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ASSESSMENT OF WATER LEVELS VARIATIONS OF SHALLOW WELLS IN KUMBOTSO LOCAL GOVERNMENT AREA, KANO STATE, NIGERIA

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Abstract

This study assesses and analyze the groundwater potentials of shallow wells in Kumbotso Local Government Area, Kano State, by leveraging geologic and topographic data. The research utilizes recuperation (recovery) tests, monthly groundwater level monitoring data, and well coordinates as primary data sources. The grid sampling technique was employed, resulting in forty-five (45) sampling points. However, only three (3) points located at Challawa axis lacked wells due to the presence of hard rock formations. The results indicate that the topography of the northern and eastern parts of the area exhibits very high altitude, with elevation decreasing from the northern to the southern part. The study classifies certain areas as having very high seasonal variations of water level, with fluctuations hardly exceeding 4 meters. Specifically, the mean [redacted] water level is recorded as 15.03 meters during the dry season and 11.73 meters during the rainy season. Similarly, the study identifies other areas falling under high, moderate, and low categories, each exhibiting distinct seasonal variations of water level.

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Considering areas with hard rock formations, like Challawa axis, the study recommends the implementation of geophysical surveys before establishing wells to ensure successful water resource exploitation.

Introduction

Water is an indispensable resource that sustains life and supports various socio-economic activities in communities across the globe (Chang, Chang, Huang and Kao, 2016). Groundwater levels is the depth at which water is found below the Earth's surface in underground aquifers or water-bearing rock formations (Gurdauno and Foster, 2008). These levels play a crucial role in maintaining ecological balance and sustaining human and agricultural needs.

The fluctuation of groundwater levels is influenced by various factors, including precipitation, surface water runoff, evaporation, and human activities such as pumping for irrigation and municipal water supply (Brenner *et al.,* 2018). During periods of abundant rainfall and recharge, groundwater levels tend to rise, replenishing the aquifers. Conversely, during dry spells or intense groundwater abstraction, the water levels can drop, leading to a depletion of available groundwater resources (Adelana *et al.,* 2008).

In many regions, especially in developing countries like Nigeria, where water scarcity is a prevailing challenge, shallow wells serve as critical sources of potable water for domestic and agricultural purposes. Kano State, located in northern Nigeria, is no exception to this, with the Kumbotso Local Government Area being of particular interest due to its significant reliance on shallow wells as a primary water supply (Abdulhamid, 2010).

Monitoring groundwater levels is vital for understanding the overall health and sustainability of water resources (Christopherson, 2006). Hydrologists and environmental agencies use various methods to measure groundwater levels, such as wells, piezometers, and remote sensing technologies. Understanding the variations in water levels in these shallow wells is of utmost importance for effective water resource management, sustainable development, and community well-being (Brenner et al., 2018). The availability and reliability of water from these wells directly impact the livelihoods of the local population and play a crucial role in agriculture, sanitation, and overall health (Seth, 2008).

Collins (2010) stated that for a given aquifer, the yield is proportional to the square of depth penetration into the aquifer. Water flows into the well through porous

areas of intake until water level inside the well drop by pumping or by bucket, the water level inside the well drop relative to the level in the aquifer causing a pressure difference. Shallow wells are used where water table is fairly close to ground surface. The diameter may range from 3 to 20 feet are common. The principal advantage of shallow well is that they can be constructed with hand tools. Also their large diameter provides a reservoir of fair size within the well. In areas where surface is highly polluted a shallow well near the shore of lake or stream will yield a better quality of water because of the filtering action of the porous soil. The discharge of open shallow well is limited (Mahajan, 2008).

The top of an unconfined aquifer is water table which is the place where groundwater pressure is equal to atmospheric pressure. The water table height corresponds to equilibrium of water level in a well, penetrating the aquifers (Mahajan, 2008). Unconfined aquifer is commonly found in alluvium valleys, coastal plains, dunes and glacial deposits (Longe et al, 2009). When groundwater flows from an unconfined aquifer into a pumped well; the water table drops and air moving through vadose zone replaces water that has drained from the pores or other interstices in the upper aquifer material (Mahajan, 2008).

Gehral and Gieske (2008) stated that Groundwater level fluctuations are a direct expression of the dynamic behavior of aquifers. Every change in water balance of a hydrological systems brings about groundwater level fluctuations in one way or the other. Such fluctuations are therefore a key to understanding the processes, whether natural or man- induced, controlling the hydrological systems (Dennis, 2004). Groundwater level is one the easiest hydrological variables to measure, being monitored regularly in many countries throughout the world. The data contain relatively small measurement errors which practically independent of the determination of the method. The spread availability and relatively unambiguous means of measurement make this data extremely valuable for monitoring hydrological processes and identifying hydrogeological conditions (Abdulhamid, 2010).

This study aims to comprehensively investigate and analyze the fluctuation patterns of water levels in shallow wells in Kumbotso Kumbotso Local Government Area, Kano State, Nigeria to gain valuable insights into the dynamics of the groundwater system, identify potential challenges, and formulate evidence-based strategies to address water-related issues. This study employs a combination of field surveys, hydrological data collection, and geospatial analysis to map the distribution of shallow wells and assess how water levels respond to seasonal changes, human activities, and climatic influences. Additionally, factors

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such as land use changes, population growth, and hydrogeological conditions was considered to provide a holistic understanding of the water level variations.
The groundwater abstraction through Shallow wells in Kumbotso Local Government Area in particular and Kano state in general became more serious activity by exploiting large quantity of groundwater on daily basis. Due the fact that the area has high groundwater potentials there is need to assess the groundwater levels in order to ensure sustainability of the groundwater resources in the area. It is highly significant to assess the condition of shallow wells in view to identify and examine the water levels in the study area.

The Study Area

Kumbotso Local Government Area, Kano state is located in southern part of the sprawling urban Kano. The local government is presently part of Kano metropolitan area found between Latitude 11° 52¹ N and Latitude 11° 58¹ North of the Equator and Longitude 8° 24¹ E and Longitude 8° 37¹ East of the Greenwich Meridian. It covers the total area of 158km² sharing boundaries to the north by Ungogo, Gwale, Kano Municipal and Tarauni Local Governments, to the west by Tofa and Madobi Local Governments to the south by Madobi and Dawakin Kudu Local Government to the East by Nassarawa and Gezawa Local Governments (see Figure 1).

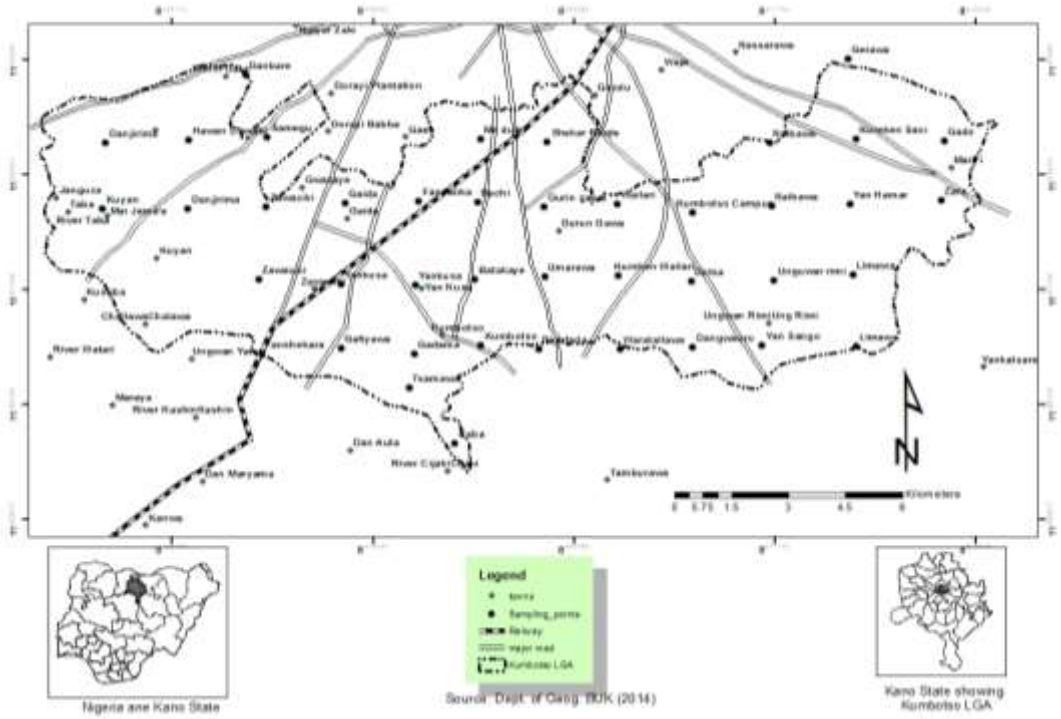

Figure 1: Study Area
Source: Department of Geography Bayero University, Kano (2022)

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MATERIALS AND METHODS

The data used for this study originates from various sources. Topographic and Geological map were gotten from Kano State Bureau for Land Management. Satellite imagery of 2021 covering the study area was downloaded from Global Land Cover Facility. The geographic coordinates of the sample shallow wells were collected from the field using a Garmin 76CSX Model GPS Receiver. Surface, Sub-surface and Hydrological investigation were carried out using Participatory Observation and Measurement with the aid of analytical and Geographical Information Systems (GIS) tools.

Table 1: Types and Sources of Data Required

Data Required	Year	Source
Topographic and Geological Map	2010	Kano State Bureau for Land Management
Level monitoring data (dry and wet season)	2022	Participatory Observation and Measurement
Coordinates of Shallow Wells	2022	Field survey (Using Garmin 76CSX Model GPS)
Satellite Imagery	2021	Global Land Cover Facility

Source: Author's Work, 2022

Grid sampling technique was adopted in this research work to obtain a good representation of the entire area. Grid interval of 2km by 2km was done with Arabic numerals 1 to 5 in the horizontal grid lines (Northing) and letters A to L in the vertical grid lines (Easting) the intersection of these two lines marked the sample point and named based on the letter against the numeric (see Figure 2). Forty-five (45) sample points were obtained with three (3) having no wells in the locations due to the geology of the area A4, B4 and B5 in Rafin Kashin, Challawa and Rinkusawa area respectively.

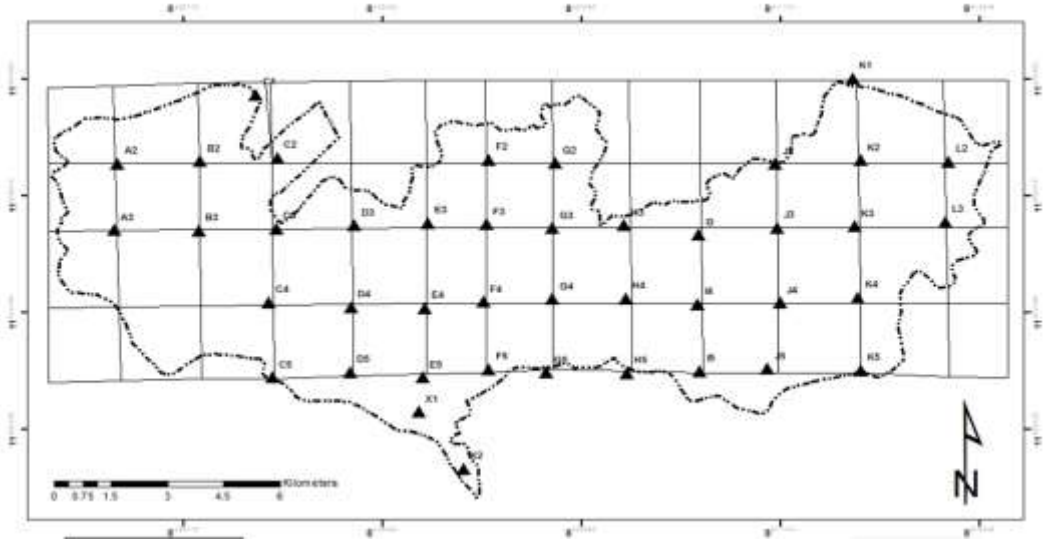

Figure 2: Sampling Frame

Source: Field Survey, 2022

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Determination of Depth (Water Level and Table)

Depth to water level was obtained using dip meter for six (6) month from April to September, April, May and June representing dry season while July, August and September representing wet season enabled mapping water table in both dry and wet season. According to Mahajan (2008) Depth to water table (equipotential) maps is derived from the elevation between the contour line of ground surface and those of water table. The study measured the water table in the dry season in the months April, May and June the averaged water levels of these three (3) months representing dry season as well as in the rainy season. Likewise, in the wet season in the months of July, August and September averaged water levels of these three (3) months representing wet season. The total hydraulic head which is the same as water table of each sampled well was obtained using the equation: $H = h + z$ where **h** is negative (water level) in meter, **z** is height above sea level in meter (Hendrckx et al, 2003).

Table 2: Locations of Sampling Points and their Elevations

S/No	Samples	Location	Geographic Coordinates	Elevations (M)
1	A2	Danjirima	11^0 56.972`N 08$^0$24.394`E	447.3
2	A3	Kuyan	11^0 55.467`N 08$^0$25.698`E	444.2
3	A4	No Well Found In This Location		
4	B2	Hawan Dawaki	11^0 57.505`N 08$^0$25.146`E	457.9
5	B3	Danjirima	11^0 56.791`N 08$^0$25.164`E	458.8
6	B4	No Well Found In This Location		
7	B5	No Well Found In This Location		
8	C1	Danbare	11^0 57.874`N 08$^0$26.480`E	463.0
9	C2	Samegu	11^0 56.624`N 08$^0$27.112`E	462.0
10	C3	Zawaciki	11^0 55.429`N 08$^0$27.400`E	460.0
11	C4	Zawaciki	11^0 54.331`N 08$^0$27.307`E	456.0
12	C5	Fanshekara	11^0 53.537`N 08$^0$27.332`E	449.5
13	D3	Gaida	11^0 56.381`N 08$^0$28.451`E	490.5
14	D4	Yankusa	11^0 54.897`N 08$^0$28.653`E	471.5
15	D5	Gafiyawa	11^0 53.863`N 08$^0$28.804`E	469.5
16	E3	Fandanka	11^0 55.593`N 08$^0$29.104`E	454.0
17	E4	Yankusa	11^0 54.636`N 08$^0$29.416`E	468.6
18	E5	Gadama	11^0 53.905`N 08$^0$29.770`E	452.6
19	F2	Me Dule	11^0 56.865`N 08$^0$30.655`E	462.0

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20	F3	Bechi	11^0 55.840`N 08$^0$30.590`E	482.0
21	F4	Batakaye	11^{0}54.844`N 08$^0$30.306`E	467.4
22	F5	Kumbotso	11^0 53.606`N 08$^0$30.234`E	458.0
23	G2	Shekar Barde	11^0 56.381`N 08$^0$31.811`E	471.0
24	G3	Guringawa	11^0 55.551`N 08$^0$31.201`E	463.0
25	G4	Umarawa	11^0 54.591`N 08$^0$31.554`E	458.0
26	G5	Rigafada	11^0 54.361`N 08$^0$31.103`E	460.0
27	H3	Wailari	11^0 55.953`N 08$^0$32.198`E	451.0
28	H4	Kureken Wailari	11^0 54.331`N 08$^0$32.415`E	455.7
29	H5	Waratallawa	11^0 53.612`N 08$^0$32.156`E	468.2
30	I3	Kumbotso Campus	11^0 55.262`N 08$^0$32.989`E	473.2
31	I4	Dotsa	11^0 54.327`N 08$^0$32.493`E	450.0
32	I5	Dangwauro	11^0 53.632`N 08$^0$32.989`E	468.2
33	J2	Naibawa	11^0 56.619`N 08$^0$32.988`E	484.8
34	J3	Naibawa	11^0 55.586`N 08033.986`E	470.0
35	J4	Unguwar Rimi	11^0 54.583`N 08$^0$34.044`E	463.0
36	J5	Yan Sango	11^0 53.077`N 08$^0$34.646`E	469.0
37	K1	Gerawa	11^0 58.077`N 08$^0$36.344`E	476.0
38	K2	Kureken Sani	11^0 56.322`N 08$^0$35.117`E	478.0
39	K3	Yan Hamar	11^0 55.266`N 08$^0$35.558`E	478.5
40	K4	Limawa	11^0 54.373`N 08$^0$36.004`E	478.9
41	K5	Limawa	11^0 53.630`N 08$^0$35.906`E	476.4
42	L2	Gado	11^0 57.196`N 08$^0$37.213`E	487.0
43	L3	Zara	11^0 55.709`N 08$^0$36.536`E	483.5
44	X1	Tsamawa	11^{0}52.677`N 08$^0$30.218`E	441.0
45	X2	Kaba	11^0 52.090`N 08$^0$29.208`E	433.8

Source: Field Survey, 2022

RESULTS AND DISCUSSIONS

The monthly and seasonal groundwater level data obtained during groundwater level monitoring exercise at all the 42 observation points that ended up with producing equipotential (areas having equal groundwater potential) maps as well as seasonal groundwater level fluctuations.

Observation Wells and Topographic Mapping

The topographic map displays contour lines that represent elevations and land surface configurations, indicating the three-dimensional terrain relationship in a

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specific area. This map presents both horizontal and vertical positions of points. The relief, which denotes the difference in elevations, is represented on the map (Punmia et al., 2005). Table 3 classifies all 42 observation wells at sampling points based on the area's topography. Figure 3 illustrates these 42 observation wells and their classifications. The highest percentage (38.10%) of wells is found in the high elevation area, followed by 30.95% in the moderately elevated area, 23.81% in the very high elevation area, and the lowest percentage (7.14%) in the low elevation area. The highest point in the region is D3 (Gaida), situated at an elevation of 490.5m. Conversely, the lowest point is X2 (Kaba), which has an elevation of 433.8m.

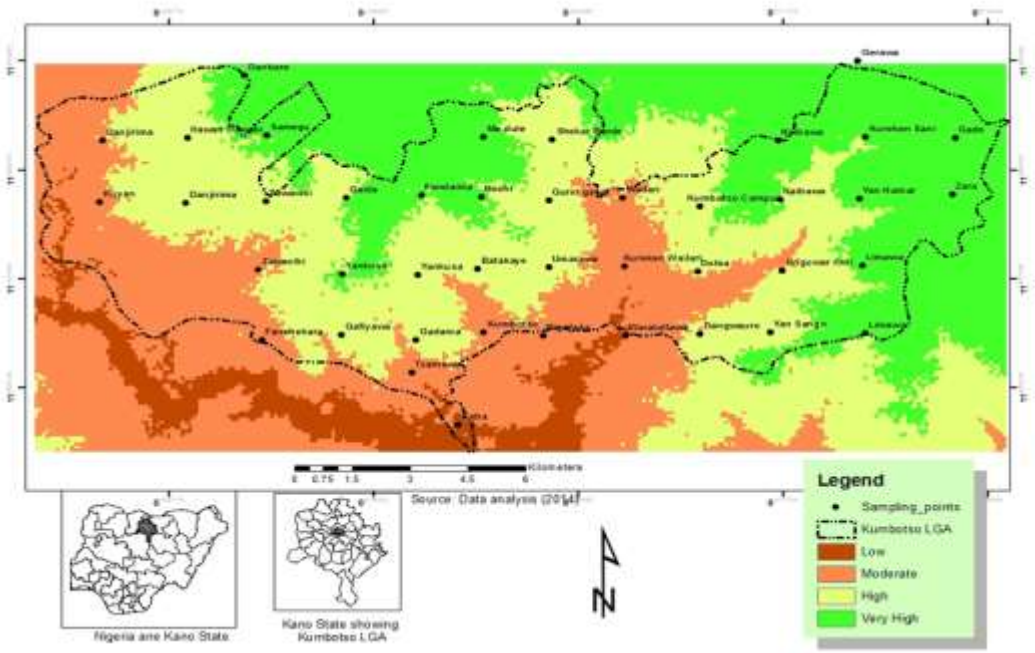

Figure 3: Observation Wells
Source: Author's Work, 2022

The area is divided into different elevation classifications. In the low elevation category, we have Kaba, Tsamawa, and Kuyan ta Inna. The first two shares a boundary with River Cijaki in the southern part of the area, while the third one shares a boundary with Watari River in the western part of the area. Moving on, the northern and eastern parts of the area are characterized by very high elevations. These areas include Gaida, Bechi, Gerawa, Gado, Kureken Sani, Yan Hamar, Zara, as well as Limawa. In the central part of the area, we find the areas with high elevations, such as Danbare, Samegu, Zawaciki, Yankusa, Umarawa,

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Medule, Batakaye, Shekar Barde Guringawa, Kumbotso Campus, Dangwauro, Naibawa, and Unguwar Rimi. Lastly, there are areas with moderately elevated terrain, namely Danjirima, Kumbotso town, and Fanshekara. These locations are situated immediately after the low-class areas in the southern part of the region.

Monthly Depth to Groundwater Level

Monthly groundwater level data is being monitored for six consecutive months, April, May, June, July, August and September. The monthly depth of groundwater level was further group into five (5) classes: very high, high, moderate, low and very low as presented in Table 3, 4, 5 and 6.

Table 3: Monthly Depth to Groundwater Level (Very High)

Water Level	Points	Locality	April	May	June	July	Aug	Sept
VERY HIGH								
1	K4	Limawa	13.3	13.8	14.1	12.2	7	8.5
2	K5	Limawa	12.6	13	13	10.9	6.9	7.2
3	L2	Gado	15	15.2	15.3	14.9	12.9	13.6
4	L3	Zara	18.5	18.5	18	17.5	14.1	15.2
	Total		**59.4**	**60.5**	**60.4**	**55.5**	**40.9**	**44.5**
	Mean		**14.9**	**15.13**	**15.1**	**13.88**	**10.23**	**11.13**
	S.D		**2.28**	**2.10**	**1.86**	**2.54**	**3.30**	**3.35**
	Cv%		**15.30**	**13.80**	**12.30**	**18.30**	**32.26**	**30.10**

Source: Author's Work, 2022

Table 4: Monthly Depth to Groundwater Level (High)

Water Level	Points	Locality	April	May	June	July	Aug	Sept
HIGH								
5	A3	Kuyan	9.5	10.1	10.3	7.8	4.7	4.8
6	B2	Hawan Dawaki	7.2	7.6	7.6	6.5	3.8	4.1
7	C2	Samegu	8.4	8.7	8.7	8	5.9	6.2
8	E3	Fandanka	9.3	9.8	9.8	6.9	2.2	3.7
9	E4	Yankusa	6.8	7	7.2	6.4	4.4	5.6
10	F2	Medule	9.4	9.8	10	8.9	6	6.6
11	J5	Yansango	9.6	10.5	10.4	8.3	4.2	5.1
12	K1	Gerawa	9.1	9.6	10	7.8	3.9	4.8

13	K3	Yan Hamar	9.2	10	10.1	8.6	5.5	6.7
14	X1	Tsamawa	7.9	8.4	8.4	7.8	4.6	5
	Total		**86.4**	**91.5**	**92.5**	**77**	**45.2**	**52.6**
	Mean		**8.64**	**9.15**	**9.25**	**7.7**	**4.52**	**5.26**
	S.D		**1.70**	**1.10**	**1.11**	**0.81**	**1.07**	**0.96**
	Cv%		**19.68**	**12.02**	**12.00**	**10.52**	**23.67**	**18.25**

Source: Author's Work, 2022

Table 5: Monthly Depth to Groundwater Level (Moderate)

Water Level	Points	Locality	April	May	June	July	Aug	Sept
MODERATE								
15	B3	Danjirima	5	5.1	5.4	4	1.9	2.2
16	C1	Danbare	4.4	4.8	5	4.1	2.2	2.5
17	D4	Yankusa	3.9	4.4	4.5	3.7	2.1	2.3
18	D5	Gafiyawa	6	6.1	6.3	5	2.6	2.8
19	E5	Gadama	5.5	5.9	6	5.5	4	4.6
20	F3	Bechi	4.8	5	5	4.2	1.9	2.5
21	G2	Shekar Barde	5.9	6	6.2	5	2.9	3.2
22	G3	Guringawa	5.1	5.6	5.6	4.1	2	2.6
23	G4	Umarawa	4.2	4.5	4.6	3.2	1.5	2.5
24	G5	Rigafada	4.5	4.4	4.7	3.5	2.1	2.7
25	H4	Kureken Wailari	4.5	4.6	4.8	3.5	2.3	3
26	I3	Kumbotso Campus	4.1	4.5	4.4	3	1.9	2.3
27	I5	Dangwauro	6	7	7.3	5.7	3	4.1
28	J4	Unguwar Rimi	5.5	6	5.9	4	1.7	2.7
29	K2	Kureken Sani	4.4	5	5.5	4	1.4	2.5
30	X2	Kaba	5.3	6.1	6.2	5.8	4	4.3
	Total		**79.1**	**85**	**87.4**	**68.3**	**37.5**	**46.8**

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	Mean	**4.94**	**5.31**	**5.46**	**4.27**	**2.34**	**2.93**
	S.D	**0.67**	**0.77**	**0.77**	**0.85**	**0.76**	**0.72**
	Cv%	**13.56**	**14.50**	**14.50**	**19.91**	**32.48**	**24.58**

Source: Author's Work, 2022

The observation wells in the area indicate varying depths to water levels, ranging from up to 18.5 m to about 2 m, depending on the location. The four points, Gaida and Naibawa being the first two, and the last two, are situated at high altitudes, but their groundwater levels differ significantly. The water levels are categorized into several categories based on their variations. The "Very high water level" category shows minimal variations, not exceeding 5m, with mean water levels of 14.90m in April, 15.13m in May, 15.10m in June, 13.88m in July, 10.23m in August, and 11.13m in September (see Table 3).
In the "High water level" category, variations do not exceed 4 m, and the mean water levels are 8.64m in April, 9.15m in May, 9.25m in June, 7.7m in July, 4.52m in August, and 5.26m in September (see Table 4). For the "Moderate water level" category, variations in water level hardly exceed 3.5 m, with mean water levels of 4.94m in April, 5.31m in May, 5.46m in June, 4.27m in July, 2.34m in August, and 2.93m in September (see Table 5). The "Low water level" category experiences variations not exceeding 3 m, with mean water levels of 14.94m in April, 5.31m in May, 5.46m in June, 4.27m in July, 2.34m in August, and 2.93m in September (see Table 6).

Table 6: Monthly Depth to Groundwater Level (Low and Very Low)

Water Level	Points	Locality	April	May	June	July	Aug	Sept
LOW								
31	A2	Danjirima	3.1	3.3	3.4	2.4	1	1.6
32	C3	Zawaciki	3.9	4.1	4.2	3	0.9	1.8
33	C4	Zawaciki	3	3.3	3.4	2.1	0.6	1.1
34	C5	Fanshekara	2.6	2.5	2.7	1.5	0.5	0.6
35	D3	Gaida	4	4.1	4	3.4	1.8	2.1
36	F4	Batakaye	2.1	2.5	2.5	1.9	0.8	1.2
37	F5	Kumbotso	3.2	3.2	3.4	2.8	1.1	1.7
38	H3	Wailari	3.3	3.2	3.4	2.6	1	2.1
	H5	Waratallawa	3.7	3.6	3.7	3.5	1.5	2.1
39	I4	Dotsa	2	2.4	2.5	1.4	0.4	0.9
40	J3	Naibawa	4	4	4.1	2.9	0.9	1.6

	Total		**34.9**	**36.2**	**37.3**	**27.5**	**10.5**	**16.8**
	Mean		**3.17**	**3.29**	**3.39**	**2.50**	**0.96**	**1.53**
	S.D		**1.17**	**0.60**	**0.58**	**0.68**	**0.38**	**0.49**
	Cv%		**37.02**	**18.20**	**17.03**	**27.10**	**40.10**	**32.08**
VERY LOW								
41	J2	Naibawa	1.9	2.2	2.2	1.4	0.4	0.5

Source: Author's Work, 2022

Only one point, Naibawa (J2), falls under the "Very low water level" category, with variations in water level and mean water levels of 1.90m in April, 2.20m in May, 2.20m in June, 1.40m in July, 0.40m in August, and 1.5m in September (see Table 6).

Seasonal Depth to Groundwater Level

Seasonal groundwater level data is being monitored for six consecutive months, April, May, June, July, August and September. The seasonal depth of groundwater level was further group into five (5) classes: very high, high, moderate, low and very low as presented in Table 7, 8, 9 and 10. First three months representing dry season while the other three representing wet season.

Table 7: Seasonal Groundwater Level (Very High)

Water Level	Points	Locality	Dry Season Mean	Wet Season Mean
VERY HIGH				
1	K4	Limawa	13.7	9.2
2	K5	Limawa	12.9	8.3
3	L2	Gado	15.2	13.8
4	L3	Zara	18.3	15.6
Total			**60.1**	**46.9**
Mean			**15.03**	**11.73**
S.D			**2.06**	**3.06**
Cv			**13.73**	**26.07**

Source: Author's Work, 2022

Table 8: Seasonal Groundwater Level (High)

Water Level	Points	Locality	Dry Season Mean	Wet Season Mean
HIGH				
5	A3	Kuyan	10	5.8
6	B2	Hawan Dawaki	7.5	4.8
7	C2	Samegu	8.6	6.7

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8	E3	Fandanka	9.6	4.3
9	E4	Yankusa	7	5.4
10	F2	Medule	9.7	7.2
11	J5	Yansango	10.2	5.9
12	K1	Gerawa	9.6	5.5
13	K3	Yan Hamar	9.8	6.9
14	X1	Tsamawa	8.2	5.8
Total			**90.2**	**58.3**
Mean			**9.02**	**5.83**
S.D			**0.93**	**0.86**
Cv%			**10.33**	**14.82**

Source: Author's Work, 2022

Table 9: Seasonal Groundwater Level (Moderate)

Water Level	Points	Locality	Dry Season Mean	Wet Season Mean
MODERATE				
15	B3	Danjirima	5.2	2.7
16	C1	Danbare	4.7	2.9
17	D3	Gaida	4	2.4
18	D4	Yankusa	4.3	2.7
19	D5	Gafiyawa	6.1	3.5
20	E5	Gadama	5.8	4.7
21	F3	Bechi	4.9	2.9
22	G2	Shekar Barde	6	3
23	G3	Guringawa	5.4	2.9
24	G4	Umarawa	4.4	2.4
25	G5	Rigafada	4.5	2.8
26	H4	Kureken Wailari	4.6	2.9
27	I3	Kumbotso Campus	4.3	2.4
28	I5	Dangwauro	7	4.3
29	J4	Unguwar Rimi	5.8	2.8
30	K2	Kureken Sani	5	2.6
31	X2	Kaba	5.9	4.7
Total			**87.9**	**52.6**
Mean			**5.17**	**3.09**
S.D			**0.80**	**0.43**
Cv%			**15.69**	**13.87**

Source: Author's Work, 2022

Table 10: Seasonal Groundwater Level (Low and Very Low)

Water Level	Points	Locality	Dry Season Mean	Wet Season Mean
LOW				
32	A2	Danjirima	3.3	1.7
33	C3	Zawaciki	4.1	1.9
34	C4	Zawaciki	3.2	1.3
35	C5	Fanshekara	2.6	0.9
36	F4	Batakaye	2.4	1.3
37	F5	Kumbotso	3.3	1.9
38	H3	Wailari	3.3	1.9
39	H5	Waratallawa	3.7	2.2
40	I4	Dotsa	2.3	0.9
41	J3	Naibawa	4	1.8
		Total	**32.2**	**15.8**
		Mean	**3.22**	**1.58**
		S.D	**0.59**	**0.43**
		Cv%	**18.44**	**26.88**
VERY LOW				
42	J2	Naibawa	2	0.8

Source: Author's Work, 2022

Based on Tables, the seasonal water levels were categorized as follows: Very high water level category: In this category, the areas experience seasonal variations in water level that hardly exceed 4 meters. The mean water level is 15.03 meters in the dry season and 11.73 meters in the wet season (Table 7). High water level category: The areas falling under this category have seasonal variations in water level that hardly exceed 3 meters. The mean seasonal water level is 9.02 meters in the dry season and 5.83 meters in the wet season (Table 8). Moderate water level category: In this class, the seasonal variations in water level hardly exceed 2 meters. The mean seasonal water level is 5.17 meters in the dry season and 3.09 meters in the wet season (Table 9). Low water level category: The seasonal variations in water level in this class hardly exceed 1.5 meters. The mean water level is 3.22 meters in the dry season and 1.58 meters in the wet season (see Table 9). Very low water level category: Only one point falls under this category (J2) in Naibawa. The mean seasonal water level is 2.0 meters in the dry season and 0.80 meters in the wet season (see Table 10).

GROUNDWATER TABLE MAPPING

Water table maps are prepared by plotting the water levels of all observation points on topographic map and connecting points of equal water table elevations (water table contour lines or equipotential lines).

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Dry Season Groundwater Table Mapping

The dry season water table mapping combined the groundwater level data of April, May and June. The dry season groundwater elevation data were classified with high and moderate groundwater elevations having the highest percentage of 30.96% each, followed by very high classification with 28.57%, very low groundwater elevation percentage with of the percentage of 7.14%, the class identified as low groundwater elevations has the least percentage of 2.38%. as shown in Figure 4.

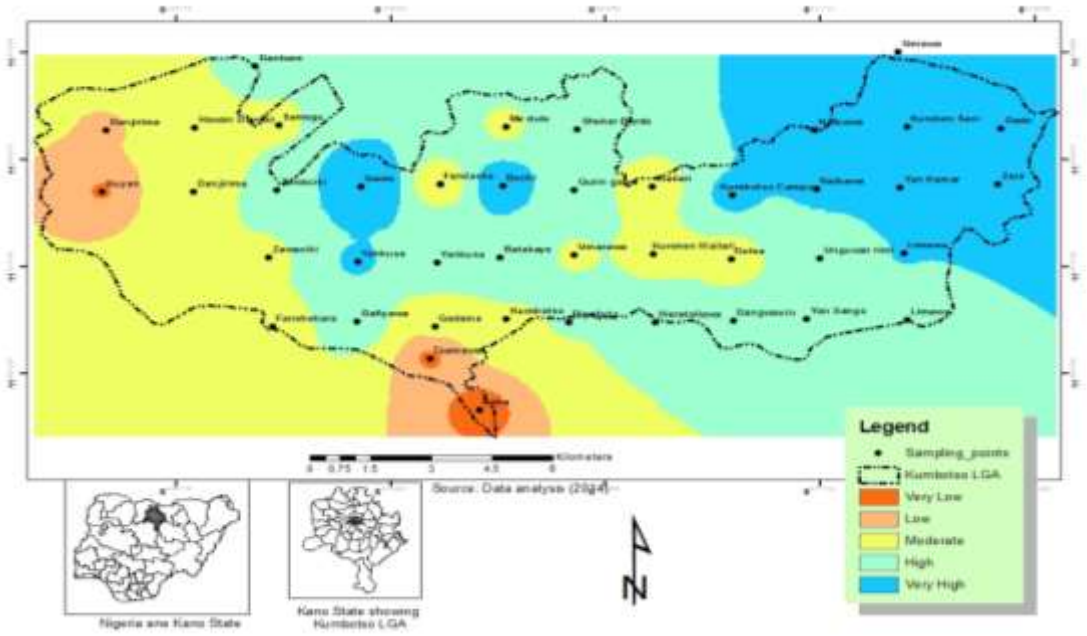

Figure 4: Dry Season Water Table of Kumbotso Local Government Area
Source: Author's Work, 2022

The water table is very high in the south-eastern part of the area comprises of Gerawa, Naibawa, Kureken Sani, Gado, Kumbotso Campus, Yan Hamar, Zara and Limawa Kaushi, it is also very high at Gaida, Bechi, and Yankusa in the central part of Kumbotso. While the high dominated water table is around the south-eastern part of the area which comprises of Limawa Madabo, Yansango, Dangwauro, Waratallawa, and Rigafada, but it is also high at Gafiyawa Yankusa gidan gona, Batakaye, Zawaciki Housing Estate and Guringawa in the central Kumbotso, Danbare and Shekar Barde in the Northern part of the area.

Wet Season Groundwater Table Mapping

The wet season water table mapping combined the groundwater level data of July, August and September. The wet season groundwater elevation data were

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classified with very high groundwater elevations having the highest percentage of 40.48% followed by high groundwater elevation class with the percentage of 28.57%, the class identified as moderate groundwater elevations has the percentage of 23.81%, the low class has the percentage 4.76% and very low classification with the least percentage of 2.38% as presented Figure 5.

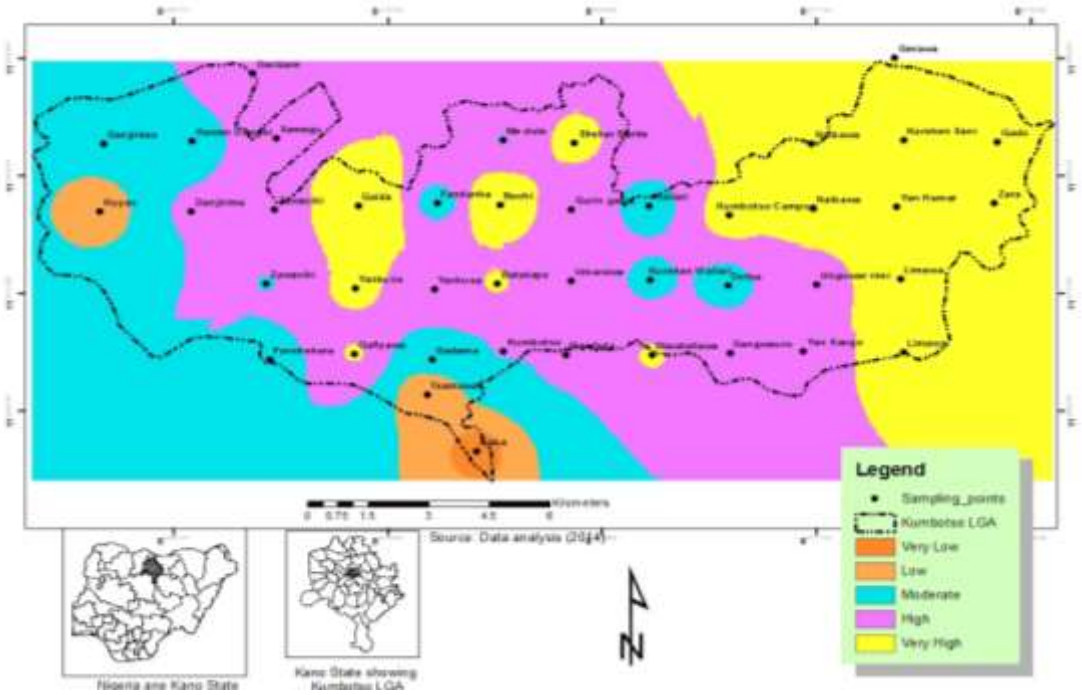

Figure 5: Wet Season Water Table of Kumbotso Local Government Area
Source: Author's Work, 2022

Groundwater Table Fluctuations

Groundwater fluctuations tend to follow a fairly seasonal pattern. For example, high water levels occur during the wet months and low water levels occur during dry months. It is apparent that the seasonal variations of water levels largely reflect the general climate balance between rainfall and evaporation. Seasonal fluctuations, reflecting as they do seasonal change storage are normally of considerable interest to the hydrologist, in the sense they represent large scale contrast in water availability as presented in Table 11.

Table 11: Seasonal Groundwater Fluctuations

S/No	Points	Location	Seasonal Fluctuation (M)
1	A2	Danjirima	2.6
2	A3	Kuyan	4.2
3	B2	Hawan Dawaki	2.7

4	B3	Danjirima	2.5
5	C1	Danbare	1.8
6	C2	Samegu	1.9
7	C3	Zawaciki	2.2
8	C4	Zawaciki	1.9
9	C5	Fanshekara	1.7
10	D3	Gaida	1.5
11	D4	Yankusa	1.6
12	D5	Gafiyawa	2.6
13	E3	Fandanka	5.3
14	E4	Yankusa	1.5
15	E5	Gadama	1.1
16	F2	Medule	2.5
17	F3	Bechi	2.0
18	F4	Batakaye	1.1
19	F5	Kumbotso	0.4
20	G2	Shekar Barde	3.0
21	G3	Guringawa	2.4
22	G4	Umarawa	2.0
23	G5	Rigafada	1.7
24	H3	Wailari	1.4
25	H4	Kureken Wailari	1.7
26	H5	Waratallawa	1.5
27	I3	Kumbotso Campus	1.9
28	I4	Dotsa	1.4
29	I5	Dangwauro	2.8
30	J2	Naibawa	1.2
31	J3	Naibawa	2.2
32	J4	Unguwar Rimi	3.0
33	J5	Yansango	4.3
34	K1	Gerawa	4.1
35	K2	Kureken Sani	2.4
36	K3	Yan Hamar	2.9
37	K4	Limawa	4.8
38	K5	Limawa	4.6
39	L2	Gado	1.4
040	L3	Zara	2.7
41	X1	Tsamawa	2.4
42	X2	Kaba	1.2

Source: Author's Work, 2022

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Table 11 summarizes the seasonal fluctuations of all the 42 observation points with the mean seasonal fluctuation of 2.3m, standard deviation of 1.1m and coefficient of variability of 48%. The groundwater table fluctuations in the area from 1.5m to 2.5m are classified as medium class with the highest percentage of 40.9% while areas with the fluctuations values above 2.5m are classified as high having 33.3% and then the areas with fluctuations less than 1.5m are classified as low have 26.2%.

CONCLUSION AND RECOMMENDATION

Groundwater resources play a crucial role in supporting the livelihood of the area's inhabitants, serving domestic, commercial, and agricultural needs. Despite the area experiencing significant population growth, industrial development, and urban expansion, it still exhibits promising groundwater potential throughout both dry and rainy seasons. Even during the dry months, the water table remains moderately high. The water levels in the area show distinct seasonal variations, with very high seasonal variations not exceeding 4 meters. During the dry season, the mean water level is 15.03 meters, while in the rainy season, it is 11.73 meters. Similarly, the areas falling under the high, moderate, and low categories also display comparable patterns of seasonal water level variations. The findings of this study have shown the ability of combining GIS, Remote Sensing and Geotechnical techniques in assessing and analyzing groundwater potentials for decision making and groundwater resources management. In this light the following recommendations are made;

i. Diverse geological formations require different type of wells for tapping groundwater. The design procedure for open shallow wells in basement rocks is quite different to that of hard rock terrain and sedimentary formations.
ii. In case of hard rock terrains, open wells are recommended. Open well can tap the weathered zone better than boreholes and are cheaper for shallow depth. A large rectangular open well is preferable to the traditional circular wells. Larger cross sectional area has greater chances of cutting across fracture zones and thereby increasing recharge into the well this provides provision for the storage of large amount of water. The longer side of the rectangular well should be normal to the direction of the fracture system to ensure better yield.
iii. Open dug wells in granitic area should touch the basement rock this is because the top of the basement rock is more fruitful zone than the

remaining part of the weathered zone. It is advisable to tap granites for groundwater.

iv. In case of sedimentary formation open well should penetrate the entire thickness of the aquifer.

v. There is a need to conduct a geophysical survey before establishing a well point especially in areas with hard rock formations.

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Appendix: Groundwater Level Monitoring Data (Monthly and Seasonal) Water Table

S/No	Point	Dry Season Water Level (M)			Wet Season Water Level (M)			Dry Season Mean (M)	Wet Season Mean (M)	Hasl (M)	Dry Season Water Table (M)	Wet Season Water Table (M)
		APR	MAY	JUN	JUL	AUG	SEP					
1	A2	3.1	3.3	3.4	2.4	1.0	1.6	3.3	3.3	447.3	444.0	445.6
2	A3	9.5	10.1	10.3	7.8	4.7	4.8	10.0	10.0	444.2	434.2	438.4
3	B2	7.2	7.6	7.6	6.5	3.8	4.1	7.5	7.5	457.9	450.4	453.1
4	B3	5.0	5.1	5.4	4.0	1.9	2.2	5.2	5.2	458.8	453.6	456.1

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5	C1	4.4	4.8	5.0	4.1	2.2	2.5	4.7	4.7	463.0	458.3	460.1
6	C2	8.4	8.7	8.7	8.0	5.9	6.2	8.6	8.6	462.0	453.4	455.3
7	C3	3.9	4.1	4.2	3.0	0.9	1.8	4.1	4.1	460.0	455.9	458.1
8	C4	3.0	3.3	3.4	2.1	0.6	1.1	3.2	3.2	456.0	452.8	454.7
9	C5	2.6	2.5	2.7	1.5	0.5	0.6	2.6	2.6	449.5	446.9	448.6
10	D3	4.0	4.1	4.0	3.4	1.8	2.1	4.0	4.0	490.5	486.5	488.0
11	D4	3.9	4.4	4.5	3.7	2.1	2.3	4.3	4.3	471.5	467.2	468.8
12	D5	6.0	6.1	6.3	5.0	2.6	2.8	6.1	6.1	469.5	463.4	466.0
13	E3	9.3	9.8	9.8	6.9	2.2	3.7	9.6	9.6	454.0	444.4	449.7
14	E4	6.8	7.0	7.2	6.4	4.4	5.6	7.0	7.0	468.6	461.6	463.1
15	E5	5.5	5.9	6.0	5.5	4.0	4.6	5.8	5.8	452.6	446.8	447.9
16	F2	9.4	9.8	10.0	8.9	6.0	6.6	9.7	9.7	462.0	452.3	454.8
17	F3	4.8	5.0	5.0	4.2	1.9	2.5	4.9	4.9	482.0	477.1	479.1
18	F4	2.1	2.5	2.5	1.9	0.8	1.2	2.4	2.4	467.4	465.0	466.1
19	F5	3.2	3.2	3.4	2.8	1.1	1.7	3.3	3.3	458.0	454.7	455.1
20	G2	5.9	6.0	6.2	5.0	2.9	3.2	6.0	6.0	471.0	465.0	468.0
21	G3	5.1	5.6	5.6	4.1	2.0	2.6	5.4	5.4	463.0	457.6	460.0
22	G4	4.2	4.5	4.6	3.2	1.5	2.5	4.4	4.4	458.0	453.6	455.6
23	G5	4.5	4.4	4.7	3.5	2.1	2.7	4.5	4.5	460.0	455.5	457.2
24	H3	3.3	3.2	3.4	2.6	1.0	2.1	3.3	3.3	451.0	447.7	449.1
25	H4	4.5	4.6	4.8	3.5	2.3	3.0	4.6	4.6	455.7	451.1	452.8
26	H5	3.7	3.6	3.7	3.1	1.5	2.1	3.7	3.7	468.2	464.5	466.0
27	I3	4.1	4.5	4.4	3.0	1.9	2.3	4.3	4.3	473.2	468.9	470.8
28	I4	2.0	2.4	2.5	1.4	0.4	0.9	2.3	2.3	450.0	447.7	449.1
29	I5	6.0	7.0	7.3	5.7	3.0	4.1	7.0	7.0	468.2	461.2	464.0
30	J2	1.9	2.2	2.2	1.4	0.4	0.5	2.0	2.0	484.8	482.8	484.0
31	J3	4.0	4.0	4.1	2.9	0.9	1.6	4.0	4.0	470.0	466.0	468.2
32	J4	5.5	6.0	5.9	4.0	1.7	2.7	5.8	5.8	463.0	457.2	460.2
33	J5	9.6	10.5	10.4	8.3	4.2	5.1	10.2	10.2	469.0	458.8	463.1
34	K1	9.1	9.6	10.0	7.8	3.9	4.8	9.6	9.6	476.0	466.4	470.5
35	K2	4.4	5.0	5.5	4.0	1.4	2.5	5.0	5.0	478.0	473.0	475.4
36	K3	9.2	10.0	10.1	8.6	5.5	6.7	9.8	9.8	478.5	468.7	471.6
37	K4	13.3	13.8	14.1	12.2	7.0	8.5	13.7	13.7	478.9	465.2	470.0
38	K5	12.6	13.0	13.0	10.9	6.9	7.2	12.9	12.9	476.4	463.5	468.1
39	L2	15.0	15.2	15.3	14.9	12.9	13.6	15.2	15.2	487.0	471.8	473.2
40	L3	18.5	18.5	18.0	17.5	14.1	15.2	18.3	18.3	483.5	465.2	467.9
41	X1	7.9	8.4	8.4	7.8	4.6	5.0	8.2	8.2	441.0	432.8	435.2
42	X2	5.3	6.1	6.2	5.8	4.0	4.3	5.9	5.9	433.8	427.9	429.1

Source: Field Survey 2021

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