Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.6, No.2, 2016 

# Determination of The Hydraulic Conductivity, Transmissivity And The Environment of Deposition of Owelli Sandstone, in Anambra Basin, Southeastern Nigeria, Using Grain Size Distribution Analysis

*Aganigbo C. I., Akudinobi B. E. B., Okoro A. U., and Okoyeh E. I.

Geological Sciences Department, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

**Abstract**

This study estimated hydraulic conductivity, transmissivity, and interpreted the environment of deposition of the Owelli Sandstone in Mbanabor area of Anambra Basin, Southeastern Nigeria. These were achieved using grain size distribution analysis, and borehole lithological logs. The results indicated that values of hydraulic conductivity (m/s) and transmissivity ($m^2$/s) range between 2.89 x $10^{-2}$ – 1.52 x $10^{-1}$, and 4.8 x $10^{-1}$ - 5.3 x$10^{-1}$, respectively, indicating prevalence of aquifer of good performance. The aquifer units are predominantly unconfined, with variable thicknesses and depth of occurrence. The values of the mean, sorting, skewness and kurtosis, from sieve data range between 0.2 - 0.9Φ, 0.49 - 1.97Φ, -0.05 - 0.21Φ and 0.96 - 1.52Φ respectively. Multivariate discriminate functions revealed that Owelli Sandstone may have been deposited dominantly by beach process, in shallow agitated marine, and shallow marine environment.

**Key words:** Hydraulic Conductivity, Transmissivity, Owelli Sandstone, Anambra Basin, Depositional Environment.

## 1. Introduction

Groundwater accounts for the major portion of the world's fresh water resources. Many urban and rural dwellers depend entirely on groundwater for their daily water needs. Groundwater provides a reasonably constant source of water supply that is not likely to dry up under natural conditions. Freeze and Cherry (1979) stated that the primary motivation for the study of water has traditionally been because of its importance as a resource. Evaluation of groundwater in this work has been taken to include: the estimation of some aquifer parameters (including hydraulic conductivity, and transmissivity), and the determination of the environment of deposition of the rock samples that constitute the aquifer analyzed. Obasi, et al. (2013) noted that hydraulic conductivity is a very useful parameter in the evaluation of groundwater resources. Hazen formula (1911) relies on the effective grain size $d_{10,}$ to predict the relationship with hydraulic conductivity (K). Odong (2007) and Abdullahi (2013) observed that Hazen's formula of determining hydraulic conductivity is used for uniformly graded sands. However, it could also be used for fine sand to gravel range, provided the sediment has a uniformity coefficient less than 5 and effective grain size between 0.1 and 3mm. Salarashayeri, and Siosemarde, (2012), described equations to estimate saturated hydraulic conductivity (K), from $d_{10}$, $d_{50}$ and $d_{60}$ data. The results were successful in predicting hydraulic conductivity. The results of regression analysis showed that $d_{10}$ play a more significant role with respect to saturated hydraulic conductivity, and has been noted as the effective parameter in K's calculation. Transmissivity describes the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer. It is the rate at which water at prevailing kinematic viscosity is transmitted through a unit width of an aquifer under hydraulic head. Freeze and Cherry (1979) expressed transmissivity (T) as the product of the hydraulic conductivity and the aquifer thickness. The study is aimed at estimating the aquifer parameters (hydraulic conductivity and transmissivity) of Owelli Sandstone in Anambra Basin, Southeastern Nigeria and also establish the environment of deposition.

## 2. The study area

The study area lies between latitudes $6^0 10^1$N and $6^0 15^1$N, and longitudes $7^0 25^1$E and $7^0 30^1$E, covering an area of about 324$km^2$. It comprises Ihe, Agbogugu, Isu-Awaa, Agbudu, Owelli, Amaowelli, and Ogugu towns. It is accessible by Enugu to Portharcourt express way. Accessibility is also possible through the old Enugu-Portharcourt road, in Enugu state Nigeria. There are also minor link roads and footpaths, connecting the various towns and villages Fig 1. The area is located in the southeastern part of Nigeria, characterized by low climatic conditions. The rainy season (April-October), and the dry season (November-March). The study area is underlain

 

by two geologic formations; the Owelli Sandstone and the Enugu Shale. While the Owelli Sandstone is Late Campanian in age, the Enugu Shale is Campanian – Santonian (Reyment, 1965). The study tends to concentrate on Owelli Sandstone to determine its aquifer parameters for potential project.

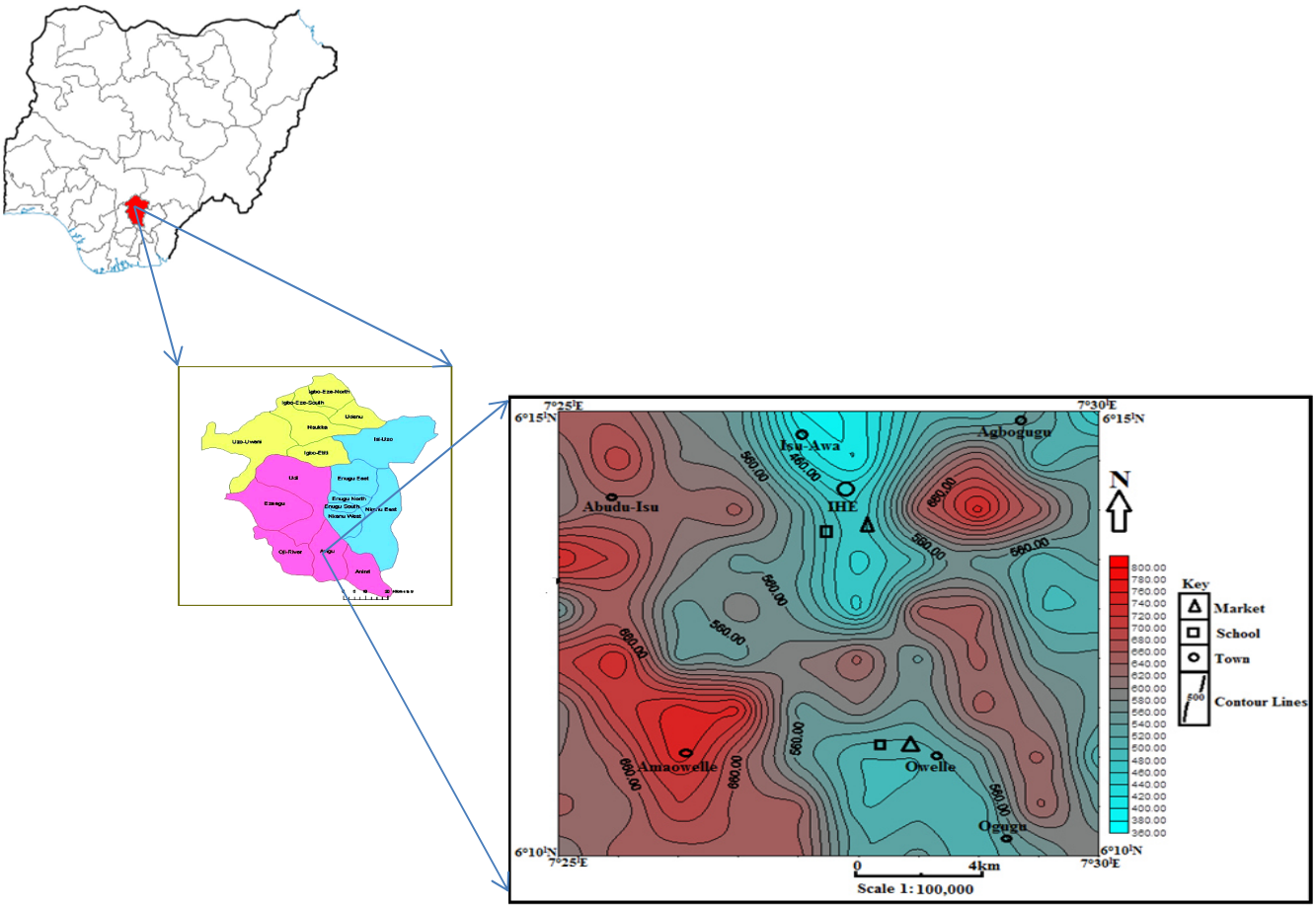


Fig. 1: Location of the study area in Enugu State, Nigeria.

## 3. Materials and Methods

The methods applied in the study include geological mapping and grain size distribution analysis. Field work examined lithology, textures, sedimentary structures, which helped in identifying the lithofacies. Eleven representative samples were sieved and Folk and Ward (1957) statistical formulae were used to calculate the grainsize parameters eg mean, standard deviation (sorting), skewness, and kurtosis. Hydraulic conductivity was determined using $d_{10}$ value from cumulative frequency distribution graph. These grainsize statistical parameters were further used in the multivariate discriminate functions. In order to characterize the depositional setting of the sediments, multivariate discriminate functions ($Y_1$, $Y_2$, $Y_3$) as proposed by Sahu (1964), was applied.

 

## 4. Results and Discussion

Table 1: Summary of the grain size parameters (Using Folk and Ward, 1957).

| Sample No. | Mean | Sorting | Skewness | Kurtosis |
|---|---|---|---|---|
| 1 | 0.97 | 1.29 | -0.13 | 0.96 |
| 2 | 2.40 | 0.49 | 0.21 | 1.09 |
| 3 | 0.33 | 0.94 | 0.07 | 0.98 |
| 4 | 1.00 | 0.50 | 0.03 | 1.29 |
| 5 | 1.10 | 0.78 | 0.09 | 1.30 |
| 6 | 0.90 | 0.67 | 0.03 | 1.52 |
| 7 | 1.20 | 0.81 | -0.05 | 1.00 |
| 8 | 1.5 | 0.84 | -0.31 | 1.00 |
| 9 | 0.20 | 0.80 | 0.20 | 1.18 |
| 10 | 0.70 | 0.80 | -0.20 | 1.00 |
| 11 | 0.73 | 1.09 | -0.04 | 1.14 |

### 4.1 Environment of Deposition Analysis

In order to characterize the depositional setting of the sediments (Table 1), multivariate discriminate functions ($Y_1$, $Y_2$, $Y_3$) as proposed by Sahu (1964), was applied.

**I.** For the discrimination between Aeolian process and Littoral (intertidal zone) environment, the following equation was used:

**$Y_1$ = -3.5688MN + 3.701ST – 2.0766SK + 3.1135KT (Sahu, 1964)**

Where MN is the mean grain size, ST is the inclusive graphic standard deviation (sorting), SK is the skewness, and KT is the kurtosis. When $Y_1$ is less than -2.7411, Aeolian deposition is indicated, where as when $Y_1$ is greater than -2.7411, a beach environment is indicated. The value of $Y_1$ calculated from Owelli Sandstone range from -3.79 - 5.50 (Table 2). 90% of the sandstone have $Y_1$>2.7411. Therefore the sandstone may have been deposited dominantly by beach process.

**II.** For the discrimination between beach (back shore) and shallow agitated marine environment (sub-tidal environment), the following equation was used:

**$Y_2$ = 15.6534MN + 65.7091ST + 18.10871SK + 18.5043KT (Sahu, 1964)**

When the value of $Y_2$ is less than 65.3650, beach deposition is suggested. If it is greater than 65.3650, a shallow agitated marine environment is indicated. The values of $Y_2$ calculated for Owelli Sandstone, range from 81.15 -114.88, indicating that 100% of the sandstone was deposited in shallow agitated marine environment (Table 2).

**III.** For the discrimination between shallow marine and fluvial environment, the following equation was used:

**$Y_3$ = 0.2852MN – 8.7604ST – 4.8932SK + 0.0482KT (Sahu, 1964)**

 

When $Y_3$ is less than -7.419, the sand is identified as a fluvio-deltaic deposit, and when it is greater than -7.419, the sand is said to be of shallow marine deposit. From the values of this analysis, $Y_3$ ranges from 4.00 to 12.12 suggestive of deposition in shallow marine environment.

Table 2: The discriminate function and environment of deposition of each sample.

| S/N | $Y_1$ | Environment of deposition | $Y_2$ | Environment of deposition | $Y_3$ | Environment of deposition |
|---|---|---|---|---|---|---|
| 1 | 4.51 | Beach | 114.88 | Shallow agitated marine | 12.12 | Shallow marine |
| 2 | -3.79 | Aeolian | 93.73 | Shallow agitated marine | 4.00 | Shallow marine |
| 3 | 5.21 | Beach | 86.33 | Shallow agitated marine | 8.03 | Shallow marine |
| 4 | 2.23 | Beach | 72.92 | Shallow agitated marine | 4.58 | Shallow marine |
| 5 | 2.82 | Beach | 94.15 | Shallow agitated marine | 6.77 | Shallow marine |
| 6 | 3.94 | Beach | 86.78 | Shallow agitated marine | 6.05 | Shallow marine |
| 7 | 1.93 | Beach | 89.60 | Shallow agitated marine | 7.73 | Shallow marine |
| 8 | 1.5 | Beach | 91.57 | Shallow agitated marine | 9.35 | Shallow marine |
| 9 | 5.50 | Beach | 81.15 | Shallow agitated marine | 6.14 | Shallow marine |
| 10 | 3.99 | Beach | 78.40 | Shallow agitated marine | 8.23 | Shallow marine |
| 11 | 5.04 | Beach | 103.60 | Shallow agitated marine | 9.96 | Shallow marine |

### 4.2 Hydraulic Conductivity (K)

Hydraulic conductivity values (cm/s) for the Owelli Sandstone was calculated using Hazen, (1911) formula $K = (d_{10})^2$. The calculated K ranged from $2.89 \times 10^{-2} - 1.521 \times 10^{-1}$ with the mean value of $7.5 \times 10^{-2}$ (Table 3 and 4, Figs. 2a and 2b), indicating relatively easy transmission of groundwater in the aquiferous zones (Freeze and Cherry, 1979). Movement of dissolved substances (including pollutants and contaminants) is thus enhanced. The hydraulic conductivity increases towards the Northeastern part of the study area and most prominent at Umuonwe Fig. 2.

 

Table 3: The hydraulic conductivity of different rock samples analyzed (Hazen, 1911).

| Sample number | Location | Latitude (km) | Longitude (km) | $d_{10}$ (mm) | Hydraulic conductivity (K) (m/s) |
|---|---|---|---|---|---|
| 1 | Umuogba-Ihe | 1057.46 | 1558.86 | 0.17 | 0.03 |
| 2 | Umuogba-Ihe | 1051.31 | 1561.12 | 0.33 | 0.11 |
| 3 | Umuogba-Ihe | 1034.43 | 1586.75 | 0.33 | 0.11 |
| 4 | Umuogba-Ihe | 949.19 | 1585.77 | 0.3 | 0.09 |
| 5 | Ezioha-Ogugu | 954.18 | 1591.37 | 0.2 | 0.04 |
| 6 | Ibite-Ogugu | 950.11 | 1598.49 | 0.3 | 0.09 |
| 7 | Amagu-Ihe | 1012.32 | 1513.58 | 0.19 | 0.04 |
| 8 | Umuonwe-Ihe | 1062.73 | 1549.79 | 0.17 | 0.03 |
| 9 | Umuonwe-Ihe | 1061.78 | 1550.34 | 0.39 | 0.15 |
| 10 | Umuonwe-Ihe | 1063.02 | 1552.59 | 0.31 | 0.09 |
| 11 | Obiono-River | 1031.65 | 1476.53 | 0.21 | 0.05 |

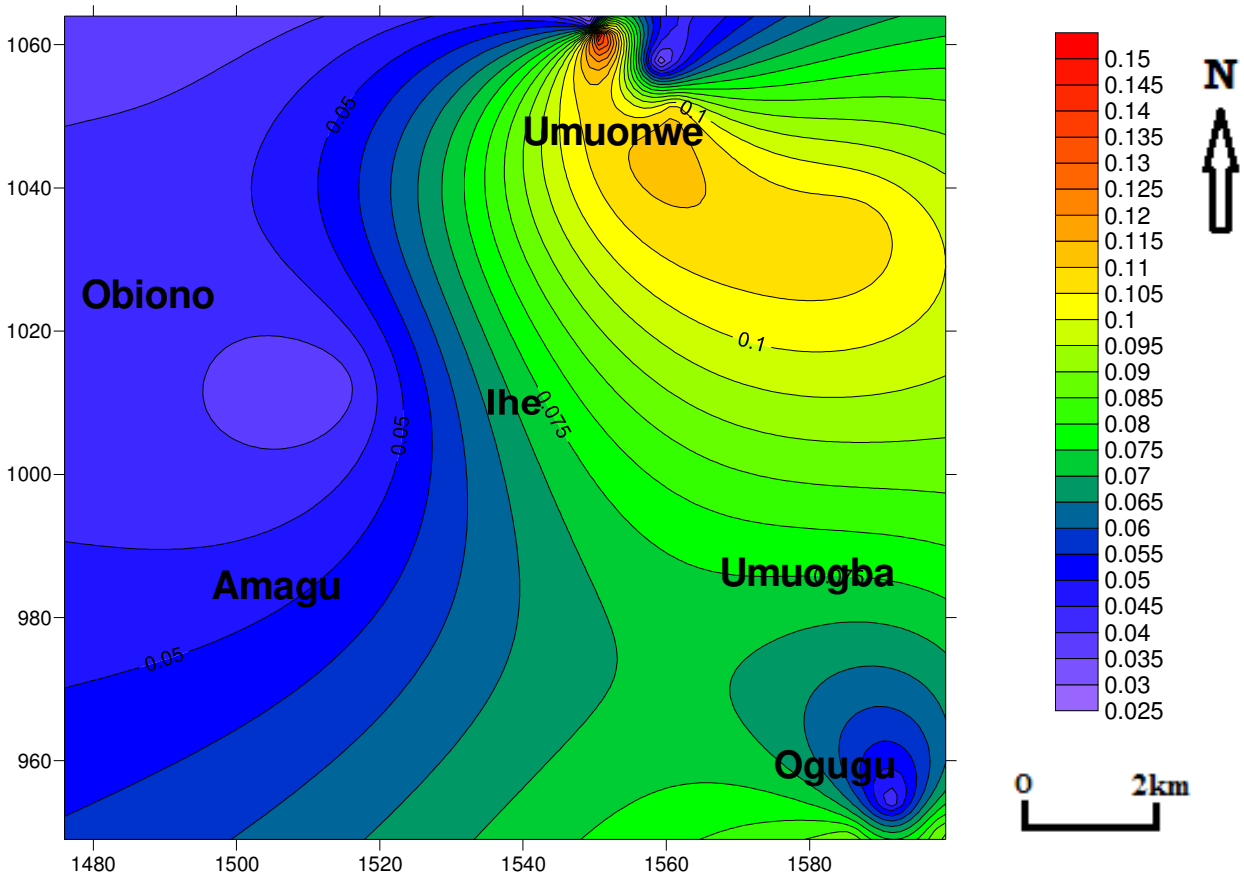


Fig. 2a: Map of the study area showing the hydraulic conductivity distribution.

 

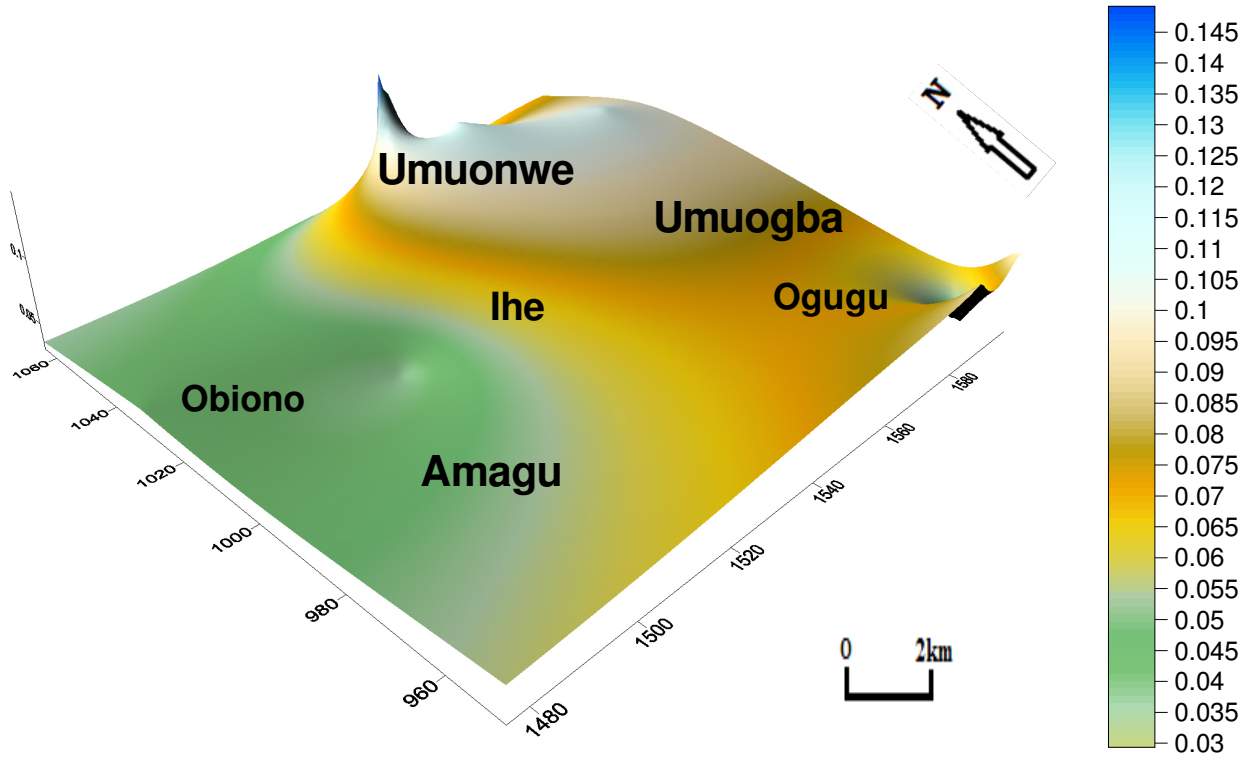


Fig. 2b: 3D map of the study area showing the hydraulic conductivity distribution.

### 4.3 Transmissivity (T)

Transmissivity values ($m^2/s$) in the study area range from $4.8 \times 10^{-1} - 5.3 \times 10^{-1}$ with the mean value of $5.0 \times 10^{-1}$(Table 5). These values are indicative of good aquifer in conformity with the hydraulic conductivity values (Kampsax-Kruger, 1985, and Kransy, 1993).

Table 4: Values of aquifer parameters in selected boreholes (Freeze and Cherry, 1979).

| BH No. | Location | Coordinate | Elevation (m) | Aquifer Thickness (b)(m) | Hydraulic Conductivity (K)(m/s) | Transmissivity (T)($m^2/s$) |
|---|---|---|---|---|---|---|
| 1 | Umuonwe | N6$^0$14'10.89" E7$^0$27'41.63" | 185 | 8 | 0.07 | 0.56 |
| 2 | Amagu | N6$^0$13'26.42" E7$^0$26'58.14" | 259 | 12 | 0.04 | 0.48 |
| 3 | Amagu | N6$^0$12'57.55" E7$^0$26'41.25" | 225 | 5 | 0.1 | 0.5 |

### 5. Summary

The hydraulic conductivity, transmissivity, and the environment of deposition of Owelli Sandstone in Anambra Basin, Southeastern Nigeria has been determined using data on grain size distribution analysis. The results of the investigation reveal that the values of hydraulic conductivity (m/s), and transmissivity ($m^2/s$), range between $2.89 \times 10^{-2} - 1.521 \times 10^{-1}$ and $4.8 \times 10^{-1} - 5.3 \times 10^{-1}$ respectively. These indicate aquifer of good performance in accordance with Kampsax-Kruger (1985) and Kransy (1993) transmissivity scales. In order to characterize the depositional setting of the sediments, multivariate discriminate functions ($Y_1$, $Y_2$, $Y_3$) as proposed by Sahu

 

(1964), was applied which revealed that owelli sandstone may have been deposited dominantly by beach process, shallow agitated marine, and shallow marine environment.

## 6. Conclusion

Mbanabor area is endowed with abundant surface and groundwater resources with prolific aquifers in existence. Well records indicate shallow groundwater sources that are unconfined, with elevated vulnerability to pollution and contamination from surface sources. Confined aquifer units are also in existence at about 45-50m depth. The hydraulic conductivity and transmissivity values range between 2.89 x $10^{-2}$ – 1.521 x $10^{-1}$ and 4.8 x $10^{-1}$ - 5.3 x $10^{-1}$ respectively**.** For the discrimination between Aeolian process and littoral (intertidal zone) environment $Y_1$ ranges from -3.79 - 5.50, suggesting 90% of beach process, while for the discrimination between beach (back shore) and shallow agitated marine (sub-tidal) environment $Y_2$ ranges from 81.15 – 114.88 indicating 100% shallow agitated marine environment. The discrimination between shallow marine and fluvial environment $Y_3$ ranges from 4.00 – 12.12 indicating 100% shallow marine environment.

## REFERENCES

Folk, R. L. and Ward, W. L., 1957. Bracos River Bar. A study in the significance of Grain Size Parameters. Jour. Sed. Pet., Vol. 27, No. 1, pp 2 – 26.

Freeze, R. A., and Cherry, J. A., 1979. Groundwater, Prentice-Hall Inc. New Jersey Chaps. pp.2 – 9.

Hazen, A., 1911. Discussion of "Dam on Sand Foundation" by A. C. Koenig. Transaction American Society of Civil Engineers. Vol. 73, pp. 199 – 203.

Idris-Nda, 2013. Estimating aquifer hydraulic properties in Bida Basin, Central Nigeria Using Empirical Methods. Earth science research; Vol. 2, No. 1; published by Canadian Center of Science and Education.

Kmpsax-Kruger, 1985. Underground Water Resources Investigation of the Metropolitan Lagos. Final Report, Federal Ministry of Works and Planning, Lagos. pp. 225.

Krasny, J., 1993. Classification of Transmissivity Magnitude and Variation. Groundwater, 31(2), pp. 230 – 236.

Obasi, P. N., Aghamelu, O. P., and Akudinobi, B. E. B., 2013. Determination of Hydraulic Conductivity of Sandstones of Ajali Formation in Uturu Area (Southeastern Nigeria) using grain size analysis. Journal of Natural Sciences Research, Vol. 3, No. 3, pp 49-54.

Odong, J., 2008. Evaluation of Empirical Formulae for Determination of Hydraulic Conductivity based on Grain Size Analysis, The American Journal of Science Vol. 4, No. 1, pp. 1 – 6.

Reyment, R. A., 1965. Aspects of Geology of Nigeria. Ibadan university Press, Ibadan, pp. 628.

Sahu, B. K., Multigroup discrimination of depositional environments using distribution statistics. Ind. Journal of Earth Sciences. 10(1), (1983), pg 20 – 29.

Sahu B. K. Depositional Mechanism from the size analysis of clastic sediments. Journal of Sedimentary Petrology, 34(1), (1964), 73 – 83.

Salarashayeri A. F. and Siosemarde, M., 2012. Prediction of Soil Hydraulic Conductivity from Particle Size Distribution Analysis. World Academy of Science, Engineering and Technology Vol. 6, 24th January, 2012.