IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

# Identification of aquifer potential by using geoelectrical resistivity technique in the northeastern part of the Jordan Valley, Jordan

**Mohammad Tarawneh[1], Janardhana M. R[2].**

[1] DOS in Earth Science, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

[2] Department of Geology, Yuvaraja's College, University of Mysore, Mysuru, Karnataka, India

**Abstract**

The present study was carried out by conducting vertical electrical sounding at 43 points (VES) in the northeastern part of the Jordan Valley, Jordan to evaluate the aquifer protective capacity (APC) and potential capacity of the aquifer. IPI2win software was used to accomplish the interpretation of VES data. The VES interpreted data was used to prepare spatial distribution maps of aquifer apparent resistivity (AR), layer thickness, longitudinal conductance (LC) and transverse resistance (TR) for the subsurface layers using Rockwork14 software. The results showed that the study area had four subsurface geoelectric layers. The results also indicated that the APC values increase with the increase in the depth of the geological column. The second layer characterised by high values of TR in the southern part of the study area indicate higher yield potential as compared to the northern and central parts. The third and fourth layers characterised by low values of TR in the northern and southern parts of the study area imply low yield potential owing to the occurrence of clay-rich deposits. The present investigator is in favour of creating recharge zone in the southern part of the study area by taking the gradient and geology of the area into consideration. Based on geological data, TR and LC values, the central part of the study area is relatively more permeable in the third and fourth layers thus, there is more scope for the loss of recharged water.

***Keywords:*** *VES, Jordan valley, aquifer protective capacity (APC), longitudinal conductance (LC), transverse resistance (TR).*

## 1. Introduction

Arid regions, including hyper arid, arid, semiarid and sub-humid regions, cover more than 18% of the Earth's surface and are considered the most vulnerable areas with regard to the water crisis. These regions face the greatest pressure with regard to their limited freshwater resources (UNESCO, 2012). The challenge of sustainable water management in semi-arid countries is magnified by the country's geography, hydrology, climate and trans-boundary issues as in the case of Israel (www.un.org/agenda21/nattiinto/countr/Israel/drought.paf) and Jordan.

Jordan is considered as one among the poorest countries in the world in terms of its water resources. The arid climate, the low and variable precipitation rates, high rate of population growth, the limited resources, and over-exploitation of groundwater are all factors which rendered the problem more critical and challenging (Mohammad Tarawneh and Janardhana, 2017). Geophysical methods, especially Vertical Electric Soundings (VES) have been used successfully for investigating groundwater quality and Aquifer Protective Capacity (APC) in different lithological settings (Ojo et. al., 2015). The VES survey technique also has been used effectively for the study of groundwater conditions and to assess the APC of subsurface geoelectrical layers (Lashkaripour et. al., 2005). The VES survey data can be employed to develop spatial distribution maps of groundwater quality, layer thickness, APC and to determine water-bearing formation potential (Sahu and Sahoo, 2006). The present study deals with the evaluation of the aquifer protective capacity (APC) and potential capacity of the aquifer based on the VES data of the northeastern part of the Jordan Valley, Jordan.

### 1.1 Study Area

The study region is located in the north eastern part of Jordan Valley and the latter is located in the northwestern part of the Jordan. It extends from Yarmouk River in the north and Suleikhat area in the south and from the Jordan River in the west to the escarpment foothills in the east. The study region, covering an area of 504.3 $Km^2$ lies between $32^0$ 41' and $32^0$ 18' N latitude; $35^0$ 42' and $35^0$ 33' E longitude (Fig.1).

The topography of the area ranges from gently sloping Jordan River Valley plains in the western part of the study area to rugged hilly lands in the eastern part of the study area. The elevation of the study area ranges from 328 m below mean sea level to 860 m above mean sea level. The study area can be subdivided into two geomorphic units: (1) Rift Valley Floor; this unit is composed of alluvium, colluvium, lacustrine sediments and soil. (2) Rift Valley Escarpment; this unit bordering the highlands consists of sedimentary formations of Cretaceous age. The sedimentary rocks of the Upper Cretaceous age are largely exposed in the eastern side of the study area and the sediments of Tertiary age are encountered all along the escarpment regions of the eastern part of the study area bordering the Dead Sea Transform Fault. The western part of the study area is largely represented by soil and alluvium of Recent and Quaternary ages and is underlain by sediments of Lisan Marl Formation of Pleistocene age. The Jordan valley area (western side of the study area) is largely covered with sandy loam and loamy soils.


Fig. 1: SPOT panchromatic image of the study area.

The dominant tectonic structural feature in Jordan is the N-S trending Dead Sea Transform Fault forming the boundary between the African and Arabian plates. The Dead Sea Transform Fault with its N-S trending sinistral movement is the major structural feature in the study area, in addition to a group of tensional faults trending NW-SE, dextral shears trending E-W, and compressional structures trending NE-SW (Bender, 1968; Basem Khalil, 2000).

The study area has arid to semi-arid climate with hot summer and warm winter. The mean maximum temperature is 38.8 °C in the summer season. In the winter season, night temperatures may drop to a few degrees centigrade or even reach the freezing point. The rainfall period starts in October and ends in March and the amount of precipitation in the study area varies from 200 mm/a in dry years to 650 mm/a in rain-rich years with an average of 400 mm/a. The humidity ranges from 30% during hot summer to 70% in the cold winter and the potential evaporation is around 2100 mm/a (Salameh, 2001).

Surface flows due to precipitation are negligible in the study area because of the porous nature of the alluvial deposits. Only in places covered by fine-grained sediments with very low permeabilities does surface runoff take place. The Jordan Valley receives the surface water from the Jordan River tributaries, which drain the catchments extending into the highlands.

Groundwater in the study area is mainly found in the Quaternary deposits composed of friable sediments, which were brought in from the surrounding mountains. The depositional environment of these sediments, especially the decreasing gradients from the mountain foothills to the Jordan River course, led to rapid decline in the permeabilities of the sediments towards the Jordan River. Hence, the rain and surface water, instead of getting infiltrated into the alluvium, finds its way to the Jordan River. The sources of groundwater are: runoff from the surrounding mountains, rain water, surface water, domestic waste water and irrigation return flow. Groundwater discharge occurs mainly in the form of springs and seepages along the Jordan Valley and in tributary wadis (Salameh, 2001).

## 2. Materials and Methods

The geoelectrical resistivity method is one of the most effective geophysical methods for investigating the presence of groundwater and for groundwater potential sites (Janardhana Raju N et al., 1996; Ballukraya PN et al., 2004). One of the most widely used DC resistivity methods is Vertical Electrical Sounding (VES) (Pozdnyakova L, et al., 2001; Bisdorf RJ, 2002). Using Schlumberger configuration, VES at fourty three locations (Fig.2) were carried out by Campus Geopulse Resistivity meter. The maximum current electrodes separation extends to 600 m. The field measurements were processed and interpreted by IPI2win (GEOSCAN, 2001) software program.

The apparent resistivity values were obtained by multiplying the field resistance measurements by configuration factor at each of the electrodes separations. The calculated apparent resistivity measurements were plotted against half of the current electrode spacing (AB/2) on bi-logarithmic scale. Traditional interpretation techniques such as curve matching and drawing auxiliary point diagram were applied. Based on these preliminary interpretations, an initial estimation of resistivities and thicknesses of various geoelectrical layers were obtained.

The Dar Zarrouk parameters (Mailet, 1947) consist of longitudinal conductance (LC) and transverse resistance (TR). The thicknesses of the aquifer (h) and the apparent resistivity ($\rho a$) of the aquiferous layer were obtained from the interpreted VES data and these parameters were used in the determination of the transverse resistance (TR) and the longitudinal conductance (LC). The LC and TR were computed to evaluate the aquifer protective capacity as well as the potential capacity to hold water in the aquifer of the study area.

Longitudinal conductance (LC) = h/ $\rho a$…… (1)

Transverse resistance (TR) = h* $\rho a$……….. (2)

The VES data was used to prepare spatial distribution maps of aquifer apparent resistivity (AR), layer thickness, longitudinal conductance (LC) and transverse resistance (TR) for the subsurface layers using Rockwork14 software.

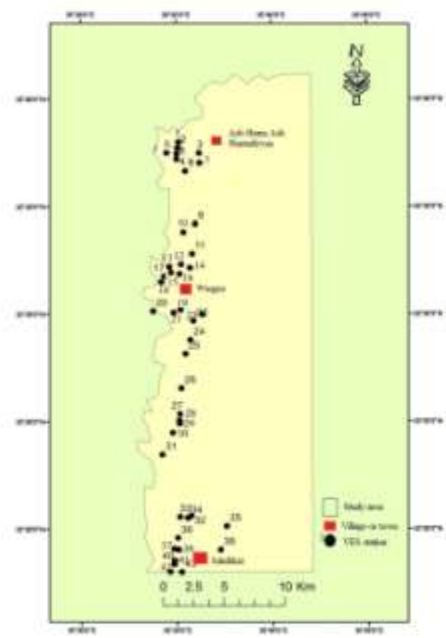

Fig. 2: Location map of VES-Stations in the study area.

## 3. Results and Discussion

The overburden protective capacity was evaluated based on the protective capacity rating approach of Henriet (1976) and Oladapo (2004). Table 1 shows the protective capacity rating for various LC values. Further, Table 2 shows the derived LC and TR values computed using eq. 1 and 2 and provides the estimation of protective capacity of the aquifer based on the AR and thickness values of different subsurface layers. The LC and TR distribution maps were prepared and produced based on the computed LC and TR values and using Rockwork14 software.

### 3.1 Spatial Distribution Maps of Isoresistivity

The resistivity of the first layer varies from 6.36 to 212 ohm m, while its thickness is about 3.2 m. The first layer largely consists of top dry soil in the south and wet soil in the north (Fig.3). The second layer (Fig.4) with a thickness of about 14.56 m consists of unsaturated alluvium in the southern part of the study area and saturated alluvium (mostly represented by clay) in the northern part of the study area. The central part of the second layer consists of fine grained soil developed over limestone. The third layer with a thickness of 58 m consists of unsaturated to saturated alluvium in the south and saturated alluvium with rich clay in the north (Fig.5). The resistivity values of the saturated and unsaturated alluvium range from 3.9 to 399 ohm m and from 1.45 to 156 ohm m respectively. The third layer is underlain by 60 m thick clay-rich alluvium bed in the

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

north and saturated to unsaturated alluvium with minor amounts of clay in the south (Fig.6). The resistivity values of the forth layer ranges from 0.098 to 188 ohm m.

Table 1: Aquifer Protective Capacity Rating (after Oladapo et al, 2004)

| Longitudinal conductance (LC in mho) | Protective capacity rating |
|---|---|
| < 0.10 | Poor |
| 0.10 – 0.19 | Weak |
| 0.20 -0.69 | Moderate |
| 0.70-0.49 | Good |
| 5.0-10.00 | Very Good |
| >10.00 | Excellent |

Table 2: Geoelectrical and Dar Zarrouk Parameters with aquifer protective capacity rating

| VES | Resistivity (Ohm m) $\rho_1/\rho_2/\rho_3/\ldots/\rho_n$ | Thickness (m) $h_1/h_2/h_3/\ldots/h_n$ | LC (mho) $S=\sum_{i=1}^{n}\frac{h_i}{\rho_i}$ | TR (Ohm $m^2$) | Protective Capacity |
|---|---|---|---|---|---|
| 1 | 9.91/3.95/9.82 | 10/55.2 | 15 | 218.04 | Excellent |
| 2 | 14.9/7.96/2.21/12.9 | 2.54/5.81/31.9 | 15.33 | 70.5 | Excellent |
| 3 | 8.46/4.15/2.86/13.8/3.12 | 2.79/5.8/14.6/24.8 | 6.83 | 342.2 | Very good |
| 4 | 19.7/7.86/2.45/10.3 | 1.92/5.35/39 | 16.7 | 95.6 | Excellent |
| 5 | 13.6/6.1/2.75/11.8 | 1.34/4.5/62 | 23.4 | 170.5 | Excellent |
| 6 | 6.36/8.3/2.75 | 31.3/63.5 | 12.6 | 572.05 | Excellent |
| 7 | 26.3/20.3/3.6/7.86 | 4.67/14.8/50.8 | 15 | 182.9 | Excellent |
| 8 | 22.8/6.18/1.87/13.3/3.89 | 1.68/7.76/7.88/26.1 | 7.5 | 347.13 | Very good |
| 9 | 35.1/6.05/1.45 | 1.75/49.3 | 8.2 | 298.3 | Very good |
| 10 | 33.9/19.6/3.56/0.098 | 0.281/6.86/26.9 | 7.9 | 95.8 | Very good |
| 11 | 116/20/17/0.669 | 3.67/9.67/238 | 14.5 | 4046 | Excellent |
| 12 | 49.4/20.9/6.65/10.8/2.88 | 1.09/6.53/23.4/47.5 | 8.3 | 513 | Very good |
| 13 | 15.6/8.95/11/4.34 | 3.88/15.3/40.7 | 5.7 | 447.7 | Very good |
| 14 | 30.8/20.2/24.9/9.76 | 11.1/45.1/87.5 | 6.1 | 2178.8 | Very good |
| 15 | 69.7/20.3/5.41/14.8/0.363 | 0.591/2.56/22.1/120 | 4.2 | 1776 | Good |
| 16 | 27.3/47.6/16.4/7.43 | 1.99/8.01/137 | 8.6 | 2246.8 | Very good |
| 17 | 31.8/17.5/34.5/9.23 | 3.02/6.21/77.8 | 2.7 | 2684.1 | Good |
| 18 | 70.3/25.3/8.78/2.83 | 0.862/2.13/54.3 | 6.3 | 476.75 | Very good |
| 19 | 87.3/50.3/18.5/8/10.2/2.31 | 0.892/5.28/9.16/16.3/140 | 16.4 | 1428 | Excellent |
| 20 | 38/31.6/19.6/0.109 | 0.125/18.2/106 | 6 | 2077.6 | Very good |
| 21 | 61.7/14.2/8.15/0.815 | 1.16/25.1/127 | 17.4 | 1035.1 | Excellent |
| 22 | 118/78.6/20.3/24.4/17.6 | 0.261/1.55/13.4/61.9 | 3.2 | 1510.4 | Good |
| 23 | 64.8/45.9/4.26 | 7.05/54.3 | 1.3 | 2492.4 | Good |
| 24 | 142/62.2/9.01/28.2/9.61 | 1.2/4.74/6.34/11.9 | 1.2 | 335.6 | Good |
| 25 | 31.8/17.5/34.5/9.23 | 3.02/6.21/77.8 | 2.7 | 2684.1 | Good |
| 26 | 56.4/28.2/36.9/7.07 | 3.23/38/120 | 4.7 | 4428 | Good |
| 27 | 54.2/135/47.2/21.4 | 5.06/33.7/140 | 3.3 | 6608 | Good |
| 28 | 103/130/81.5/145/34.7 | 0.593/2.03/10.3/87.7 | 0.75 | 12716.5 | Good |
| 29 | 179/226/156/188/29.4 | 2.31/1.72/15.5/56.4 | 0.42 | 10603.2 | Moderate |
| 30 | 31.1/6.81/10/2.99/2.4 | 1/5.69/14.9/40.6 | 16 | 121.4 | Excellent |
| 31 | 17.5/12.2/51.4/12.7 | 6.19/17.6/173 | 5.2 | 8892.2 | Very good |
| 32 | 85.7/15.5/44.4/13.6 | 1.76/15.3/98.7 | 3.2 | 4382.3 | Good |
| 33 | 31/16.1/20/31/9.87 | 0.833/5.04/30/73.9 | 4.2 | 2290.9 | Good |
| 34 | 212/39.3/16.8/26.8 | 4.24/17.4/66.2 | 4.4 | 1112.16 | Good |
| 35 | 37.8/206/25/6.42 | 1/15/46.4 | 1.96 | 1160 | Good |
| 36 | 18.4/165/27.2/0.213 | 0.234/17/116 | 4.4 | 3155.2 | Good |
| 37 | 26.3/46.7/5.32/3.47/9.28/4.26 | 0.968/7.34/9.81/43.6/152 | 31 | 1410.6 | Excellent |
| 38 | 21.3/201/2.03/38/0.31 | 0.333/14.2/6.5/45.1 | 4.5 | 1713.8 | Good |
| 39 | 31/95.3/4.84/144/2.78 | 0.195/7/6.59/16.9 | 1.6 | 2433.6 | Good |
| 40 | 37.6/49.3/1.81/11.6/0.328 | 1/3.29/4.91/174 | 17.8 | 2018.4 | Excellent |
| 41 | 44//399/12.9/3.16 | 0.41/12/56.9 | 4.5 | 734 | Good |
| 42 | 27.3/8.78/21.8/1.47 | 9.82/20.4/81.6 | 6.4 | 1778.9 | Very good |
| 43 | 54.6/89.9/94.8/54.9/13.4 | 1.08/1.76/4.14/51 | 1 | 2799.9 | Good |

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

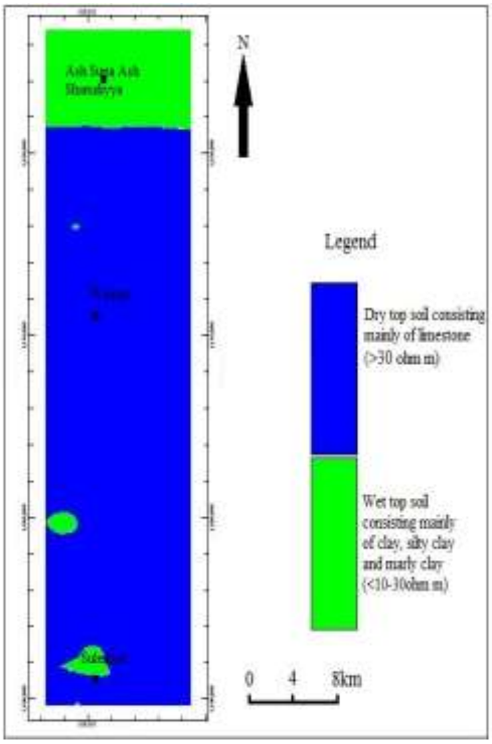


Fig. 3: Map showing zonation based on the Apparent Resistivity (AR) and lithology of layer one of the aquifer

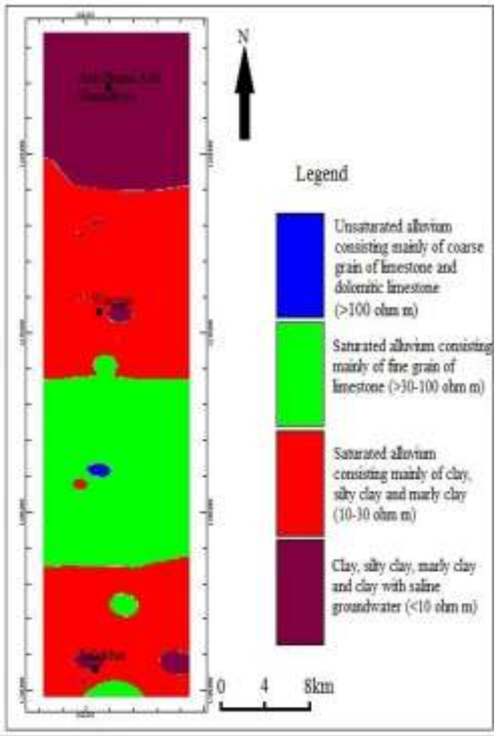


Fig. 5: Map showing zonation based on the Apparent Resistivity (AR) and lithology layer three of the aquifer

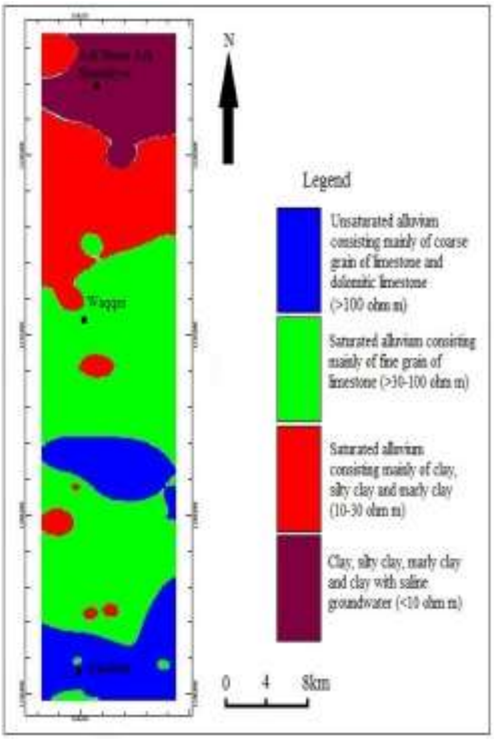


Fig. 4: Map showing zonation based on the Apparent Resistivity (AR) and lithology of layer two of the aquifer

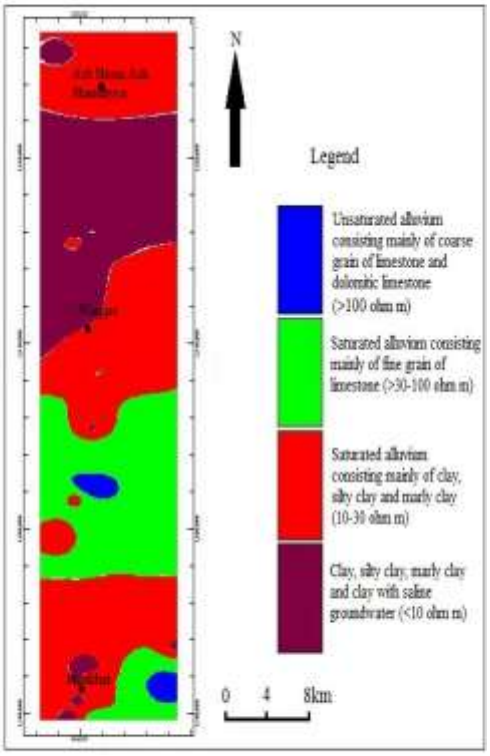


Fig. 6: Map showing zonation based on the Apparent Resistivity (AR) and lithology layer four of the aquifer

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

## 3.2 Layer-wise Spatial Distribution Maps of Longitudinal Conductance

Layer-wise longitudinal conductance maps (Figs.7 to 10) were prepared to evaluate the aquifer protective capacity of the geoelectric subsurface layers of the study area. The map shown in fig.7 depicts the special distribution map of LC for the layer 2. As could be made out from the maps, the study area can be divided into six zones as 'Excellent', 'Very Good', 'Good', 'Moderate', 'Weak' and 'Poor' based on LC values. Most part of the study area in the south shows 'Moderate' protective capacity whereas the northern part displays 'Good' protective capacity. The LC values in the third layer (Fig.8) shows that 70% of the study area is covered by alluvium of 'Good' protective capacity indicating clay rich alluvium. The clay-rich alluvium zone extends even to the fourth layer (Fig.9) also wherein about 80% of the fourth layer is covered by clay rich alluvium. From the LC maps of the various layers as well as from the average LC value (Fig.10), it can be concluded that the APC values increase with the increase in the depth of the geological column.

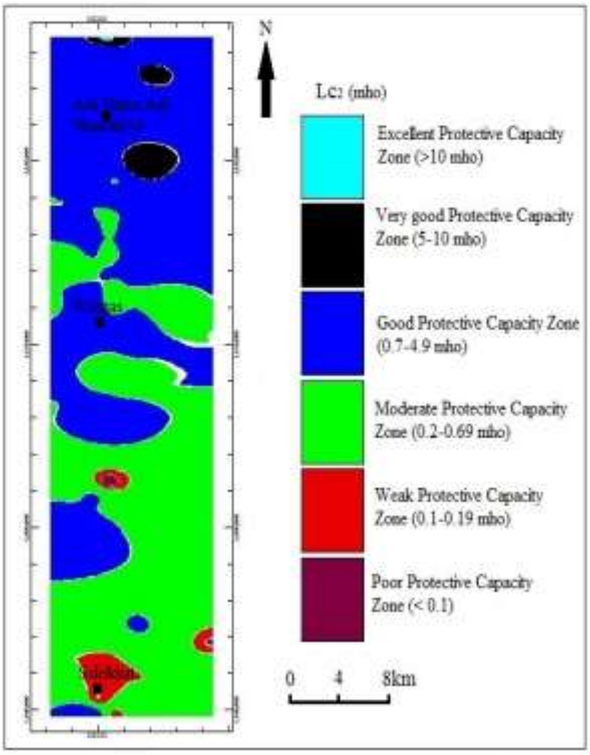


Fig. 7: Longitudinal conductance (LC) map of layer two of the aquifer

## 3.3 Layer-wise Spatial Distribution Maps of Transverse Resistance

The transverse resistance maps (Figs.11 to 14) constructed for the three layers of the subsurface in the study area supplement the findings based on the resistivity and LC values. In general the southern part of the study area is characterised by high values of TR indicating higher yield potential as compared to the northern and central parts. The third and fourth layers characterised by low values of TR in the northern and southern parts of the study area imply low yield potential because of the clay-rich deposits.

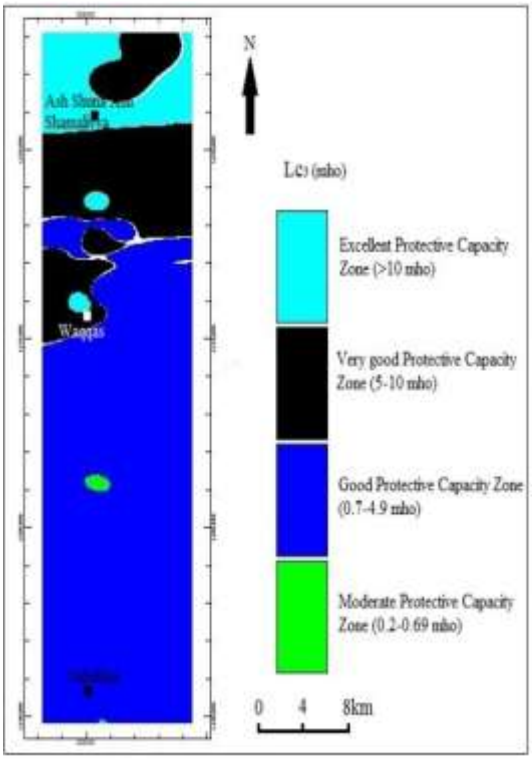


Fig. 8: Longitudinal conductance (LC) map of layer three of the aquifer

## 3.4 Potential Capacity of the Aquifer

Potential capacity of the aquifer was calculated by taking into consideration of the thickness of the layer and the horizontal extent of the aquifer. The computed results (Table 3) indicate that the southern and central parts of the study area have relatively high potential for the storage of groundwater in comparison to the northern part. However, the present investigator is in favour of creating recharge zone in the southern part by taking the gradient and geology of the area into consideration. The gradient of the land is gentle from north to south which facilitates the gravity flow of the water. Geologically, and also based on TR and LC values, the central part of the study area is relatively more permeable in the third and fourth layers thus, there is more scope for the loss of recharged water.

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

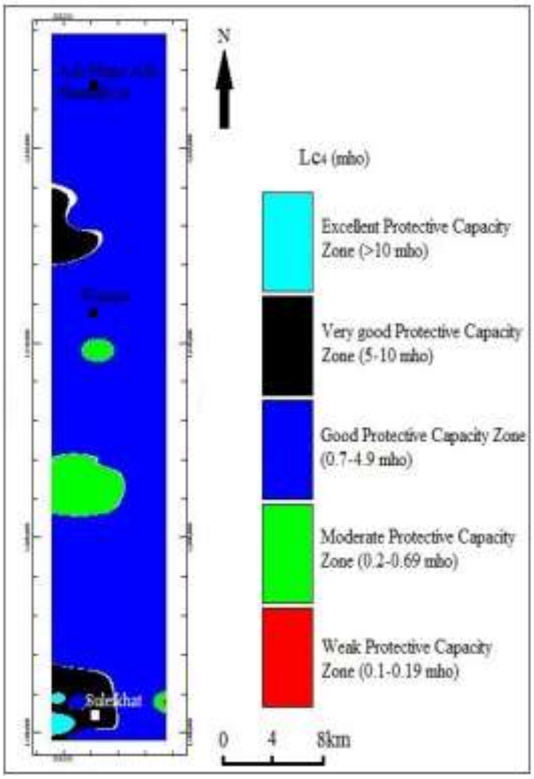


Fig. 9: Longitudinal conductance (LC) map of layer four of the aquifer

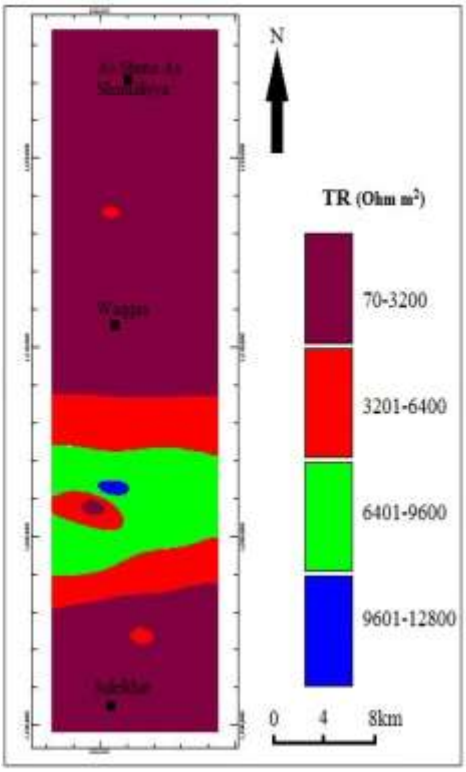


Fig. 11 Transverse resistance (TR) map of the aquifer of the study area

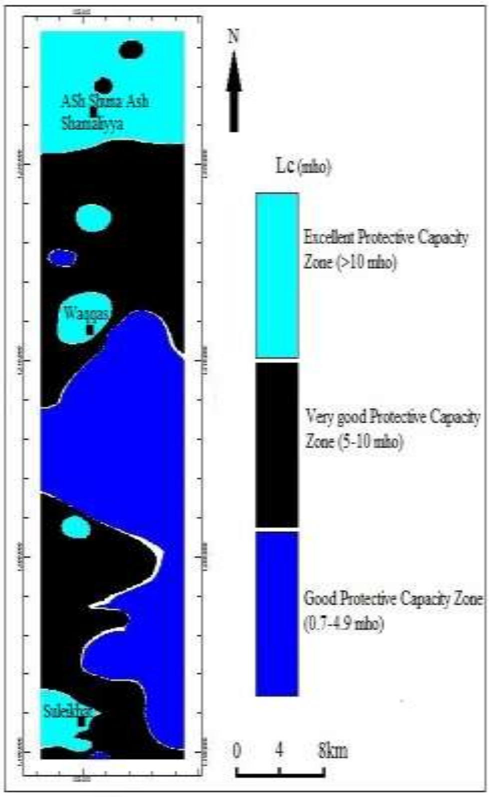


Fig. 10: Longitudinal conductance (LC) map of the aquifer of the study area

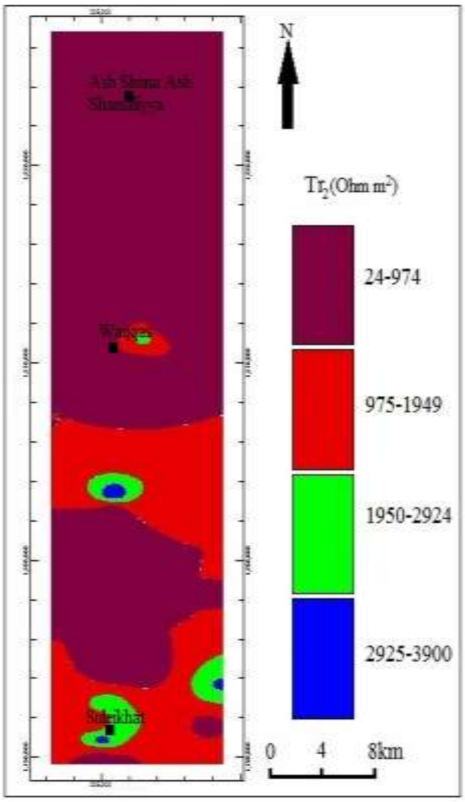


Fig.12: Transverse resistance (TR) map of the layer two of the aquifer of the study area

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 7, July 2018
www.ijasrm.com
ISSN 2455-6378

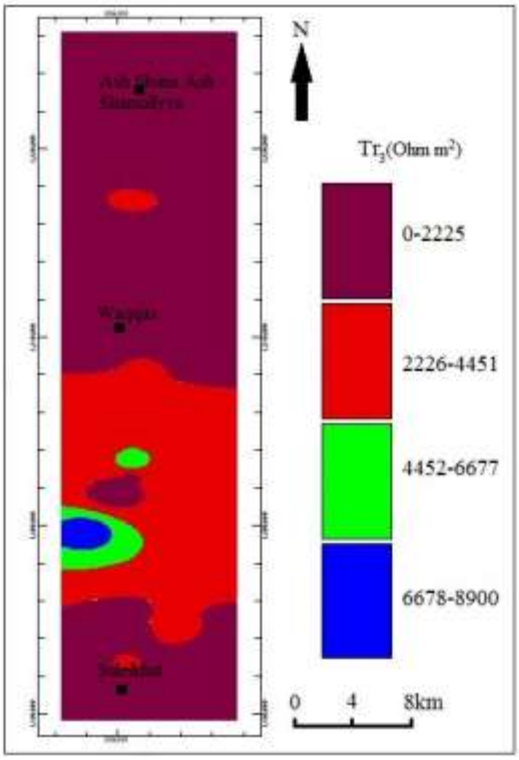


Fig. 13: Transverse resistance (TR) map of the layer three of the aquifer of the study area

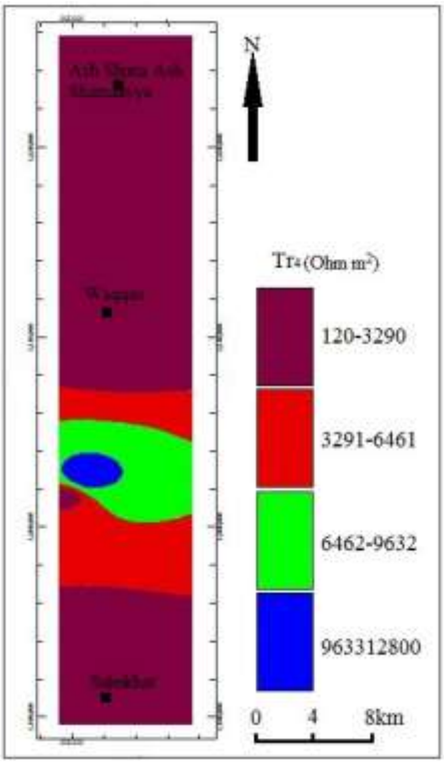


Fig.14: Transverse resistance (TR) map of the layer four of the aquifer of the study area

Table 3: Estimated Potential Capacity of the aquifers in the study area

| Potential Capacity ($m^3$) | | | |
|---|---|---|---|
| | North (Ash Shuna) | Middle (Waqqas) | South (Suleikhat) |
| Layer 2 | $0.07*10^9$ | $1.3*10^9$ | $0.91*10^9$ |
| Layer 3 | $0.02*10^9$ | $5.1*10^9$ | $3.4*10^9$ |
| Layer 4 | $0.71*10^9$ | $2.8*10^9$ | $3.1*10^9$ |
| Total | $0.8*10^9$ | $9.2*10^9$ | $7.41*10^9$ |

## 4. Conclusions

The aquifer potential capacity values increase with the increase in the depth of the geological column for about 100 m. In the second layer, the southern part of the study area is characterised by high values of transverse resistance thus indicating higher yield potential as compared to the northern and central parts. The third and fourth layers characterised by low values of TR in the northern and southern parts of the study area imply low yield potential owing to the presence of clay-rich deposits. The southern and central parts of the study area have relatively high potential for the storage of groundwater than the northern part. Based on geological data, TR and LC values, the central part of the study area is relatively more permeable in the third and fourth layers thus, there is more scope the loss of recharged water. Hence, the present investigator is in favour of selecting recharge zone in the southern part by taking the gradient and geology of the area into consideration.

## References

[1] Basem, K.,. The geology of Irbid and Ash Shuna Ash Shamaliyya (Waqqas), NRA, Amman, Jordan., map sheets; 3154-II and 3154-III, 2000.

[2] Bender, F., Geologie Von Jordanian- Beitrage Zur Regionalen Geologic Der Erde, Gebruder Borntraeger, Berlin.; Vol. 7, pp.230. 1968.

[3] Bisdorf RJ., Schlumberger soundings at the Amargosa Desert Research Site, Nevada: U.S. Geological Survey Open-File Report; 140:65., 2002.

[4] Geological Survey of Canada (GEOSCAN), open file, 2001.

[5] J. P. Henriet, Direct applications of Dar Zarrouk parameter in groundwater survey, Geophys. Prospect., vol. 24, pp. 344-353, 1976.

[6] Janardhana Raju N, Reddy TVK, Nayudu PT., Electrical resistivity survey for groundwater in theupper Gunjanaeru Catchment, Cuddapah District, Andhra Pradesh., Jour. Geol. Soc. India; 47:705-716, 1996.

[7] Lashkaripour, G.R., Ghafoori, M., Dehghani, A., Electrical resistivity survey for predicting Samsor aquifer properties, southeast Iran. Geophysical Research Abstracts,. European Geosciences Union, 7, 01999, 2005.

[8] M.I Oladapo, M.Z. Mohammed, O.O. Adeoye, and B.A. Adetola, Geoelectrical investigation of the Ondo State Housing corporation Estate, Ijapo, Akure, South-Western Nigeria, J. Min. Geol., vol. 40, no.1, pp. 41-48, 2004.

[9] Maillet, R., The fundamental equations of electrical prospecting, Geophys., vol. 12, pp. 527-556, 1947.

[10] Mohammad Tarawneh and M. R. Janardhana, Integrated approach of field and geophysical methods for the investigations of subsurface geology and potential sites for the artificial groundwater recharge in the NW part of Jordan. International Journal of Multidisciplinary Research and Development, Vol. 4, pp. 1-11, 2017.

[11] OJO E.O., Adelowo. A., Abdulkarim H.M., DaudaA.K., A Probe into the Corrosivity Level and AquiferProtective Capacity of the Main Campus of the University of Abuja, Nigeria: Using Resistivity Method. Physics Journal, 1 (2), 172. 2015.

[12] Pozdnyakova L, Pozdnyakov A, Zhang R., Application of geophysical methods to evaluate hydrology and soil properties in urban areas Case study. London; 3:205-216, 2001.

[13] Sahu, P.C., Sahoo, H., Targeting groundwater in tribal dominated Bonai area of drought-prone Sundargarh District, Orissa, India. A combined geophysical and remote sensing approach. J Hum Ecol 20, 109. 2006.

[14] Salameh, E., Sources of Water Salinities in the Jordan Valley. Acta hydrochim. Hydrobiol. 29 6–7, 329–362, 2001.

[15] UNESCO, Managing water resources in arid & semi-aridregions of Latin America & the Caribbean, 2012.

[16] www.un.org/agenda21/nattiinto/countr/Israel/drought.paf.