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Application of Electrical Resistivity Method in Designing a Structural Model for a Proposed Filling Station Site, Akure, Southwestern Nigeria

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Keywords: subsurface characterization, structural model, filling station.

I. Introduction

Due to the high quest for power and fuel, construction of filling station has become the business of the day especially in a fast developing city like Akure, Southwest, Nigeria. The building of filling station is the final stage on the Exploration & Production (E&P) cycle. This structure has both positive and negative impact on the society and its proposed location.

Positive impacts of the development of a fuel service station and convenience store at this location are likely to include the injection of spending into the local economy, the creation of jobs and the value of increased convenience and efficiency. These likely impacts are examined by investigating three key economic indicators– namely, gross domestic product (GDP), employee remuneration and job creation. The negative impacts are the after effects it leaves on the society if not well controlled. Seepage and leakage of these products might get to the water table and therefore contaminate the aquifer. This can spread to the community and cause harm to the community. Most investigations are done after pollution to delineate the rate and extent of contaminant infiltration. This is done by various geophysical methods.

These effects and survey could be limited or eliminated if subsurface characterizations using geophysical methods are done before the construction is carried out. This subsurface characterization helps to know suitable soil that is less corrosive, the flow of ground water and competent layer for super structure if need be. This helps in the planning of the filling station, to reduce or eliminate threats to the community. Various geophysical methods has been used in recent past to characterize the subsurface (Ayolabi, et.al., 2009; Bale, et.al., 2010; Oyedele, et.al., 2011; Bayode, et.al., 2012; Eluyemi, et.al., 2012, Adeyemo and Omosuyi, 2012; Adelusi, et.al., 2013; Adelusi, et.al., 2014) . Al-Garni (2010) used magnetic method to delineate the subsurface structure and depth to source rock. This research work is targeted at using the electrical resistivity method in characterizing the subsurface and subsequently generate a plan for the proposed filling station.

II. Site Description, Topography, Climate and Vegetation

The study area is located at Adebowale gas junction along Ilesha road, in Akure south local government area of Ondo State, Southwestern Nigeria. It lies on Northings N804960-N804915 and Eastings E739080-E739040 of the universal transverse Mercator (UTM). The study area is readily accessible through Oba-Adesida road, Akure (Figure 1).

Topographic elevation values ranges from 356m-361m above the sea level. The study area is located sub-equatorial climatic belt of the tropical rain-forest with evergreen and broad-leaved trees and with luxuriant growth layer arrangement (Balogun, 2003). The area is characterized by uniform high temperature and heavy, well distributed rainfall throughout the year. The

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average annual temperature ranges between 24°C and 27°C, while the annual rainfall is mostly conventional, peak twice in July and September and varies between 1500mm and 2000mm per annum (Balogun, 2003).

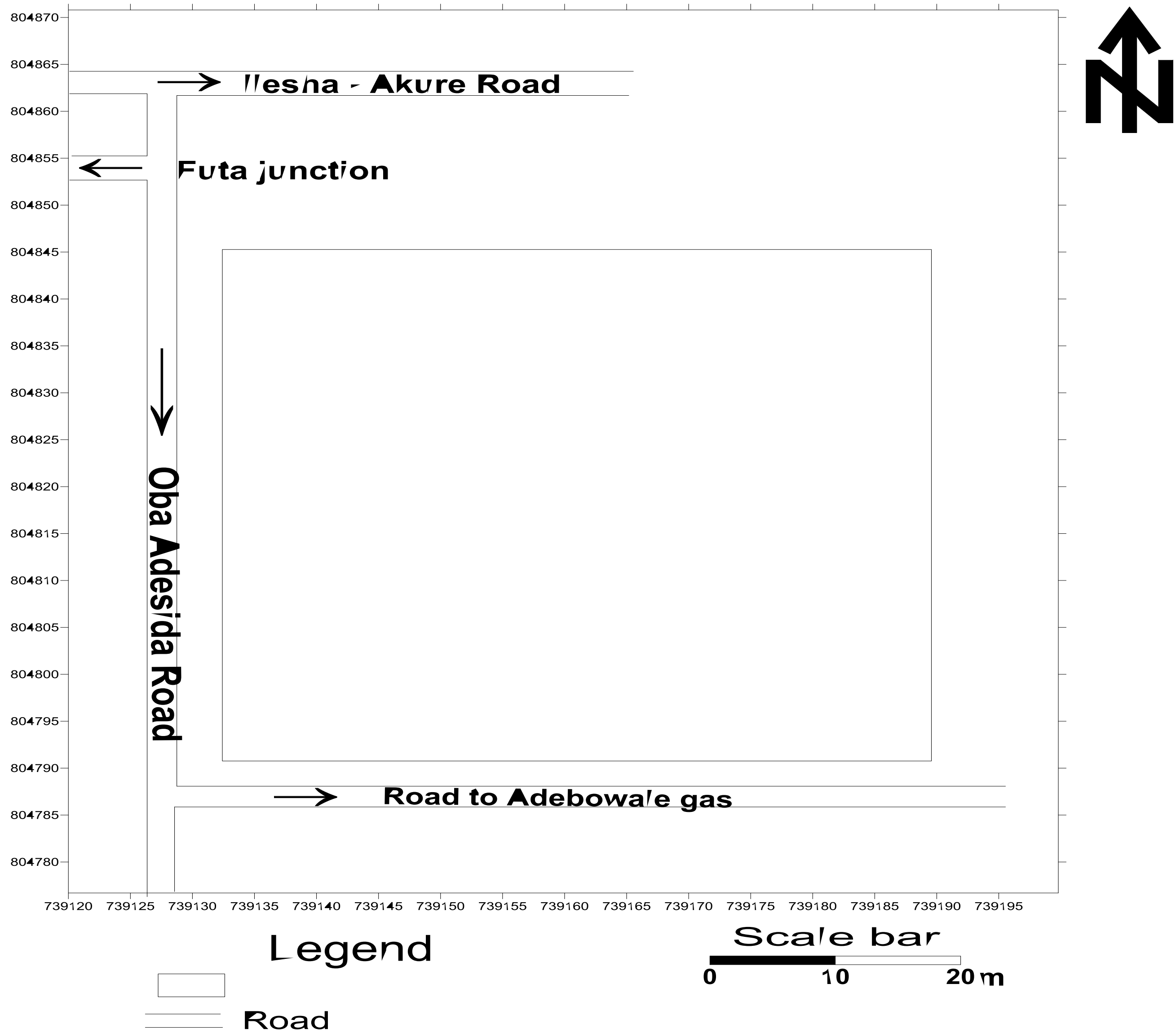

Figure 1: Base Map of the Study Area

III. Geologic Setting

The study area is located within the crystalline basement complex terrain of southwestern Nigeria (Figure 2). The area is generally underlain by basement rocks categorized by Rahaman (1976, 1989) as migmatite gneiss, quartzite, pelitic schist, biotite granite, charnockite, granite gneiss and porphyritic granites. There are no visible crystalline rock outcrops in the study area. The area is covered by reddish-brown lateritic clay.

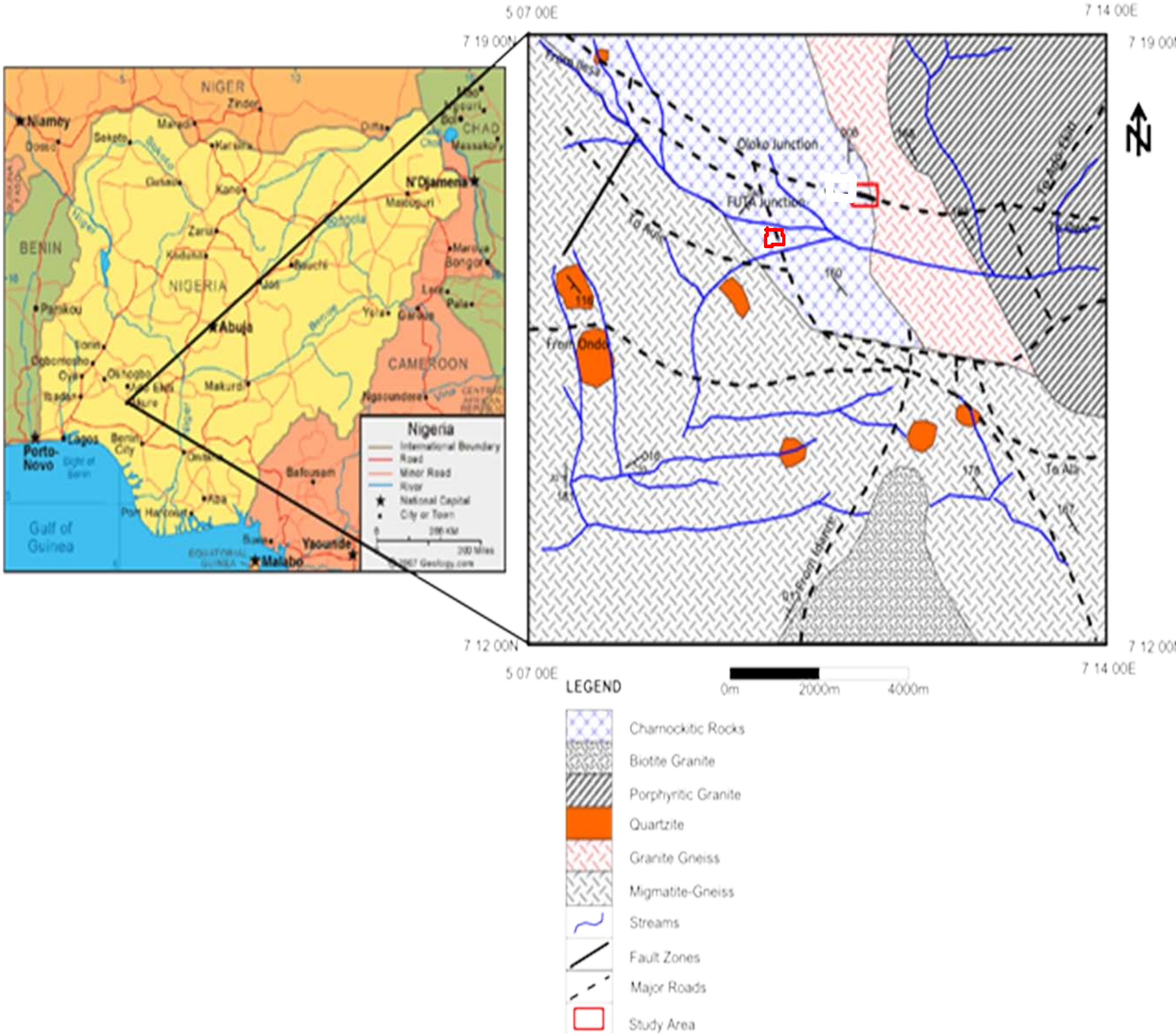

Figure 2: Simplified geological map of Akure, showing the study area (Modified after Owoyemi, 1996), Left: Administrative map of Nigeria

IV. Materials and Methods

Ohmega resistivity meter was employed to acquire the data in the study area. Electrical resistivity techniques adopted are the vertical electrical sounding (VES) using the Schlumberger configuration and the combine Horizontal Profiling (HP) and VES using the Dipole-Dipole Configuration. Vertical electrical sounding (VES) survey is a measure of variation of electrical resistivity with depth. This is achieved by a gradual increase in the current electrode spacing about a fixed center of electrode spread. Dipole – Dipole resistivity profiling technique was also adopted in the research to determine the lateral and vertical variation in ground apparent resistivity beneath each specific traverse lines. The study area with a coverage of 45m X 40m (1800m^2) was gridded and Dipole-Dipole traverse lines were established along five (5) traverses in the N-S direction. Twenty five (25) Vertical Electrical Sounding (VES) points were occupied across the study area with five VES points occupied on each of the traverse at 9m interval(Figure 3). Electrode spacing of a=5 with n ranging from 1-5 was adopted for the dipole-dipole configuration while VES electrode spacing (AB/2) was varied from 1-100m. The location of each of the sounding was taken in Universal Transverse Mercator (UTM) coordinate system with the aid of the "GARMIN 12" channel personnel navigation Global Positioning System (GPS) unit.

The obtained VES data were quantitatively interpreted using partial curve matching and iteration modeling technique with the aid of Win Resist geophysical software (Patrax and Nath, 1998, Vander Velpen, 2004,). The apparent resistivity dipole-dipole data were inverted using DIPPRO SOFTWARE (DIPPRO^{TM} 4.0, 2000) which produced the field data pseudo section, theoretical data pseudo section and the 2-D resistivity structure images of the subsurface.

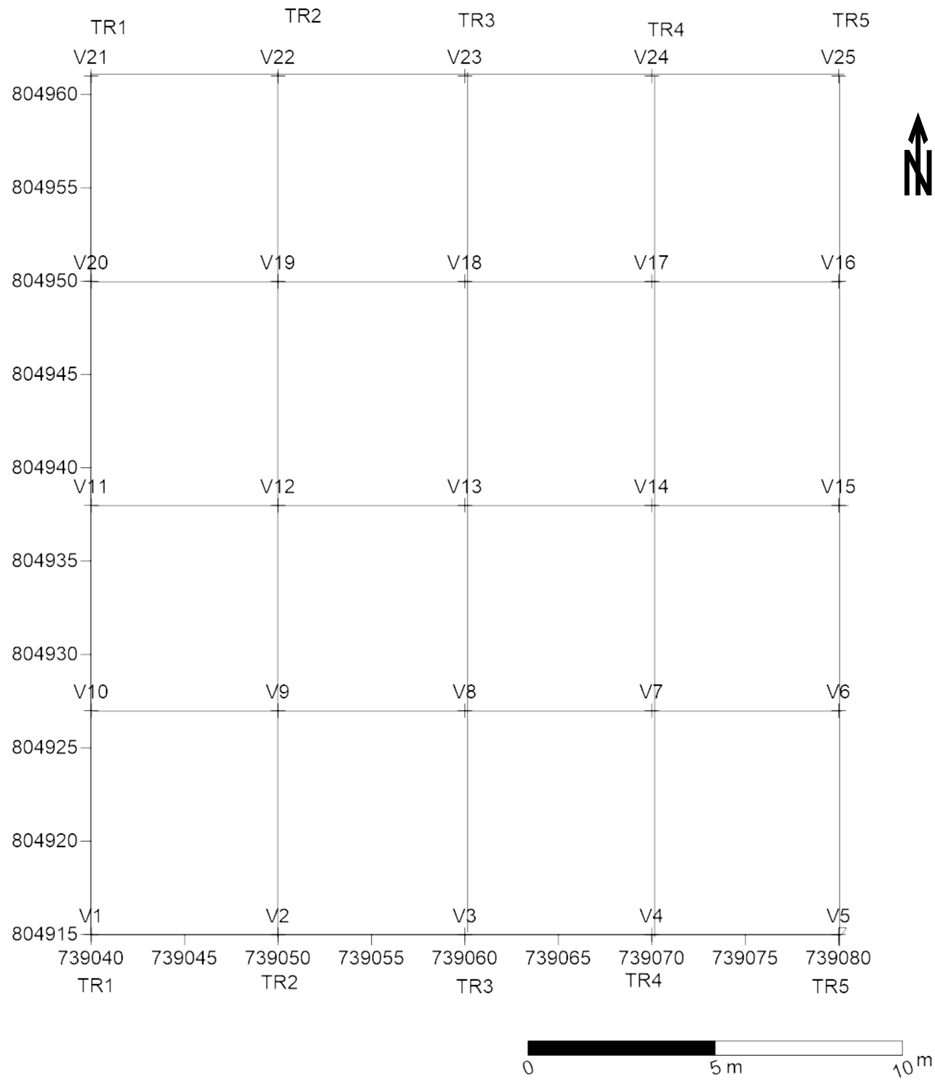

Figure 3: Data Acquisition Map of the Study Area

V. Results and Discussion

a) *Subsurface Characterization*

2-D Resistivity structure image produced from the Dipole-Dipole data were correlated with the geo-electric sections to characterize the sub-surface and identify suitable location for tank burial and competent layers for super structures and fuel pumps that will be erected on the proposed filling station site.

Figure 4 shows the 2-D resistivity structure along traverse 1 with resistivity ranging from 20 – 120 ohm-m which is generally low. Around 10m, the resistivity is relatively higher than the other points. This attribute suggest that the medium is highly weathered/Clayey and thus can store water because it is an impervious layer and with time lead to the corrosion of the tank. The geo-electric section shows that the area is characterized by four distinct geologic sequences namely; topsoil, weathered layer, partly weathered/fractured layer and a fresh basement. The resistivity of the top soil range from 22 – 46 ohm–m, for the weathered layer it ranges from 18 – 415 ohm – m, the partly weathered/fractured layer has a resistivity of range of 295 – 480 ohm – m and the fresh basement ranges from 2999 – 14856 ohm – m. For proper correlation, the 2-D resistivity structure imaging the depth up to 5m of the geo-electric section will be taken to consideration. Looking at the geo-electric section from VES 11 to VES 1, resistivity is very low which correspond to that of the 2-D resistivity structure image.

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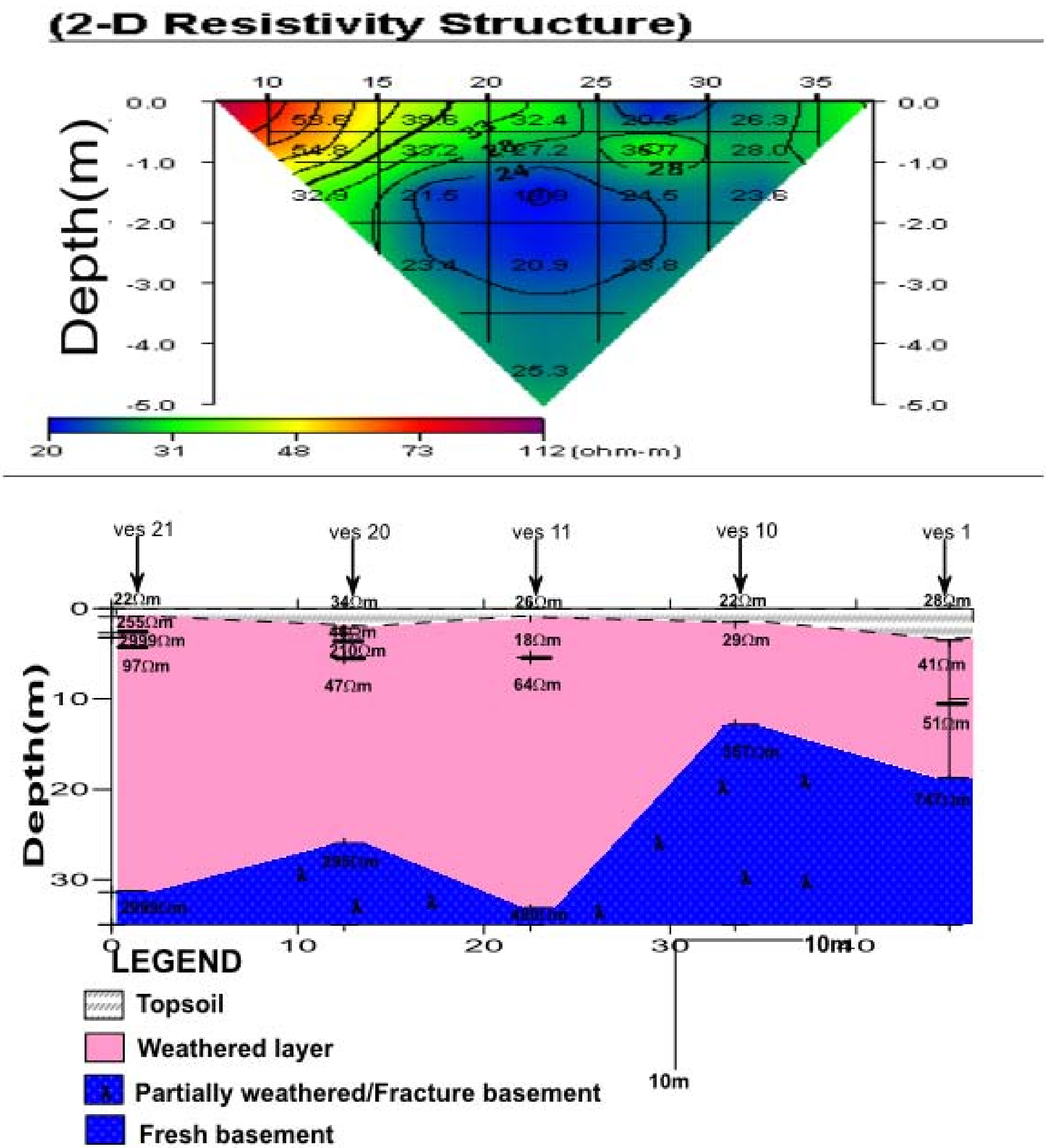

Figure 4: 2-D Resistivity Structures and Geo-Electric Section along Traverse 1

Figure 5 shows the 2-D resistivity structure along traverse 2 with resistivity value ranging from 19-123 ohm –m which is from very low to moderate resistivity. Around 10m, the resistivity is higher than the resistivity observed along the traverse. At about 1 – 2m deep around 15- 35 m, a very low resistivity was observed. The geo-electric section shows thin overburden from VES 12 – VES 2 and the overburden increases from VES 2 to VES 22. The top soil has resistivity ranging from 21– 28 ohm –m, the weathered layer have resistivity ranging from 12 – 496 ohm-m. The fresh basement lies between partly weathered/fractured layers with resistivity ranging from 2634 – 2325 ohm – m. At depth of 5m, resistivity decreases from VES 12 – VES 2 which correlate with the 2-D resistivity structure image of the subsurface. However, the medium having very low resistivity is very small in size.

Figure 6 shows the 2-D resistivity structure along traverse 3 with the resistivity values ranging from 29- 106 ohm – m which is of low resistivity throughout the traverse. Depth around 1 – 2m at distance 25 – 35m display very low resistivity. The geo-electric section shows that most points sounded has thin overburden apart from VES 13 and VES 3. VES 13 might be suitable for groundwater because it has a partly weathered/ fractured rock. The topsoil has resistivity ranging from 25 – 39 ohm – m, the weathered layer has resistivity values ranging from 28 – 600 ohm –m. The partly weathered / fractured rock was delineated in VES 23, VES 18, VES 13& VES 8.Resistivity in this medium ranges from 87 – 8793 ohm –m. At about 5m on the geo-electric section, VES 18, VES13 & VES 8 show relatively low resistivity in the medium which can be related to the 2-D resistivity image of the subsurface. The medium is of moderate resistivity.

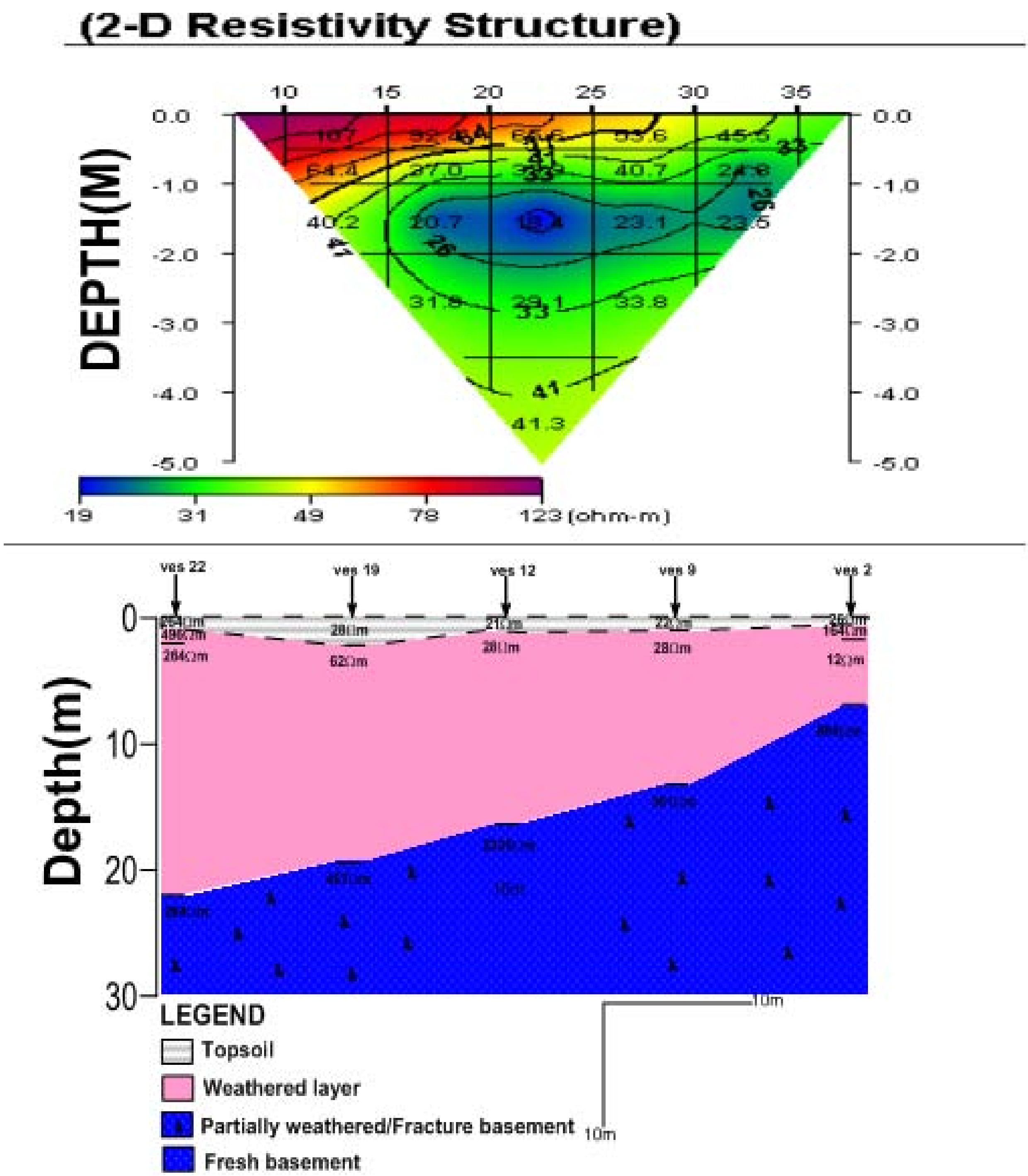

Figure 5: 2-D Resistivity Structure and Geo-Electric Section along Traverse 2

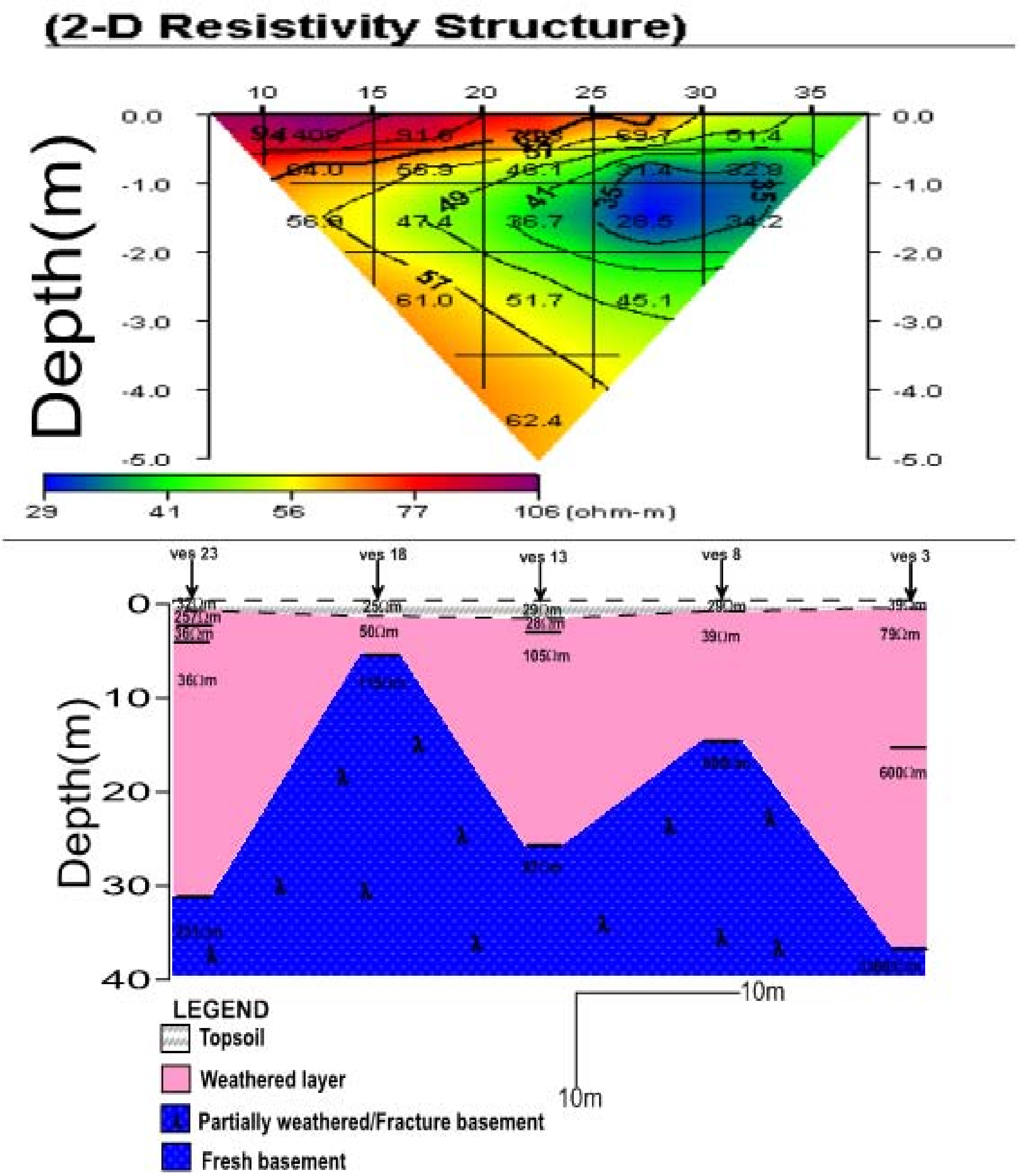

Figure 6: 2-D Resistivity Structures and Geo-Electric Section along Traverse 3

Figure 7 reveal the 2-D resistivity structure along traverse 4 with resistivity value ranging from about 49 – 195 ohm- m which indicates that the region contains areas of medium to relatively high resistivity values. From distance 0 – 35 m, relatively high resistivity values are present at depth of about 0 – 2.5m with the highest resistivity values of 195 ohm-m occurring around distance 10m. From depth of 2.5m downward, low resistivity medium was delineated. The presence of relatively high resistivity in an appreciable depth shows that the area/region is competent and can harbor engineering structure (building) and can be used for tank burial because water cannot be stored in this medium. The geo-electric section has an appreciable depth and thickness of overburden except for VES 24 which has thin overburden. Regions of thick overburden over a fractured layer shows possible zone for groundwater accumulation. At depth ranging from 1-5m moderate to high resistivity values were delineated around the VES stations. These high and moderate resistivity value shows that the region is competent and can sustain engineering structures (building).

Figure 8 shows the 2-D resistivity structure with resistivity ranging from 19 – 516 ohm – m which shows that resistivity is from very low to relatively high resistivity. High resistivity was present across the region at a depth of 0-2.5m. However, very low resistivity typical of weathered materials like clay or a fractured zone typifies the location at depth ranging from 2.5 – 5 m at distance between 10-25m. However, beyond 25m, the relatively high resistivity zones tend to continue with depth and thus suggesting a competent layer for engineering structure (building), and also for tank burial at that location. The geo-electric section shows that the topsoil has resistivity varying from 47 – 83 ohm –m, for the weathered layer the resistivity ranges from 28 – 439 ohm – m, the partly weathered/ fractured basement and fresh basement have resistivity ranging from 185 – 9578 ohm- m. Thin overburden were observed around VES16 and VES15 and appreciable overburden thickness for the other VES points. VES 25 will be preferable for groundwater development due to its relatively high overburden thickness and the delineation of a fracture basement. To correlate with the 2-D resistivity structures, we consider the information from 0-5m depth on the geo-electric section since the foundation will probably be within this zone. At 5m depth, the resistivity is relatively high which correlate with the 2-D resistivity structure image and proved that the area on the studied location is suitable for engineering structures (building).

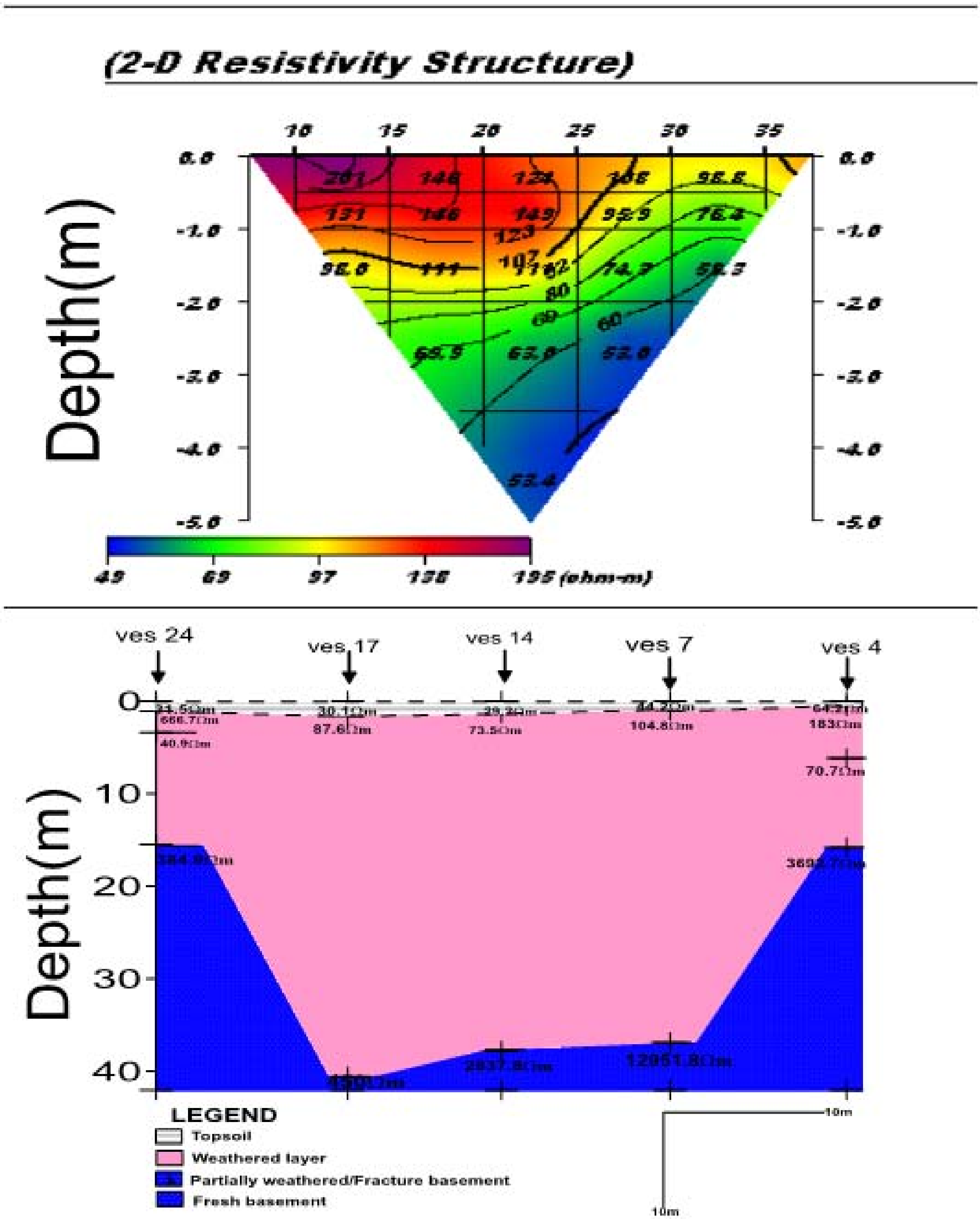

Figure 7: 2-D Resistivity Structures and Geo-Electric Section along Traverse 4

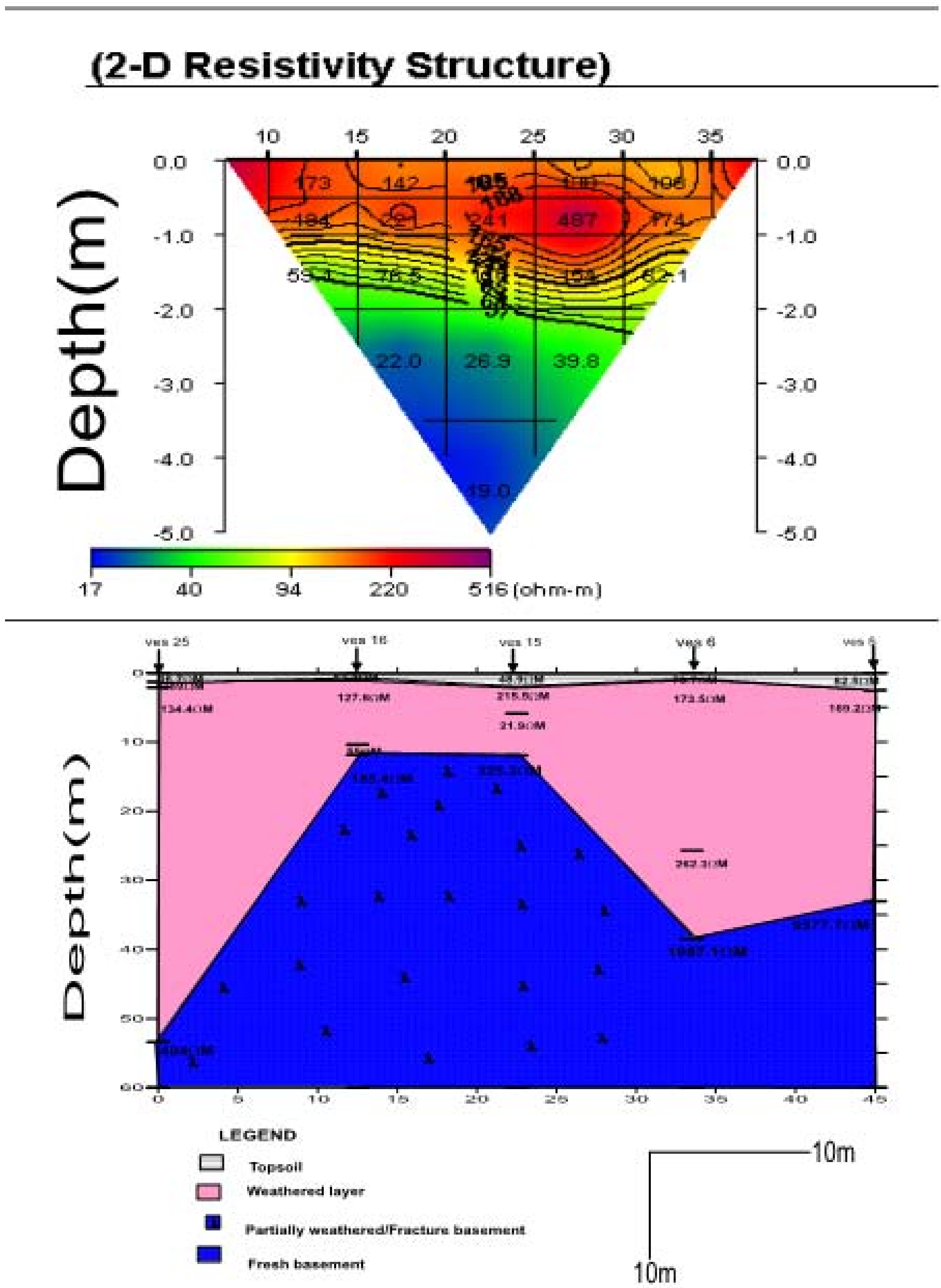

Figure 8: 2-D Resistivity Structures and Geo-Electric Section along Traverse 5

b) *Sounding Curves*

The curve type present in the area are KH, A, AKH, HK, HA. Curve type A is the dominant curve type occurring at about 50% of the studied location. Curve type KH having 32%. The summary of the geo-electric parameters are presented in Table 1.

c) *Groundwater Potential of the Study Area*

A total of 25 VES were occupied in the study location. Four (4) VES points namely VES 11, VES 13, VES 22 and VES 25 show good potential for groundwater development. VES 11 has relatively thick overburden and a partly weathered/fractured basement zone was delineated. However, due to the fact that VES 11 lies at the area suitable for tank burial, the point was not recommended for groundwater development. VES 13 also is a good point for groundwater accumulation with similar characteristics with VES 11 but it is located at the center of the area which could be used for pump unit for sales point. VES 22 is also a suitable point for groundwater accumulation, however it is also located along the possible exit route. VES 25 is the perfect location for possible groundwater development due to its relatively thick overburden, relatively low aquifer resistivity and a fractured basement. The location will also not obstruct zones suitable for building construction in the area. VES 25 has a KH curve type as shown in figure 9.

Table 1: Summary of VES Intepretation Results

VES NO	Resistivity (ohm – m)					Thickness (m)				Curve Types
	ρ1	ρ2	ρ3	ρ4	ρ5	h1	h2	h3	h4	
1	28.8	41.0	51.4	747.4		3.5	0.3	15.4		A
2	25.5	163.5	12.3	863.7		0.6	1.0	5.4		KH
3	39.9	79.3	599.8	8792.6		0.8	4.9	11.6		A
4	64.2	183.0	70.7	33692.7		0.5	5.7	9.6		KH
5	82.5	169.2	9577.7			2.5	30.6			A
6	70.7	173.5	262.3	1987.1		0.8	24.8	12.9		A
7	44.2	104.8	12951.8			1.0	35.8			A
8	29.4	39.3	684.8			1.1	13.7			A
9	21.9	27.8	361.0			1	12.4			A
10	22.5	29.2	366.9			1.5	11.5			A
11	25.8	18.1	63.7	479.9		0.7	4.7	28.1		HA
12	20.8	28.4	2325.4			1.1	15.5			A
13	28.8	27.5	105.4	86.6		1.7	1.4	23.0		HK
14	29.2	73.5	2837.8			1.3	36.6			A
15	48.9	215.5	21.9	325.3		1.9	4.1	6.0		KH
16	53.3	127.6	55	185.4		0.7	9.7	1.6		KH
17	30.1	87.6	450			1.6	39.6			A
18	24.6	49.7	114.8			1.6	4.0			A
19	27.5	62	497.4			2.2	35.5			A
20	33.8	45.5	209.7	47.4	295.2	2.2	0.6	2.6	20.6	AKH
21	21.7	254.5	415.2	96.8	2999.2	0.9	1.8	0.6	28.1	AKH
22	26.4	496.4	103.6	263.7		0.9	1.0	49.9`		KH
23	31.8	257.1	35.9	231.1		2.1	4.2	12.3		KH
24	31.5	666.7	40.9	384.9		1.1	2.3	12.0		KH
25	46.7	438.9	134.4	404.0		1.3	0.8	51.3		KH

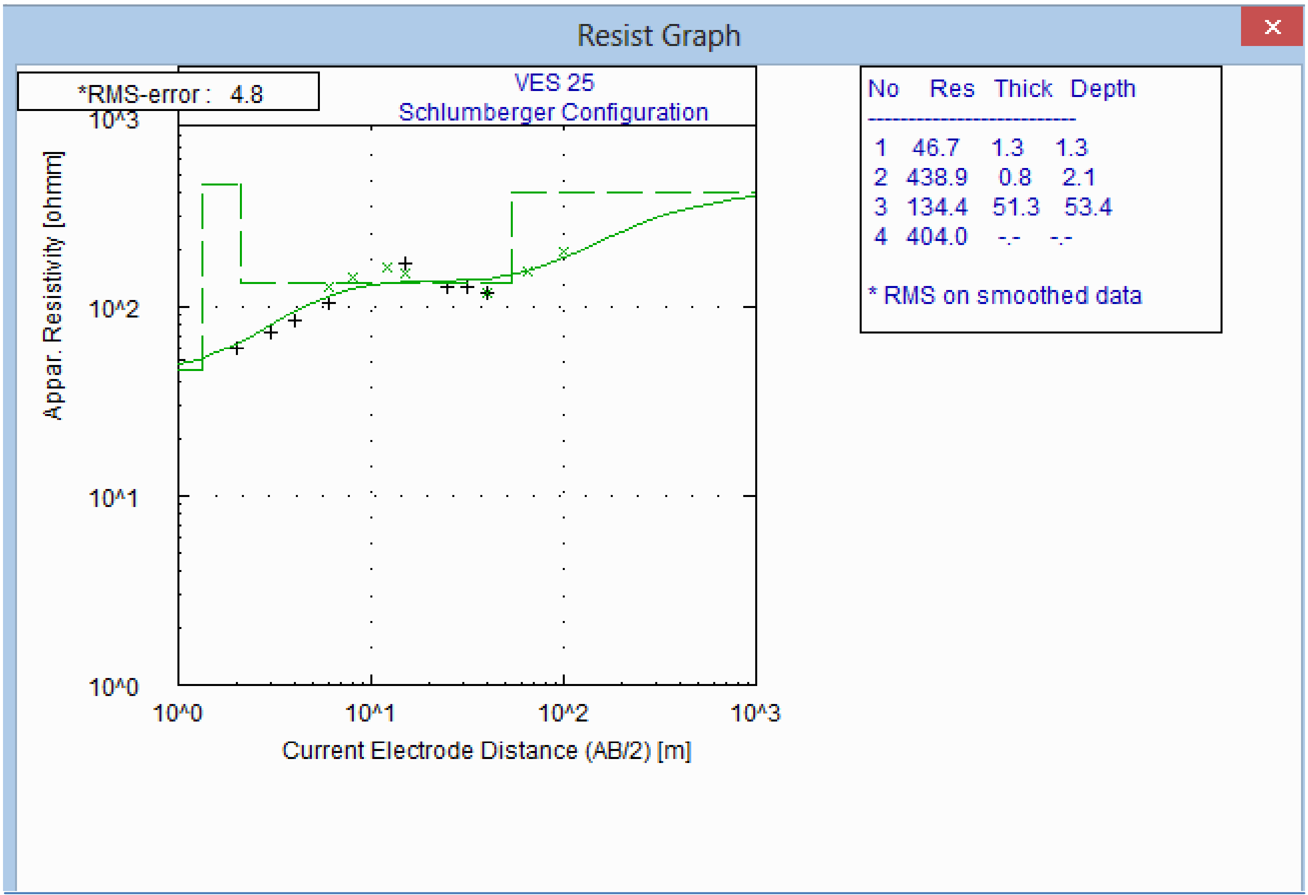

Figure 9: VES 25 With Typical KH Curve Type

d) *Isoresistivity Map of the Study Area*

Figure 10 shows the isoresistivity map of the second layer. The second layer was recognized as the area falling within the depth range suitable for shallow foundation within the study area. The area is predominantly characterized by low resistivity which is unfavorable to both engineering structure (buildings) and tank burial. Nevertheless, some area display relatively high resistivity which can sustain these structures. Relatively high resistivity in these area are in three (3) different locations around the north, northwest region and the last with relatively large area extent around edge of the east stretched down to the southeast edge of the area. These areas are going to be the suitable locations for the erection of buildings and also for the burial of tank. The borehole location as proposed by the VES is at the right top corner of the north east region. These information will guide in designing the model for the structural plan of the filling station.

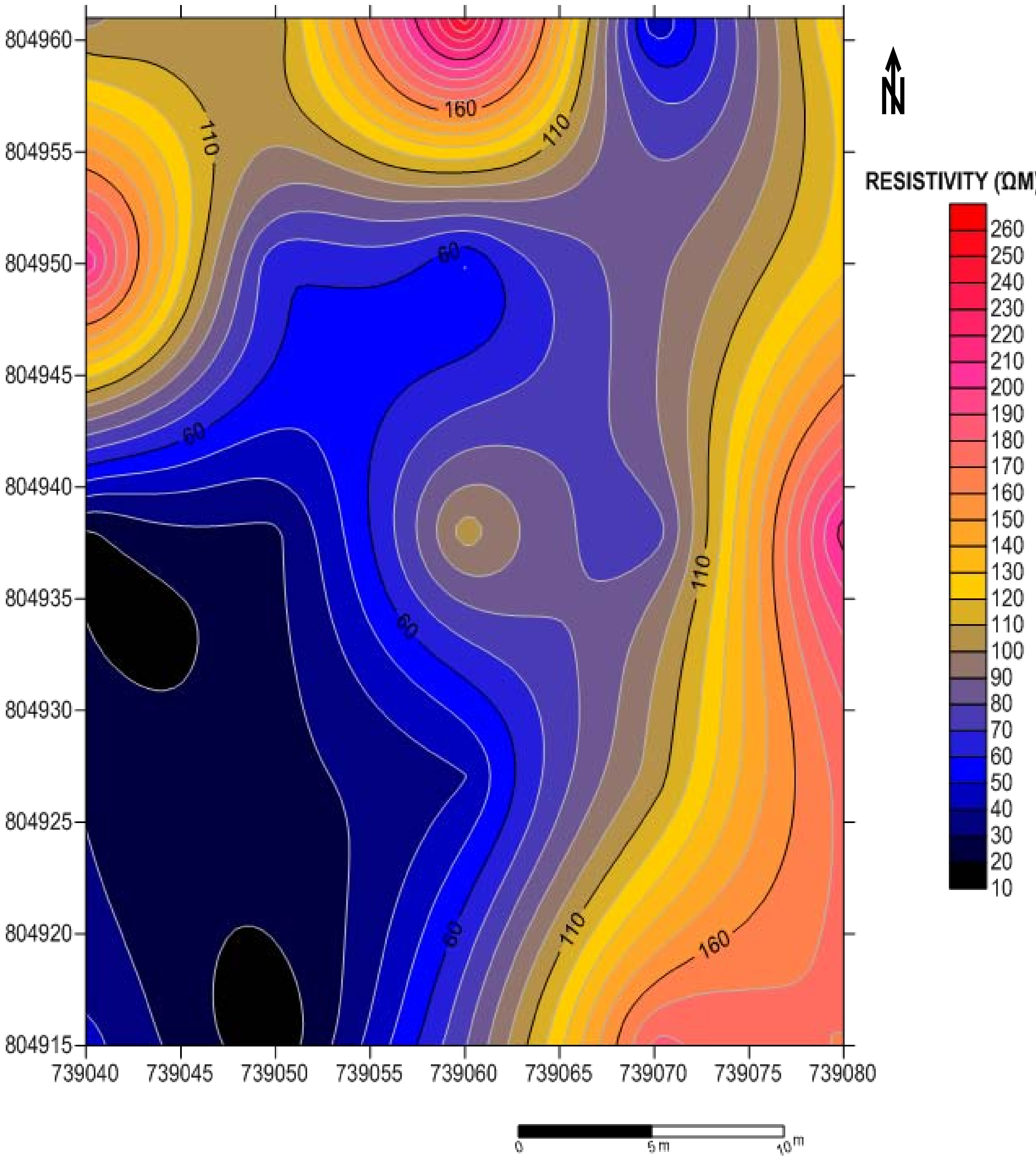

Figure 10: Isoresistivity Map of the Second Layer

e) Station Model

Due to the information obtained from the electrical resistivity survey and the isoresistivity map, Figure 11 shows the model and plan of the station. This will help tackle and minimize the threat or hazards that the filling station might face after development. The station has the tank burial point at the southwest location of the study area. This is due to the area being characterized by relatively high resistivity zone and thus resistant to corrossion. The petrol pump unit is proposed towards the center of the study area, it has the area competent for building streching from south east to north eastern part of the study area. The proposed location for groundwater development through borehole is at the extreme of the north eastern part of the study area. The kero unit is at the northern section while the disel is at at the western zone. The entry point is proposed to be at the southern section of the study area and finally exit point located at the north western part of the study area.

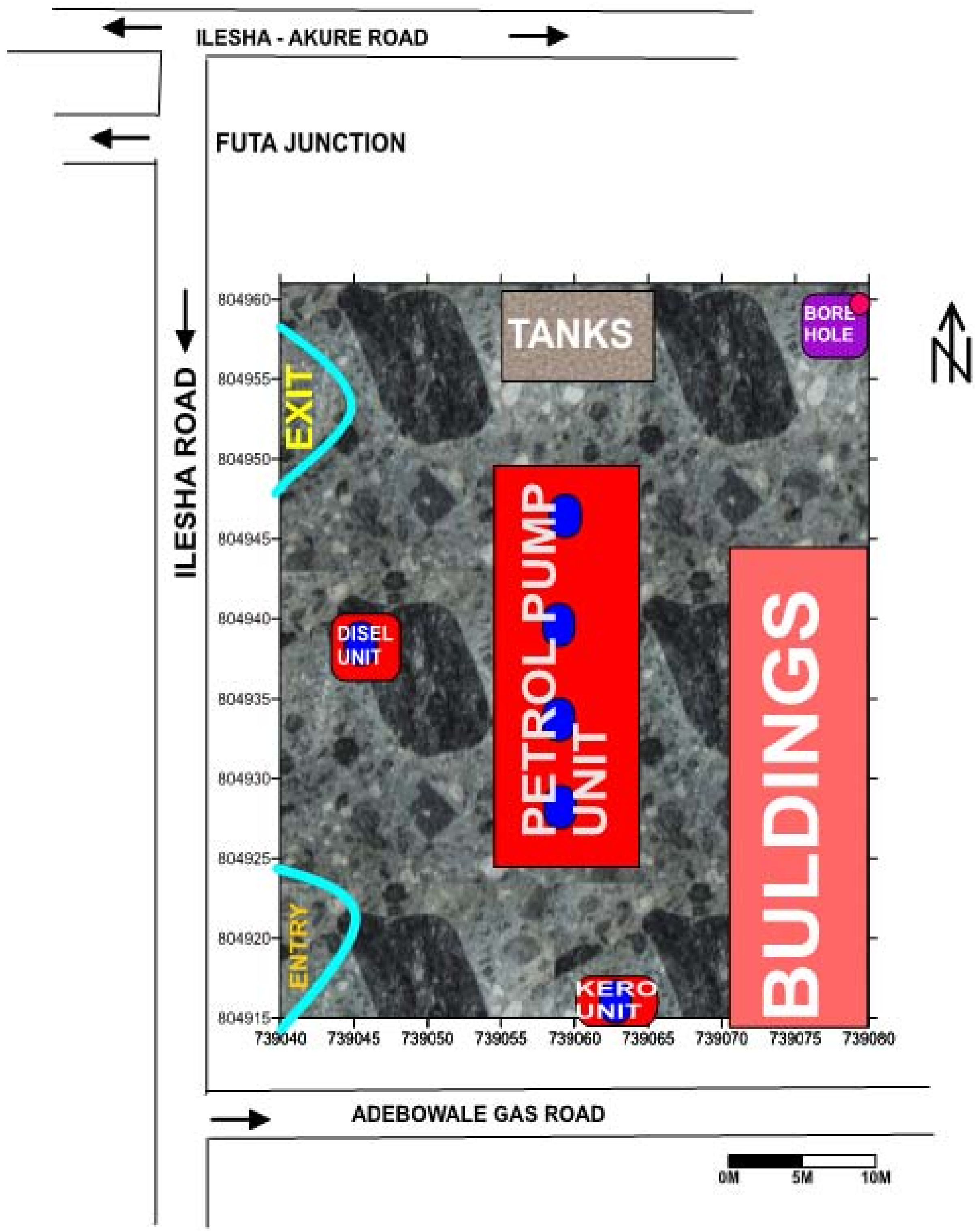

Figure 11: Model for the Proposed Filling Station

f) Conclusion

The usefulness of Electrical resistivity method in producing a model for a proposed filling station has been discussed. The subsurface characterization of the study area shows the heterogeneous nature of the subsurface particularly in a basement complex terrain. The study was able to delineate weathered layer and fractured zones that are inimical to engineering works and also useful for groundwater development. Competent zones suitable for tank burial and erection of buildings were also delineated. This study has successfully brought to fore the relevance of geophysics particularly electrical resistivity method as an important tool in pre-construction studies. The study proffer solution to environmental hazard such as contaminant plume and leachates into the groundwater system of the environment that might have occurred if the tank were to be buried within a porous and or permeable location. The study also assist in ascertaining the foundation integrity of the proposed structures in the study area.

VI. Acknowledgement

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