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Assessment of Ground Water Potential of Layered Aquifer System in Ekpoma and Irrua, Edo State, Nigeria.

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ABSTRACT: The aim of this study was to assess ground water potential of layered aquifer system in Ekpoma and Irrua, Edo State, Nigeria. The study adopted an empirical research design. It considered local geologic setting, hydro-geologic setting, hydrologic setting, vertical electric sounding (VES), geo-electric layer and apparent resistivity. Data on local geologic setting and hydro-geologic setting was obtained from information on existing borehole section, integrated with data from Geographic Positioning System (GPS). The litholog was generated using Geographic Information System, GIS (Rockworks 15 and Sufer 11). For data on vertical electric sounding, the Schlumberger array was used. For preliminary quantitative interpretations of Vertical Electric Sounding (VES) curves, in terms of resistivity and thickness, IXID Interpex software (version 2.1) was employed. The study found out that water tables were rather difficult to reach in the study area due to the presence of solid materials and that the two locations considered showed a maximum drill depth of 528.90 m for Ekpoma, and 476.67 m for Irrua, respectively. It therefore concluded that in both locations, it is possible to have fresh water flow under ordinary conditions in these soils at a steady state phenomenon, ignoring forces or accelerations. The study recommended that it is important to consider first the water balance of the entire soil profile in terms of individual process (such as precipitation, applied irrigation water and surface runoff) and that more soil horizons have to be penetrated to meet aquifer layers.

I. INTRODUCTION

Ground water is the surface water that seeps into the ground through a process called infiltration [2]. The growing demand for water supply has been the major problem of most urban centres in Nigeria. Potable drinking water is the basic need for any society to lead a healthy and productive life and for industries and agriculture to flourish. It is estimated that approximately 100l/day of safe drinking water is the minimum amount of water required per person for good health [4]. Ground water accounts for an appreciable percentage of water supply in most communities. Groundwater is generally seen as fresh water (from rain, melting of ice and snow) that soaks into the soil and is stored between pore-spaces, fractures and joints found in within rocks and other geological formations. Groundwater occurs in various geological formations, the ability of geological formations to store water is a function of its textural arrangement [5].

The source of groundwater most times could be linked to surface run-off and infiltration of rainwater into the subsurface and streams from which it leads to the establishment of the water table and serve as a primary supplier of streams, springs lakes, bays and oceans [6]. The textural arrangement (uniformly or tightly arranged texture, loosely arranged texture) found within most geological formations and rocks have a strong role to play in *water retention* and *storative* capacity of any rock or geological formation.

Rocks/Geological formation with uniformly or tightly arranged texture have high water retaining ability (porosity) but less transmitting or mobility ability (permeability) while those with higher porosity and higher permeability have sufficiently enough to yield significant quantities of groundwater to wells and springs as such any geological formation with such characteristic is been referred to as an Aquifer. An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt). Aquifers in geological terms are referred to as bodies of saturated rocks or geological formations through which volumes of water find their way (permeability) into wells and springs [5]. Classification of these is a function of water table location within the

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subsurface, its structure and hydraulic conductivities into two namely; Confined Aquifers and Unconfined Aquifers and then characterized these aquifers. The characterization of aquifers could be done using certain geophysical techniques like Electrical Resistivity, Electromagnetic Induction, Ground Penetrating Radar (GPR) and Seismic Techniques. Aquifer Characterization is dependent on the petro-physical properties (porosity, permeability, seismic velocities etc.) of the subsurface. Results of this Aquifer Characterization could be observed and analyzed using varying geophysical software (WinRESIST, RADpro etc.) to better image the subsurface [5].

Aquifers must not only be permeable but must also be porous and are found to include rock types such as sandstones, conglomerates, fractured limestone and unconsolidated sand, gravels and fractured volcanic rocks (columnar basalts). While some aquifers have high porosity and low permeability others have high porosity and high productivity. Those with high porosity and low permeability are referred to as poor aquifers and include rocks or geological formation such as granites and schist while those with high porosity and high permeability are regarded as excellent aquifers and include rocks like fractured volcanic rocks. Estimating groundwater storage dynamics requires a three-dimensional numerical modeling of a groundwater system. This requires advanced knowledge and expertise.

However, acceptable estimate of static groundwater storage could be made with relatively fewer resources using readily available secondary data and geographic information system (GIS) tool(s). GIS and GIS-based tools are widely used in groundwater studies to analyze and visualize results of groundwater vulnerability [8], groundwater storage potential [13] [14], groundwater flow and contaminant transport modeling [1], among others. Because of the strengths and comparably low-cost of the GIS techniques in terms of analysis and visualization, some studies have used it as a tool to effectively estimate and map groundwater storage potentials for management purposes [7].

Assessment of ground water resources of an area requires proper identification and mapping of geological structures, geomorphic features along with sound information regarding slope, drainage, lithology, soil as well as thickness of the weathered zones.

Ground water is expected to form a significant part of the water resources of Ekpoma and its environs, considering the enormous tropical rainfall experienced each year. Unfortunately, Ekpoma lacks enough ground water resources because of its distinct location and geological complexities. In Ekpoma, some major challenges are encountered by the residents in a bid to have access to water. These include: poor management at the water factories; absence of rains from November to February; preponderance of obsolete water extraction facilities; inadequate storage facilities; absence of hydrologists; and existence of pervious catchment basins which is a long time physical result of the displaced geological formation of the settlement.
The recent hike in fuel price has raised the overall water cost in the settlement. Field studies reveal that a big plastic tank of water sells between N3,000.00 and N3,500.00; a small plastic tank of water sells between N1,000.00 and N1,500.00 while the little 20 litre-jerry can of water is purchased at N20.00 during the wet season and N25.00 at the start of the dry season.

Efforts by the government and individuals to sink boreholes have not been very successful. When boreholes are drilled, the cost is prohibitive, aquifer depths are large if any and the yields in most cases are not encouraging. The unspecific nature of the aquifers and the lack of detailed hydrogeophysical data bank of the town are the major factors militating against the search for portable ground water. There is limited uncorrelated literature on groundwater mapping in the study area, using remote sensing and geographic information system (GIS); hence the need for this research.

The main objective of the study was to apply remote sensing and geographic information system (GIS) in appraising the ground water withdrawal potential of layered aquifer system in Ekpoma and its environs.

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II METHODOLGY

This study used both primary and secondary data. The primary data was obtained from the researcher's personal observations, fieldwork/ site visitations, oral interviews and focus group discussions. The secondary data was obtained from existing relevant literature such as textbooks, journals, periodicals and laboratory manuals. Data on local geologic setting, hydro-geologic setting, hydrologic setting, vertical electric sounding (VES), geo-electric layer and apparent resistivity were also required. Data on local geologic setting, hydro-geologic setting and hydrologic setting was obtained from information from existing borehole section, integrated with data from (GPS).

The map and litholog were generated using GIS (Rockworks 15 and Sufer 11). For data on vertical electric sounding, the Schlumberger array was used. For preliminary quantitative interpretations of VES curves, in terms of resistivity and thickness, IXID Interpex software (version 2.1) was employed. This made clarifications where there was conflict of values.

ABEM Terrameter SAS 300B: In this configuration, the four electrodes of the ABEM Terrameter were positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes were displaced outwards while the potential electrodes in general, were left at the same position.When the ratio of the distance between the current electrodes to that between the potential electrodes became too large, the potential electrodes were also displaced outwards otherwise the potential difference would have become too small to be measured with sufficient accuracy [9].

Measurements of current and potential electrode positions were marked such that AB/2 > MN/2.

Where AB/2 = Current electrode spacing and

MN/2 = Potential electrode spacing

Generally, the arrangement consisted of a pair of current electrodes and a pair of potential electrodes. These were driven into the earth in a straight line to make a good contact with the earth. The current electrode spacing was expanded over a range of values for measurements in the field. The values of AB/2 were increased as the measurements progressed while the potential electrodes separations were guided accordingly. The potential electrodes were kept at small separations relative to the current electrodes separations [10]. One of the major advantages this method had over other methods was that only the current electrodes needed to be shifted to new position for most readings while potential electrodes were kept constant for up to three or four readings [12].

During the exploration work (field work) taking a sounding, the ABEM Terrameter SAS 300B (Self Averaging System) performed automatic recording of both voltage and current, stack the results, computed the resistance in real time and digitally displayed it [3].

Geographic Information System (GIS): This study adopted a GIS with raster format to enable storage of varying data on grids of cells or pixels.

Geographic Positioning System (GPS): A multi- frequency GPS receiver was used in this study. Each signal had a dedicated frequency. The multi- frequency processing took in a wide variety of signals, regardless of their frequency and used the influx of data to correct common errors in signals.

III RESULTS AND DISCUSSION

Table 1 and Figure 1 below, show the model parameters for Ekpoma soil profile and Variation of Resistivity with Geoelectric layer for Ekpoma Soil Profile, respectively

Table 1: Model Parameters for Ekpoma Soil Profile (Researchers' fieldwork, 2020)

Geoelectric Layer	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)
1	1120.00	5.70	5.70
2	2990.00	31.10	36.80
3	23900.00	36.10	72.90
4	12500.00	41.10	144.00
5	9600.0	51.30	165.30

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6	17800.00	86.60	251.90
7	2050.00	108.00	359.90
8	1170.00	169.00	528.90
9	767.00	Infinity	Infinity

From Table 1 and Fig. 1, there were observed variations in the values of resistivity at different geo-electric layers. There was an initial resistivity value of 1120 ohm-m at cumulative thickness of 5.70m and this increased significantly to 23900.00 ohm-m at cumulative thickness of 72.90m. A reduction was observed thereafter to 12500 ohm-m at cumulative thickness of 144.00m and to 9600 ohm-m at cumulative thickness of 165.30m. This suddenly increased to 17800 ohm-m at 251.90m and continued to 2050.0 ohm-m at cumulative thickness of 359.90m. This suddenly dropped to 1170.00 ohm-m at 528.90m and further to 767.00 ohm-m beyond 528.50m. The aquatic layer was therefore established at layer 9. At this point, layer 8 acted as a semi- confining layer or aquitard, having a relatively small horizontal hydraulic conductivity and overlies layer 9 with a relatively high horizontal hydraulic conductivity enhancing both vertical and horizontal groundwater flows.

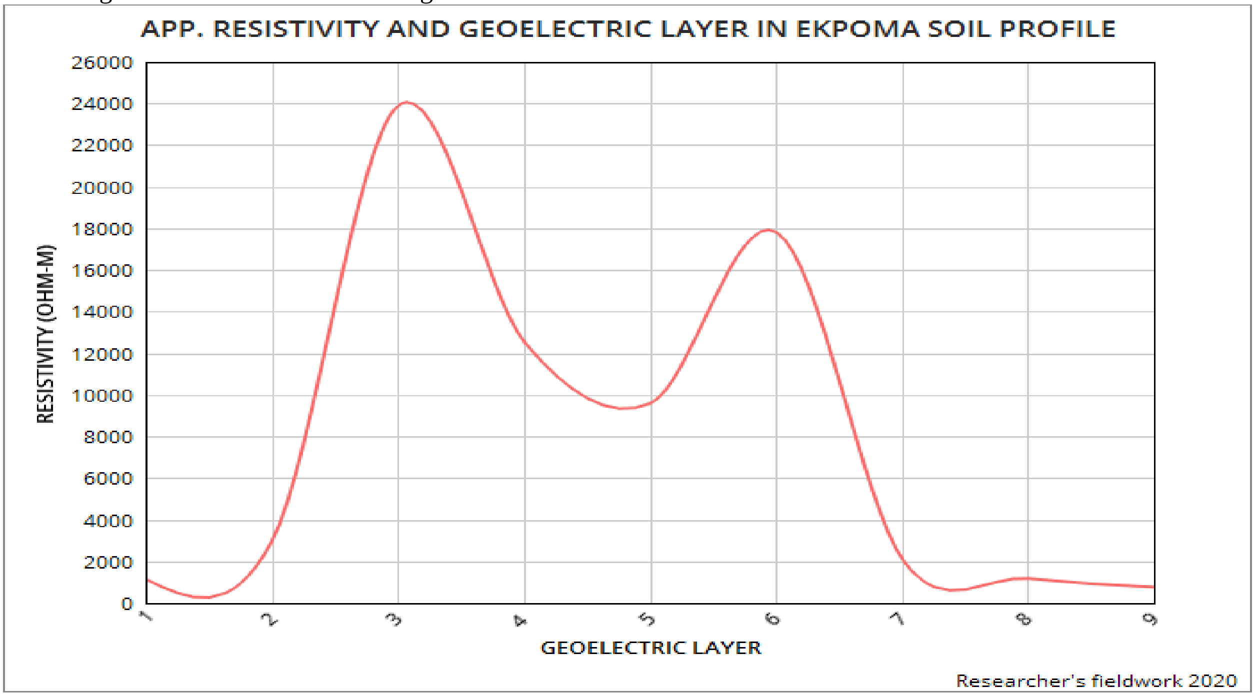

Fig. 1: Variation of Resistivity with Geoelectric layer for Ekpoma Soil Profile (Culled from Table 1)

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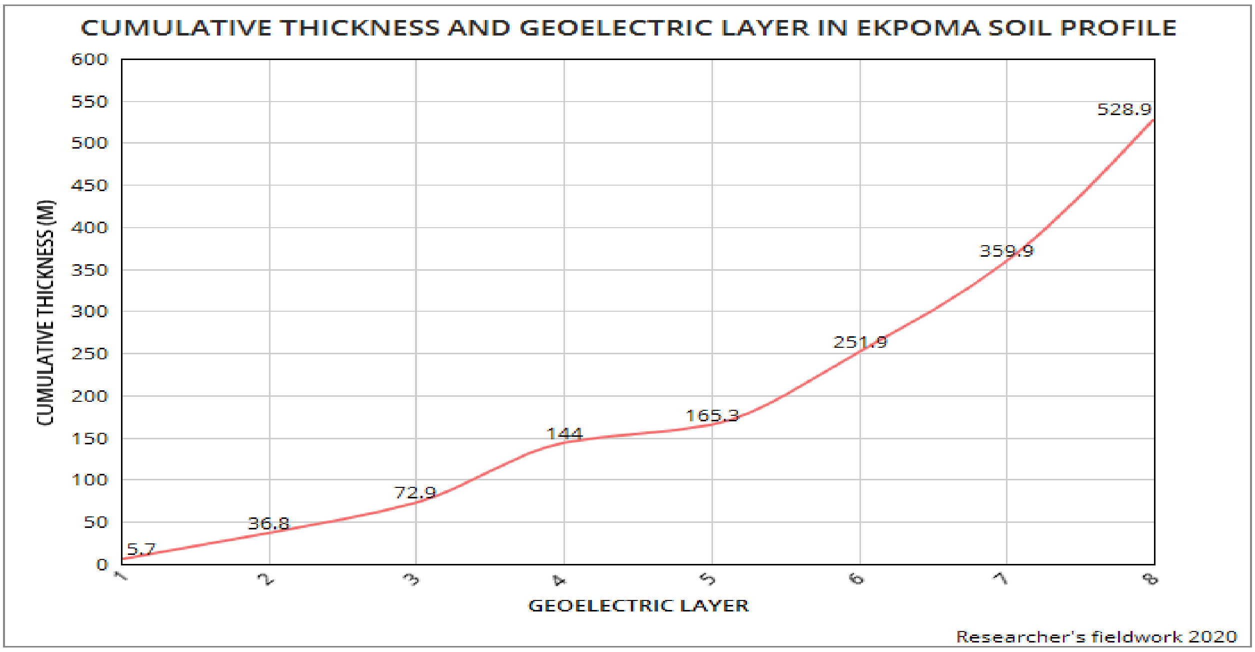

Fig. 2: Variations of cumulative thickness with geoelectric layer in Ekpoma Soil Profile (Culled from Table 1)

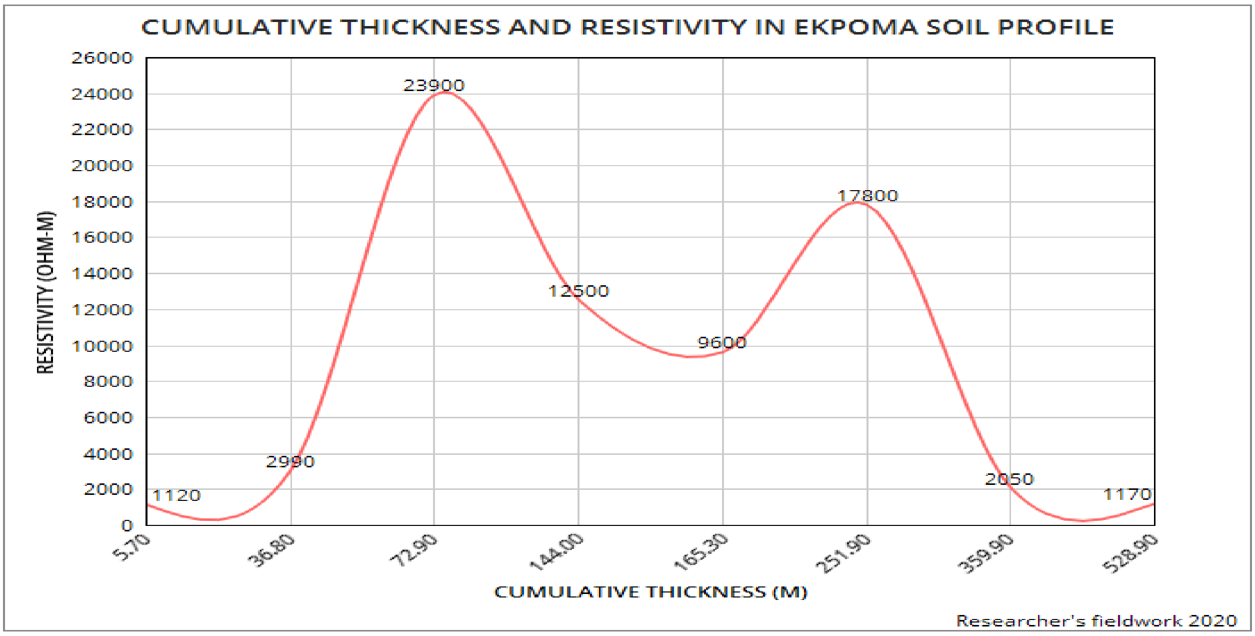

Fig. 3: Variations of apparent resistivity with cumulative thickness in Ekpoma Soil Profile (Culled from Table 1)

From Fig. 3, it was observed that the resistivity values were sinusoidal as the cumulative thicknesses increased, forming crests at 72.90m and 251.90m (resistivity values of 23900 ohm-m and 17800 ohm-m, respectively. This occurred because of variations in moisture contents of the different geo- electric layers and cumulative depths.

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Table 2: Apparent Resistivity Variations in Irrua Soil Profile (Researchers' fieldwork, 2020)

Current Electrode Spacing	Field data (ohm-m)	Theoretical data (ohm-m)
1.00	301.06	303.20
1.47	369.88	380.34
2.15	464.84	490.04
3.16	629.11	613.40
4.64	756.74	713.29
6.81	770.92	753.26
10.00	607.94	735.13
14.70	1484.99	739.34
21.50	1001.48	875.89
31.60	2759.93	1185.60
46.40	825.36	1643.62
68.10	2257.78	2251.33
100.00	3795.58	3045.05
147.00	6738.35	4090.77
215.00	7654.67	4800.00
250.00	7698.89	5100.00
300.00	6789.12	5000.00
400.00	4987.32	4700.00
500.00	4500.00	4000.00

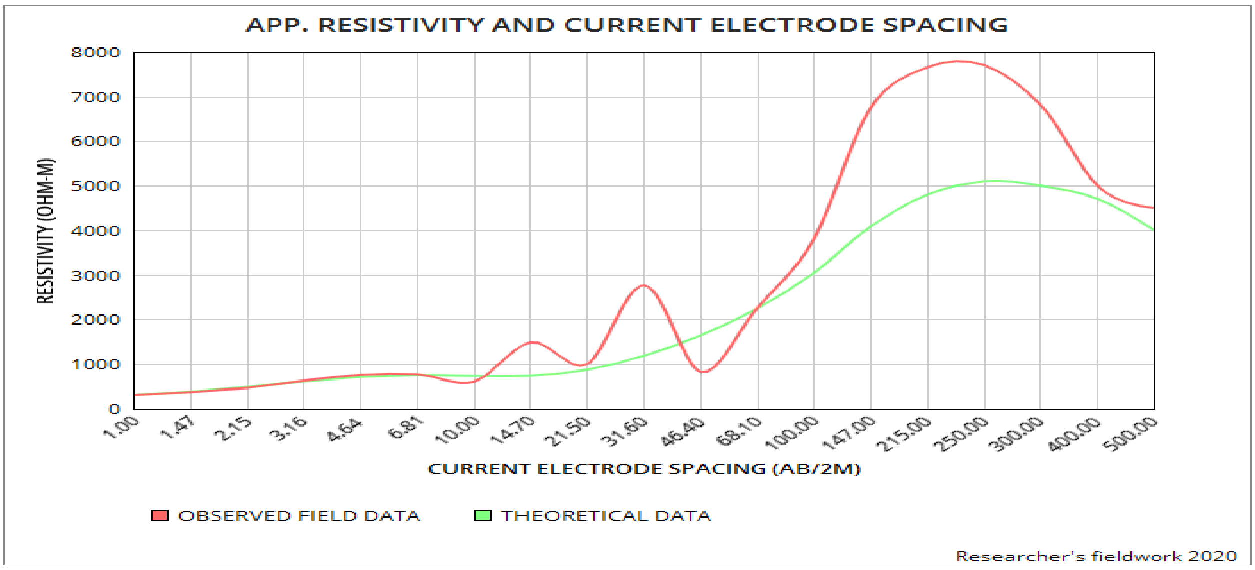

Fig. 4: Resistivity Variations of apparent resistivity and current electrode spacing in Irrua Soil Profile (Culled from Table 2)

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From Table 2 and Fig. 4, apparent resistivity increased from the initial value of 301.06 ohm-m at spacing of 1.00 to 770.92 ohm-m at a spacing of 6.81. This reduced to 607.94 ohm-m at spacing of 10.00 and increased to 1484.99 ohm-m at 14.70 spacing. The resistivity further decreased to 1001.48 at a spacing of 21.50 and increased to 2759.93 ohm-m at a spacing of 31.60. This significantly reduced to 825.36 ohm-m at a spacing of 46.40 and increasedup to 7698.89 ohm-m at a spacing of 250.00 and reduced to 4500.00 ohm-m at spacing of 500.00. Summarily, the apparent resistivities varied as the spacings varied due to some intrinsic geo-hydrological features. However, the resistivities observed at Irruah were closely related to their theoretical values, showing a better natural hydrological formation than that of Ekpoma.

Table 3: Model Parameters for Irrua Soil Profile (Researchers' fieldwork, 2020)

Geo-electric Layer	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)
1	219.00	0.67	0.67
2	1400.00	3.30	3.93
3	1816.00	9.10	13.07
4	2190.00	15.20	28.27
5	3070.00	60.60	88.87
6	4460.00	91.80	180.67
7	666.00	123.00	303.67
8	668.00	173.00	476.67
9	657.00	Infinity	Infinity

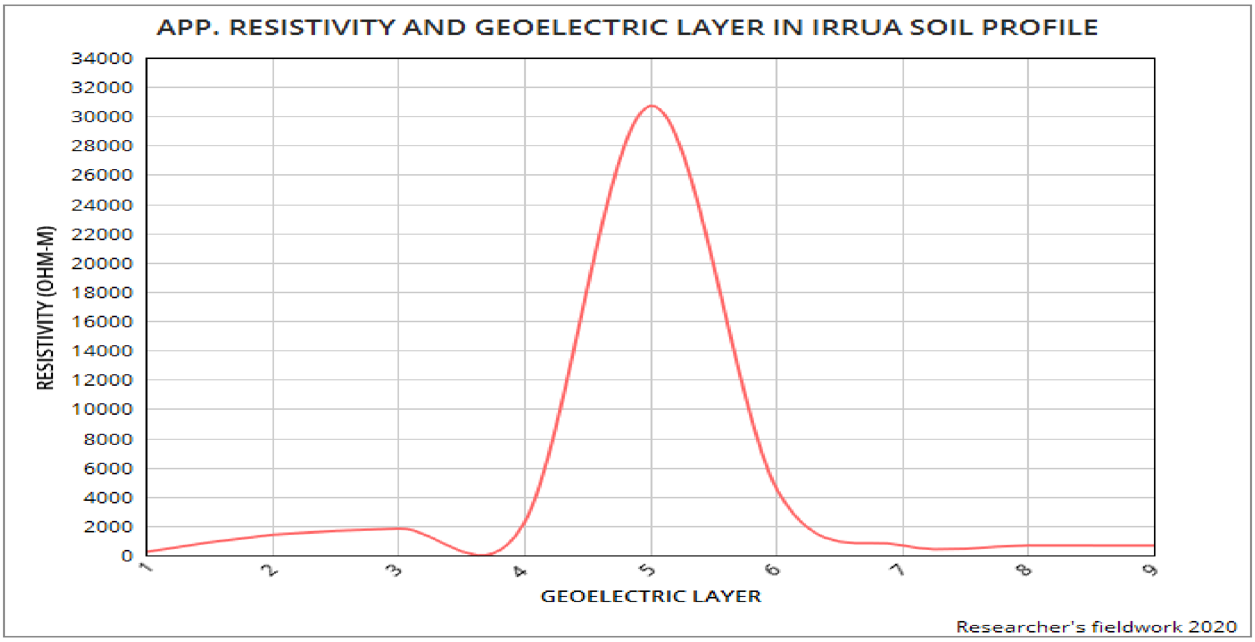

Fig. 5: Variations of apparent resistivity with geoelectric layer in Irrua Soil Profile (Culled from Table 3)

From Table 2 and Fig. 5, the apparent resistivities increased from 219 ohm-m at layer 1 and cumulative thickness of 0.67m to 4460.00 at a cumulative thickness of 180.67m. This significantly reduced to 666.00 at layer 7 and cumulative thickness of 303.67m and continued to 657.00 ohm-m at layer 9 and cumulative thickness of more than 476.67m.

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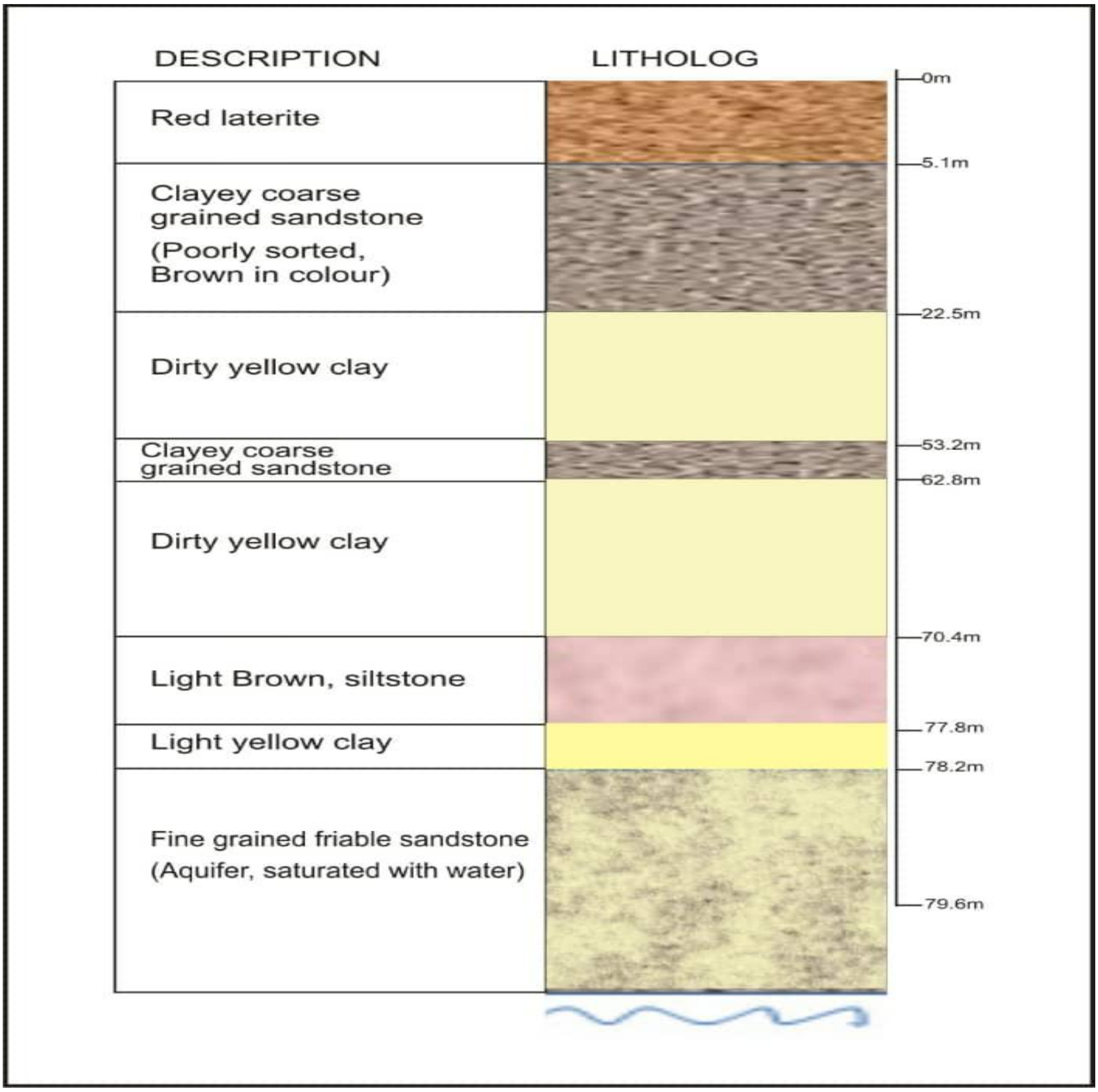

Fig. 6: Litholog of Groundwater in the study area (Researchers' fieldwork, 2020)

From Fig. 6, the section showed red laterite at 5.1m depth; clayey coarse grained sandstone, poorly sorted, brown in colour at a depth of between 5.1-22.5m; dirty yellow clay was found at a depth between 22.5 -53.2m; clayey coarse grained sandstone was found between 53.2-62.8m depth; dirty yellow clay was found between 62.8-70.4m depth; light brown siltstone was observed at between 70.4-77.8m; light yellow clay was found between 77.8-78.2m while fine grained, friable sandstone was found at a depth exceeding 78.2m. This was established as the aquifer of the area. The various soil types and depths exhibited different intrinsic permeabilities.

IV CONCLUSION

The study has shown that the occurrence of groundwater and surface water in Ekpoma and Irrua is generally controlled by the geology and geological structure (scarp fault and scarp fault line) in the area. It is very important to first use the geologic map and hydrogeologic map of the area in order to identify the formation that underlies the prospective area where borehole is intended to be sunk so as to have better planning and know the kind of borehole that is feasible in such area.

The thin aquiferous units were observed in Imo Shale and Ogwashi-Asaba Formations in the study area and this is responsible for the inability of water pumping machine to sustain continuous pumping in a convectional borehole (Rig drilled borehole) and that is why boreholes are drilled by hands (unconventional) in the area, in order to have larger surface area of exposure to aquifer so as to avoid water-cut while pumping. The two locations considered in the study area showed a maximum drill depth of 528.90 m for Ekpoma, and 476.67 m for Irrua, respectively. It is possible to have fresh water flow under ordinary conditions in these soils at a steady state phenomenon, ignoring forces or accelerations. The flux of water under these conditions is proportional to the gradient of water potential and the conductivity in a way similar to the flux of electricity being proportional to the electrical potential difference in a circuit and electrical conductivity (ohm's law). However, the nature of the forces that give rise to the potential varies in soil water systems and the kind of forces involved have an important bearing upon the way that flow takes place. The soil profile in the field is a very dynamic and complex system.

V RECOMMENDATION

It is important to consider first the water balance of the entire soil profile in terms of individual process which is precipitation, applied irrigation water and surface runoff. Hydrologist must know how much of the precipitation will result in direct runoff and in deep percolation to ground water. It might be inferred that aquifer layers are depending mostly on topography and areas on higher locations, would experience difficulties to reach the aquifer layers. The heat of radiation from the sun would dry the profile and moisture becomes insufficient within the soil. The presence of solid materials makes the water table not to be easily accessible. Therefore more soil horizons have to be penetrated to meet aquifer layers.

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