indicates a low concentration of cations and anions. The general low concentration of major ions in the groundwater samples is attributed to the paucity of soluble materials in the bed-rock of the formation and the overlying soil. Also, the coarse grained sandy formation in the area allows rapid infiltration into the water table and thus results in little or no contact and residence time between the percolating water and the few soluble materials present.

Discussion of Results

Rocks with similar hydrogeologic properties such as specific yield, transmissivity, storativity and hydraulic conductivity 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 Imo State revealed that most boreholes are wrongly located due to inadequate pre-drilling geophysical and hydrogeological studies (Amadi, 2007).

The results of the pre-drilling geophysical survey and the sieve analysis indicate that the area is predominantly sandy formation. The transmissivity value ranges from 88.0m²/day to 135.0m²/day. The hydraulic conductivity is of the order of 0.05cm/sec to 0.50cm/sec. The pH value varies from 4.5 to 6.8 with a mean value of 5.5, which indicates slightly acidic. Gas flaring might be responsible for the low pH observed in the water samples. In view of the findings, the aquifers in the area are of good groundwater potentials. The microbial analysis of the water samples indicate high value of "total coliform" which is attributed to anthropogenic interference while the chemical analysis of the water samples from the same area indicates a low concentration of cations and anions. The general low concentration of major ions in the groundwater samples is attributed to the paucity of soluble materials in the bed-rock of the formation and the overlying soil. The results of the microbial and chemical analyses show no negative health implication at present. The findings indicate that the area has good groundwater potentials and high aquifer recharge.

Conclusion and Recommendation

The area has a good groundwater potential as revealed by the transmissivity and hydraulic conductivity values determined using Theis 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 values of transmissivity 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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APPENDICES

Table 1: Stratigraphic Succession of Rocks in Owerri area (After, Uma and Egboka, 1985).

	Age	Formation	Lithology
Tertiary	Miocene-Recent	Benin Formation (Afam Member)	Medium to Coarse grained, poorly consolidated Sand with clay lenses and stringers
	Oligocene-Miocene	Ogwashi-Asaba Formation	Unconsolidated Sand with lignite seams at various layers
	Eocene	Ameki Formation Nanaka Sand	Grey Clayey Sandstone and Sandy Claystone
	Paleocene	Imo Shale	Laminated Clayey Shale
Upper Cretaceous	Maastrichian	Nsukka Formation	Sandstone intercalated with Shale and Coal beds

Table 2: Summary of Pumping Test Result.

S/No	Borehole Locations	Pumping Rate (Q) m^3/day	Slope (Δs)	Transmissivity (T) m^2/day	Borehole Radius (r) mm
1	Orji-Owerri	144.3	0.23	88.0	76
2	Ihiagwa	192.0	0.40	112.0	76
3	Eziobo	192.0	0.26	91.0	76
4	Emeabiam	144.3	0.29	135.0	76
	Mean	168.3	0.29	107.0	76
	Range	144.3-192.0	0.23 – 0.40	88.0 – 135.0	-

Table 3: Gheorghe and Krawny Standards for Aquifer Transmissivity.

Gheorghe		**Krawny**		K m/day	Materials
T	Potential	T	Potential	0.01-0.2	Surface Clay
› 500 m²/day	High	› 1,000	Very High	$10^{-8} - 10^{-2}$	Deep Clay
50–500m²/day	Moderate	100-1,000	High	0.1-1	Surface Loam
5-50 m²/day	Low	10-100	Intermediate	1-5	Fine Sand
0.5-5 m²/day	Very Low	1-10	Low	5-20	Medium Sand
‹ 0.5 m²/day	Negligible	0.1-1	Very Low	20-100	Coarse sand
			Imperceptible	100-1,000	Gravel
				5-100	Sand & Gravel
				0.001-0.1	Clay, Sand & Gravel

Local-time		**Time(Min)**		**Water-level(M)**	
Drawdown	Recovery	Drawdown	Recovery	Drawdown	Recovery
9.01am	4.01pm	0	0	70.00	72.20
9.02am	4.02pm	2	1	70.40	71.88
9.04am	4.03pm	4	2	71.62	71.56
9.06am	4.05pm	6	4	71.70	71.47
9.08am	4.07pm	8	6	71.99	71.22
9.10am	4.09pm	10	8	72.27	70.00
9.12am	4.11pm	12	11	72.50	70.00
9.14am	4.13pm	14	13	72.50	70.00
9.19am	4.18pm	19	18	72.50	70.00
9.24am	4.23pm	24	23	72.50	70.00
9.29am	4.28pm	29	28	72.50	70.00
9.44am	4.43pm	44	43	72.50	70.00
9.59am	4.58pm	59	58	72.50	70.00
10.29am	5.28pm	88	88	72.50	70.00
10.59am	5.58pm	119	118	72.50	70.00
11.59am	6.58pm	179	178	72.50	70.00
12.59pm	7.58pm	239	238	72.50	70.00
1.59pm		299		72.50	
2.59pm		359		72.50	
3.59pm		419		72.50	

Table 4: Pumping Test data for Eziobo Borehole

Table 5. Water Static Level and Hydraulic head distribution

Borehole S/No	Location	Static Water Level (SWL) (m)	Hydraulic head (%)
1	Nekede	20	9
2	Ihiagwa	20	9
3	Amaeze	19	9
4	Irete	17	9
5	Obube	24	10
6	Ugwu-Orji	34	12
7	Akabo	45	22
8	Amaimo	48	22
9	Azara	38	22
10	Ogbor	60	22
11	Oboama	50	22
12	Afara	45	22
13	Ogwa	64	22
14	Umunaka	65	22
15	Oguta	19	9
16	Nkworji	65	22
17	Umuegbe	64	22
18	Isi Ogwugwa	65	22

Table 6. Result of Chemical and Bacteriological analyses of groundwater and surface water in parts of Imo State.

Locations	Ca^{2+}	Mg^{2+}	K^{+}	HCO_3^-	SO_4^{2-}	Cl^-	pH	E. Coli	Total coliform
Imsu	24	7.6	6.5	42.0	17.0	3.6	4.8	0.0	129
Alvan	26	4.8	0.63	39.0	4.0	4.0	6.8	0.0	52
Nekede Poly	21	3.7	1.6	36.0	5.0	2.4	6.8	0.0	48
Ihiagwa	22	3.8	1.4	25.0	2.0	2.9	6.5	0.0	68
Futo	18	5.1	0.4	17.9	4.0	1.3	6.0	0.0	72
Eziobodo	16	1.6	3.6	19.6	15.0	5.3	4.8	0.0	81
Agbala	49	8.8	0.2	45.0	3.0	3.1	6.6	0.0	38
Ulakwo	30	7.5	1.1	27.0	3.5	2.3	5.6	0.0	61
Avu	39	7.2	2.3	23.0	2.0	1.8	4.6	0.0	53
Obinze	32	7.7	0.6	16.0	1.0	2.6	4.7	0.0	92
Ohambele	9.6	3.5	0.1	4.0	4.0	2.0	6.5	0.0	84
Oramiriukwa river	26	9.8	0.3	30.0	3.0	1.6	4.5	0.0	359
Otamiri river	17	3.2	1.8	42.0	5.0	1.7	4.6	0.0	462
Egbeada	4.0	7.8	0.0	8.0	4.0	2.0	6.8	0.0	78
Arondizuogu	12.1	7.4	0.2	3.0	3.0	2.1	7.0	0.0	65
Mean	27.2	5.5	1.8	30.8	5.1	2.8	5.5	0.0	121.8
Range	16-49	1.6-9.8	0.2-6.5	16.0-45.0	1.0-17.0	1.6-5.3	4.5-6.8	-	38-462