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Full Length Research

Road vulnerability and the dynamics of rainfall along Igbara-Oke road, Ondo State, Southwestern Nigeria

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ABSTRACT: This research showed the significance of rainfall, Very Low Frequency Electromagnetic (VLF-EM) and electrical resistivity method for road vulnerability along Igbara Oke road, Ondo State, Nigeria. In doing this, a geophysical approach has been adopted with the use of two geophysical methods involving Very Low Frequency Electromagnetic (VLF-EM) and electrical resistivity method using Lateral Resistivity Profiling (LRP) and Vertical Electrical Sounding techniques (VES) for a distance of more than half a kilometer. The lateral resistivity profiling allowed for evaluation of lateral variation in resistivity with respect to a fixed depth while the vertical electrical sounding for the understanding of the layer stratification of the study area in term of thickness and layer resistivity. VLF-EM was engaged to define the study area with respect to conductive and resistivity zone, while the methodological data of rainfall pattern within the last ten years was engaged to understand the dynamics of rainfall within this period. The Wenner profiling has a resistivity distribution/variation ranging between 16 to 520 Ωm, while VLF -EM profiling was characterized by conductivity ranging from 0.1 to 2.0 % and -0.1 to -4.1%. Vertical electrical sounding identified three to four geoelectric sections which are topsoil, weathered layer, fractured basement and fresh basement with varying resistivity and thickness. The results from the VES was used to determine the second order parameters for better understanding of the dynamic nature of the subsurface that may lead to further vulnerability. The rainfall data exhibits the reasons for the unprecedented vulnerability witnessed in recent years, coupled with the geological factors, and hence, the possible solution towards securing a sustainable future in foundations especially on road construction.

Keywords: Conductivity, foundation, geoelectric section, horizontal profiling, rainfall, vulnerability.

INTRODUCTION

Over the years, road vulnerability to failure has been largely attributed to geological factors or man-made factors such as poor construction and poor workmanship, however, recent events has proven that there may be more to this previously held views (Bawallah et al., 2019a; Ozegin et al., 2019a; Ozegin et al., 2019b; Ilugbo et al., 2018a; Adebiyi et al., 2018; Aigbedion ,2007). This is as a result of the observations of this research, to the fact that the rate at which most of our roads are prone or tends to fail, is at a proportionate increase or directly proportional to the rate of rainfall in a particular year, as a reflection of the geodynamic seasonal variation (Bawallah et al., 2019b, Ilugbo et al., 2018b). This became a matter of major concern in year 2019, when virtually all parts of the Nigerian road suffered partial or total failure in the year that witnessed the highest rainfall in recent times, thereby necessitating the need for this research as a way of providing solution to this persistent problem in the face of global seasonal variation. Despite government efforts in rehabilitation and reconstruction of these failed roads, several segments still record perpetual failure. In this country today, such rehabilitations have become annual ritual with little or no effort made by Government and road engineers to identify factor(s) responsible for the persistent pavement failures (Oni and Olorunfemi, 2016). However, research by several authors showed that several factors are responsible for road failure and road pavement performance. These factors include geological, geomorphological, and geotechnical factors, road usage, construction practices and maintenance (Adegoke-Anthony and Agbada, 1980; Ajayi, 1987 and Akintorinwa et al., 2011, Oni and Olorunemi, 2016). The nature of the sub-grade soils on which roads are founded, the bearing capacity and/or hosting fitness of existing soil to bear engineering structures can also initiate pavement failure (Mesida, 1981; Ajayi, 1987). All the roads do not carter for same amount of traffic volume or intensity. Since the funds available at hand for financing road construction projects were not properly managed, it is necessary to have a standardized road that will last a test of time. There are different types of roads vis-à-vis; earth and gravel, soil stabilized**,** water bound macadam, bituminous or black top and cement concrete roads (Devendra, 2017). Now while these are all popular types of road construction and still employed in projects all across the globe, they are obviously far from perfect. That is where these research works come into the picture, their revolutionary dust control and soil stabilization techniques represent the next major step forward in terms of construction and infrastructure building, as they deliver superior results in terms of both performance and cost to essentially the entire more traditional road building methods and materials in use today. Therefore, this research work was directed at evaluating the relationship between the geological factors responsible for road vulnerability and the realities of global seasonal changes and variations as it may affects sudden increase in rainfall pattern with its resultant effects to bring about vulnerability factors of failure, even beyond human expectations. The occurrence of global thermodynamic changes and its effects on variations in the rainfall pattern over the years has its own effects on vulnerability of foundation and its susceptibility to failure (Ozegin et al., 2019b). Therefore implication of these global phenomena as it may continue to affect the dynamics of local, regional and global geology is the focus of this present study, especially with a view to modeling for the purpose of prediction of foundation failure of roads as it may result from the compelling factors of trends of rain pattern, aided by the local geologic dynamics as competing factors for vulnerability to road failure.

METHODOLOGY

Description and geology of the study area

The study area, Igbara-Oke to Igbara-Odo roadway, cuts across Ondo and Ekiti States in the Southwestern part of Nigeria (Plate 1 and 2). It is situated between latitudes 7 23' 52'' and 7 30' 08'' and longitudes 5 03' 14'' and 5 04' 01'' with surface elevation of 384 m and the investigated road is gently undulating (Figure 1). The tropical climatic condition prevails in the study area. It is characterized by short dry season (November - March) and a long wet season (April – October) with mean annual rainfall ranging between 1000 and 1500 mm (Iloeje, 1981). The annual mean temperature is between 22ºC (wet season average) and 31ºC (dry season average) with relatively high humidity that ranges from about 60 to 85% from November to March, and about 80 to 90% around August (Adeleke and Leong, 1978; Federal Survey, 1978; NIMET, 2007, Oni and Olorunfemi, 2016). The vegetation is the evergreen thick forest type with varieties of hardwood timbers, broad-leave trees and grasses. The geology is underlain by the Precambrian rocks of southwestern Nigeria (Rahaman, 1976). The investigated roadway is underlain by the migmatite gneiss and biotitemuscovite granite (Figure 2).

Plate 1. Failed Segment at location 1 before its recent reconstruction/rehabilitation.

Methods

The research involves metrological rainfall data, Very Low Frequency Electromagnetic and electrical resistivity method (Figure 3). The Electrical resistivity method involves two techniques vis-a-vis 2D- Wenner profiling and the Vertical Electrical Sounding (VES). The 2D-Wenner

Plate 2. Failed Segment at location 2 before its recent reconstruction/rehabilitation.

profiling and vertical electrical sounding techniques were done along the road. Twelve VES points and Wenner profiling were acquired using the R-50 resistivity meter. The rainfall data acquired over a space of ten years (daily, monthly and yearly) using rain-gauge apparatus from the university observatory weather station, Federal University of Technology Akure while Very Low Frequency Electromagnetic (VLF-EM) profiling was engaged to define the study area with respect to conductive and resistivity zone. The rainfall data was plotted in form of bar chart using excels words to reflect the rain pattern within a space of ten years and the very low frequency electromagnetic method (VLF-EM) survey was conducted along the proposed road at an interval of 20 meters using ABEM WADI VLF equipment. Although both the real and quadrature components of the VLF-EM were measured, the real component data, which are usually more diagnostic of linear features, were processed for qualitative interpretation. The raw real VLF data were converted (with the aid of an in-built filtering program provided in the ABEM WADI equipment and a software known as KH Filt version 1.0 (Pirttijärvi, 2004)) into filtered real data in which anomaly inflections appear as peak positive anomalies and false VLF anomaly inflections as negative anomalies (Reynolds, 1997) of the profiles. The electrode configuration for wenner was occupied with a constant spacing of “a” equals to 10 and 20, and corresponding values of ‘N’ being varied between 1 and 2 while electrode movement was at 5 m intervals. The VES data were presented as sounding curves, which are plots of apparent resistivity values against electrode separation (AB/2) on bi-logarithmic paper resulting in a VES curve. The VES curve showed the change of resistivity with depth, since the effective penetration increases with increasing electrode spacing. The interpretation of the VES curve is both qualitative and quantitative. The qualitative interpretation involved visual inspection of the sounding curves while the quantitative interpretation utilized partial curve matching technique using 2-layer master curve which was later refined by a computer iteration technique resist version (Ghosh, 1971) that is based upon an algorithm of Vander Velpen (2004). The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer resistivity and layer thickness). The geoelectric parameters were used to determined second order parameters and the integration of results was used to generate vulnerability section which was correlated with different types of road for proper stability.

RESULTS AND DISCUSSION

The results of the study were presented as sounding curves, geoelectric sections and graphs.

Metrological data

The dynamic of rainfall in the last few year has indicated a sudden change in trend in the rate of rainfall which may not be unconnected with the ozone layer challenges vis-à-vis green house effects which have brought a sudden rise/increase in the amount of rainfall, especially within the last ten years (Figure 4). The principles of stress, strains and geodynamic pressure and activities of temperature variations, internal and external pressures on the earth and tectonic activities overtime ultimately has a direct effect on rainfall pattern which invariably affect rate of weathering (Bawallah et al., 2019a). This has also lend credence to unprecedented road failure, which makes it imperative that beyond geological factors, environmental factors regarding rain dynamics should also be of major concern in consideration of factors affecting stability/vulnerability to failure of foundations, and most especially roads.

Vertical electrical sounding

Characteristic of the VES Curves

Curves types identified ranges from H, HA and KH varying

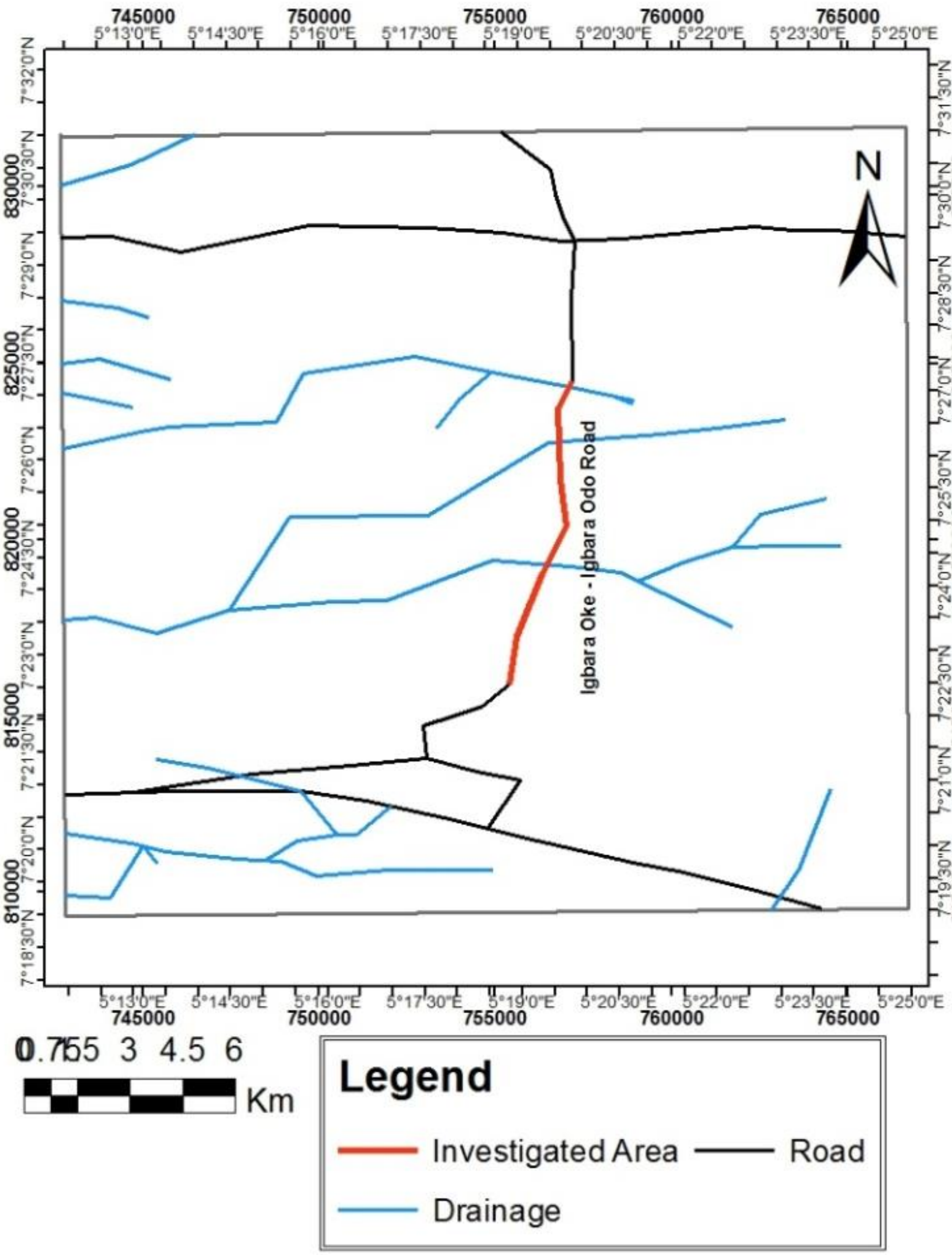


Figure 1. Location map showing the study area.

between three to four geoelectric layers. The H curve type predominates. Typical curve types in the area are as shown in Figure 5(a – c).

Geoelectric and lithological characteristic along the road

The geoelectric sections were represented by the 2-D view of the geoelectric parameters (depth and resistivity) derived from the inversion of the electrical resistivity sounding data (Figure 6). The results obtained also showed effective correlation with other method and techniques that were engaged in the course of this study. The geoelectric sections identified five geoelectric/ geologic subsurface layers. The topsoil comprising of clay, clayey sand, sandy clay and sand with the resistivity values ranges from 63 to 248 Ωm and its thickness varies

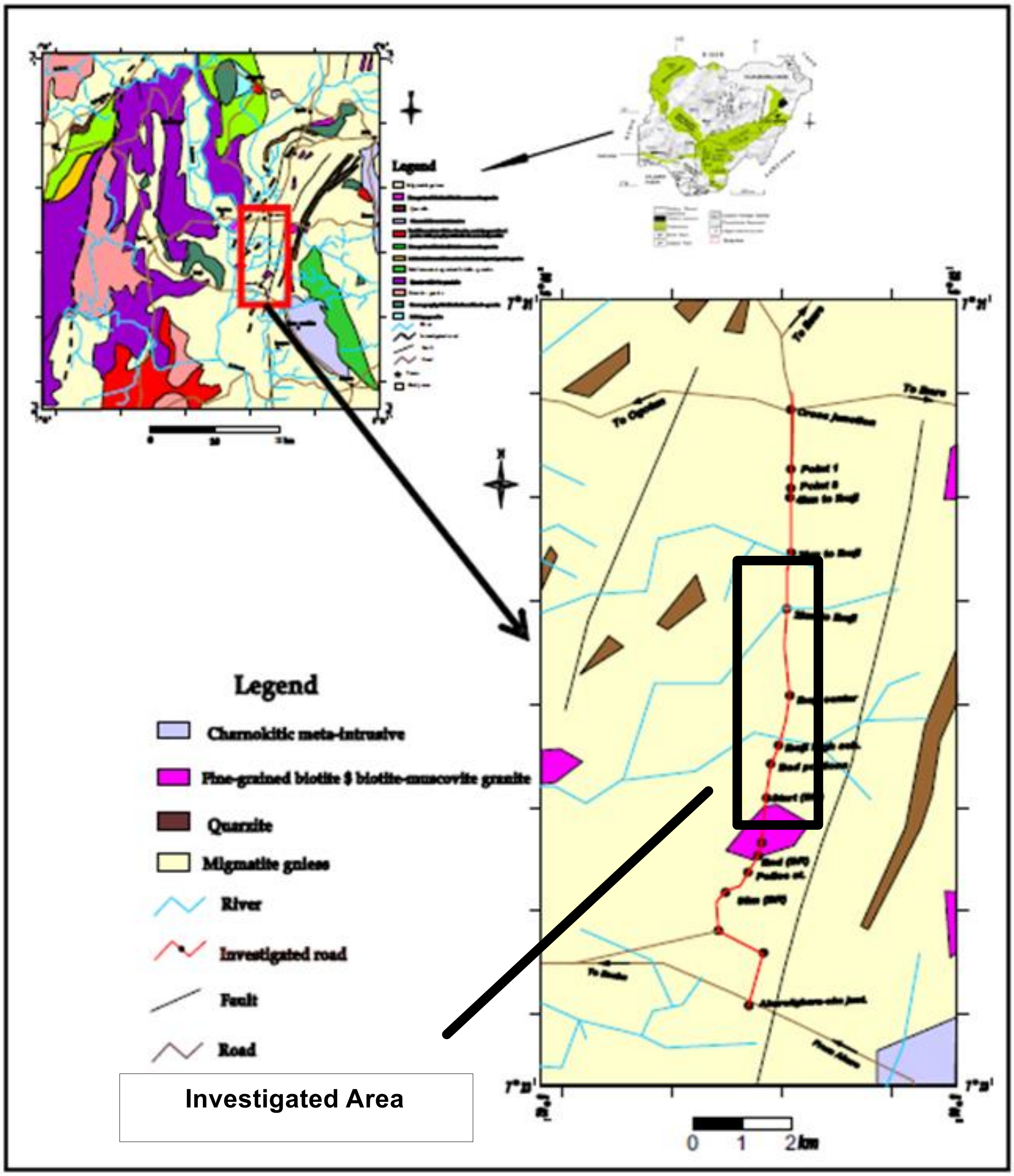


Figure 2. Geological Map of the Study Area (Modified after Geological Survey of Nigeria, 1976 cited in Oni and Olorunfemi, 2016).

from 0.1 to 1.2 m, the lateritic layer resistivity values range from 217 to 539 Ωm with thickness varies from 3 to 18 m, while the weathered layer resistivity values range from 8 to 174 Ωm and thickness ranges from 1.1 to 10 m. The fracture has a resistivity values ranged from 368 to 755 Ωm and thickness ranges from 8 to 20 m while fresh basement has a resistivity values ranged from 735 to 1287 Ωm with depth to basement ranging from 12 to 23.8 m.

Dar Zarrouk parameters

Results obtained from the VES interpretations were used to determine the second order parameters. Total longitudinal conductance (Figure 7) was generated from the second order parameters which reflect the inherent weakness of the subsurface geologic materials, especially between 5 to 130 m, 210 to 290 m and 420 to 530 m. Its

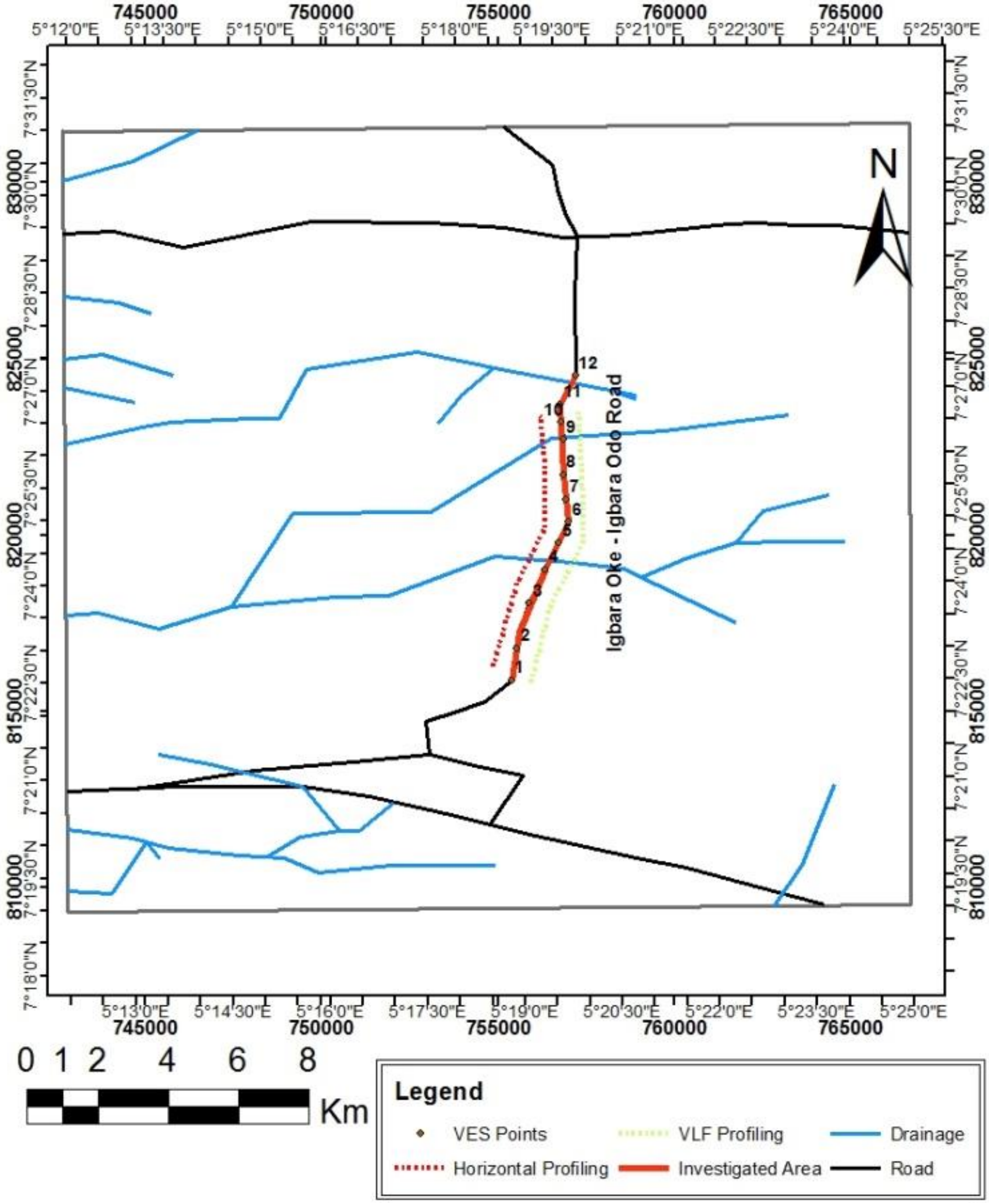
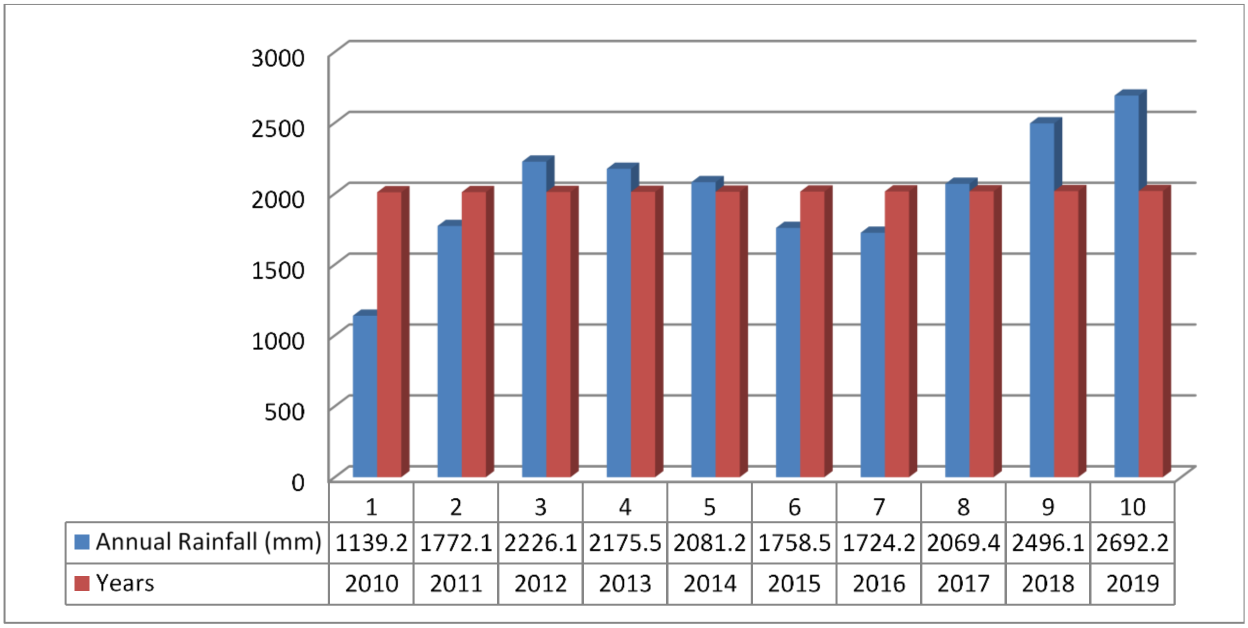


Figure 3. Data acquisition map of the study area.

constitute about 60% and majorly account for the reason why the soil integrity and the superficial geological material that constitute the founding materials are of doubtful integrity, aiding vulnerability to failure, coupled within the sudden rise in rainfall pattern and seasonal variations in global weather condition over the years, resulting in esteem temperature condition during dry season and unprecedented increase in rainfall pattern during the raining season, a trend that has rainfall dynamic in the last ten year probably as a result of green house effects and the depletion of ozone layer (Bawallah et al., 2019a).

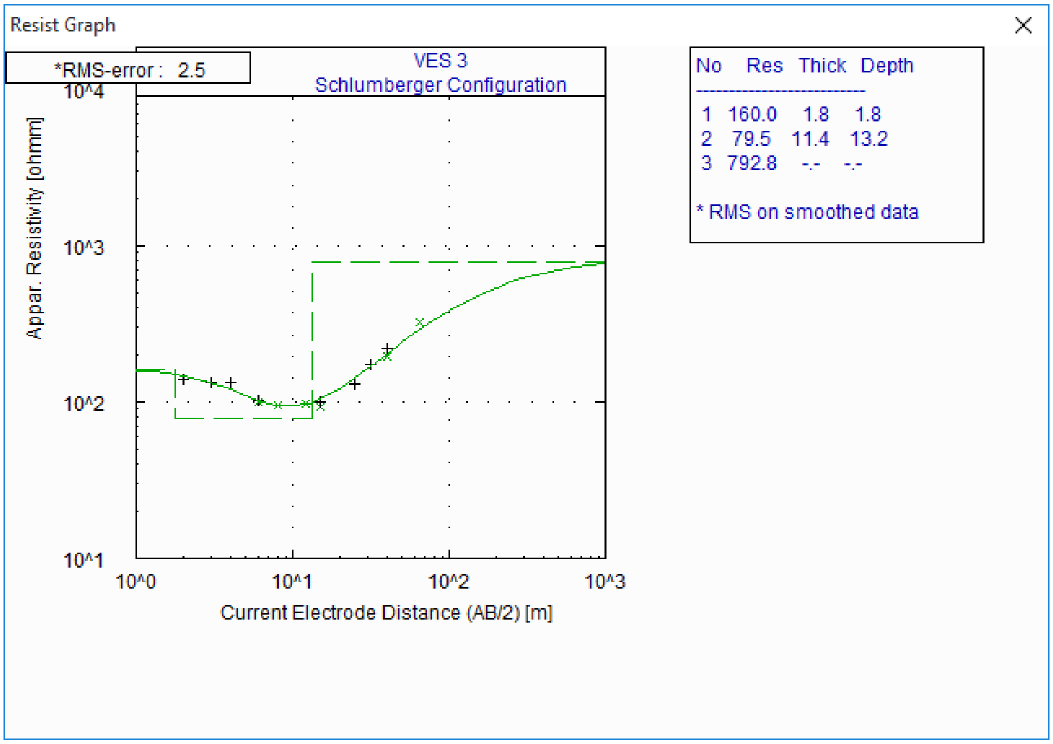
Wenner profiling

Figure 8 exhibit plot of apparent resistivity against station position using wenner array configuration where electrode



	1	2	3	4	5	6	7	8	9	10
🟦 Annual Rainfall (mm)	1139.2	1772.1	2226.1	2175.5	2081.2	1758.5	1724.2	2069.4	2496.1	2692.2
🟥 Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

Figure 4. Rainfall Distribution/trend in the last ten years.



*RMS-error : 2.5

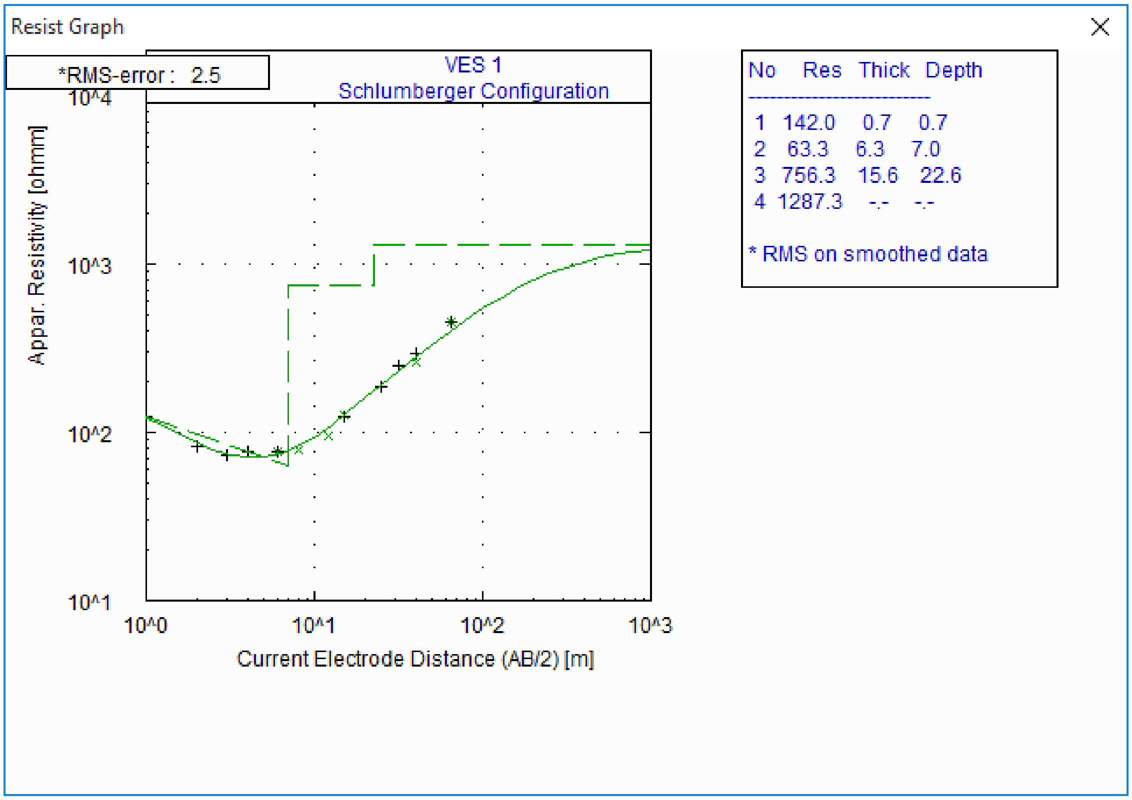
VES 3
Schlumberger Configuration

No	Res	Thick	Depth
1	160.0	1.8	1.8
2	79.5	11.4	13.2
3	792.8	-.-	-.-

* RMS on smoothed data

Figure 5a. Typical H sounding curve.

movement was 5 m and inter-electrode spacing of 10 m. This profile covers a distance of 600 m for better understanding of lateral variation in resistivity which gave a fair representation of the structural features and physical parameters. The resistivity distribution at 0.0 m could be described as moderately low and very low with the worst areas been located at distance between 20 to 60 m, 120 to 160 m, 200 to 240 m, 260 to 280 m and 420 to 460 m; the resistivity varies between 20 to 100 Ωm which was almost 30% in terms of materials distribution (Table 1).



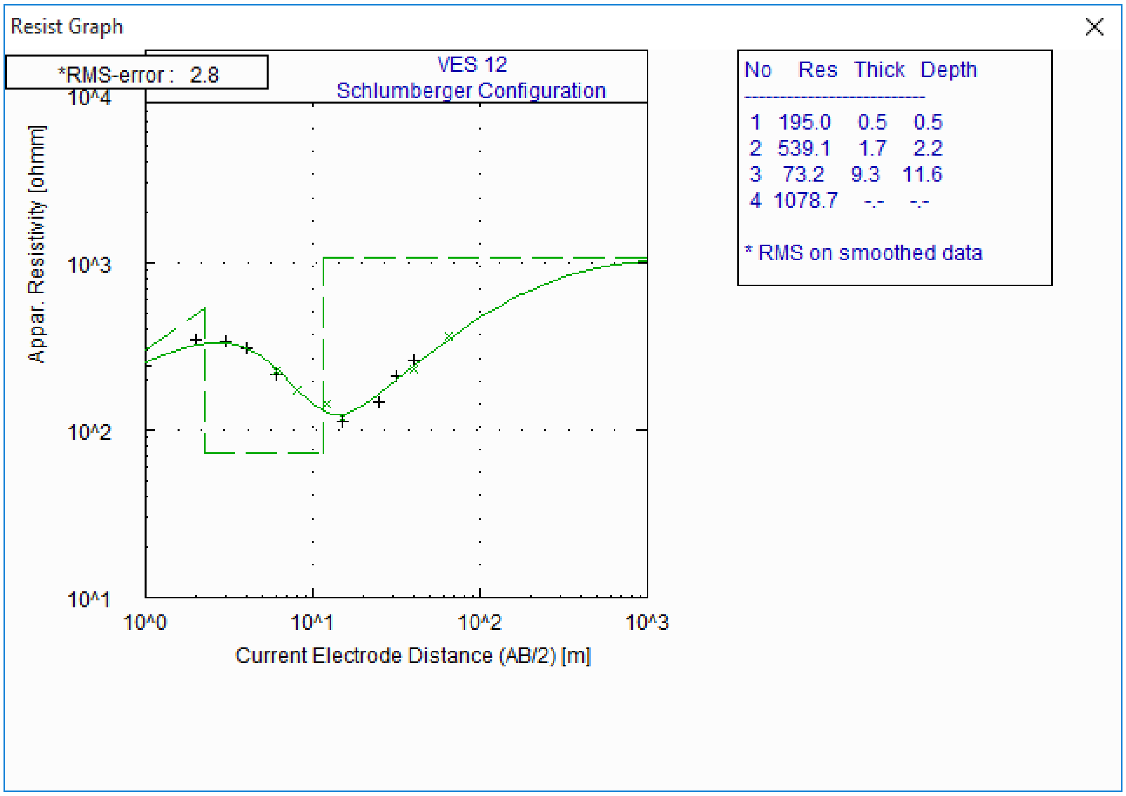
*RMS-error : 2.5

VES 1
Schlumberger Configuration

No	Res	Thick	Depth
1	142.0	0.7	0.7
2	63.3	6.3	7.0
3	756.3	15.6	22.6
4	1287.3	-.-	-.-

* RMS on smoothed data

Figure 5b. Typical HA sounding curve.



*RMS-error : 2.8

VES 12
Schlumberger Configuration

No	Res	Thick	Depth
1	195.0	0.5	0.5
2	539.1	1.7	2.2
3	73.2	9.3	11.6
4	1078.7	-.-	-.-

* RMS on smoothed data

Figure 5c. Typical KH sounding curve.

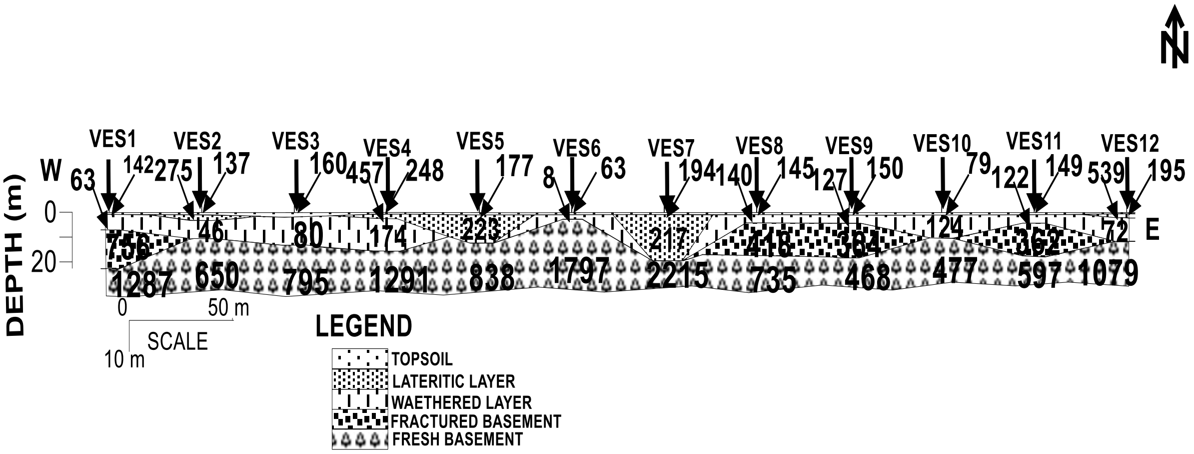


Figure 6. Geoelectric section along the investigated road.

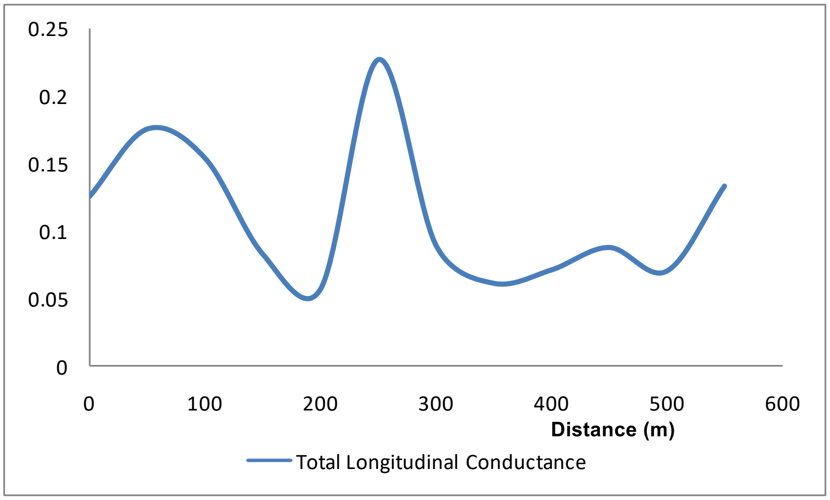


Figure 7. Total longitudinal conductance along the investigated road.

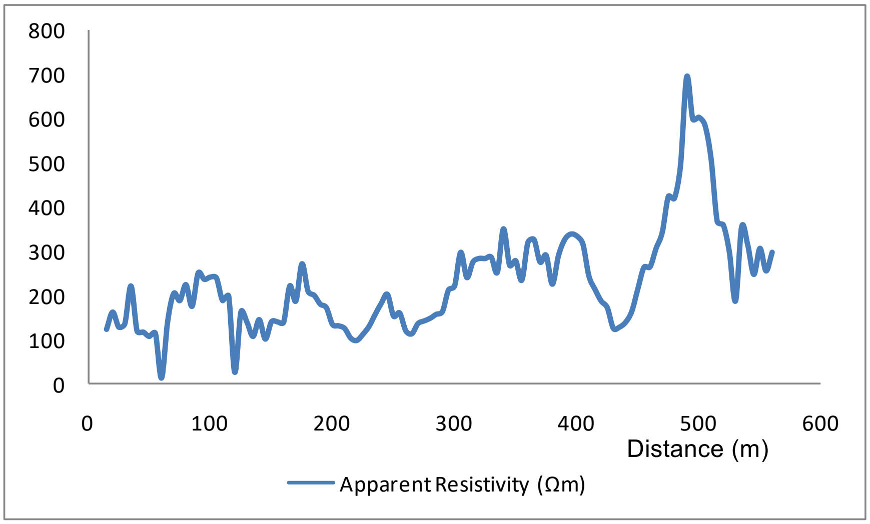


Figure 8. Horizontal profiling of the study area.

Table 1. Data distribution of resistivity parameters.

Resistivity value range (Ωm)	Lithologies	Number of points
0 - 50	Silt/clay	1
51 - 120	Sandy clay	10
121 - 170	Clayey sand	29
171 - 250	sand	30
251 - 350	Hard pan/Weathered/Fractured basement	26
351 and above	Fresh basement	13

Number of data point = 109.

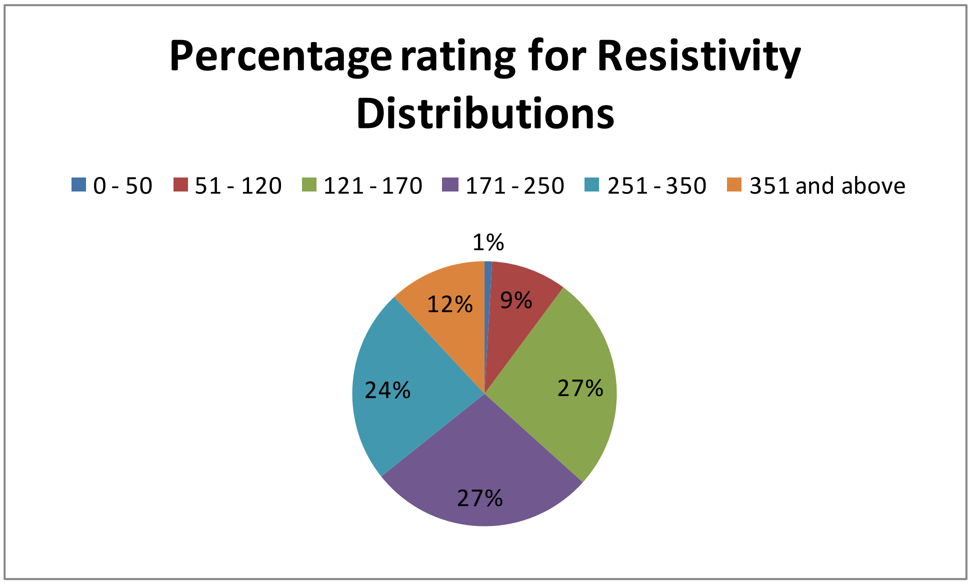


Figure 9. Percentage rating for resistivity distribution of the study area.

Furthermore, the moderately low regions are located between zero to 30 m, 80 to 120 m, 170 to 190 m, 300 to 410 m; with resistivity ranging between 150 to 250 Ωm, and this account for about 33.3% of the material distributions in the study area. While the rest of the materials distribution has apparent resistivity values range from 255 to 750 Ωm and percentage rate of resistivity distribution (Figure 9). Therefore, the combined effect of very low resistivity materials when combined with moderately low resistivity material has an overwhelming and over siding effect on the high resistivity materials within study area. Along with the seasonal variations and the gradual global weather changes responsible for the sudden changes in rainfall pattern within the last few years (Figure 3), may be majorly accountable for the apparently vulnerability of the road to incessant failures that has brought about its rehabilitation for three times within the last ten years. The pattern also reflects the general nature of the materials within the study area when viewed against the background of its conductivity. The percentage rating for failure index (A) and stability index (B) was calculated to get the vulnerability factor of 1.54 (Table 2). Therefore, for any road to be stable, vulnerability or stability factor A/B must be less than or equal to one (≤ 1). The conductivity profile (Figure 10) clearly demonstrate that the study area is generally conductive, reflecting on the weak nature of the near surface material apparently occurring throughout the study area.

Data point range responsible for failure is A, B, C, and E

Data point range responsible for stability is D and F

Therefore, failure index = A

A is addition of all the percentage rating for failure index = 0.92 + 9.2 + 26.6 + 23.9 = 60.62%

Stability index = B

B is addition of all the percentage rating for stability index = 27.5 + 11.9 = 39.40%

Table 2. Data point distribution and percentage per data points.

S/N	Resistivity value range (Ωm)	Lithologies	Number of points	Percentage per data point	Percentage rating
A	0 - 50	Silt/clay	1	$\frac{1}{109}x\ 100$	0.92%
B	51 - 120	Sandy clay	10	$\frac{10}{109}x\ 100$	9.2%
C	121 - 170	Clayey sand	29	$\frac{29}{109}x\ 100$	26.6%
D	171 - 250	sand	30	$\frac{30}{109}x\ 100$	27.5%
E	251 - 350	Hard pan/Fractured basement	26	$\frac{26}{109}x\ 100$	23.9%
F	351 above	Fresh basement	13	$\frac{13}{109}x\ 100$	11.9%

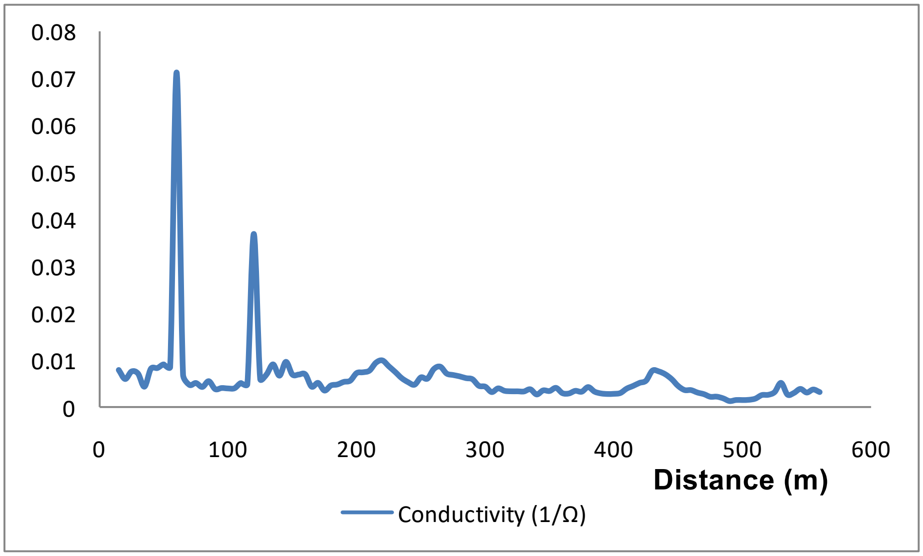


Figure 10. Conductivity profile of the study area.

However, vulnerability factor = A/B = 60.62/39.40 = 1.54%

Vulnerability factor = 1.54%

Therefore, for any road to be stable, vulnerability or stability factor A/B must be less than or equal to one (≤ 1).

VLF-EM profile

Figure 11 displays the Karous-Hjelt filter 2-D inversion current densityplots for the VLF-EM profile which provides a pictorial indication of various current concentrations and the spatial distribution of subsurface geologic features. The conductors are indicated by the positive current density distribution (green to red colour) and are interpreted as possible fractures beneath the subsurface. These suspected fractures are observed to be dipping in both northeast-southwest and northwest-southeast directions (shown as red coloured lines). The profile correlates effectively with the lateral resistivity profiling which justifiably explain the probable reasons for the vulnerability to failure. The greater part of the area was characterized by high conductivity/conductive zones, especially between the zero to 20 m, 60 to 80 m, 120 to 240 m and 280 to 550 m; implying that more than 65% of the area studied was dominated by weak/conductive zones while the rest of the study area account for the resistive zones (non conductive zone) of less than 35% (Figure 12). The percentage rating for failure index (A) and stability index (B) was calculated to get the vulnerability factor of 1.12 (Table 3). Therefore, for any road to be stable, vulnerability or stability factor A/B must be less than or equal to one (≤ 1). This no doubt is a major reason

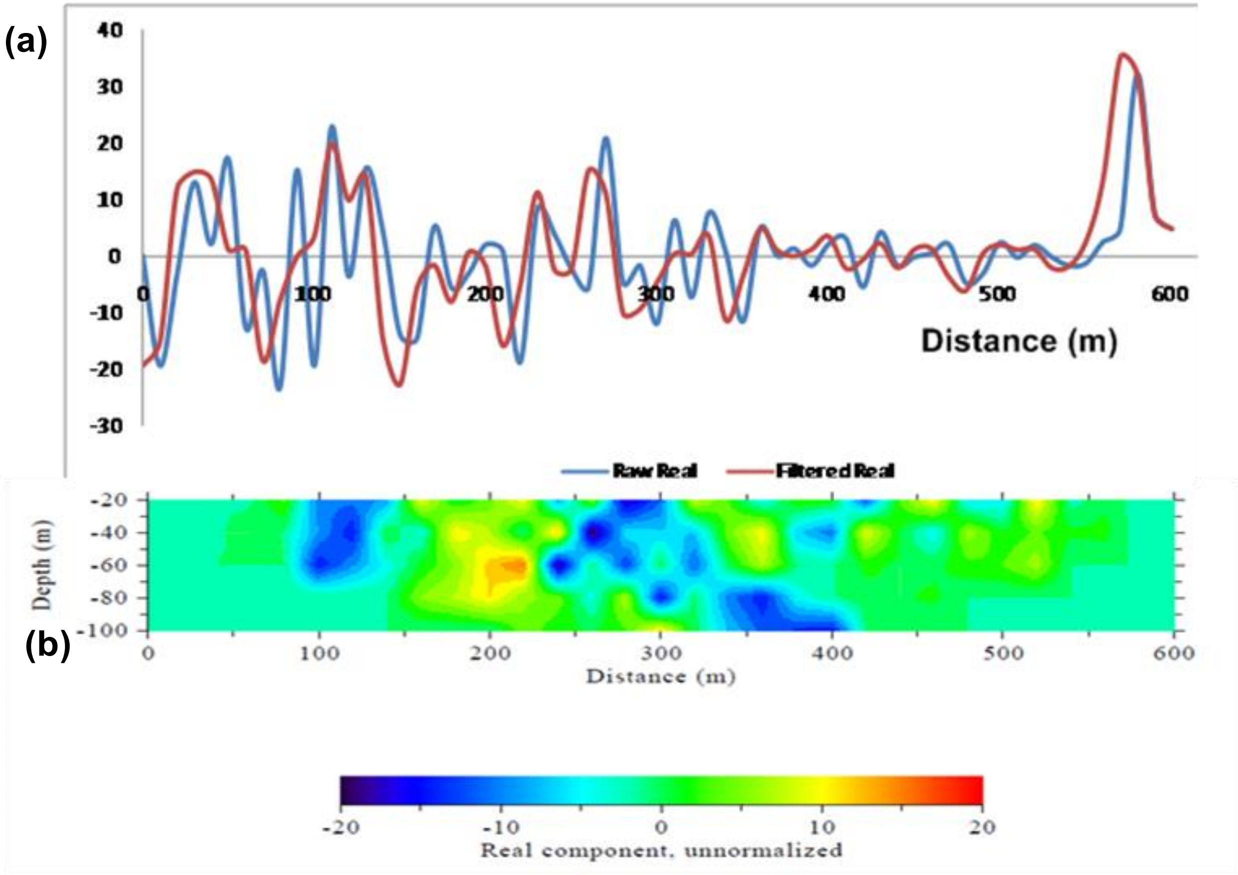


Figure 11. VLF-EM profiles along failed road traverse (a) Raw Real Vs Q-Factor, (b) 2D Inverted model.

accountable for the vulnerability of the study area to failure.

Data point range responsible for failure is A, B, C, D, E and F

Data point range responsible for stability is G, H, I, J, K and L

Therefore, failure index = A

A is addition of all the percentage rating for failure index = 21.5 + 12.9 + 6.6 + 1.7 + 1.3 + 8.9 = 52.9%

Stability index = B

B is addition of all the percentage rating for stability index = 16.2 + 10.9 + 6.6 + 4.0 + 2.7 + 6.6 = 47%

However, vulnerability factor = A/B = 52.9/47 = 1.54%

Vulnerability factor = 1.12%

Therefore, for any road to be stable, vulnerability or stability factor A/B must be less than or equal to one (≤ 1).

Synthesis of geophysical results

Figure 13 displays the correlation of results obtained from the geophysical techniques. The Wenner profiling displays that the resistivity of the geologic material is generally low, especially from the origin to about 450 m with resistivity ranging between 20 to 150 Ωm is an indication that the subsurface materials is generally weak in nature as a result of clay material constituting a major component of the formation within the studied area. The total longitudinal conductance is very high showing a reflection on the heavy presence of clay material as major/dominant geologic materials that characterized almost the entire investigated area with value ranges from 0.08 to 0.24 with a minima deviation at between 450 to 600 m, which also correlated with the lateral resistivity profile. The VLF-EM profile also showed effective correlation with the Wenner profiling. The result obtained clearly demonstrates that the entire investigated area is characterized by low conductive materials to highly conductive geologic materials. It has a value ranging from 1% to high as 24%, indicative of heavy presence of clayey/weak geologic materials as major components of the geologic formations making up the study location. A similar situation also obtained from the

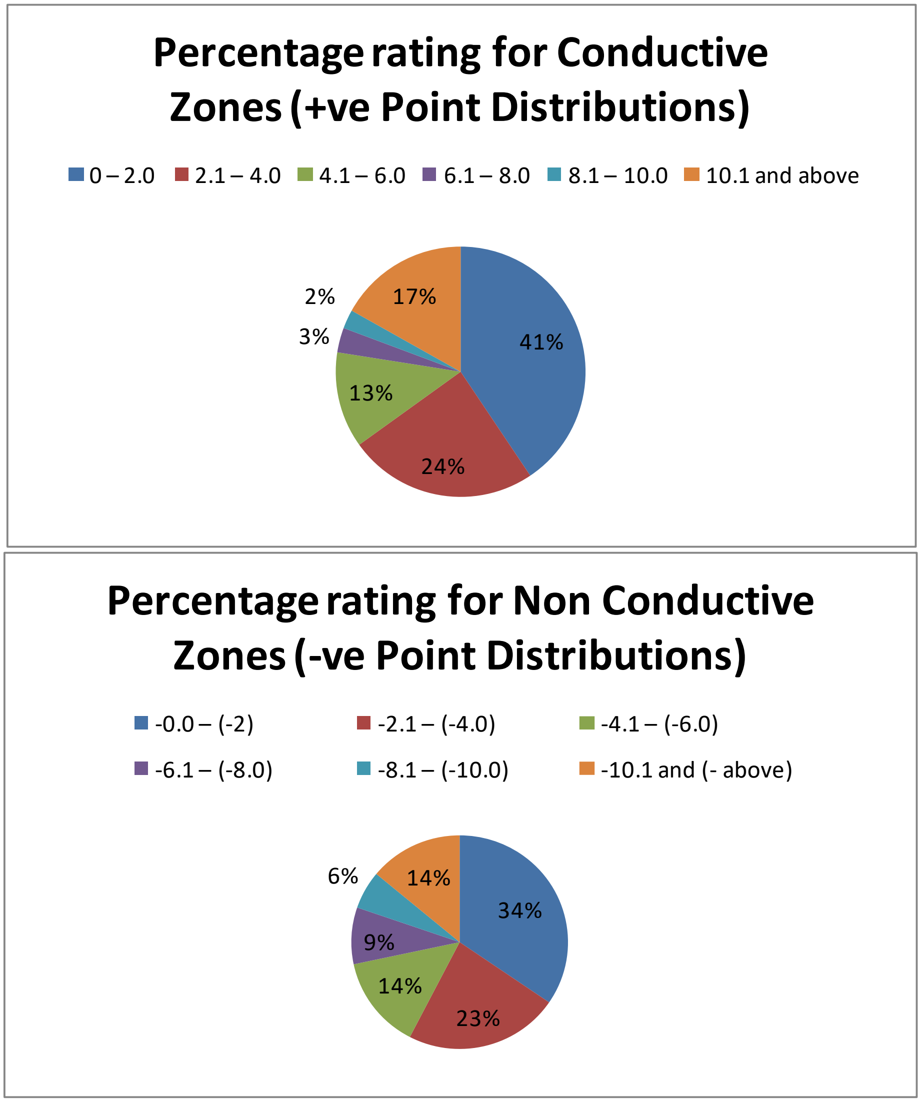


Figure 12. Percentage rating for conductive and non conductive zone distribution of the study area.

Vertical Electrical Sounding (VES) results. The integrated results of geophysical investigations have enabled the development of the road failure vulnerability section of the studied road. The road segments are categorized into four zones of vulnerability to failure. These zones are high, high/moderate, moderate and low vulnerability zones (Figure 14). It is estimated that about 35% of the road segments is rated to be of high/moderate vulnerability and 35 % of the section has moderate vulnerability.15 % each of the segments are rated to be of high and low vulnerability.

Comparing of different types of road with vulnerability section

Proposed different types of roads vis-à-vis; earth and gravel, soil stabilized**,** water bound macadam, bituminous or black top and cement concrete roads to be overlay on these investigated areas. Earth and gravel roads will not last a test of time because they are built without any sub-grade preparation and generally washed out in rainy season. Soil stabilized roads are also built the same way as earth roads or gravel roads but the sub-grade soil is generally compacted which in turns stabilizes the road under heavy loads but is not mostly used in the recent ages. Also, in the tar road, bitumen plays an important role to create a bond between the aggregate. But tar road does not give more strength than concrete road, because bitumen responds to heat and water. Furthermore, concrete road has more life than tar road. However, the initial cost of concrete road is higher than tar road. Moreover, concrete road is highly recommended

Table 3. Data point distribution and percentage per data points.

S/N	Conductivity +ve value range (Ω^{-1})	Lithologies	Number of points	Percentage per data point	Percentage rating
A	0 – 2.0	Coarse sand	65	$\frac{65}{302} x\ 100$	21.5%
B	2.1 – 4.0	Fine sand	39	$\frac{39}{302} x\ 100$	12.9%
C	4.1 – 6.0	Clayey sand	20	$\frac{20}{302} x\ 100$	6.6%
D	6.1 – 8.0	Sandy clay	5	$\frac{5}{302} x\ 100$	1.7%
E	8.1 – 10.0	Clay	4	$\frac{4}{302} x\ 100$	1.3%
F	10.1 and above	Silt/plastic clay	27	$\frac{27}{302} x\ 100$	8.9%
	Conductivity -ve value range (Ω^{-1})	**Lithologies**	**Number of points**	**Percentage per data point**	**Percentage rate**
G	-0.0 – (-2)	Coarse sand/fine sand	49	$\frac{49}{302} x\ 100$	16.2%
H	-2.1 – (-4.0)	Coarse sand	33	$\frac{33}{302} x\ 100$	10.9%
I	-4.1 – (-6.0)	Sand	20	$\frac{20}{302} x\ 100$	6.6%
J	-6.1 – (-8.0)	Weathered material/resistive sand	12	$\frac{12}{302} x\ 100$	4.0%
K	-8.1 – (-10.0)	Weathered Basement	8	$\frac{8}{302} x\ 100$	2.7%
L	-10.1 and (- above)	Fresh Basement	60	$\frac{60}{302} x\ 100$	6.6%

within this investigated area due to high durability but the region for high, high/moderate and moderate vulnerability must be put into cognizance against the background of the clayey nature of the surface material, dynamic of rainfall pattern and variations resulting from ozone layer depletion and other associated geodynamics activities (Figure 15). Because clay is a natural material composed primarily of fine-grain minerals. It consists of tiny particles that have plastic and adhesive properties. It also possesses small voids and pores, so it is capable of retaining water. In this condition, it tends to expand and shrink, which can lead to settlement. When exposed to increments of water, clay tends to soften and liquefy. It also causes difficulties in construction with its low strength and stiffness. This has caused serious problems in road construction because weak soil may cause damage to the cracks along the road pavement (Bawallah et al., 2019b).

Conclusion

This research work has been able to establish the factors responsible for foundation and road vulnerability to failure were not only limited or restricted to geological factors alone, but rather environmental factors and geodynamics activities resulting into sudden changes in trend/rise in rainfall pattern, as is the case in the last ten years within the investigated area. All of which are major factors to be seriously considered in any foundation or road construction work. Therefore, the future of foundation studies may not be complete without giving necessary consideration to geodynamics activities, especially, as it affects sudden changes in rainfall pattern. The era of construction, continuous reworking and rehabilitation which is the order of the day in this part of the world should be considered for a change of attitude towards a durable and sustainable foundation of structures and roads. Therefore, it is recommended that the geodynamics activities should be considered as a major factor in recommending type of foundation especially road. In this study area, concrete road is hereby recommended as a lasting solution to contend with the effects of geodynamics activities leading to variation and drastic changes in rainfall trends. Hence, due to the rapid growth and development of infrastructures facilities in Nigeria, it is imperative to

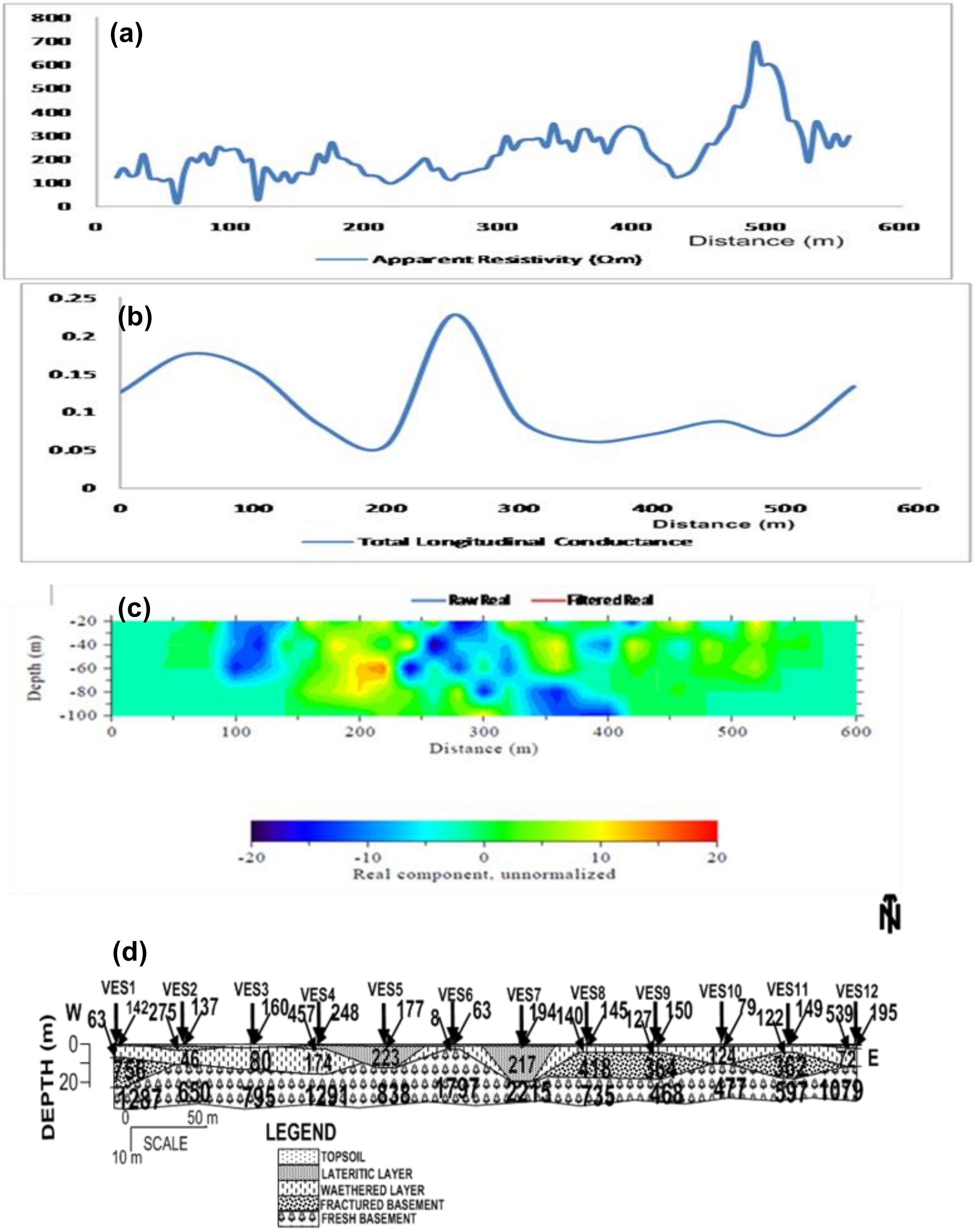


Figure 13. Correlation of the (a) Horizontal Profiling, (b) Total Longitudinal Conductance (c) K-H pseudo section and (d) geo electric section along the proposed road.

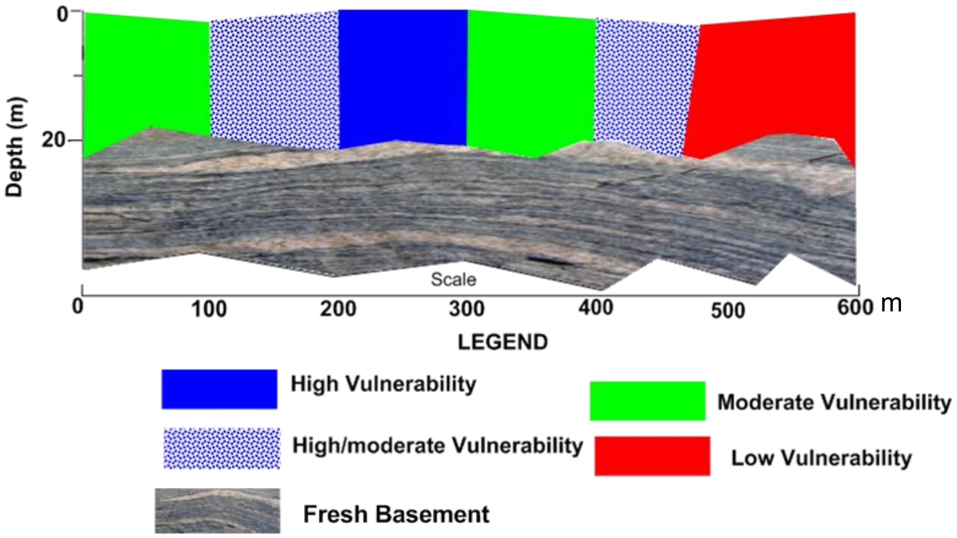


Figure 14. Road vulnerability section for the investigated area.

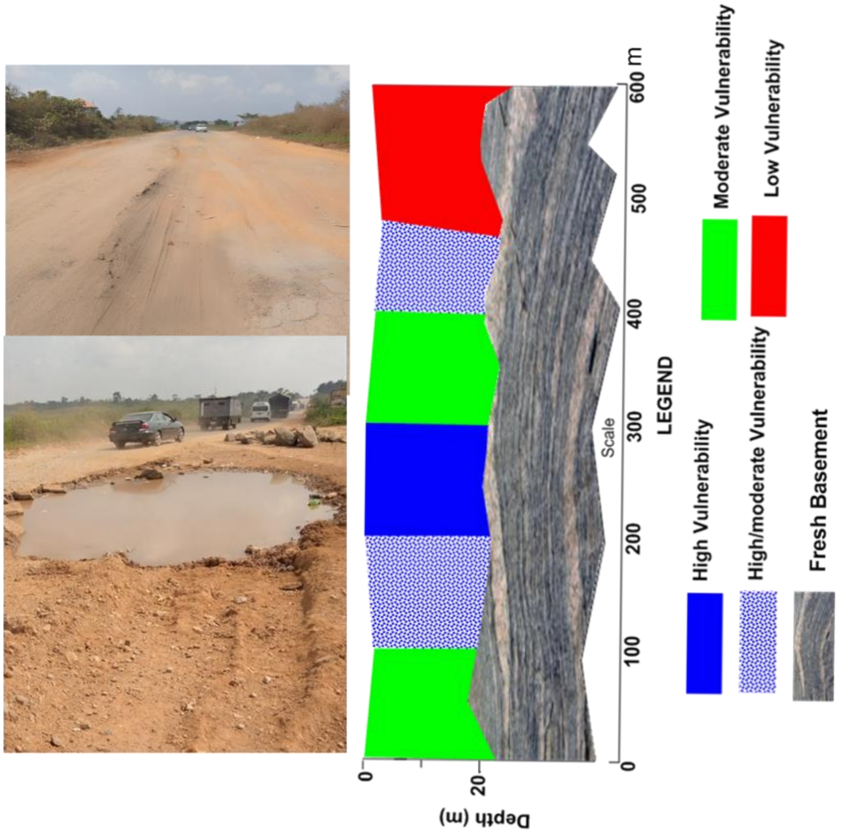


Figure 15. Fail segment on road vulnerability section of the study area.

construct base on a sound understanding of all the contending parameters that will prevent vulnerability, ensure as well as enhance sustainability of our structures especially roads.

CONFLICT OF INTEREST

The authors confirm that the data supporting the findings of the study are available within the article and its suppletary materials. Authors have declared that no competing interests exist and the data was not use as an avenue for any litigation but for the advancement of knowledge.

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