Nigerian Journal of Water Resources
2021, 7(1): 1-10
Print ISSN: 115-9944
Online ISSN: 2795-3793

HYDROGEOLOGICAL ASSSESSMENT AT PANDA, A PROPOSED DAM SITE - NORTHCENTRAL NIGERIA

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ABSTRACT
An attempt to determine the quality and quantity of groundwater for domestic and agricultural purpose in a proposed dam site was undertaken. The area is underlain by the Precambrian Basement Complex Crystalline rocks which include; schist, Migmatite and granite. All the hand dug wells in the area are shallow therefore tap water from soft overburden aquifer. Physical parameters of groundwater were measured in-situ. These are pH ranging from 4.14 to 6.38 with an average of 4.97; EC ranging from 24 to 242 µS/cm with an average of 88 µS/cm; temperature ranging from 26 to 29 °C with an average of 27°C; and TDS ranging from 12 to 125 mg/l with an average of 44 mg/l. Based on mineralization (TDS), water in the area is fresh water (mineralization < 1000 mg/l). Based on the conductivity, the water is excellent for irrigation (conductivity < 250 µS/cm). Static water level in the area ranges from 0.2 m at Okkon and 6.7 m at Kogin Taru-Koro with an average of 3.45 m during the rainy season; and 2.4 m at Okkon and 7.8 m at Kogin Taru- Koro with an average of 5.1 m during dry season respectively. The total static water resources of the drainage basin of the proposed Dam site are 57 x 10^6 m^3, while that of the study area is 17 x 10^6 m^3. The total dynamic water resources of the proposed Dam site is 76 x 10^6 m^3/a, while that of the study area is 8,418,000 m^3/a, which is sufficient for domestic and agricultural purpose in the area.

KEYWORDS: *Hydrogeological, groundwater, dam, water resources*

INTRODUCTION

Hydrogeological assessment of an area around a proposed dam site at the Panda Agro Novum Limited, located along Gitata - Panda Road was undertaken. Hydrogeological Investigation included water level measurement in hand dug wells, Lithological mapping of the exposed outcrops, In-situ measurement of physical parameters of water from hand dug wells, and Stream water monitory/ observation within the area. The proposed dam is going to be used for domestic and irrigation purposes.

The face of irrigated agriculture is changing with respect to water quantity and quality. In the distant past, irrigators and agricultural crop advisors did not give much attention to either the supply or the quality of irrigation water. Provisions of good quality water, well-matched to crop irrigation, were plentiful, generally uncontested, and not necessarily closely monitored or regulated. However, there is growing competition for accountability of the use of water which has contributed to increasing scrutiny about how water is used, how much

water is available to the public for domestic uses, and what practices impact the quality of the water resources.

The assessment was completed to provide a general characterization of the hydrogeological settings and guidance to the engineering storm water management for the proposed dam.

SITE CHARACTERIZATION

Climate, Topography, Vegetation and Land Use

The area lies within the Northern Guinea Savannah zone (Ariyo, 1993) and has tropical climate with moderate rainfall (mean annual rainfall of about 1,403 mm/a, -Nigerian Meteorological Agency, Lafia 2012). The rainfall starts in March and lasts till October while dry season starts from November and lasts till February. The raining season on average lasts for 215 days while the dry season lasts for 150 days. The area is made up of undulating land measuring up to 400 m above sea level at some points (Federal Survey Agency, 2008). The vegetation type is an open forest and affected in most places by human activities which reduced the vegetation to tree savannah (mostly economic trees) where clusters of trees stand amongst grass and shrubs.

The area also consists of cropped farm land and grassed or cropped farm and which includes farm residence and barn, and some villages with associated landscaping features as well as Panda Agro Novum Complex. The area is bounded by Panda River to the west, Kuda River to the southeast, and several rural residential areas directly to the northern and to the southern parts of the area (Figure 1).

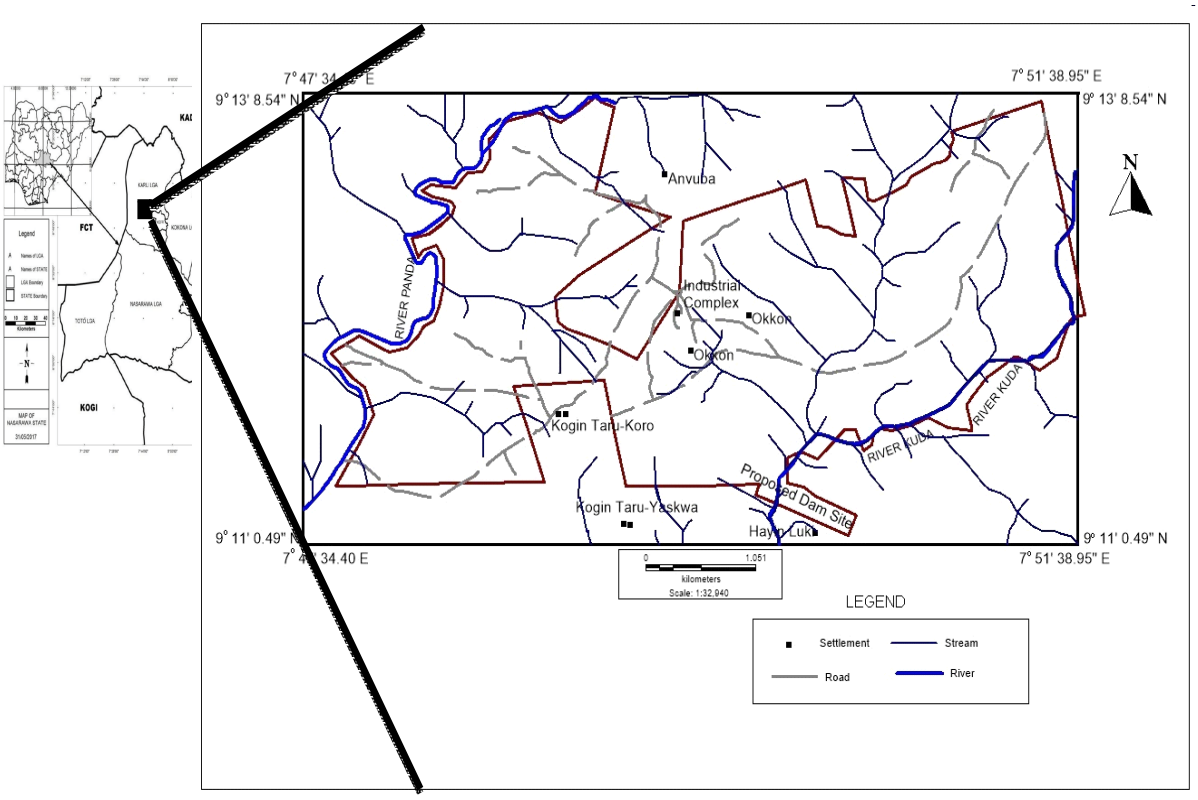


Figure 1: Location of the study area showing area of the proposed Dam site

MATERIALS AND METHODS

The methods followed were hydrogeological which included measurement of depth to water table in hand-dug wells, and mapping the exposed outcrops within the Study area. The hydrogeological mapping involved repeated measurements of depth of water levels in hand-dug wells with the help of a measuring tape. Global Positioning System was used to take coordinates and exact elevations of wells in metres above sea level. Physical parameters of the water from hand dug wells were also taken. Past works on the area were consulted, compiled and made use of both in reference and research. Field work was done at the peat of both rainy and dry seasons of 2018. Data on water levels of 15 hand dug wells were taken. This was done simultaneously with identification of rocks within the area. The values obtained were used to draw water table configuration maps of both the dry season and rainy season by subtracting the water level measured in a well from the elevation of that same well. Geological map of the study area was also produced. Spatial distributions of the physical parameters of water from hand dug wells were also plotted.

GEOLOGIC SETTING

The area is part of the Precambrian Basement Complex of North Central Nigeria. The Rock types mapped in the area include schist, granite, and Migmatite (Figure 2). Granite in the area is mostly fine to medium grained granite and occupied southeastern part of the area. Its essential minerals which can be identified with the naked eyes are quartz, feldspars, biotite and muscovite. Granite forms by the cooling magma below the earth surface and is the commonest rock type of the continents.

Schist of the study area has minerals that are easily seen by eyes and the mineral grains have highly oriented fabric. They have platy mineral grains (e. g. amphiboles and micas) and they tend to lie with their long directions parallel. The schist is rich in mica and show pronounced mineralogical layering; quartz layers a few millimeters or centimeters in thickness lie between mica layers. The schist occupied southwestern part of the area, while the predominant area is underlain by migmatite (Figure 2).

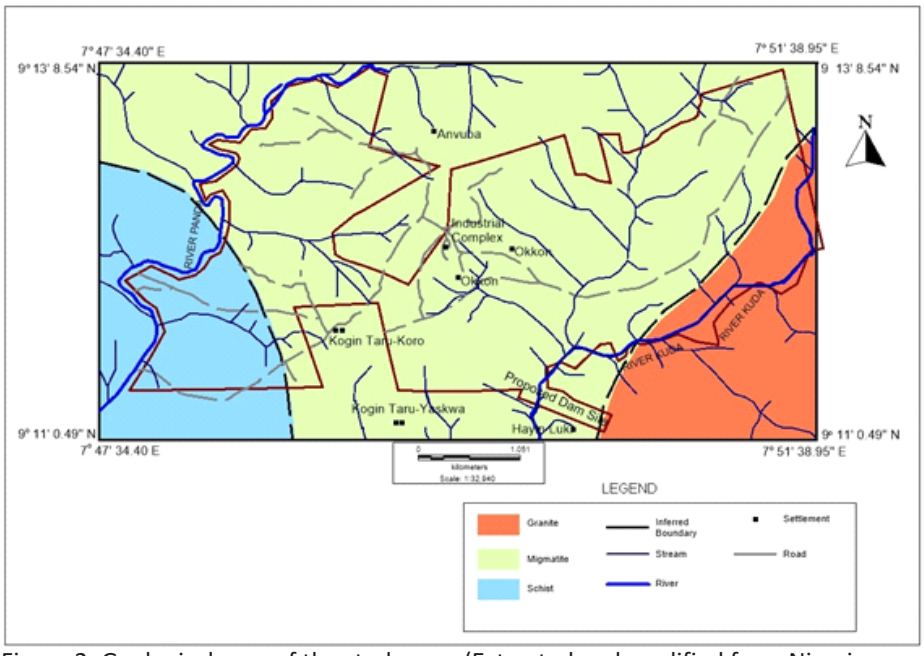


Figure 2: Geological map of the study area (Extracted and modified from Nigerian Geological Survey Agency, 2006

HYDROGEOLOGICAL SETTING

Depth of Rainfall in the Study Area

Mean annual depth of rainfall in the area is 1,403 mm/a (Nigerian Meteorological Agency, Lafia 2012). The volume of rainfall within the study area has been calculated as follows: area of the entire map including the property site as calculated from Global Mapper, 30 km^2 = 30 x 10^6 m^2. The volume of rainfall in the study area is 1.403 m/a x 30 x 10^6 m^2 = 42.09 x 10^6 m^3/a.

Groundwater in the Study Area

The lithosphere consists of water in soil and rocks under the soil. On a large scale, it is the largest reservoir of fresh water available for human consumption, although exact measurements of its volume are elusive. The estimates of groundwater volume (water in the saturated zone) range from 8 million km^3 to 10 million km^3 (Shiklomanov, 1993). The parameters that described any given well include location, total depth, diameter and static water level. Static water level in the area ranges from 0.2 m at Okkon and 6.7 m at Kogin Taru-Koro with an average of 3.45 m during the rainy season; and 2.4 m at Okkon and 7.8 m at Kogin Taru- Koro with an average of 5.1 m during dry season (Tables 1, 2, 3).

Groundwater in the study area occurs in the soft overburden aquifer and fractured bedrock aquifer. Hand dug wells within the study area are shallow; therefore, they tap water only from soft overburden aquifer. The thickness of soft overburden aquifer in most parts of the Basement Complex of Nasarawa State ranges between 10 m and 30 m (Kana, 2014).

Water Table Configuration Map and Directions of Groundwater Flow

All the fifteen (15) hand dug wells in the area are shallow, the deepest being 8.0 m. The average depth to water level at the rainy season was 3.45 m, and that of dry season was estimated to be 5.1 m (Table 3). Depth to water level measured in the field were used for the construction of water table map. The groundwater that results from recharge flows laterally towards streams and river channels; this is indicated by arrows drawn perpendicular to equipotential lines and tends to diverge from the recharge areas (watershed) and converge towards the drainage channels (Figures 3 and 4).

Movement of water is strongly influenced by topography of the area; recharge is mainly by percolating rainwater and in some places by seepages from adjacent surface water. Recharge areas consists of decomposed (soft overburden aquifer) and fractured rocks in which pressure heads quickly spread through local water-bearing fissures and interconnected voids, thereby leading to abrupt rise in discharges in response to precipitation (Idowu *et al.,* 1999). Groundwater flow directions are dictated by surface topography. This may be a reflection of varying degrees of weathering at different groundwater fronts and the occurrence of the fresh basement at different depths at different locations.

Table 1: Data of groundwater table at rainy season in the area. The last two columns were used for construction of map

S/N	Location	Coordinates	Depth to Water Table (mbgs)	Well Elevation (mawt)	Water Table Elevation (mawt)
1	Okko	1017160 N, 0371778 E	4.2	393	388.8
2	Okko	1016848 N, 0371192 E	2.4	394	391.6
3	Okko	1016930 N, 0371244 E	2.0	391	389.0
4	Okko	1016918 N, 0371173 E	3.0	395	392.0
5	Anvuba	1018501 N, 0370851 E	1.0	398	397.0
6	Kogin Taru-Koro	1016499 N, 0369945 E	3.6	395	391.4
7	Kogin Taru-Koro	1016566 N, 0369936 E	1.7	396	394.3
8	Kogin Taru-Koro	1016473 N, 0370056 E	6.3	399	392.7
9	Kogin Taru-Koro	1016352 N, 0369911 E	6.7	399	392.3
10	Kogin Taru-Koro	1016328 N, 0369952 E	5.7	399	393.3
11	Kogin Taru-Koro	1016572 N, 0369721 E	2.8	395	392.2
12	Kogin Taru-Yaskwa	1015403 N, 0370408 E	2.6	390	387.4
13	Kogin Taru-Yaskwa	1015338 N, 0370516 E	2.6	389	386.4
14	Kogin Taru-Yaskwa	1015437 N, 0370527 E	2.5	394	391.5
15	Hayin Luki	1015338 N, 0372325 E	0.2	376	375.8

Table 2: Data of groundwater table at dry season in the area. The last two columns were used for construction of map

S/N	Location	Coordinates	Depth to Water Table (mbgs)	Well Elevation (mawt)	Water Table Elevation (mawt)
1	Okko	1017160 N, 0371778 E	7.4	393	385.6
2	Okko	1016848 N, 0371192 E	4.0	394	390.0
3	Okko	1016930 N, 0371244 E	4.1	391	386.9
4	Okko	1016918 N, 0371173 E	4.4	395	390.6
5	Anvuba	1018501 N, 0370851 E	4.8	398	393.2
6	Kogin Taru-Koro	1016499 N, 0369945 E	5.2	395	389.8
7	Kogin Taru-Koro	1016566 N, 0369936 E	5.0	396	391.0
8	Kogin Taru-Koro	1016473 N, 0370056 E	7.2	399	391.8
9	Kogin Taru-Koro	1016352 N, 0369911 E	7.8	399	391.2
10	Kogin Taru-Koro	1016328 N, 0369952 E	6.8	399	392.2
11	Kogin Taru-Koro	1016572 N, 0369721 E	6.0	395	389.0
12	Kogin Taru-Yaskwa	1015403 N, 0370408 E	5.5	390	384.5
13	Kogin Taru-Yaskwa	1015338 N, 0370516 E	5.8	389	383.2
14	Kogin Taru-Yaskwa	1015437 N, 0370527 E	6.5	394	387.5
15	Hayin Luki	1015338 N, 0372325 E	2.4	376	373.6

Table 3: Parameters measured in-situ during field work in the study area

S/N	Location	Coordinates	Elevation (m)	Depth of Wells (mbgs)	pH	Conductivity	Temperature (°C)	TDS (mg/l)
1	Okko	1017160 N, 0371778 E	393	8.0	6.38	242	27	125
2	Okko	1016848 N, 0371192 E	394	4.5	5.50	70	26	35
3	Okko	1016930 N, 0371244 E	391	4.2	5.25	81	27	39
4	Okko	1016918 N, 0371173 E	395	5.0	4.55	31	28	16
5	Anvuba	1018501 N, 0370851 E	398	5.8	4.38	27	29	15
6	Kogin Taru-Koro	1016499 N, 0369945 E	395	6.0	5.40	181	29	91
7	Kogin Taru-Koro	1016566 N, 0369936 E	396	5.5	4.64	24	28	12
8	Kogin Taru-Koro	1016473 N, 0370056 E	399	7.4	5.50	61	29	32
9	Kogin Taru-Koro	1016352 N, 0369911 E	399	8.4	4.55	54	28	27
10	Kogin Taru-Koro	1016328 N, 0369952 E	399	7.5	4.14	44	28	22
11	Kogin Taru-Koro	1016572 N, 0369721 E	395	6.6	4.75	116	27	57
12	Kogin Taru-Yaskwa	1015403 N, 0370408 E	390	6.4	4.74	84	27	41
13	Kogin Taru-Yaskwa	1015338 N, 0370516 E	389	6.2	4.50	72	27	36
14	Kogin Taru-Yaskwa	1015437 N, 0370527 E	394	7.5	4.62	77	27	38
15	Hayin Luki	1015338 N, 0372325 E	376	2.9	5.65	157	27	78

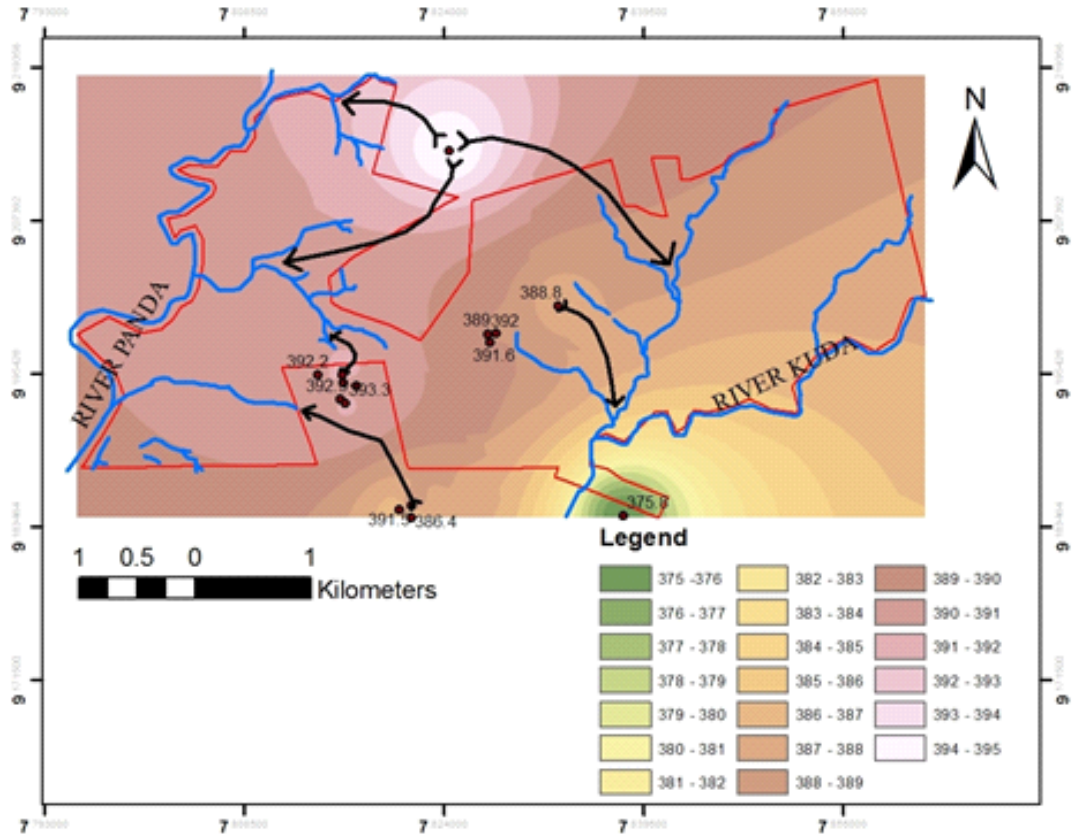


Figure 3: Map of configuration of groundwater table during rainy season

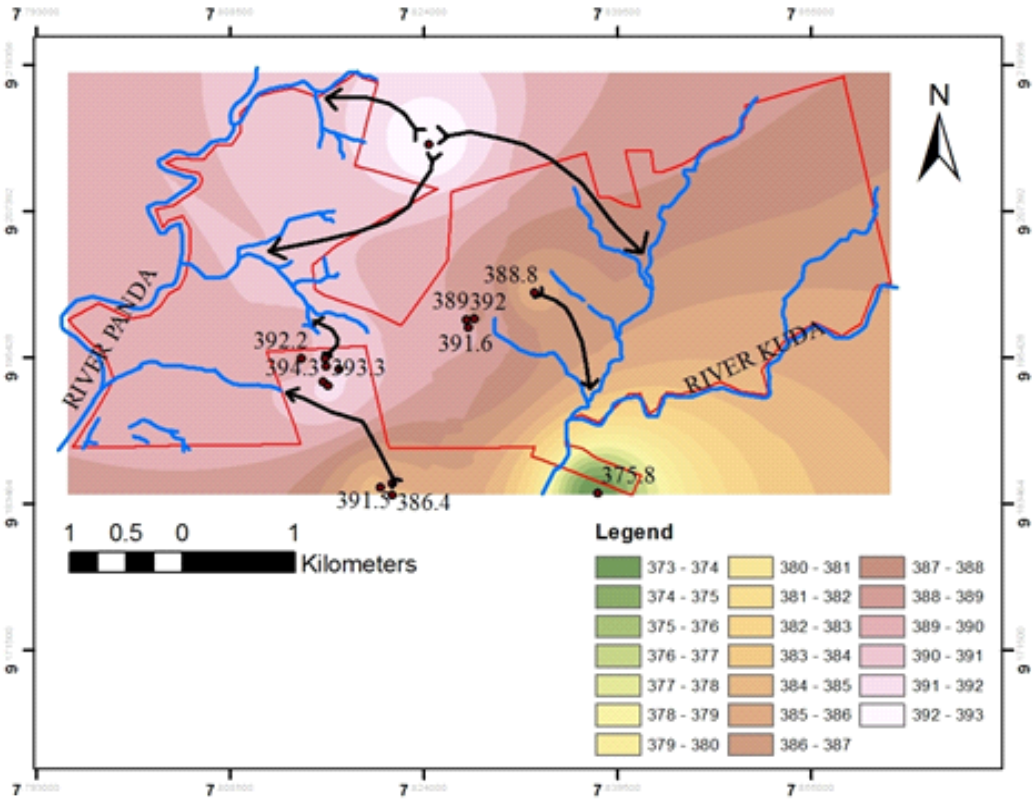
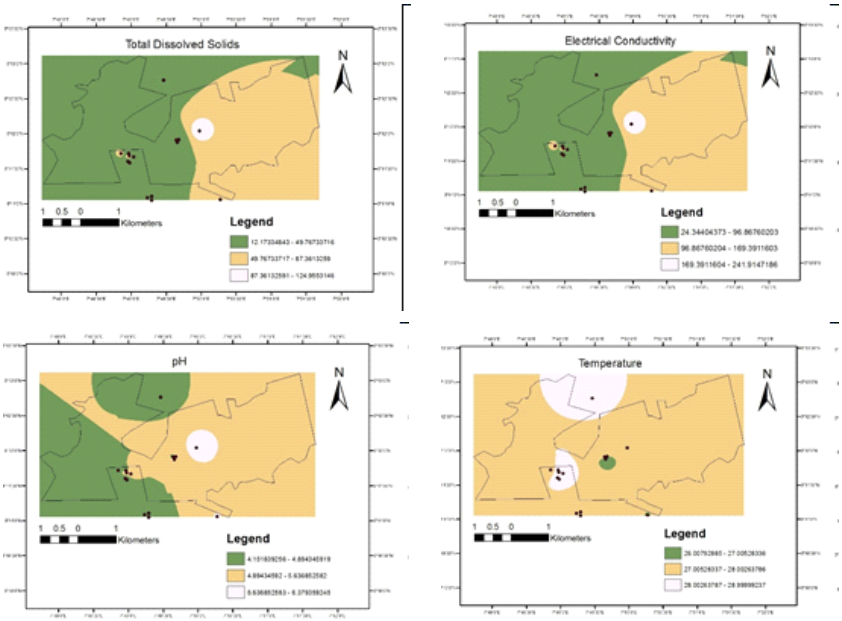


Figure 4: Map of configuration of groundwater table during dry season

Classification of Water Type Based on the Physical Parameters

Water can be classified chemically based on mineralisation; prevailing mega-ions; and some trace elements or some dissolved gases (Schoeneich, 2001). Based on mineralisation (TDS), all the waters are oligomineral waters (fresh waters) because they have mineralisation < 1 g/l (1000 mg/l – Figure 5). Based on the conductivity of the water samples, all the samples are excellent for irrigation (conductivity < 250 µS/cm – Figure 6). All the water samples have pH < 7 which shows that all are slightly acidic (Figure 7). While the temperature of all the water samples are within normal temperature (Figure 8).



Figures 5, 6, 7, and 8: Spatial Distributions of TDS, EC, pH, and Temperature

STATIC WATER RESOURCES

Static water resources (WRs), depends on the hydrogeology of any given area. Hydrogeology determines static groundwater resources (gWRs) which constitute most of the total static water resources, (tWRs) and, to a lesser extent static surface water resources. Study area falls within Crystalline Hydrogeological Province of the country having little water in terms of static water resources as compared to the Sedimentary Hydrogeological Province.

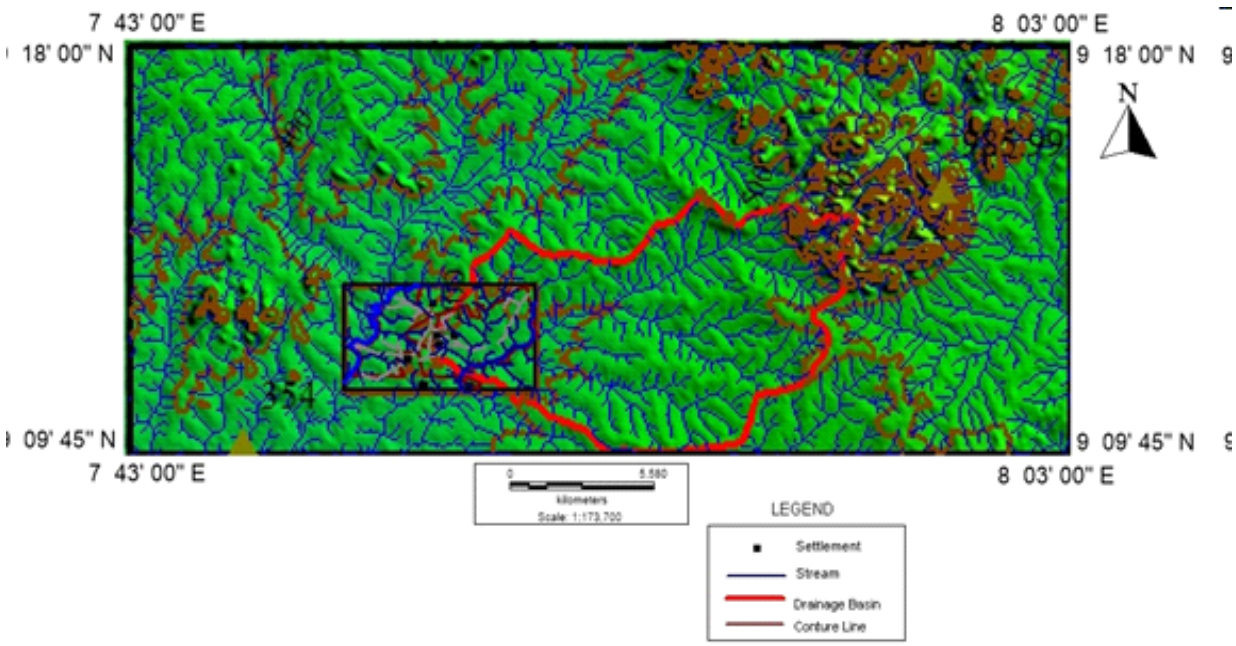
Total drainage area of the proposed Dam site is 101 km^2 = 101 x 10^6 m^2 (Figure 9). Depth of rainfall in the study area is 1,403 mm/a (1.403 m/a). Therefore volume of rainfall is 101 x 10^6 m^2 x 1.403 m = 142 x 10^6 m^3/a. Since most parts of the area is underlain by metamorphic rocks, as such the average thickness of the soft overburden developed on these rocks is 30 m (Nasarawa State Ministry of Water Resources, Lafia, 2006) with an average depth to water table during dry season in the study area, 5.1 m (Table 2). The probable thickness of the water saturated zone in the soft overburden aquifer at the peak of dry season is about 20 m in most places. The average effective porosity of the soft overburden aquifer in Nigeria estimated as 0.028 (Schoeneich and Garba, 2010). The static water resources in the drainage basin upstream of the proposed dame site are: 101 x 10^6 m^2 x 20 m x 0.028 = 57 x 10^6 m^3, as static groundwater resources in the soft overburden aquifer of the drainage basin upstream of the proposed Dam site. While the static water resources in the study area are: 30 x 10^6 m^2 x 20 m x 0.028 = 17 x 10^6 m^3, as static groundwater resources in the soft overburden aquifer of the study area.

DYNAMIC WATER RESOURCES

Dynamic water resources are related to the climatic condition of an area. The study area lies within the Guinea Savannah region of the country and has tropical climate with moderate rainfall. Depth of rainfall in most part of Nasarawa state is 1,403 mm/a (1.403 m/a). Therefore volume of rainfall is 101 x 10^6 m^2 x 1.403 m/a = 142 x 10^6 m^3/a. Total runoff coefficient (dynamic water resources) corresponds to depth of rainfall 1,403 mm/a, is 0.54 (Schoeneich and Garba, 2010) (Figure 10). Therefore, 142 x 10^6 m^3 x 0.54 = 76 x 10^6 m^3/a, of water is flowing through the streams and rivers upstream of the proposed Dam site.

Dynamic Groundwater Resources of the area is calculated as follows: area covered by the property is 30 km^2 or 300,000 ha or 30,000,000 m^2. Depth of rainfall in the property area is 1,403 mm/a (1.403 m/a). Base flow coefficient (dynamic water resources) corresponds to depth of rainfall 1,403 mm/a, is 0.2 (Schoeneich and Garba, 2010 – Figure 10). Volume of rainfall over area is Pv = A x D. Where Pv is volume of precipitation, A is area, and D is depth of rainfall. So volume of rainfall is 30,000,000 m^2 x 1.403 m/a = 42,090,000 m^3/a. Therefore, Volume of Base Flow (total dynamic groundwater resources of the area) is 42,090,000 m^3/a x 0.2 = 8,418,000 m^3/a, which is enough to serve the people of the area for domestic and even agricultural purposes.

Figure 9: Drainage Basin of the Proposed Dam Site



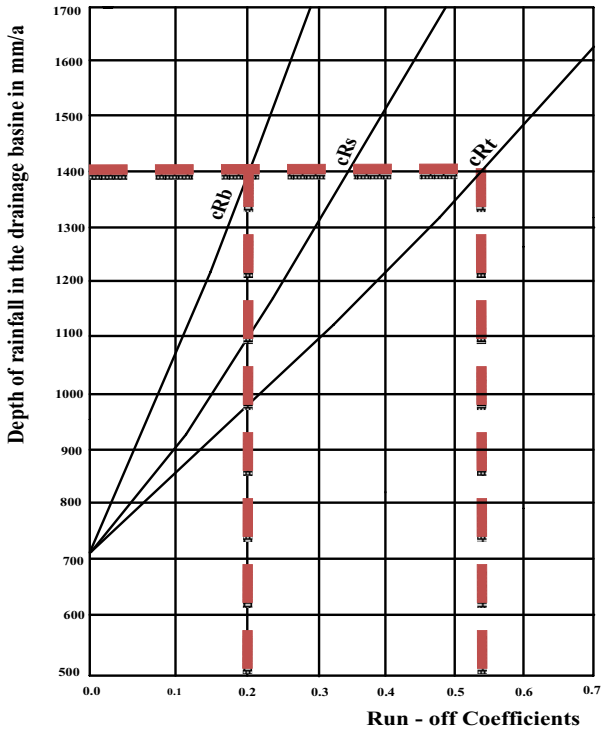


Figure 10: Correlation between depth of rainfall and runoff coefficient in drainage basins (Schoeneich and Garba, 2010). Legend: cRt = total runoff coefficient; cRs = surface runoff coefficient; cRb = base flow coefficient

CONCLUSION

Shallow water table exists within the weathered zone of the study area. The water table mimics topography and shallow groundwater flow directly towards the streams. The water table in the southern part rises to near ground surface more than in the northern part of the area. The observed physical parameters of pH, TDS, Temperature and Conductivity are within WHO (2008 and 2011) permissible limits for drinking water. Total static water resources of the drainage basin of the proposed Dam site are 57 x 10^6 m^3, while that of the study area is 17 x 10^6 m^3. The Dam drainage basin also has a total dynamic water resources of 76 x 10^6 m^3/a, while that of the study area is 8,418,000 m^3/a, which is sufficient for domestic and agricultural purpose in the area. The quality of water in the area in terms of Total Dissolved Solids (TDS) and Electrical Conductivity (EC) is good for irrigation as well as for domestic purpose respectively.

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