ISSN: 3029-0724

Review Article

Journal of Environmental Science and Agricultural Research

Topographical, Geotechnical and Hydrological Assessment of River Tsatu and Tserefu for Bridge Infrastructural Development, Kwara North, Nigeria

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Received: December 16, 2024; **Accepted:** January 06, 2025; **Published:** January 11, 2025

ABSTRACT
This Environmental assessment aim to facilitate the design and construction of a bridge along the axis that will play a vital role in enhancing the socio-economic activities of the area. South GNSS Galaxy high-precision survey equipment was used for the topographic survey with a reference station equipped with a static GNSS receiver. The data was processed using Global Mapper and Golden Surfer software. Geotechnical field work entailed boring exploratory pits at 2.5-3.0 meters depth intervals using auger tools for sampling and laboratory inference analysis. Hydrological work included measuring the river flow, height and catchment using the flow and dip meters. Findings has shown the area is a northwest-southeast trending ridge line with a centrally located and northerly trending sub-ridge line. Slopes ranged from 0-5% around the lower lying (drainage) areas and ranged between 15% and 40% for the side. Grain size analysis revealed silty-clayey sandy and clayey sandy soil with the sand ranging between 88-96%, followed by clay with 1-13%, silt recorded 0-5% and gravel gave a value of 0-2%. Angle of internal friction varied between 19-31° and shear strength varied between 2-22KN/m2. Free Swelling Index varied between 5.49-14.00. Hydrological properties of the area showed length of Tserefu river to be 7.48km, bed slope of 1.6% and area of watershed of 19,13324607Km2. Tsafu recorded 1.4% bed slope, 2.67km river length and 3,436672092 Km2 watershed. The study concluded that the soil and condition of the area are good for the bridge infrastructural design and construction to facilitate its socio-economic activities.

Keywords: Topography, Exploratory, Internal friction, Silty-sandy soil, Swelling Index, Watershed

Introduction

Societal infrastructure plays a crucial role in enhancing socio-economic status of any nation. The proposed bridge and culvert in the study area will thus play a vital role in enhancing the connectivity and accessibility of Lata Village, which is a rural community with a primary occupation of farming. Lata Village serves as a gateway between other neighboring villages, farmlands and markets, making the construction of a reliable and durable bridge, a critical infrastructure development need of the area. The village host markets on specific days of the week, attracting traders and buyers from far and near. However, the lack of a bridge over the River Tserefu, which is the main site, has hindered the socio-economic development of the area. These 2 rivers ie river Tsatu and Tserefu are tributaries and sub-tributaries of river Niger with vast potential for different hydrological regime in their areas for agricultural and industrial activities. Civil infrastructure involving earthworks such as pavements, pipelines, dams, bridges and buildings are severely distressed due to the expansive nature of the native soil and the reason for this Geoscientific environmental assessment of the area for the bridge infrastructure. The use of test/trial pits, borrow and deep borings are crucial to understand the lithological facies of any area for Civil Engineering projects as advanced by Ibrahim et al [1,2].

Citation: Ibrahim OI, Adams SJ, Adebowale SB, Umar YA, Abubakar IM. Topographical, Geotechnical and Hydrological Assessment of River Tsatu and Tserefu for Bridge Infrastructural Development, Kwara North, Nigeria. J Envi Sci Agri Res. 2025. 3(1): 1-11. DOI: doi.org/10.61440/JESAR.2025.v3.43

Location

The proposed bridge and culvert construction project is located in the Pategi Local Government Area of Kwara State (Figure. 1), specifically along River Tserefu (8°39’50.10”N, 5°27’2.02”E) and Tsafu Stream (8°40’23.28”N, 5°27’46.64”E). These watercourses are situated southwest of Lata Village (8°40’57.16”N, 5°28’23.92”E), a rural community that relies heavily on agricultural activities.

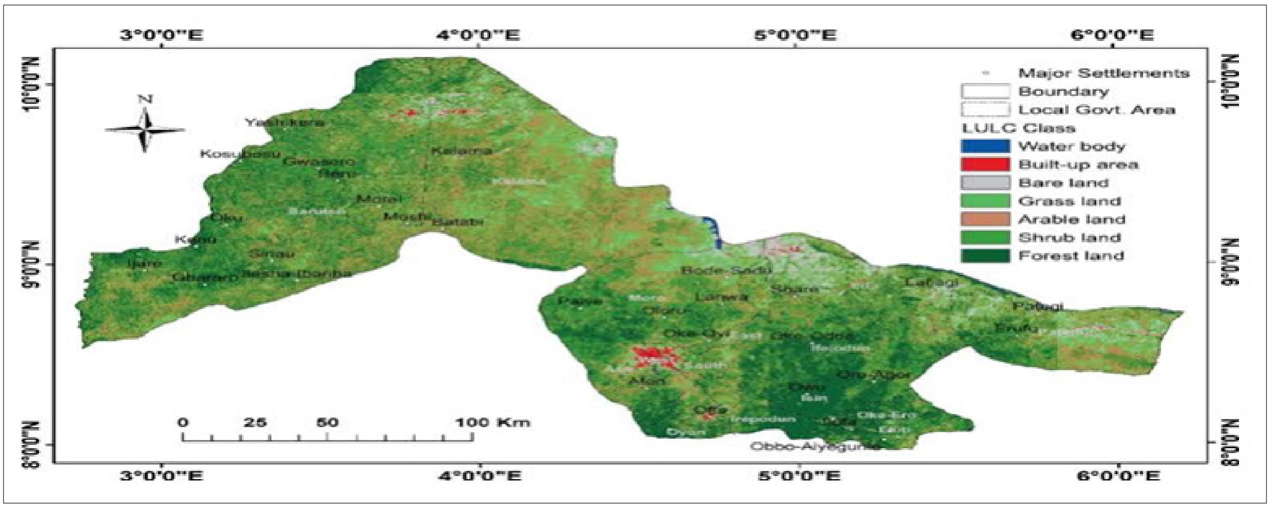

Figure 1: Map of Kwara State Showing its Vegetation and Urbanized Areas

The two sites are strategically located along the major road to Lata Village with Tsafu Stream (Site 2) situated 1.36 km from the village and River Tserefu (Site 1) located 3.14 km away. The distance between the two sites is approximately 1.56 km, highlighting the importance of this infrastructure development project in connecting the communities and facilitating trade and transportation of goods, services and people. The location is characterized by dry and wet seasons. The village hosts markets on specific days of the week, attracting traders and buyers from far and near. However, the lack of a bridge over the River Tserefu, which is the main site, has hindered the socio-economic development of the area. Idrees et al emphasized the need for estimating agricultural and forest lands for Improved Post COVID-19 crop production using open remote sensing to enhance food security of the area and state [3].

Vegetation and Climatic Condition of The State

The annual rainfall depth ranges between 800 to 1200mm with average daily temperature ranging between 30°C to 35°C (Figure. 2). According to data retrieved from the Center for Hydrometeorology and Remote Sensing, peak monthly precipitation and rainfall intensity recorded at the study area experienced significant drop in 2021 as obtained from the location between 2000 to 2022 (Figure 2).

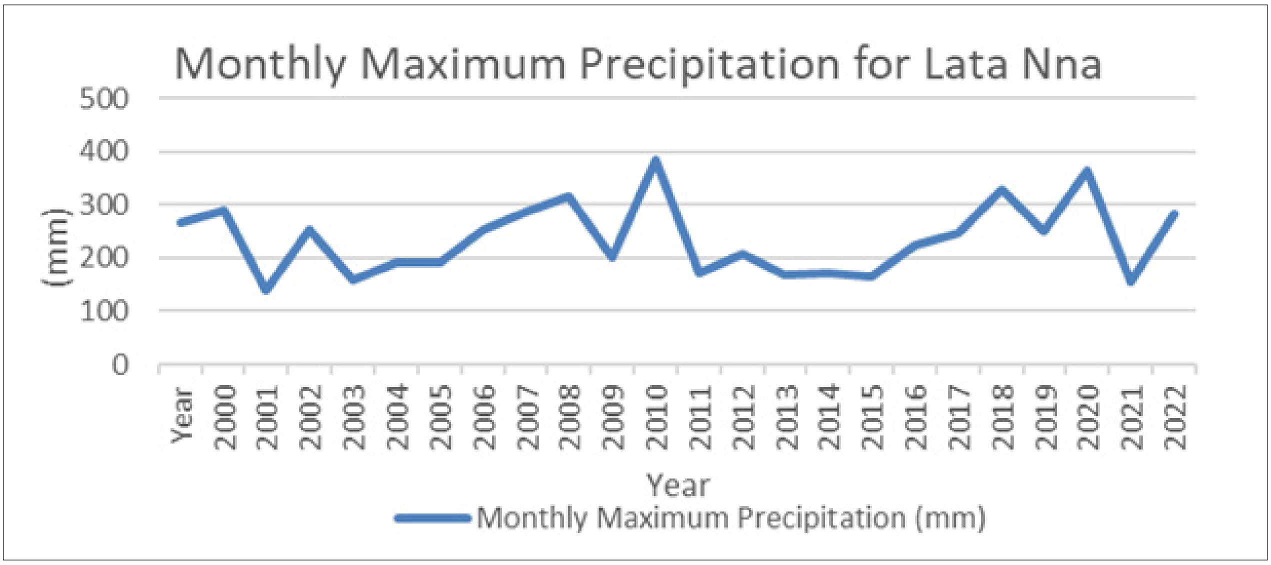

Figure 2: Monthly Maximum Precipitation for Lata Nna (2000 – 2022).

More importantly, the vegetation of the study area is that of forest and savanna with common tree in the region is Vitellaria paradoxa (shear butter), Acacia spp, Parkia spp etc (Figure. 1). Lata Nna has a sparsely densed land area with shrubs and trees. felling activities have been intense and happening over time which has led to the high deforestation rate in the area. Agricultural activities in the zone is also high subsequently exposing the soil to extreme climate problem with lots of gullies traced to extreme exposure of the land cover to intense weather variability associated with massive soil erosion of the area. Akande et al studied rock samples from the area with inclination for the source rock facies of the Lower Maastrichtian Patti Formation [4]. This has given the possibility of hydrocarbon deposit in the area, a subject that is currently ongoing for further assessment.

Materials and Methodology

South GNSS Galaxy G1 is a high-precision GNSS survey equipment was used as its receiver is capable of delivering accurate and reliable data. The equipment was used in Real-Time Kinematic (RTK) mode, which enabled fast and accurate data acquisition in the field. The internal radio feature of the equipment allowed for seamless communication and data transfer between the receiver and the reference station. A reference station was established at two locations to provide a stable and accurate base for the survey. The reference station was equipped with a static GNSS receiver which provided a fixed point of reference for the survey. This allowed the survey team to achieve high accuracy and precision in the data acquisition process. The equipment's ability to operate in RTK mode and communicate with the reference station in real-time ensured that the data was collected efficiently and effectively. Moreso, exploratory pit samples of the area were collected for laboratory inference at defined depths intervals that ranged from 2-3m and this enabled the Geotechnical analysis of the area for adequate evaluation of the soil properties. The flow chart (Figure. 3) has shown 3 teams that started from field work and ended the study by desk study after adequate ground-truthing technique through laboratory inference. Moreso, the stream flow and water depths were measured at different time intervals.

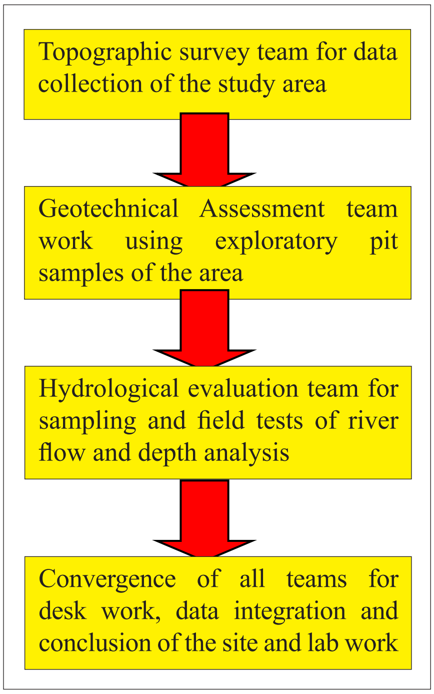

Figure 3: Flowchart of Workplan

The resulting topographic data was then processed using Global Mapper and Golden Surfer software to produce accurate and reliable topographic data of the area. The collected data was processed using a combination of GNSS processing software and AutoCAD software to produce the final topographic map.

Findings

It is worthy of note that the Topographic findings, Geotechnical and Hydrologic data all revealed the feasibility of the proposed infrastructural bridge in the area that will enhance the socio-economic activities of the inhabitants.

Topographic Study

The slope and topography of the area is dominated by a northwest-southeast trending ridge line with a centrally located and northerly trending sub-ridge line (Figure. 4). The maximum vertical relief across the area is approximately 60 metres. Slopes ranged from 0-5% around the lower lying (drainage) areas to between 15 and 40% for the side slopes. The ridge tops are characterized by narrow (generally less than 15-20 meter) flat areas breaking quickly into very steep slopes

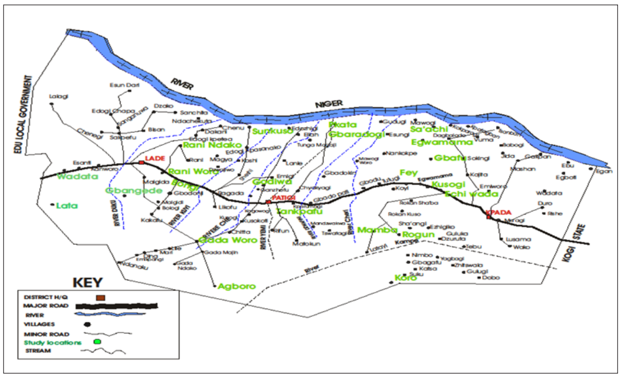

Figure 4: The Survey Map of Patigi, with Lata Nna Study Location at the Extreme left of the Map

The site is characterized by the presence of sediments along the river courses, indicating a high level of fluvial activity. Notably, gully erosion is evident within the chainage 0+040m, highlighting a specific area of concern where soil erosion and degradation are occurring. The river's dynamic shape along its course, with frequent changes in direction and curvature, contributes to the complexity of the site situation. Chethan and Vishnu estimated the geomorphologic parameters of the Thuthapuzha River Basin in central Kerala using GIS and remote sensing to get similar topographic parameters [5].

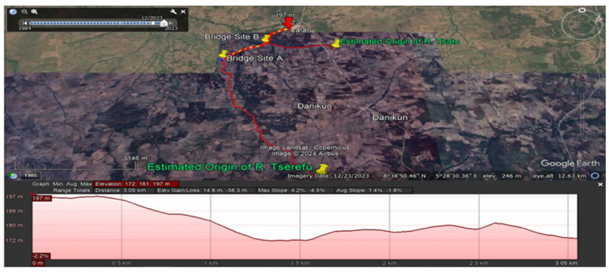

Figure 5: Modified Topographic Map of the Area Showing Estimated Origin of River Tserefu

Table 1: List of Established Reference Points (WGS 84: UTM Zone 31)

S/N	Point ID	Easting (m)	Northing (m)	Height (m)
1	TB 001	769765.355	958612.754	195.360
2	TB 002	771004.614	959549.843	195.894

River and road chainage: A map showing the chainage (linear measurement) of the river and road was established with the following properties.

a. Rive chainage: 0+000m to 0+700m
b. Road chainage Site 1: 0+000m to 0+380m
c. Road chainage Site 2: 0+000m to 0+320m

Longitudinal Profile and Cross-Sections: Drawings depicting the longitudinal profile of the river and road, as well as cross-sections of the river and stream channels were produced as part of the topographic analysis of the area. This enabled salient features of the area to be established thus.

d. Longitudinal profile for river: 10m interval deducted
e. Cross section for river between chainage 0+360 and 0+560: 5m with on offset of 40m on both side of the centreline of the river ealuated
f. Longitudinal profile for road: 20m interval assessed
g. Cross section for road between chainage 0+060 and 0+180: 5m with on offset of 20m on both side of the centreline of the river mapped

Figure 6: Topographic and Hydrological View of the Mapped and Studied River Channel

Figure 7: Hydrological and Topographical Data Collection of the River

Geotechnical Study of the Area

The Geotechnical Assessment of the area for the design and subsequent construction of the bridge was done to reveal the soil characteristics and load bearing capacity of the anticipated bridge load in the area. In essence, grain size analysis, free swell test and shear box tests were done to establish the suitability of the soil in the area for the bridge design and emplacement.

Grain Size Analysis

The grain size analysis of the samples were done with the mapping out of the percentage of each grains contained in each of the analyzed sample (Figures. 8-11). PA1-PA4 are also represented diagrammatically, while PA5-PA8 are contained in quantitative tabular form (Table 2). Amu et al recorded a wide gradational data of the investigated lateritic soil used to stabilize with sugarcane straw ash [6].

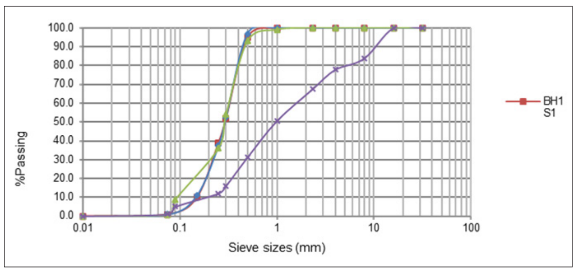

Figure 8: PA1 Sample Grain Size Analysis Gradational Curve

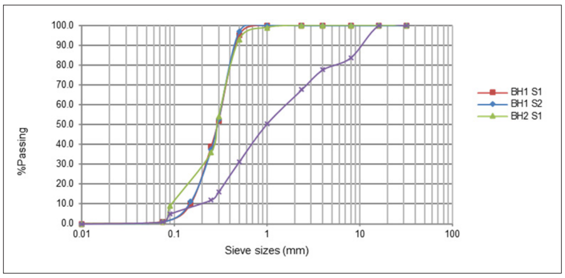

Figure 9: PA2 Sample Grain Size Analysis Gradational Curve

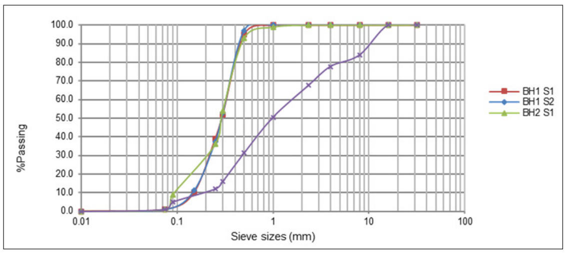

Figure 10: PA3 Sample Grain Size Analysis Gradational Curve

The analyzed samples of the area has shown a more dominant sand grained fraction with minor amount of varied clay and silt components that has classified the soil of the area into about 3 different categories ie Clayey-sandy soil of PA1, PA3, PA5, PA6, PA7 and PA8 (Table 2). These samples reflects clay content in the matrix of the soil samples with appreciable low content that ranged from 13% - 1% and this has revealed that the bridge construction will be on a fair foundation of low clay content, as such may not need excavation. P4A has reflected same ratio of silt and clay, thus inferenced as silty-clayey sandy soil. This shows a minimal content of 4% compared to the main desirable sand lithological facie of 92%. Gravely supported facie sandy soil was traced to sample PA2, and this is reflection of a good component facies for the foundation of the bridge in the area. In essence, this area is known to be good for the desired infrastructure.

Table 2: Summary of Findings of the Soil Composition in the Collected Samples

SAMPLE CODES	% Gravel	% sand	% silt	% clay	Findings
PA1	0	96	0	4	Clayey-sandy soil
PA2	2	96	1	1	Gravely-sandy soil
PA3	1	82	4	13	Clayey-sandy soil
PA4	0	92	4	4	Silty-clayey-sandy soil
PA5	0	95	2	3	Clayey-sandy soil
PA6	1	88	5	6	Clayey-sandy soil
PA7	0	89	1	10	Clayey-sandy soil
PA8	1	92	5	2	Clayey-sandy soil

The grain size analysis of the assessed samples of the area has shown the soil material of the area to be good for bridge infrastructure. The effect of high clay content of soils as they cause massive expansion possibility due the swelling property of the clay minerals was similarly advanced by Azam and Chowdhury where Swell-shrink-consolidation behavior of compacted expansive clays were measured in the laboratory and shown to be non-desirable for infrastructural development [7].

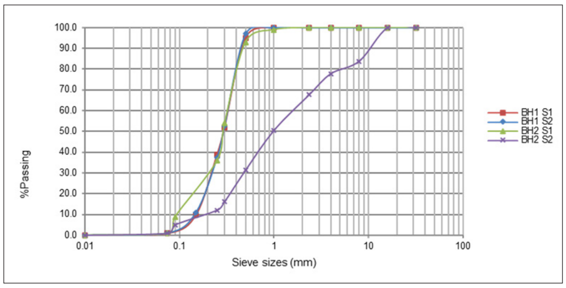

Figure 11: PA4 Sample Grain Size Analysis Gradational Curve

Table 3: Shear Strength Result at Different Time Intervals of Sample Pa1

TIME	Kg/div	Kg/div	Kg/div	KN	KN	KN	KN/m²	KN/m²	KN/m²
	5Kg	10Kg	15Kg	5Kg	10Kg	15Kg	5Kg	10Kg	15Kg
0	0	0	0	0	0	0	0	0	0
5sec	4	5	7	0.047	0.059	0.083	4.748	5.935	8.309
10sec	9	11	12	0.107	0.131	0.142	10.683	13.057	14.244
15sec	11	18	15	0.131	0.214	0.178	13.057	21.366	17.805
30sec	13	22	18	0.154	0.261	0.214	15.431	26.114	21.366
1min	16	24	21	0.190	0.285	0.249	18.992	28.488	24.927
2min	18	27	27	0.214	0.320	0.320	21.366	32.049	32.049
3min	20	29	31	0.237	0.344	0.368	23.740	34.423	36.797
4min	22	31	33	0.261	0.368	0.392	26.114	36.797	39.171
5min	24	34	37	0.285	0.404	0.439	28.488	40.358	43.919
6min	25	35	40	0.297	0.415	0.475	29.675	41.545	47.480
7min	26	38	45	0.309	0.451	0.534	30.862	45.106	53.415
8min	27	40	49	0.320	0.475	0.582	32.049	47.480	58.163
9min	27	42	54	0.320	0.499	0.641	32.049	49.854	64.099
10min	27	44	59	0.320	0.522	0.700	32.049	52.228	70.034

Shear Box Test

The strength of the soil was assessed using shear box to evaluate the shear strength, angle of internal friction at a proving ring constant of 1.21 kg/div and area of sample of 0.01m². The graph of the normal stress against shear stress (kg/m²) was plotted at 5, 10 and 15 kg of load. It is worthy of note that 12 representative samples were subjected to this test at a time interval of 0-10 minutes with a summary of findings (Table 6).

Table 4: Shear Stress Against Normal Stress of Evaluated Sample Pa1

Load Kg	5	10	15
Shear Stress KN/m²	32.05	52.23	70.03
Normal Stress KN/m²	4.91	9.81	14.72

Porosity of the sand sized fraction of the soil in the area can be said to be low and this has made it possible to estimate its influence on the shear strength recorded across the investigated samples as earlier done by Vallejo and Mawby who discussed the Porosity influence on the shear strength of granular material-clay mixtures [8].

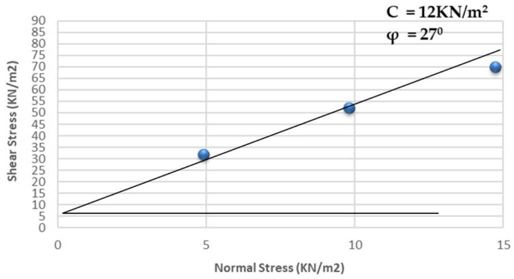

Figure 12: Sample Pa1 Shear Box Test of Shear Stress Against Normal Stress

Table 5: Shear Strength Result at Different Time Intervals of Sample Pa2

TIME	Kg/div	Kg/div	Kg/div	KN	KN	KN	KN/m²	KN/m²	KN/m²
	5Kg	10Kg	15Kg	5Kg	10Kg	15Kg	5Kg	10Kg	15Kg
0	0	0	0	0	0	0	0	0	0
5sec	7	9	13	0.083	0.107	0.154	8.309	10.683	15.431
10sec	9	13	21	0.107	0.154	0.249	10.683	15.431	24.927
15sec	12	19	26	0.142	0.226	0.309	14.244	22.553	30.862
30sec	17	23	32	0.202	0.273	0.380	20.179	27.301	37.984
1min	21	26	38	0.249	0.309	0.451	24.927	30.862	45.106
2min	24	30	40	0.285	0.356	0.475	28.488	35.610	47.480
3min	26	32	42	0.309	0.380	0.499	30.862	37.984	49.854
4min	28	35	45	0.332	0.415	0.534	33.236	41.545	53.415
5min	29	37	49	0.344	0.439	0.582	34.423	43.919	58.163
6min	31	39	52	0.368	0.463	0.617	36.797	46.293	61.725
7min	32	41	54	0.380	0.487	0.641	37.984	48.667	64.099
8min	34	43	57	0.404	0.510	0.677	40.358	51.041	67.660
9min	34	45	59	0.404	0.534	0.700	40.358	53.415	70.034
10min	34	48	62	0.404	0.570	0.736	40.358	56.976	73.595

Table 6: Shear Stress Against Normal Stress of Evaluated Sample Pa2

Load Kg	5	10	15
Shear Stress KN/m²	40.36	56.98	73.59
Normal Stress KN/m²	4.91	9.81	14.72

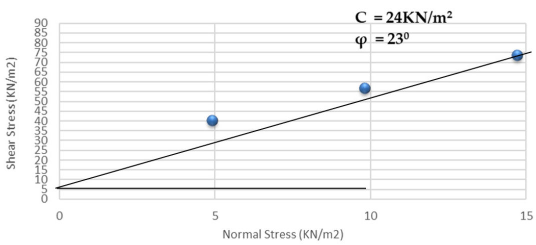

Figure 13: Sample Pa2 Shear Box Test of Shear Stress Against Normal Stress

Table 7: Summary of Shear Box Test Findings of the Area

No	Sample codes	Angle of internal friction(ϕ)	Shear strength (KN/m²)	Findings
1	PA1	27	2	Internal friction (ϕ) that ranged between 19 to 31° and recorded shear strength that ranged between 2 to 18 KN/m2 of the soil in the study area of Tserefu and Tsafu are moderate and good for the bridge infrastructural development
2	PA2	23	4	
3	PA3	29	5	
4	PA4	31	9.5	
5	PA5	28	6	
6	PA6	19	22	
7	PA7	30	18	
8	PA8	26	17	
9	PA9	24	16	
10	PA10	27	16	
11	PA11	26	15	
12	PA12	26	12	

Free Swell Potential Index Test

The free swell test was carried out on selected samples (PA1-PA10) to establish the potential of swelling clay content and its percentage composition to corroborate the findings of grain size analysis of the area (Table 7).

Table 8: Free Swell Potential Index Test Result

SAMPLE ID	Vd (m3)	Vk (m3)	Free Swell Index (%)
PA1	0.00042	0.000395	6.33
PA2	0.00046	0.00043	6.05
PA3	0.00048	0.000455	5.49
PA4	0.00034	0.000305	11.48
PA5	0.00044	0.00041	7.32
PA6	0.00049	0.00042	16.67
PA7	0.00055	0.00049	12.24
PA8	0.00057	0.0005	14.00
PA9	0.00054	0.000475	13.68
PA10	0.00056	0.000495	13.13

Vd is the volume of soil specimen read from the graduated cylinder containing distilled water.

Vk is volume of soil specimen read from the graduated cylinder containing kerosene

$$\text{Free swell index} = \frac{[Vd - Vk]}{Vk} \text{ X } 100\%$$

This is crucial for such an infrastructural design and construction. The result obtained has corroborated the findings of the grain size analysis of low clay contents with the capacity of swelling of the soil in the area, as such, less swelling clay minerals (smectite, montmorillonite etc). Moreover, PA6 with FSI of 16.67% is the highest in the area, while PA3 with 5.49% is the lowest recorded in the area. Major finding also is that most samples have moderate FWI for the Bridge infrastructure to be designed and constructed in the area as they fall within the tolerant level of 5.49% to 13.68%.

Hydeological Assessment

This entailed the rainfall pattern of the area, velocity and depth of river flow, area of watershed and flood estimation of the area using different hydrological models and methods. The pollution of the river is currently high due to activities of the local inhabitants and if this is contained and minimized, River Tserefu and Tsafu will serve the community better to enhance agricultural outputs as most shallow wells go completely dry during the peak of dry season, a condition traced to climate change effects. Ibrahim et al [9,10].

The Rainfall Pattern of the Area

The rainfall pattern of the area is common in the months of August to November in recent years and this short rainfall pattern can be traced to the global pandemic of climate change which has shorten the total period of precipitation globally. Though the rainfall is commonly heavy that leads to destruction of properties and farmlands in most communities.

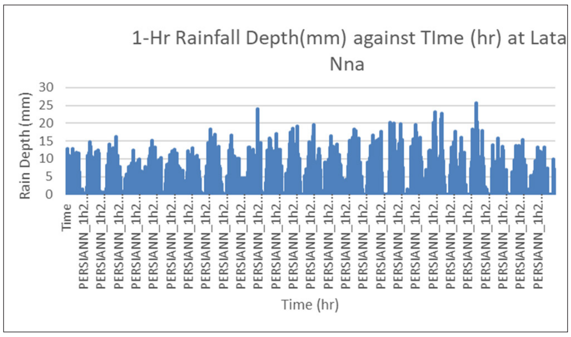

Figure 14: Rainfall Precipitation Depth at Varying Time Intervals

The rainfall pattern of Lata Nna (figure. 14) has shown a maximum depth of 17.6mm commonly noticeable around the month of October to November in recent years. Cliamte change is bringing lots of uncertainty as published by Cunderlik and Simonovic [11].

Velocity and Depth of River Flow

Hydrological Survey was done at the period when the rivers are at their lowest ebb, thus, velocity and depth could not be measured with our equipment but a floating bob was used to measure the flow by measuring the time it took for the water to move the floating bob from point A to point B. Ayodele elaborated on hydrological survey as published in applied Hydrology and Sedimentology for Ungauged Watersheds [12].
Distance from Point A to Point B = 2.19m
Time = 51 sec. Velocity = 0.07m/s,

Figure 15: Estimated Length and Bed Slope of River Tserefu

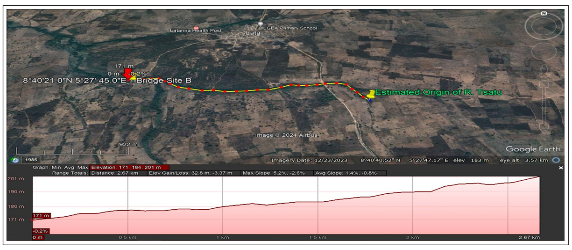

Figure 16: Estimated Length and Bed Slope of River Tsafu

Area of Watershed

The Area of Watershed can be calculated using this relationship: Length of main channel (L) = 1.273 * Area of Watershed (A) ^ 0.6

The estimated Area of both watershed is shown on

Table 9: Length of Both Rivers and Area of Watershed

S/N	River	Average Bed slope	Length of River (km)	Area of Watershed (Sq Km)
1	Tserefu	1.6%	7.48	19.13324607
2	Tsafu	1.4%	2.67	3.436672092

It should be noted that there is a possibility of change of catchment area because of the intense human activities that have reshaping the area over time such as agriculture and deforestation which have made the soil vulnerable to erosion, thus subsequently leading to sedimentation.

Another major finding during field assessment exercise was the observation of cross-sectional channels at River Tserefu that showed a precise shape of a trapezium with effective top and bottom width not more than approximately 39.155m and 32.4m respectively unlike that of Tsafuwho's channel that showed mild depression that stretches as far as over 45m. Hydrologic modelling through numerical analysis was similarly used by Bhaskaran and Kumaraswamy for the Identification of influential geomorphic parameters [13,14].

Figure 17: Flood Estimation of the River Area Showing the Trapezoidal Shape

Flood Estimation

a). Flood Estimation Using Slope-tbcArea Method

Flood estimation of the river channel was estimated using Manning Equation;

- **River Tserefu**

Table 10: Estimated Discharge Capacity at River Tserefu

SLOPE-AREA METHOD			
Max Bed Slope	**n**	**Velocity (m/s)**	**Q (Estimated Discharge capacity - cumec)**
0.06	0.4	0.761717766	49.63500574

- **River Tsafu**

Table 11: Estimated Discharge Capacity at R. Tsafu

SLOPE-AREA METHOD			
Max Bed Slope	**n**	**Velocity (m/s)**	**Q (Estimated Discharge capacity - cumec)**
0.052	0.4	0.123648886	5.199466558

Due to the relatively flat land, it was difficult to estimate precisely the cross-sectional area of the channel of River Tsafu.

Flood Estimation Using Rational Method

The Design Peak runoff for both rivers using rational method is given as follows;

- **River Tserefu**

Table 12: Estimated Peak Discharge Capacity at River Tserefu

Peak Intensity (mm/hr) - 25year data	Length of River (L)	Area of Watershed (Sq Km)	Runoff Coefficient (C)	F (constant)	Q peak (cumec)
25.57	7.48	19.13324607	0.4	0.278	**54.40317**

- **River Tsafu**

Table 13: Estimated Peak Discharge Capacity at River Tsafu

Peak Intensity (mm/hr) - 25year data	Length of River (L)	Area of Watershed (Sq Km)	Runoff Coefficient (C)	F (constant)	Q peak (cumec)
25.57	2.67	3.436672092	0.4	0.278	9.77177844

From the Table 4a and b, peak discharge of R. Tserefu and R. Tsafu are estimated as 54.4cumec and 9.77cumec respectively which is way higher than the capacity of the channels of both rivers, thus resulting to the current flooding happening in the area.

- **River Tserefu**

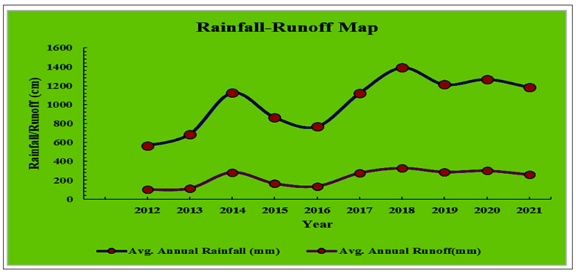

Figure 18: Rainfall-Runoff Correlation Graph Using SCS Curve Method of The Study Area

Rainfall-Runoff Correlation

The relationship between potential runoff and rainfall at a specific temporal scale demonstrates a strong positive correlation, evidenced by a correlation coefficient (R-value) of 0.967. This high R-value suggests a nearly perfect linear association, indicating that increases in annual rainfall correspond to proportional increases in annual runoff. An R2 value approaching +1 signifies a robust linear relationship, with positive values confirming the direct correlation between these variables. The graph (figure. 18) presents the scatter plot of average annual rainfall against runoff, showcasing the data points alongside the best-fit line. This further substantiates the rainfall-runoff relationship within the area. The analysis indicates a commendable correlation, affirming the direct dependency between these two hydrological parameters. Moreover, daily correlation coefficients for rainfall and runoff spanning from 2012 to 2021 of the area consistently reflect this positive linear trend. This reinforces the findings of a significant relationship between rainfall and subsequent runoff of Trerefu and Tsafu, emphasizing the importance of understanding this interaction for effective watershed management.

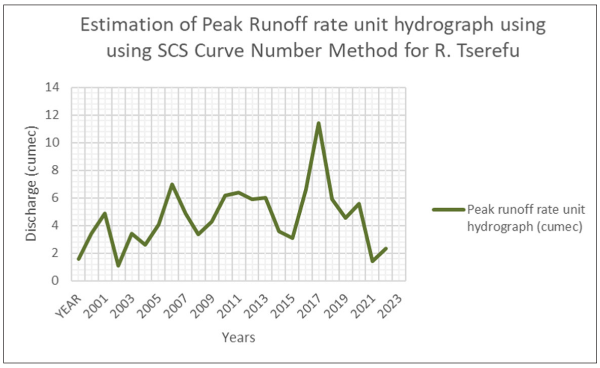

Figure 19: Peak Runoff Discharge Rate Unit Hydrograph of River Tserefu

According to SCS Curve Number method, estimation of Peak Runoff rate unit hydrograph as shown in Figure 8a and 8b. are 11.43983984 cumec and 4.298714319 cumec for R. Tserefu and R. Tsafu respectively.

- **River Tsafu**

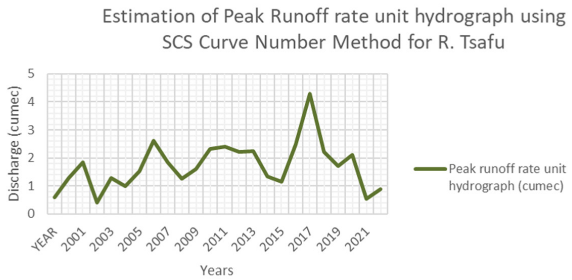

Figure 20: Peak Runoff Discharge Rate Unit Hydrograph of River Tsafu

Return Period (Weibull Method)

Using the Log-Pearson Type II distribution as recommended by U.S Water Advisory Committee on Water Data for flood frequency, the return period of both rivers was given as follows;

- **River Tserefu**

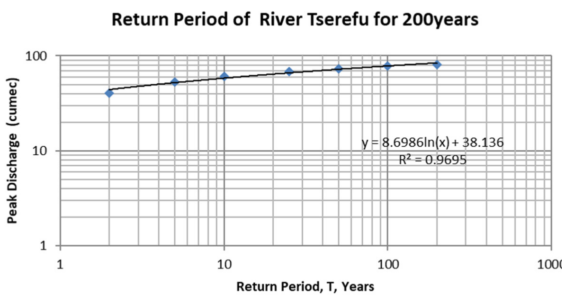

Figure 21: Return Period of River Tserefu for 200 Years

Variance	0.023
Standard deviation	0.150
Skew coefficient	-0.51845229

Table 14: River Tserefu Estimated Peak Discharge for 200 Years Return Period

	Interpolated from table		
Return period	K(0.545)	log Q (m^3/s)	Q (m^3/s)
2	0.079952366	1.604585479	40.23328362
5	0.889476183	1.726197809	53.23506744
10	1.272077386	1.783674837	60.7679852
25	1.614648836	1.835138317	68.41294981
50	1.822142901	1.866309526	73.50375507
100	1.98326792	1.890514854	77.71678989
200	2.114208416	1.910185651	81.31780567

The charts above show the 200year- return period for River Tserefu and Tsafu with values of estimated peak discharge to be; 81.31780567cumec and 34.11275446 cumec respectively. The prediction model are the same because of the same value of maximum daily precipitation that lead to their corresponding peak discharge;

$Y = 8.6986\ln(x) + 38.136$ $R^2 = 0.9695$

The coefficient of determination (R^2), as seen above is 0.9695 which shows the high predictive nature of the model.

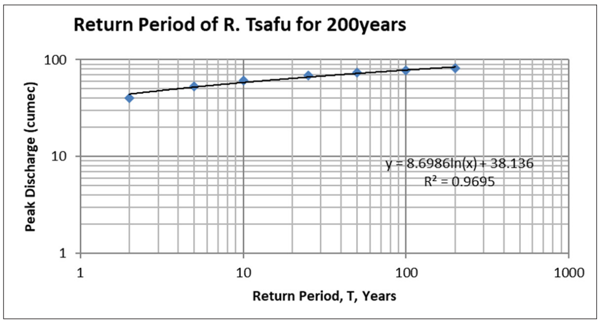

Figure 22: Return Period of River Tsafu for 200 Years

Variance	0.089
Standard deviation	0.299
Skew coefficient	-0.85246805

Table 15: River Tsafu Estimated Peak Discharge for 200 Years Return Period

	Interpolated from table		
Return period	K(0.545)	log Q (m3/s)	Q (m3/s)
2	0.133394888	1.031705885	10.75736453
5	0.916197444	1.265684492	18.43675532
10	1.255376598	1.367064674	23.28437977
25	1.517784266	1.445497965	27.89317586
50	1.661815336	1.488548654	30.7998537
100	1.752797046	1.515742961	32.79011663
200	1.810254075	1.532916788	34.11275446

The river water potential can be more useful as a reservoir dam resource so that a dam site investigation study similar to that of

Umoren et al and Shahid et al should be carried out to prolong the life-cycle of the water for urban utilization and as advanced by Lundie et al [15-17].

Discussions

The evaluation of the area has shown a result that its feasible for the construction of a bridge in the area due to favorable topographic terrain, moderate values of the grain size analysis that is mostly composed of sand size fraction (88-96%) in the soil components, more importantly the Free Swelling Index of analyzed samples are moderately low signifying the clay minerals in the soil samples of the area is low and this finding has been corroborated by the 1-13% clay content in the geotechnically evaluated samples compared to the very highly desirable sand size fraction of 88-96% fraction [18,19]. Hydrological assessment has revealed the flow regimes to be very high during rainy season, thus not favorable to enhance socio-economic activities of the area and the need for the bridge infrastructure [20,21].

Conclusions

The river courses are having large active sediments, indicating a high level of fluvial activity. This is commonly activated by yearly rainfall precipitation and gully erosion which is much more pronounced within the chainage 0+040m, highlighting a specific area of concern where soil erosion and degradations are occurring. The river's dynamic shape along its course is known to be influenced by the geomorphology and geotechnical components of the soil fraction established in the area ie silty-clayey sandy soil and clayey sandy soil with the sand ranging between 88-96%, followed by clay with 1-13%, silt recorded 0-5% and gravel gave a value of 0-2%. Angle of internal friction varied between 19-31° and shear strength recorded in the soil of the area varied between 2-22KN/m2.and these properties are known to be characterized by frequent changes in direction and curvature of the river courses that contributes to the complexity of the site situation. More importantly, the floe regime of the river in the area has revealed the need for a modern bridge that will enhance the socio-economic activities of the area.

Acknowledgements

Appreciation goes to friends for providing the financial and material support to get the manuscript completed despite challenges during data collection. The authors specially acknowledge the invaluable and unquantifiable support received from the publisher, thanks so much. The authors specially thank Mrs. Ibrahim Bilqees for typesetting and amending the manuscript despite tight teaching schedules.

Funding

No external funding from home country has been received but donations from friends and well-wishers to facilitate the article preparation and its publication. I also appreciate the publisher for the review work done and its timely publication.

Conflict of Interest

No conflict of interest has been declared in this manuscript as the content of the work has been put together to contribute to novel knowledge dissemination and sharing globally.

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