International Research Journal of Engineering, IT & Scientific Research
Available online at https://sloap.org/journals/index.php/irjeis/
Vol. 3 No. 4, July 2017, pages: 117~125
ISSN: 2454-2261
https://sloap.org/journals/index.php/irjeis/article/view/557

Aquifer Hydraulics Parameters Determination regarding One Well Base on Geolistric Data: A Case Study in Bugbug Karangasem Bali

I Nengah Simpen [a]
I Nyoman Sutarpa Sutama [b]
I Wayan Redana [c]
Siti Zulaikah [d]

Article history:

Received: 9 January 2017
Accepted: 30 May 2017
Published: 31 July 2017

Keywords:

aquifer;
geoelectric;
hydraulics parameter;
single well;
transmissivity;

Abstract

Aquifer parameters knowledge was necessary for interpreting the aquifer state. It included porosity (Φ), hydraulic conductivity (K), specific *storativity* (Ss), *storativity* (S) and *transmissivity* (T). There were some methods for knowing the aquifer hydraulics parameters was Chow Method, Jacob Method, and Theis Method. These methods employed two wells i.e. one as test wells and another one monitored well for monitoring the water depth. The one assumption in this method was the aquifer equal thickness to the infinite width. What if the aquifer has an unequal thickness and limited width as well as on aquifer with buried veins or trenches? A research has been conducted to determine the aquifer hydraulic parameters with a single geoelectric on data-based wells. The steps that were taken i.e. firstly was measured by geoelectric method currently place to know the magnitude of aquifer resistivity/conductivity. Secondly, drilling was carried out in the place of the suspected aquifer. Thirdly, it was the water conductivity measurement obtained from the aquifer. After the measurement of aquifer resistivity with the geoelectric method, it was found that the aquifer conductivity was 0.0325 S/m, the water conductivity was 0.02 S/m. The step draw-down test was done in five levels of discharge. The hydraulics parameter was calculated using a single well. The results of the analysis was obtained aquifer porosity (Φ) 36,90%, hydraulic conductivity (K) 0,00368 m/s transmissivity (T) 0,05792 m2/s, specific storage (Ss) 9,7358 10-4 / m, *storativity* (S) 0,0055883.

Author correspondence:
I Nengah Simpen,
Doctorate Program, Linguistics Program Studies, Department of Physics,
Udayana University, Jalan P.B. Sudirman, Denpasar, Bali, Indonesia
Email address: *simpen.nengah@yahoo.com*

[a] Udayana University, Indonesia
[b] Udayana University, Indonesia
[c] Udayana University, Indonesia
[d] Malang State University, Indonesia

1. Introduction

Aquifer parameters knowledge is necessary for interpreting the aquifer state. The aquifer parameters include porosity (Φ), hydraulic conductivity (K), specific *storativity* (Ss), *storativity* (S) and *transmissivity* (T). Several methods for knowing the aquifer hydraulics parameters are Chow Method, Jacob Method and Theis Method (Redana, 2012). These methods employ two wells one as test wells and one monitored well to monitor the water depth. A presumption in this method is the aquifer equal thickness to the infinite width. The results of field monitoring based on geoelectric data found that the aquifer does not have the same thickness and limited width. (Simpen & Redana, 2016; Indriatmono, *et al.*, 2005; Gifts, *et al.*, 2012; Mudiarto, *et al.*, 2013). How to get the aquifer hydraulics parameter? In the present research will be discussed how to get the aquifer hydraulic parameter for the well case which has an unequal thickness and limited width. The analysis has been conducted using single geo-electrically-based wells.

2. Materials and Methods

2.1 Theoretical Framework

A well through an isotropic homogeneous aquifer. The groundwater surface at first is flat. If the well is taken from the water discharge Q will be formed a round basin (Figure 1). It is called the *curve of depression*, whereas the drop in the water surface is called *drawdown* (Sw). *Unconfined well*, reducing groundwater levels due to pumping and the water flows coming from the soil pores. The soil pore will be filled in by the air. In the *confined well*, there is a potentiometric drop in the water level, no drained material.

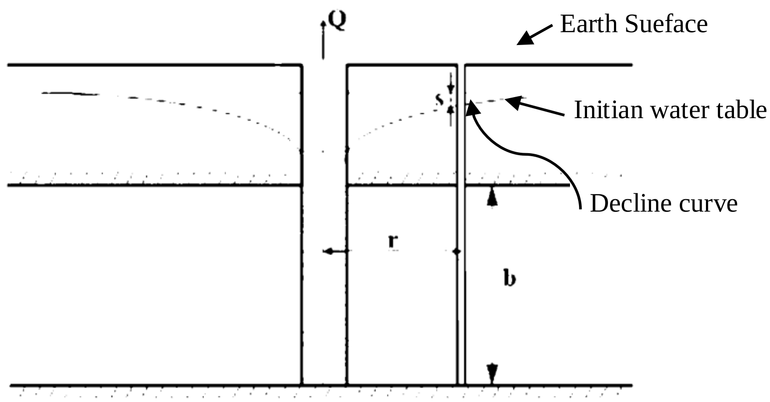

Figure 1. Decreasing of Ground Water Levels due to Pumping
Source: Tizro et al., (2014)

The water amount discharge that can be taken depends on the aquifer physical properties which include porosity (Φ), hydraulic conductivity (K), transmissivity (T), specific storativity (Ss), and storativity (S). Porosity is the ratio of void volume towards a total volume, expressed in the percent (%). Aquifer material has a porosity ranging from 20-40%. Table 1 provides the porosity range values for some rock types.

Table 1
Porosity range value of some rock types

No.	Soil Type	Porosity (%)
1	Clay	45
2	Sand	35
3	Gravel	25
4	Gravel and sand	20

5	Rough sand	15
6	Limestone, shale	5
7	Quartzite, granite	1

Source: Linsley & Franzini (1989)

Porosity (Φ) is calculated by equation (Sen *et al.*, 1988; Arafa, 2013; Simpen *et al.*, 2016):

$$\sigma = \Phi^{m}\{\Phi_w + A \frac{Q_v}{\left(1+C\frac{Q_v}{\sigma_w}\right)}\} \text{..............................(1)}$$

m, A, Qv, and C are constants that are empirically obtained.

Descriptions:
m = 2; A = 1,93 x m; Q_v = 2,04; C Q_v = 0,7 ohm/m; σ = aquifer conductivity
σ_w = water conductivity; Φ = porosity; conductivity = 1 / resistivity

The aquifer conductivity is measured by the geoelectric method, whereas the water conductivity that consists of the aquifer is measured by conductivity at taking a water sample. Hydraulic conductivity (K) display how far the water can pass through the aquifer in one unit of time. K depends on the fluid nature (water) and rock properties, unlike porosity, grain size, grain arrangement and grain shape, and its distribution (Hudak, 2004). Hydraulic conductivity value (K) several kinds of rocks can be seen in the following table (Todd, 1980).

Table 2
Hydraulic conductivity value (K) multiple rocks

Rock	K (m/day)	Rock	K (m/day)
Rough gravel	150	Clay	0,0002
Medium gravel	270	Limestone	0,94
Rough sand	450	Dolomite	0,001
Rough sand	45	Secis	0,2
Fine sand	12	Stone slats	0,00008
Pasir halus	2,5	Tuff	0,2
Medium sand stone	3,1	Basalt	0,01
Soft sandstone	0,2	Gabro	0,2
Lanau	0,08	Granite weathered	1,4

Source*: Todd, (1980)*

Hydraulic conductivity (K) of the aquifer can be known based on *drawdown test* (Sw) with the following relationship (Redana, 2012).

$$K = \frac{Q}{(F\,Sw)} \text{..............................(2)}$$

Q is a pumping discharge, Sw: decreasing of the water surface due to pumping, and F: constant, its value depends on the well. The well use *casing* and filter without a *sand pack*, F value will be:

$$F = 27{,}5\ (\delta r) \text{..............................(3)}$$

The well uses a *casing* and *sand pack* around the filter, on a sieve sealed with *bentonite* or cement, F value becomes:

$$F = \frac{2\,\pi\,L}{\ln(\frac{L}{R})} \quad \text{......(4)}$$

L is the length *screen*, R: trellis casing, for L> 8R.
Transmissivity (T) is related to hydraulic conductivity (K). Transmissivity (T) states the aquifer's ability to pass water horizontally through the vertical plane, passing through the aquifer thickness, and one hydraulic slope unit (Hudak, 2004). The transmissivity equation (T) can be written:

$$T = Kb \quad \text{......(5)}$$

T is transmissivity, K: hydraulic conductivity, and b: aquifer thickness. The potential of underground water based on the transmissivity value according to U.S Dept. Of the Interior in Wibowo (2012) can be seen in Table 3.

Table 3
The potential of groundwater based on transmissivity and its use

Transmissivity (m^2/day)	Domestic	Irrigation
<1	bad	very bad
1-8	moderate	very bad
8-50	good	very bad
50-300	very good	bad
300-1000	very good	moderate
1000-10.000	very good	good
>10.000	very good	very good

Source: U.S Dept. Of the Interior in Wibowo (2012)

Specific storativity (Ss) represents the water volume released by one unit of aquifer volume in one hydraulic head drop unit, therefore it can be expressed as follows (Redana, 2012).

$$Ss = \rho\, g\, (\alpha + \Phi\, \beta) \quad \text{......(6)}$$

Description:
- Ss: specific storativity
- ρ : water density (1000 kg/m^3)
- g : earth's gravity acceleration (9,72 m/s^2)
- α : rock / aquifer compressibility (α sand 10^{-8} m^2/N, Hudak, 2004)
- Φ : aquifer porosity (above calculated porosity)
- β : water compressibility (4,4 10^{-10} m^2/N, Hudak, 2004)

Storativity (S) the aquifer represents the water volume released by one unit of the aquifer area in a unit of a hydraulic head drop or pyrometric plane, therefore it can be stated according to Redana (2012):

$$S = Ss\, b \quad \text{......(7)}$$

Description:
- S : storativity
- Ss : specific storage
- b : aquifer thickness or well part thickness wherein the water entrance.

The *storativity* value towards free aquifer is 0.01-00.35, whereas in the aquifer is depressed 0.00005-0.005 (Todd, 1980).

2.2 Location and time of collecting the data

The present was conducted in Bugbug Karangasem (Figure 2). The research was begun in June 2014 until December 2015.

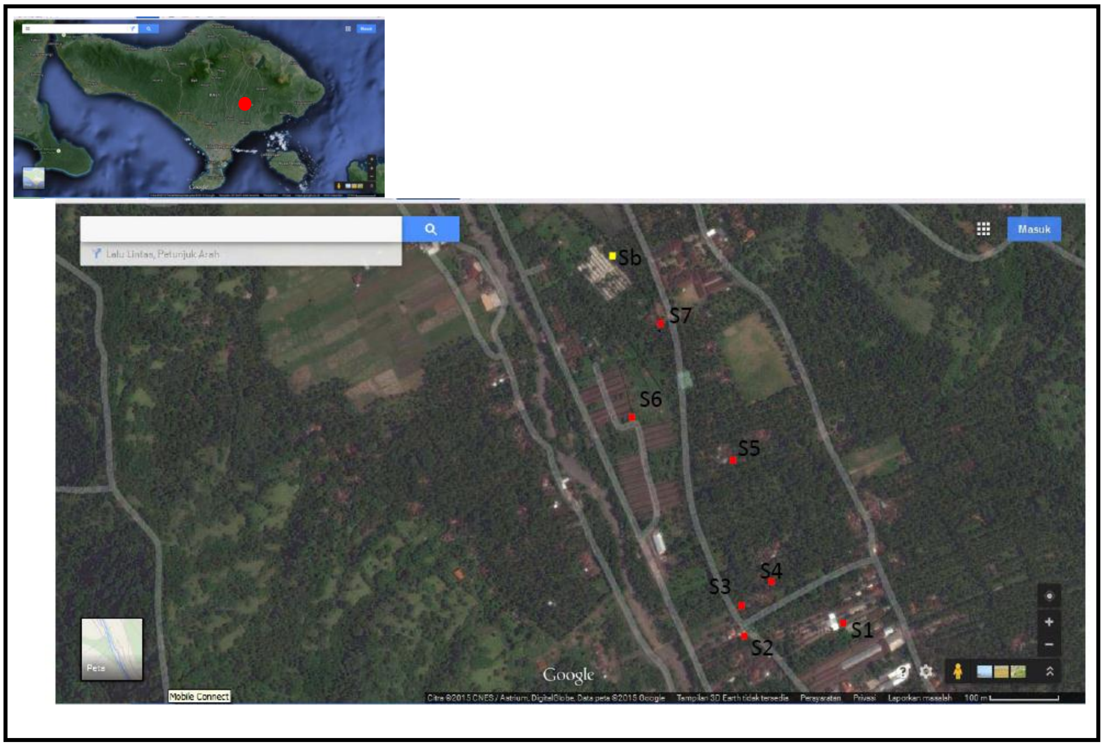

Figure 2. Research location
S1 ... S7: dug wells; Sb: drilled well, Main Map Source: Google Map

2.3 Data and equipment needed

The data that has been needed includes:

a) The data of aquifer conductivity is taken with the geoelectric set equipment
b) The data of well water conductivity is collected by a conductivity meter.
c) The data of water level drop due to pumping (Sw) is measured by *dipthmeter*.
d) The data of Pumping water discharge is collected by a pump and measuring tank.

2.4 Analysis method of aquifer characteristics

Aquifer characteristics parameters include porosity (Φ), hydraulic conductivity (K), transmissivity (T), specific storativity (Ss), and storativity (S). Porosity (Φ) is calculated by the equation. (1). hydraulic conductivity (K) is calculated by the equation. (2). The transmissivity (T), the aquifer is calculated by equation (5) *Specific storativity* (Ss) is calculated by the equation. (6). Aquifer storage is calculated by the equation. (7).

3. Results and Discussions

3.1 Geographical status in research location

ISSN: 2454-2261

The height of the research location is 10-20 m dpl, the coordinates about 8,500,584 LS 115,594636 BT. The rock formations consist of rock formations, volcanic of Mount Agung that was erupted in 1963 and earlier (Hadiwidjojo, 1971). The rock formations cover the fields, rivers, and moats.

3.2 Measurement results

Geoelectric data shows there is an aquifer in the depth for 18.5 m, width is 34 m unknown thickness due to it is beyond the reach of the geoelectric apparatus (Fig. 3). Aquifer conductivity is 0.0325 S/m and water conductivity is 0.02 S/m. Based on the geoelectric data, it appears that the aquifer width is limited, therefore when making the test well, it must be within the range of aquifer wide range is 34 m. The well drilling in this area is very difficult due to the rock formations of rock formations occurring from volcanic eruptions, in accordance with Hadiwidjojo (1971) opinion that drilling results when making wells. After the wellbore is made, aquifer thickness, which is part of the water entry into well or the casing portion of screened plus unidentified well section is 5.74 m. The casing trellis is 0.063 m.

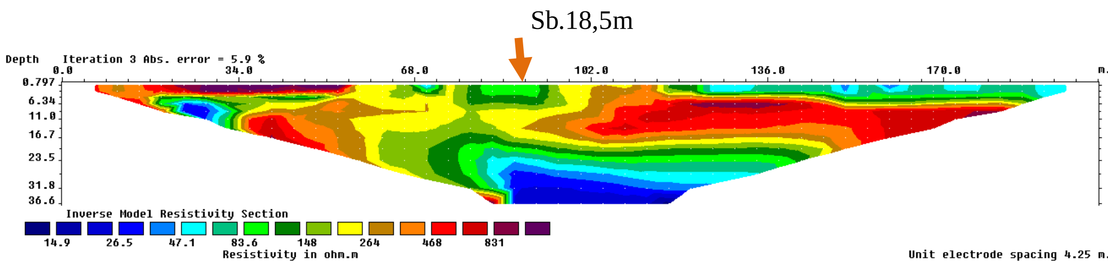

Figure 3. Contour Section of Measurement Resistivity Trajectory

The results of well testing using *step draw-down test* method can be illustrated in Table 4.

Table 4
The Result of Drill Well Testing

Step	Q (m^3/s)	Sw (m)
1	0,00078	0,088
2	0,00125	0,187
3	0,00181	0,320
4	0,00233	0,428
5	0,00278	0,533

Description: Q pumping discharge and *Sw* decreasing of water level at the well due to pumping

Based on the data and the analysis method that is mentioned above, it can be calculated an aquifer hydraulic parameter, the results are described in the following table.

Table 5
Characteristics of aquifer

Aquifer Parameter	Unit	Quantity
Aquifer porosity (Φ)	%	36,90
Hydraulic Conductivity (K)*)	m/s	0,00368
Transmisivity (T)	m^2/s	0,05792
Specific Storage (Ss)	/m	9,7358 10^{-4}
Storativity (S)		0,0055883

*) K average

Based on the aquifer parameter is obtained, it is interpreted that aquifer porosity is 36.90%, according to Linsley & Franzini (1989) aquifer is in the sand form, hydraulic conductivity 0.00368 m/s, according to Todd (1980) aquifer in the sand form, transmissivity 0.05792 m^2/s, according to U.S Dept. of the Interior in Wibowo (2012) the well productivity is very good for domestic purposes and as well as good for irrigation purposes, storativity 0,0055883, according to Todd (1980) the aquifer is an aquifer distressed. The prediction result is also proved by drilling result that is in the aquifer area in the sand form. The geoelectric measurements results show that around an aquifer, there is a layer with higher resistivity which means the aquifer is an aquifer distressed. The analysis results are to show that well parameters can be calculated by single wells based on geoelectric data.

4. Conclusion

The results of the present study are obtained that the aquifer has been limited thickness and width. The calculation of aquifer hydraulics parameters can be obtained with a single geo-electrically-based well. The calculation results i.e. aquifer porosity 36.90%, hydraulic conductivity 0.00368 m/s transmissivity (T) 0.05792 m^2/s, specific storage (Ss) 9,7358 10^{-4}/m, storativity 0,0055883.

Conflict of interest statement and funding sources
The author(s) declared that (s)he/they have no competing interest. The study was financed by Directorate of Research and Community Service.

Statement of authorship
The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

Acknowledgments
This research is conducted funding by the Directorate of Research and Community Service, Directorate General of Higher Education, Ministry of Education and Culture. In accordance with the Letter of Appointment Implementation Agreement No106/UN14.2/PNL.01.03.00/2015, on March 3, 2015. Regarding it, we say thanks for the funding that was given as well as thank the Rector of Udayana University and Head of LPPM, Udayana University for the opportunity given to do the research.

References

Araffa, S. A. S. (2012). Delineation of groundwater aquifer and subsurface structures on North Cairo, Egypt, using integrated interpretation of magnetic, gravity, geoelectrical and geochemical data. *Geophysical Journal International*, *192*(1), 94-112. https://doi.org/10.1093/gji/ggs008

Bear, J., & Cheng, A. H. D. (2010). *Modeling groundwater flow and contaminant transport* (Vol. 23). Springer Science & Business Media.

Hudak, P. F. (2004). *Principles of hydrogeology*. CRC Press.

Karunia, D.K., Darsono, Darmanto. (2012). Identification of Underground Flow Pattern in Easy, Pracimantoro with Geolistrik Method. *Indonesian Journal of Applied Physics.* 2(2): 91-101.

Linsley, R. K., & Franzini, J. B. (1989). Water resources engineering, 3rd.

Mudiarto, A. Supriyadi dan Sugiyanto, 2013. *Pemodelan Fisik Untuk Monitoring Kebocoran Pipa Air Dengan Metode Geolistrik, Unnes Physics Journal*, *1*(1), 1-6.

Purbo-Hadiwidjojo, M. M. (1971). The status of engineering geology in Indonesia: 1970. *Bulletin of the International Association of Engineering Geology-Bulletin de l'Association Internationale de Géologie de l'Ingénieur*, *4*(1), 33-41.

Redana, I. W. (2012). Air tanah.

Said, N. I., Indriatmoko, R. H., Raharjo, P. N., & Herlambang, A. (2005). Aplikasi teknologi pengolahan air sederhana untuk masyarakat pedesaan. *Jurnal Air Indonesia*, *1*(2).

Sen, P. N., Goode, P. A., & Sibbit, A. (1988). Electrical conduction in clay bearing sandstones at low and high salinities. *Journal of Applied Physics*, *63*(10), 4832-4840.

Simpen, I. N. (2015). Solusi Permasalahan Sumur Bor Versus Sumur Gali dengan Metoda Geolistrik dan Uji Pemompaan Sumur (Suatu Studi Kasus di Bugbug Karangasem Bali). *Prsiding SeminarNasional Fisika dan Pembelajarannya 2015, Universitas Negeri Malang*.

Simpen, I. N., Redana, I. W., Pujianiki, N. N., & Umratul, I. (2017). Aquifers Selection to Aid Geoelectrical Methods on Drilled Well Building near the Beach. *International Journal of Physical Sciences and Engineering (IJPSE)*, *1*(3), 41-50.

Simpen, I., Sutama, I., Redana, I., & Zulaikah, S. (2016). Aquifer Porosity Prediction Based on Resistivity Data and Water Conductivity. *International Research Journal Of Engineering, IT & Scientific Research (IRJEIS)*, *2*(5), 8-21.

Tebbutt, T. H. Y. (1997). *Principles of water quality control*. Elsevier.

Tizro, T. A., Voudouris, K. S., & Kamali, M. (2014). Comparative study of step drawdown and constant discharge tests to determine the aquifer transmissivity: the Kangavar aquifer case study, Iran. *Water Res. Hydraul. Eng*, *3*, 12-21.

Tjia, H.D. (1987). *Geomorphology. Language and Library Board of the Malaysian Ministry of Education. Kuala Lumpur.*

Todd, D. K. (1980). Groundwater Technology. *Associate Professor of Civil Engineering California University. Jihn Wiley and son. New York*.

Wibowo, N. A. (2012). Micromagnetic Study of Switching Mode Behavior on Perpendicularly Magnetized Nano-Dot at a Room Temperature.

Biography of Authors

	Dr. I Nengah Simpen, M.Si, was born in Karangasem August 2, 1960. A lecturer in Department of Physics, FMIPA Udayana University. He as well as teaches at the Department of Civil Engineering Faculty of Engineering Udayana University Denpasar, Bali-Indonesia. He is interested in Geophysics / Ground Water. *Email: simpen.nengah@yahoo.com*
	Prof. Dr. Ir. I Nyoman Sutarpa Sutama, M.S, was born in Singaraja, on January 1, 1956. A lecturer in Department of Animal Husbandry, Udayana University, Denpasar Bali-Indonesia. He is a Professor in Animal Husbandry / Microbiology field studies.
	Prof. Ir. I Wayan Redana, MA.Sc, Ph.D., IPU, was born in Denpasar, on October 25, 1959. A lecturer in Department of Civil Engineering, Faculty of Engineering, Udayana University Denpasar Bali-Indonesia. He is a Professor of Engineering Geology, teaching several subjects included Philosophy of Science, Foundation Technique, Soil Mechanics, Ground Water, Engineering Dams, and Soil Dynamics. He is interested in Technical Geology field studies.
	Dr. Siti Zulaikah. M.Si., was born in Terenggalek on August 11, 1971. A lecturer in Department of Physics, FMIPA, Postgraduate Program Studies, Malang State University, Malang, East Java, Indonesia. She is interested in Geophysics / Paleomagnetic field studies.