

ELECTRICAL RESESTIVITY INVESTIGATION FOR GROUNDWATER OF THREE VILLAGES IN SUMEL DISTRICT- DUHOK CITY NORTH OF IRAQ

Zainab M. Shanshal

Geology Department , College of Science , Mosul University , Mosul , Iraq

DOI: <http://dx.doi.org/10.25130/tjps.23.2018.016>

ARTICLE INFO.

Article history:

-Received: 12 / 9 / 2017

-Accepted: 12 / 12 / 2017

-Available online: / / 2018

Keywords: Resistivity,
groundwater, Sumel, north of
Iraq.

Corresponding Author:

Name: Zainab M. Shanshal

E-mail:

Saifalnajar75@yahoo.com

Tel:

Affiliation:

Abstract

A geophysical Electrical survey was conducted by applying Electrical Resistivity Sounding (VES) in three different villages located in Sumel district, which are belongs to Duhok city within the southern limb of Baikher anticline in northern of Iraq, in order to investigate the groundwater to dig wells for drinking and agriculture purposes which didn't have available wells in villages. The survey involved sixteen vertical electrical sounding (VES) points along three profiles using a schlumberger array to investigate the subsurface aquifer of the area as well as evaluation of the groundwater aquifer characteristics in the regions. The depth of the penetration in the current study reached more than (150) m. The electric resistivity values ranged between (10-70) $\Omega.m$. It has been recognize three geoelectrical zones at different depths in the three study areas. The first zone have electric resistivity values ranged between (20-50) $\Omega.m$, which represented the recent deposits with the presence clay in some areas. The second zone have electric resistivity values ranged between (11-17) $\Omega.m$, which represented a layer of sandstone of multiple sizes and saturated with groundwater, the third zone have electric resistivity values ranged between (22-55) $\Omega.m$, which represented layers of claystone with the presence of silt in some depths. it has been observe the existence of a semi-confined groundwater aquifer due to the presence of permeable layers of sandstone and in most of the regions it is surrounded by impermeable layers of claystone rocks, and it has been determined the level of groundwater in the study areas. According to this information it has been dig the wells in those areas and found the water in depths very close from that it is reached in the vertical electrical sounding.

1. Introduction

Due to the increasing people living in villages and where there is a need for a permanent sources of water for drinking, consuming purposes and agricultural requirements, and because unavailable wells in the villages, The geophysical group in FAO sub-office in Duhok governorate made many exploration surveys in order to determine the areas where the groundwater are present and for dig wells in these villages so, Many villages were surveyed in Sumel district which belongs to Duhok city, according to these surveys groundwater conditions were determined and several wells were drilled in

some of those areas according to the geophysical electrical data.

The electrical resistivity method is widely used in the identification of groundwater, especially in arid and semi-arid areas where electrical resistivity can be very clearly distinguished because the good contrast between saturated and unsaturated layers. The vertical electrical sounding (VES) using the Schlumberger arrangement is the more successful instrument and low cost technique in studies Hydrogeology of sedimentary basins [1].

Resistivity methods are widely used in prospecting engineering, Hydrological, Environmental studies and

seek to the shallow structure like cavities, faults, joints [2]. Geological targets e.g., layered aquifers of different properties, sedimentary rocks of different lithology, sedimentary rocks overlying igneous rocks, or the weathering zones has been explored by Vertical Electrical Soundings (VES). The geo-electrical investigation is mainly concerned with study of groundwater; it has long been used as an effective method for geologic mapping [3].

The applications of resistivity surveys in hydrogeological investigations, as important information can be provided on structure of layers, lithology and underground water resources instead of the large cost of drilling, and to determine the locations of boreholes that control the geophysical interpretation.

2. Locations of Study Area

Three study areas are investigated by VES survey, first one from north: Mergasoor village ($37^{\circ}4'56.14''\text{N}$, $42^{\circ}29'0.63''\text{E}$), the second is Koly village ($37^{\circ}3'30.67''\text{N}$, $42^{\circ}36'29.20''\text{E}$); and Bawardy village ($36^{\circ}58'58.60''\text{N}$, $42^{\circ}37'12.42''\text{E}$), and are located in the district of Sumel of the province of Duhok Northern Iraq, and to the South-West side of the highway between Dohuk-Zakho, as shown in the (Figure.1). The study area is located in the region consist of syncline and anticline folds that are compatible with the exist of terrain in the area. Generally, geomorphology is an undulating area penetrated by several valleys and streams, some of

these are persistent and seasonal streams flowing from Baikher anticline and flow south toward Mosul Dam. Because the flattening of sedimentary rocks the streams and rivers run in all directions to take tree-like that form Dendritic drainage [4]. The aim of the current study is to prove the validity of the vertical electrical sounding method to know subsurface lithology and identify layers of reservoir groundwater then digging the wells according to its results. The study was for three villages has been chosen because they are close to each other in addition to applying the survey on it in the same year, and have availability of well's information for that villages. The survey was conducted in 2013 and dug wells in that period.

3. Geological Setting

The study area is located in the high folded zone, which is a part limb of Baikher Anticline, The anticline is a double plunging, asymmetrical fold [5]. The Cretaceous rocks occupy the core of Baikher anticline which underlay the Kolosh Formation.

The formations in the study areas belongs to Cretaceous, and Tertiary periods in addition to the Quaternary. The recent top soil and rock fragments as recent deposits covered Injana (Upper Fars) formation (upper-Miocene) and these deposits cover all most study area [6]. Injana formation mainly consists of thin bedded calcareous sandstone and green mudstones with thin gypsum bed, whereas limestone and shale exist in the lower part of the formation [7].

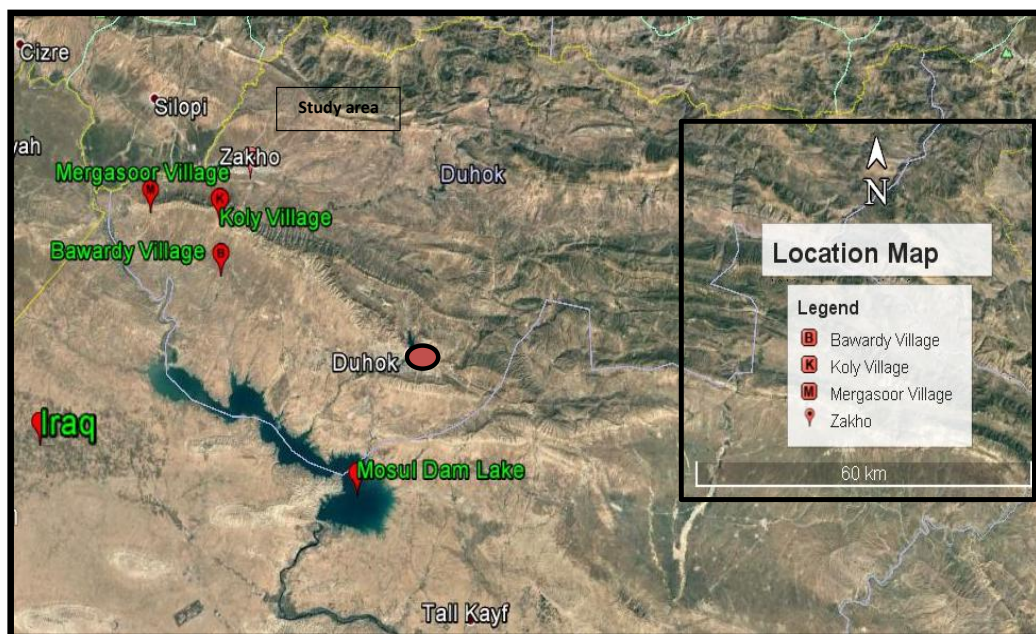


Figure (1): Satellite image of Duhok Governorate, Image satellite shown the locations of study areas

4. Basic Resistivity Theory

Resistivity of the ground is measured by transmitting a direct currents of very low frequency alternating current into the earth by means of pair of electrodes and measuring the resulting potential differences between another pair of electrodes at a multiplicity of locations at the surface. These measurements are

inverted into a distribution of electrical resistivity in the subsurface. The resistivity boundaries are interpreted in terms of lithological boundaries, the foundation of this is Ohm's law. Geoelectric data are commonly expressed as apparent resistivity and given by the equation:

$$\rho_a = K (\Delta V / I)$$

Where ρ_a is the apparent resistivity, K is a geometric constant that depends only on the reciprocal positions of the current and potential electrodes; ΔV is the measured potential difference (Volt), and I is the intensity of the current (Ampere).

The type of structure to be investigated, the sensitivity of the resistivity meter and the background noise level are factors specified the kind of array for a field survey. The array that is most commonly used for hydrogeological surveys is Schlumberger array (Figure.2) and Wenner arrays[8,9]. The apparent resistivity (ρ_a) that applying Schlumberger array can be written in the form:

$$\rho_a = \pi \Delta V / I * ((AB/2)^2 - (MN/2)^2) / MN) \dots 1$$

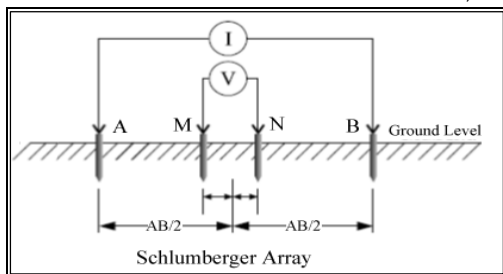


Figure (2) Configuration of Schlumberger Array

The lower resistivity values of Sedimentary rocks was when it have higher water content. The resistivity values are largely dependent on the porosity of the rocks (assuming all the pores are saturated) as well as

the clay content, and the salinity of the contained water. Clayey soil is normally has a lower resistivity value than sandy soil. However, the resistivity of groundwater varies from (10-100) $\Omega \cdot m$. depending on the salinity. The greatest limitation of the resistivity sounding method (VES) is not taking into account the lateral changes in the layer resistivity. Such changes are probably the rule rather than the exception [10].

5. Field Work

Vertical Electrical Sounding (VES) traverses were conducted in the year 2013, The geoelectrical survey for groundwater exploration was done from the geophysical group in (FAO) sub-office in Duhok governorate within UN program to treatment the aridity in Iraq. Sixteen VES points were carried out by used ABEM Terrameter SAS 300 C for data acquisition with Schlumberger array configuration through using four electrodes, two current electrodes (A&B) for transmitting current, and two potential electrodes (M&N) for measuring potential difference. The distance-separating electrode ranged between (500-700) m in three traverses, and with different traverses lengths (Table. 1). The (16) points represent three (N-S) traverses which are mostly perpendicular to the axis of the Baikher Anticline, and two (E – W) traverses mostly parallel with the same Anticline (Figure.3).

Table (1) traverses length

Area (village)	Traverses direction	Coordinates start –end of traverses	traverses length(m)
Mergasore	N-S	37°4'24.18 " N, 42° 29'38.62 "E- 37° 4'10.41 " N, 42° 29'36.75 "E	400
Koly	N-S	37° 3'30.69 " N, 42° 36'39.31 "E- 37° 2'55.10 " N, 42° 36'39.3 "E	1200
	E-W	37° 2'45.78 " N, 42° 36'20.18 "E	500
Bawardy	E-W	36°59'1.45 " N, 42° 37'1.81 "E- 36°58'49.42 " N, 42° 37'31.82 "E	900
	N-S	36°59'36.20 " N, 42°37'26.81 "E- 36°58'43.36 " N, 42° 36'59.67 "E	1800

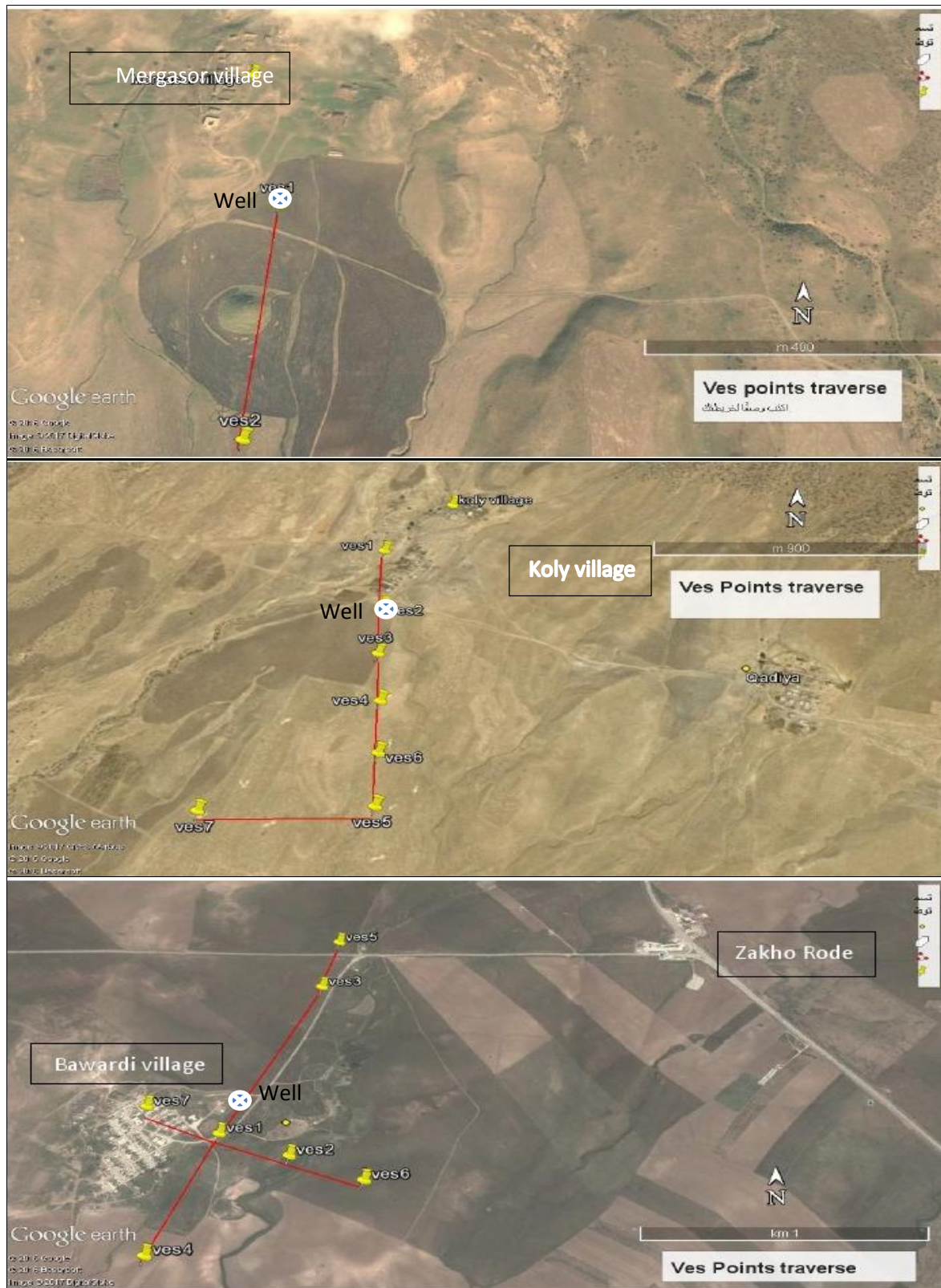


Figure (3): Satellite image of VESs point traverses

6. Processing And Interpretation Of VES Data

To get the true resistivity values and thickness of the layers, the inverse interpretation is performed on the vertical electrical sounding data which processed automatically by using the software (IPIWin) along

single profile [11]. The field curves of the VES points can be interpreted into two types, qualitative and quantitative to get a good image of the subsurface layers. The shape of the curves is related to the subsurface geology [12], therefore, during the interpretation process, the field data (field curve)

were compared with master curves and different segments of each field curve were interpreted according to their values. The shapes of a VES curves

depend on the apparent resistivity value and the thickness of each layer and the number of layers in the subsurface, (Figure. 4).

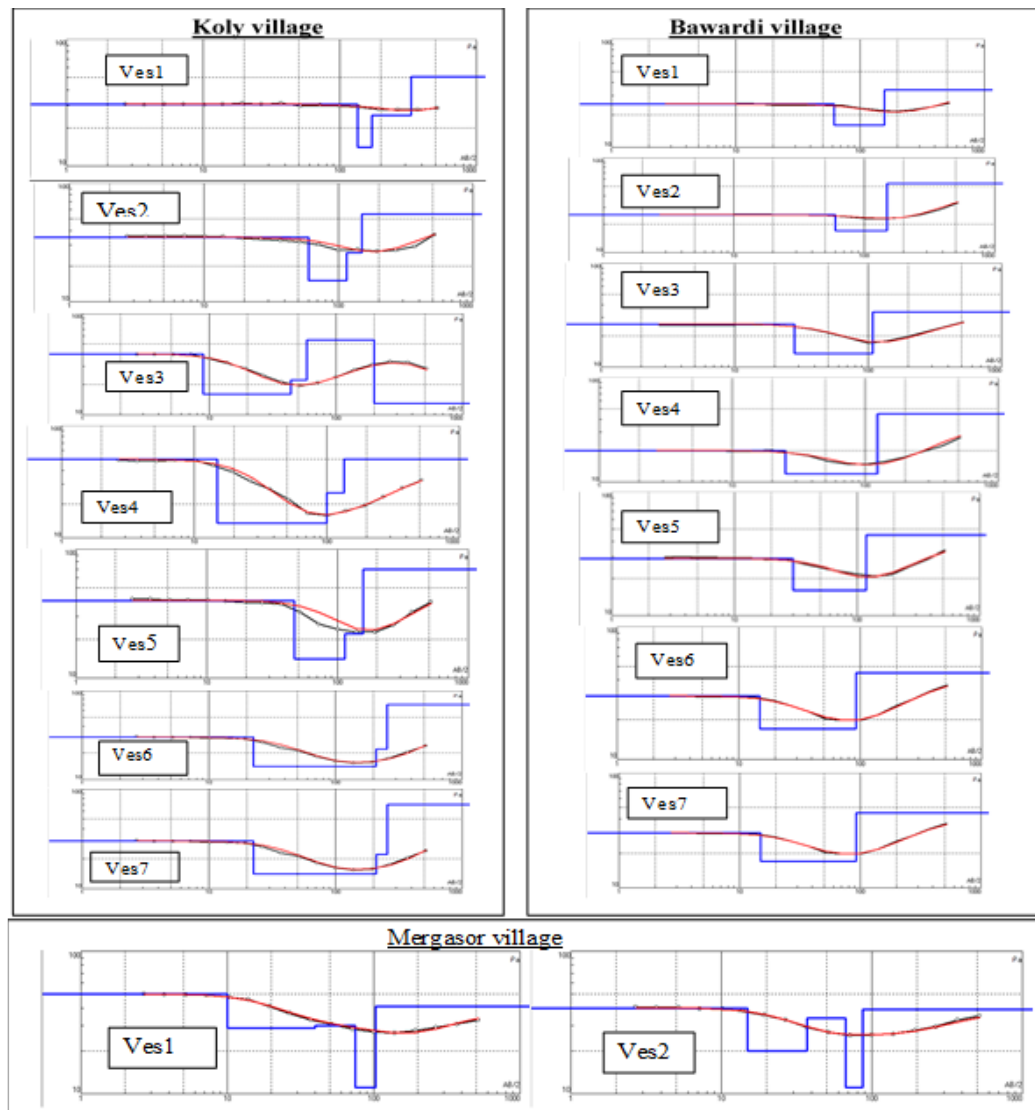


Figure (4): Field measurements curves for (16) VES points & three traverses

7. Results And Discussion

1. Mergasore Village

The geoelectrical profiles in of Mergasore village, (Figure.6) shows five zones with depth reached (113)m, The first refers to the recent deposits have (40-50) $\Omega.m$ values of apparent resistivity, with thickness ranging between (10-15) m. The second zone consists of fine sand & clay. Its resistivity range from (20-25) $\Omega.m$ with thickness range of (35-31) m. The third zone is claystone beds and has varying resistivity from (30-34) $\Omega.m$. with thickness (30-42) m. The fourth zone comprises softy sandstone beds of (28-30)m thickness and resistivity (11.5) $\Omega.m$. The fifth zone was compact and dry claystone with resistivity (40) $\Omega.m$. These zones are probably belonging to Injana Formation.

2. Koly Village

The geoelectrical profiles of Koly village (Figure.7) shows four zones with depth reached (210)m; The

first zone refers to the recent deposits have (30-50) $\Omega.m$ values of apparent resistivity, with thickness ranging between (8–60) m. It reflects the variable composition and moisture content of the topsoil. The second zone consists of mainly sandstone beds with thickness ranges of (27-113)m ,which have low resistivity range (13-16) $\Omega.m$ because it is saturated of groundwater. The third zone of claystone beds has a resistivity varying from (22-26) $\Omega.m$ and thickness ranging from (15-95) m. The fourth zone the resistivity of it range from (50-70) $\Omega.m$. represent sand & siltstone beds, these zones are probably belonging to Injana Formation.

3. Bawardy village

The geoelectrical profiles of Bawardy village, (Figure.8) shows three zones with depth reached (157)m; the first refers to the recent deposits & claystone its thickness ranged between (15-62) m, have (20-36) $\Omega.m$ values of apparent resistivity. It

reflects the variable composition and moisture content of the topsoil. The second zone is consist of coarse sand & gravel beds, the resistivity is ranged from (12-17) Ω .m with thickness ranged of (76-98) m. The third zone comprises of claystone beds and has resistivity varying from (34-54) Ω .m. The resistivity of fourth zone is ranged from (50-70) Ω .m.

from claystone beds. These zones are probably belonging to Injana Formation. The following information in tables (2,3,4) about the various VES stations related to: the field name of the VES station, the apparent resistivity (ρ_a), thickness (h) and number of geological layers present at the subsurface of each station, and lithology description.

Table (2): The geophysical results in Mergasor village

Geoelectric zone	VES- 1		VES- 2		Lithology description
	ρ_a	h	ρ_a	h	
1	40	15	50	10	Recent deposits
2	20	35	25	31	Fine Sandston with clay
3	34	30	30	42	claystone beds
4	11	28	11.2	30	Softy sandstone
5	39	–	40	–	Compacted and dry claystone
Total (m)		108		113	

Table (3): The geophysical results in Koly village

Geoelectric Zones	VES- 1		VES- 2		VES- 3		VES- 4		VES- 5		VES- 6		VES- 7		Lithology description
	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	
1	30	13.5	40	9	35	60	40	8	50	15	40	46.5	30	22.5	recent deposit Mainly claystone&
2	14	27	16	35	15	55	14	90	13.5	100	14	113	14	98	mainly sandstone with water
3	25	24	22	15	26	95	23	55	25	35.5	22	47	22	45	Claystone beds
4	50	146	55	141	55	-	60	–	50	–	70	–	70	–	Sand + siltstone
Total (m)		210.5		200		210		153		150.5		210		165.5	

Table (4):the geophysical results in Bawardy village

Geoelectric Zone	VES- 1		VES- 2		VES- 3		VES- 4		VES- 5		VES- 6		VES-7		Lithology description
	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	ρ_a	h	
1	25	60.9	26	28.7	25	62.4	36	24	20	25	29	30.8	30	15	Recent deposits& Claystone
2	17	90	13.5	80	16	95	14.5	85	12	98	16	88	17	76	Corse Sandston saturated with water
3	54	–	34	-	34	–	40	-	45	–	45		30	–	Claystone beds
Total (m)		150.9		108.7		157.4		109		123		118.8		91	

From stratigraphy correlation (for sandstone layers) between the sections, it has been notes a correlation between the geological lithology is clearly indicated of being part of an aquifer extends from north to south adjacent to the southern limb of the Baikher anticline. It consists of layers of sand and saturated with groundwater surrounded by layers Isolating clay (Figure.5). The sequence and the lithological description of the geo-electric zones which appeared in the geoelectrical sections in the three study areas, are belong to the Injana formation (upper - Miocene), which consists mainly of different types of sandstone, clay stone ,silt stone covered by recent sediments

represented by clays and pieces of rock erosion and transferred, the difference in this sequence of the strata from one study area to another because different locations of it and there distance to the geologic structure (Baikher anticline). The location of both the villages of Mirgasore and Koly, are located at the southern limb of the anticline, while Bawardy village is located far from this limb at the edge of the syncline fold towards Mosul Dam lake, which caused a difference in the erosion and sedimentation process, and this led to a difference in the sequence in the three areas study. From a structural point of view, it has been found that the layers in Bawardy and

Mergasor villages, are semi- horizontal and show a some equivalent in the depths at most points of the survey (Figure 6,7,8). in Koly village it has been notice a sudden difference in the geoelectrical zones (Figure7), where the sandstone layer appeared at the first and second points VSE 1,2 and a large thickness up to (130) m and a distance of (300) m and then disappear at the other points of the survey path VES 3,4,5,6, In addition to a difference in the height of the geoelectrical zones between the two groups above, which gives a strong possibly for the presence of fault in the region toward east-west, resulting from the process of folding and pressure, which is exposed to the geological layers.

From a hydrological point of view of the three study areas, it has been observed the existence of a semi-confined groundwater aquifer due to the presence of permeable layers of sandstone and in most of the regions it is under laid and over laid by impermeable layers of claystone rocks. In the Mergasor region, the W.T. was found at the boundary of the aquifer at a depth of (70) m and in accordance with the depth (74) m within the well of water that was dug in that area. In the Koly village presence of W.T of the groundwater between the depths (15-40) m at the

upper limit of the first layer and the depth of up to (40-110) m, or between the depths (60-70) m at the upper limit for the second layer and the depth of up to 200 m, in accordance with the depth (108) m within the well water dug in that area.. In Bawardy village the W.T. of groundwater table was found in depths (25-60)m, which represents the limits of the aquifers of groundwater and in accordance with the level of groundwater at the depth (43) m within the water well dug in the study area.

8- Digging Wells

After interpreting the geophysical survey data and obtain adequate information about geological stratigraphy and presence geological layers that have the ability to store groundwater and there depths, according to this information the groundwater directorate of Duhok governorate in corporation with FAO sub-office in Dohuk Governorate drilling wells in the study villages in that time to get a wells for people for drinking and agriculture purposes. Then make a borehole description. A connection between the boreholes discretion and geoelectrical profiles was done, and give similarity in lithology and depths of layers and groundwater table, (Figure,6 ,7,8).

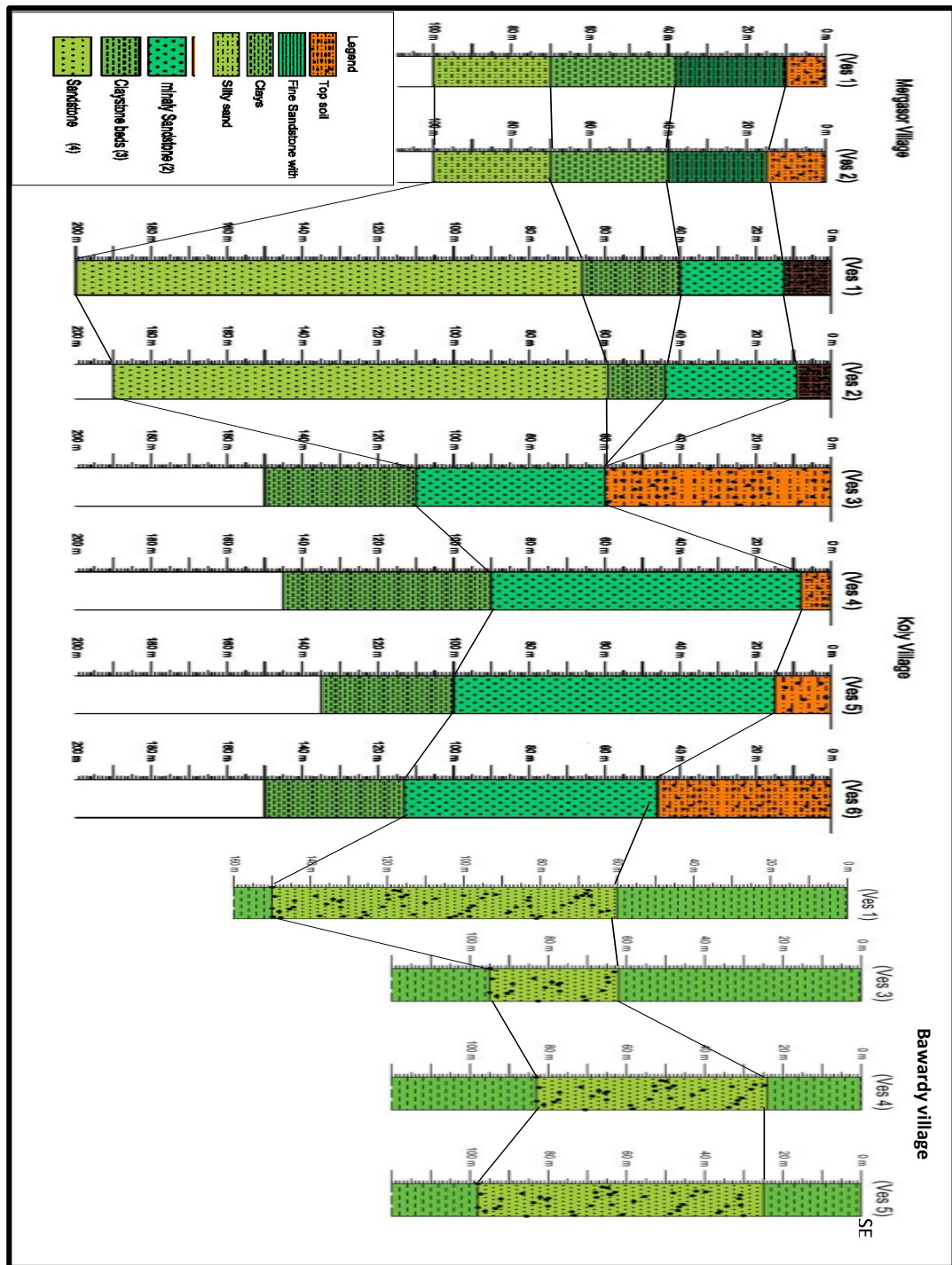


Figure (5) Geo-electrical correlation between VES points for sandstone layers

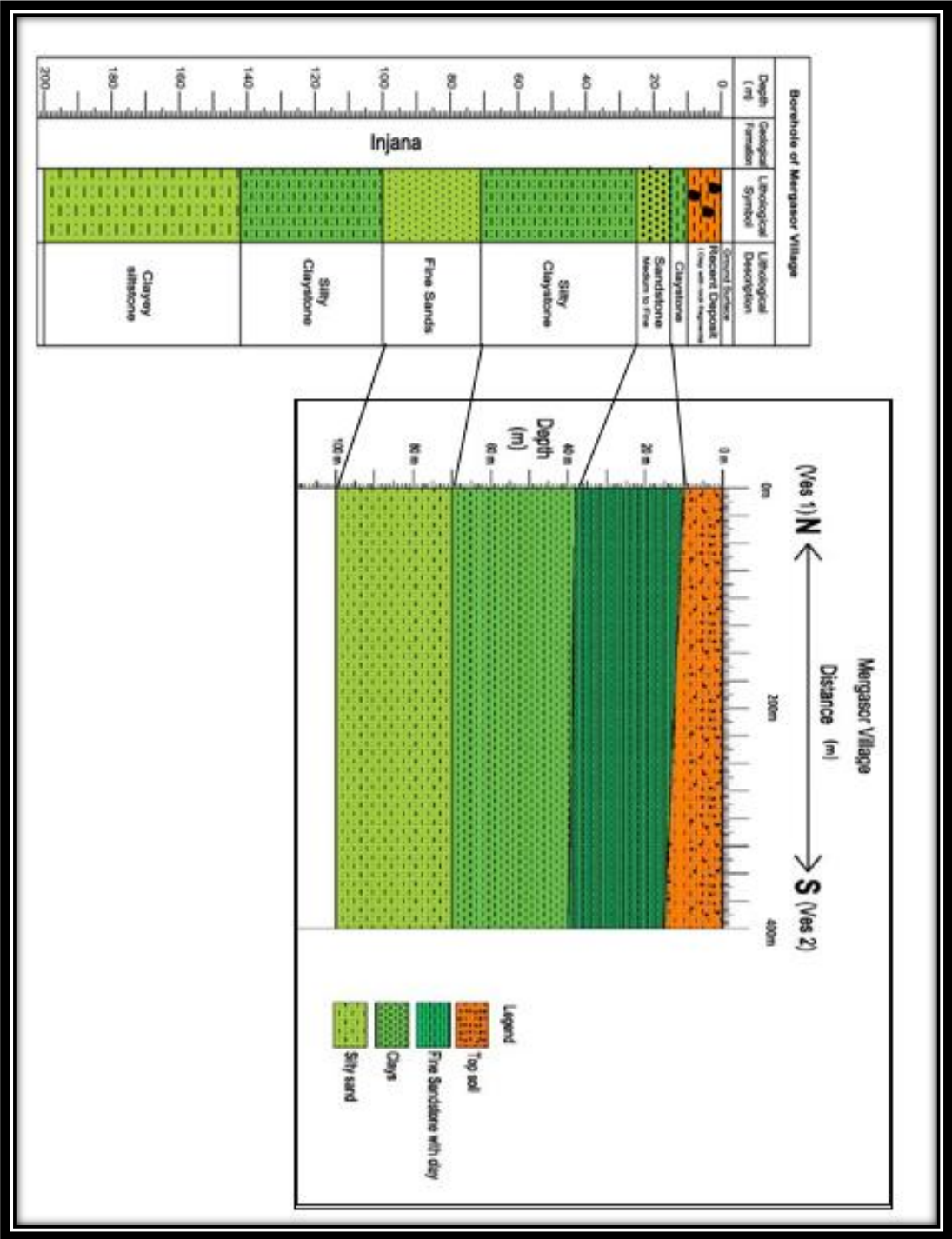


Figure (6): Geoelectrical profile of Mergasor village Borehole description of study areas(groundwater directorate of Duhok governorate)

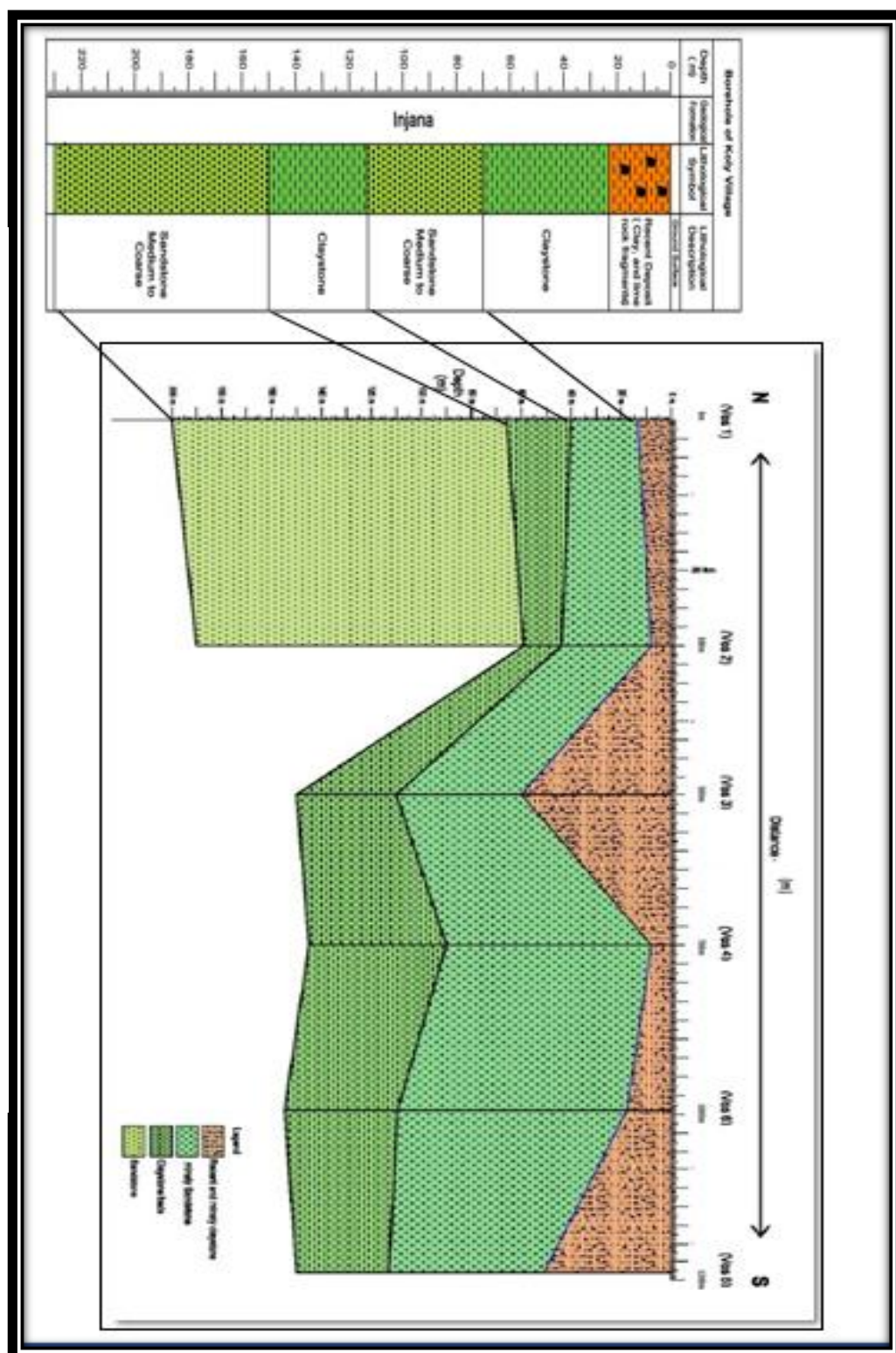


Figure (7): Geoelectrical profile of Koly village Borehole description of study areas (groundwater directorate of Duhok governorate)

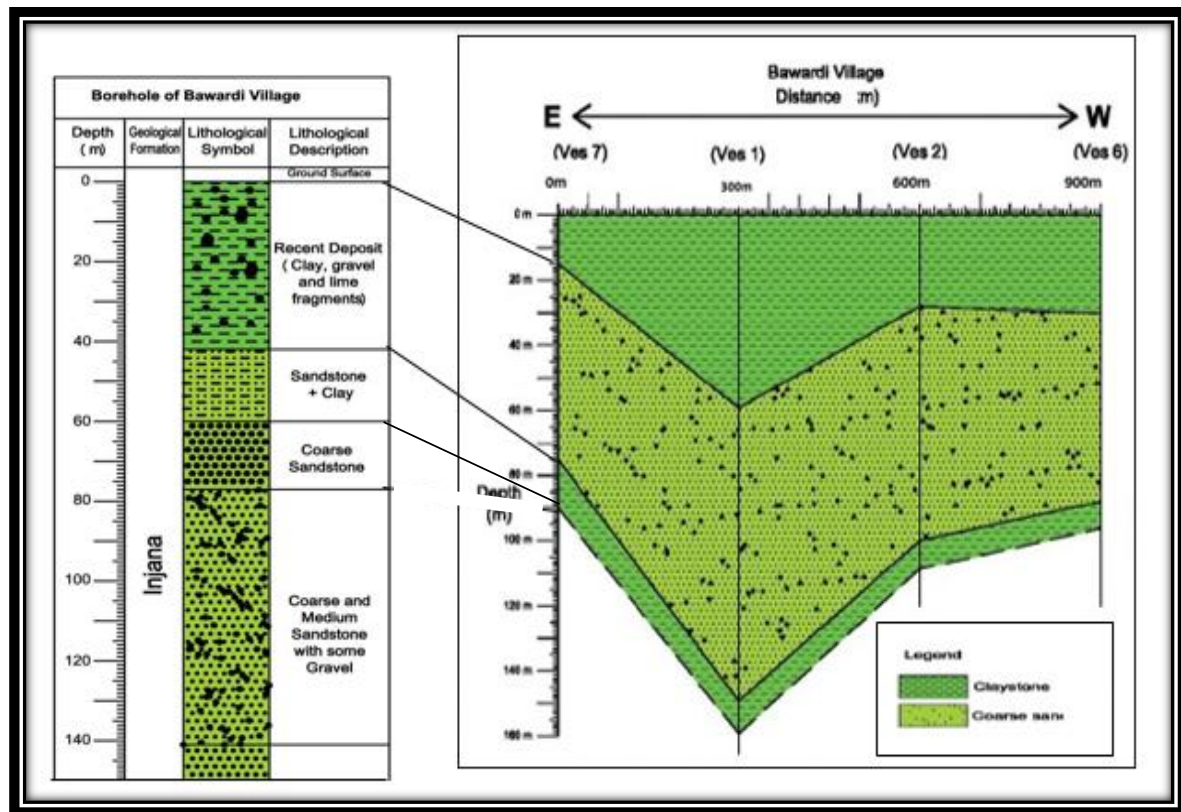


Figure (8): geoelectrical profile (a) of Bawardi village (EW)

Borehole description of study areas(groundwater directorate of Duhok governorate)

(SW-NE) **Figure (9): geoelectrical profile (a) of Bawardi village**

9-Conclsoions & Recommendation

The layers depth in the current study reached more than 150 m in the three study areas. The electric resistivity values ranged between (10-70) $\Omega.m$. It has been determined three strata at different depths in the three study areas. The first layer ranged between (20-50) $\Omega.m$, which represented the recent deposits with the presence of the clay in some areas. The second layer ranged between the electric resistivity values between (11-17) $\Omega.m$, which represented a layer of sandstone and saturated with groundwater, the third layer ranged between the values of resistance (22-55) $\Omega.m$, which represented layers of claystone with the presence of silt sometimes in some depths. This results came very near to that appears from well's information after digging it near survey points. That mean the vertical electrode sounding is effective

References

- [1] Nejad, H.T., M. Mumipour, R. Kaboli and O.A. Najib, 2011. Vertical Electrical Sounding (VES) Resistivity Survey Technique to Explore Groundwater in an Arid Region, Southeast Iran. Journal of Applied Sciences, 11: 3765-3774.
- [2] Reynolds J. (1998). An introduction to applied and environmental geophysics. 2nd edition, Gohn Wily and Sons, New York, USA, 796p.

technique for distinguishing the level of the groundwater and the determination of the isolating layers and subsurface geological layers.

Geological structures bodies have been identified in the village of Koly, such as the possibility of a normal type of structural fault toward north-south. Other geophysical techniques or geological studies are recommended to enhance or ascertain the existence of a fault has been notes in this study.

Acknowledgements

The author likes thanks the groundwater directorate of Duhok governorate in corporation with FAO sub-office in Dohuk Governorate, for their help in data acquisition. Thanks go to Dr. Ayman Mahmood, College of Petroleum and Mining Engineering/ Mosul university for his suggestions and help, thanks to Mr. Ahmed Jaddoa Al-Heety/ Ministry of Oil/Oil Exploration Company/ Baghdad. And thanks to Mr. Sadam Issa, Geology Department, College of Science/ Mosul University for theirs help.

- [3] Zhdanov, M.S. and Keller, G.V., 1994; The geoelectrical methods in geophysical exploration, Elsevier Scientific publishing Company, Amestrדם, 873 p.

- [4] Ramadhan, H.M. (2015). Spatial Analysis and Risk Assessment Study of the proposed Duhok Airport Project for Selevanii plane sumel district-Dohok city. Civilized dialogue, Number 4761.

- [5] Nabeel K. Al-Azzawi., And Safwan T. Al-Hubiti., 2008. The Fold Style Variations of Baikher Anticline - Northern Iraq, Iraqi Journal of Earth Sciences, Vol. 9, No. 1, pp. 1– 20, 2009.
- [6] Jassim SZ, Goff JC (2006) Geology of Iraq. first Edition, Dolin, Prague and Moravian Museum, Brno, Czech Republic, 408 P.
- [7] Buday T. (1980) The regional geology of Iraq stratigraphy and paleogeography. Dar Al-Kutub publication House, Mosul -Iraq, 352 p.
- [8] Dahlin T, Zhou B (2004) A numerical comparison of 2D resistivity imaging with ten electrode arrays. Geophysical Prospect 52:379–398.
- [9] Loke MH (2001) Electrical imaging surveys for environmental and engineering studies. A practical guide to 2-D and 3-D surveys, RES2DINV Manual, IRIS Instruments, www.iris-instruments.com
- [10] Loke M. H. (2009). Tutorial: 2-D and 3-D electrical imaging surveys www.geoelectrical.com.
- [11] IPI2Win (MT) Instruction Manual (2008) IPI2 Win (MT) v. 2.0 Moscow State university Geological Faculty Dept. of Geophysics.
- [12] Koefoed, O., 1979; Geo-sounding principles, 1. Receptivity sounding Measurements, Elsevier Scientific publishing company, Amsterdam, 276 p.

التحري الكهربائي المقاومي عن المياه الجوفية لثلاثة قرى في قضاء سميل – محافظة دهوك

شمال العراق

زينب مصدق شنشل

قسم علوم الارض ، كلية العلوم ، جامعة الموصل ، الموصل ، العراق

Saifalnajar75@yahoo.com

الملخص

تم اجراء مسح جيوفيزيائي كهربائي من خلال تطبيق تقنية الجس الكهربائي العمودي (VES) في ثلاث قرى مختلفة في قضاء سميل التابع لمحافظة دهوك ضمن الجناح الجنوبي لطية بيخير شمال العراق، لغرض التحري عن المياه الجوفية وحفر الابار في تلك القرى لاغراض الشرب ولاغراض زراعية حيث لم يكن تتواجد ابار في تلك القرى. المسح تضمن (16) نقطة جس كهربائي عمودي على طول ثلاث مسارات باستخدام ترتيب شلمبرجر لتوزيع الاقطاب لغرض التحري عن الخزانات تحت سطحية بالاضافة الى تحديد حدود خزان المياه الجوفية في المنطقة. عمق الاختراق في منطقة الدراسة وصل الى اكثر من (150) م. قيم المقاومة الكهربائية تراوحت بين (10-70) اوم. متر، حيث تم ايجاد ثلاث انطقة جيوكهربائية تم قياسها عند اعماق مختلفة في مناطق الدراسة الثلاث. النطاق الاول تراوحت قيم المقاومة فيه بين (20-25) اوم. متر والتي مثلت الترسبات الحديثة مع تواجد الاطيان في بعض المناطق. النطاق الثاني تراوحت قيم المقاومة فيه بين (11-17) اوم. متر، والتي مثلت طبقة من الحجر الرملي متعدد الاحجام والمشبعة بالمياه الجوفية. النطاق الثالث تراوحت قيم المقاومة فيه بين (22-25) اوم. متر، والتي مثلت طبقات من الاطيان مع تواجد حجر السلت في بعض الاعماق. تم ملاحظة وجود خزان مائي شبه جوفي نتيجة لوجود طبقات نفاذة من الحجر الرملي محاطة في اغلب الاحيان من الاعلى والاسفل بطبقات عازلة من صخور الحجر الطيني. على ضوء هذه المعلومات تم حفر الابار في تلك المناطق وايجاد المياه على اعماق قريبة جدا من النتائج التي تم التوصل اليها في الجس الكهربائي العمودي.