Evaluation of Hydrogeologic Conditions of Crystalline Basement Aquifers in Lere Local Government Area, Eastern Part of Kaduna State, Nigeria

[1]Olaniyan I.O. & [2]Omotoso A.S.

[1]Department of Civil Engineering, Olusegun Agagu University of Science & Technology, Okitipupa
[2]Department of Applied Geophysics, Olusegun Agagu University of Science & Technology, Okitipupa
Corresponding author: io.olaniyan@oaustech.edu.ng

Received: 15/05/2025 Revised: 23/05/2025 Accepted: 30/05/2025

The study assessed the hydrogeologic conditions of the crystalline basement rocks in Lere Local Government Area, Kaduna State, based on the data collected from 36 active boreholes. Data obtained were used to examine and analyze the aquifer's hydrogeologic properties that influence well productivity. A summary of the minimum, maximum, and average values of these parameters is provided. Additionally, a piezometric surface map was created, revealing that the water table is relatively shallow in the northwest region but deepens progressively toward the central and southern parts of the LGA. The water samples were found to be slightly acidic at eight locations, as the pH values fell outside the WHO drinking water standard limit, while the EC values were within the limit. The basement isochore map showed similar depth variation from the shallowest points at the northwest part of the LGA, to the deepest locations around the midsection of the study area. A graphical comparison between screen lengths and well yield indicated that screen length has minimal or no influence on yield. Additionally, the Pearson Product Moment Correlation analysis revealed a very weak positive relationship of +0.209 between drawdown and pumping rate, and similar weak positive correlations between drawdown and specific capacity (+0.455) and between drawdown and well yield (+0.371), indicating that drawdown alone is not the only factor affecting borehole productivity in crystalline basement terrains. Regression Analysis, on the other hand, generally showed average to fairly strong positive relationship in all the cases considered. The hydrologically, the results obtained showed that groundwater depth is shallow at the north-west corner, indicating low productivity, and increases southward where deeper wells can be drilled with higher productivity. Furthermore, drawdown has little effect on well productivity in the study area.

Keywords: Hydrogeology, basement, aquifer, Lere, piezometric, statistical evaluation

Introduction

Groundwater constitutes a major source of water supply for livelihood in most urban and rural populations around the world. It is the water contained in the saturated voids beneath the ground and occurs more widely and readily potable than surface water. Nearly half of Nigeria is underlain by Basement Complex rocks, most of which are located in semi-arid regions where surface water is either seasonal or absent, making groundwater the primary reliable water source. Although these rocks generally have poor hydrogeological properties, they remain vital for groundwater development in the country. Under humid conditions, crystalline rocks tend to weather more extensively and deeply, enhancing water storage potential in areas with sufficient rainfall. The hydrogeological behaviour of the rocks is largely influenced by their porosity, which in turn depends on the rock’s texture and mineral composition. The extent of weathering, fracturing and erosion is generally limited in crystalline rocks, but the permeability depends on the degree of interconnectivity of the voids (Todd & Mays, 2005).

The quality of ground water was assessed by Adamu et al (2013) for safe drinking in the basement complex region of Kano state by testing 13 water quality parameters on twenty borehole water samples. The study concluded that groundwater in the area met the standard requirement of WHO and is safe for drinking. According to a study by Bala and Ike (2001), two main types of aquifers—weathered basement and fractured basement aquifers—are predominant in the Gusau area of northwestern Nigeria. The authors found that the aquifer has an average thickness of approximately 30 meters, with specific capacity ranging from 0.31 to 38.40 m³/day/m and an average of 12.33 m³/day/m. Transmissivity values range from 0.40 to 21.17 m²/day, with an average of 5.92 m²/day. Hassan, and Rilwanu (2025) carried out geoelectrical investigation for groundwater exploration in basement complex terrain of Kaita Area, Katsina State, and concluded that low spatial variability of hydraulic conductivity suggests strong homogeneity of the aquifer system, and the results obtained, indicated that the greater part of the study area has low groundwater potential.

In a related study by Akintorinwa *et al*. (2020), vertical electrical sounding (VES) and remote sensing techniques were employed to develop groundwater potential and aquifer vulnerability maps for parts of Idanre in southwestern Nigeria. A total of 101 depth soundings were quantitatively interpreted, while remote sensing data were analyzed using GIS-based multi-criteria techniques in ArcGIS software. Key parameters considered included lineament density, drainage density, slope, transmissivity, hydraulic conductivity, coefficient of anisotropy, aquifer thickness and resistivity. They were used to construct both groundwater potential and vulnerability models. The accuracy of the groundwater potential model was validated through correlation with existing hand-dug wells. Shuaibu and Murana (2024) conducted a SWAT hydrological model of Zamfara watershed of Sokoto-Rima river catchment, North West Nigeria, and found out that there is a high amount of groundwater reserve within the study area for both agricultural and domestic usage. Bayowa *et al*. (2023) assessed the groundwater potential of shallow aquifers in Osogbo metropolis, southwestern Nigeria. Based on geoelectric data from 109 sites, thematic maps of resistivity anisotropy coefficients were generated using Kriging interpolation. A groundwater prospect map was also created using a weighted linear combination overlay method. Findings indicated that the Osogbo area generally has low to moderate groundwater potential. Obaje *et al*. (2023) carried out hydrogeophysical evaluation of groundwater potential of Makurdi in north-central Nigeria and its environs using VES and GIS. The study found out that 37% of the area under study shows very poor to poor groundwater potential, 40% indicates fair potential and 23% displayed good to excellent potentials. In Ijebu-Jesa area of southwestern Nigeria, the capability of artificial neural network (ANN) for modelling nonlinear system was explored (Adiat *et al*., 2020) to predict groundwater level (GWL) from geoelectric parameters. The research utilized interpreted vertical electrical soundings (VES) data from fifty-one (51) stations as input for ANN model, and concluded that ANN can be used to predict GWL in a basement complex terrain from geoelectric parameters with reasonably good accuracy. Adedokun *et al*. (2024) used electrical resistivity method to investigate the basement complex aquifers in parts of Eruwa, southwestern Nigeria, and the study concluded that 12 out of 20 vertical electrical resistivity sounding points reveal promising locations for prolific boreholes.

Groundwater evaluation in the basement regions, therefore, require proper understanding of the hydrology and the underlying geology, hence this study aims at evaluating the hydrogeologic conditions of crystalline basement aquifers in Lere Local Government Area of Kaduna State, Nigeria, through a systematic approach to the study of the geohydrologic conditions as obtained from drilling data.

Study Area

Lere Local Government Area is situated in the southeastern region of Kaduna State, Nigeria (Figure 1). It is geographically positioned between latitudes 9° 58’ and 10° 37’ North, and longitudes 8° 24’ and 8° 51’ East, with its administrative headquarters located in Saminaka. Covering a land area of 2,634 km², the LGA had a population of 339,740 according to the 2006 census, which was projected to rise to 458,600 by 2016 (NBS, 2020). Lere LGA is bordered by Kauru LGA to the west and south, Kubau LGA to the northwest, Doguwa LGA in Kano State to the north, Toro LGA in Bauchi State to the east, and Bassa LGA in Plateau State to the southeast (Salihu & James, 2024).

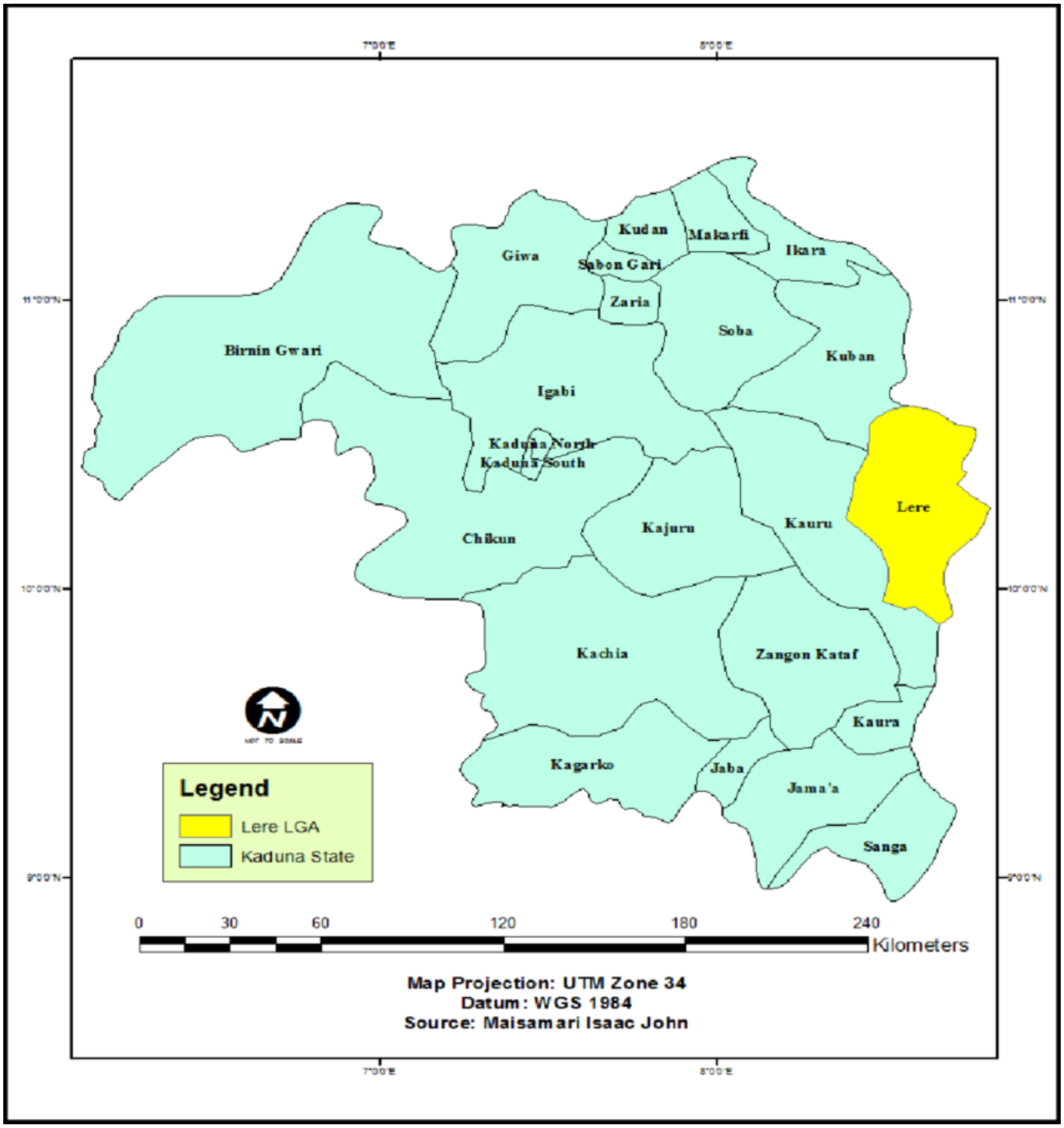

Figure 1: Map of Kaduna State of Nigeria showing Lere Local Government Area

Climate, Geology and Hydrogeology

Lere experiences a climate with distinct wet and dry seasons, typical of many parts of Nigeria. The rainy season lasts from April to October, while the dry season typically runs from November to March. During December and January, the harmattan winds bring cooler temperatures. The area receives an average annual rainfall of about 1200 mm. Lere's climate is generally hot throughout the year, with dry seasons marked by partial cloud cover and frequent overcast skies. Temperatures typically range from 13°C to 36°C, seldom falling below 11°C or rising above 39°C (Weather Spark, 2023). The vegetation of the area is classified as Guinea Savannah, predominantly consisting of tall grasses and herbs, with a few widely scattered deciduous trees. Evergreen trees are more common along the perennial rivers and streams. The landscape features a variety of landforms, including hills, inselbergs, and gently rolling plains, with elevations between 609 and 690 meters above sea level (Jatau & Ajoodo, 2005; Olaniyan *et al*., 2020).

The geology of Kaduna State (Figure 2) generally consists of basement complex rocks made up of a series of biotite-gneiss, granite-gneiss and migmatites which were formed by igneous and metamorphic processes that occurred on a regional scale. The area lies at the southwestern edge of the Jos Plateau, which is part of the Nigerian Younger Granite province, dating back to the Jurassic period. Early geological studies of Nigeria's basement complex suggest that the rocks of the migmatite-gneiss-quartzite complex are primarily a sedimentary sequence, with some minor igneous rocks. These rocks have undergone significant alterations due to metamorphism, migmatization, and granitization processes. The metasedimentary and basic rocks are seen as remnants that resisted the processes of migmatization and granitization (Olaniyan, 2020; Michaels *et al*., 2023). The basement rocks are covered by a thick layer of decomposed, kaolinized, weathered schists and gneiss, which is further topped by superficial lateritic clay and regoliths. The folding episodes in the area caused two main sets of faults, one trending North-North-East (NNE) with an associated shattered belt, and the other aligned in an East-South-East direction (Olasehinde *et al*., 2015).

The hydrogeology of the area involves groundwater found in the weathered residual overburden or regolith, as well as in the bedrock. Extractable groundwater is primarily located within the weathered, fractured, or jointed sections of the metasediments and granite gneisses, often relying on the storage in the overlying or nearby saturated regolith or other appropriate formations like alluvium for its supply (Hazell *et al*., 1992; Umar *et al*., 2021).

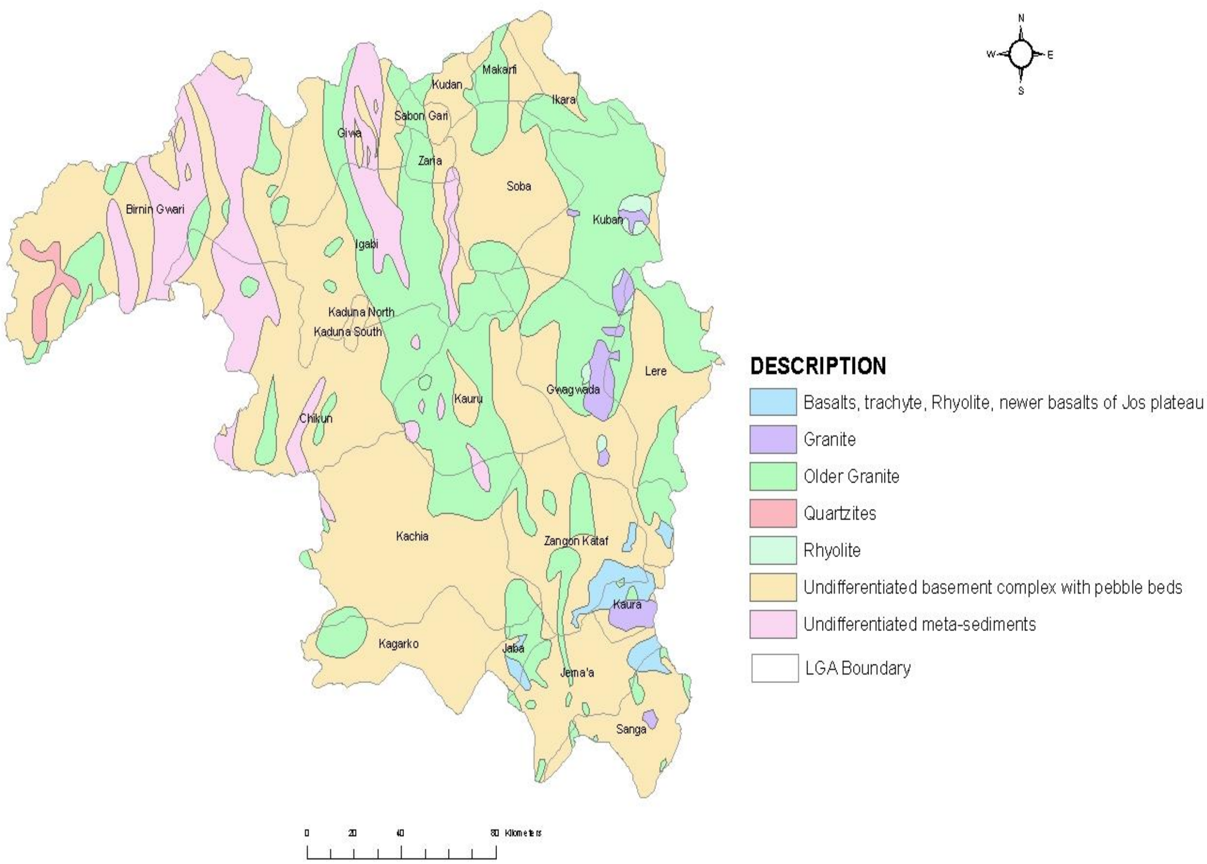

Figure 2: Geological Map of Kaduna State

Materials and Methods

Many boreholes were drilled for rural water supply by the Kaduna State Government in the crystalline basement complex rocks in Lere LGA, and 36 of them that were successfully drilled and completed were selected for this study. Aquifer hydrogeophysical, hydrogeologic and hydrochemical quality data required for this study were partly obtained from the Kaduna State Ministry of Water Resources, and partly from the National Water Resources Institute, Kaduna. These data include depth to water table, depth to basement, screen length, yield, pumping rate, drawdown, thickness of overburden (regolith) and saturated thickness, specific capacity, pH and EC, all of which were used to evaluate the hydrogeologic conditions of groundwater aquifers in the area.

Results and Discussion

The data in Table 1 show the summary of hydrogeologic characteristics obtained from thirty-six (36) productive boreholes in the study area. The table shows that the depth to water table across the area ranges from 1.3 m at Alwalo village to 10.5 m at Ungwan-Gero, with an average value of 5.43 m. The depth to the basement rocks in the area varies between 10 m and 38 m, with an average depth of 24.6 m. The screen lengths range from 6 m to 36 m, with an average of 20 m, while the average pumping rate is 49.3 l/min, with values ranging from 16 l/min to 150 l/min. Well yield refers to the volume of water discharged per unit time, and the average well yield in the area is 56.4 l/min. Drawdown, the difference between static and pumping water levels, has an average of 13.4 m in the area. Specific capacity, which provides a more accurate measure of aquifer performance than yield, considers aquifer transmissivity and thickness (Uma & Kehinde, 1994). The specific capacity values range from 0.5 l/min/m to 17.8 l/min/m, with an average of 5.0 l/min. The pH is a logarithmic scale used for quantitative measure of the acidity or basicity of aqueous solutions such as water. The pH values range from 6.1 (slightly acidic) to 7.8 (slightly alkaline) with a mean value of 6.8. The range is not totally within the World Health Organization (WHO) drinking water standard limit of 6.5 to 8.5. The water samples are slightly acidic at eight (8) locations, namely Noganzi, Karau, Ungwan-Kura, Yarkasuwa, Ungwan-Sarki, Kinugu, Kusheka and Fadan-Kiwolio. The Electrical Conductivity (EC) of water is the ability of water to conduct electric current, and it is induced by the concentration of dissolved salts and minerals present in water. It is also an indicator of water quality in terms of saltiness. The values range from 40 μS/cm to 241 μS/cm, with a mean value of 129 μS/cm, and it is within the WHO drinking water standard limit of0 -1500 μS/cm.

Table 1: Hydrogeologic parameters of boreholes in Lere LGA

Hydrogeologic Parameters	Unit	Minimum value	Maximum value	Average value
Depth to Water table	m	1.3	10.5	5.3
Depth to Basement	m	10	38	24.6
Screen length	m	6	36	20
Yield	l/min	9	135	56.4
Pumping Rate	l/min	16	150	49.3
Drawdown	m	4.5	32.8	13.4
Specific Capacity	l/min/m	0.5	17.8	5.0
pH		6.1	7.8	6.8
EC	μS/cm	40	241	129

Piezometric surface map

Figure 3 presents the piezometric surface contour map, created from the water table depth data at the well locations. It illustrates the horizontal variation in water table depth across the study area, with the levels being largely influenced by the subsurface geology. The figure shows that the water table is generally shallower around the northwest corner and the depth increases generally southwards and reaches the deepest points around the mid-section and at the southern flanks of the LGA boundary. The depth to the water table was found to be shallowest (1.3m) at Alwalo and deepest at Ungwan-Gero (10.5m) with an average value of 5.3m.

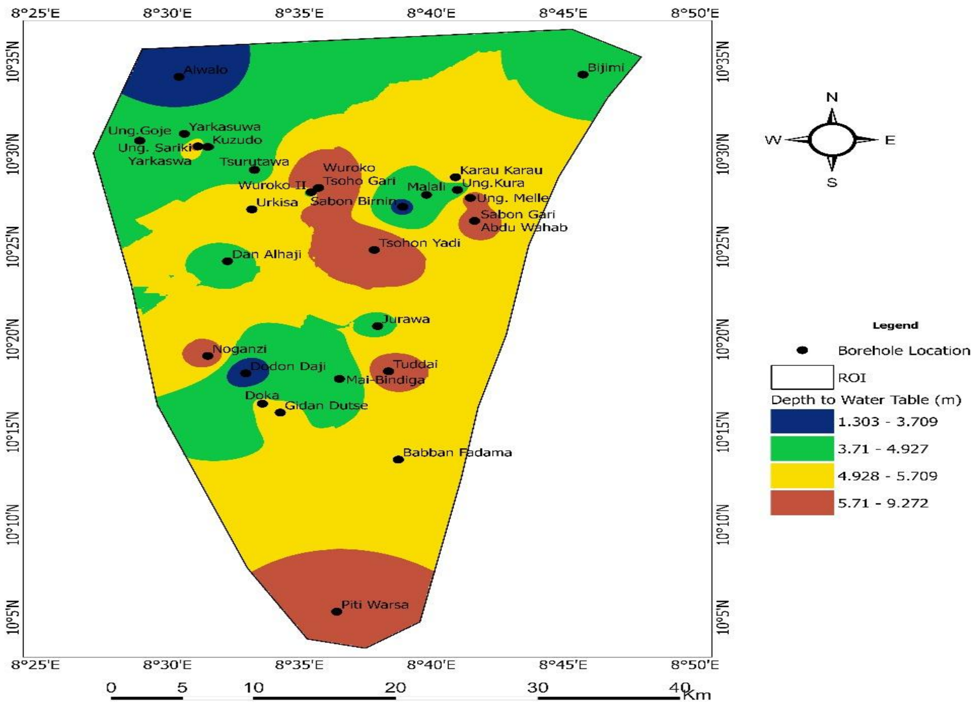

Figure 3: Piezometric Surface Map

Basement isochore map

The basement isochore map shown as Figure 4 was prepared by using the data obtained for the depths to basement complex rocks at each of the 36 well locations. The figure depicts the variation in the depths at which the crystalline basement rock occurred at different locations in the study area. The depth also increased from the shallowest points at the northwest part of the LGA to the deepest locations around the midsection of the study area. The shallowest depth to the basement rock exists at Kahugo (Ungwan-Kuchikari) at 10m, while the deepest point is found at Noganzi (38m) with an average depth of 24.6m.

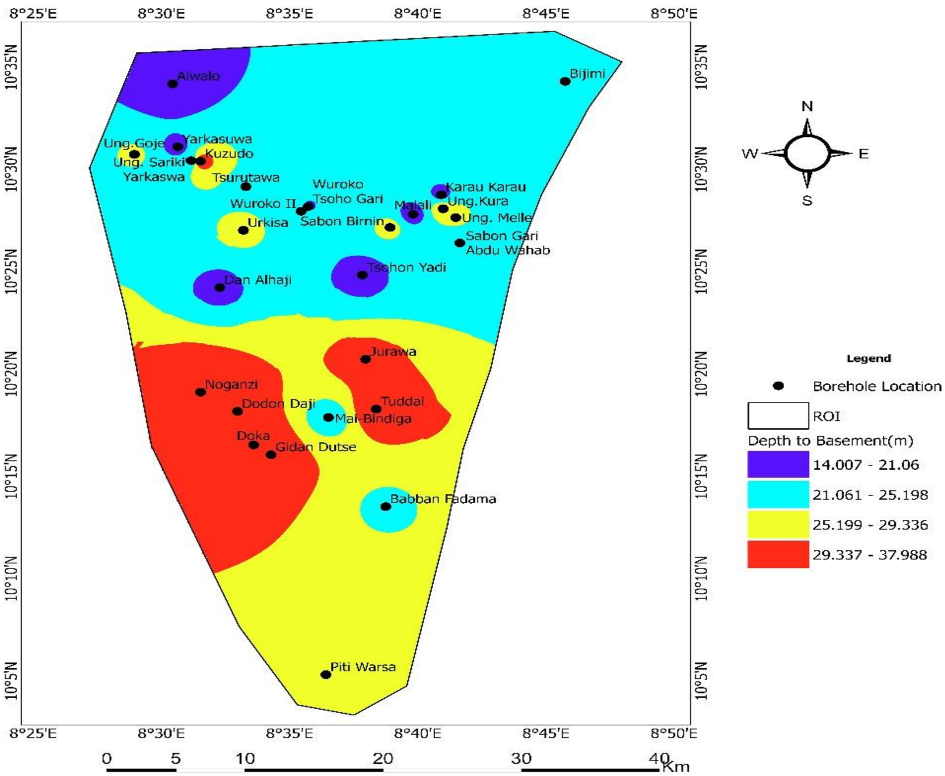

Figure 4: Basement Isochore Map

Relationship between screen length and well yield

The screen length defines the amount of pathway through which groundwater can be drawn into a pumping well. The yield of a well, on the other hand, is defined as the quantity of water that can be pumped or withdrawn from a well at a continuous rate over a period of time. Figure 5 shows plots of screen lengths and well yields at various well locations. From the pattern of variation from one well location to the other, the figure shows a very poor relationship between the two quantities. This, therefore, suggests that the screen length has little or no direct effect on well yield in the study area.

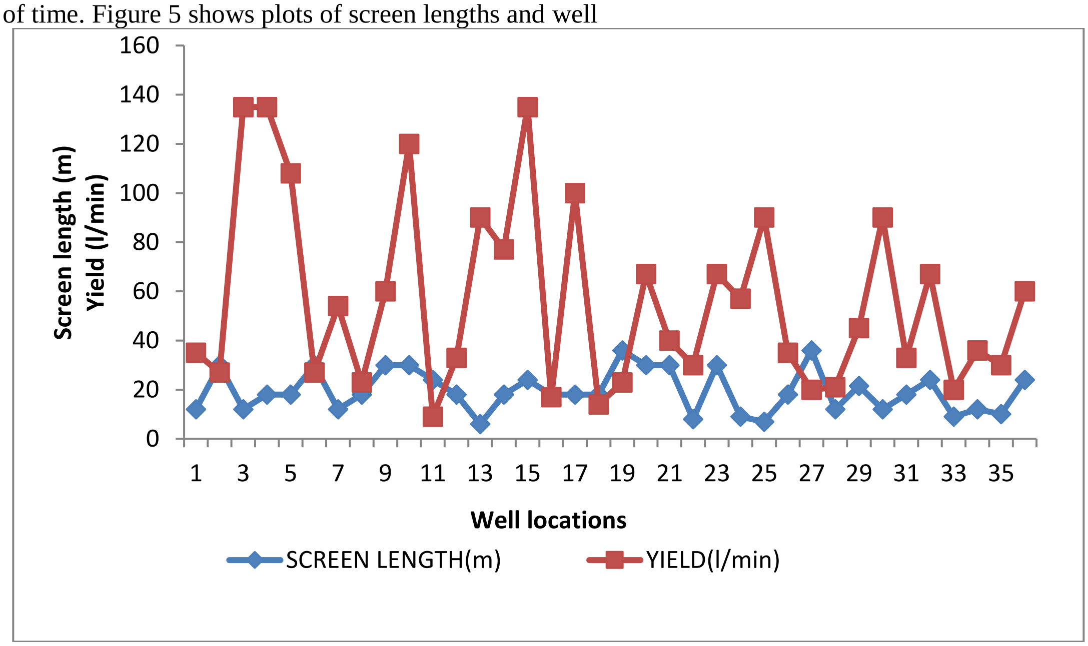

Figure 5: Comparison of screen length and well yield

Statistical evaluation of hydrogeologic parameters

The degree and nature of interrelationship among major hydrogeologic parameters of interest were investigated by using Pearson Product Moment Correlation analysis. The interrelationships include drawdown and pumping rate (Figure 6), drawdown and specific capacity (Figure 7), and drawdown and yield (Figure 8). The result showed a weak positive correlation with a value of +0.209 between drawdown and pumping rate. Similar weak positive correlations were obtained with a value of +0.455 between drawdown and specific capacity and +0.371 between drawdown and well yield, respectively. The implication of this is that, the rate of drawdown of wells in the crystalline basement terrains is significantly affected by the pumping rate, specific capacity and well yield.

Additional statistical analysis was conducted to examine the linear relationship between relevant parameters using regression analysis. The regression line for drawdown and pumping rate yielded a coefficient of 0.457 (Figure 6a), drawdown and specific capacity had a coefficient of 0.674 (Figure 6b), and drawdown and yield resulted in a coefficient of 0.609 (Figure 6c). The regression coefficients generally showed average to fairly strong positive relationship in all the cases considered, indicating that drawdown has little effect on pumping rate, specific capacity and yield of wells in the study area. The average to fairly strong positive values suggest that as one parameter increases, the other is also increasing, although the true relationship between these parameters may require further analysis than just a simplified linear model for more detailed results.

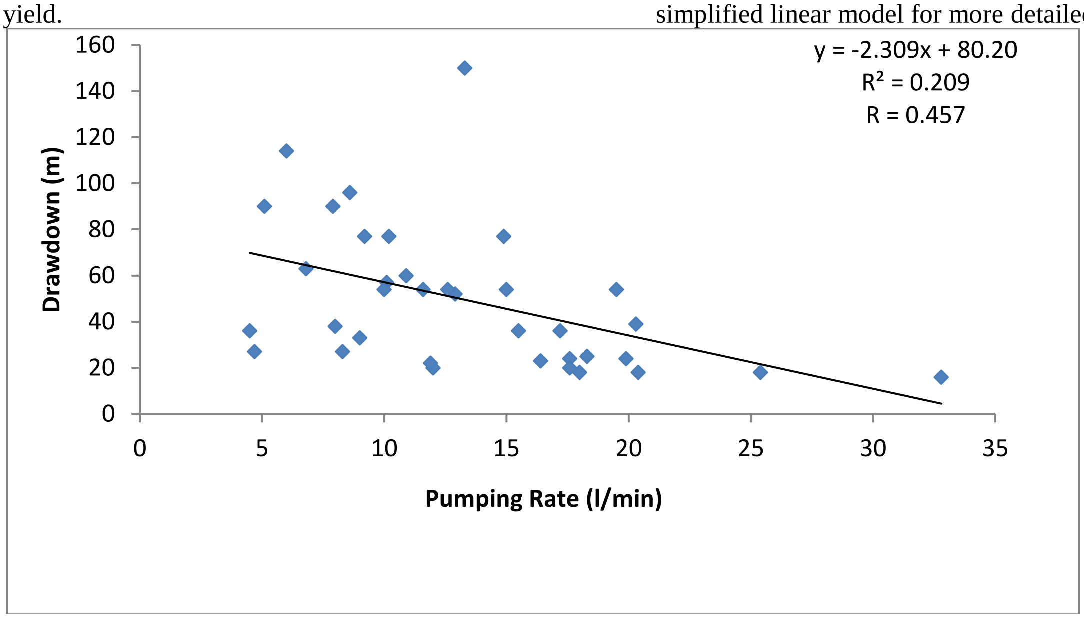

Figure 6a: Regression line of drawdown vs pumping rate

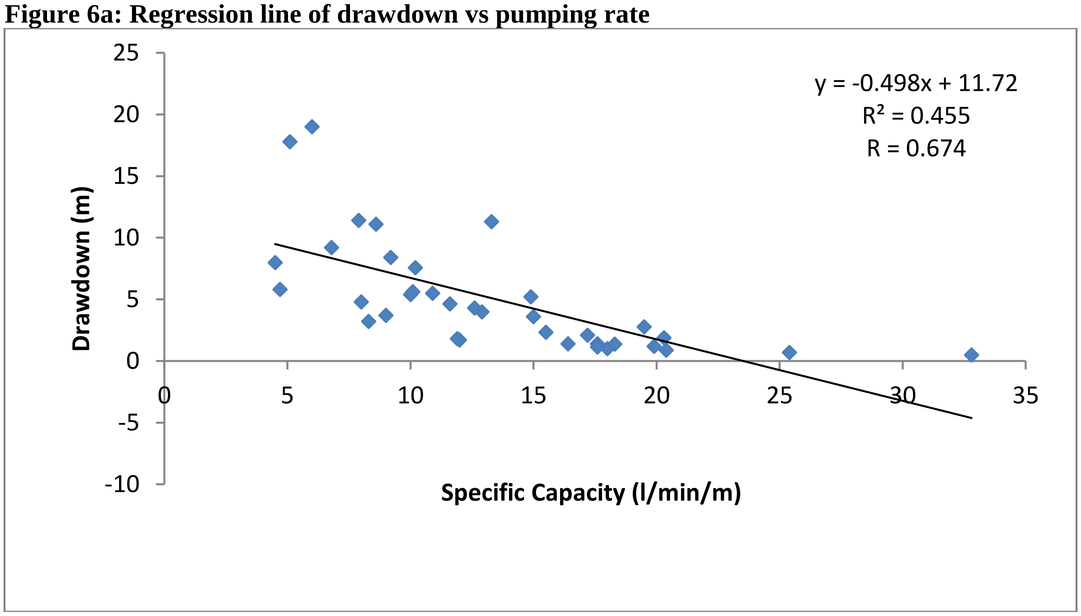

Figure 6b: Regression line of drawdown vs specific capacity

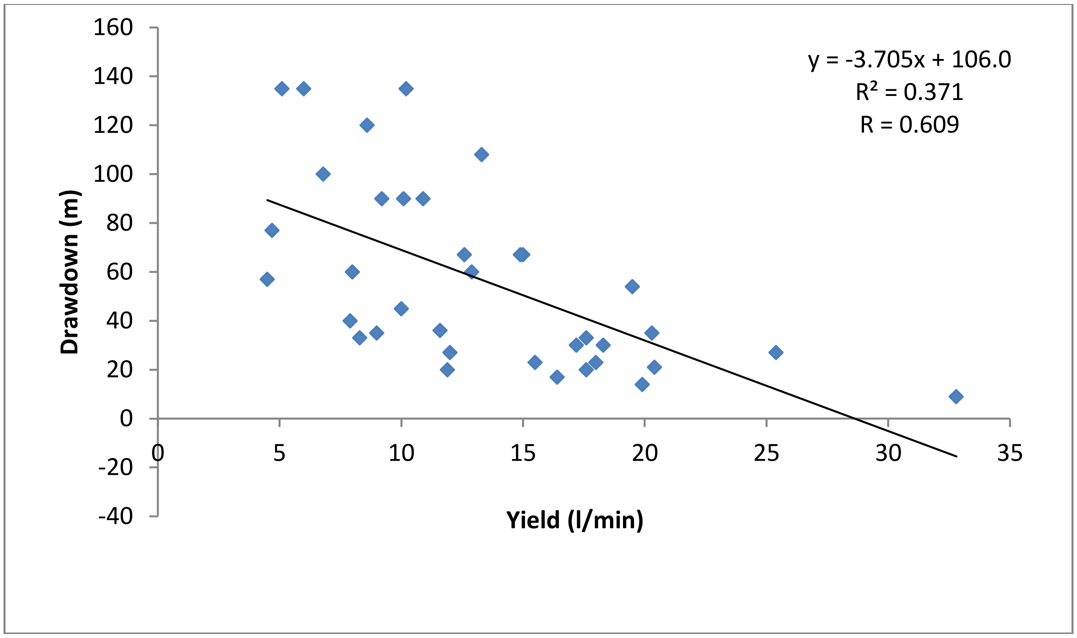

Figure 6c: Regression line of drawdown vs yield

Conclusion

An evaluation of the hydrogeologic conditions of Lere LGA has been carried out. The pH of the water samples revealed a slightly acidic condition at eight locations, while the EC values were within the WHO limit. The piezometric surface map of the area was prepared, and it showed that the water table is generally shallow around the northwest corner and increases in depth southwards to the deepest points at the mid-section and southern part of the LGA boundary. The basement isochore map also varied in depth from shallow points at the northwest part of the LGA, to deeper locations at the midsection of the study area. Screen lengths and well yield comparison showed that screen length has little or no effect on the yield. The Pearson Product Moment Correlation analysis showed weak positive correlation between drawdown and pumping rate, and between drawdown and specific capacity as well as between drawdown and well yield, indicating that drawdown is not the only factor affecting borehole productivity in crystalline basement terrains. The regression analysis showed average to fairly strong positive relationship in all the cases considered.

References

Adamu, G.K., Tukur, R. & Kankara, A.I. (2013). Ground water quality assessment in the basement complex areas of Kano State Nigeria. *American Journal of Engineering Research*, 2(7), 171-175 www.ajer.org

Adedokun, D.R., Ishola, K.S., Alli, A.K. & Ibitomi, M.A. (2024). Groundwater investigation using electrical resistivity method in a basement terrain of Sanngo Elere, Eruwa, Southwestern Nigeria. *Pakistan Journal of Geology*, 8(1), 44-56 DOI: http://doi.org/10.26480/pjg.01.2024.44.56

Adiat, K.A.N., Ajayi, O.F., Akinlalu, A.A. & Tijani, I.B. (2020). Prediction of groundwater level in basement complex terrain using artificial neural network: a case of Ijebu-Jesa, southwestern Nigeria. *Applied Water Science*, 10, 8 https://doi.org/10.1007/s13201-019-1094-6

Akintorinwa, O.J., Atitebi, M.O. & Akinlalu, A.A. (2020). Hydrogeophysical and aquifer vulnerability zonation of a typical basement complex terrain: A case study of Odode Idanre southwestern Nigeria. *Heliyon*, 6, 1-19 https://doi.org/10.1016/j.heliyon.2020.e04549

Bala, A.E. & Ike, E.C. (2001). The aquifer of the crystalline basement rocks in Gusau area, Northwestern Nigeria. *Journal of Mining and Geology*, 37(2), 177-184

Bayowa, O., Ogungbesan, G., Adelere, I.O., Olasunkanmi, N., Olatunbosun, A.S. & Alagbe, A.O. (2023). Groundwater potential assessment of shallow aquifers in the basement complex underlain Osogbo metropolis, Southwest Nigeria, using geo-electric attributes. *Environmental Earth Sciences*, 82(9), 239- https://doi.org/10.1007/s12665-023-10907-1

Hassan, M. & Rilwanu, T.Y. (2025). Geoelectrical investigation for groundwater exploration in basement complex terrain of Kaita Area, Katsina State, Nigeria. *Caliphate Journal of Science and Technology*, 7(1), 73-99 https://www.ajol.info/index.php/cajost/index DOI: 10.4314/cajost.v7i1.8

Hazell, J.R.T., Cratchley, C.R. & Jones, C.R.C. (1992). The hydrogeology of crystalline aquifers in northern Nigeria and geophysical techniques used in their exploration. In: E.P. Wright and W.G. Burgess (Eds.) The hydrogeology of crystalline basement aquifers in Africa. *Geological Society Special Publication No. 66*, London. pp. 155-162.

Jatau, B.S. & Ajoodo, R.O. (2005). A preliminary assessment of groundwater quality of some shallow wells around Kaduna metropolis, North Central, Nigeria. *Water Resources*, 16, 72-79

Michaels, S.P., Gibrilla, A., Gyamfi, C., Eduvie, M.O. & Anomu, G. (2023). Aquifer characteristics in the Basement complex of Lere, Kaduna, north-western Nigeria. *Sustainable Water Resources Management*, 9(66), 1-9 https://doi.org/10.1007/s40899-023-00837-y

NBS (2020). City Population Figures for Lere Local Government Area of Kaduna State. National Bureau of Statistics, Abuja, Nigeria. Retrieved September 26, 2020.

Obaje, B.O., Garba, M.L., Ahmed, I.I. & Mahmud, I. (2023). Hydrogeophysical evaluation of groundwater potential of Makurdi and its environs using VES and GIS, northcentral Nigeria. *FUDMA Journal of Sciences*, 7(6), 180 - 191 DOI: https://doi.org/10.33003/fjs-2023-0706-2115

Olaniyan, I.O. (2020). Estimation of Aquifer Protective Capacity, Soil Corrosivity and Dar-Zarrouk Parameters in Kaura Area of Kaduna State, Nigeria. *European Journal of Engineering Research and Science*, 5(10), 1142-1151. DOI: http://dx.doi.org/10.24018/ejers.2020.5.10.2108

Olaniyan, I.O., Adegoke, A.O., Aladeboyeje, A.I. &Adewoye, O.E. (2020). Quantitative and Qualitative Appraisals of Aquifer Properties in Kachia Area of Kaduna State, Nigeria. *Advances in Research*, 21(6), 6-15 DOI: 10.9734/AIR/2020/v21i630208

Olasehinde, P.I., Amadi A.N., Idris-Nda, A., Katu, M.J., Unuevho, C.I. & Jimoh, M.O. (2015). Aquifers Characterization in Agaie, North-Central Nigeria Using Electrical Resistivity Method and Borehole Lithologs. *American Journal of Environmental Protection*, 3(3), 60-66. doi: 10.12691/env-3-3-1.

Salihu, M. & James, K.E. (2024). Northern Nigeria: History, Politics and Culture.*Advances in Applied Sociology*, 14, 546–572. https://doi.org/10.4236/aasoci.2024.1410037

Shuaibu, A.M. & Murana, K.A. (2024). SWAT hydrological model of Zamfara watershed of Sokoto-Rima river catchment, North West Nigeria. *Nigerian Journal of Technology*, 43(4), 818 - 828 www.nijotech.com https://doi.org/10.4314/njt.v43i4.22

Todd, D.K. & Mays, L.W. (2005). *Ground Water Hydrology* (3rd Edition). New York: John Wiley and Sons Inc.

Uma, K.O. & Kehinde, M.O. (1994). Potentials of regolith aquifers in relation to water supplies to rural communities: A case study from parts of Northern Nigeria. *Journal of Mining and Geology*, 30(1), 97-109.

Umar, N.D., Omonona, O. V. & Okogbue, C.O. (2021). Groundwater quality assessment using multivariate analysis and water quality index in some saline fields of Central Nigeria. *Journal of the Nigerian Society of Physical Sciences*, 3(4), 267-277 https://doi.org/10.46481/jnsps.2021.183

Weather Spark (2023). *Lere Climate, Weather By Month, Average Temperature (Nigeria)*. weatherspark.com. Retrieved 2023-08-26.