

PAPER • OPEN ACCESS

Modeling of aquifer using vertical electrical sounding data with kriging interpolation in Padang City

To cite this article: A Octova *et al* 2020 *J. Phys.: Conf. Ser.* **1481** 012008

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing together innovative digital publishing with leading authors from the global scientific community.

Start exploring the collection—download the first chapter of every title for free.

Modeling of aquifer using vertical electrical sounding data with kriging interpolation in Padang City

A Octova^{1*}, M Gusman¹, P Razi², R R Putra¹, and A E Putra¹

¹Department of Mining Engineering, Faculty of Engineering, Universitas Negeri Padang, Jl. Prof Hamka, Padang 25131, Indonesia

²Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Jl. Prof Hamka, Padang 25131, Indonesia

*adree@ft.unp.ac.id

Abstract. Aquifer is an underground layer of water. Currently, many residents of Padang do not know the exact position of the aquifer. Many drilling activities have been carried out to find ground water. But the results are not in accordance with the predetermined depth targets. This situation will be affected to the costs incurred for drilling. This study aims to model aquifers in Padang and find out their depth and thickness. One way to identify aquifers is to use geoelectrical resistivity method. In this study, researchers used a one-dimensional vertical electrical sounding (VES). The collection of geoelectrical sounding data is spread in 36 points in Padang. To modeling the aquifer layer, kriging interpolation method is used. Based on the results of processing rock resistivity models, it was found that the average aquifer depth in Padang is about 6.23 meters, with the shallow depth in 1.01 meters and the deepest in 20.02 meters. While the average thickness of aquifers is about 7.47 meters, with the thinnest thickness in 1.68 meters and the thickest in 11.74 meters. The aquifer layer was identified as unconfined aquifer.

1. Introduction

Aquifer is an underground layer of water. Currently, many residents of Padang do not know the exact position of the aquifer. Many drilling activities have been carried out to find ground water, but the results are not in accordance with the predetermined depth targets. This problem will be affected to the cost incurred for drilling activities.

Information of the depth aquifer in Padang is still limited and there is no much references to identify the position of aquifer became one of the backgrounds to do this survey. This research aims to model aquifer Padang and find out their depth and thickness. The author hopes that with this research, Padang residents will later be helped and easier to find out the position of aquifers in Padang, so the costs incurred by residents for groundwater drilling activities can be estimated more precisely.

2. Characteristics of Rock Resistivity

The rock electrical resistivity is rocks characteristic when electric current flows through the rock. Electric current could divide to natural and artificial. Natural electric current occurs by the presence of the atoms making up the earth's crust that interact with each other due to the charge imbalance, or electric current accidentally put into it. Some of the electrical properties of rocks that are useful in the geoelectrical exploration particularly in resistivity method is the natural electrical potential, electrical conductivity, and dielectric constant [1] [2]. Resistivity value of some materials as follows:



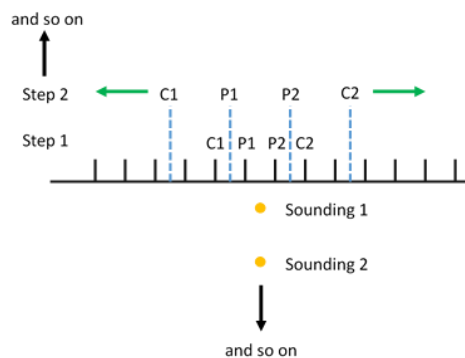
Table 1. Some of Resistivity value [3]

Resistivity (Ωm)	Interpretation
0	Water
200-8,000	Sandstones
1-1,000	Sand
1-100	Clay
0.5-300	Groundwater
0.2	Sea Water
600-10,000	Dry Gravel
10-800	Alluvium
100-600	Gravel
$3 \times 10^2 - 10^6$	Granite
$10^2 - 10^5$	Diorite
$20 - 5 \times 10^7$	Diabase
$10 - 1.3 \times 10^7$	Basalt

3. Geoelectrical Method

Geophysics is one of exploration method that can be used to knowing subsurface imaging with a relatively short time and low cost [4]. one of the geophysical exploration methods is the geoelectrical method. Geoelectrical method is a geophysical method that study the nature of the flow of electricity below the earth's surface and how to detect it on the surface of the earth [2]. By displaying the subsurface resistivity section of the geoelectrical measurements results, it can be known and predicted layers of rocks or layer of groundwater (aquifer), thickness and depth. Geoelectrical research is intended to know the arrangement of subsurface geological layers, so it can be known there is a layer of aquifer that exist [5].

Vertical electrical sounding or VES method was used to collecting data technique. This method also called 1-dimension detection method. This method produces ID resistivity data. In this method the distance between two currents electrode (C1 and C2) is set to equal. Similarly, distance between P1 and P2 (potential) electrodes. This configuration illustrated in Figure 1 [6].

**Figure 1.** Electrode configuration

Based on log resistivity value of each geoelectrical sounding data, an interpretation of depth and thickness of aquifer is then performed. Rocks that can serve as the best water carrier layers are sand, crust, and gravel.

4. Kriging Interpolation Method

The term kriging is taken from the name of an expert, namely D.G. Krige, who first used spatial correlation and unbiased estimators [7][8]. Kriging is a method of estimating the value of a variable at

a point or block for which there is no sample value by using a linear combination of known variables.

In modeling the kriging interpolation, we will conduct univariate statistical analysis and variogram analysis. A variogram is a vector function that can be used to quantify the degree of similarity or variability between two samples that are separated by a certain distance [9]. Variogram analysis begins with making an experimental variogram. After that, it is continued with fitting variogram, which is matching experimental variogram with theoretical variogram. From the fitting variogram, the theoretical variogram will be selected. There are three theoretical variogram usually used, they are spherical, exponential and Gaussian [9]. Variogram can be seen in Figure 2.

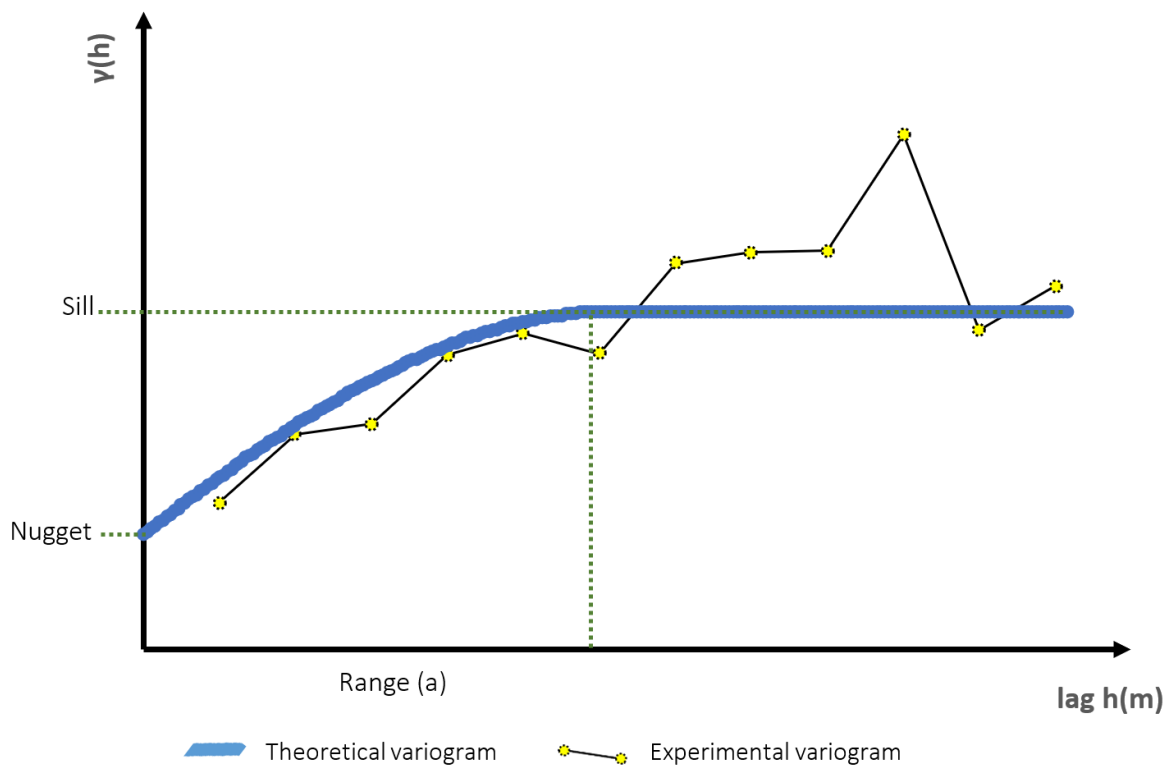


Figure 2. Variogram

Interpolation with the kriging method will produce a model, but the model must be corrected with the topographic value, top elevation and bottom elevation of the model. After that the results of the correction will be plotted into the software to get a picture of the block model and solid model [7][10].

5. Analysis and Result

5.1 Data Collecting

The location of data collection is spread in 36 points in Padang. Acquisition data point location of electrical sounding (VES) can be seen in Figure 3.

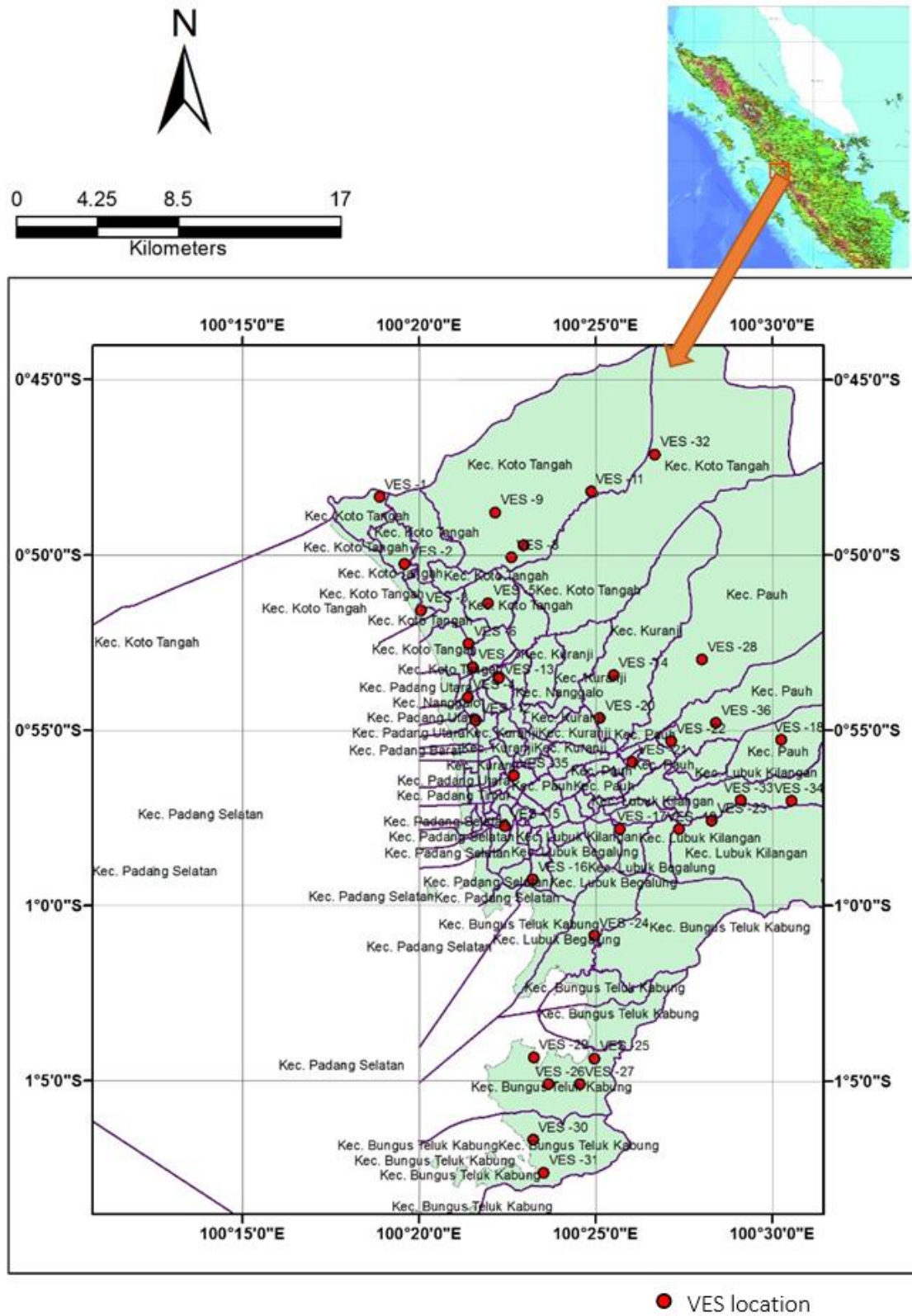


Figure 3. Geoelectrical VES data locations

5.2 Data Processing

From acquisition data of the geoelectrical sounding survey shows the rock resistivity at the research area ranges from 0.86 to 129264.4 Ohm-m. The following resistivity value of each point data can be seen in Table 2.

Table 2. Resistivity value of measurements results

VES	From (m)	To (m)	Resistivity	VES	From (m)	To (m)	Resistivity
VES01	0	5.1	613.52	VES19	0	0.98	24.76
	5.1	10.32	3.72		0.98	2.94	224.82
	10.32	200	7316.66		2.94	11.47	99.69
VES02	0	1.37	8282.6		11.47	172	27.81
	1.37	6.43	101.31		172	200	16.45
	6.43	200	4.29	VES20	0	0.99	27.24
VES03	0	4.67	44.11		0.99	2.69	870.2
	4.67	12.86	4.78		2.69	148.11	87
	12.86	200	7021.28	VES21	0	4.74	118.36
VES04	0	5.59	58.54		4.74	93.05	66.47
	5.59	24.48	6.75		93.05	195.43	39.65
	24.48	200	2165.17	195.43	200	142.18	
VES05	0	0.95	38.29	VES22	0	0.58	16.06
	0.95	5.82	113.2		0.58	2.86	953.26
	5.82	28.77	60.17		2.86	9.15	21.62
	28.77	59.57	14.39		9.15	200	115.01
	59.57	200	4431.16		VES23	0	0.95
VES06	0	0.91	242.49	0.95		2.32	198.22
	0.91	6.39	53.37	2.32		93.91	73.41
	6.39	36.22	14.9	93.91		200	37.92
	36.22	57.1	2.81	VES24		0	6.58
	57.1	200	639.49		6.58	68.97	25.38
VES07	0	7.02	130.3		68.97	200	57.44
	7.02	11.35	1.55	VES25	0	3.78	98.85
	11.35	200	3332.73		3.78	28.88	42.97
VES08	0	17.37	93.76		28.88	48.58	5.78
	17.37	136.38	38.05	48.58	200	2076.98	
	136.38	200	5021.39	VES26	0	2.49	37.08
VES09	0	0.85	26.9		2.49	7.29	4405.65
	0.85	5.41	15.68		7.29	39.52	36.75
	5.41	131.64	28.05	39.52	200	9678.3	
	131.64	200	5170.1	VES27	0	0.28	150.28
VES10	0	1.04	64.44		0.28	0.41	216.54
	1.04	8.12	146.68		0.41	7.81	25.62
	8.12	16.54	41.2	7.81	29.42	22.77	

	16.54	42.4	10.75		29.42	200	1140.73
	42.4	200	23.21	VES28	0	0.91	103.05
VES11	0	2.74	204.19		0.91	1.09	417.76
	2.74	5.14	21.94		1.09	13.64	61.56
	5.14	13.79	148.81		13.64	100.12	21.44
	13.79	24.87	4.4		100.12	200	3644.18
	24.87	200	49.47	VES29	0	20.02	52.5
VES12	0	5.97	64.01		20.02	28.26	6.44
	5.97	12.21	9.86		28.26	200	20853.35
	12.21	200	25571.39	VES30	0	0.78	379.15
VES13	0	0.85	110.55		0.78	6.38	91.01
	0.85	1.98	23.63		6.38	17.29	23.29
	1.98	4.41	116.85		17.29	200	65.72
	4.41	27.48	16.78	VES31	0	0.89	225.54
	27.48	35.78	0.86		0.89	2.25	480.78
	35.78	200	1526.07		2.25	7.4	111.86
VES14	0	1.17	117.41		7.4	16.42	38.44
	1.17	2.85	1462.04		16.42	200	100.3
	2.85	48.7	69.07	VES32	0	5.28	671.89
	48.7	114.23	19.51		5.28	17.02	17.99
	114.23	200	2083.29		17.02	60.75	836.57
VES15	0	14.05	36.59		60.75	200	10.27
	14.05	19.11	1.59	VES33	0	5.67	56.72
	19.11	200	11244.16		5.67	11.41	14.16
VES16	0	1.01	795.67		11.41	21.08	80.59
	1.01	8.6	12451.09		21.08	153.94	17.75
	8.6	97.81	275.77		153.94	200	1514.73
	97.81	200	1371.53	VES34	0	0.69	167.21
VES17	0	1.63	24.13		0.69	1.86	129264.36
	1.63	8.07	103.26		1.86	200	96.08
	8.07	160.67	20.94	VES35	0	3.17	50.46
	160.67	200	2020.6		3.17	26.02	32.2
VES18	0	1.79	80.26		26.02	54.89	9.31
	1.79	3.94	169.79		54.89	200	4591.28
	3.94	58.59	73.42	VES36	0	0.74	235.05
	58.59	87.71	18.4		0.74	9.24	389.04
	87.71	200	7518.22		9.24	52.63	68.18
					52.63	200	245.07

5.3 VES Interpretation

From the results of the VES interpretation, it was found that the constituent material of the aquifer is sand. The depth of aquifers show in the Table 3.

Table 3. Result of aquifer identification

VES	Depth(m)
VES01	5.1
VES02	1.37
VES03	4.67
VES04	-
VES05	-
VES06	-
VES07	7.02
VES08	-
VES09	0.85
VES10	8.12
VES11	5.14
VES12	5.97
VES13	1.98
VES14	1.17
VES15	14.05
VES16	1.01
VES17	1.63
VES18	1.79
VES19	2.94
VES20	-
VES21	-
VES22	2.86
VES23	-
VES24	-
VES25	-
VES26	2.49
VES27	-
VES28	-
VES29	20.02
VES30	6.38
VES31	7.4
VES32	5.28
VES33	5.67
VES34	-
VES35	-
VES36	-

The result of identification of aquifer in the study area indicates that the average depth of the aquifer found in the study area is 6.23 meters.

5.4 Aquifer Modeling with Kriging Interpolation

The results of univariate analysis is display in histogram imaging (Figure 4). Mean, varians and maximum thickness are sequentially 7.21, 5.76, and 11.74. Especially for variance will be used to determine sill parameter in variogram analysis.

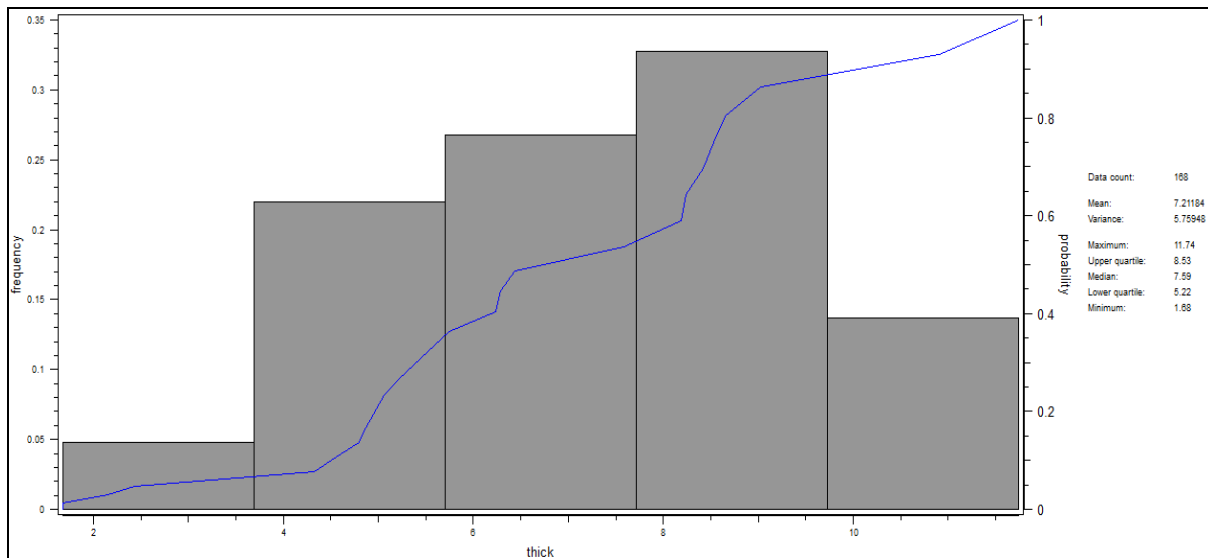


Figure 4. Histogram of aquifer thickness

The sequences of variogram was implemented. Spherical model was chosen as the theoretical variogram In fitting variogram process. This model gives best fit with experimental variogram. This model can be seen in Figure 5. The variogram parameters obtained from fitting variogram process can be seen in Table 4.

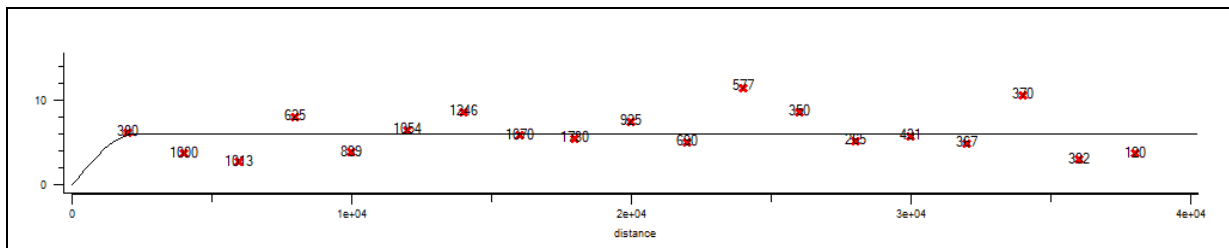


Figure 5. Variogram model of aquifer thickness

Table 4. Variogram parameters

Parameter	Value
Nugget variance (Co)	0
Sill (C)	6
Range (a)	2300
Total sill (Co+C1)	6

The result of kriging interpolation of aquifer thickness in the research area indicates that the average thickness of the aquifer found in the study area is 7.47 meters, with the thinnest in 1.68 meters and the thickest in 11.74 meters. Aquifer model can be seen in Figure 6 and aquifer block model can be seen in Figure 7.

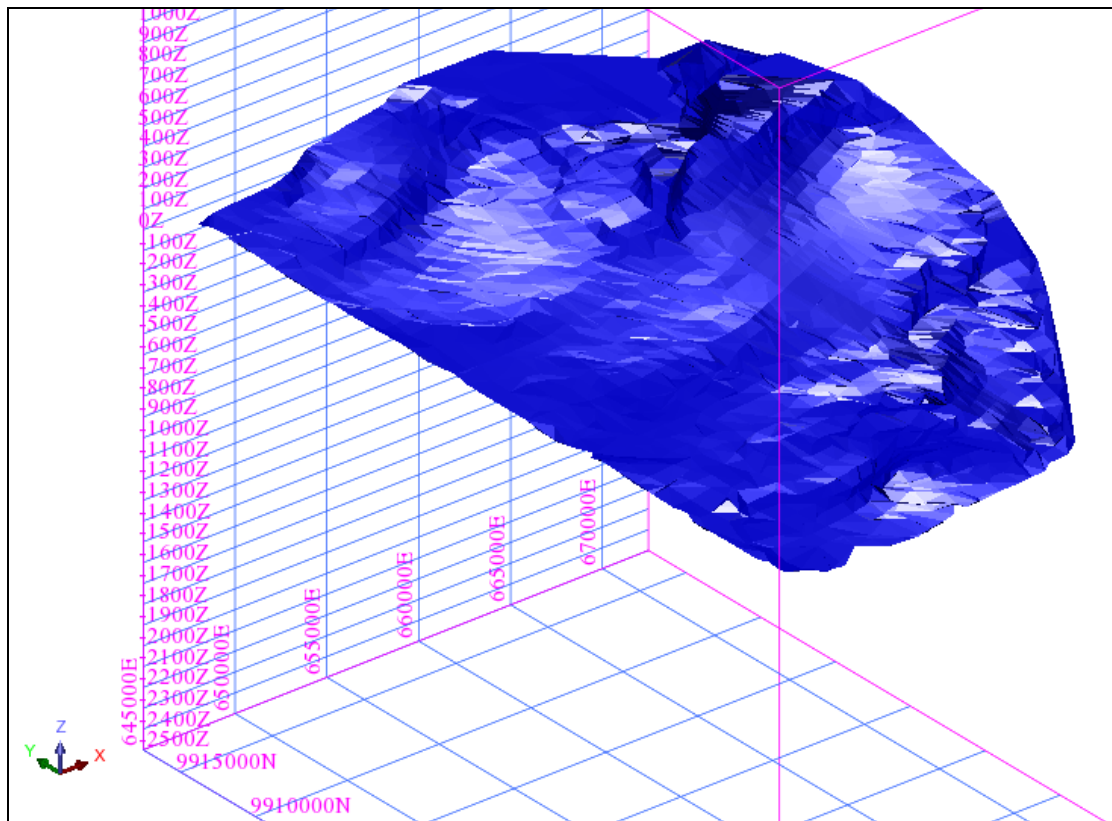


Figure 6. Aquifer solid model

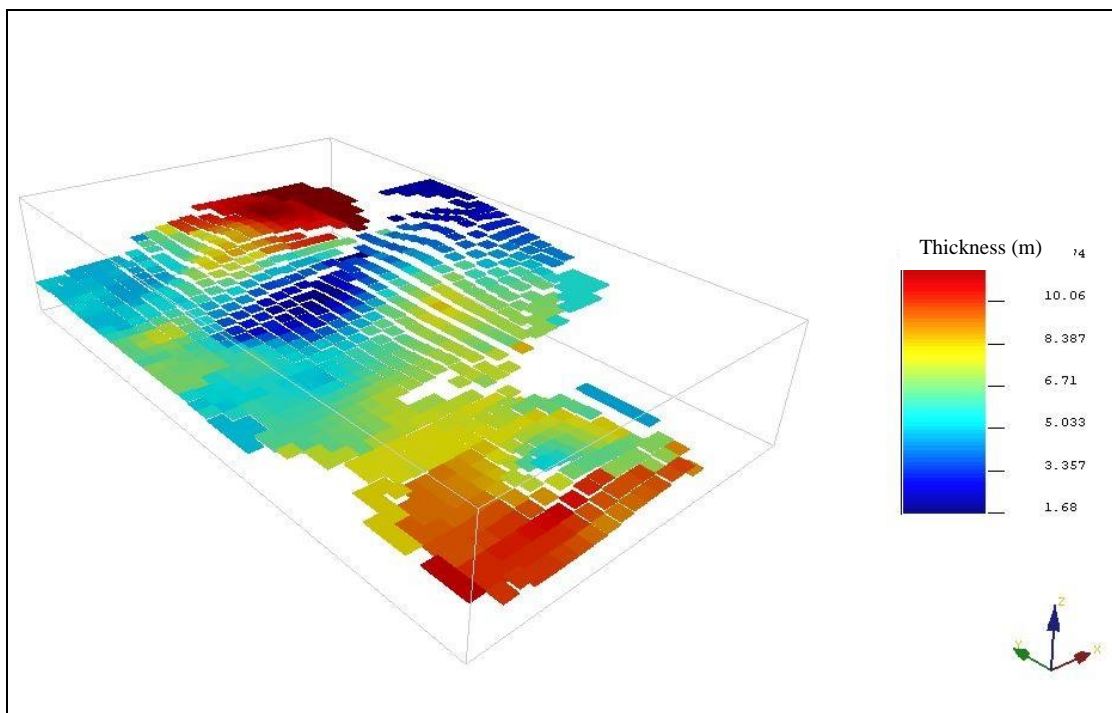


Figure 7. Aquifer block model

From Figure 7, The thickest aquifer layer is in Koto Tengah sub-district, and the thinnest is in Kuranji sub-district. Aquifer model in different perspective can be seen in Figure 8, 9, 10, and 11.

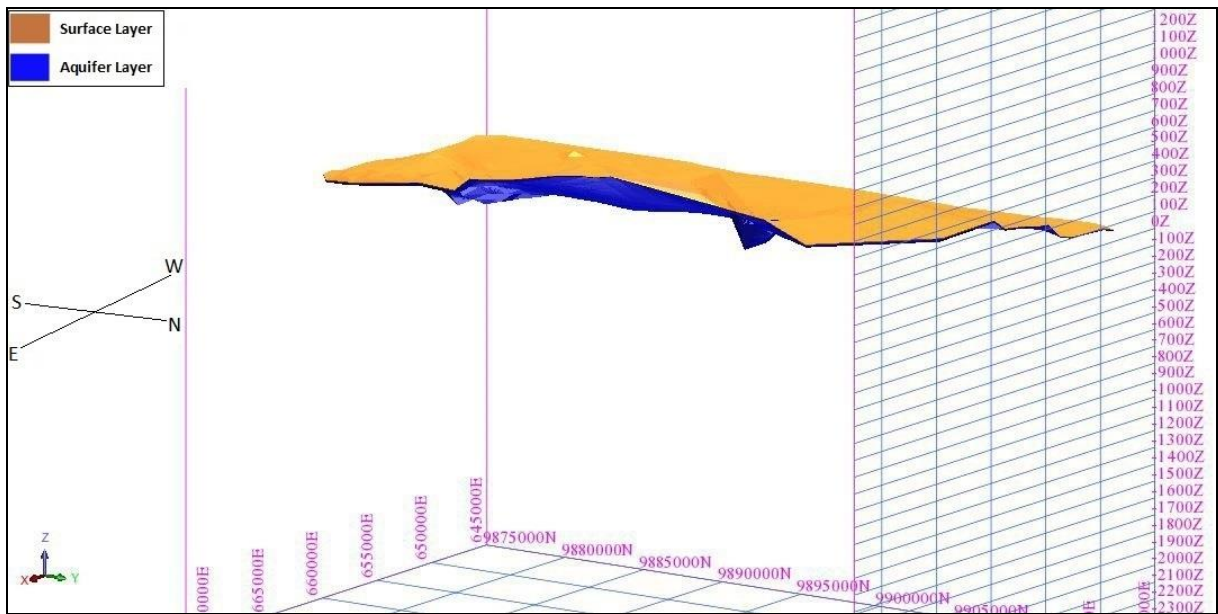


Figure 8. Aquifer layer with surface layer seen from the Northeast perspective

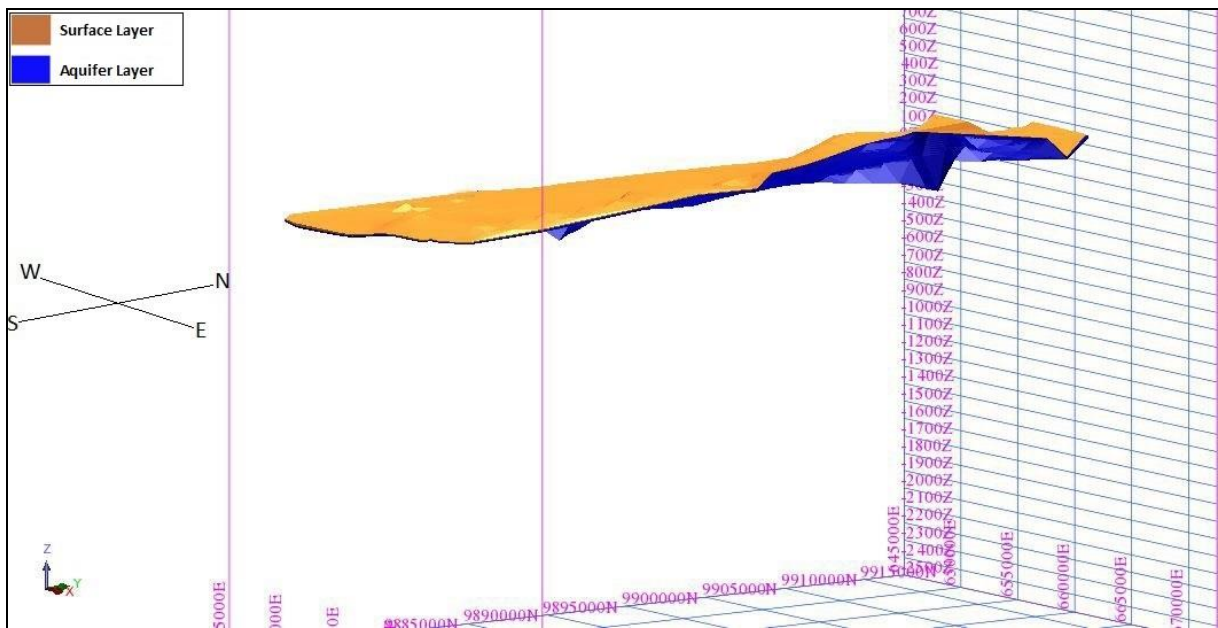


Figure 9. Aquifer layer with surface layer seen from the Southeast perspective

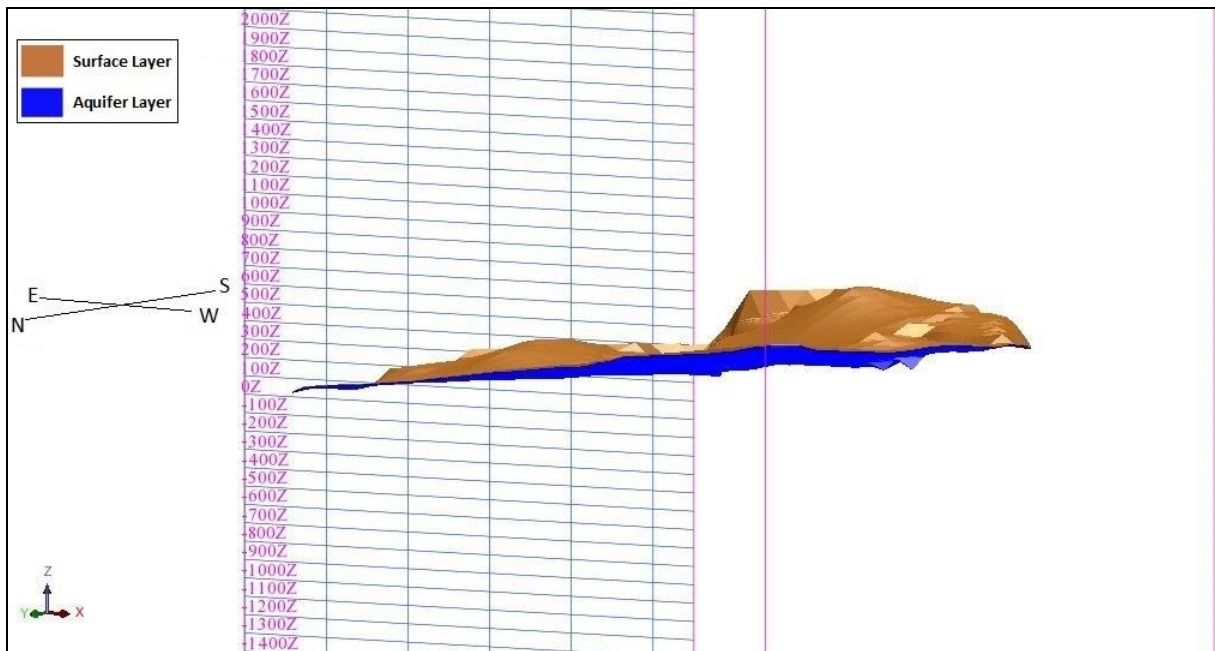


Figure 10. Aquifer layer with surface layer seen from the Northwest perspective

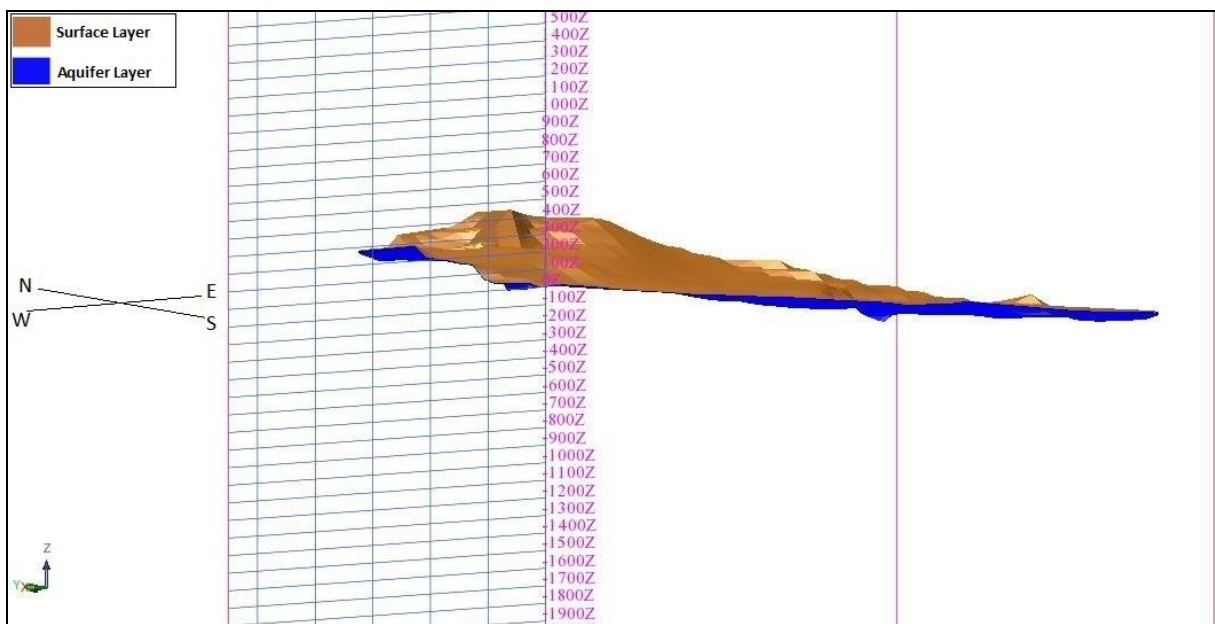


Figure 11. Aquifer layer with surface layer seen from the Southwest perspective

6. Conclusion

Based on the result of geoelectrical interpretation of the points indicated, there is aquifer layer in the point VES01, VES02, VES03, VES07, VES09, VES10, VES11, VES12, VES13, VES14, VES15, VES16, VES17, VES18, VES19, VES22, VES26, VES29, VES30, VES31, VES32 and VES33 with average depth of 6.23 meters. The shallowest depth of this aquifer layer is 1.01 meters, and the deepest is 20.02 meters. The average thickness of this aquifer layer is 7.47 meters, with the thickest is 11.74 meters in Koto Tangah sub-district and the thinnest is 1.68 meters in Kuranji sub-district. This aquifer layer is identified as unconfined aquifer.

References

- [1] Octova, A., & Yulhendra, D. (2017). Iron ore deposits model using geoelectrical resistivity method with dipole-dipole array. In MATEC Web of Conferences (Vol. 101, p. 04017). EDP Sciences.
- [2] Octova, A., Muji, A. S., Raeis, M., & Putra, R. R. (2019, April). Identification of Aquifer using Geoelectrical Resistivity Method with Schlumberger Array in Koto Panjang Area, Nagari Tigo Jangko, Lintau Buo Sub-District, Tanah Datar Regency. In Journal of Physics Conference Series (Vol. 1185, No. 1, p. 012009). IOP Publishing.
- [3] Telford W M, Geldart L P and Sheriff R E 1990 *Applied Geophysics, Second Edition, Cambridge and Hall* (New York)
- [4] Octova, A., & Sule, R. (2018, April). Seismic Travel Time Tomography in Modeling Low Velocity Anomalies between the Boreholes. In IOP Conference Series: Materials Science and Engineering (Vol. 335, No. 1, p. 012056). IOP Publishing.
- [5] Gisland, G., Alam, B. C. S., & Nur, A. A. (2017). Potensi Akuifer Air Tanah Pada Batuan Sedimen Tersier Berdasarkan Analisis Data Geolistrik Di Distrik Waisai Kota Kabupaten Raja Ampat, Provinsi Papua Barat. Bulletin of Scientific Contribution: GEOLOGY, 15(2), 181-192.
- [6] Putra, R. R., Octova, A., & Gusman, M. (2018). Pemodelan Akuifer Hasil Pengukuran Resistivity Studi Kasus Kota Padang. Bina Tambang, 3(2), 744-755.
- [7] Armstrong, M. (1998). Basic linear geostatistics. Springer Science & Business Media.
- [8] Rehfeldt, K. R., Boggs, J. M., & Gelhar, L. W. (1992). Field study of dispersion in a heterogeneous aquifer: 3. Geostatistical analysis of hydraulic conductivity. Water resources research, 28(12), 3309-3324.
- [9] Heriawan, M. N., & Koike, K. (2008). Identifying spatial heterogeneity of coal resource quality in a multilayer coal deposit by multivariate geostatistics. International Journal of Coal Geology, 73(3-4), 307-330.
- [10] Ramazi, H., & Jalali, M. (2015). Contribution of geophysical inversion theory and geostatistical simulation to determine geoelectrical anomalies. Studia Geophysica et Geodaetica, 59(1), 97-112.