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RESEARCH ARTICLE

Analysis Of Aquifer Characteristics Using The Method Cooper Jacob At Block X Pt. Geomine Bara Studio Site Kutai Kartanegara, East Kalimantan, Indonesia

Avellyn Shinthya Sari[1,*], Novandri Kusuma Wardana[2] , Yudho Dwi Galih Cahyono[1] , Ristya Mahda Sarastika[1]

[1] *Mining Engineering, Faculty of industrial Engineering, Adhi Tama Surabaya Institute of Technology, Surabaya, East Java, Indonesia.*
[2] *Geomine Bara Studio, Sleman, Yogyakarta, Indonesia.*

* Corresponding author : avellyn.ss@gmail.com
Tel.:+81-72-867-1686; fax: +81 -72-867-1658
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Abstract

Using the Cooper-Jacob method, this research analyzes the characteristics of the aquifer in Block X of Geomine Bara Studio Site Ltd., Kutai Kartanegara. This method can determine the main hydrogeological parameters, such as the aquifer's hydraulic conductivity/permeability coefficient, transmissivity, and storage coefficient (storativity) of the aquifer. Data from the pumping test served to understand the aquifer's response to pumping. The research results showed that the aquifer in Block X had a transmissivity of 193,9949 m^2/day, hydraulic conductivity of 6,0634335 m/day, and a storage coefficient (storativity) of 0,000137. The soil type at the test location was fine sandy with a low porosity value of n = 0,499%, and the soil permeability was low at k = 0,056403975 mm/ sec. Groundwater in the study area had quite potential for meeting the needs of Geomine Bara Studio Site Ltd in Kutai, Kartanegara, with a groundwater availability of H219,398 m^3 and a withdrawal rate of Q 182,0678 m^3/day. This study indicated high water flow capacity with low storage ability, suggesting a confined aquifer. It benefits sustainable groundwater management and mitigates environmental impacts in the study area.

Keywords: aquifer, confined aquifer, Cooper-Jacob method, aquifer characteristics, pumping test.

1. Introduction

PT. Geomine Bara Studio Site Kutai Kartanegara, East Kalimantan, is a company engaged in the mining industry using open-pit mining methods. Mining activities significantly impact the hydrogeological environment, affecting aquifer systems through groundwater depletion and potential pollution (Younger et al., 2002; Dhakate et al., 2018). The analytical framework for aquifer characterization has evolved significantly over time. Theis (1935) established the non-equilibrium flow analysis for confined aquifers, which Cooper and Jacob (1946) subsequently simplified into a straight-line approximation method that remains fundamental in hydrogeological assessments. Kruseman and de Ridder (2000) validated this approach specifically for confined aquifers with extended pumping periods. Recent studies have further refined these methodologies for various geological settings.In mining contexts specifically, Youger and Robins (2002) documented how open-pit operations create drawdown cones that alter regional groundwater flow patterns. Singh et al. (2017) demonstrated that accurate transmissivity and storativity values are essential for predicting mine dewatering requirements and environmental impacts. Taufiq et al. (2018) showed that excessive groundwater pumping in Indonesia has led to significant aquifer degradation, highlighting the importance of proper characterization before extraction. Within Indonesia specifically, Putra et al. (2019) conducted pumping tests in coastal aquifers to determine the extent of saltwater intrusion, while Rahmawati et al. (2013) employed similar methodologies to characterize aquifers in lowland areas of Semarang. Alviyanda et al. (2023) further applied hydraulic testing to identify saltwater distribution in coastal aquifers, emphasizing the importance of proper testing protocols. These studies highlight the growing importance of aquifer characterization in Indonesian resource management. Despite these advances, there remains limited research on confined aquifer characterization in East Kalimantan's mining regions, particularly regarding the relationship between transmissivity and sustainable extraction rates. This research gap is significant given the increasing water demands of mining operations in the region and the potential environmental impacts of improper groundwater management. This study aims to analyze aquifer characteristics and groundwater potential at PT. Geomine Bara Studio Site using the Cooper-Jacob method through pumping tests at hydrogeological drilling holes. The results will inform sustainable groundwater management strategies essential for mining operations and environmental protection in Kutai Kartanegara.

2. Research Methods

This research investigates the aquifer characteristics in Block X of PT. Geomine Bara Studio Site Kutai Kartanegara, East Kalimantan through field pumping tests and laboratory analysis. The study area is situated within an operational mining site where open-pit mining methods are employed, making groundwater characterization essential for operational planning and environmental management. The research employs the Cooper-Jacob method for analyzing pumping test data alongside laboratory testing of soil samples to determine comprehensive aquifer properties. The Cooper-Jacob method was selected because it effectively analyzes time-drawdown data from pumping tests to estimate hydraulic parameters of confined aquifers without requiring specialized observation wells.

Field data collection centered on pumping tests conducted in former drilling holes at points DH_2_2 and DH_3_1. These tests involved continuous pumping of groundwater while measuring the water level decline over time. The pumping discharge was measured to analyze the aquifer's response to extraction. Water level measurements were taken at regular intervals during the pumping phase and the subsequent recovery phase. The comparison between water level decline during pumping and recovery time forms the core data for aquifer characterization. These measurements allow for determining critical hydrogeological parameters including transmissivity, hydraulic conductivity, and storage coefficient (storativity). For the pumping test analysis, the time-drawdown data were plotted on semi-logarithmic graphs with drawdown (s) in meters on the y-axis and pumping time (t) in minutes on the x-axis. Following Cooper-Jacob methodology, a straight line was fitted to the data points to determine the slope (Δs) and the time intercept (t_0), which are essential for calculating transmissivity using the equation:

Field investigations centered on pumping tests conducted in former drilling holes. These tests involved:

1. Continuous pumping of groundwater at a controlled discharge rate
2. Measurement of water level decline (drawdown) over time
3. Recording of water level recovery after pumping cessation
4. Measurement intervals followed standard hydrogeological protocols
5. Collection of soil samples for laboratory analysis

2.1 Laboratory Testing

Soil samples underwent laboratory testing to determine physical properties including:

1. Specific gravity
2. Water content
3. Porosity
4. Permeability

2.2 Data Analysis Methods

2.2.1 Soil Parameter Analysis

To determine the characteristics of the aquifer, the steps taken after obtaining the values from laboratory tests for the soil, then calculations are carried out using the following formula equations:

1. Calculation of Soil Specific Gravity (G)

$$G = \frac{Ws}{Ww}$$

Information :
G = Specific Gravity of Soil
Ws = Soil Grain Weight (g)
Ww = Weight of Water With The Same Volume (g)

2. Porosity Calculation (N)

$$Water\ Content\ (w) = \frac{w2 - w3}{w3 - w1}\ x\ 100\%$$

Information :
w2 – w3 = Weight of Water (G)
w3 – w1 = Dry Soil Weight (G)

After obtaining the soil water content value (w), the next step is calculating the dry and wet volume weight using the following equation.

$$Wet\ Volume\ Weight\ \ (\gamma_b) = \frac{W}{V}$$

$$Dry\ Volume\ Weight\ \ (\gamma_d) = \frac{W_s}{V}$$

Information :
W = Dry Volume Weight of Soil (gr)
V = Soil Volume (cm^3)

After getting the dry and wet volume weight values, here is how to calculate the equation for the pore number value (e).

$$Pore\ Number\ (e) = \frac{Vv}{Vs}$$

$$Vs = \frac{Ws}{G\gamma \mathrm{dw}}$$

$$Vv = V - Vs$$

Information :
Ws = Dry Weight of Soil (gr)
G = Specific Gravity of Soil
γw = Berat Volume Air (1 gr/cm^3)

and then calculate the porosity equation (n).

$$Porosity\ (n) = \frac{e}{1 + e}$$

Description : e = Pore Number

3. Calculation of Soil Permeability (k)

$$Permeability\ (k) = \frac{2.3\ a\ l}{A\ t}\ xlog\ (\frac{h1}{h2})$$

Information :
a = Surface Area of Hose (cm^2)
L = Height of Test Soil (cm)
A = Surface Area of Test Soil (cm^2)
t = Time (seconds)
h1 = Initial Water Level Height (cm)
h2 = Final Water Level Height (cm)

Test data is used to calculate the aquifer characteristic values. Pumping test the drilled hole. The pumping test results were then plotted using Microsoft Excel and Cooper Jacob. Here are the curve results.

2.2.2 Aquifer Parameter Analysis (Cooper-Jacob Method)

The Cooper-Jacob method, as described by Cooper and Jacob (1946) and refined by Taufiq et al. (2018), was selected because it effectively analyzes time-drawdown data from pumping tests without requiring specialized observation wells. Time-drawdown data were plotted on semi-logarithmic graphs, with a straight line fitted to determine:

1. Transmissivity (T):

$$T = \frac{2.3\ x\ Q}{4\ x\ \pi\ x\ \Delta s}$$

Information :
T= Transmissivity (m^2/day)
Q= Pumping Discharge (m^2/day)
Δs= Change in Ground Water Level (m)

2. After that, the hydraulic conductivity value (K) is analyzed by multiplying the transmissivity value by the aquifer thickness (b) with the following equation.

$$K = \frac{T}{b}$$

Information :

K = Hydraulic Conductivity (m/day)
T = Transmissivity (m^2/day)
b = Aquifer Thickness (m)

2.2.3 Groundwater Potential Analysis

After determining the aquifer parameters, the following calculations were performed:
The area of the groundwater potential zone is used in the area of the test location A = 500,453 m^2. The availability of groundwater is analyzed by the following equation.

H = A x D x Sy(100%)
H = 500,453 m^2 x 32 m x 0.000137x100=0.0137
H = 219,398 m^3

The calculation results obtained the availability of groundwater in the aquifer of H = 219,398 m^3. In the calculation of groundwater discharge (Q), the slope number at the test site is 6% based on the slope map at the IUP Jobsite location of PT. Geomine Bara Studio, with the cross-sectional area of the flow used is the area of the test location. The following is the calculation of groundwater discharge (Q) in m^3/day using Darcy's law.

Q = KxIxA
Q = 6.0634335 m/day x 0.06 x 500.453m^2
Q = 182.0678 m^3/day

The results of the calculation obtained a groundwater discharge figure of Q = 182.0678 m^3/day

The research methodology followed a systematic approach as illustrated in Figure 1, beginning with field investigations and culminating in comprehensive aquifer characterization and groundwater potential assessment.

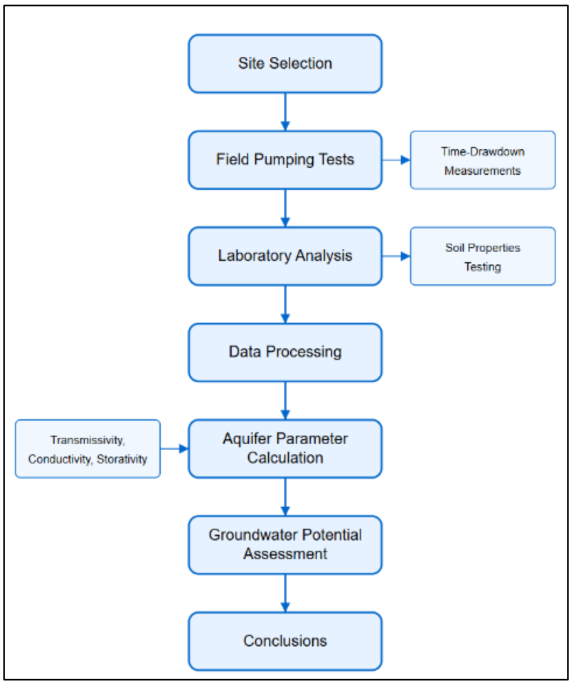

Fig.1 Flow Diagram

3. Result

Research results on block X PT. Geomine Bara Studio Site Kutai Kartanegara obtained soil characteristic data,including soil specific gravity, porosity, and soil permeability, while pumping test data included Transmissivity, Hydraulic Conductivity, Permeability, and Storativity values.

The research data was obtained from geotechnical exploration activities in the drilling holes at points DH 2_2 and DH 3_1. The results of the aquifer characteristic values are as follows:

Table 1. Trans Values Missivity (T), Hydraulic Conductivity (K) and Storativity (S)

Characteristic	Testing to		Avarage Value
	1	2	
Transmissivity (T) (M^2/day)	146,1883 m^2/day	241,8715 m^2/day	193,9949 m^2/day
Hydraulic Conductivity (K) (m/day)	4,568383 m/day	7,558484 m/day	6,0634335 m/day
Storativitas (S)	0,000103	0,000171	0,000137

The transmissivity value of 193.9949 m^2/day indicates excellent water transmission capabilities through the full saturated thickness of the aquifer. This high transmissivity value suggests that the aquifer can readily transmit substantial volumes of water horizontally, which is favorable for groundwater extraction operations. The hydraulic conductivity value of 6.0634335 m/day represents the ease with which water can move through the aquifer material. This very high value indicates that water flows readily through the pore spaces of the aquifer medium, facilitating efficient well production when properly developed. The storativity value of 0.000137 is particularly significant as it confirms the presence of a confined aquifer system. This low storativity value is characteristic of confined conditions where water is released from storage primarily through the elastic properties of the aquifer and water rather than by gravity drainage.

3.1 Soil Physical Properties

Laboratory analysis of soil samples collected from the study area determined several critical physical properties that influence water movement and storage capabilities:

1. Soil type: Fine sand
2. Porosity (n): 0.499%
3. Permeability coefficient (k): 0.05640397594 mm/sec
4. Pore number (e): 1.083

The identified fine sand composition corresponds with the measured hydraulic properties. The relatively low porosity value of 0.499% indicates limited void space within the soil matrix, which affects the water storage capacity. The permeability coefficient falls within the low classification, suggesting moderate resistance to water flow through the soil matrix despite the overall good transmissivity of the aquifer system. This apparent contradiction likely indicates preferential flow paths or zones of higher permeability within the broader aquifer structure.

The pore number of 1.083 provides additional insight into the ratio of void volume to solid volume within the soil matrix, complementing the porosity measurement and helping to characterize the soil's mechanical properties in addition to its hydrological characteristics.

3.2 Groundwater Potential

Based on the comprehensive analysis of aquifer parameters and site characteristics, the groundwater potential was determined with high confidence:

1. Study area: 500,453 m^2
2. Aquifer thickness: 32 m
3. Available groundwater volume (H): 219,398 m^3
4. Sustainable withdrawal rate (Q): 182.0678 m^3/day
5. Hydraulic gradient (I): 6% (based on slope map analysis)

The substantial available groundwater volume of 219,398 m^3 represents the total water volume that can potentially be extracted from the aquifer within the study area. This volume is derived from the combination of the area extent, aquifer thickness, and the storage characteristics as represented by the storativity value.

The sustainable withdrawal rate of 182.0678 m^3/day represents the volume of water that can be reliably extracted on a daily basis without causing excessive drawdown or depletion of the aquifer system. This rate is influenced by the hydraulic conductivity of the aquifer material, the hydraulic gradient across the study area, and the cross-sectional area of flow.

The analysis indicates that the aquifer in Block X has significant potential to fulfill the water requirements of PT. Geomine Bara Studio Site Kutai Kartanegara's mining operations. The substantial daily withdrawal rate relative to the available groundwater volume suggests that sustainable extraction can be maintained over extended periods, providing a reliable water source for operational needs while minimizing environmental impacts through proper management.

4.Discussion

The pumping test analysis reveals significant hydrogeological characteristics that provide valuable insights into the aquifer system in Block X. The time-drawdown curves illustrated in Figures 2 and 3 demonstrate classic confined aquifer response patterns, with rapid initial drawdown followed by more gradual decline over time. This behavior aligns with theoretical expectations for confined aquifers under pumping stress (Kruseman and de Ridder, 2000) and provides strong evidence for the confined nature of the aquifer system in the study area. The semi-logarithmic straight-line relationship between drawdown and time further validates the applicability of the Cooper-Jacob method for this analysis. The transmissivity value of 193.9949 m^2/day falls within the "very high" classification according to Todd and Mays (2005), comparable to values reported by Taufiq et al. (2018) for productive aquifers in Indonesia. This high transmissivity indicates exceptional water flow capacity through the aquifer, suggesting it can sustainably deliver substantial water volumes. Such high transmissivity is particularly advantageous for mining operations where dewatering and water supply requirements are significant concerns (Younger et al., 2002).

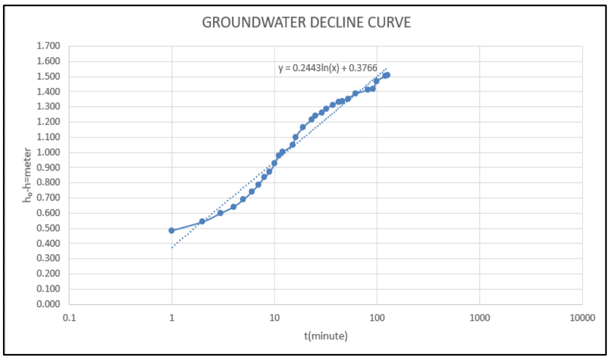

Fig.2 First Stage Groundwater Decline Curve

In practical terms, this level of transmissivity means that water can move horizontally through the aquifer with minimal resistance, allowing for efficient well production and potentially reducing the number of wells needed to achieve target dewatering rates. For comparison, Putra et al. (2019) reported that most productive aquifers utilized for industrial purposes typically exhibit transmissivity values between 50-500 m^2/day, placing this aquifer in the upper tier of industrial water sources.

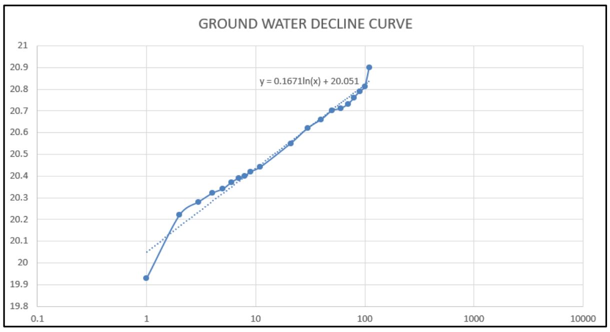

Fig.3 Second Stage Groundwater Decline Curve

Table 2. Transmissivity Class Parameters

Transmissivity (m^2/day)	Domestic	Irrigation
< 1	Signs	Very Ugly
1-8	Currently	Very Ugly
8-50	Good	Very Ugly
50-300	Very Good	Signs
300-1000	Very Good	Currently
1000-10.000	Very Good	Good
> 10.000	Very Good	Very Good

Table 3. Parameters of Hydraulic Conductivity Class / Aquifer Permeability

Category	Hydraulic Conductivity Value (m/day)
Very Low	4.08 x 10-7 m/day
Low	4.08 x 10-6 – 4.08 x 10-4 m/day
Currenly	4.08 x 10-4 – 4.08 x 10-1 m/day
Hight	4.08 x 10-1 – 4.08 m/day
Very Hight	>4.08 m/day

Table 4. Permeability of Aquifer Materials

Material	**Permeability (m/day)**
Coarse Gravel	150
Medium Gravel	270
Fine Gravel	450
Coarse Sand	45
Medium Sand	12
Fine Sand	2,5
Silt	0,08
Clay	0,0002
Fine Sandstone	0,2
Medium Sandstone	3,2
Lime Stone	0,94
Dune Sand	20
Peat	5,4
Schist	0,2
Slate	0,00008
Tuff	0,2
Basalt	0,01
Weathered Gabbro	0,2
Weathered Granite	1,4

The hydraulic conductivity value of 6.0634335 m/day corresponds to medium sandstone aquifer material, as indicated in Table 4, consistent with findings by Alviyanda et al. (2023) for similar geological formations. This value represents the ease with which water moves through the aquifer and aligns with the lithological composition observed in the drilling cores. The relatively high hydraulic conductivity further confirms the excellent water-transmitting properties of this aquifer system. This value aligns with typical ranges for medium sandstone formations (5-15 m/day) reported by Singh et al. (2017), providing validation for the field and analytical methods employed in this study. In contrast, the storativity value of 0.000137 is characteristic of confined aquifer conditions, consistent with findings by Rahmawati et al. (2013) who reported storativity values between 10^{-5} and 10^{-3} for confined aquifers in Indonesia. This low storage coefficient indicates that while the aquifer can transmit water efficiently (high transmissivity), its storage capacity is limited. This hydrogeological characteristic is typical of pressurized confined aquifers where water is released through aquifer compression rather than gravity drainage (Kruseman and de Ridder, 2000). The combination of high transmissivity with low storativity suggests that the aquifer will respond quickly to pumping but may also exhibit rapid recovery when pumping ceases, a finding consistent with observations by Listiawan et al. (2015) in coastal aquifers of Java.

The soil analysis results complement the aquifer parameter findings and provide insight into the confining layer characteristics. The low porosity value (n = 0.499%) suggests a dense, well-consolidated confining material that effectively prevents vertical water movement, similar to values reported by Dhakate et al. (2018) for mining regions with confined aquifers. The permeability coefficient (k = 0.056403975 mm/sec) is consistent with fine sand material as classified by Morris and Johnson (1967) and represents the confining layer properties rather than the aquifer itself. These values collectively describe fine-grained sediments with restricted water movement capabilities, which effectively create the pressurized conditions necessary for confined aquifer development. The groundwater potential assessment yielded promising results for operational water supply. With an estimated groundwater availability of 219.398 m^3 and a sustainable withdrawal rate of 182.0678 m^3/day, the aquifer can fulfill the water demand for mining activities, comparable to results reported by Taufiq et al. (2018) for mining operations in Indonesia. This extraction rate, when compared to the calculated available volume, suggests that approximately 83% of the available groundwater could be utilized daily, indicating a need for careful management to prevent overexploitation. These findings align with sustainability thresholds proposed by Singh et al. (2017), who suggested that extraction rates exceeding 80% of available volume require careful monitoring and management strategies. These findings have important implications for mine drainage system design and sustainable water resource management. The high transmissivity suggests that dewatering operations could be efficiently conducted with relatively few extraction wells, a finding supported by Younger et al. (2002) who demonstrated inverse relationships between transmissivity and required well density. However, the confined nature of the aquifer with its limited storage capacity means that strategic planning is essential to prevent excessive drawdown that could lead to regional groundwater depletion or potential land subsidence, concerns also raised by Putra et al. (2019) for Indonesian mining operations.

The aquifer characteristics also inform environmental protection strategies. The confined nature of the aquifer provides some natural protection from surface contaminants, but any breaches in the confining layer could potentially expose the aquifer to pollution, as demonstrated by Dhakate et al. (2018) in their study of mining impacts on groundwater quality. The high transmissivity would facilitate rapid contaminant transport if pollution were to occur, underscoring the importance of preventive measures. Additionally, changes in pressure within the confined aquifer could potentially affect groundwater discharge to surface water bodies in the region, highlighting the need for an integrated approach to water resource management that considers both groundwater and surface water systems (Alviyanda et al., 2023). From a regional perspective, the identified aquifer characteristics contribute valuable data to the broader understanding of hydrogeological conditions in the Kutai Kartanegara region, complementing previous studies by Rahmawati et al. (2013) and Taufiq et al. (2018) in other Indonesian mining regions. The results can be compared with other studies in similar geological settings to establish patterns and anomalies that enhance the conceptual model of groundwater resources in East Kalimantan. This regional context is particularly important for assessing cumulative impacts from multiple extraction points and for developing coordinated management approaches that transcend individual project boundaries.

5. Conclusion

The analysis of aquifer characteristics in Block X of PT. Geomine Bara Studio Site revealed a confined aquifer with very good transmissivity (T = 193.9949 m^2/day) and high hydraulic conductivity (K = 6.0634335 m/day). The aquifer material consists predominantly of medium sandstone with a storativity value of 0.000137. The soil at the test location is fine sand with low porosity (n = 0.499%) and permeability (k = 0.056403975 mm/sec). The groundwater system has significant potential to fulfill the operational needs of PT. Geomine Bara Studio Site Kutai Kartanegara, with an available groundwater volume of 219.398 m^3 and sustainable withdrawal rate of 182.0678 m^3/day. The aquifer characteristics indicate high water flow capacity with low storage ability, confirming a confined aquifer system that requires careful management. These findings provide essential information for developing an effective mine drainage plan system and sustainable groundwater management strategy. By understanding the hydrogeological characteristics and aquifer capacity in the research area, mining activities can be conducted with appropriate water resource management plans that minimize environmental impacts while supporting operational requirements.

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References

Abdul, A. (2013). Permodelan Hidrologi Mudah bagi Pasang Surut di Sungai Pulai, Johor. Universiti Teknologi Malaysia.

Alviyanda, Anjar Dwi Asterina, Redhatul Irma, 2023. Identification of Saltwater Intrusion Distribution in North Padang Cermin Area, Lampung, Indonesia. J. Geosci. Eng. Environ. Technol. 8, 281–287. https://doi.org/10.25299/jgeet.2023.8.4.12236

Bisri, M. (2012). Air Tanah. Universitas Brawijaya Press.

Cooper Jr, H. H., & Jacob, C. E. (1946). A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History. Eos, Transactions American Geophysical Union, 27(4), 526–534.
Hardiyatmo, H. C. (2002). Mekanika Tanah I (3rd ed.). Gramedia Pustaka Utama.
Harjito, H. (2014). Metode Pumping Test sebagai Kontrol Untuk Pengambilan Air Tanah Secara Berlebihan. Jurnal Sains & Teknologi Lingkungan, 6(2), 138–149.
Johnson, A. I. (1967). Specific Yield: Compilation of Specific Yields for Various Materials (Issue 1662). US Government Printing Office.
Kodoatie, R. J. (2010). Tata Ruang Air Tanah. Penerbit Andi.
Linsley, R. K. (1979). The Hydrologic Services of the Weather Bureau. Weatherwise, 2(5), 105–109.
Linsley, R. K. (1994). The Relation Between Rainfall and Runoff. Journal of Hydrology, 5, 297–311.
Listiawan, Y., Suganda, N.B., Cipta, E., 2015. Kajian Potensi Intrusi Air Laut Berdasarkan Karakteristik Hidrokimia Airtanah Di Daerah Karangwuni Kecamatan Wates Kabupaten Kulon Progo Provinsi DI Yogyakarta, in: Seminar Nasional Ke-II FTG Universitas Padjadjaran.
Lohman, S. W. (1972). Ground-Water Hydraulics (Vol. 708). US Government Printing Office.
Morris, D. A., & Johnson, A. I. (1967). Summary of hydrologic and physical properties of rock and soil materials, as analyzed by the hydrologic laboratory of the U.S. Geological Survey, 1948-60. U.S. Geological Survey.
Moss, S. J., & Chambers, J. L. C. (1999). Tertiary Facies Architecture in the Kutai Basin, Kalimantan, Indonesia. Journal of Asian Earth Sciences, 17(1–2), 157–181.
Purnama, S. (2010). Hidrologi Air Tanah. Yogyakarta, DI Yogyakarta, Indonesia: Kanisius.
Putra, D.B.E., Yuskar, Y., Kausarian, H., Wan Yaacob, W.Z., Hadian, M.S.D., 2019. Saltwater Intrusion Zone Mapping on Shallow Groundwater Aquifer in Selat Baru, Bengkalis Island, Indonesia. J. Geosci. Eng. Environ. Technol. 4, 16. https://doi.org/10.25299/jgeet.2019.4.1.2672
Rahmawati, N., Vuillaume, J.F., Purnama, I.L.S., 2013. Salt intrusion in coastal and lowland areas of semarang city. J. Hydrol. 494, 146–159. https://doi.org/10.1016/j.jhydrol.2013.04.031
Riyadi, A. (2005). Identifikasi Potensi Air Tanah di Kecamatan Mangkubumi Tasikmalaya dengan Metode Uji Pompa. Jurnal Teknologi Lingkungan, 6(2).
Rizal, N. S., & Kuryanto, T. D. (2015). Teknik Pendugaan dan Kplotasi Air Tanah. LPPM Ummuh Jember.
Santosa, L.W dan Adji, T.N. (2014). Karakteristik Akuifer dan Potensi Air tanah Graben Bantul. Yogyakarta: Gadjah Mada University Press
Shiddiqy, M. H. (2014). Pemetaan Keberadaan Akuifer Menggunakan Metode Resistivitas Konfigurasi Schlumberger di Daerah Nanggulan, Kabupaten Kulonprogo, Provinsi Daerah Istimewa Yogyakarta. Universitas Gadjah Mada Press.
Sjarif, L. (2003). Penentuan Nilai Karakteristik Akuifer Sumur Air Tanah Melalui Uji Pemompaan (Pumping Test) Dengan Metode Cooper-Jacob di Leuwikopo, Darmaga. IPB (Bogor Agricultural University).
Supriatna, S., Sukardi, R., & Rustandi, E. (1995). Peta Geologi Lembar Samarinda, Kalimantan Timur. Pusat Penelitian Dan Pengembangan Geologi.
Susiloputri, S., & Farida, N. S. (2011). Pemanfaatan Air Tanah untuk Memenuhi Air Irigasi di Kabupaten Kudus Jawa Tengah. Laporan Tugas Akhir Universitas Diponogoro. Semarang.
Taufiq, A., Hosono, T., Ide, K., Kagabu, M., Iskandar, I., Effendi, A.J., Hutasoit, L.M., Shimada, J., 2018. Correction to: Impact of excessive groundwater pumping on rejuvenation processes in the Bandung basin (Indonesia) as determined by hydrogeochemistry and modeling (Hydrogeology Journal, (2018), 26, 4, (1263-1279), 10.1007/s10040-017-1696-8). Hydrogeol. J. 26, 1281–1284. https://doi.org/10.1007/s10040-018-1728-z
Todd, D. K., & Mays, L. W. (1980). Groundwater Hydrology. John Wiley & Sons.
Todd, D. K., & Mays, L. W. (2005). Groundwater Hydrology (3rd ed.). Wiley & Sons.
Waterloo Hydrogeologic. (2019). Quaternary Geology of Southern Ontario and Applications to Hydrogeology. Canadian Journal of Earth Sciences, 55(7), v–viii.