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Preliminary Integrated Assessement of Hydrogeological Conditions a Case Study of Parts of Ilorin Crystalline Rocks Southwestern Nigeria

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Abstract
The heterogeneous and undifferentiated nature of rocks within the Basement Complex posed a serious challenge to any hydrogeological studies. Coupled with this is the discontinuity of the aquifers nature which is considered to be naturally localized. This study takes in to consideration the relationship between flow direction and flownet construction as indispensable preliminary studies necessary for adequate hydrogeological assessment of an area. The field work involved measurement of 950 hand dug wells within parts of Ilorin metropolis Southwestern Nigeria. This took place at the peak of dry season between December and March. Garmin GPS was used to measure the Coordinates and Elevation of the well locations while Deep meter and Tape were used to determine the static water level of the well and the total depth. The hydraulic head of each of the well were also determined. The study area consists of crystalline rocks such as migmatite-gneiss, banded gneiss, augen gneiss, quartzites and granites. Adequate correlation of groundwater flow direction with flownet will enhance appropriate delineation of locations that can be considered suitable for further and more extensive groundwater exploratory activities. Flownet is constructed by plotting flow lines against equipotential lines orthogonally. Analysis and interpretation of flownet shows that the western part of the study area which covers areas such as Olorunsogo, Agbooba and Gbagba have very wide divergent equipotential lines which imply easy groundwater movement. The Southeastern part which include places such as Oko-Erin, Baba-Ode, Gaa-Akanbi and Northeastern parts such as Fate, Tanke reflect convergent equipotential lines, an indication of difficulty (less permeable zones) in the water movement within the media. The primary technique of constructing the groundwater flownet is considered basic since it is cheap and fast as a reconnaissance tool. The study area has been divided into divergent and convergent areas using inferences from flownet construction and analysis.

Keywords*: Flownet, Equipotential lines, Flowlines, Convergent, Heterogeneous.*

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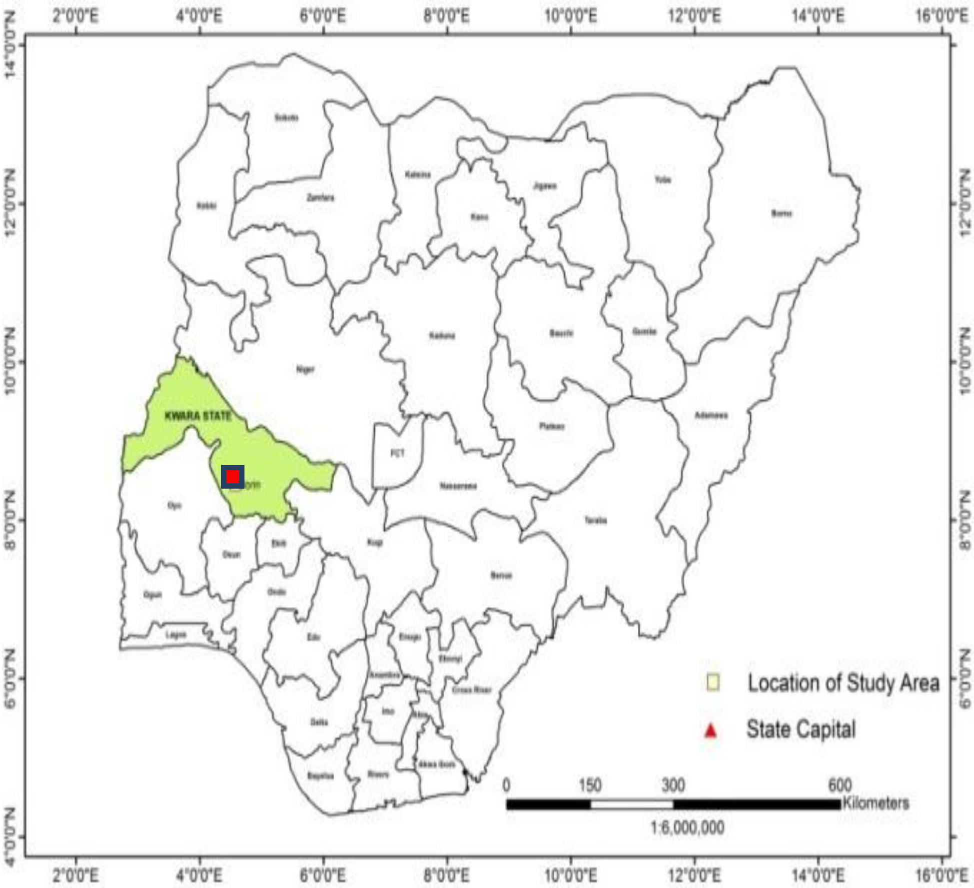
I. Introduction

The heterogeneous and undifferentiated nature of rocks within the Basement Complex posed a serious challenge to any hydrogeological studies. Coupled with this is the discontinuity of the aquifers nature which is considered to be naturally localized. This study takes in to consideration the relationship between flow direction and flownet construction as indispensable preliminary studies necessary for adequate hydrogeological assessment of an area. Evaluation of groundwater potential in the Crystalline Basement Complex has been problematic due to the complex nature of rocks and tectonic activities that have affected them [1, 2]. This study has become necessary in view of the dwindling surface water sources in the face of climate change and economic recession militating against the construction and maintenance of surface water sources through dams and weirs. The use of Flownet analysis for aquifer identification was first proposed by [3]. Equipotentials are the loci of points of equal potential (or head), and flow lines (or stream lines) correspond to directions of groundwater flow [4, 5, 6,].Constructing flownet map is a well-accepted practice in investigation of groundwater flow directions[7, 8].Water table surface is a representation of the surface of saturated zone, below which all the geological formation voids are fully filled with water[9]. The position of the water table is asa result of natural processes controlling the rate at which water enters and leaves the saturated zone. If the rate water enters the saturated zone (recharge) exceeds the rate of water leaving (discharge) the aquifer, the water table rises and vice versa. The water table surface is not static, nor flat, but reflects the climatic, vegetative and geomorphic conditions. The groundwater water table could be subdued replica of the land surface [10]. [11] Employed graphical inverse method as a hydrogeological tool that can be used for site characterization and flow system conceptualization, understanding and defining the subsurface geologic structures and flow system controls.The most direct method of determining the direction of groundwater movement is by measuring the elevation of groundwater at multiple locations over the aerial extent of an aquifer [4]. Measurements are plotted on a map of the area and lines are drawn to connect points of equal elevation. These lines represent equal pressure between connected points and are called equipotential lines [26]. Groundwater moves along a flow path perpendicular to equipotential lines and the direction of movement is from lines of higher value to lines of lower value (i.e., higher to lower elevation or pressure). Groundwater flow paths are usually shown by arrows on equipotential surface plots pointing in the direction of groundwater flow [26].

II. Materials and Methods

Study Location

The study location is parts of Ilorin metropolis (fig. 1). The area is bounded by longitudes $4^{0}28^{'}0''$E and $4^{0}38^{'}0''$E and latitudes $8^{0}27'0^{''}$N and $8^{0}34'15''$N.The area covered is about 242.79km^{2}. Weather condition in the region is of two broad types (i.e. rain season and dry season). The rain season commences around March and ends in October with annual average rainfall of 1,200mm, while dry season begins in November and ends in March. The humidity ranges between 60 % and 89% and mean annual temperature is between 27^{0}C and 30°C. The area is well drained by various streams and their tributaries. The tributaries show dendritic drainage pattern. The main rivers are Asa and Agba Rivers, while minor rivers include Oyun and Aluko Rivers. The terrain is undulating and dissected by rivers and streams. The highest altitude is about 1200m above sea level corresponding to the top of Sobi Hill (migmatite), while along major streams the altitude is about 250 m above sea level. The vegetation cover is basically Guinea savannah with ruminant tropical forest [12].

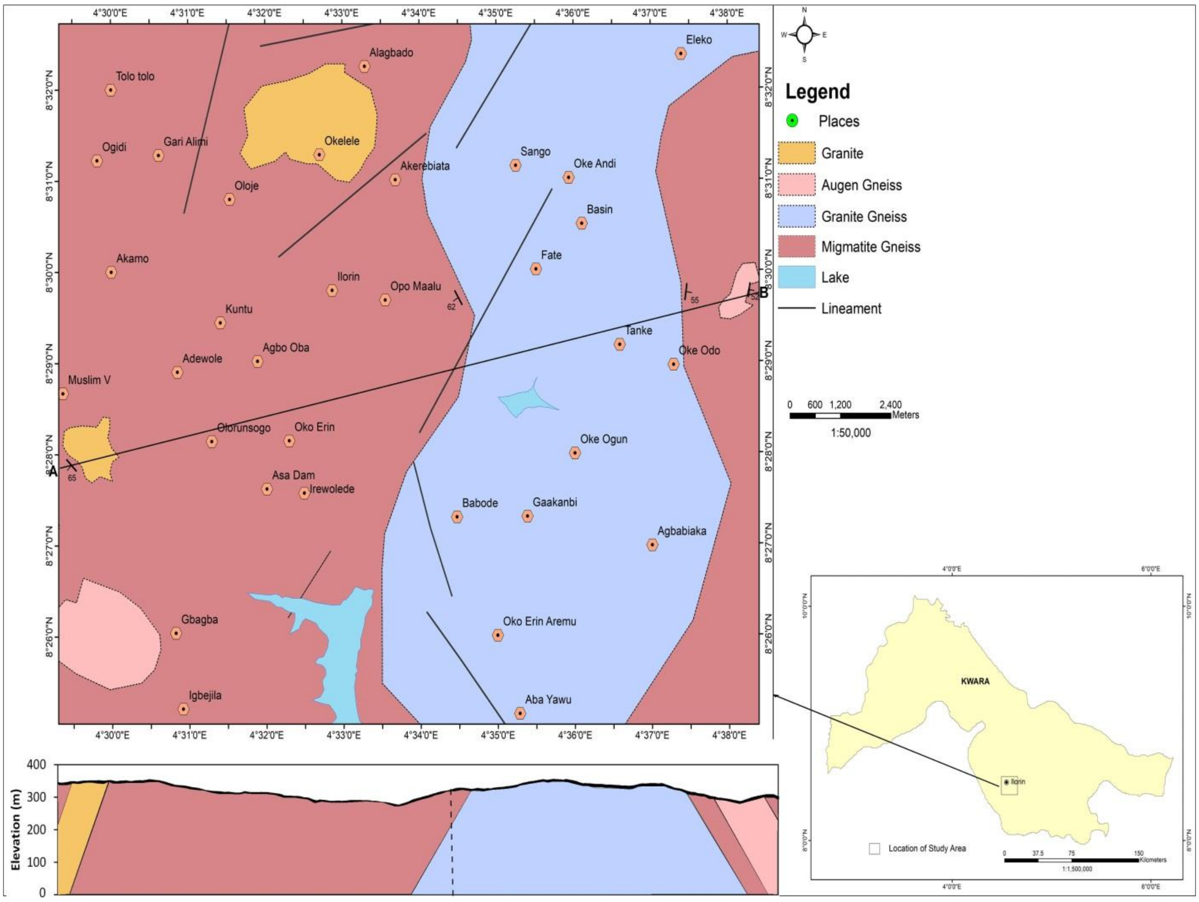


Ilorin the Study area

Figure. 1 Map of Nigeria showing Ilorin, Kwara State Nigeria

Geology and Hydrogeology of Ilorin

The study area falls in the Basement Complex of Southwestern part of Nigeria, which is of Precambrian to Lower Paleozoic in age[13, 14]. This Precambrian Crystalline Basement Complex consists of gneisses and migmatities; metasediments i.eschists, quartzites and metavolcanics; and Pan-African (older) granite and late-stage minor pegmatitic and aplitic intrusives[15]. According to [16], Ilorin is situated on the undifferentiated Precambrian Basement Complex rocks of granitic and metamorphic origin. These rocks represent the deeper, fractured aquifer which is partly overlain by a shallow, porous aquifer within the lateritic soil cover [17]. The rock units form part of the regional Southwestern highlands of Nigeria running NW-SE parallel to the River Niger [18, 17]. The subsurface comprises the weathered, slightly weathered and fresh (fractured or unfractured) crystalline basement rocks. The oldest rocks in the area comprise gneiss complex whose principal member is biotite-hornblende gneiss with intercalated amphibolites. This underlies, over half of the city. Other rock types are the older granite mainly porphiritic granite, gneiss and granite-gneiss and quartz schist. Ilorin is underlain by crystalline rocks mainly gneisses and migmatite with pegmatite veins. Rock types within the study areas include;migmatite- gneiss, banded gneiss, granite gneiss, augen gneiss, quatzitesgranites as shown in Fig.2[19, 20].



F**igure2** Geological Map of Ilorin Modified after NGSA 2007, Olatunji, *et al.,* 2020

Field Work

The coordinates and elevations of hand dug wells were measured with the aid of Garmin Global Positioning System (GPS). The Static water levels of the wells were also measured and this helps to calculate the corrected water level in the subsurface. A total of 950 Wells were covered to give information on the groundwater flow dynamics of the study area. Well positions and their respective elevation relative to the main sea level were determined using (GPS). These helped in determining the hydraulic water head in wells and thus groundwater head elevation contour which gave information on the groundwater flow direction.

III. Results and Discussion

Analysis and Evaluation of the Flownet

Well data collected from Ilorin metropolis were used to construct flownet for the study area. Fig. 3 shows the groundwater flow direction of parts of Ilorin the study area. Under certain conditions such as homogeneous, isotropic and orthogonal system, the set of equipotential lines and flow lines so exposed constitutes a flownet.

Fig.3 Flownet Contour map Analysis and Evaluation

Fig. 3 shows the Flownet constructed for the study area and its hydrogeological implications. This helps in identification of Divergent and Convergent areas within a location. Divergent areas have widely spaced equipotential lines while convergent areas has closely spaced equipotential lines. The western part and the north southern parts of the study area which covers areas such as Olorunsogo, Agbooba, Gbagba, Ogidi, Baba-ode andOpo-Malu, have very high divergent equipotential lines which imply easy groundwater movement. The greater the distance between contours, the slower the flow. Such areas are considered to be highly permeable, have better accumulation and discharge rate and can be explored for further groundwater exploratory activities [21, 22, 23,24]. Similarly, NE-SE parts of the study area reflect a closely spaced equipotential lines otherwise refers to as convergent area, an indication of difficulty (less permeable zones) in the water movement within the aquifer [23, 5]. Locations such as Tanke, Fate, Basin, Sango, part of Gaa-Akanbi, Kuntu, Eko-Erin areas are considered to be within the convergent areas Table 1. Also, from fig.3, the groundwater flows along the areas considered to be divergent areas which implies a very good correlation (agreement) between flownet and groundwater flow direction

Table 1 Flownet Classification within the study area

Divergent areas	Convergent Areas
Ogidi	Fate
Akerebiata	Agbabiaka
Baba –ode	Oke-odo
Adewole	Basin
Gbagba	Gaa-akanbi

Okelele	Tanke
Opo-malu	Okeandi
Oko-erin	Sango
Olorunsogo	
Agbooba	

IV. Conclusions

The study examines the use of flownet construction analysisin aquifer identification and groundwater flow direction determination as a basic preliminary tools in assessing the hydrogeological condition of an areaaimed at delineate an appropriate location that can be considered for further groundwater exploratory activities. Static water levels, total depth, coordinates of hand dug well were measured using deep meter, GPS and tape respectively. From the data collected, analysis and interpretation of flownet shows that the western part of the study area which covers areas such as Olorunsogo, Agbooba and Gbagbahas very wide divergent equipotential lines which imply easy groundwater movement. The Southeastern part which include places such as Oko-Erin, Baba-Ode, Gaa-Akanbi and Northeastern parts such as Fate, Tanke reflect convergent equipotential lines, an indication of difficulty (less permeable zones) in the water movement within the media. The greater the distance between contours, the slower the flow.The primary technique of constructing the groundwater flownet is considered basic since it is cheap and fast as a reconnaissance tool. Other exploratory activities are considered after flownet construction. Generally, the hydrogeological point of view, the study areas has been divided into Divergent and Convergent areas. The groundwater flow direction within the study areas as shown in figure 3 is toward the North-central, SW and SE areas.

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Table 2 Sample of Well Data Collected Within the Study Area

S/N	**Location**	**SWL (m)**	**T/D (m)**	**W/C (m)**	**N**	**E**	**ELEVATION. (m)**
1	Adewole	8.6	9.7	1.1	08 28 49.7	00430 46.3	347
2		8.6	9.6	1	08 28 55.3	004 30 45.0	345
3		7.7	8.0	0.3	08 28 57.5	004 30 47.3	349
4	Agbooba	5.8	6.0	0.2	08 28 58.6	004 31 40.4	322
5		4.8	5.0	0.2	08 28 59.2	004 31 39.7	320
6		2.9	3.1	0.2	08 29 04.1	004 31 40.7	317
7		2.8	3.0	0.2	08 29 01.7	004 31 41.7	327
8		1.0	1.2	0.2	08 29 00.9	004 31 29.5	315
9		2.9	3.1	0.2	08 28 57.2	004 31 27.6	325
10		5.2	7.3	2.5	08 28 48.6	004 31 24.3	334
11		3.7	4.2	1.5	08 29 03.0	004 31 37.6	317
12		1.7	2.0	0.3	08 29 04.7	004 31 36.4	301
13		2.2	2.5	0.3	08 29 04.5	004 31 34.4	309
14		1.5	2.5	1.0	08 29 01.0	004 31 31.6	308
15		5.9	6.0	0.1	08 29 06.3	004 32 05.3	286
16		4.4	4.5	0.1	08 29 07.8	004 32 05.3	296
17		4.7	5.8	1.1	08 29 10.0	004 32 06.3	340
18		1.5	2.5	1.0	008 29 10.3	004 32 05.3	302
19		3.0	3.1	0.1	08 29 04.9	004 32 00.0	312
20		5.2	5.5	0.3	08 29 05.3	004 32 00.5	320
21		3.8	4.0	0.2	08 29 04.7	004 32 00.8	305
22		6.2	6.5	0.3	08 29 04.7	004 32 02.5	304
23	Oko-Erin	4.0	4.1	0.1	08 29 09.7	004 32 10.1	300
24		4.5	6.0	1.5	08 29 08.5	004 32 09.5	327
25		2.9	3,0	0.1	08 29 08.2	004 32 08.4	304
26		4.9	5.0	0.1	08 29 07.4	004 32 08.0	313
27		1.9	2.0	0.1	08 29 10.4	004 32 04.5	307
28		3.7	4.1	0.4	08 29 11.7	004 32 07.8	298
29		4.0	4.2	0.2	08 29 12.0	004 32 08.6	303
30		4.7	6.1	2.6	08 29 10.8	004 32 09.1	308
31		4.0	4.1	0.1	08 29 09.7	004 32 10.1	300

Lengend: SWT- Static Water Level, T/D- Total Depth, W/C- Water Colum

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