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Use of Electrical Resistivity Methods (2-D and VES) in Proposed Landfill Site Investigation – A Case Study of Al Fukhari Landfill, Southeastern Gaza Strip, Palestine

Zeyad H. Abu Heen
Dept. of Environment & Earthsciences, Islamic University of Gaza, Palestine
P.O Box:108, Gaza City, Palestine

Abstract
Electrical resistivity tomography (ERT) and vertical electrical sounding (VES) are widely used in environmental and engineering purposes. In the present study, both ERT and VES were used to investigate the suitability of a proposed landfill site area in south of Gaza Strip, Palestine to delineate the presence of any linear structure, depth and characterization of the unsaturated zone, layer resistivities, soil type, bedrock depth and subsurface structures with priority of groundwater protection. Measurements procedure for electrical imaging resistivity survey is taken along 9 spreads with Wenner-Schlumberger configuration with maximum spread length of 115m, in E-W and N-S direction, in addition to three VES points with Schlumberger configuration with electrode spacing (AB/2) ranging from 0.5 to 150 m. VES location has been selected much closed to the 2D lines and near the proposed boreholes to integrate all the data. Data from 6 drilling boreholes (up to 25m depth) and 14 drilling test pits (up to 5m depth) are also used to support the geophysical models. The proposed geoelectrical models show that resistivity values change horizontally and vertically as a result of inhomogeneous of soil contents. Top soil layers and dry Sands are characterized by high resistivity values, whilst low resistivities reflect a Clay or Silty Clay layers to Sandy Clay layers. Layer thicknesses and the subsurface structure proposed by the geoelectrical interpretation showed a good correlation with that of the boreholes and drilling test pits.
Keywords: Electrical Resistivity Tomography, VES, Landfill Investigation, Al Fukhari , Gaza Strip, Palestine.

1. Introduction

Geophysical methods are playing an increasingly role in ground water, engineering and geotechnical investigation. Of all surface geophysical methods, the electrical resistivity method (DC Current) has been the mostly widely used in exploration processes. Resistivity survey in many cases substantially reduces the drilling costs by allowing a more intelligent selection where and how depth must be drilled to the reach the target. In most cases, the combination and integration data from different geophysical techniques and drilling will provide the optimal solution for an investigated area (Keller, 1988; Dahlin, 1996; Dahlin et al., 1997; Sharma, 1997, Reynolds, 1998; Loke, 1999, 2015).

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the minerals, fluid content, porosity and degree of water saturation in the rock (Niwas et al., 2003; Sinha, 2009; Adegbola et al., 2010; Akintorinwa et al., 2011; Utom et al., 2012; Vafai et al., 2014; Thabit et al., 2014). The Geophysical investigations have many useful applications in shallow engineering and in environmental engineering studies (Olorunfemi and Mesida, 1987; Sharma, 1997; Saksa and Korkealasko ,1987). It can be successfully used both before waste disposal operations for evaluation of site characteristics and for monitoring of possible leachate flow after dumping of waste (Bernstoe et al., 1997; Joshi, 2013; yang et al., 2014). Examination of contaminated sites are necessary by setting up boreholes around the landfill area but these boreholes only provide a very limited and point-source typed information, disregarding areal extent of the contamination at the sites (Zume et al., 2006). However, geophysical methods, especially geo-electrical methods, have proven their credibility in landfill-related studies, and become standard tools over the past decades in the determination of internal landfill structure, leachate levels and cap material thickness (Loke, 1999; Radulescu et al., 2007; 2007; Zhu et al., 2008; Yang et al., 2014).

The management of solid waste landfills has been a major problem in Gaza Strip as wastes are generated daily and disposed in landfills without recourse to the groundwater, environment, local geology and their proximity to the living quarters. The mobilization of toxic fluid to areas of outside the landfills, leading to possible surface water, groundwater, soil and air pollution.

The present research used integrated electrical resistivity geophysical investigations (2D and VES) of a proposed site near Al Fukhari Landfill (sometimes called Sofa Landfill), southeast of Rafah Governorates, to delineate the presence of any linear structure, depth and characterization of the unsaturated zone, layer resistivities, soil type, bedrock depth and subsurface structures to determine the suitability of the proposed location for disposal of waste with priority of groundwater protection.

2. Location of the Studied Are

The proposed studied area is a site of solid waste dump located in southeastern corner of Gaze City (South of Palestine), located at town of Al Fukhari between Rafah and Khan Younis Cities and very close to Gaza strip Eastern borders and located directly to the north of Sofa road (so it sometimes called Sofa Landfill).

The site is at an open area (a part of farms in that area) with almost flat terrain elevation (51-52m) above mean sea level and a dimensions of about 400x500m. The old solid waste dump and sewage waste dump are located at its northern part of the land (Figure 1). The solid waste dump is becoming full and wastes are dumped in nearby lands.

Figure 1. Location of the investigated area and VES and 2D geophysical survey lines

3. Material and Methods

The geology of Gaza Strip consists of a sequence of geological formations ranging from upper Cretaceous to Holocene sloping gradually from east towards the west. The Tertiary formations consist of Saqiya group (upper Eocene to Pliocene) with a thickness of 400 m to 1000 m underlined by Eocene Chalks and limestone. The Quaternary deposits throughout the Gaza Strip overlie the Saqiya Group, while at the east they overlie the Eocene Chalks and Limestones. The thickness of the Eocene deposits reaches to about 200 m. The Coastal Aquifer is composed of Loose Sand dunes (Holocene age) and Kurkar Group (Pleistocene). The Kurkar Group is composed of marine and Aeolian Calcareous Sandstone (locally known as "kurkar"), reddish Silty Sandstone ("hamra"), Silts, interlayers of Clay deposited during the Last Glacial stage and during the Holocene, unconsolidated Sand and Conglomerates. Close to the present shoreline, the sequence of the Kurkar Group attains an average thickness of 200 m in the South and around 120 m in the North. The Holocene deposits are found at the top of the Pleistocene formation with a thickness up to 25m. (Abed et al., 1999).

Soil in the proposed Sofa Landfill area has been investigated by drilling 4 boreholes (Up to depth of 25m) and another 2 boreholes west to the existing Sofa Landfill (Both the two boreholes penetrated the depth more than 48m) where soil types and layer depths described (MSL, 2005). The top layers of the proposed area is a thick Silty Clay to Sandy Silty Clay with a depth ranges from 15 m to 25m from ground surface overlying a deep Calcaleous Sand (Kurkar) ridges. The Kurkar deposits are mainly composed of fine to coarse sand grains mostly Quartz and rare Feldspars and Carbonate shell fragments partially cemented by Calcite. The ground water table was not observed up to 25m depth, but it is expected to be found at 55 m depth from ground surface at site, as the ground water level at Gaza strip is almost same as the elevation of the area above the sea.

The integrated geophysical investigation for the proposed area involving both the Electrical Resistivity Tomography (2D ERT) and Vertical Electrical Sounding (VES) methods. Measurements procedure for electrical imaging resistivity survey is taken along 9 spreads with Wenner-Schlumberger configuration for all the survey (R1 to R9) with 115m in length and at different spacing (Figure 1). Spreads R1, R2, R3, R4, R5, R6 and R7 are running N-S direction, while spreads R8 and R9 are E-W direction. The survey area is almost flat, therefore the topographic difference was not considered in any of the inverted profiles. 2D survey data were acquired using YSCAL JUNIOR, 2D IMAGING SYSTEM from IRIS- Instruments, France, with 24 electrodes and a multi core cable of 24 takeout with a maximum spacing of 5 m. This gives a maximum penetrating depth of about 20 m. The data was processed and inverted using RES2DINVsoftware (Geotomo Software, 2010).), a computer program that automatically determines the true resistivity model for the subsurface from the measured data. The program is also used to determine the layer parameters from the measured resistivity imaging data and to generate the inverted resistivity-depth image for each profile line. Vertical Electrical Soundings were carried out for further detailed study. Three vertical electrical soundings with Shlumberger configuration has been executed in the investigated area with electrode spacing (AB/2) ranging from 0.5 to 150 m. The selected AB/2 intervals are: 0.5, 1, 2, 3, 4, 5, 6, 7, 10, 15, 20, 30, 40, 50, 70, 100 and 150 m. Field data (AB/2, MN, Apparent resistivity) for the three soundings are listed in table (1). VES location has been selected much closed to the 2D lines and near the proposed boreholes to integrate all the data. All resistivity soundings were inverted using IPI2win software (Bobachev, 2010).

Table 1. VES field data of the study area

VES 1			VES 2			VES 3		
AB/2 (m)	MN/2 (m)	Rho (Ω.m)	AB/2 (m)	MN/2 (m)	Rho (Ω.m)	AB/2 (m)	MN/ (m)2	Rho (Ω.m)
0.5	0.2	100	0.5	0.2	-	0.5	0.2	-
1	0.2	47.3	1	0.2	78.2	1	0.2	-
2	0.2	16.8	2	0.2	74.7	2	0.2	20.8
3	0.2	13.8	3	0.2	77.1	3	0.2	-
4	0.2	14	4	0.2	77.5	4	0.2	14.3
5	0.2	14.1	5	0.2	47.1	5	0.2	-
6	2	-	6	2	-	6	2	-
7	2	15.5	7	2	60.9	7	2	14.3
10	2	15.1	10	2	41.8	10	2	15.3
15	2	14.7	15	2	29.1	15	2	16.9
20	2	14.6	20	2	22	20	2	17.7
30	2	14.2	30	2	17.1	30	2	17.3
40	5	13.8	40	5	15.6	40	5	17.6
50	5	12.9	50	5	14.9	50	5	19.4
70	5	11.5	70	5	13.9	70	5	25.6
100	5	7.5	100	5	13.7	100	5	-
150	5	3.1	150	5	-	150	5	-

4. Results and Discussion

4.1. 2D Resistivity Tomography Survey

Table (2) summarized some statistical data for the geoelectrical tomography interpretation where maximum, minimum and RMS for all the 2D sections are presented. Inspection the table revealed that the minimum calculated resistivity value in the study area is about 7.49 (Ω.m), while the maximum value is about 69.98 (Ω.m). RMS ranges between 1.93% to 6.3%.

Inverse models resistivities for all the studied area are shown from figure (2) to figure (10). General inspection of the 2D inverse models shows that resistivity values change horizontally and vertically as a result of inhomogeneous of soil contents. A large resistivity values on top soil layer represents a dry top soil layer or dry sands, where low resistivity values reflects a clay or silty clay layer to sandy clay layers. Detailed description of the geoelectrical 2D profiles will be given below.

4.1.1. 2D Resistivity Model of Sofa R1

Sofa R1 profile located in south-west of the studied area (Figure1). The inverted resistivity model shown in figure (2). Resistivity values decreases from east to west and from surface to depth. Horizontal Silty Clay to Sandy Silty layers are proposed for the resistivity values ranges between less than 12.9 Ω.m to 16.8 Ω.m extends from east to west with thickness of about 8 m in the profile center and increased at the start and at the end of the profile to more than 16m.

Table 2. Minimum, maximum and RMS for observed electrical resistivity of 2D profiles

Profile No	Min. Resistivity (Ω.m)	Max. resistivity (Ω.m)	RMS (%)
Sofa R1	13.92	21.04	1.94
Sofa R2	10.85	18.78	3.40
Sofa R3	10.35	50.88	3.50
Sofa R4	7.89	22.89	6.30
Sofa R5	11.27	69.98	3.70
Sofa R6	8.83	17.94	1.93
Sofa R7	8.31	39.30	2.80
Sofa R8	7.49	42.01	3.70
Sofa R9	10.14	18.99	2.60

The second well observed layer in this profile is shown at the profile center at depth of 8m up to more than 18 m with high resistivity values (from 16. 9 Ω.m to more than 21.59 Ω.m) which may reflect a Sandy Clay layer. The vertical contour lines at marks 35 and 85m may reflect fault or horizontal changes of layer lithology from Silt Clay to Sandy Clay facies. A good correlation between the resistivity model and Borehole BH.1 drilled near this profile is achieved.

4.1.2. 2D Resistivity Model of Sofa R2 Profile

Sofa R2 profile located in the same area of Sofa R1 and extends from the end of R1 westwards to about 120 m (Figure1). The inverted 2D resistivity model is shown in figure (3). Resistivity values of this profile rages between less than 6 Ω.m to about 19 Ω.m. The model presents a very conductive layer with low resistivity less than 10 Ω.m at depth of about 14 m extends from 30m mark at the east of the profile to 75m mark westward that may reflect a Clay Layer. A thin layer of medium resistivity values (14.5 to 16.5 Ω.m) is shown at the profile center at shallow depth that overlay conductive layer (from 9 to 12.5 Ω.m. Lateral changes of resistivity values are also observed at low depth on the profile as a result of litholgy change from Silty Clay to Silty Sand soils.

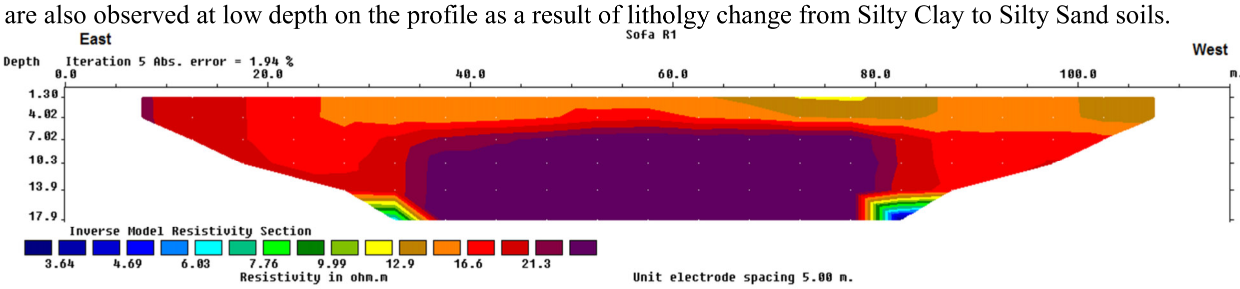

Figure 2. Inverse model resistivity of Sofa R1

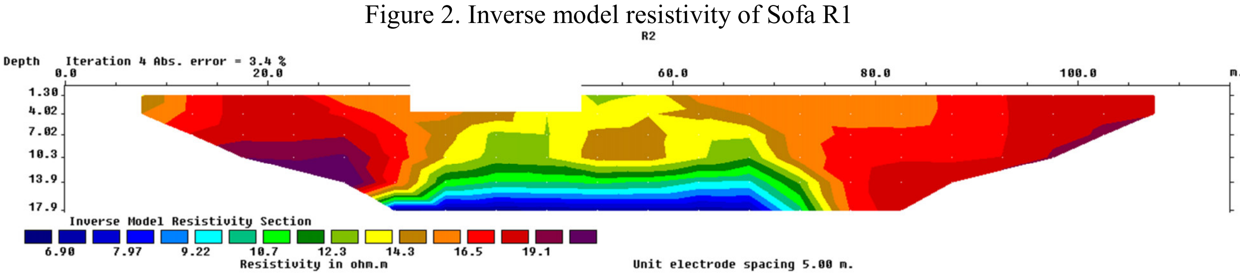

Figure 3. Inverse model resistivity of Sofa R2

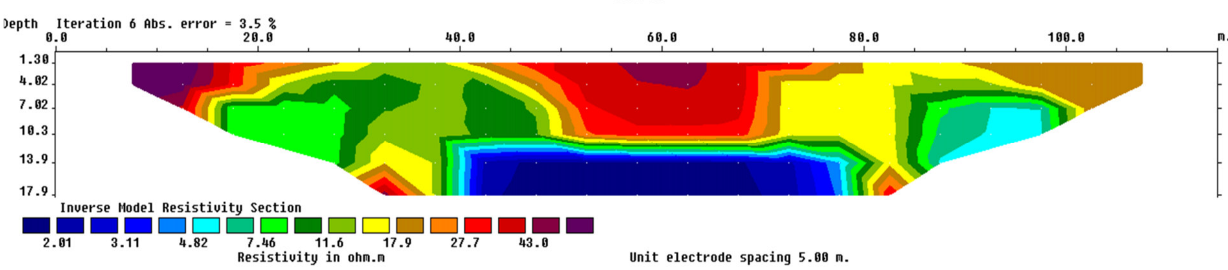

Figure 4. Inverse model resistivity of Sofa R3

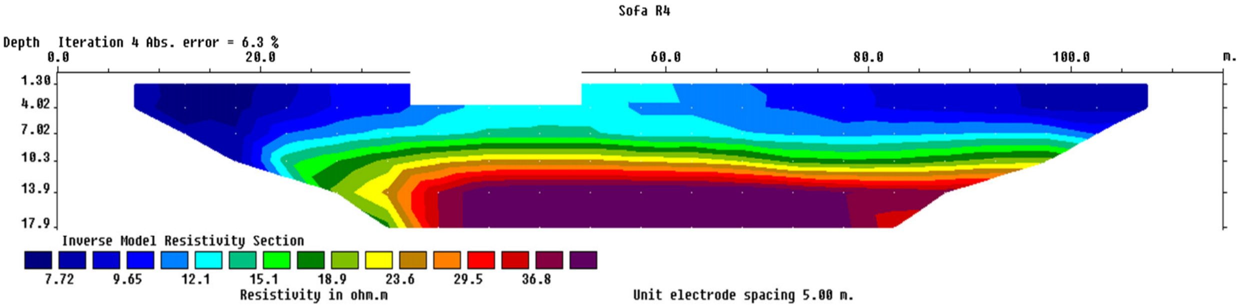

Figure 5. Inverse model resistivity of Sofa R4

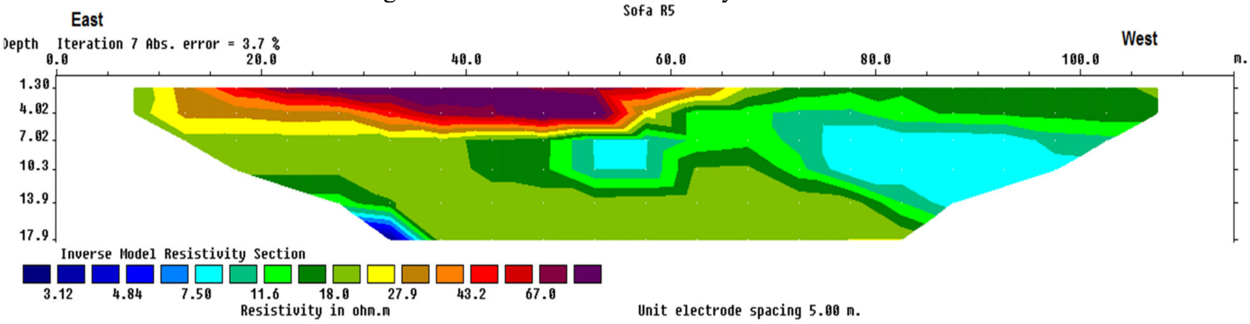

Figure 6. Inverse model resistivity of Sofa R5

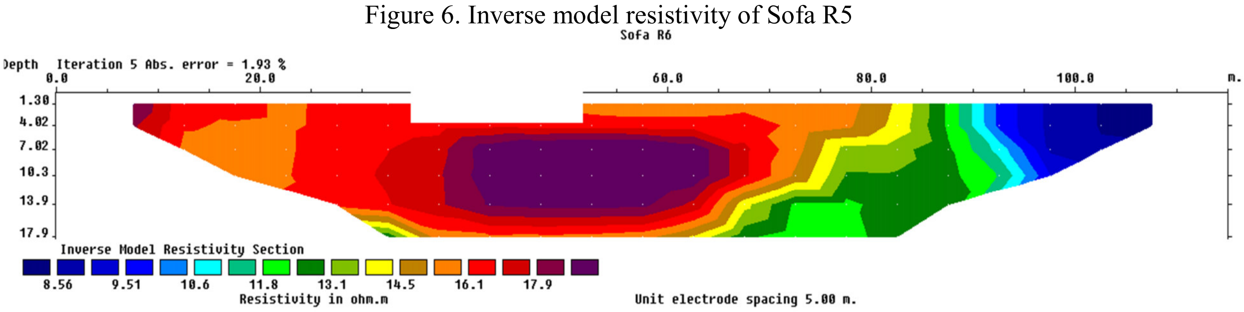

Figure 7. Inverse model resistivity of Sofa R6

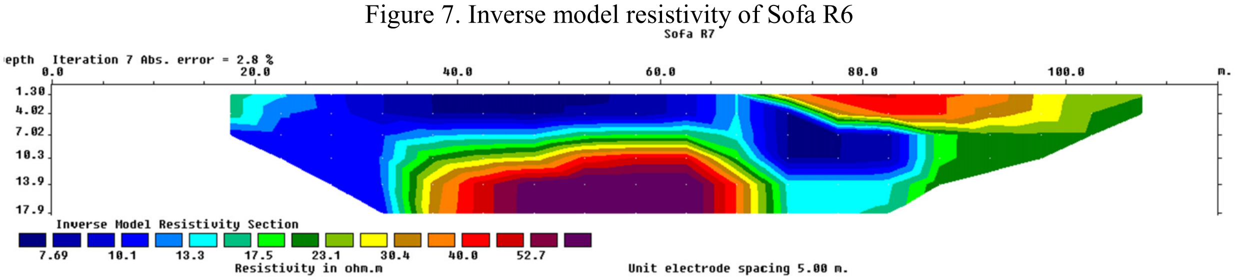

Figure 8. Inverse model resistivity of Sofa 7

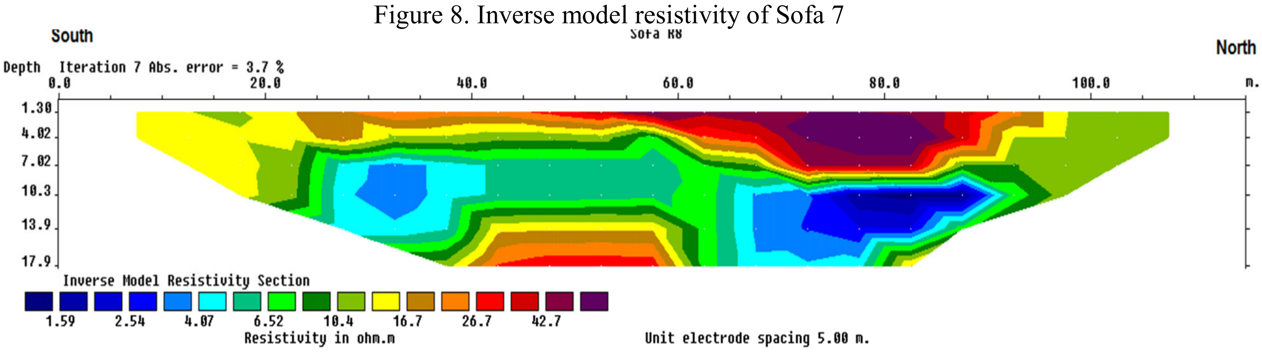

Figure 9. Inverse model resistivity of Sofa R8

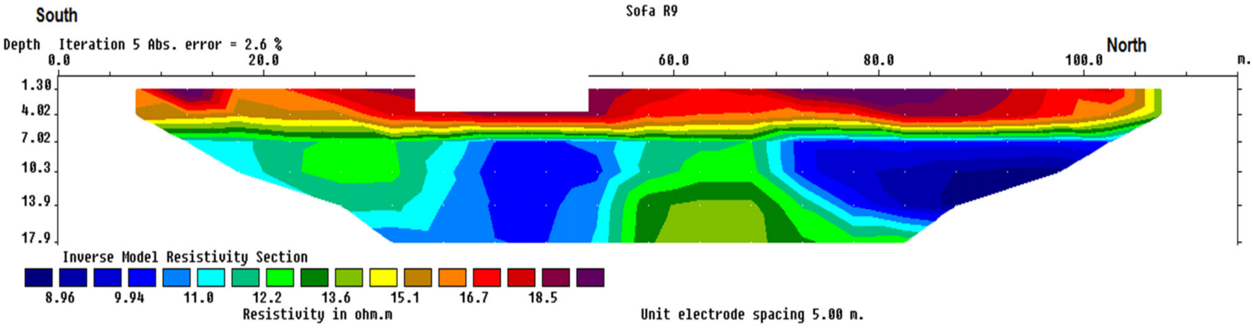

Figure 10. Inverse model resistivity of Sofa R9

A conductive layer with low resistivity less than 8 Ω.m is observed at the bottom of the profile which may reflect a Sandy Silty layer saturated with landfill leachate from Sofa Landfill 300 m north of the profile location.

4.1.3. 2D Resistivity Model of Sofa R3 Profile

Profile Sofa R3 runs E-W direction, parallel to R1 and R2 and with a distance of about 260 m to north direction and about 150 m south of sofa landfill (Figure 1). Low resistivity value (less than 4 Ω.m) characterized the deep layers at depth of about 10 m below the surface and extends to about 40 m at the profile center (figure 4). This low resistivity layer may be affected by landfill leachate comes from north direction. A high resistive layer overly this layer with resistivity value more than 50 Ω.m at profile center with a length of about 40 m that may represents a very dry sands. This high resistivity layer surrounded from west and east by low to middle resistivity values which reflect lateral changes of soil contents. A Silty Clay layer of 10 m thick is observed in bore hole and testing pit executed at 150 m south of profile R3.

4.1.4. 2D Resistivity Model of Sofa R4 Profile

Profile Sofa R4 runs E-W direction, parallel to R1, R2 and R3 (Figure 1) and very closed to the landfill border. Geoelectrical model of this profile is shown in figure (5). High conductive layer with resistivity value less than 12 Ω.m is well observed along all the profile from the surface up to depth 9 m. This layer represents Silty Clay layer. This low resistivity layer may be affected by landfill leachate comes from east and north direction from the landfill.

4.1.5. 2D Resistivity Model of Sofa R7 Profile

Profile Sofa R7 runs in the same direction of R4 and starts from the end of R4 westward (figure 1) and its resistivity model is shown in figure (8). Inspection of the two figures shows almost the same features. Low resistivity layer at the top of the profile extends from east to about 70m mark, followed by a high resistivity layer of about 50 m long of depth of about 5 m followed by resistivity decreases westward. It is believed that this low resistivity Silty Clay to Clay layer is affected by landfill leachate. A high resistive layer is also observed at depth of about 9 m from the surface. Vertical contouring lines at 35m, 50m, and 85m marks maybe interpreted as a sharp lateral change of soil layers or structural contact (faults).

4.1.6. 2D Resistivity Model of Sofa R5 Profile

Profile R5 runs in the south-east part of the project area (figure 1) near borehole 2 and VES2. Geoelectrical inverted model is shown in figure (6). A top soil layer characterized by a wide variety of electrical resistivity values (from less than 3 Ω.m to more than 80 Ω.m that reflect top soil layer litholgy variation. However, the high resistive top soil layer observed at the begging of the profile until 60m mark westward with layer thickness of about 5m. Borehole 2 near this profile describe 5m Silty Clay layer overly a thick Sandy Clay layer which presented in the geometrical model by thick layer of resistivity ranges from 10 to 30 Ω.m at different depths. It outcrops on surface at 65m mark up to profile end.

4.1.7. 2D Resistivity Model of Sofa R6 Profile

Profile Sofa R6 executed in the same area, parallel to R5 and of about 180m apart northward and very closed to the landfill area (figure 1). Borehole 3 has been drilled at 70m north of Sofa R6 profile. Inverted resistivity model is shown in Figure (7). Comparing Sofa R5 and Sofa R6 inverted resistivity sections reveals that R6 model characterized by low resistivity values (between less than 8 Ω.m to about 18 Ω.m. This could be interpreted due to the short distance between profile location and landfill site. A lateral changes in electrical resistivities are observed in both horizontal and vertical directions. The western part of this profile (from 80m mark to 115m mark) is more conductive than the eastern side. Test pit 14 (refer to geotechnical report of the project) penetrated 5m of Silty Clay layer at 100m mark of profile R6, while borehole 3 (near the eastern side of R6 at 30m mark) indicated a relatively dry, very stiff thick layer of Silty Clay.

4.1.8. 2D Resistivity Model of Sofa R8 Profile

Profile Sofa R8 executed in N-S direction perpendicular to profile Sofa R3 and its northern end is very closed to landfill site (figure 1). Geoelectrical 2D section of this profile is depicted in figure (9). Electrical resistivity values of this profile range between less than 1.59 Ω.m and 50 Ω.m. The top soil layer represents by high resistivity values (16 Ω.m to more than 50 Ω.m) at the surface up to different depths. The resistivity values increased from south to north to reach the maximum values between marks 60m and 95 m that represent Silty Sand to Sand layer with maximum depth of about 7 m beneath 80m mark. This layer also observed at the bottom of the of the profile at depth more than 13m between 35m and 60m marks which believed to represents a dense Sand layer. A low resistivity layer with values between less than 1 Ω.m to about 10 Ω.m is sandwiched in between the two layers that reflect Silty Clay to Clay layer. The lowest resistivity calculated values of this profile (less than 2 Ω.m) is observed at the north end of the profile at depth of 8m. This low resistivity values may be as a result of landfill leachate.

4.1.9. 2D Resistivity Model of Sofa R9 Profile

Profile Sofa R9 runs in N-S direction, to continue R8 to south direction (Figure 1). Geoelectrical 2D model of this profile illustrates in figure (10). Top soil layer with high resistivity (between 15 Ω.m to 19 Ω.m) well observed in all the profile with depth of around 6m. A low resistivity layer with resistivity values between 10 Ω.m to less than 8 Ω.m underlay the upper top one. This layer crossed by intermediate resistivity values (between 10 Ω.m and 15 Ω.m) in the south and in the center of the section, which may indicate an increasing of sand content.

4.2. 1D Vertical Electrical Sounding Interpretation (VES)

4.2.1. VES1 Interpretation results

Table (1) shows the observed resistivity data of VES1. It's maximum AB/2 equal to 150m. The interpreted model is illustrated in figure (11). It must be noted that geoelectrical layer is not a geologic layer or litholgy layer. Geology layer could be interpreted as more than one layer according to difference in resistivity values. So, borehole description may not in good agreement with geoelectrical model.

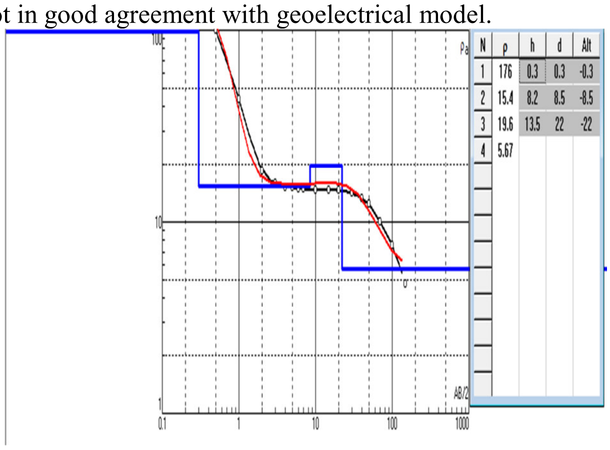

Figure 11. Geoelectrical model of VES1:

Geoelectrical model of VES1 shows four layers (Figure 14) with resistivities of 176, 15.4, 19.6 and 5.67 Ω.m with layer depths of 0.3, 8.5 and 22 m respectively. This 1D geoelectrical model shows a good agreement with 2D model of Sofa R1 and borehole1 data. RMS is about 9%. The first layer represents a top Soil layer, the second is a Silty Clay layer, the third layer represents a Silty Sand layer, while the low resistivity one (5.67 Ω.m) may represents a sandy layer saturated with saline water at depth of about 22 m (zeyad et al., 2016).

4.2.1. VES2 Interpretation results

Field observed data of VES2 are listed in table (1), whilst the interpreted 1D model is shown in Figure (12). VES2 located at the center of Sofa R5 profile and near borehole 2. The calculated model assume five geoelectric layers of resistivities; 86.4, 49.5, 166, 22.6 and 13.4 Ω.m corresponding to layer depths of 0.6, 1.25, 2.6 and 11.45 m from the surface with RMS about 1.3%. This model shows good a good agreement with 2D and adjacent boring results.

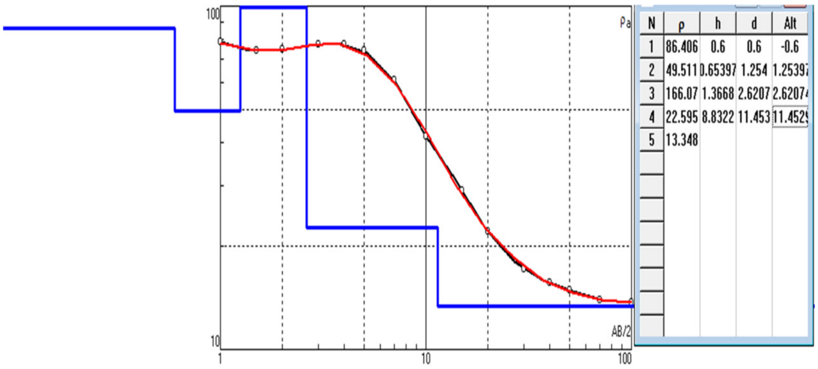

Figure 12. Geoelectrical model of VES2

4.2.3. VES 3 Interpretation results

Location VES3 is shown in figure (1). It is closed to Sofa R4 profile. The interpreted 1D model presented in figure (13). The model shows five layer models with resistivities of 28.15, 6.45, 22.9, 7.97 and 153.4 Ω.m corresponding to layer depths of 1.2, 2.8, 15.12 and 35.06 m below the surface with RMS of about 1.48%. The first and second layer correlated will with the first layer thickness of 2D resistivity profile R4 (Silty Clay), whilst the third layer of VES3 matching well with high resistivity second layer of R4 profile. The very high resistive layer of VES3 (153.4 Ω.m) may reflect a deep massive Sandstone layer.

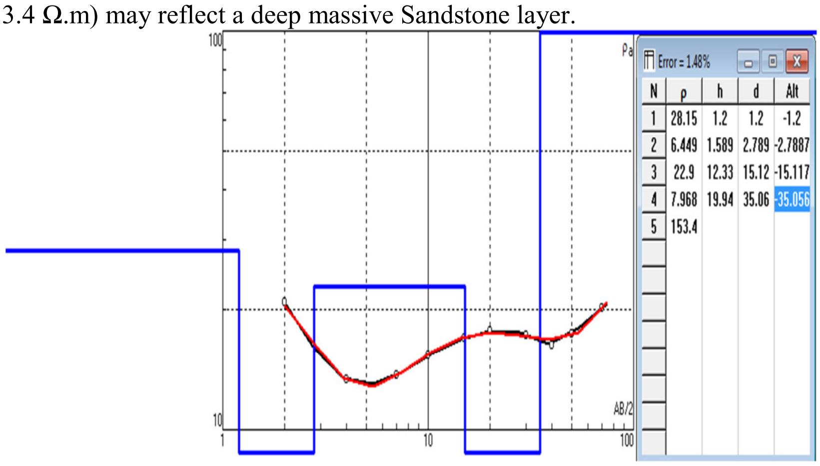

Figure 13. Geoelectrical model of VES3

5. Conclusions

The suitability of a proposed area as a sanitary landfill area is examined by applying both Electrical Resistivity Tomography (ERT) and Vertical Electrical Soundings (VES). Nine ERT spreads with Wenner-Schlumberger configuration with maximum spread length of 115m, in both E-W and N-S direction, in addition to three VES points with Schlumberger configuration with electrode spacing (AB/2) ranging from 0.5 to 150 m are used in the present study, in addition to 6 drilling boreholes (up to 25m depth) and 14 drilling test pits (up to 5m depth) are also used to support the geophysical models. The layers resistivities, thicknesses and there lithology are well defied, in addition to sub surface structures of the proposed area. Landfill leachate from the old landfill is also delineated so by ERT technique. Both geoelectrical models and geotechnical data showed excellent correlation which mean the validity of electrical methods (ERT and VES) for landfill investigations and for environmental researches.

References

Abed, A., AlWeshahy, S. (1999). Geology of Palestine. Palestinian Hydrogeological Group, Jerusalem.

Adegbola R. B., Oseni S. O., Sovi S. T Oyedele . K. F. and Adeoti L.(2010): Subsurface Characterization and its Environmental Implications using the Electrical Resistivity Survey: Case with LASU Foun dation Programme Campus Badagry, Lagos State, Nigeria. Nature and Science. 8(8) pp. 146-151.

Akintorinwa, O. J. & Abiola, O. (2011), Subsoil Evaluation for Pre-foundation study using Geophysical and Geotechnical Approach. Journal of Emerging Trends in Engineering and Applied Sciences (JETAS).2(5):858-863.

Bobachev. (2010). IPI2Win v.2.1, IPI_Res, IPI_Res3 users guide. Mascow state University.

Dahlin, T., 1996. 2D resistivity surveying for environmental and engineering applications.First Break, vol. 14, pp: 275-284.

Dahlin, T., Bernstone, C. (1997). A roll-along technique for 3D resistivity data acquisition with multi-electrode arrays, Procs. SAGEEP'97 (Symposium on the Application of Geophysics to Engineering and Environmental Problems), Reno, Nevada, March 23- 26 -1997, vol 2, pp: 927-935.

Dahlin, T., Zhou, B. (2004). A numerical comparison of 2D resistivity imaging with ten electrode arrays. Geophysical prospecting, vol. 52, pp: 379-398.

Geotomo Software (2010). Geoelectrical Imaging 2D & 3D. Malaysia www.geoelectrical.com.

Reynolds, John, M., , (1998). An Introduction to Applied and Environmental Geophysics, 1st Edition, John Wiley & Sons Ltd, Chichester, England.

Keller, G.V. and Frischknecht, F.C. 1988. Electrical Methods in Geophysical Prospecting. Pergamon Press Inc.: New York, NY. 38-39,519.

Loke, M. H. (1999). Electrical Imaging Surveys for Environmental and Engineering Studies, A Practical Guide to 2D and 3D Surveys. http://www.geoelectrical.com

Loke, M. (2015). Electrical imaging surveys for environmental and engineering studies, a practical guide to 2D and 3D surveys. http://www.geoelectrical.com.

Niwas, S., & de Lima, O. A. (2003). Aquifer parameter estimation from suface resistivity data. *Ground Water, 41(1), 94-99.*

Sinha, R., Israil, M., Singhal, D.(2009). Hydrogeophysical model of the relationship between geoelectric and hydraulic parameters of anisotropic aquifers, Hydrogeology Journal vol. 17, pp:495–503.

Utom, A., Odoh, B., Okoro, A. (2012). Estimation of Aquifer Transmissivity Using Dar Zarrouk Parameters Derived from Surface Resistivity Measurements: A Case History from Parts of Enugu Town (Nigeria). Journal of Water Resource and Protection, vol. 4, pp:993-1000.

Vafai, F., Abolghasemi, H. (2014). Investigation of sea and groundwater level changes on seawater intrusion in an unconfined coastal aquifer, Journal of Middle East Applied Science and Technology (JMEAST) Issue 20, pp: 684-688.

Thabit, J., AL-Hameedawie, M. (2014). Delineation of groundwater aquifers using VES and 2D imaging techniques in north Badra area, Eastern Iraq, Iraqi Journal of Science, vol. 55(1), pp:174-183.

Olorunfemi MO, Mesida EA. Engineering geophysics and its application in engineering site investigation – Case study from Ile-Ife area. The Nigerian Engineer 1987; 22:.57- 66.

Sharma, P. V. (1997). *Environmental and engineering geophysics*. Cambridge university press.

Saksa, P., & Korkealaakso, J. (1987). Application of geophysical methods in environmental and municipal engineering. Valtion teknillinen tutkimuskeskus.

Yang, J. W., & Joshi, S. D. (2014). Hydro-Geophysical Investigation of Contaminant Distribution at a
Closed Landfill in Southwestern Ontario, Canada. Journal of Geoscience and Environment Protection, 2, 8-15. http://dx.doi.org/10.4236/gep.2014.23002

Joshi, S. D. (2013). Hydrogeophysical Investigation of Contaminant Distribution at a Closed Landfill in Southwestern Ontario, Canada. M.Sc. Thesis, Windsor: University of Windsor.

Bernstone, C., & Dahlin, T. (1997). DC Resistivity Mapping of Old Landfills: Two Case Studies. European Journal of Engineering and Environmental Geophysics, 2, 121-136.

Zeyad H. Abu Heen & shehda A. Muhsen, (2016). Application of Vertical Electrical Sounding for Delineation of Sea Water Intrusion into the Freshwater Aquifer of Southern Governorates of Gaza Strip, Palestine, IUGNS Vol 24, No 2, pp 07-20. ISSN 2409-4587.

Zume, J. T., Tarhule, A., & Christenson, S. (2006). Subsurface Imaging of an Abandoned Solid Waste Landfill Site in Norman, Oklahoma. Groundwater Monitoring and Remediation, 26, 62-69.

Radulescu, M., Valerian, C., & Yang, J. (2007). Time-Lapse Electrical Resistivity Anomalies Due to Contaminant Transport around Land Fills. Annals of Geophysics, 50, 453-468.

Zhu, K., & Yang, J. (2008). Time-Dependent Magnetometric Resistivity Anomalies of Groundwater Contamination: Synthetic Results from Computational Hydro-Geophysical Modeling. Applied Geophysics, 5, 322-330.

MSL (Material & Soil Laporatories, Islamic University of Gaza (2009) .Soil Investigation Report of Al Fukhari Infiltration Basin Pilot Well, Khan Younis waste water treatment plant. Internal report.