INDONESIAN JOURNAL ON GEOSCIENCE
Geological Agency
Ministry of Energy and Mineral Resources

Journal homepage: http://ijog.geologi.esdm.go.id
ISSN 2355-9314, e-ISSN 2355-9306

Determination of Deep Well Using Resistivity Method in South Amanuban, Timor Tengah Selatan Regency, Indonesia

Supandi

Department of Mining Engineering, Faculty of Mineral Technology,
Institut Teknologi Nasional Yogyakarta (ITNY)

Corresponding author: supandi@itny.ac.id
Manuscript received: June, 16, 2020; revised: August, 10, 2020;
approved: September, 02, 2020; available online: July, 6, 2021

Abstract - South Amanuban often experiences drought during dry seasons, because the area is composed of Quaternary deposits with plain topography. Therefore, this research aims to identify and to evaluate the Quaternary deposit of groundwater potential, and to determine the deep well points in South Amanuban. The study utilized the geo-electrical method with the resistivity value approach to find high resistivity soils as aquifer layers. In addition, the deep well points are determined based on consideration of the aquifer positions from the resistivity analysis. The results show that aquifer positions are found in the limited zone of 50-150 m depth with lense shapes that are not related to each other.

Keywords: deep well, geo-electrical, resistivity, South Amanuban

© IJOG - 2021

How to cite this article:
Supandi, 2021. Determination of Deep Well Using Resistivity Method in South Amanuban, Timor Tengah Selatan Regency, Indonesia. *Indonesian Journal on Geoscience*, 8 (2), p.255-264. DOI: 10.17014/ijog.8.2.255-264

Introduction

Background

The geological condition of South Amanuban makes it necessary to carry out subsurface mapping to determine the materials and aquifer positions of the drilling points in order to obtain an overview of groundwater potential. This method is based on the theory that each material has a different resistivity value, where groundwater is lower than the rock minerals. The two-dimensional geo-electrical resistivity acts as an alternative method used to map the subsurface condition. This method used the resistivity characteristics of rock layers to study the subsurface geological condition. The electric current inside rocks or minerals is categorized into three types, namely:

- Electronic conduction: a normal type of electric current inside rocks/minerals.
- Electrolytic conduction: this type occurs in many porous rocks with pores that are filled with an electrolyte solution.
- Dielectric conduction occurs in dielectric rocks with fewer or no free electrons (Hendrajaya and Arif, 1990).

The resistivity method basic principle involves the measurement of the potential difference of a pair of electrodes that inject current into the ground. According to Kearey *et al.* (2002), the deviations from the pattern of potential differences expected from the homogenous ground provide information on the form and electrical properties of subsurface inhomogeneities. Therefore, every material on earth has a specific resistivity value capable on displaying subsurface rock layers based on its resistivity value. Telford *et al*. (1990) stated that various compositions of rock produced a range of resistivity values on earth as shown in Figure 1.

Resistivity is closely related to the subsurface water pattern with its importance to the related pore pressure. The following factors influence the relationship between resistivity values and rock types:

- An unconsolidated sedimentary rock with a lower resistivity value than a solid sedimentary rock.
- A porous rock with lower resistivity than a nonporous rock.
- Low pH of water indicates acid rock with low resistivity.
- The resistivity of rocks varies in accordance with the depositional environment.
- Resistivity is different among rock layers.
- Water with high temperature has a lower resistivity than low-temperature water (freshwater).
- Permeability or the ability of rocks to drain the fluids.

Porosity of rock is the comparison between the volumes of the cavity with the volume of a rock. High porosity means that the volume of the water stored is large.

Several studies have been conducted by using the geo-electric method. For instance, Alile *et al.* (2008) carried out a research to determine the ground potential of the exploration activity and vertical electric sounding in the sedimentary rocks using the configuration method and automatic analysis. Alile and Ujunabi (2009) applied the Dar Zarrouk parameters to evaluate aquifer transmissivity using the configuration method. Furthermore, Alile and Amadasun (2008) researched the direct measurement of the current probing into the subsurface to identify resistivity layers with the stratigraphy characteristics of the soil layers obtained from the research. Badmus and Olatinsu (2010) also studied the aquifer system and characteristics based on the basement complex type using the Vertical Electrical Sounding (VES) and Schlumberger electrode array. Aizebeokhai *et al*. (2010) carried out a research using two dimensional and geo-electrical resistivity imag-

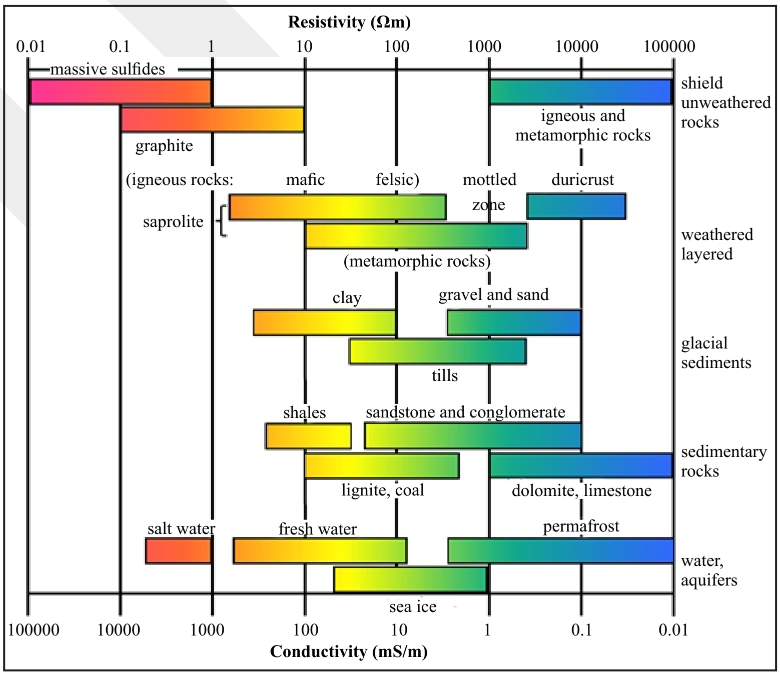

Figure 1. Resistivity value of materials in the earth (Telford, 1976).

ing for an engineering site investigation. Their research made the use of orthogonal set of two-dimensional geo-electrical resistivity field data consisting of six parallel and five perpendicular profiles collected in an investigation site using the conventional Wenner array. Aizebeokhai (2010) also carried out a research on the basic theory and field design of the application and the importance of two-dimensional resistivity imaging. Wisen *et al*. (2005) combined 1D laterally constrained inversion and two-dimensional smooth inversion of resistivity data with priori data from boreholes. The result shows that two dimensional smooth inversions properly resolve lateral changes, while 1D-LCI leads to a properly defined horizontal layer interface.

Al-zoubi *et al*. (2007) used the two dimensional geo-electrical resistivity imaging method to analyze the stratigraphy profile with the resistivity value profile. The deformation of the layered continuity and the direct contact between high and low resistive layers can only appear in the subsidence area or active sinkhole zones. The result shows that dry soil or sand with gravels or asphalt buried on the roadway is known as sinkholes with high material resistivity compared to soil with groundwater and silt with moisture and saturated clay.

Geology

Rosidi, Tjokrosapoetro, and Gafoer (1996) mapped the regional geology of the Kupang-Atambua-Timor Quadrangle including the Quaternary material (Qa) which consists of alluvium with gravel sand, intercalated by claystone as shown in Figure 2. Alluvium is fine- to coarse-grained materials with a layer thickness of 5 - 15 m without sedimentary structures. Grey claystone is present as intercalation in the upper part of the formation with the thickness of beds at 1 - 2.5 m. This region also consists of sedimentary rock boulder observed on a restrictive area. In some places at the Kupang-Atambua-Timor, lenses of grey limestone are recognized.

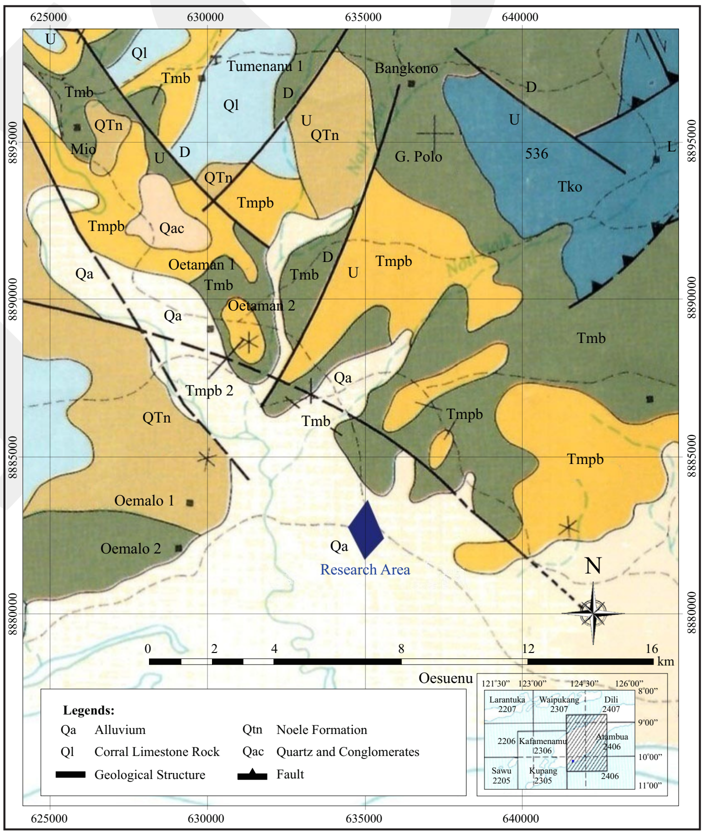

Figure 2. Researched area in the regional geology map of Kupang-Atambua-Timor (Rosidi, Tjokrosapoetro, and Gafoer, 1996).

Methodology

This research used the geo-electrical method with primary data to obtain current and potential differences. The distribution of groundwater aquifer potential is identified based on the resistivity value, lithology variation, thickness, and depth. The geo-electrical measurement is conducted by sounding geo-electric Wenner-Schlumberger array (600 m) with a total of ten geo-electrical measurement units as shown in Figure 3.

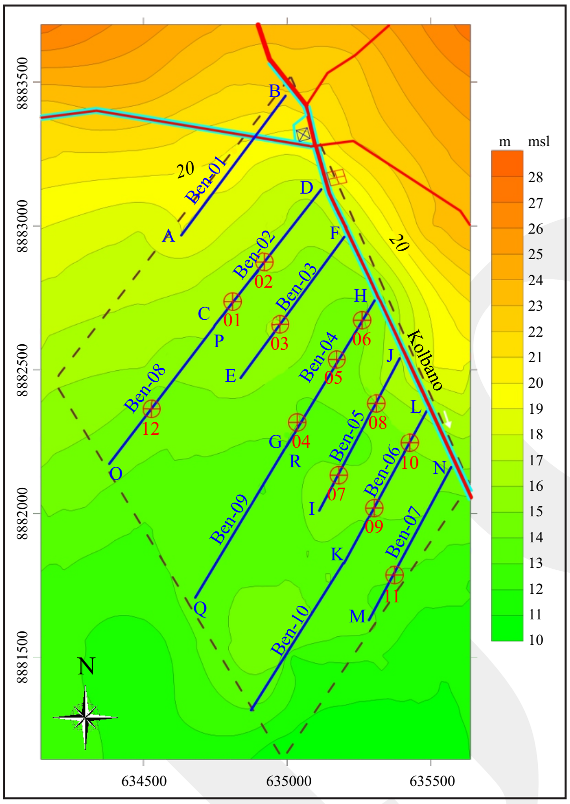

Figure 3. Geo-electrical measurement line map.

The tools to carry out this research are a resistivity meter, two electrodes, four cable reels, two dry batteries, a GPS, and a measuring tape. The RES2DINV *software* was used to obtain field data, while the Wenner-Schlumberger configuration method and standard operational procedure of ASTM D7852 - 13 were used for its acquisition.

Wenner-Schlumberger configuration is a constant spacing system configuration the "n" facto used as a spacing comparison between electrodes C1-P1 (or C2-P2) with P1-P2 space, as shown in Figure 4. When the distance between the potential electrodes (P1 and P2) is "a", then the distance between current electrodes (C1 and C2) is 2na + *a*. Sakka (2002) stated that the determined resistivity value uses four electrodes placed in a straight line.

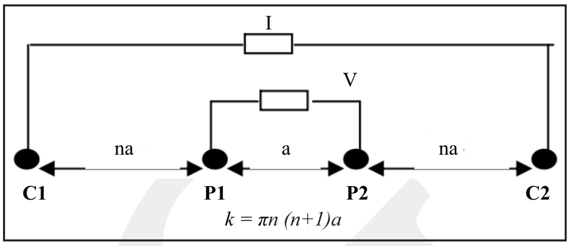

Figure 4. Electrodes setting on the Wenner-Schlumberger configuration.

When a direct current is delivered through a medium, then the ratio of potential difference (V) and current (I) is constant and dependent on its medium. This constant is resistance (R) expressed as follows:

$$R = \frac{V}{I} \quad (1)$$

The acquisition data in the field were conducted by making a straight line along 500 m with the target depth of approximately 70 m. The distance between measurement points is 15 m with ten pseudo layers. The data acquisition illustration of the two-dimensional configuration is shown in Figure 5.

Data processing uses mathematical calculations with resistivity input supported by RES-

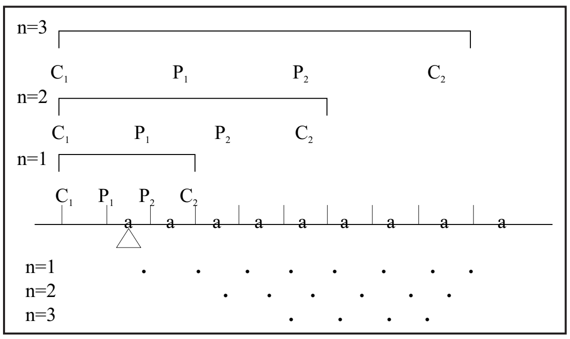

Figure 5. Data acquisition design of two-dimensional configuration.

2DINV software. Furthermore, geo-electric cross-sections appear between the pseudo and the calculated data, with the results inverted to get the actual resistivity. The result of two-dimensional processing data is a cross-section of subsurface resistivity distribution.

Result and Analysis

The researched area is dominated by alluvium consisting of clays, sands, pebbles, and cobbles from a flood plain in the western part. The exploration area is a moderate productive aquifer with local distribution and low field coefficient of permeability. The hydrogeological map of the researched area is shown in Figure 6 with a noncontinuous aquifer that is thin, with shallow groundwater level and well debit of less than 5 l/sec. The agricultural land in the exploration area is plain morphology with a height variation of 10 - 28 m asl. and a surveyed area of 169 ha.

This research utilized mathematical calculations to obtain the real resistivity value. The data processing was carried out using the RES2DINV software with the result of the pseudo section distributed to the subsurface cross-section area. The result of processing data is a resistivity cross-section that reflects the subsurface distribution value in each sounding point. Geo-electrical measurement lines can be seen in Figure 3. Changes in resistivity values are expressed in different colours with certain depth and thickness.

The processing data result in the RES2DINV software can be classified into isoresistivity layers (the same resistivity value) with approximately 10% RMS of error. The A-B line (NE - SW) in the northern part of the researched area is 500 m with the elevation of 20 m asl. Furthermore, the variation of the resistivity value in lateral with a depth of 100 m has a difference of 2 - 5 Ωm. The resistivity value is dominated by blue and light blue colours as shown in Figure 7.

The C-D and O-P are 1,000 m lines divided into two measurement points as shown in Figures 8 and 9. The lateral variation of resistivity value is 2 - 15 Ωm with 10 - 16 Ωm indicating the lense aquifers that are not related to each other. The C-D and O-P lines show the three aquifer potential points with different dimensions. In the C-D line, two aquifer points namely Deep Well_01 and 02 are found, while the O-P

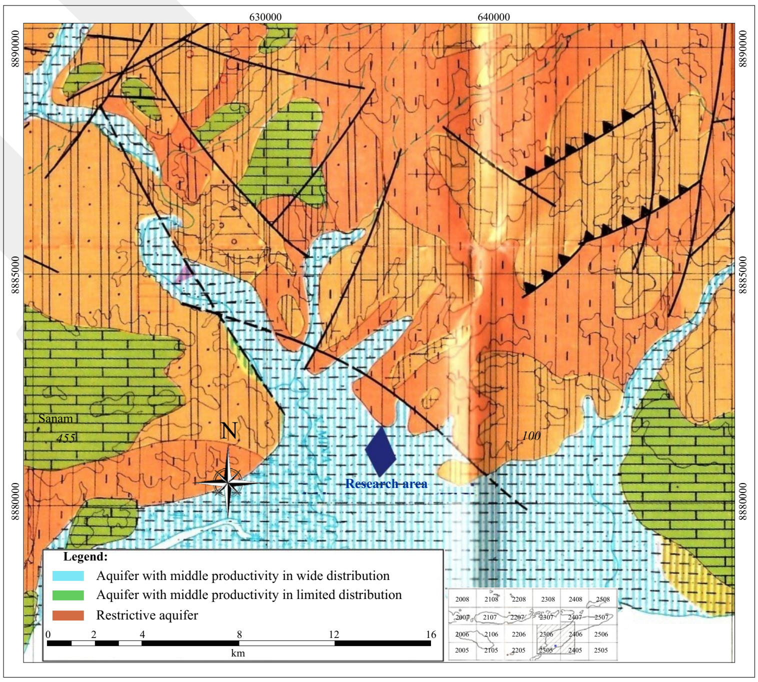

Figure 6. Hydrogeological map of the researched area (Struckmeier and Soetrisno, 1996).

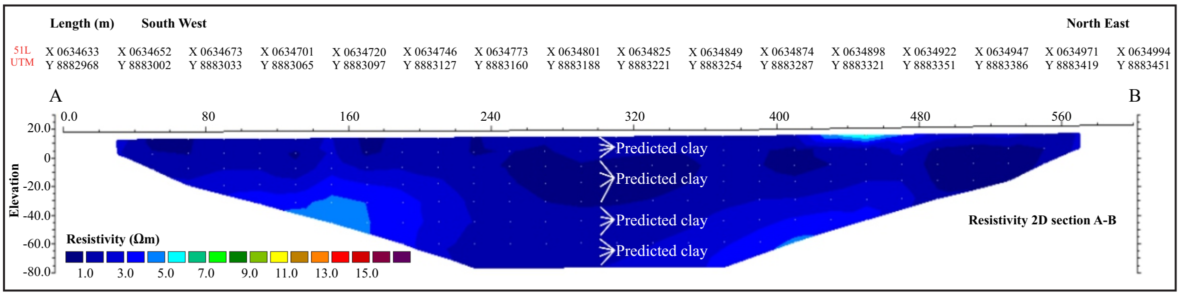

Figure 7. Resistivity cross-section of the A-B line.

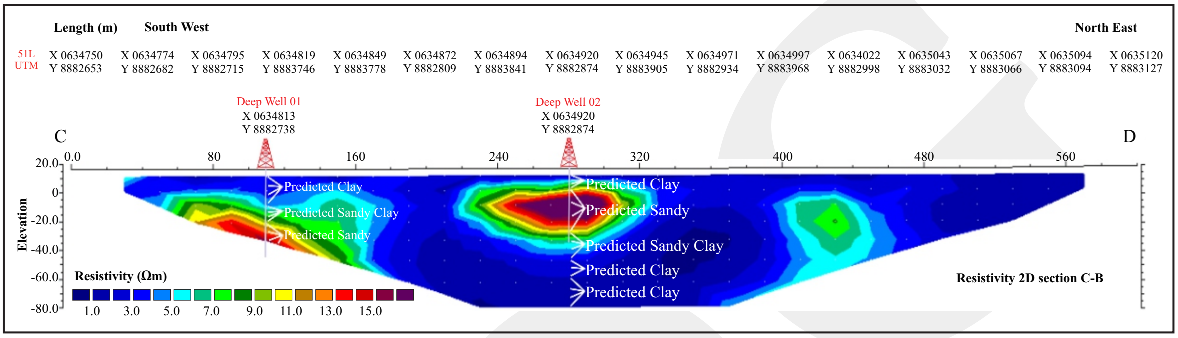

Figure 8. Resistivity cross-section of the C-D line.

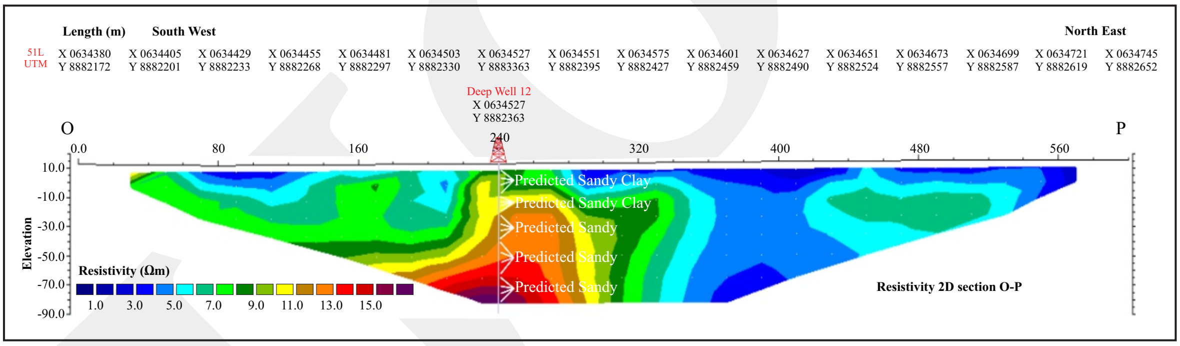

Figure 9. Resistivity cross-section of O-P line.

line contains one aquifer. The length of a large aquifer in the O-P line is 160 m at a thickness of 70 m (TRB_12). The debit estimation for each point in the Deep Well_01 and Deep Well_02 is 1-2 l/sec. While in the Deep Well_12 it is 2-3 l/sec.

The aquifer potential can be found in the E-F line with a depth of 40 m and resistivity value of 10-16 Ωm with a yellow-red colour, as shown in Figure 10. The 500 m of the geo-electrical line leads to a cross-sectional area of 80 m. The resistivity value is dominated by 2-5 Ωm with a debit estimation of 1-2 l/sec.

A lot of aquifer potentials are found in the G-H line with different dimensions and the same relative depth. The potential aquifers are identified at the Deep Well_04 and Deep Well_06 with the need for additional data to replace those in the missing locations. Furthermore, it is important to detail data in both locations to make a clear aquifer dimension. Deep well_05 is predicted to have a debit value of 2-3 l/sec., while others have 1-2 l/sec. The estimated debit of Deep Well_05 and Deep Well_06 still use the existing data with limited aquifer dimension having potential debit based on the value

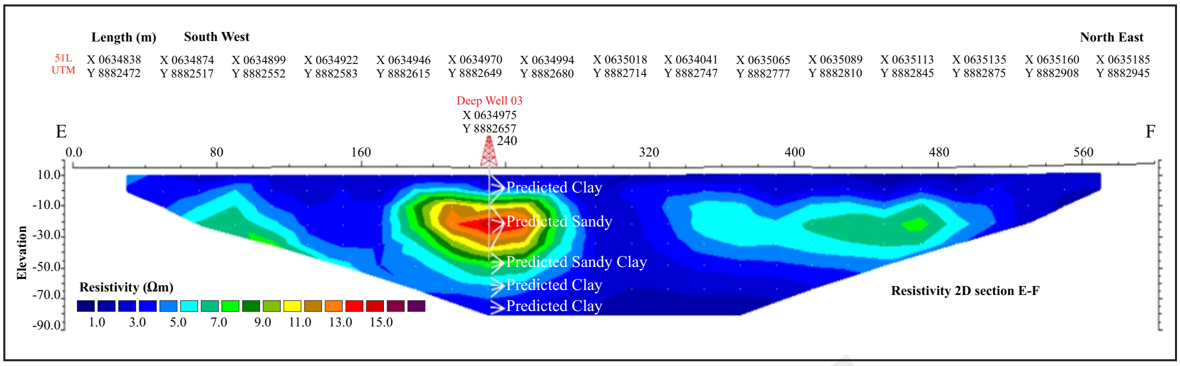

Figure 10. Resistivity cross-section of the E-F line.

of resistivity. It is important to provide detailed data to identify the aquifer dimension which is recommended to drill due to the limit of the aquifer dimension of 10-16 Ωm. G-H line is continued to Q-R line with potential groundwater resources found at resistivity values of 2-10 Ωm as shown in Figures 11 and 12. A 1,000 m of G-R line shows groundwater in the east with detailed data gathering found on the Deep well GH and Q-R used to make deeper stratigraphy interpretation. The maximum stratigraphy for deep well from 04 to 30 has a potential upgraded of -70m. The dimension aquifer on the deep well 04 is clear, assuming the stratigraphy appears more than the existing depth.

Approximately, two aquifer potential locations are in the I - J line with depth of 40 m and resistivity value of 11 - 16 Ωm as shown in Figure 13. Both aquifers are 400 m apart and predicted to have a debit of 1 - 2 l/sec. In addition, they also have lens shaped with diameter of 80 m.

The K-L and S-T lines have a total length of 1,100 m as shown in Figures 14 and 15. The

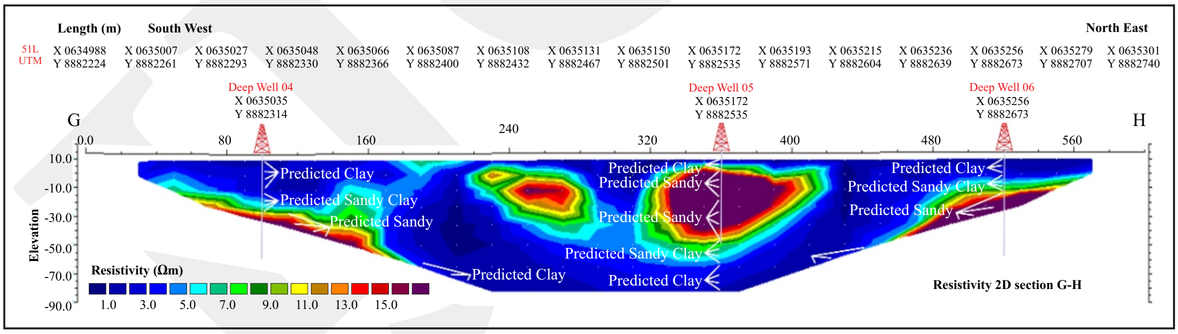

Figure 11. Resistivity cross-section of the G-H line.

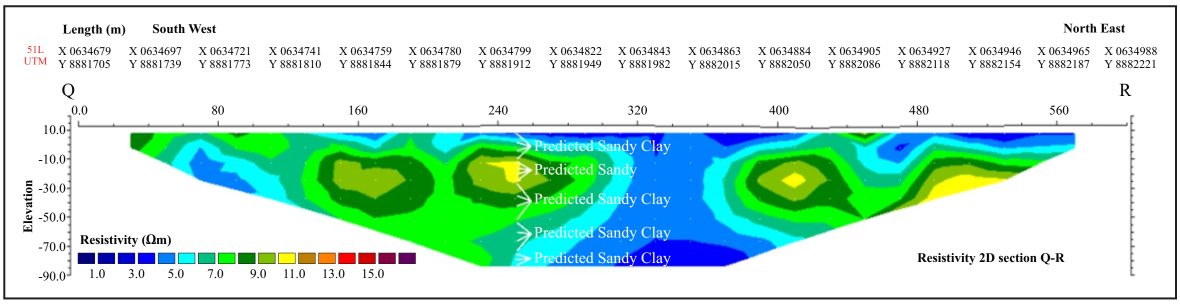

Figure 12. Resistivity cross-section of Q-R line.

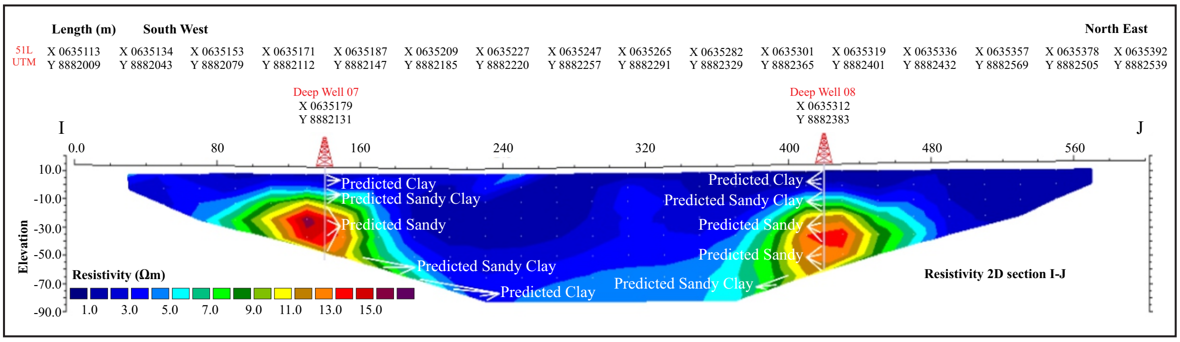

Figure 13. Resistivity cross-section of I-J line.

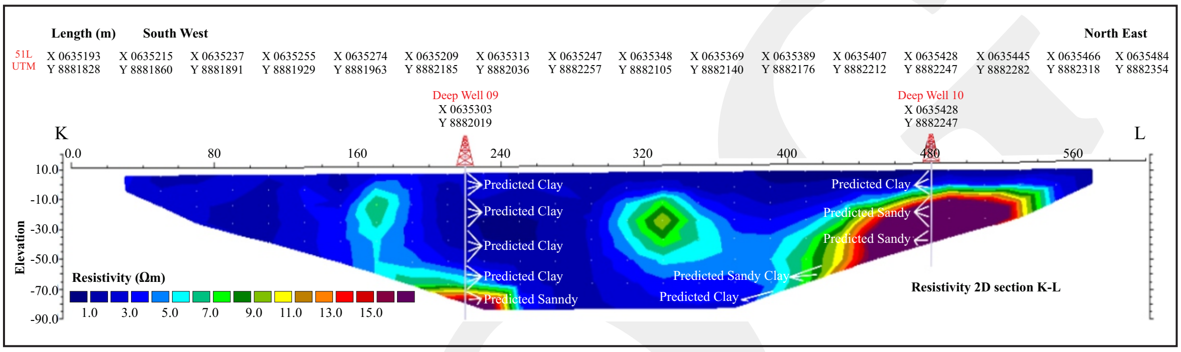

Figure 14. Resistivity cross-section of K-L line.

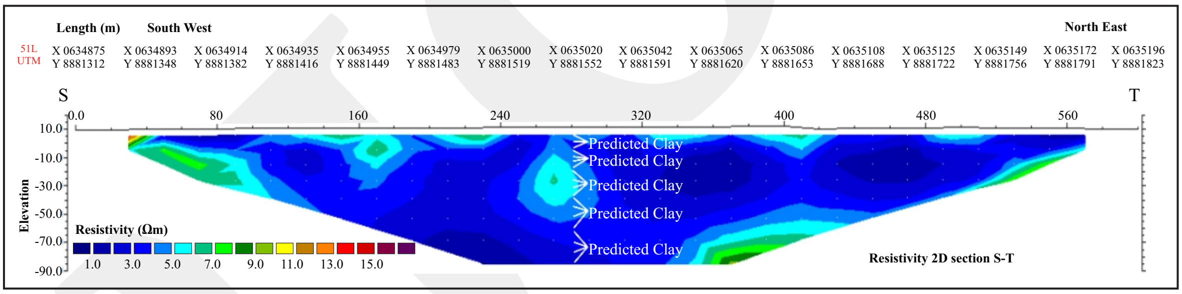

Figure 15. Resistivity cross-section of the S-T line.

aquifer is found in the K-L line that is 30 m in depth, and located in the NE-SW direction. The 15-16 Ωm resistivity value shows a large dimension of the aquifer that is approximately 100 m with an estimated debit of 2-3 l/sec. This aquifer is recommended because of its shallow position, large dimension, and large debit estimation. On the other hand, it consists of a relatively deep aquifer, which is 8 m in dimension and 1-2 l/sec. of debit estimation.

The aquifer in the M-N line is not clear with a depth of 80 m, the circular shape of 100 m, and 10 Ωm resistivity value as shown in Figure 16.

The resistivity value of data processing shows that the researched area has the potential of lens-shaped aquifers that are not related to each other. The dimensions of lenses are tens to hundreds of meters with a depth of 20 - 95m, estimated debit value of 1-3 l/sec. and the average of 1,5 l/sec. The total of three aquifer locations have 2-3 l/sec. of debit namely Deep Well_05, Deep Well_10, and Deep Well_12, while others have 1-2 l/sec. of debit. The two largest aquifers are TRB_10 and Deep Well _12 with 30 - 65 and 40 - 95 m in depth. Detailed measurements of the aquifer depth and debit estimation are shown in Table 1.

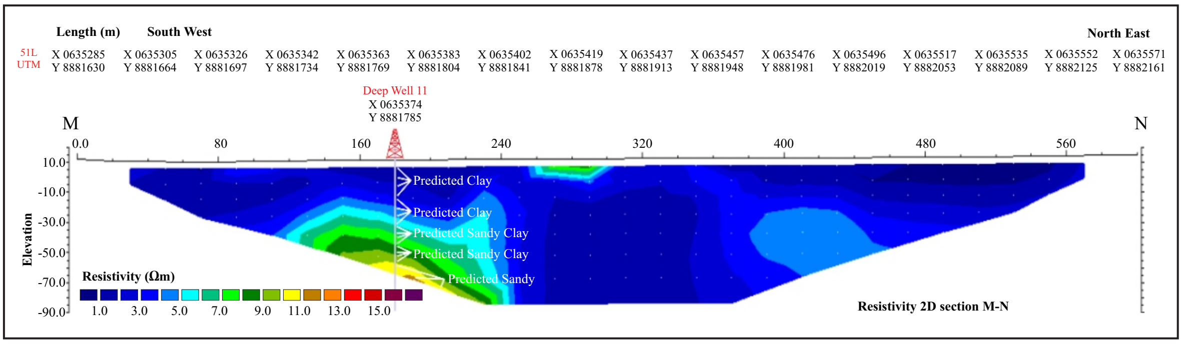

Figure 16. Resistivity cross-section of M-N line.

Table 1. Aquifer Depth and Debit Estimation

No.	Point Code	UTM	Coordinate		Drill Target (m)	Aquifer Depth (m)	Debit Estimation (l/sec.)
			X	Y			
1	Deep Well-01	51 L	634813	8882738	60	40 - 55	1 - 2
2	Deep Well-02	51 L	634920	8882874	50	20 - 45	1 - 2
3	Deep Well-03	51 L	634975	8882657	60	30 - 55	1 - 2
4	Deep Well-04	51 L	635035	8882314	70	40 - 65	1 - 2
5	Deep Well-05	51 L	635172	8882535	60	30 - 55	2 - 3
6	Deep Well-06	51 L	635256	8882673	60	30 - 55	1 - 2
7	Deep Well-07	51 L	635179	8882131	60	30 - 55	1 - 2
8	Deep Well-08	51 L	635312	8882383	70	35 - 65	1 - 2
9	Deep Well-09	51 L	635303	8882019	100	80 - 95	1 - 2
10	Deep Well-10	51 L	635428	8882247	70	30 - 65	2 - 3
11	Deep Well-11	51 L	635374	8881785	100	70 - 95	1 - 2
12	Deep Well-012	51 L	634527	8882363	100	40 - 95	2 - 3

Conclusions

Based on geo-electrical measurement supported by the surface geological data in the southern Amanuban, Timor Tengah Selatan Regency, the conclusions are as follows:

- The surveyed area is a low undulating plain and a flood plain.
- The lithology is dominated by alluvium consisting of clays, sands, pebbles, and cobble from flood plain obtained from the western part of the researched area.
- The exploration area is a moderate productive aquifer with local distribution and low field coefficient of permeability.
- The aquifers have lense shapes with the depth of 50 - 80 m, resistivity value of 20 - 50 Ωm, and unconsolidated sand layers.
- The drilling point priority can be carried out in the TRB-12 due to the presence of a big aquifer with a debit of 2 - 3 l/sec.

Additional data is required to detail some areas with potential water resources in order to calculate the estimation of groundwater reserves properly.

Acknowledgment

The authors are grateful to the AB Omah Geo team and PT AOG for supporting this research.

References

Aizebeokhai, A.P., 2010. Geo-electrical Resistivity Imaging: Theory and Field Design. *Scientific Research Essay,* 5(23), p.3592-3605.

Aizebeokhai, A.P., Olayinka, A.I., and Singh, V.S., 2010. Application of 2D and 3D Geo-electrical Resistivity Imaging for Engineering Site Investigation in A Crystaline Basement Terrain, Southwestern Nigeria. *Journal Environmental Earth Sciences.* DOI: 10.1007/s12665.010-0.474, p.1481.

Alile, O.M., Amadasun, C.V.O., and Evbuohuwan, A.I., 2008. Application of Vertical Electrical Sounding Method to Decipher the Existing Subsurface Stratification and Groundwater Occurrence Status in a Location in Edo North of Nigeria. *International Journal of Physical Sciences,* 3 (10), p.245-249.

Alile, O.M. and Amadasun, C.V.O., 2008. Direct Current Pobing of the Subsurface Earth for Water Bearing Layer in Oredo Local Government Area, Edo State, Nigeria. *Nigeria Journal of Applied Science,* 25, p.107-116.

Alile, O.M. and Ujunabi, O., 2009. Application of Dar Zarrouk Parameters to Evaluate Aquifer Transmissivity in Epkoma Edo State in Nigeria. *Journal of the Nigerian Association of Mathematical Physics,* 14 (36).

Al-zoubi, A., Abdel-Rahman, A., Abueladas, and Rami, I. AlRzouq, 2007. Use of 2D Multi-electrodes Resistivity Imaging for Sinkholes Hazard Assessment along the Eastern Part of the Dead Sea, Jordan. *American Journal of Environmental Sciences,* 3 (4), p.230-234. DOI: 10.3844/ajessp.2007.230.234

Badmus, O., 2010. Aquifer Characteristics and Groundwater Recharge Pattern in Typical Basement Complex: A Case Study of Federal College of Education, Osiele, Abeokuta, Southwestern, Nigeria. *African Journal Environmental Science Technology*, p.328-342. DOI: 10.5897/ajest09.214

Hendrajaya, L. and Arif, I., 1990. *Resistivity Geoelectric*, Earth Physic Laboratory, Physics Department, FMIPA ITB, Bandung.

Kearey, P., Brooks, M., and Hill, I., 2002. *An Introduction to Geophysical Exploration*. Oxford: Blackwell Science Ltd.

Rosidi, H.M.D., Tjokrosapoetro, S., and Gafoer, S., 1996. G*eological Map of Kupang-Atambua, Timor, Scale 1:250.000.* Geological Research and Development Centre, Bandung.

Sakka, 2002. *Resistivity Geo-electric Method*, Mathematic and Science Faculty, UNHAS, Makassar.

Struckmeier, W. and Soetrisno, S., 1996, *Indonesia Hydrogeology Map*, *Scale 1:250.000*, Directorate of Environment Geology, Bandung.

Telford, W.M., Geldart, L.P., and Sheriff, R.E., 1990. *Applied Geophysics*, Cambridge University Press, pp.

Wisén , R., Auken, E., and Dahlin, T., 2005. Combination of 1D laterally constrained inversion and 2D smooth inversion of resistivity data with a priori data from boreholes, *Near Surface Geophysics,* 3 (2), p.71-79. DOI: 10.3997/1873-0604.2005002