IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 6 Ver. III (Nov. - Dec. 2015), PP 34-45
www.iosrjournals.org

Application of Two-Dimensional Earth Resistivity Imaging for Groundwater Exploration and Assessment of Salt-Water Intrusion Problemin Wadi AlRuheib and Wadi Al Basserah Drainage Basins, Northeastern United Arab Emirates

A. M. Ebraheem[1], H. K. Garamoon[2], Z. E. Rizk*[3], M.F. Khalil[1],
A. S. Al Matari[4],M. M. Al Mulla[4], A.V. Shetty[5]

[1]*GeologyDepartment, Faculty of Science, Assiut University, Assiut, Egypt*
[2]*Department of Geophysics, Ain Shams University, Cairo, Egypt*
[3]*Institute of Environment, Water and Energy, Ajman University of Science and Technology, Ajman, UAE*
[4]*Ministry of Environment and Water, Dubai, UAE*
[5]*Faculty of Engineering, UAEUniversity, Al Ain, UAE*

Abstract: *An intensive two-dimensional (2D) earth resistivity imaging survey was conducted in wadis Al Ruheib and Al Basserah areas, northeastern United Arab Emirates (UAE) toexplore the availability groundwater resources and assess water quality. The study also intended to delineate major structural elements affecting groundwater flow and recharge. The 2D earth resistivity imaging method was used to evaluate water quality in the alluvial gravel aquifer near the outlet area of wadi Al Ruheib. Existing drilling information of the monitoring wells were used to improve the interpretation of earth resistivity imaging data. The obtained results indicate that this method is a relatively quick, inexpensive and reliable surface geophysical method for mapping water-filled fracturesand assessment of groundwater quality.*

Keywords: *Two-dimensional earth resistivity imaging, Wadi Al Ruheib, Wadi Al Basserah, Northeastern United Arab Emirates*

I. Introduction

Sustainable management of available natural water resourcesis crucial for the success of water development projects in northern UAE. Successful water resources management depends on the planners' knowledge of the available water resources and ability to predict the consequences of certain management options in the short and long terms.

Renewable and non-renewable groundwater resources in shallow alluvial aquifers and deep carbonate aquifers represent the main source of fresh water in the northern emirates of the UAE. A major decline in water table elevations has been observed since the beginning of 1980s. This groundwater depletion is mainly a result of increasing groundwater pumping for domestic and agricultural purposes. Groundwater over-pumping is partially compensated for by natural replenishmentof depleting aquifers during rare rainstorms.

The imbalance between recharge and groundwater abstraction during the last four decades has created severe groundwater depression cones to the extent that most of wells with depths less than 100m have dried up and the Quaternary aquifer itself is threatened with total groundwater depletion. The problem of salt-water intrusion has been reportedin aquifers along the eastern coast of the UAE[1].In Wadi Al Ruheiband Wadi Basserah basins, the rapid depletion of groundwater induces salt-water intrusion in the coastal side of the aquifersystems in Dibba and Dadnah areas(Fig. 1).Despite serious deterioration of the groundwater quality, water demands for urban development, growing industries and agricultural activitiesare increasing constantly.

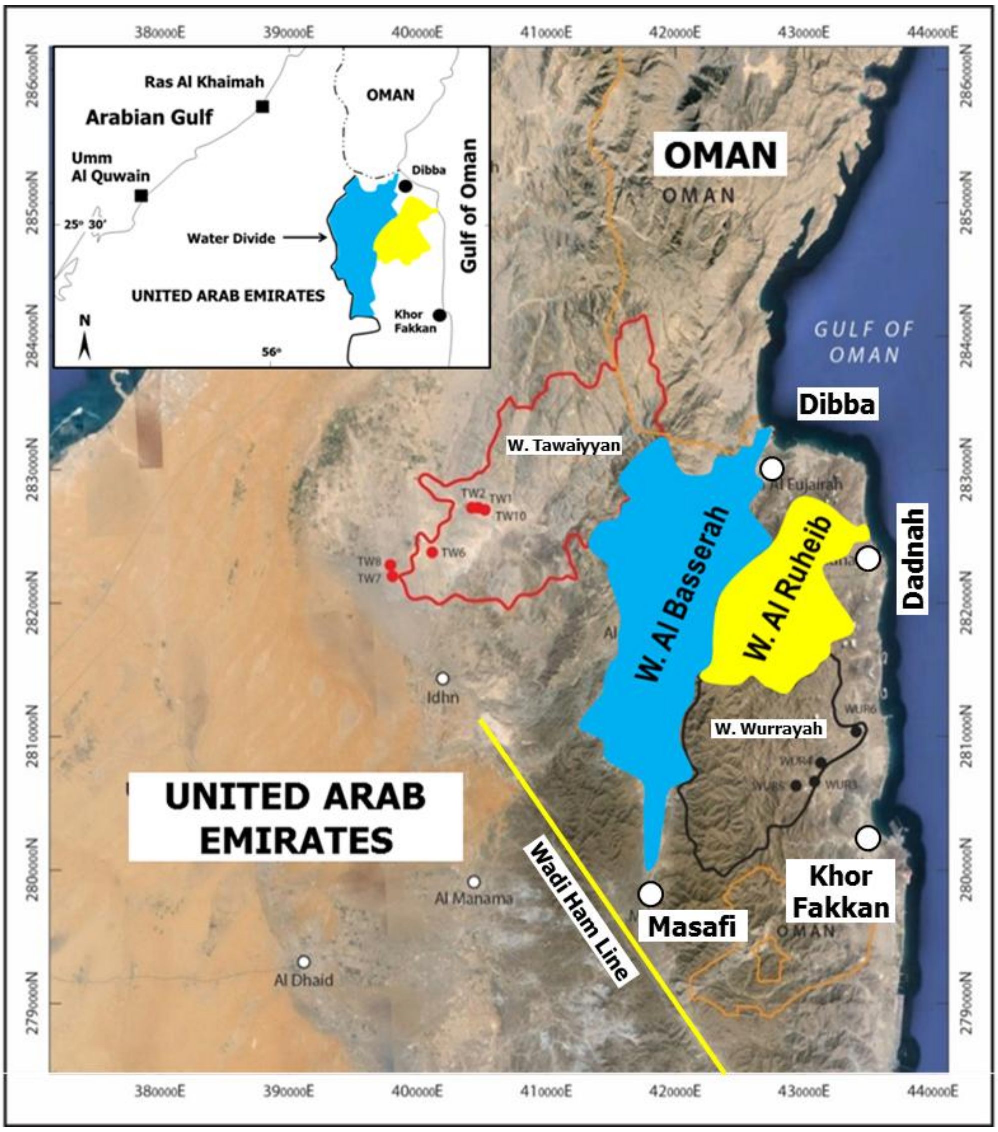


Fig. 1 Location map of the study area.

The application of surface resistivity methods to delineate the contaminated zones has the following advantages: (1) reduce the need for intrusive techniques of direct groundwater sampling, (2) relatively inexpensive data which can be used for rapid and economical monitoring of large areas as well as to optimize the future placement of monitoring wells, and (3) electrical conductivity/resistivity represent intrinsic properties of groundwater chemistry that can be interpreted in terms of the degree of groundwater salinity in clay-free environment [1-6]. The development of resistivity surveying techniques has been very rapid in the last three decades. The advent of automated data acquisition systems, inversion codes, and easy access to powerful and fast computers has increased the practical applicability of the 2D and 3D earth resistivity imaging methods. Geoelectrical resistivity imaging is increasingly being used in environmental, engineering and hydrological investigations as well as geothermal and mineral prospecting, where detailed knowledge of the subsurface is sought [7].In this study, an extensive 2D earth resistivity imaging (ERI) survey was conducted in the northern part of UAE for assessment of groundwater resources in the shallow Quaternary aquifer, determinationof the of extent salt-water intrusion in the coastal areas and exploration of the groundwater resources in the fractured bedrock aquifers.

1.1 Geologicaland Hydrogeological Settings

The upstream part of the east coast area of UAE is dominated by the Masafi Mountains whereas the alluvial plains prevail in its lower part. Sediments of the lower plains are composed of Pleistocene wadi gravels. The alluvium gravels layer overlay the consolidated rocks of the Semail Ophiolite sequence, with a separating mantle of fractured zones in some locations (Fig.2). Two hydraulically connected aquiferswere identified in the study area [8];the Quaternary aquifer and the fractured Ophiolites and limestone aquifer.

The Quaternary aquifer dominates the gravel plain and is composed alluvial deposits range in size from large boulders to fine silts and meet the mountain front at high angles. In the eastern coastal area, the Quaternary sediments overlie the consolidated rocks of the Semail Ophiolites sequence(Fig 2). The fractured Ophiolites aquifer is composed of gabbros and serpentiniteof the Semail Ophiolite, underling the unconsolidated sediments in Wadi Al Ruheib basin (formerly known as Wadi Zikt and labeled “ZKT” in Fig. 2), in addition to the fractured limestone rocks exposed in the mountain outcrops overlooking Wadi Al Basserah basin (labeled “BSR” in Fig. 2).

II. Principles of Surface Geophysical Techniques

2.1 Direct Current (Dc) Resistivity

The Dc resistivity methods measure the electrical resistivity distribution of the subsurface using current transmitted into the ground from dc- or low-frequency sources, by two electrodes (C1 and C2), and measuring the potential difference between a second pair of electrodes (P1 and P2) (Fig. 3a, b, c and d). The apparent resistivity of the subsurface can be calculated by applying a geometric correction (K) to Ohm's law ($R = \Delta V/I$, where R is the resistance, ΔV is the measured potential difference, and I is the injected current), based on the specific electrode spacing and geometry. These geometrically corrected measurements are defined as apparent resistivities rather than true resistivities because a resistively homogeneous subsurface is assumed. Measured resistivity values are controlled by material resistivity, and the presence, quality, and quantity of groundwater[9, 2, 3, 10]. The resistivity of a fracture zone is controlled by the secondary porosityand the presence of altered secondary minerals and/or precipitate.

The maximum penetration depth is directly proportional to the electrode spacing and inversely proportional to the subsurface conductivity [11, 12]. 2D dc-resistivity profiling is conducted by making many measurements at different locations along the profile and at different offsets (Fig. 3e). The 2D dc-resistivity profiling data are inverted to create a tomogram-like model of resistivity along a section of the subsurface that can be used to detect and define individual fracture zones.

In the present survey eight channels Memory Earth Resistivity and IP instrument and Switch Box manufactured by Advanced Geosciences, Inc. The linear array of each profile consisted of 112 electrodes where the distances were controlled automatically by using an eight channel switch box. Dipole-Dipole and Schlumberger arrays were used in this survey(Fig. 3). Forty 2D resistivity profiles with a profile length ranging from 550 to 2220 meters and total length of 93 kilometers were conducted in the eastern coast area of UAE during the period October 2005-December 2007. In the present article only the obtained results for Wadi Al Ruheib and Wadi Al Basserah are presented.

By using an iterative smoothness-constrained least-squares inversion method [13, 14], apparent resistivity data collected by the 2D dc-resistivity system are inverted to create a model of subsurface resistivity that approximates the true subsurface resistivity distribution [15, 7]. Linear zones of low resistivity that are continuous with depth are interpreted as fracture zones.

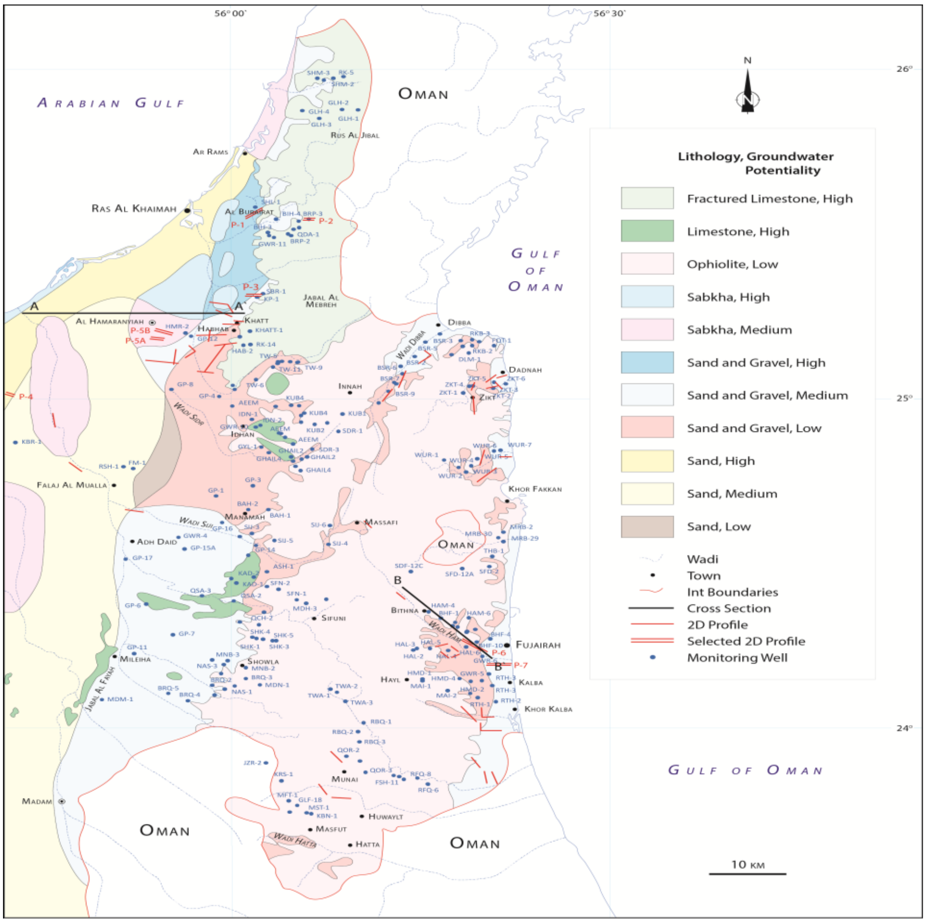


Fig. 2 Hydrogeological Map of the northern area of UAE [6].

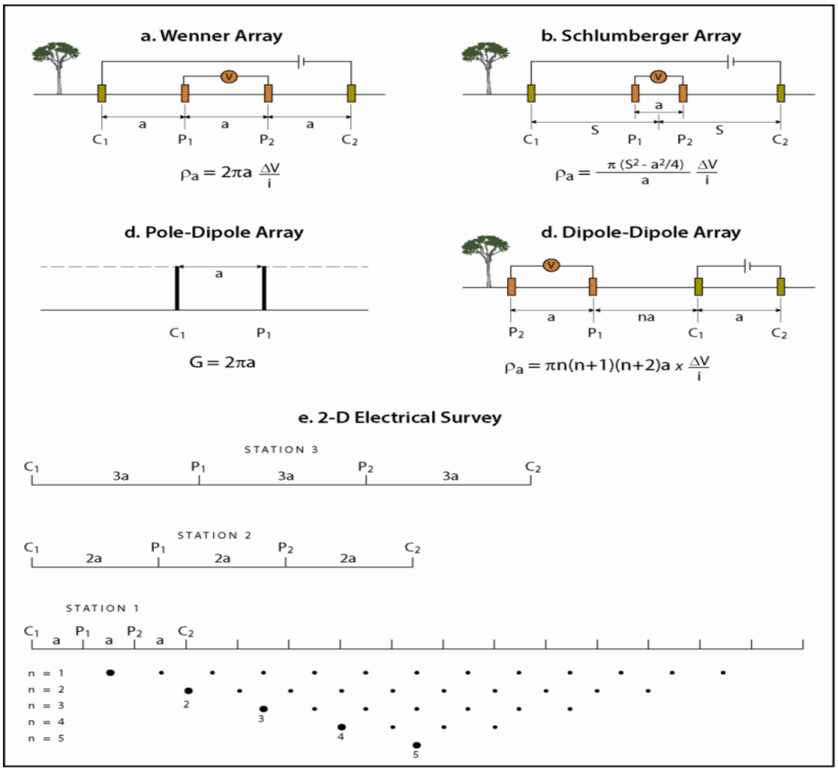


Fig. 3Top: a conventional four electrode array to measure the subsurface resistivity, a-d:common arrays used in resistivity surveys and their geometric factors. Bottom: thearrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudo section [15].

III. Data Acquisition And Interpretation

3.1 Wadi Al Ruheib and its Outlet Area (Dadnah)

Nine profiles were conducted in this area (four in Wadi Al Ruheib and five in Dadnah area; (Fig. 4), the profile length ranged from 550 to 2220 meters based on the accessibility. The inversion results of these profiles are discussed in the following:

Profile Al Ruheib-1 is located upstream from the dam along a perpendicular direction (Fig.4). The interpretation results indicate the presence of two layers; the upper one is the unconsolidated materials which vary in thickness from less than 10 m in the southwest to more than 50 m in the northeast (dam side). This layer is dry in the southwestern part of the profile and saturated with fresh water in some parts in the northeastern side of the profile where the resistivity is around 70 Ohm m (Ωm) (Fig. 5). This layer overlies a thick Ophiolitessequence which is fractured up to the depth of penetration (200m) in some places in the southwestern side of the profile and probably saturated with slightly fresh water in these areas (dipole-dipole interpretation).

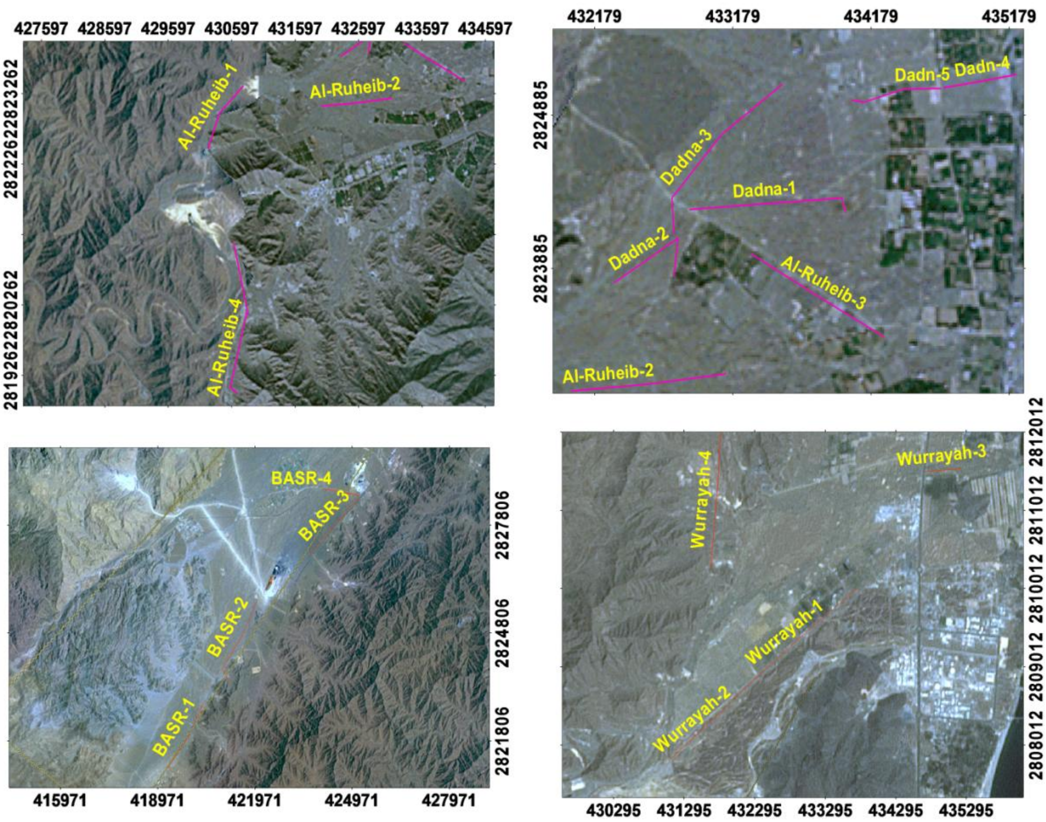


Fig. 4Locations of the 2D earth resistivity profiles in Wadi Al Ruheib (top left), Dadnah (top right), and Wadi Al Basserah (bottom left[3])

Profile Al Ruheib-2 is located just downstream from the dam and also along a perpendicular direction (Fig.4). Its interpretation results indicate the presence of two layers; the upper one is the unconsolidated materials which vary in thickness from less than 10 m in the western side of the profile to more than 150m in the eastern side (the closer end to the Gulf). This layer is dry in the western part of the profile and saturated with fresh water in some parts in the eastern side of the profile where the resistivity is around 60 Ωm(Fig. 6). This layer overlies a thick Ophiolitessequencewhich is fractured up to the depth of penetration (200m) in some places in the western side of the profile and probably saturated with slightly fresh water in these areas.

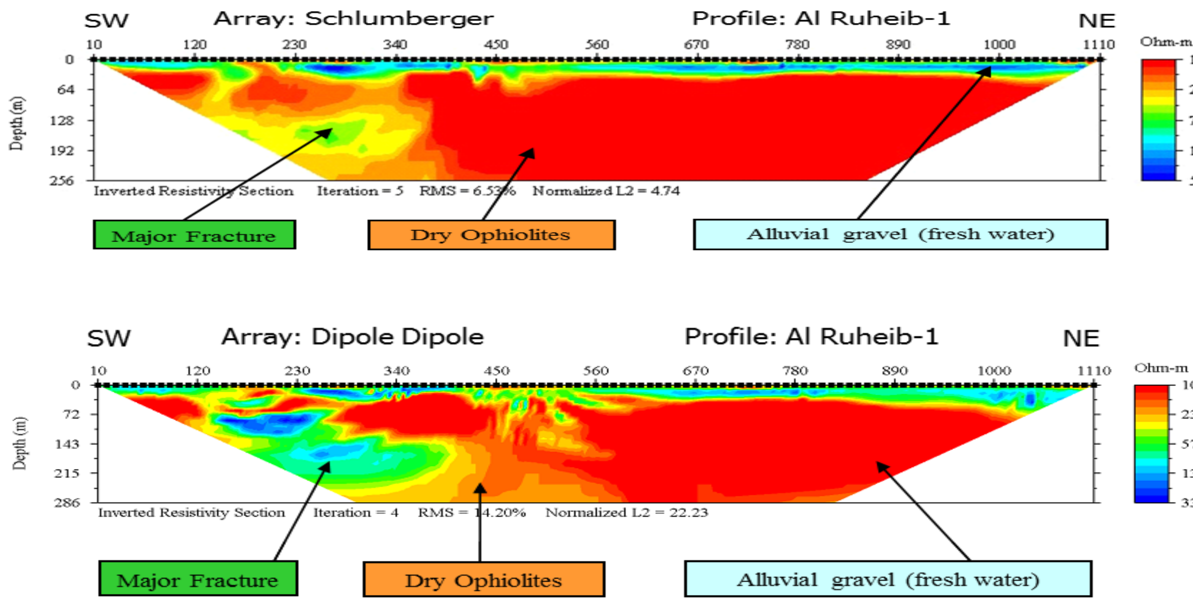


Fig.5Results of 2D dc-resistivity data and modeling for profile Al-Ruheib-1. (See Fig. 4 for profile location).

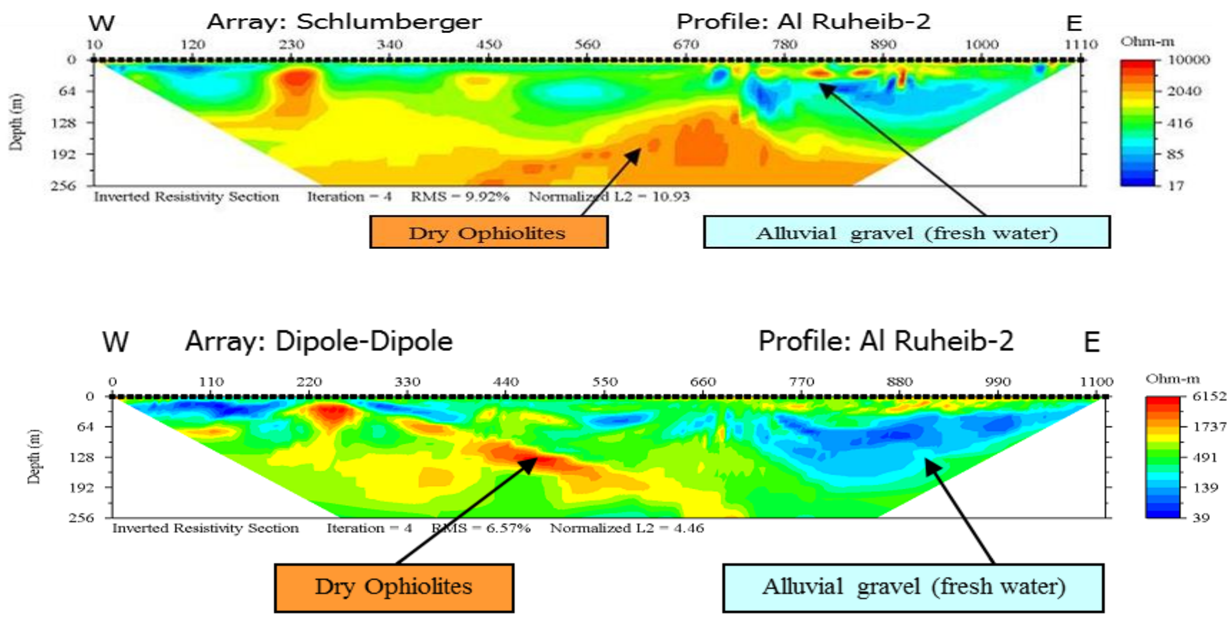


Fig. 6 Results of 2D dc-resistivity data and modeling for profile Al-Ruheib-2 (See Fig. 4 for profile location).

Profile Al Ruheib-3 is in the alluvial fan of wadi Al Ruheib (Fig.4). The interpretation results indicate the presence of two layers; the upper one is the unconsolidated materials which vary in thickness from less than 30 m in the northwestern side of the profile to more than 150m in the southeastern side (the closer end to the Gulf). This layer is dry in the northwestern part of the profile and saturated with fresh water in some parts in the middle and eastern parts of the profile where the resistivity is around 60 Ωm(Fig. 7). This layer overlies a thick Ophiolitessequence which is fractured up to the depth of penetration (200m) in some places in the northwestern side of the profile and probably saturated with slightly fresh water in these areas.

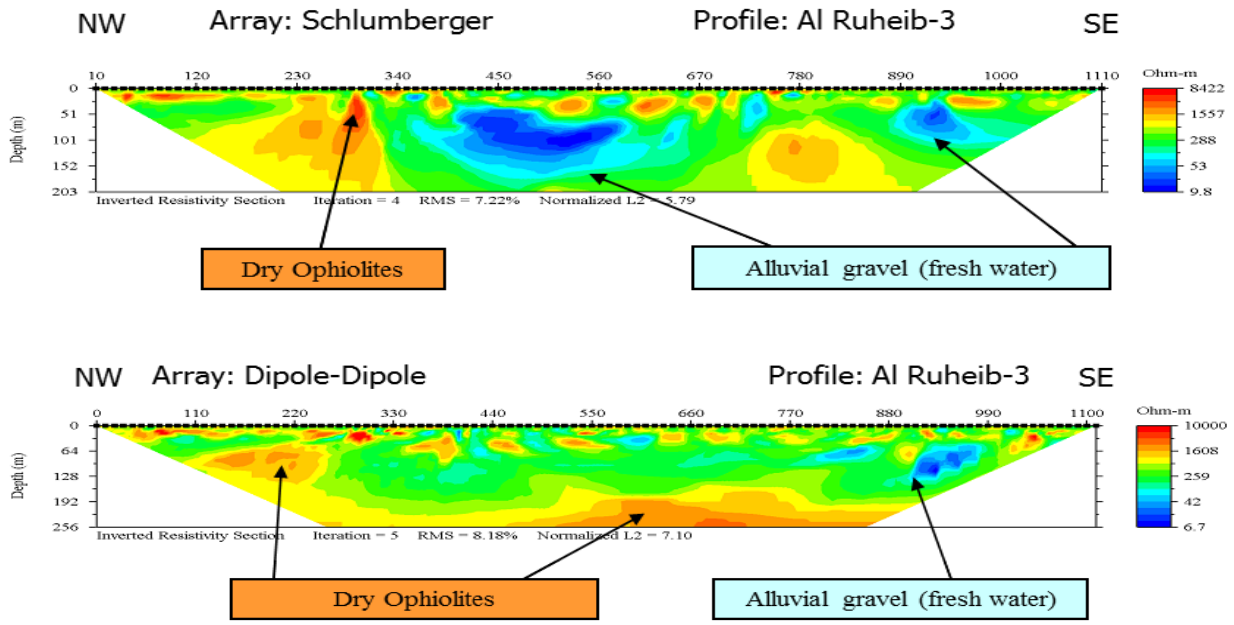


Fig.7Results of 2D dc-resistivity data and modeling for profile Al-Ruheib-3. (See Fig. 4for profile Al Ruheib-3 location).

Profiles Dadnah-1, Dadnah-2, and Dadnah-3 are located in the outlet area of Wadi AlRuheib (Fig. 4). However profile Dadnah-3 is close to mountain side. The interpretation of profiles 1 and 2 indicate that there is a fault extending SW-NE which is responsible for increasing permeability in the eastern part of profile Dadnah-1 (Fig.8) and the northeastern part of profile 2 where the total thickness of the unconsolidated materials could reach more than 100m. The interpretation of profile Dadnah-3 indicates the thickness of the unconsolidated materials across the whole profile does not exceed 40 m and groundwater potentiality in the profile area is generally low (Fig. 9).

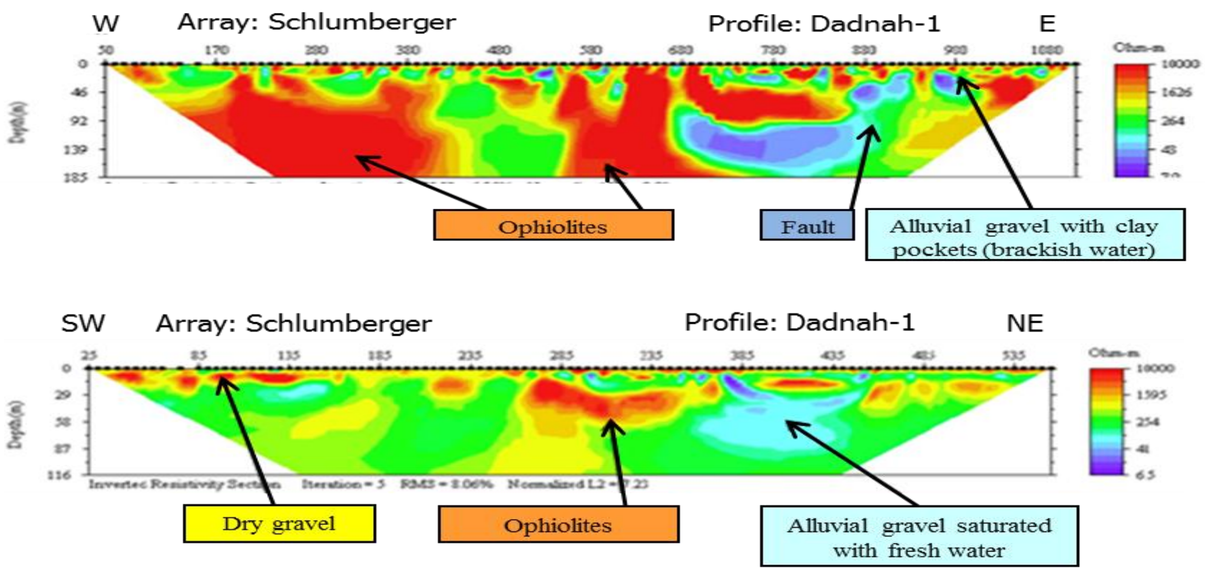


Fig.8Results of 2D dc-resistivity data and modeling for profile Dadnah-1.

Profile Dadnah-4 and Dadnah-5 are located along the northern side of the alluvial fan of Wadi Al Ruheib (Fig. 4). Their interpretation results (Figures 10 and 11) indicate the presence of two layers; the upper one is the unconsolidated materials which have an average thickness of 60 m; at least the upper 30 m are dry and the other 30 m are saturated with slightly brackish water. The interpretation results of profile Dadnah-4, which is close to the sea, indicate that the saturated part of layer has a very low resistivity and thus it is either intercalated with lenses of clay layer and/or saturated with brackish water (Fig. 10). This layer overlies a thick Ophiolites sequence which is fractured up to the depth of penetration (200bm) in some places in the northwestern side of the profile and probably saturated with slightly fresh water in these areas.

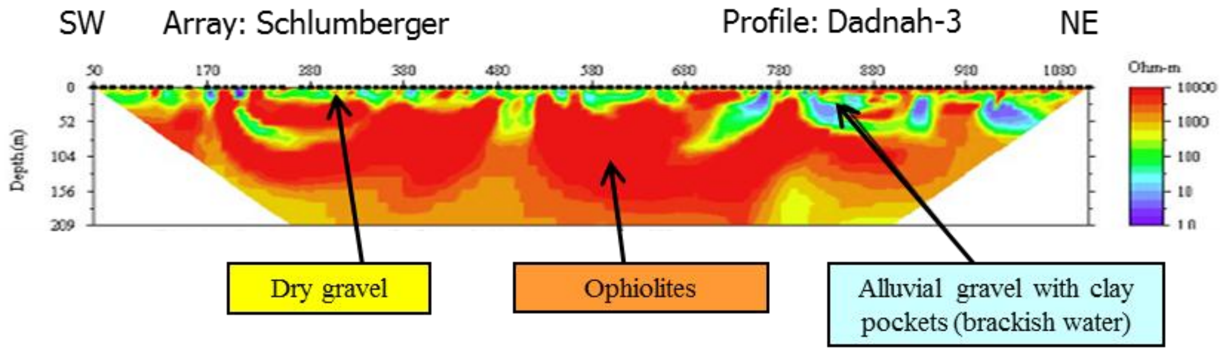


Fig. 9Results of 2D dc-resistivity data and modeling for profile Dadnah-3.

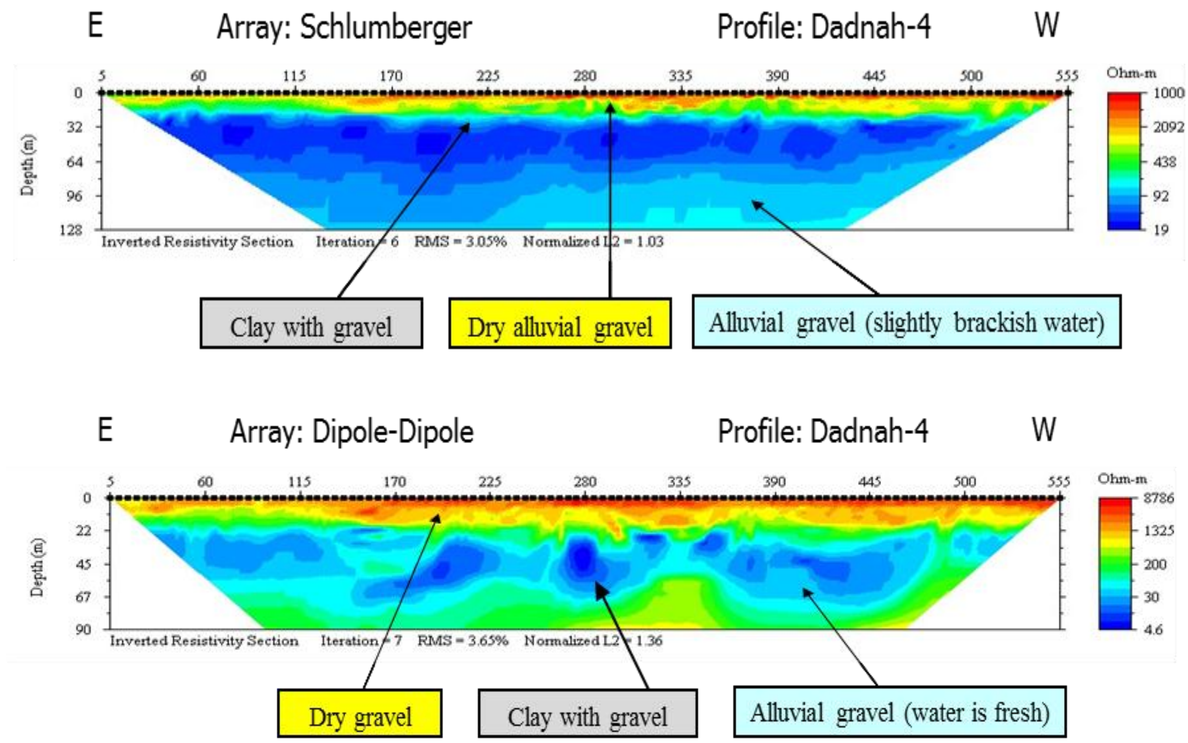
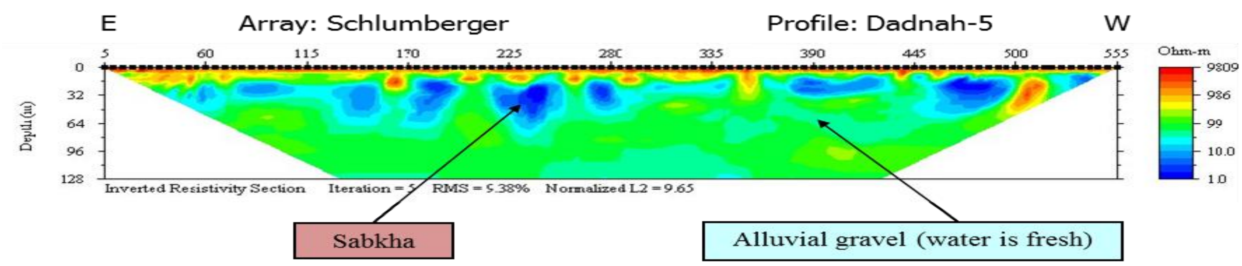


Fig.10Results of 2D dc-resistivity data and modeling for profile Dadnah-4.



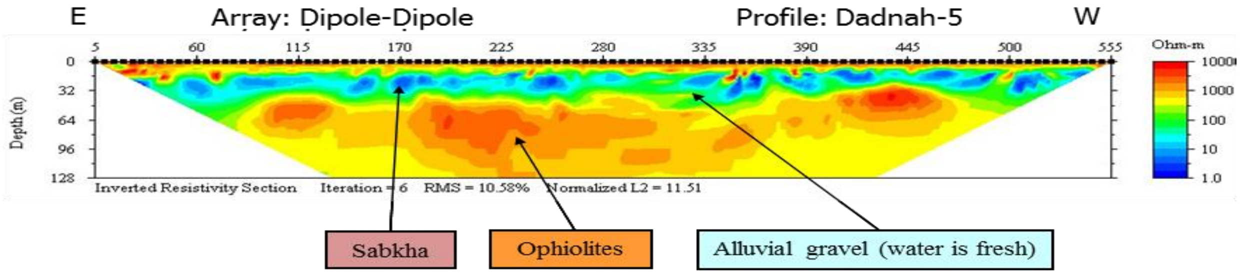


Fig.11Results of 2D dc-resistivity data ad modeling for profile Dadnah-5. (SeeFig. 4 for profile location).

3.2 Wadi Basserah

Four profiles conducted in Wadi Al Basserah are located along the main wadi (two south of the cement factory and two north of it; Fig. 4). Wadi Al Basserah is running in a SW-NE direction along a major fault running on the same direction and splitting between Ophiolites in the east and limestone in the west (Fig. 4). This major fault has strongly affected both of the layers in terms of fracturing and increasing their groundwater potentiality to be the highest in the Eastern Regionof the UAE. The interpretation results of all of the four profiles (Figures12-15) confirm that the Ophiolitessequenceis strongly fractured from its top to the depth of penetration in this area (500m). This layer is most probably saturated with fresh water. Despite the fact that that interpretation of profiles 4 (Fig. 15) indicates that the effect of the fault is more on the Ophiolitessequence (eastern side), it is still worth to conduct another three profiles along the western side of the wadi (limestone side) to determine the physical dimension of this layer and its groundwater potentiality. Due to that fact that Wadi Al Basserah has the greatest groundwater potentiality in the Eastern Region of the UAE and it is relatively far from the sea, it is recommended to conduct detailed studies to provide the necessary information needed for sustainable water resources planning and management in this area.

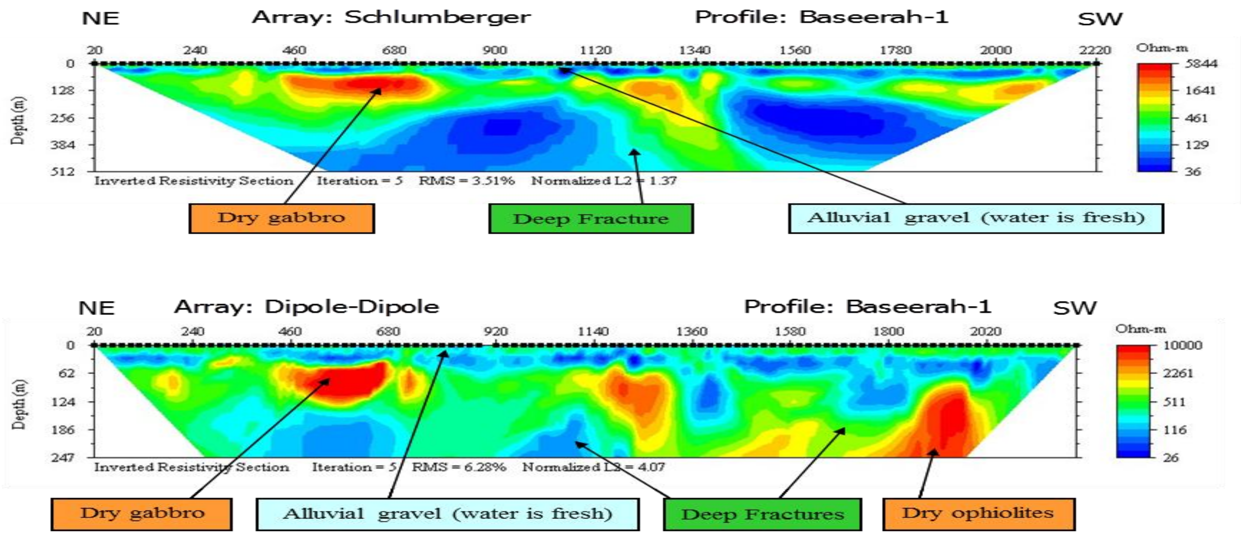


Fig.12Results of 2D dc-resistivity data ad modeling for profile Al Basserah-1. (SeeFig. 4for profile location).

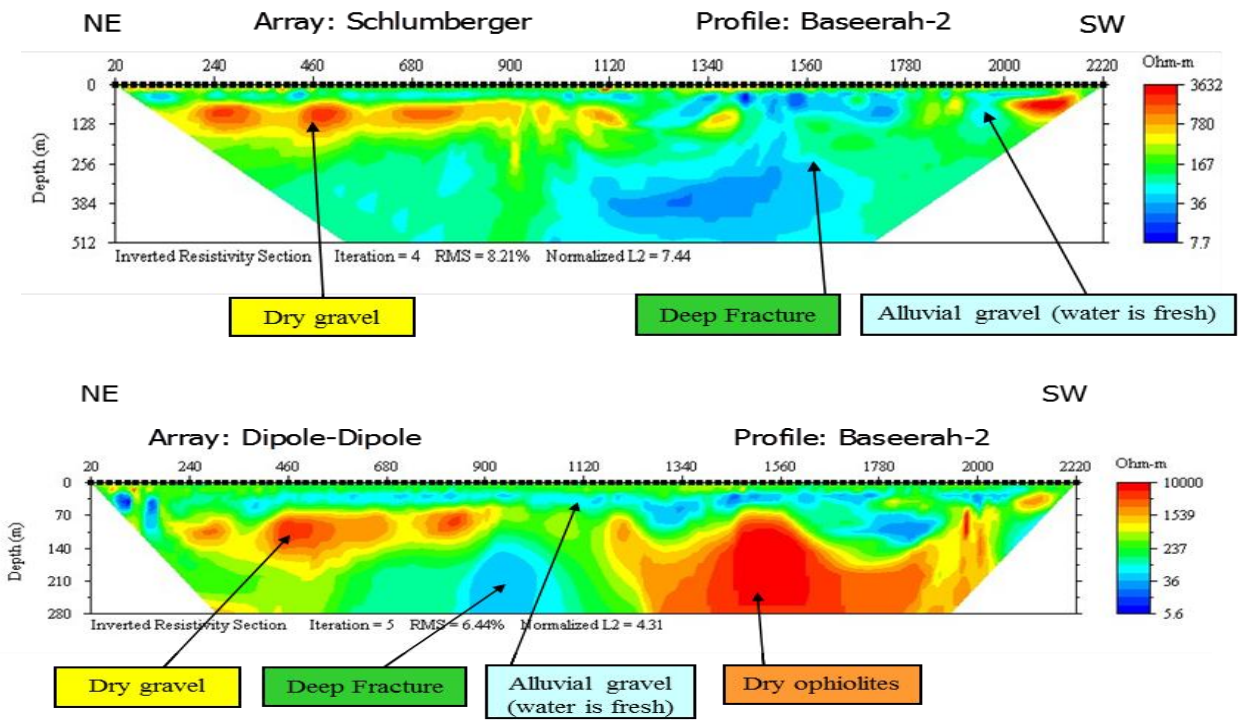


Fig.13Results of 2D dc-resistivity data ad modeling for profile Al Basserah-2. (SeeFig. 4for profile location).

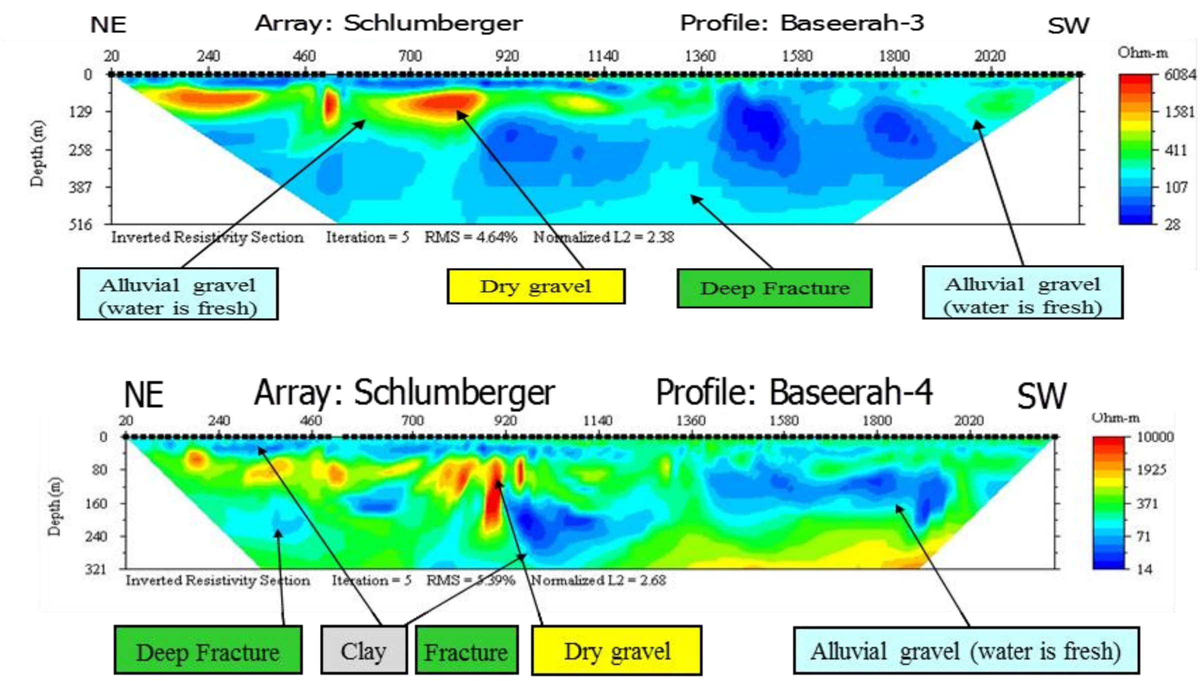


Fig.14Results of 2D dc-resistivity data ad modeling for profile Al Basserah-3. (SeeFig. 4for profile location).

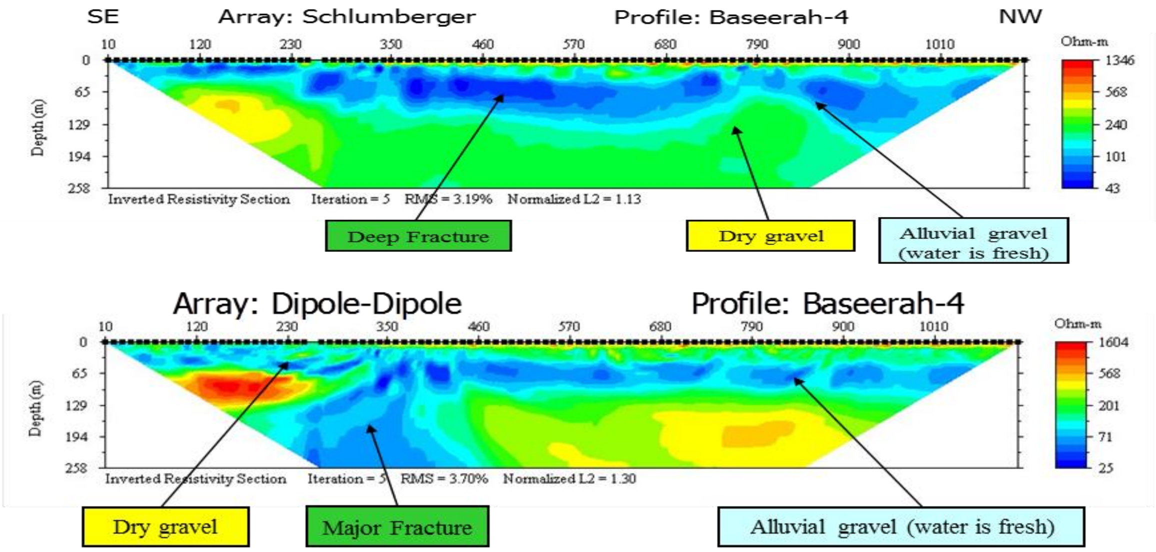


Fig.15Results of 2D dc-resistivity data ad modeling for profile Al Basserah-4. (SeeFig. 4for profile location).

IV. Conclusions

Groundwater resources in the Quaternary alluvium and fractured Ophiolites aquifers in Al Ruheib and Al Basserah drainage basins in the Eastern Region of UAE were explored using the 2D earth resistivity imaging techniques.

The results confirmed that the 2D earth resitivity imaging technique is a useful tool for groundwater exploration in the Quaternary aquifer due to high resistivity contrast between saturated and dry gravel or sand. Where the clay content is low or abscent, it was possible to classify the groundwater as fresh, brackish or saline in the study area. Therefore, it was possible to identify areas suffering from salt-water intrusion problem. This problem is posing a major threat to the limited groundwater resources in the outlet area of Wadi Al Ruheib drainage basin, which is a crucial information for proper water resources development schemes.

The 2D Earth Resistivity imaging technique is also useful for differentiating the saturated fractured limestone or Ophiolitesfrom the dry unfractured limestone or Ophiolites due to the very high resistivity contrast.

The nine 2D earth resitivity imaging profiles conducted in Wadi Al Ruheib basinindicated the presence of a Quaternary alluvial aquifer varying in thickness from less than 10 m to more than 150 m and averaging 60 m. The upper part of this aquifer is dry and the lower portion is mostly saturated with fresh groundwater in upstream areas. However, the groundwater salinity increases near the outlet of the basin indicating the influence of salt-water intrusion from the Gulf of Oman. Groundwater pumping for different purposes in this area accelerated the problem of saline-water intrusion.

A fractured Ophiolites aquifer extends from the base of Quaternary alluvial aquifer within the study area to the maximum depth of penetration of profiles, which varied between 200 and 500 m. The four 2D earth resitivity imaging profiles conducted in Wadi Al Basserah revealed the influence of major faults separating the Ophiolitic rocks in the east from the limestone in the west and increasing the groundwater potentiality of this area to be the highest in the Eastern Region of the UAE. The fractured Ophiolites aquifer is saturated with fresh water, but the aquifer's yield is highly dependent on the intensity of fractures. Salt-water intrusion is not a serious problem in Wadi Al Basserah basin because it is relatively far from the sea.

References

[1] M.M Sherif, A. Al Mahmoudy, H.K. Garamoon, A. Kasimov, S. Akram, A.M. Ebraheem, and A. Shetty, Geoelectrical and Hydrogeochemical Studies for Delineating Ground-Water Contamination Due to Salt-Water Intrusion in the outlet of Wadi Ham, UAE, Environmental Geology, 49 (4), 2006, 536-551.

[2] A.M. Ebraheem, M.W. Hamburger, E.R. Bayless, and N.C. Krothe, A study of acid mine drainage using earth resistivity measurements. Ground Water,28(3),1990, 361-368.

[3] A.M. Ebraheem,M.M. Senosy,and K.A. Dahab, Geoelectrical and Hydrogeochemical Studies for Delineating Groundwater Contamination Due to Salt-Water Intrusion in the Northern Part of the Nile Delta, Egypt. Ground Water, 35(2), 1997, 216-222.

[4] A.M. Ebraheem, A.S. Al Matari, A. Shetty, S.F. Akram, and M.M. Al Mulla, Application of GIS-Based 2D Earth Resistivity Imaging Techniques for the Assessment of Water Resources in the Eastern Region of UAE, Internal Report, Ministry of Environment and Water (MOEW), Dubai, UAE, 2008.

[5] A.M. Ebraheem, M.M. Sherif, M.M. Al Mulla, S.F. Akram, and A.V. Shetty, A geoelectrical and hydrogeological study for the assessment of groundwater resources in Wadi Bih, UAE, Environmental Earth Sciences, 67(3), 2012, 845-857.

[6] A.M. Ebraheem, M.M. Al Mulla,M.M. Sherif , O. Awad, S.F. Akram, N.B. Al Suweidi, and A. Shetty, Mapping groundwater conditions in different geological environments in the northern area of UAE using 2D earth resistivity imaging survey, Environmental Earth Sciences 09/2014, 72(5), 2014, 1599-1614.

[7] A.P. Aizebeokhai,2D and 3D geoelectrical resistivity imaging:Theory and field design, Scientific Research and Essays, 5(23), 2010, 3592-3605.

[8] IWACO, Groundwater Study Project 21/81, Drilling of deep water wells at various locations in the UAE, Groundwater Development in the Northern Agricultural Region, Internal Report 7, Ministry of Agriculture and Fisheries, Dubai, UAE, 1986.

[9] K. Cartwright, and F. Sherman, Electrical earth resistivity surveying in landfill investigations: 10thAnnual Engineering and Soils Engineering Symposium, Moscow, ID, 1972.

[10] F.P. Haeni, G. Placzek, and R.E. Trent, Use of ground-penetrating radar to investigate infilled scour holes at bridge foundations, in Hanninen, Pauli and Autio, Sini (eds.), Fourth International Conference on Ground Penetrating Radar, Rovaniemi, Finland, June 8-13, 1992, Proceedings: Geological Survey of Finland Special Paper 16, 1992, 285-292.

[11] L.S. Edwards, A modified pseudosection for resistivity and IP: Geophysics, 42(5), 1977, 1020-1036.

[12] F.P. Haeni, and G. Placzek, Use of processed geophysical data to improve the delineation of infilled scour holes at bridge piers, in Expanded Abstracts with Biographies, SEG 61st Annual International Meeting, Houston, Texas, November 10-14, 1991: Houston, Texas, Society of Exploration Geophysicists, 1991, 549-552.

[13] C. deGroot-Hedlin, and S. Constable,Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data, Geophysics, 55, 1990, 1613-1624.

[14] Y. Sasaki, Resolution of resistivity tomography inferred from numerical simulation, Geophysical Prospecting, 40, 1992, 453-464.

[15] M.H. Loke, Electrical imaging surveys for environmental and engineering studies--a practical guide to 2D and 3D surveys, Penang, Malaysia, University Sains Malaysia, unpublished short training course lecture notes, 1997.