

# Geotechnical and Geophysical Study of Ain Harrouda New City (Morocco)

Lemacha H<sup>1\*</sup>, Ghafiri A<sup>1</sup>, Bakiz A<sup>2</sup>, Soufi A<sup>1,2</sup> and EL Moutaki S<sup>1</sup>

<sup>1</sup>Laboratory of Applied Geology, Geomatics and Environment, Department of Geology, Faculty of Sciences Ben M'sik, Hassan II University, Sidi Othmane, Casablanca, Morocco

<sup>2</sup>Public laboratory for trials and studies - LPEE, Experimental Center of Sols, Casablanca, Morocco

## Abstract

A reconnaissance study of soil properties is realized in the implantation area of the future town of Ain Harrouda (Morocco). This study used two approaches: geotechnic and geophysical. The geotechnical approach begins with 11 mechanical core drilling and 5 wells using mechanical shovel with sampling for laboratory testing and particularly identification tests. This study showed that the settlement area of the new city of Ain Harrouda consists of a primary base consisting of schists and quartzites. These are surmounted by conglomerates and calcarenites plio-quaternary age. It also determined the intrinsic characteristics of the each geological formation that make up the study area, include water content, density, particle size analysis by sieving, sedimentation particle size analysis, the value of methylene blue (VBS), the equivalent of sand, limits Atterberg. The geophysical approach consists of electrical resistivity technique with 5 vertical electric sounding and 8 electrical tomography profiles. This approach was used to determine the resistivity corresponding to each type of land and also the consistency of the soil. It allowed to distinguish the substratum characterized by high resistivity (more than 3000 ohm.m), and the sedimentary cover represented by three classes of average resistivity: 200 to 1600 Ohm.m for calcareous sandstones, 50 to 100 Ohm.m for silty sands, and very low for clays (less than 50 ohms. m). The results obtained shows that the study area appears healthy and suitable for the construction of the new town of Ain Harrouda.

**Keywords:** Electrical Resistivity Tomography; *In-situ* test; Laboratory Tests; Vertical Electric sounding; Ain Harrouda.

## Introduction

The construction of the new town of Ain Harrouda (Morocco) requires prior recognition studies of soil properties on which will be built this city. This is done using two independent but complementary technics which are the geotechnic and the geophysics. Geotechnics mainly based on the recognition of mechanical properties of soils [1]; while geophysics, studied the physical properties of the latters [2,3]. The results of these two approaches will be used thereafter by planners for establishing the ground plane of the projected new city [4].

## Study area

The new town of Ain Harrouda (Morocco), will stretch along the Atlantic coast between the two cities Casablanca and Mohammedia, on a coastal strip of 6 km length ranging the SE Mohammedia to NE of Casablanca, and a width of 4 km ranging from the coast to the inside the country [5]. Its area is more than 1,700 ha (Figure 1).

## Geological setting

The study area is located in the Meseta domain. It consists of consolidated dunes taking on the appearance of elongated hills parallel to the shore. These dunes are composed of Plio-Quaternary sandstone and sandy formations of a few tens of meters thick, sitting on a Cambro-

Ordovician bedrock, composed of schist and quartzite [6,7,8]. Recently, studies have revealed neotectonic deformations in Plio-Quaternary deposits in this region [9], and particularly probable fault oriented NE-SW in south extremity of Zenata city (Figure 2).

## Material and Methods

### The geotechnical approach

The geotechnical approach includes:

- ***In-situ studies:*** 11 mechanical core holes, and 5 wells excavators (SG1 to SG5) with sampling for laboratory testing (identification tests). The implantation sites of wells and boreholes were selected after examining the geological map, documentary research, and field investigations (Figure 3). The scale of the depth data "1.10 to 2.20". While boreholes down to 50 m.
- ***Laboratory studies:*** samples taken in each of five wells were subject a lithological description and identification tests. This latter includes water content (W), density, granulometric analysis by sieving, sedimentation particle size analysis, value of methylene blue (VBS), equivalent of sand, and Atterberg limits. All identification tests were performed according to the French standard [10-13].



Figure 1: Location of the new town of Ain Harrouda [5].

**\*Corresponding author:** Lemacha H, Laboratory of Applied Geology, Geomatics and Environment, Department of Geology, Faculty of Sciences Ben M'sik, Hassan II University, B.P 7955, Sidi Othmane, Casablanca, Morocco, Tel: 06 14 000 400; E-mail: [hassanlemacha@voila.fr](mailto:hassanlemacha@voila.fr)

Received September 13, 2016; Accepted October 27, 2017; Published November 03, 2017

**Citation:** Lemacha H, Ghafiri A, Bakiz A, Soufi A, EL Moutaki S (2017) Geotechnical and Geophysical Study of Ain Harrouda New City (Morocco). J Geol Geophys 6: 312. doi: 10.4172/2381-8719.1000312

**Copyright:** © 2017 Lemacha H, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

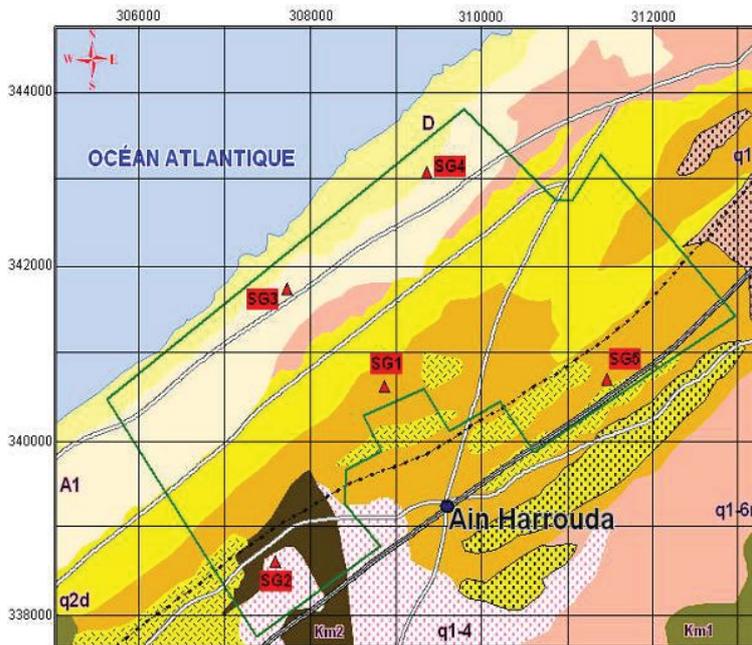
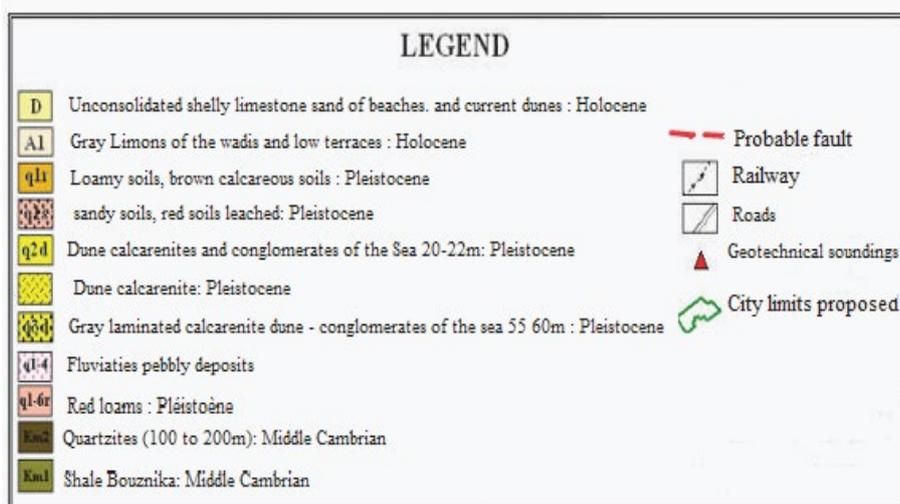


Figure 2: Geological map of the study area [8].



Lithologic section SG 4	Depth (m)	lithology	W %	VBS	Atterberg limits		Granulometric analysis	
					WL	IP	<2 mm	<80µm
	0 - 0.2	Topsoil						
	0.2- 1.2	Fine sand	6	-	-	-	7	0.2/1.2
	1.2 -2.5	Fine sand with blocks sandstone	6	-	-	-	3	1.2/2.5

Figure 3: Intrinsic characteristic of sediments encountered in the well SG4.

## The geophysical approach

The resistivity survey techniques is a method of electrical prospecting studying the resistivity variations generated by geological structures or heterogeneities in the basement. It involves the passage of current into the ground by means of two current electrodes while the potential difference is measured using a second pair of potential electrodes. Two separate electrical resistivity techniques are used, the Schlumberger vertical electrical sounding (VES) and the Schlumberger tomography

(a) **The Schlumberger vertical electrical sounding (VES):** The Schlumberger VES investigation measures the changes in formation resistivity with depth [14] (Figure 4). It requires that current electrodes spacing, AB is increased after every reading while potential electrodes spacing, MN is kept constant for most readings but increased when necessary using the control  $AB/2 > MN/2$  [15]. In our case, the sedimentary cover on the basement is not as thick as to warrant large current electrode spacing for deeper penetration therefore the largest current electrode spacing AB used was 200 m, that is,  $1/2AB=100$  m. For this survey, five vertical electrical soundings were performed

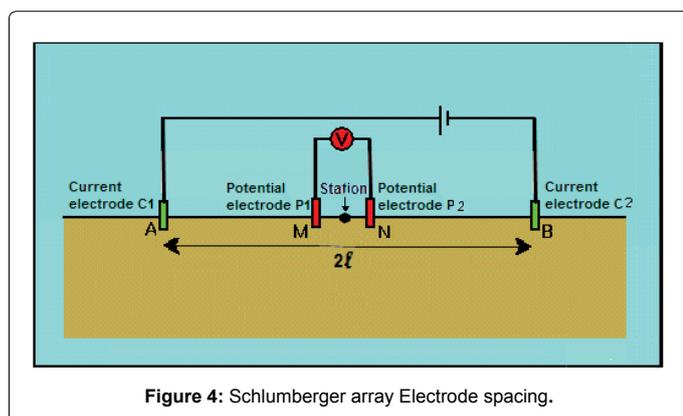


Figure 4: Schlumberger array Electrode spacing.

(figure 5). The principal instrument used is Geotrad. With the Schlumberger vertical electrical sounding (VES), the obtained apparent resistivity data  $\rho_a$  were plotted against half current electrode spacing ( $1/2AB$ ) on a log-log scale. The curves were then interpreted qualitatively by visual inspection and quantitatively by partial curve matching and modelled using computer iteration with the aid of Winsev version 6 computers software to generate depth strata for analysis.

(b) **Electrical Resistivity Tomographic Pseudo-sections:** Electrical tomography gives an idea of changes in subsurface resistivity in 2D, i.e. the both lateral and vertical along the line of electrodes [16]. It in fact corresponds a succession of electrical surveys one beside the others. For this, an array of electrodes is installed along a rectilinear profile with a constant spacing chosen to optimize the length of the profile, the depth of investigation and the desired resolution. Measurements are presented as a pseudo-section of apparent resistivity as a function of the position along the profile. In this study eight profiles of 630 m each have been used (Figure 5). The spacing between the selected electrode is 10 m, and the acquisition hardware used is Terra meter LS.

## Results and Discussion

### Results of geotechnical approach

- Observations *in-situ* allows to recognize, identify and characterize the land forming the study area.
- Land observed in five wells on the first two meters show upward sandstone, limestone, sand, and finally topsoil (Figure 3).
- The field studies well as those of drilling until 50 m depths show that the geological formations of the study area are all of sedimentary origin and consist of primary plinth formed of schists and quartzites of Cambro-Ordovician age; above, come the Plio-Quaternary formations usually composed, from bottom to top by coquina conglomerates, surmounted

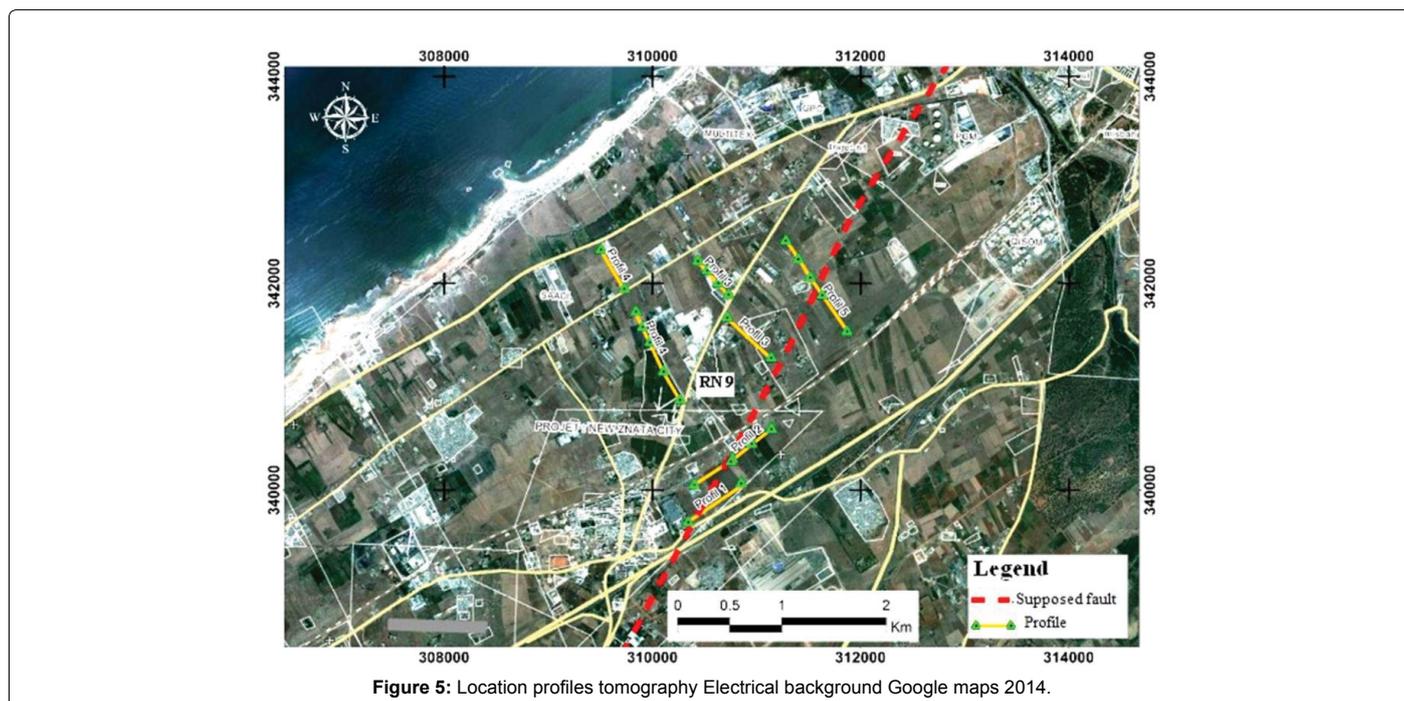


Figure 5: Location profiles tomography Electrical background Google maps 2014.

by marine calcarenite beach, passing progressively dune calcarenites intercalated locally by rubefies and often altered continental spreading.

The identification tests carried out on samples taken from each of the five wells were used to determine the intrinsic characteristics of different lands that form the study area (water content W, expressed in %, Value of Methylene Blue of Sol, VBS, liquid limit WL, plasticity index IP and granulometric analysis). An example of results concerning the well SG4 is given in the table below.

### Results of geophysical approach

The sounding curves obtained by the vertical electrical sounding Schlumberger (VES) have in the general form of "inverted cloche" which translates, first, by a decrease in the apparent resistivity values followed by an increase of these. This form of electrical diagram sounding matching to a model of the basement formed of at least four layers, corresponding to the superposition of two resistant terrains, separated by a third conductor, and sitting on a conductive substratum.

We give two examples of vertical electrical sounding, those of SEV1 and SEV3 (Figures 6 and 7).

Curve of this sounding SEV<sub>1</sub> above survey brings out from top to bottom the following entities:

A resistant terrain R1 with intrinsic resistivity  $\rho=258$  Ohm.m corresponding to surface coverage type limestone at lumachelles.

- A conductor level C1 ( $\rho=47$  Ohm.m) representing limestones at lumachelles with intercalation of thin clay layers.
- A resistant level R2 ( $\rho=363$  Ohm.m). The characteristics of this terrain are calcareous.
- A resistant terrain R3 ( $\rho=348$  Ohm.m). This formation is attributed to the top of the quartzitic schists little altered.
- A conductor C2 ( $\rho=4.86$  Ohm.m) terrain. This sudden drop in resistivity may be caused by the intrusion of saline Atlantic waters.

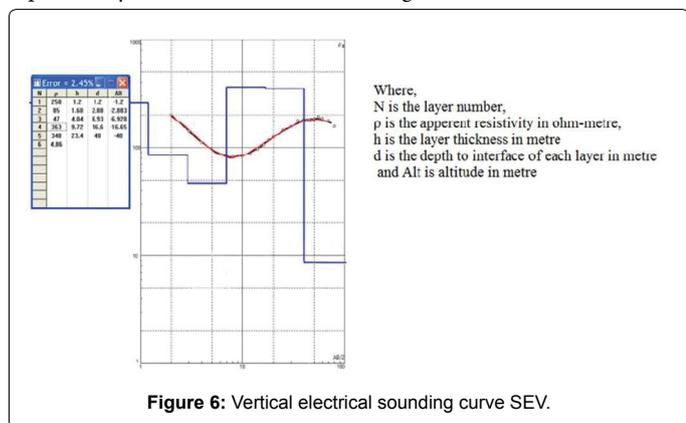


Figure 6: Vertical electrical sounding curve SEV.

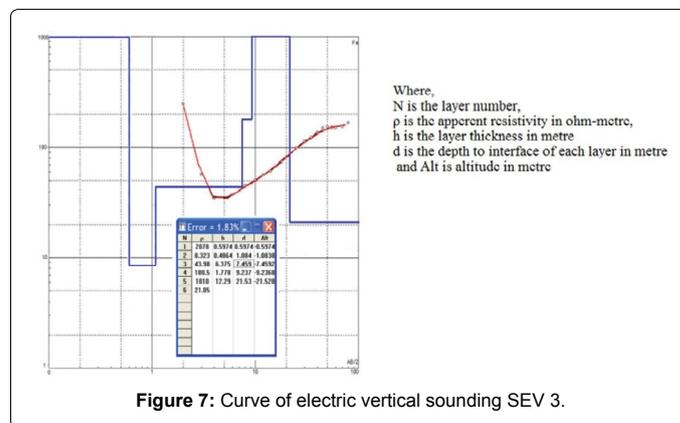


Figure 7: Curve of electric vertical sounding SEV 3.

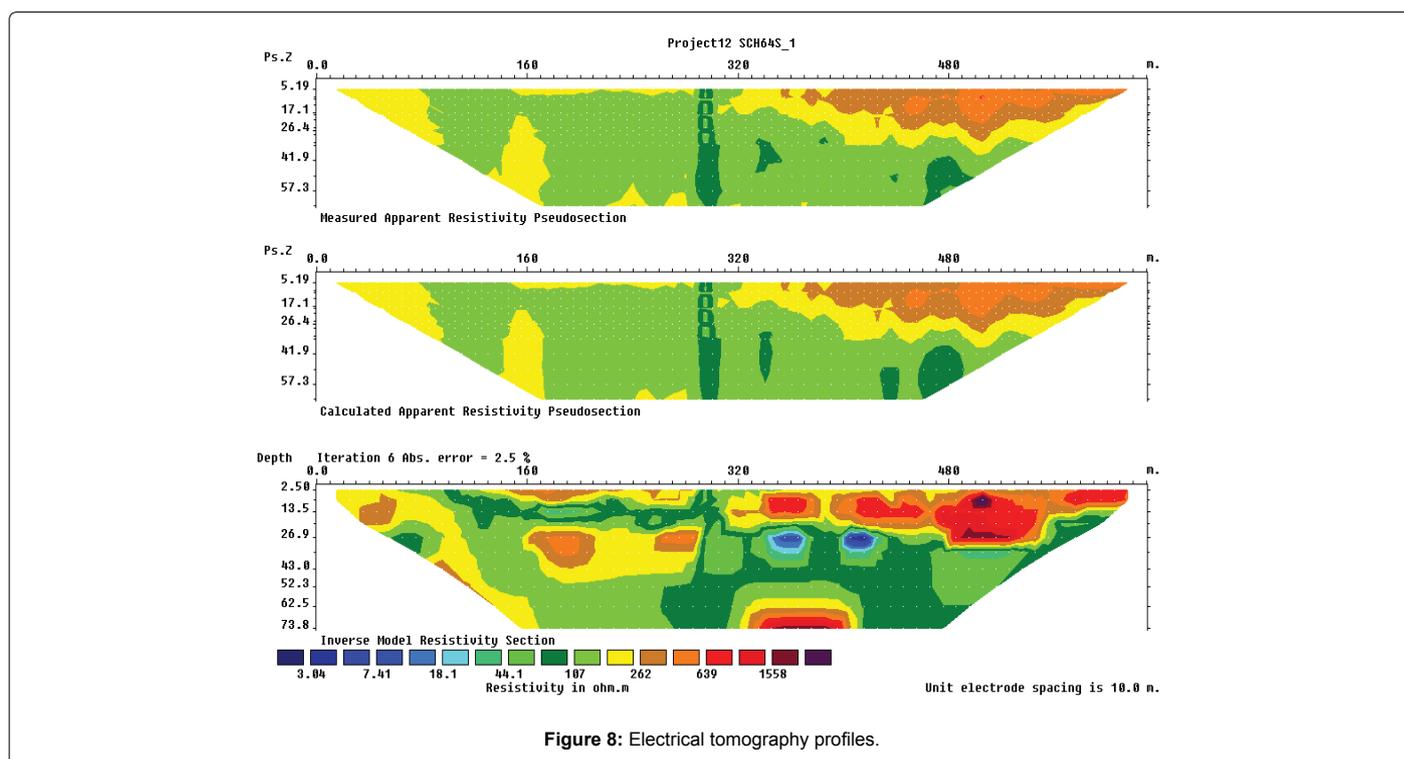


Figure 8: Electrical tomography profiles.

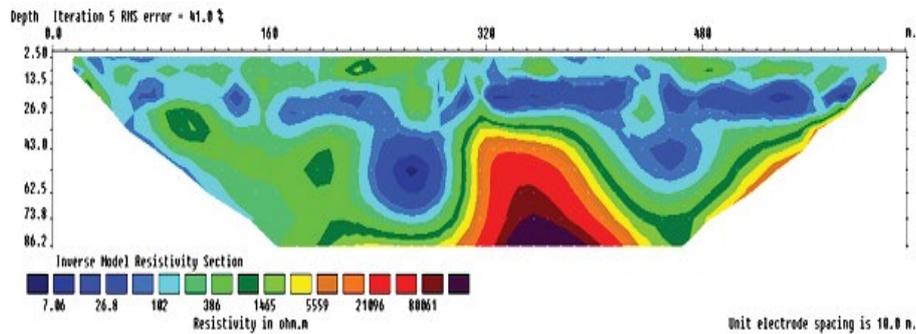


Figure 9: Resistivities obtained by electrical tomography profiles. Example profile 2.

- The curve of this sounding brings out from top to bottom the following entities:
- A Resistant level R1, intrinsic resistivity  $\rho=2078$  Ohm.m corresponding to the superficial coverage type quartzitic sandstone.
- A conductor level C1 ( $\rho=43$  Ohm.m) representing micaceous sandstone fractured which are the subject of thin aquifer of water.
- A resistant level R2 ( $\rho=1010$  Ohm.m) matching quartzitic sandstone fractured.
- A terrain conductor C2 ( $\rho=5.21$  Ohm.m), representing a thicker aquifer.
- The results obtained by electrical tomography are represented by three images (Figure 8).

The top image shows the results of true resistivity measured field, the middle one shows the results of resistivity given by the Res2div software, the final image below is that which results from the combination of the first two. Each profile is formed from a single device 640 m, depending on accessibility to the ground.

Electrical tomography profiles whose average depth of investigation is 70 m, sometimes up to 130 m can give an image of the basement of the future city of Ain Harrouda (Figure 9). They show resistivity 200-1600  $\Omega.m$  corresponding to calcareous sandstone exposed in places like the above profile. Medium resistivity around 50-100  $\Omega.m$  representative loamy sands. Low resistivity, below 50  $\Omega.m$  corresponding clays. While the substratum, it is deeply marked in depth by high resistivity superior to 3000  $\Omega.m$ , as the profile below where only the inverse model resistivity is shown.

In addition, concerning the search on the field of the fault NE-SW suspected in the study area, none of 8 profiles electrical tomography performed on the probable line of the fault or either side of it was able to show clearly the presence of such a fault.

## Conclusion

The preliminary study developed in this work shows that the geographic study area appears healthy and suitable for the construction of the new town of Ain Harrouda. The geotechnical approach currently serves as a guide for planners to establish the ground plane of the new city. The results obtained so far concern the identification tests. They must be supplemented by mechanical tests on soil and rock.

The geophysical approach, vertical electrical sounding and electrical

tomography allowed the determination of the consistency of the soil will be sitting the works that will be projected in the study area. It shows a lateral variation of electrical resistivity clearly visible. The substratum is characterized by high resistivity (greater than 3000 Ohm.m); and sedimentary cover is represented by three classes of resistivity, medium for calcareous sandstone (200-1600 Ohm.m), low for loamy sands (50-100 Ohm.m) and very low for clays (less than 50 ohm.m).

## References

1. Taylor DW (1955) Fundamentals of Soil Mechanics, Wiley, New York, Geotech Geoenviron J 141: 712.
2. Punmia BC, Ashok KJ, Arun KJ (2017) Soil mechanics and foundations. [16 edn], Laxmi publications LTD p. 940.
3. Clayton CRI, Matthews MC, Simons NE (1995) Site Investigation [2nd edn] UK: Blackwell Science Ltd. P. 584.
4. Barker RD (1997) Electrical imaging and its application in engineering investigations: Modern geophysics in engineering geology, Geological Society. Engineering Geology Special Publication 12: 141.
5. Gigout M, Le Coz J (1952) The coastal meseta in Aspect of the Geomorphology of Morocco, Geological Survey of Morocco. 96, 19th Cong Geol Int, Monogr. Region, 3: 135-159.
6. Destombes J, Jeannette A (1966) Explanatory memorandum of the geotechnical map of the coastal Meseta east of Casablanca at 1/50,000, Mohammedia region, Bouznika and Benslimane. Notes and Memories, Geological Survey of Morocco 180: 103.
7. Chabli A, Galindo-Zaldivar J, Akil M, Marín-Lechado C, Chalouan A, et al. (2005) Neotectonic deformations in the plio-quadernary deposits of the Casablanca-Mohammedia region (coastal Meseta, Morocco). Magazine of the Geological Society of Spain 18: 169-178.
8. Sitel A (1996) Geomorphological and sedimentological studies of coastal quaternary deposits between Casablanca and Bouznika. 3rd cycle thesis, Univ pp.184.
9. French Standard: P94-056 (1996) Soils: Recognition and testing, Particle size analysis. Dry sieving method at close wash. p. 1-16.
10. French Standard: P18-592 (1990) Aggregates: methylene blue tests-method by task. pp.1-5.
11. French Standard: P94-051; (1993). Soils: Recognition and testing. Determination of Atterberg limits: Limit of liquidity at the cup. Roll plasticity limit. pp.1-16.
12. French Standard: P94-053, (1991). Soils: recognition and testing. Determination of the density of fine soils in the laboratory. pp.1-8.
13. Okolie EC, Atakpo E, Okpikoro FE (2010) Application of linear Schlumberger configuration in delineation of formation strata and groundwater distribution in Ifon Ondo State, Nigeria. Int Physical Sciences J 5: 642-650.
14. Keller GV, Frischknecht FC (1966) Electrical Methods in Geophysical Prospecting. Pergamon Press pp.517.
15. Telford WM, Geldart LP, Sheriff, RE (1990) Applied Geophysics. [2 Edn] Cambridge University Press, p p.770.