Communication in Physical Sciences, 2025, 12(7):2019-2031

Application of the PQWT-S300 Water Detector in Mapping Groundwater for Abstraction

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Received: 12 August 2025/Accepted 06 October 2025/Published online: 17 October 2025

https://dx.doi.org/10.4314/cps.v12i7.4

Abstract:*The technological potential of the PQWT-s300 water detector was harnessed to investigate places for profitable drilling of water boreholes in 2 locations atUmuogele-Umuakwu community in IsialaNgwa North,Southern Nigeria. The inbuilt data processing and analysis tools and Liquid Crystal Display (LCD) screen of the PQWT device facilitated a less laborious, precise and fast field data collection and analysis process, with a probing depth of 300m for a 100m profile length. The study area, which falls within the Benin geologic Formation, has high water production capacity upon considering the PQWT graph and Profile maps, particularly with the intercalation of the 'blue' and 'green' colouration, which represents soft rocks rich in water, and soft rocks containing water moderately. The 'yellow/orange/red' colours are the hard rocks which are heavily fractured and weathered, resulting in secondary porosity, which makes them water-bearing. It was discovered that water can easily be abstracted before 60m depth in location 1 and less than 90m depth in location 2. However, exploration at both locations will most often require drilling through hard rocks using drill bits at some point for a deep, sustaining well. Furthermore, the interplay of the water-bearing soft rocks and the fractured water-bearing hard rocks defines the dendritic groundwater flow pattern as seen in Fig. 1. The perennial survival of the Iyi-ukwu stream, located less than 100m away from both locations, also shows that there is a good network of groundwaterways around the area.*

Keywords*: Umuogele, PQWT-s300, groundwater detector, Benin-Formation,*

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1.0 Introduction

Access to adequate potable water is fundamental for public health, socio-economic development, and environmental sustainability, particularly in developing regions where groundwater serves as the primary source of domestic and agricultural supply (Osabuohien*et al*., 2023).In Nigeria, increasing population growth and urbanization have intensified the demand for groundwater resources, making efficient exploration and abstraction techniques indispensable for sustainable water management (Osabuohien, 2019).

Recent advances in geophysical instrumentation have transformed groundwater exploration, providing faster, more accurate, and less labour-intensive methods for subsurface investigations (Haritha, 2023).Traditional devices such as the ABEM-Terrameter and IGIS Resistivity

Meter, though effective, require bulky equipment, long profile lengths, and extensive electrode arrays, making field surveys time-consuming and tedious (Resistivity Meter, 2019; Igboekwe et al., 2021).These limitations highlight the need for portable, lightweight alternatives that integrate high-speed processors and automated data analysis to improve field efficiency, cost-effectiveness, and accuracy.

The PQWT-s300 water detector, developed by the Hunan Puqi Geologic Exploration Equipment Institute (HPGEEI, 2006), represents one such innovation. Unlike earlier resistivity meters, the PQWT-s300 is equipped with pre-installed data analysis software that generates real-time profile models and graphs directly on its LCD screen (HPGEEI, 2006; GroundWater_Tech, 2018).This eliminates the cumbersome transfer of field data into external software for interpretation, thereby reducing processing time and user error. Furthermore, a 100 m profile length with the PQWT-s300 achieves an exploration depth of up to 300 m (Abdul et al., 2020), a significant improvement over the 30 m penetration depth typically achieved by IGIS devices.

Although previous studies (Haritha, 2023; Abdul et al., 2020) have acknowledged the technological potential of the PQWT series, its application in Nigeria’s hydrogeological settings—particularly within the Benin Formation—remains limited. The Benin Formation, characterized by alternating water-bearing soft rocks and fractured hard rocks, is a critical aquifer system with high groundwater potential. However, there is insufficient empirical evidence demonstrating the reliability and efficiency of the PQWT-s300 in accurately mapping groundwater within this formation.

This study therefore seeks to bridge this gap by applying the PQWT-s300 water detector in Umuogele-Umuakwu community, IsialaNgwa North, Southern Nigeria, to evaluate its effectiveness in delineating groundwater-bearing zones for sustainable borehole development.

The significance of this research lies in its potential to support sustainable access to potable water by validating a cost-effective, time-efficient, and technically reliable tool for groundwater exploration in Nigeria and similar geologic terrains. By demonstrating the practical applicability of the PQWT-s300, the study provides insights that may reduce exploration risks, improve groundwater abstraction strategies, and enhance long-term water security in rural communities.

1.1 Location and Geology of the Study Area

To investigate the unique features of the PQWT-s300 device, a geophysical survey was carried out in Umuogele-Umuakwu community. The community is situated between latitudes 05°20′ and 05°22′ North, and longitudes 07°30′ and 07°31′ East. It is located within Isiala Ngwa North Local Government Area (LGA) of Abia State, Nigeria. Umuogele-Umuakwu shares boundaries with Umuogu to the west, Amadu Nsulu to the east, Eziama to the south, and AroAchara to the north (Abia NEWMAP, 2017).

The specific survey area lies in the central part of Umuogele-Umuakwu community. Locations 1 and 2 lie between latitudes 5°20'45.77" and 5°20'36.45" North, and longitudes 7°30'48.66" and 7°30'53.90" East, with elevations ranging from 81 m to 46 m above mean sea level (Fig. 1). The topography gently slopes downwards toward the Iyiukwu stream.

1.2 Geology/Hydrogeology

Umuogele-Umuakwu is underlain by the Benin Formation (Simpson, 1955, Reyment, 1965, Nwajide, 1980). The Formation has a prolific aquifer for sustained water production (Amos-Uhegbu*et al.*, 2012). Benin formation is the youngest stratigraphic unit of the Niger Delta Basin (Short &Stauble, 1955), and is made up of coastal sands with lenses of clay and mud (Tattam, 1944; Simpson, 1955; Amos-Uhegbu*et al.*, 2012). It covers a major expanse of southern Nigeria (Short &Stauble, 1955; Rayment, 1965) and up to half of Abia State (Amos-Uhegbu, 2023). The sands are very fine to coarse grained, subangular to sub-rounded, poor to fairly well sorted and mostly lithic arenites (Amajor, 1991).The aquifers have very good capacity to transmit groundwater of very good quality, which compares favourably with WHO standards for drinking water (Amajor, 1991).

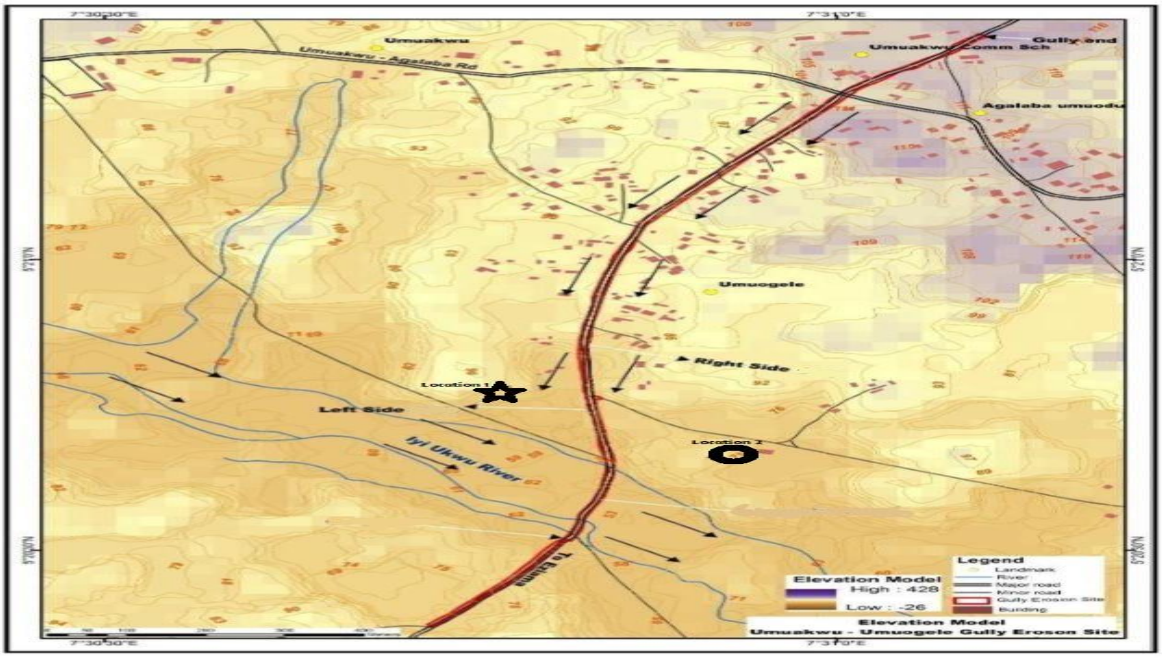

Fig. 1: Location Map of study area showing profile zones (Location 1&2) [Adapted from Abia NEWMAP, 2017]

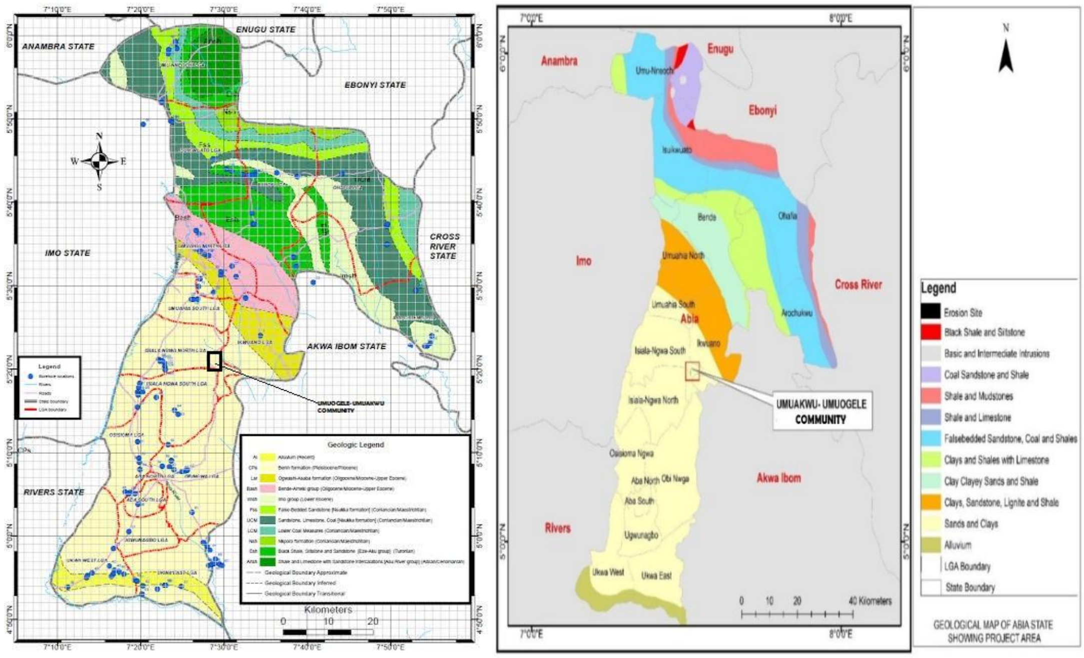

Fig. 2: Geologic Maps of Abia State showing formation and rock composition of the study area (Adapted from Abia NEWMAP, 2017)

As seen in Fig. 2 above, the study area is characterised by sand and clay as major rock materials that define the Benin formation – a claim which is in line with the findings of Amos-Uhegbu *et al.* (2012).

Fig. 3 is the groundwater flow map of the study location, which shows the flow pattern of rivers and streams within the area under consideration. The groundwater movement in the research area, like the catchment at large, is dendritic. Dendritic flow pattern is indicative of a good and productive aquifer, and an interconnectivity of groundwater ways (Dever and James, 1985). This shows that water can be accessible in any of the locations of study in the community.

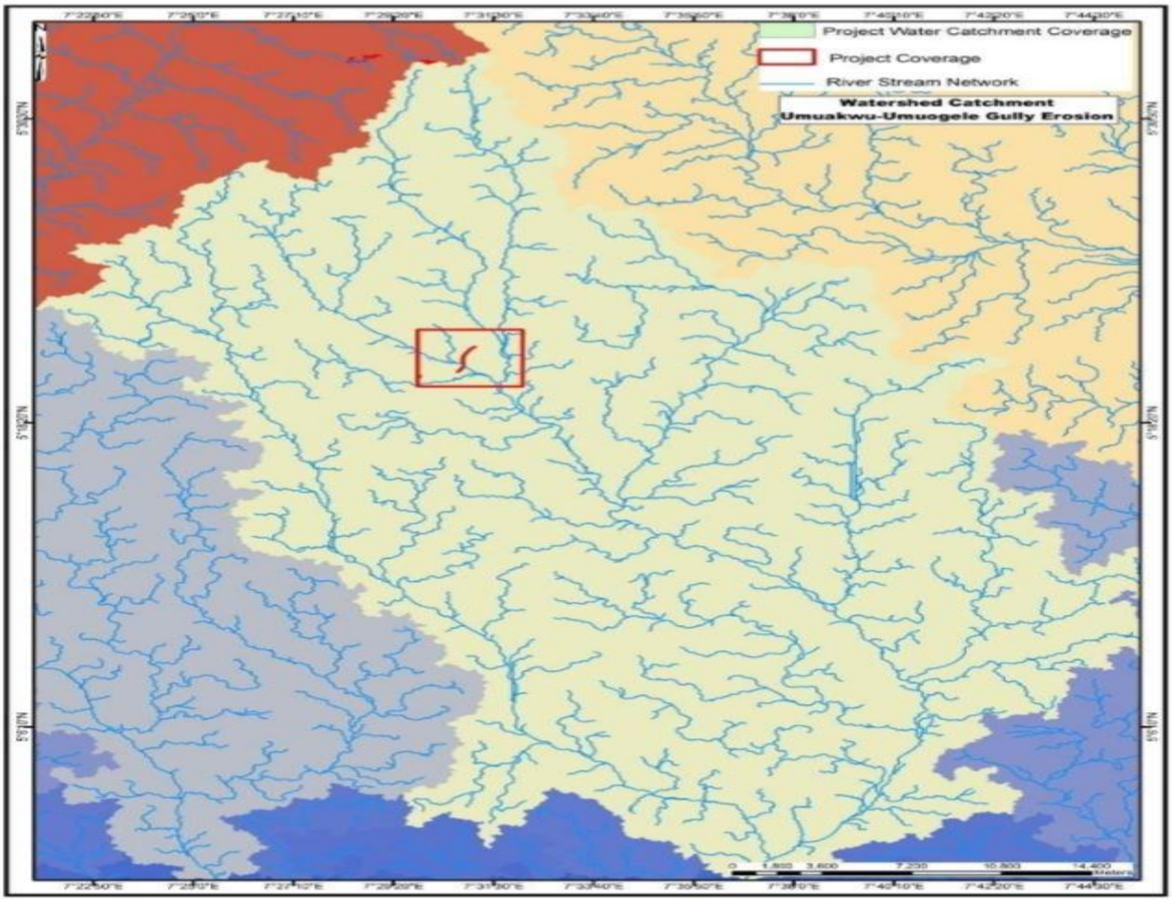

Fig. 3: Groundwater flow Map of the study area(Adapted from Abia NEWMAP, 2017)

2.0 Materials and Methods

2.1 Materials:

Materials deployed for this research included

a. The PQWT-s300 Water Detector and Accessories: The device utilizes the resistivity of rock materials, including water, to model the subsurface under investigation to delineate potential water regions for exploration. Its on-the-spot analysis and modelling of data is worth commending. It displays the models and graphs on its LCDscreen for viewing and transferring to PC as a complete model for interpretation.

The device has an inbuilt lithium rechargeable battery for power supply.

Its accessories include 2 electrodes, a hammer, a wire, and tape.

The PQWT device displays its subterranean models using profile length and depth of investigation into the earth's crust (HPGEEI, 2006; GroundWater_Tech, 2018).

b. GPS Device for coordinates recording.

2.2 Methods

The PQWT water detector operates on the principle of resistivity and least squares inversion. It applies Ohm's law, which states that the current (I) flowing through a metallic conductor is directly proportional to the potential difference across it (Lowrie, 2007; Igboekwe *et al.,* 2021; Igboekwe *et al.,* 2023). The voltage (V) can be expressed as a function of current (I) according to equations 1 and 2.

Voltage (V) α Current (I) (1)

V = IR (2)

where the proportionality constant R is the resistance to flow of current

Knowing that the resistance (R) is directly proportional to its length (*l*) and inversely proportional to the cross-sectional area (A), it follows that:

$$R = \rho \frac{l}{A} \quad (3)$$

$$\rho = \frac{RA}{l} \quad (4)$$

where the proportionality constant ρ is resistivity. Its unit is ohm-meter (Ωm).

Based on the accessibility of locations of interest, a single profile of 100m was set up at each location with electrode spacing of 10m using 2 metallic electrodes (current and potential electrodes) connected to the water detector at the M and N ports.

In analysing profile maps based on PQWT analysis sequence, PQWT colour chart, and the standards for getting water in Figs. 4 and 5, including PQWT graphs, will be used as references for the proper interpretation of survey results.

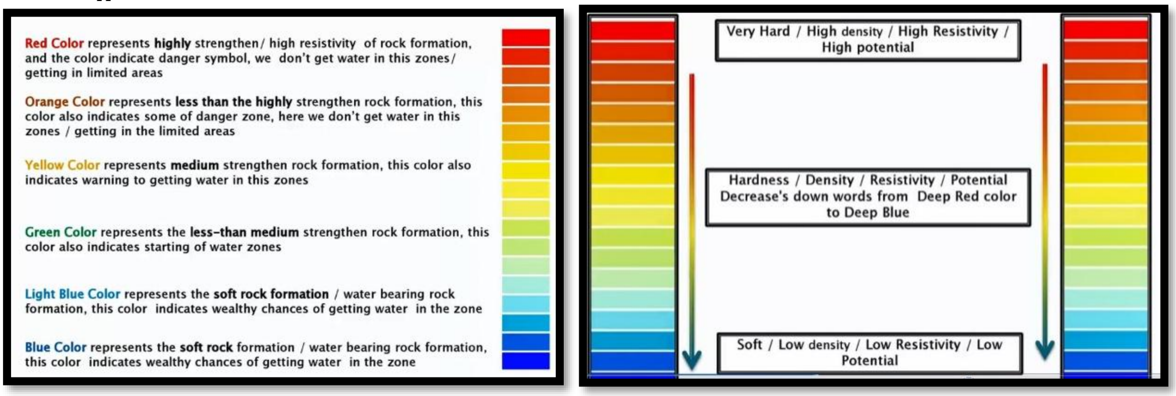

Fig. 4: PQWT Color Chart culled from GroundWater_Tech (2018)

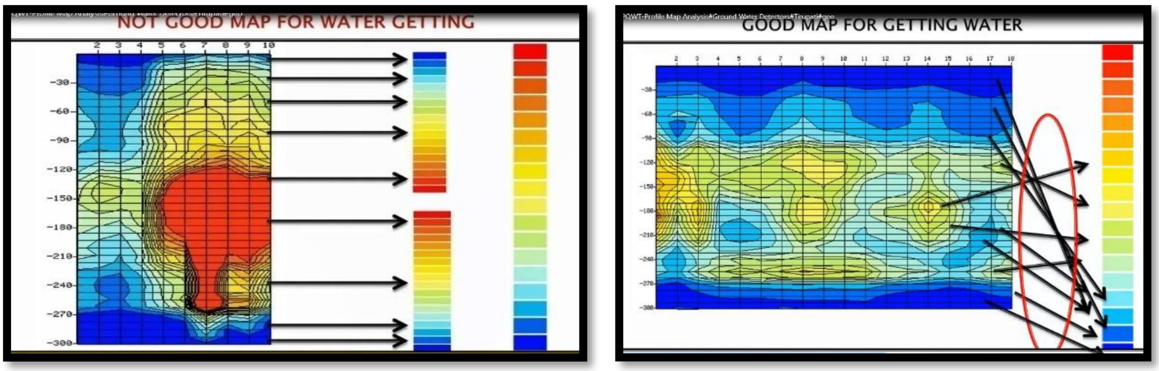

Fig.5: Sample map type for getting water culled from GroundWater_Tech (2018)

To determine how good a map is for getting water, parallel lines show that the map is not good, while the intersection of arrows implies that map is good for a successful well case as seen in Fig. 5 above.

3. Results and Discussion

3.1 Survey Profile Model and Graph for Location 1

GPS coordinates: Latitude 5°20'45.77" N, Longitude 7°30'48.66" E, with an elevation of 81 m above mean sea level.

Fig. 6 presents the resistivity profile plotted against survey distance for Location 1**.** This plot provides preliminary insight into zones of high and low resistivity along the profile, which correspond to aquifer-bearing and non-aquifer zones respectively. Higher intersections of plot lines represent enhanced electrical conductivity associated with water-saturated formations.

Fig. 7 display the integrated measured and calculated resistivity pseudosection, while Fig. 8 illustrates the inverse model resistivity section. Together, these provide a more refined interpretation of the subsurface resistivity distribution.

The Location 1 resistivity model demonstrates a relatively even distribution of groundwater potential zones along the 100 m profile length**.** In Fig. 6, clusters of intersections below 0.3 Ωm (highlighted with white rectangles) indicate high water-yielding zones**.**

From Figs. 7 and 8, lithological variations become evident. Green colouration dominates much of the section, representing moderately conductive formations with reliable groundwater potential. Blue zones, circled in purple, are highly prolific aquifers extending to depths of ~60 m and reappearing between 270–300 m. Conversely, yellow, orange, and red colours mark dense rock units with minimal water-bearing capacity, although their degree of weathering and fracturing increases secondary porosity.

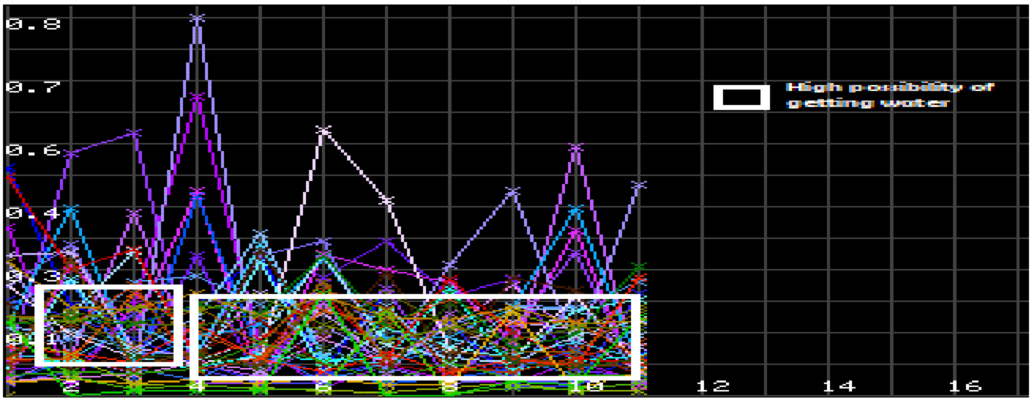

Fig. 6 : Resistivity Graph of Location 1

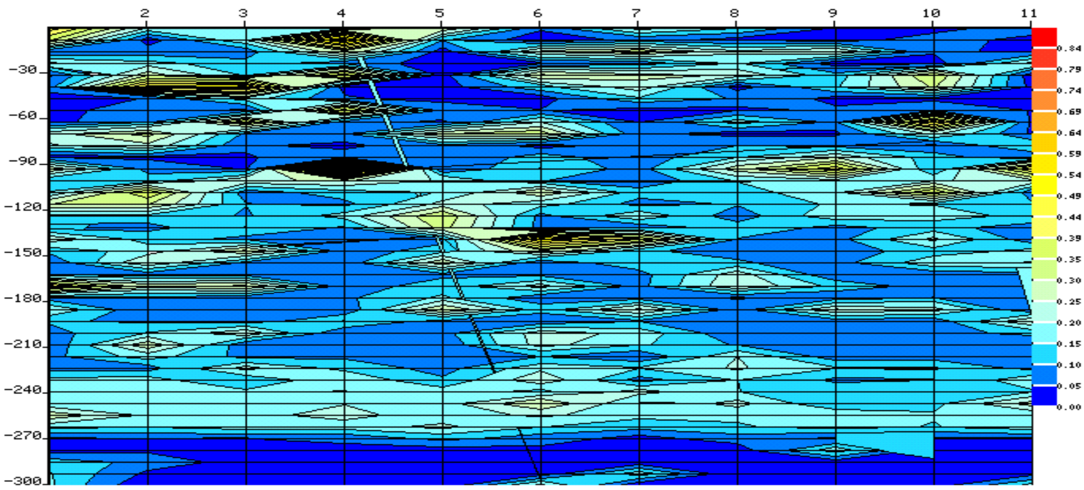

Fig.7: Integrated measured and calculated resistivity pseudosection of Location 1

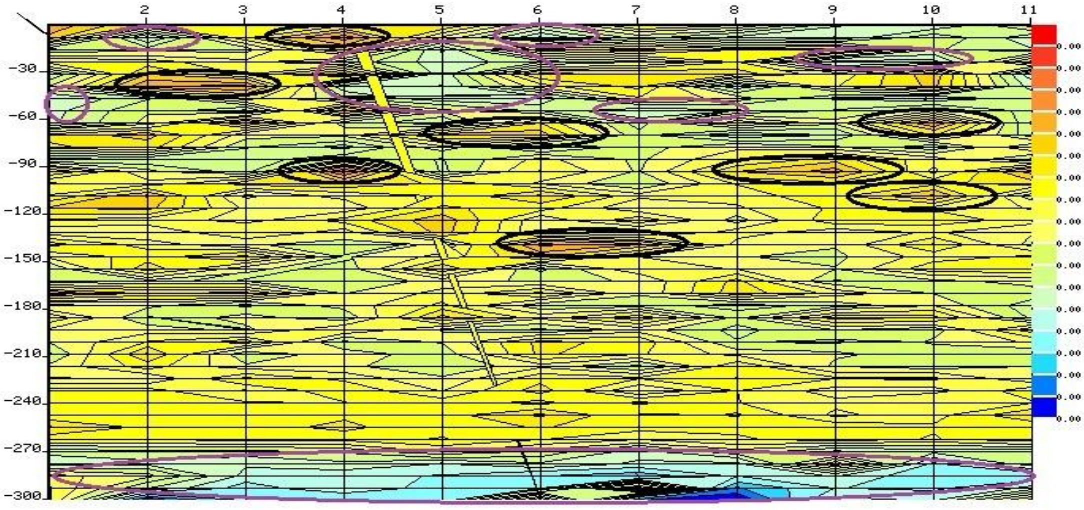

Fig. 8: Inverse model resistivity section of Location 1

The black circles highlight fractured zones, which are crucial since fracturing creates preferential flow paths and aquifer connectivity, thus improving transmissivity and recharge potential (Agada *et al*., 2022).

Anomalously, a diagonal resistivity anomaly occurs between 30–50 m along the profile and extends to depths of 300 m**.** Its geometry resembles deep exploratory boreholes or abandoned oil wells, possibly associated with historical Shell International exploration activities in south-eastern Nigeria. Such features warrant caution in groundwater exploration as they may affect aquifer integrity or pose contamination risks.

In summary, Location 1 exhibits both shallow (~60 m) and deep (>270 m) aquifer systems, sustained by structural controls such as faults and fractures**.** While drilling through hard rock presents challenges, the overall hydrogeophysical signature supports substantial groundwater availability in the area.

3.2 Survey Profile Model and Graph for Location 2

GPS coordinates: Latitude 5°20′36.45″ N, Longitude 7°30′53.90″ E, with an elevation of 46 m above mean sea level**.** Fig. 9 illustrates the resistivity graph for Location 2, while Figures 10 and 11 display the pseudosection and inverse model resistivity section, respectively.

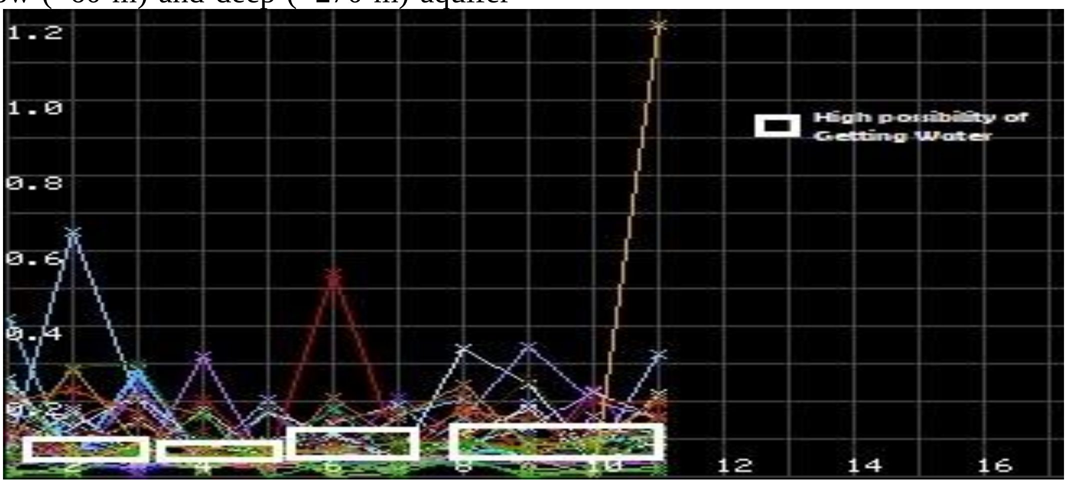

Fig. 9: Resistivity Graph of Location 2

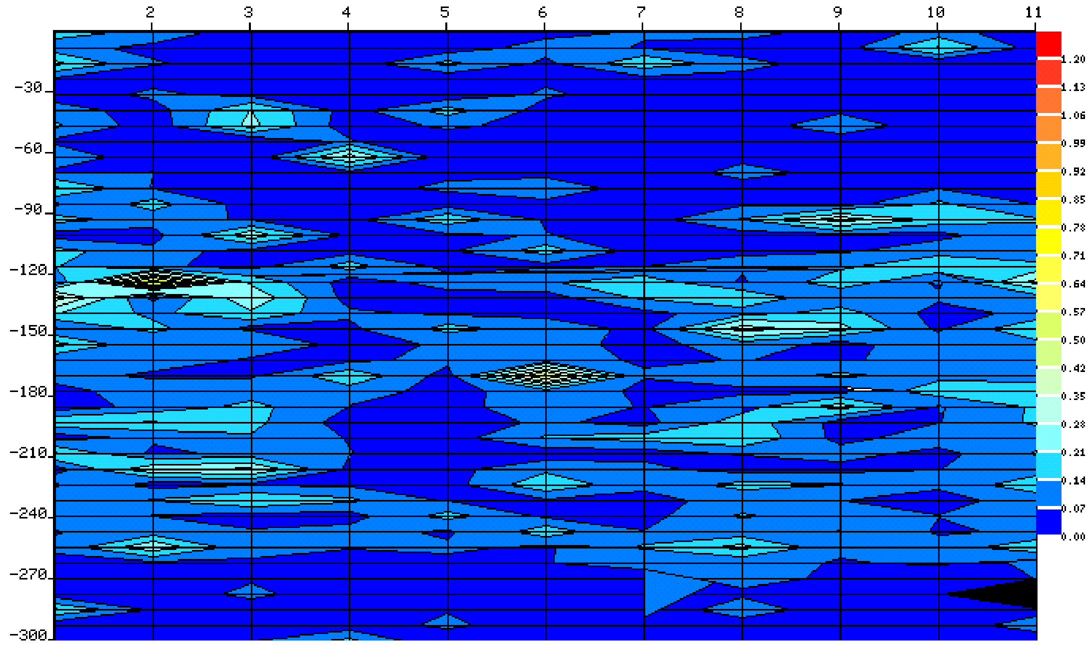

Fig. 10: Integrated measured and calculated resistivity pseudo section of Location 2

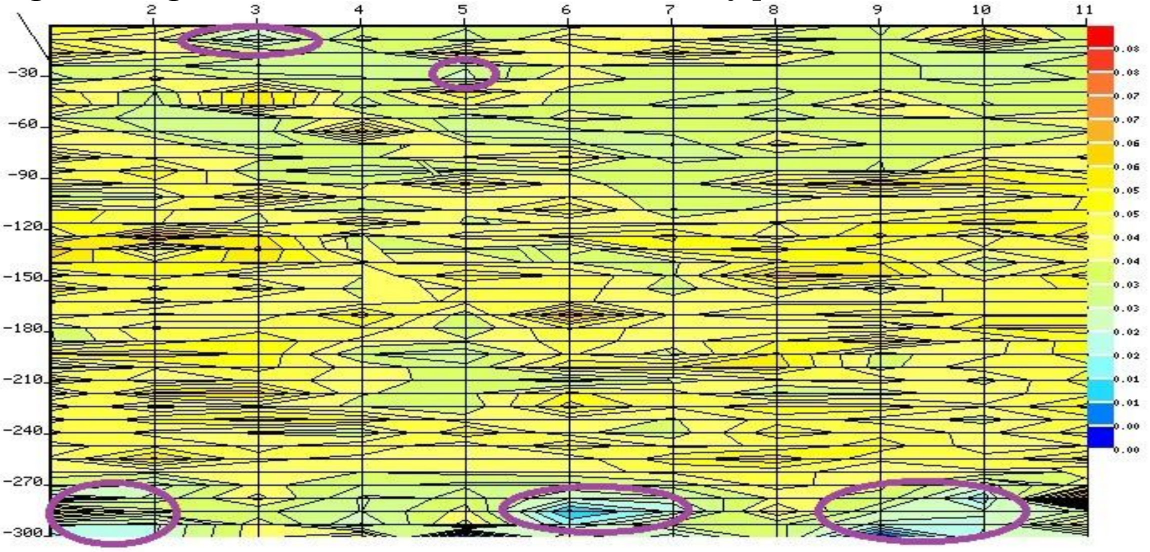

Fig. 11: Inverse model resistivity section of Location 2

The resistivity distribution at Location 2 mirrors many of the features observed in Location 1. Green and yellow zones dominate the subsurface (Fig. 11), signifying aquifers hosted in weathered and fractured bedrock. However, blue zones (circled in purple) are less frequent, indicating fewer highly prolific aquifers compared to Location 1.

Despite this, the wide distribution of green colouration across the section suggests generally favourable aquifer conditions, making drilling at nearly any point along the profile likely to yield water. The resistivity graph (Figure 9) supports this inference, although penetration through hard rock (yellow zones) will be necessary in several locations.

Hydrostratigraphically, groundwater is accessible at shallow depths of up to 90 m, while more prolific aquifers are located deeper than 270 m. Once again, fractures and faults play a critical role in secondary porosity development, thereby enhancing aquifer recharge and groundwater transmissivity.

The similarity between Locations 1 and 2 underscores a broader geological control: aquifer systems in the area are structurally governed and associated with fractured crystalline bedrock. This structural control creates localized but reliable groundwater reservoirs.

To complement the resistivity profiles presented in Figs. 8 and 11, a schematic hydrogeological cross-section (Fig. 12) was developed to visually summarise the aquifer framework within the study area. The cross-section integrates results from the PQWT-s300 resistivity survey with the established geologic context of the Benin Formation (Simpson, 1955; Short and Stauble, 1955; Amos-Uhegbu*et al.*, 2012). It illustrates the distribution of shallow unconfined aquifers (~0–60 m), fractured and weathered aquifers (60–270 m), and deep prolific aquifers (>270 m) alongside zones of secondary porosity created by fractured hard rocks.

The cross-section confirms the presence of a multi-aquifer system typical of the Benin Formation, where groundwater occurs both in primary porosity zones consisting of sands and intercalated clays, and in secondary porosity zones associated with fractured and weathered rocks. The shallow aquifer, occurring between 0 and 60 m depth and shown in light blue, corresponds to low resistivity zones in Figs. 6 and 9. These aquifers are easily accessible and can sustain hand-dug wells or shallow boreholes, although their proximity to the surface renders them more susceptible to contamination, particularly due to interaction with surface water bodies such as the Iyiukwu stream.

The fractured and weathered hard rock aquifers, extending between 60 and 270 m depth and depicted in light green, represent the main water-bearing units for moderate-yield boreholes. These aquifers are associated with secondary porosity features such as faults, fractures, and weathered zones, which were identified in the resistivity models (Figs. 8 and 10) as green and yellow bands intersected by black-circled fault zones (Agada *et al.*, 2022). These structural features enhance permeability and are critical for sustainable groundwater abstraction within the study area.

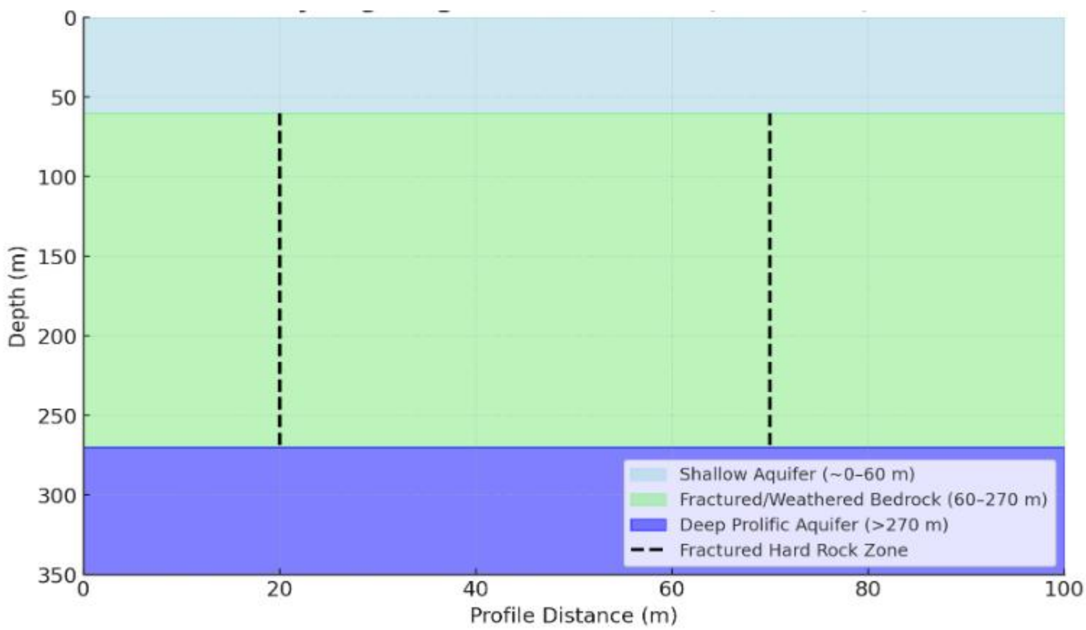

Fig. 12: Hydrogeological Cross-Section of the Study Area Showing Shallow, Intermediate, and Deep Aquifer Zones

At greater depths, the cross-section identifies prolific aquifers occurring beyond 270 m, represented in blue. These aquifers correlate with highly saturated zones of the Benin Formation and were identified in both survey locations, though they appear more prominent in Location 1. They are particularly important for high-yield and long-term groundwater supply projects at the community scale. However, access to these deeper aquifers requires drilling through resistant fractured rock units, which demands higher energy inputs and cost considerations.

The dashed black lines in Figure 12 represent fractured hard rock zones that provide essential secondary groundwater pathways linking shallow and deep aquifers. These fractures are responsible for the dendritic groundwater flow pattern observed in the regional hydrogeological map (Fig. 3), which demonstrates aquifer interconnectivity and ensures both recharge and sustainable groundwater abstraction.

The hydrogeological cross-section highlights the technical implications of these findings byshowing that groundwater is available at multiple depths, but the choice of drilling depth is a crucial factor in ensuring sustainable water supply. Shallow aquifers at less than 60 m offer quick and inexpensive access but remain vulnerable to contamination. Intermediate aquifers between 60 and 270 m, located within fractured and weathered rocks, provide more secure and reliable yields suitable for long-term abstraction. Deep prolific aquifers beyond 270 m are the most productive, but their exploitation requires substantial drilling resources. The ability of the PQWT-s300 device to delineate these depth-specific aquifer targets demonstrates its effectiveness in reducing exploration risk, optimizing borehole siting, and improving water resource management within the Benin Formation aquifer system.

3.3 Technical Implications

The results of this study carry significant technical implications for groundwater exploration and sustainable water supply in Umuogele-Umuakwu and similar geologic settings across southern Nigeria. The application of the PQWT-s300 water detector demonstrated that portable, processor-integrated geophysical devices can provide rapid, cost-effective, and accurate delineation of groundwater-bearing zones, significantly reducing the labour, time, and risk associated with conventional resistivity methods. The ability of the device to probe depths of up to 300 m with a relatively short 100 m profile length represents a substantial technological advancement, as it allows for the identification of shallow, intermediate, and deep aquifers in a single survey session without the cumbersome deployment of numerous electrodes or external data transfer software.

From the resistivity survey results, it is evident that the study area is characterized by a multi-aquifer system consisting of shallow unconfined aquifers, weathered and fractured intermediate aquifers, and deeper prolific aquifers. The delineation of these zones provides actionable guidance for borehole siting. For instance, shallow aquifers (<60 m) offer quick and inexpensive access to groundwater but remain vulnerable to contamination, particularly from surface water bodies such as the Iyiukwu stream. Intermediate aquifers (60–270 m) within weathered and fractured rocks constitute the most reliable and sustainable targets for community-scale boreholes, as their secondary porosity significantly enhances permeability and recharge capacity. Deep prolific aquifers (>270 m) hold the greatest long-term potential for high-yield boreholes, although their exploitation requires specialized drilling techniques and higher financial investment to penetrate resistant fractured units.

The hydrogeological cross-section developed in this study reinforces the importance of secondary porosity features such as fractures and faults, which interconnect aquifer systems and underpin the dendritic groundwater flow pattern observed in the area. These findings highlight that structural geology plays a decisive role in groundwater availability and should always be factored into groundwater exploration and development programs.

Overall, the integration of the PQWT-s300 survey results with regional hydrogeological data underscores the potential of modern geophysical devices to transform groundwater exploration practices in Nigeria. By providing real-time subsurface imaging and reducing reliance on labour-intensive methods, such technologies enable faster and more reliable decision-making for borehole drilling. This has direct implications for improving access to potable water, mitigating the risk of borehole failure, and supporting sustainable groundwater resource management in regions where reliance on groundwater remains the most viable solution for meeting water demand.

4.0 Conclusion

The findings of this study demonstrate that the terrain of the Umuogele-Umuakwu community has a high water production capacity, as evidenced by the PQWT graph, the profile maps, and the hydrogeological cross-sections. The intercalation of the blue and green colouration on the resistivity profiles indicates the presence of soft rock formations that are rich in water and moderately water-bearing, while the yellow to orange colouration corresponds to harder rock formations. Despite the occurrence of these hard rock units, the majority of the geological materials in the area are heavily fractured and weathered, which has enhanced their secondary porosity and enabled them to act as viable aquifer systems. This geological setting underscores the favourable hydrogeological framework of the area for groundwater development. At location 1, water can be readily abstracted at depths shallower than 60 meters, while at location 2, water can be accessed at depths below 90 meters. However, successful exploration in both locations may involve penetrating layers of hard rock, which will require the use of drill bits designed for deep and sustained well construction. The distribution of water-bearing soft rocks alongside fractured hard rocks highlights the dendritic groundwater flow pattern in the area, further reflected in the perennial survival of the Iyi-ukwu stream, located less than 100 meters from both surveyed points. This not only reinforces the evidence of a robust subsurface water network but also suggests significant recharge and groundwater flow continuity within the terrain.

In conclusion, the study confirms that the Umuogele-Umuakwu community is endowed with promising groundwater resources that can be sustainably exploited. The results provide clear evidence that the PQWT-S300 survey method offers reliable subsurface imaging for siting productive boreholes in crystalline terrains. It is therefore recommended that groundwater abstraction be focused within the identified depth ranges to maximise yield and minimize costs, with due consideration given to the fractured rock aquifers that provide long-term water storage and transmission. Furthermore, the community should adopt integrated groundwater management strategies, including periodic geophysical surveys, borehole monitoring, and protection of recharge zones, to ensure sustainable utilization of this resource for domestic and agricultural needs.

Acknowledgement

This study was sponsored by Abia State, Nigeria Erosion and Watershed Management Project (NEWMAP) atUmuogele-Umuakwuin locations 1 and 2 to delineate areas with good aquifer potentials for sustainable water projects.

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Declaration

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data public

Ethical Considerations

Not applicable

Competing interest

The authors report no conflict or competing interest

Funding

No funding

Authors' Contributions

All Authors contributed to the work. Agada, I.O: Conceptualization, data collection and analysis, writing of original manuscript. Igboekwe, M.U: Supervision and Review/ Amos-Uhegbu, C: Analysis, Review and editing of manuscript.