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Evaluating Groundwater Potential and Hydrogeological Environment by Classification of Transmissivity Magnitude and Variation in Aquifer Bearing Rocks in Parts of Oru LGA. Imo State, Southeastern Nigeria Using the Methods of Statistical Testing and Krasny's Classification

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Abstract**—** *Krasny's classification scheme for Transmissivity magnitude and variation was used to identify the ground water supply potential and the nature of the hydrogeological environment of the study Area. Spatial variation of transmissivity values were analysed using Statistical testing and Krasny's classification systems; from the results of the statistical testing; 16.67% of the eighteen vertical electrical sounding points in the study area had transmissivity index in the class of negative anomalies (withdrawals for local water supply with limited consumption) with a range of between 6.418 and 5.887 with groundwater potential rated as very low. 61.11% of the sounding points were in the class of Background anomalies (smaller withdrawals for local water supply and for private consumption) with transmissivity index range of between 6.418 and 7.479 with groundwater supply potential rated as low. 22.2% of the sounding points were in the class of positive anomalies (withdrawals of lesser regional importance) with transmissivity index range of between 7.479 and 8.009 with groundwater potential rated as moderate. The standard deviation value of 0.53 in the transmissivity index (Y) represents a moderate transmissivity variation and characterized the study area as a fairly heterogeneous hydrogeological environment. From the results of Krasny's classification system; 5.56% of the sounding points were in the class of intermediate or moderate transmissivity magnitude with groundwater potential expressed as withdrawals for local water supply for small communities and plants. Most of the sounding points (94.4%) were in the class of High transmissivity magnitude with groundwater potential expressed as withdrawals of lesser regional importance.*

Keywords**—** *Groundwater; Groundwater Potential; Transmissivity; Transmissivity Index; Transmissivity Magnitude.*

I. INTRODUCTION

Aquifer transmissivity is one of the properties that control the movement, storage and extraction of underground water. Aquifer transmissivity is defined as the product of hydraulic conductivity or permeability and thickness of the aquiferous units and is measured in m^2 /day. The majority of hydrogeology problems may be understood quantitatively (Ramakrishna, 1998), and field research is ongoing to determine and assess the transmissivity and storage coefficient of aquifers based on test results (Birpinar, 2003); It is an integral part of assessment and management of ground water study (Sarwade et al, 2007; K . Srinivasa Reddy (2014).

Agbodike I (2021) in His paper titled " Estimating Aquifer Hydraulic Conductivity and Transmissivity for parts of Oru LGA Imo State, Southeastern Nigeria Using resistivity data was able to compute the aquifer hydraulic parameters including transmissivity values for 18 vertical electrical sounding points distributed within the area of Study. A table showing these parameters according to Agbodike I (2021) is shown below.

Our discussion on classification of transmissivity magnitude and variation in aquifer bearing rocks in the study area shall be based on the data on table 1. Meanwhile Spatial variation of transmissivity magnitude and variation has been identified as best useful in groundwater management practices. K. Srinivasa Reddy (2014).

II. LOCATION AND GEOMORPHOLOGY OF THE STUDY AREA

The study area lies between longitude $6^0 50$ E and $7^0 00$E and latitude $5^0 50$N and $5^0 37$N as shown in the location map of the area as in figure 1. It covers a land mass of about 315km^2 south East Nigeria. The study area is made up of communities like Nempi, Aji, Akatta, Akuma , Mgbidi, etc .It is within the equatorial climate , which consists mainly of two major seasons; rainy season(March –October) and the dry season(November—February). The harmattan occurs within the dry season. The study area has a daily temperature range of 31^0C to 33^0C during the dry season and a range of 24^0C to 26^0C during the rainy season.

III. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

A study of the geology of Nigeria shows that the Oru Area is made up of two geological formations; the Ogwashi- Asaba and the Benin formation which was formerly known as coastal plain sands (Reyment,1965). According to, Whiteman (1982). Clays, sands, grits, and lignites alternate with one another in the Ogwashi-Asaba formation. Reyment (1965) hypothesized that this strata is Oligocene-Miocene in age. The sands and

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sandstones of the Benin formation are typically granular in texture and range in grain size from coarse to fine.

TABLE (1a): Aquifer Hydraulic parameters of the study area using data from surface electrical soundings according to Agbodike (2019)

VES NO	Location	Resistivity (Ohm-m)	Aquifer depth (m)	Aquifer Thickness (m)	Aquifer Conductivity (Siemens)	Transverse Resistance (ohm-m^2)	Longitudinal Conductance (mhos)
1	Ubachima 1	395	110	119	0.0025	47005	0.30126
2	Ubachima 2	317	92.4	79.3	0.00315	251381	0.25016
3	Umuokwe	313	96.4	68.8	0.00319	21534.4	0.21981
4	Oteru	470	200	140	0.00213	65800	0.2979
5	Umuowa	636	86	103	0.00157	65508	0.1619
6	Otulu 1	640	120	115	0.00156	73600	0.1796
7	Ubahazu 1	642	125	115	0.00156	73830	0.1791
8	Ubahazu 2	645	117	109	0.00155	70305	0.1689
9	Otulu 2	618	155	122	0.00162	75396	0.1974
10	Umuoji	221	164	123	0.00452	27183	0.55656
11	Mgbidi1	196	205	90	0.0051	17640	0.4592
12	Mgbidi2	1831	87	67	0.00055	122677	0.03659
13	Ibiasoegbe	524	84	132	0.00191	69168	0.2519
14	Nempi	3934	81.6	63.5	0.00025	249809	0.1614
15	Akatta	3466	75	74	0.00029	256484	0.02135
16	Aji	557	27	24	0.00179	13368	0.04309
17	Ubulu	2915	36	69	0.00034	201135	0.02367
18	Akuma	96.5	39	41	0.01036	3956.5	0.42487

TABLE (1b): Aquifer Hydraulic and transmissivity values for the study area according to Agbodike(2021)

VESNO	Location	Resistivity (ohm-m)	Diagnostic constant(Kr)	Aquifer conductivity(siemens)	Transmissivity(m^2/day)	Hydraulic conductivitym/day
1	Ubachima1	395	0.01188	0.0025	558.255	4.633
2	Ubachima2	317	0.01188	0.00315	2985.53	37.594
3	Umuokwe	313	0.01188	0.00319	255.753	3.717
4	Oteru	470	0.01188	0.00213	781.704	8.889
5	Umuowa	636	0.01188	0.00157	778.006	7.545
6	Otulu1	640	0.01188	0.00156	874.11	7.592
7	Ubahazu 1	642	0.01188	0.00156	876.842	7.637
8	Ubahazu 2	645	0.01188	0.00155	834.977	7.663
9	Otulu2	618	0.01188	0.00162	895.441	7.349
10	Umuoji	221	0.01188	0.00452	322.839	2.623
11	Mgbidi 1	196	0.01188	0..0051	209.501	2.327
12	Mgbidi 2	1831	0.01188	0.00055	1456.97	21.741
13	Ibiasoegbe	524	0.01188	0.00191	821.474	6.229
14	Nempi	3934	0.026	0.00025	6495.03	10.221
15	Akatta	3466	0.026	0.00029	6668.58	89.956
16	Aji	557	0.01188	0.00179	158.765	6.596
17	Ubulu	2915	0.026	0.00034	5229.51	75.777
18	Akuma	96.5	0.026	0.01036	102.869	2.508

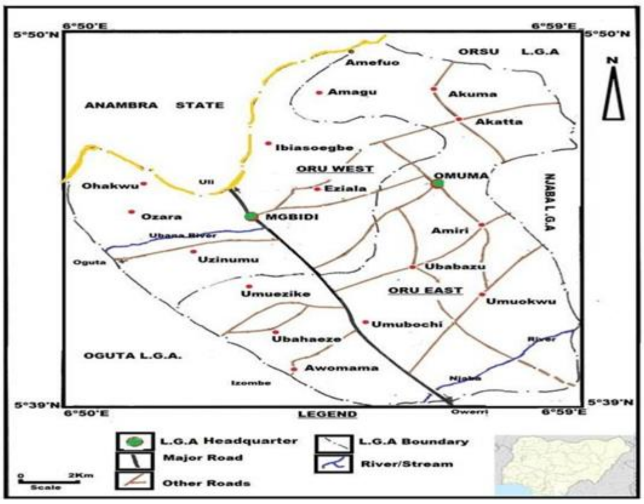

Figure 1. Location Map of the Study Are

The formation is partly estuarine, partly lagoon, partly deltaic and fluid, lacustrine in origin. Reyment(1965). The sands and sandstones in this formation are coarse grained, very granular , pebbly to very fine grained, they are either white in colour or yellowish brown. Hermatite grains and feldspars are also obtained. The shale isgreyish brown, sandy to silty and contains some plant remains and dispersed lignites (Reyment (1965). The formation has an average thickness of 600ft(196.85m) Kogbe(1976)

Surface waters are not a major feature of the Oru Area. The Njaba and Obana rivers seem to be the onlysurface waters in the area. Agbodike(2010). The two formations are known to have reliable groundwater that could sustain borehole development. The high permeability of the coastal plain sands, the overlying lateritic earth and the weathered top of this formation provides the hydraulic conditions favouring aquifer formation in the study area. The copious rainfall that prevails in the area makes the aquifer prolific and continuously provides

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the groundwater recharge. The geological map of the Study Area is in fig 2.

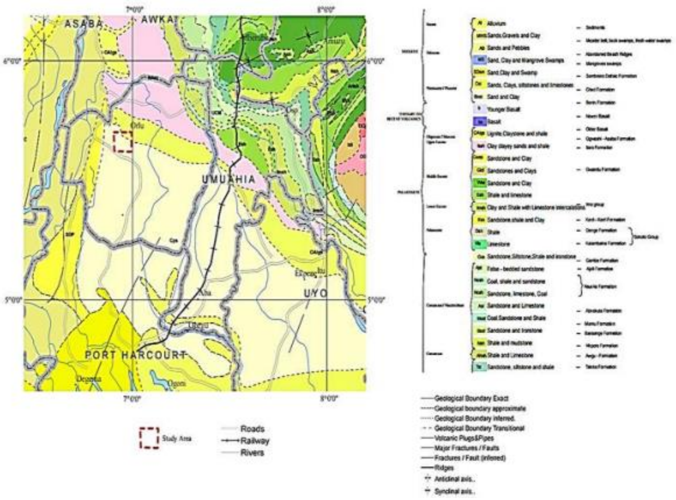

Figure 2. Geological Map of the Study Are

IV. Theory Of Spatial Analysis Of Transmissivity

The Transmissivity analysis is carried out using two methods. One method is based on descriptivestatistical testing for identification of background transmissivity and anomalies and the second method is classification scheme introduced by Krasny (1993.) for appraisal of groundwater supplypotential.

Statistical Testing Method

In this method, all the transmissivity values collected are pooled in a particular region using Transmissivity index Y, the relationship between Transmissivity (T) and logarithmic Transmissivity index
(Y) is

$$T\ (m^2/day) = 10^{Y-8.96} \times 86400 \quad (1)$$

Found by Jetal and Krasny in 1968. It is used to calculate the logarithmic transmissivity index (Y) fromtransmissivity (T) values. The above stated equation can be modified as, Logarithmic transmissivity index,

$$Y = LOG\ \{T/86400\} + 8.96 \quad (2)$$

Where T= Transmissivity in m^2/day

TABLE 2. Krasny's Classification of Transmissivity of Magnitude and Variation; Classification of Transmissivity T Magnitude

Coefficient Of T (M^2/D)	Class Of T Magnitude	Designation Of TMagnitude	Ground Water Supply Potential
>1000	I	Very high	Withdrawal of greatregional importance
1000--100	II	High	Withdrawals of lesser regional importance
100-10	III	Intermediate	Withdrawals for localwater supply(small communities and plants)
10-1	IV	Low	Smaller withdrawals forlocal water supply(private consumption)
1-0.1	V	Very low	Withdrawals for localwater supply with limited consumption
<0.1	VI	Negligible	Sources for local water supply are difficult

The logarithmic Transmissivity index (Y) values are calculated using the modified equation.

The Transmissivity classification systems for the study area based on the magnitudes and variations ofthe Transmissivity index (Y) as proposed by krasny (1993) are given in tables 2 and 3.

The Standard deviation of the transmissivity index (Y) Variations represents the degree of heterogeneity of the hydrogeological environment.

By using the transmissivity analysis based on transmissivity index (Y) classification (table 4), the ground water supply potential designation for the various localities in the study area was identified asgiven in table 5.

TABLE 3. Classification Of Transmissivity (T) Variation

Standard DeviationOf T Index (Y)	Class Of T Variation	Designation Of T Variation	Hydrogeological Environment
<0.2	a	Insignificant	Homogeneous
0.2—0.4	b	small	Slightly heteregenous
0.4 –0.6	c	moderate	Fairly heterogenous
0.6—0.8	d	large	Considerably heterogenous
0.8—1.0	e	Very large	Very heterogenous
>1.0	f	Extremely large	Extremely heterogenous

TABLE 4. transmissivity analysis based on transmissivity index (y) classification

S/N	Classification	Description	Range of y	Ground water supply potential
1	Negative extreme anomalies	Less than(mean –(2x standard deviation)	< 5.887	Negligible
2	Negative anomalies	Between (mean—standard deviation) and (mean –(2 x Standard deviation)	6.418 and 5.887	Very low
3	Background anomalies	Between (mean-standard deviation) and (mean—(2 x standard deviation)	6.418 and 7.479	Low
4	Positive anomalies	Between (mean +standard deviation) and (mean + (2x standard deviation)	7.479 and 8.009	Moderate
5	Positive extreme anomalies	Greater than(mean + (2x standard deviation))	> 8.009	High

V. Results And Discussions

Transmissivity analysis based on transmissivity magnitude Classification as in table 2 delineated the study area as follows; None (0 %) of the vertical electrical sounding points have negligible transmissivity magnitude (sources for local water supply are difficult) None (0%) of the sounding points had very low magnitude(withdrawals for local water supply with limited consumption) None (0%) had low transmissivity magnitude (smaller withdrawals for local water supply(private consumption) Only 5.56% of the vertical electrical sounding points had intermediate transmissivity magnitude (withdrawals for local water supply for communities and plants. Most of the sounding points (94.4%) had High transmissvity magnitude with ground water potential expressed as withdrawals of lesser regional importance.

TABLE 5. Results of summary statistics of transmissivity index (y) , Krasny's transmissivity magnitude and variation

S/N	Ves No	LocatiOn	T(m²/day)	T IndeX (Y)	Results of TIndex (Y)	Results of TMagnitude	Results of T Variation
1	One	Ubachima 1	558.255	6.770	Background anomalies(smallerwithdrawals for local water supplyand for private consumption)	High(withdrawals oflesser regional importance))	Fairly heterogenous
2	Two	Ubachima 2	2985.53	7.499	Positive anomalies(withdrawal for less regional importance)	High (Withdrawalsof lesser regional importance)	Fairly heterogenous
3	Three	Umuokwe	255.753	6.431	Background anomalies(withdrawals for local water supply and for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
4	Four	Oteru	781.704	6.917	Background anomalies (withdrawals for local water supplyand for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
5	Five	Umuowa	778.006	6.915	Background anomalies(withdrawal for local water supply and for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
6	Six	Otulu 1	874.11	6.965	Background anomalies(withdrawal for local water supply and for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
7	Seven	Ubahazu1	876.842	6.966	Background anomalies(withdrawals for local water supplyand for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
8	Eight	Ubahazu2	834.977	6.945	Background anomalies(withdrawal for local water supply and for private consumption)	High(Withdrawals oflesser regional importance	Fairly heterogenous
9	Nine	Otulu 2	895.441	6.976	Background anomalies(withdrawal for local water supply and for private consumption.)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
10	Ten	Umuoji	322.839	6.532	Background anomalies(withdrawal for local water supply and for private consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
11	Eleven	Mgbidi1	209.501	6.345	Negative anomalies(withdrawal for local watersupply with limited consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
12	Twelve	Mgbidi2	1456.97	7.187	Background anomalies(withdrawal for local water supply and for private consumption)	High (Withdrawalsof lesser regional importance)	Fairly heterogenous
13	Thirteen	Ibiasoegbe	821.474	6.938	Background anomalies(withdrawals for local water supplyand for private consumption)	High (Withdrawals oflesser regional importance)	Fairly heterogenous
14	Fourteen	Nempi	6495.03	7.836	Positive anomalies(withdrawal for less regional importance)	High (Withdrawalsof lesser regional importance)	Fairly heterogenous
15	Fifteen	Akatta	6668.58	7.848	Positive anomalies(withdrawal for less regional importance)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
16	Sixteen	Aji	158.765	6.224	Negative anomalies(withdrawal for local watersupply with limited consumption)	High(Withdrawals oflesser regional importance)	Fairly heterogenous
17	Seventeen	Ubulu	5229.51	7.742	Positive anomalies(withdrawal for less regional importance)	High (Withdrawalsfor lesser regionalimportance)	Fairly heterogenous
18	Eighteen	Akuma	102.869	6.034	Negative anomalies(withdrawal for local water supply with limited consumption)	Intermediate(Withdrawals for local watersupply for small communities andplants)	Fairly heterogenous

Looking at the transmissivity analysis based on transmissivity Index (Y) Classification as in table 4, the study area were delineated as follows; None (0%) of the sounding points were in the class of negative extreme anomalies (Zones without groundwater supply prospect) with transmissivity index range of < 5.887 . 16.67% of the sounding points had transmissivity index in the class of negative anomalies (withdrawals for local water supply with limited consumption) with range of between 6.418 and 5.887 with ground water potential rated as very low. 61.11% of the sounding points were in the class of Background anomalies (smaller withdrawals for local water supply(private consumption)) with transmissivity index range between 6.418 and 7.479 and groundwater supply potential rated as low. 22.2% of the sounding points were in the Class of positive anomalies (Withdrawal for less regional importance) with transmissivity index range of between 7.479 and 8.009 and a ground water supply potential rated as moderate.. None of the sounding points transmissivity index were in the class of extreme positive anomaly. The standard deviation value of 0.53 in the Transmissivity index (Y) represents a moderate Transmissivity variation and characterized the Study area as a fairly heterogenous hydrogeological environment.

VI. CONCLUSION

Spatial variation of transmissivity magnitude and variation has been identified as best useful in management practices and sustainable development of groundwater .Transmissivity analysis based on Transmissivity magnitude classification in table 2 show that in the Study area there is actually a potential for groundwater and this quantitatively expressed about 94.4% of the Eighteen sounding points had high transmissivity magnitude with groundwater potential expressed as withdrawals of lesser regional importance. Also considering transmissivity analysis based on transmissivity index(Y) classification in table 4 the study area was delineated as follows; Class of negative anomalies 16.67% with very low groundwater potential; class of Background anomalies 61.11% with low groundwater potential; class of positive anomalies 22.2 % with moderate groundwater potential .Also the standard deviation value of 0.53 in the transmissivity index (Y) represents a moderate transmissivity variation and characterized the study area as a fairly heterogenous hydrogeological environment.

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