Universitas Muhammadiyah Malang, East Java, Indonesia

Journal of Community Service and Empowerment

p-ISSN 2442-3750, e-ISSN 2537-6204 // Vol. 5 No. 3 December 2024, pp. 522-530

Water availability development through groundwater investigations and estimates: Case study at Landungsari village, Malang regency

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ARTICLE INFO

Article history
Received: 2024-03-16
Revised: 2024-06-25
Accepted: 2024-07-22
Published: 2024-11-19

Keywords
Availability
Exploration
Groundwater
Potential development
Sustainability

ABSTRACT

The population of Landungsari Village is very large, exceeding 9,000 people. With such a substantial population, the need for clean water and sanitation is also considerable. However, the potential sources of raw water for clean water reserves are very limited, especially surface water. The groundwater level at the study site is also quite deep, particularly in the southern parts of Landungsari Village. Rambakan and Bendungan hamlets have groundwater levels ranging from 15 to 25 meters deep. In contrast, Klandungan hamlet averages over 25 meters, and in the vicinity of Thursina Boarding School, it is more than 40 meters deep, making shallow wells impractical. Meanwhile, the clean water supplied by the PDAM is very limited. To address the issue of clean water availability, an investigation through groundwater estimation is necessary to ensure that the selected locations for deep well exploration are not in vain. The results of groundwater estimation must be representative and provide strong scientific justification for the accuracy of the findings. The method used in this investigation is the geoelectric resistivity method using ADMT-300H, which operates based on Darcy's law. It emits electromagnetic waves and measures soil resistivity to identify aquifer layers and determine the depth and thickness of the aquifer. The results obtained with ADMT-300H include: optimal discharge at well 1 (WL-1) of 3.07 l/s and well 2 (WL-2) of 3.14 l/s. Optimal discharge represents the sustainable limit for utilizing groundwater flow.

Kata Kunci
Airtanah
Berkelanjutan Eksploitasi
Ketersediaan
Pengembangan potensi

Pengembangan ketersediaan air melalui investigasi dan estimasi air tanah: Studi kasus di Desa Landungsari, Kabupaten Malang. Jumlah penduduk desa Landungsari sangat besar karena lebih dari 9.000 jiwa. Dengan jumlah penduduk yang demikian besar maka ketersediaan air bersih dan sanitasi yang dibutuhkan juga cukup besar. Sementara potensi air baku yang dapat digunakan untuk cadangan air bersih sangat terbatas, terutama air permukaan. Kondisi muka airtanah yang ada di lokasi studi juga cukup dalam, terutama dusun-dusun yang berada di sisi bagian selatan desa Landungsari. Dusun Rambakan dan dusun Bendungan memiliki kisaran kedalam muka airtanah antara 15m hingga 25m. Sedangkan dusun Klandungan rata-rata di atas 25m bahkan di sekitar Thursina boarding school lebih dari 40m sehingga tidak memungkinkan untuk sumur dangkal. Sementara kebutuhan air bersih yang di topang oleh PDAM sangat terbatas. Untuk menyelesaikan permasalah ketersediaan air bersih tersebut perlu dilakukan penyelidikan melalui pendugaan airtanah agar lokasi yang dipilih untuk eksplorasi sumur dalam tidak sia-sa. Hasil pendugaan airtanah yang diperoleh harus representative dan memberikan alasan yang kuat secara ilmiah tentang akurasi hasil yang diperoleh. Metode yang digunakan dalam penyelidikan ini adalah metode geolistrik resistivitas menggunakan ADMT-300H yang bekerja berdasarkan hukum Darcy, dengan memancarkan gelombang elektromagnetik dan mengukur resistivitas tanah untuk mengidentifikasi lapisan akuifer serta menentukan kedalaman dan ketebalan akuifer. Hasil yang diperoleh dengan menggunakan ADMT-300H meliputi; debit optimum lokasi sumur 1 (WL-1) 3,07 l/s dan sumur 2 (WL-2) 3,14 l/s. Debit optimum merupakan batas pemanfaatan debit air tanah yang berkelanjutan.

How to cite: Abduh, M., Abadi, K., & Yani, D. A. (2024). Water availability development through groundwater investigations and estimates: Case study at Landungsari village, Malang regency. *Journal of Community Service and Empowerment, 5*(3), 522-530. https://doi.org/10.22219/jcse.v5i3.32720

INTRODUCTION

Landungsari Village is one of the villages in Malang Regency, East Java, with a large area and significant population growth. Surrounded by several major universities and schools, it requires adequate supporting facilities, especially clean water and sanitation. The significant population and lack of surface water sources present a particular challenge. The current conditions related to clean water services are still limited, both in terms of the service system and quantity. The Landungsari Village Government, through BUMDes Tirto Landungsari, is seeking alternatives to meet water needs by conducting investigations to estimate the potential clean water sources that can be utilized.

According to the BPS data, the current population of Landungsari Village is 9,330 people and continues to grow. The availability of clean water is a top priority for improving public health. The raw water sources currently available to meet the need for clean water are still limited and do not yet match the demand. (Mochtar Nova Mulyadi et al., 2018) . The utilization of groundwater potential is still very limited to shallow wells, and there is only one bore well with limited capacity. (Dian Chandrasasi et al., 2023; Ika Rantika et al., 2023; Ja`A Khairuni et al., 2023; Muhardi et al., 2019; Sonia Y. Rompas et al., 2023).

The groundwater potential in the northern side of Landungsari Village, particularly in Ramba'an Hamlet, is relatively shallow, with the groundwater level being less than 15 meters. In Bendungan Hamlet, located in the middle part of Landungsari Village, the groundwater level is deeper, at almost 20 meters. In Klandungan Hamlet, situated on the southern side of Landungsari Village, the groundwater level is even deeper, reaching 40 meters or more. Under these conditions, it is difficult to exploit shallow wells (Mochtar Nova Mulyadi et al., 2018). To ascertain the geological condition of this layer, it is necessary to study the potential of the aquifer (Dian Chandrasasi et al., 2023; Muhardi et al., 2019; Ika Rantika et al., 2023; Sonia Y. Rompas et al., 2023; Ja`A Khairuni et al., 2023).

Following the conditions of the study location with a groundwater level that tends to be deep, to determine the planning point for a drilled well, an investigation of the groundwater potential is first carried out. This aims to ensure that the groundwater potential obtained matches predictions. The method used in this research is one of the newest methods which is very effective in estimating groundwater potential. Based on the results of this research investigation, groundwater availability data was then analyzed to obtain an estimate of the existing potential and capacity that can be explored while still considering the sustainability of the potential. This present studi is in accordance with SDGs goal point 6 concerning adequate sanitation and clean water and point 15 concerning sustainable ecosystems.

The availability of raw water sources to support clean water supply systems is a critical issue due to the imbalance between clean water demand and availability (Afifah, 2019; Dudung Mulyadi, 2023; Mac Mahon, 2022; Oddershede et al., 2022; Syafrudin et al., 2020). Efforts to address the limited water availability and the increasing demand for clean water are crucial to ensure a reliable and safe water supply for the community. Groundwater is one of the potential raw water sources that can be developed in Landungsari Village. To effectively understand the groundwater potential, it is essential to conduct a professional investigation with adequate equipment (Anas et al., 2023; Mulyadi & Biantoro, 2024). The investigation aims to help predict water needs, assess the condition of the water supply, and identify suitable drilling locations to meet the increasing demand for clean water.

METHOD

Data collection includes primary and secondary data. Primary data involves directly examining the conditions and potential of the area. Secondary data consists of population data from the Central Bureau of Statistics (BPS) and the Landungsari Village Government. Population projections are made using three methods: arithmetic, geometric, and exponential. The equipment used to investigate groundwater potential includes a complete ADMT 300H, a smartphone with the Aidu Prospecting application, a 50-meter measuring tape, and a Garmin GPS. Additional equipment includes a camera and writing tools to document area data.

In determining the drilling points, the estimated location and depth of the aquifer are first observed. This aquifer investigation uses the ADMT 300H to identify the lowest mineral layer that is considered an aquifer (Mikael Erlström & Daniel Sopher, 2019; Tian et al., 2019; Worapop Thongsame et al., 2018). The ADMT 300H is one of the latest geoelectric method tools and is increasingly being applied. To estimate aquifer potential using the ADMT (Aidu Golden Rod), the theoretical basis includes the electrical properties of rocks as well as their electronic, electrolytic, and dielectric conductivity. Resistivity, or the characteristic of the rock, indicates its ability to conduct electric current. The flow of electricity in rocks and minerals is classified into electronic conduction, electrolytic conduction, and dielectric conduction. The conductivity and resistivity of porous rocks depend on the volume and arrangement of the pores (Rahman & Rahmawati, 2022).

Conductivity increases as the water content in the rock increases, whereas resistivity increases as the water content decreases. Conduction occurs when the rock exhibits dielectric properties against the flow of electric current, meaning the rock has few or no free electrons. Electrons in the rock move and accumulate separately within the nuclei due to the influence of an external electric field, resulting in polarization (Dita Aprilia et al., 2015; H. Liu et al., 2020; Song et al., 2023; Worapop Thongsame et al., 2018; Wu, 2022). The process of investigating groundwater potential in this study is outlined as follows.

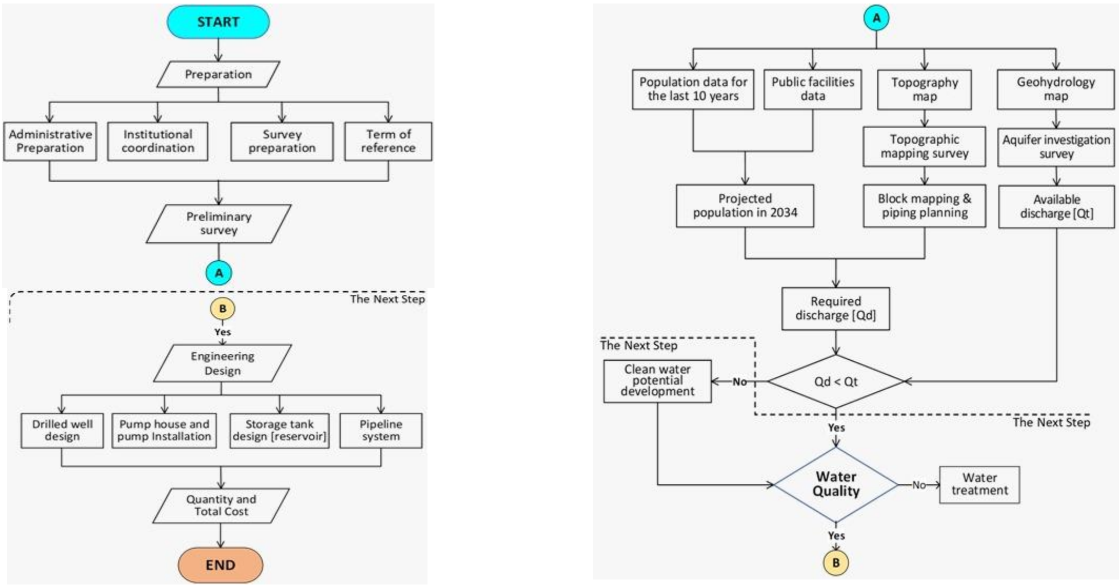


Figure 1. Flow chart of activity implementation

RESULTS AND DISCUSSION

Based on the analysis of population growth data over the past 10 years and its clean water needs, the following is outlined. The total projected population growth and clean water needs for Landungsari Village **(Surya Astuti et al., 2023)** in 2012 there were 9131 people and in 2022 there would be 9330 people spread throughout the region. Projection of the population in 2034 and t period for 12 years, the estimated population according to the projection in 2034 is 9,574 people (arithmetic method), 9,575 people (geometric method), and 9575 people (exponential method). Next, the selection was made based on the arithmetic method with Sd=73.31 and r=0.99768, projecting a population of 9,574.
The description of the area based on the Landungsari Village map is described in detail with block divisions as Figure 2 below.

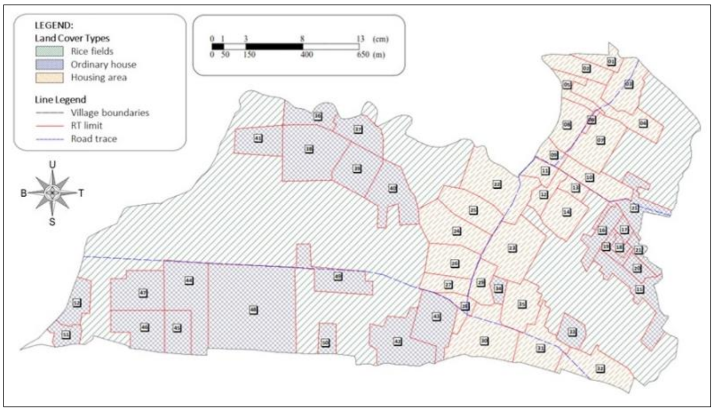


Figure 2 Map of block divisions in the Landungsari village area

As shown in Figure 2, block numbering with smaller and well-defined units is useful for identifying clean water needs in each area. Based on the population projections for 2034, the water needs for each block are outlined in the following table.

Table 1. Projection of clean water needs according to hamlet or housing areas in 2034

No	Description of area	Population estimate (2034)		Daily water requirements [Q]					
				D and nD		wl	Rate	Max	Peak
		block	person	[l/day]	[l/s]	[l/s]	[l/s]	[l/s]	[l/s]
1	Rambakan & Bendungan Village	1 – 14	2.738	160.928,95	1.86	0.37	2.24	2.68	3.80
2	Puri Landungsari Cluster	15 – 21	1.071	62.972,20	0.73	0.15	0.87	1.05	1.49
3	Klandungan Village	22 – 35	2.825	166.126,66	1.92	0.38	2.31	2.77	3.92
4	Oma Campus Cluster	36 – 41	1.224	71.968,23	0.83	0.17	1.00	1.20	1.70
5	Pondok Bestari Cluster	42 – 43	554	32.585,61	0.38	0.08	0.45	0.54	0.77
6	South side of West Clusters	44 – 51	1.162	68.369,81	0.79	0.16	0.95	1.14	1.61
	Total		9.574		6.52		7.82	**9.38**	13.28

Source: Analysis Result; [Domestic and non-domestic water needs with 20% water leakage, 70% service level, assuming 30% use shallow wells independently; D=domestic, nD=non domestic, wl= water leakage 20%].

Based on the groundwater basin (CAT) geohydrology map of East Java, specifically the Brantas groundwater basin (CAT), it is concluded that the confined aquifer conditions in Malang City are fairly uniform. According to hydrogeological data from the Ministry of Energy and Mineral Resources, the Landungsari area has aquifer productivity and aquifer lithology as shown in Figure 3 below.

The data investigation in this activity includes both primary and secondary data, in accordance with the needs and scope. In addition to a general description of the location, the conditions of the planned network, and plans for other new wells, the groundwater potential is also identified using ADMT-300H geoelectrics. Secondary data includes topographic data obtained through the ArcGIS application to acquire surface contours (M. Liu et al., 2023; Wang et al., 2023), location points for water sources and pipe networks as well as population growth data.

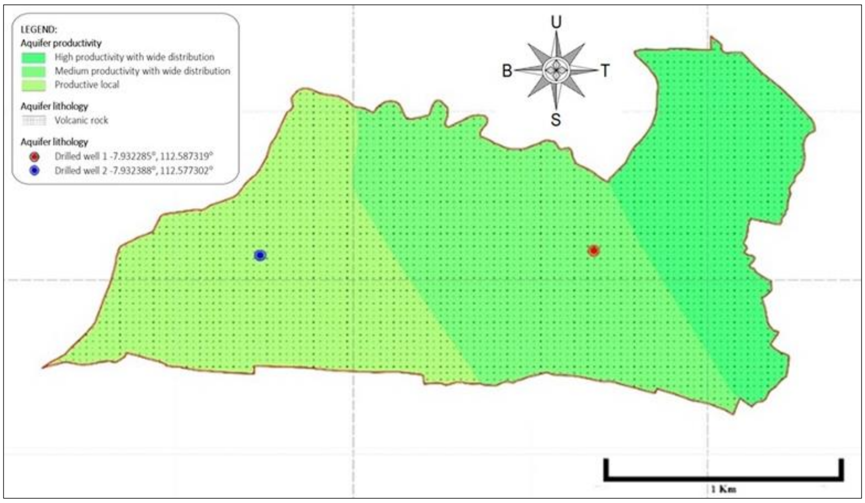
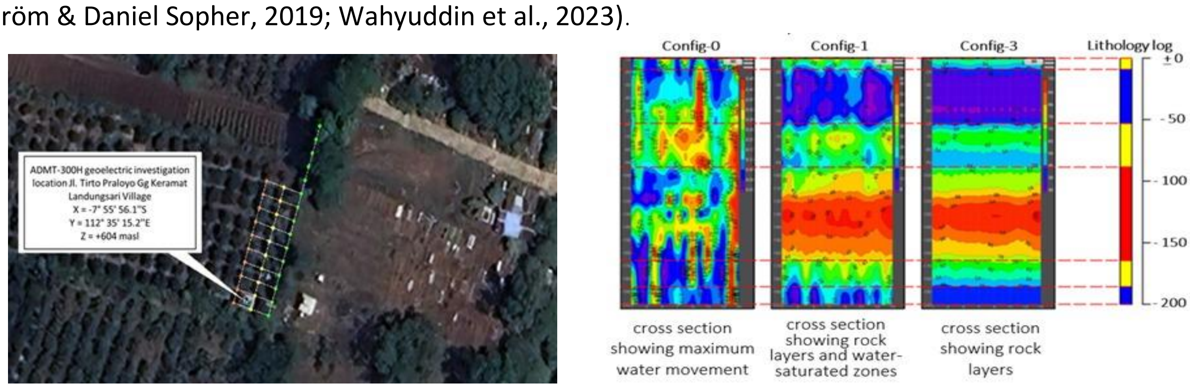


Figure 3. Geohydrological conditions of Landungsari village

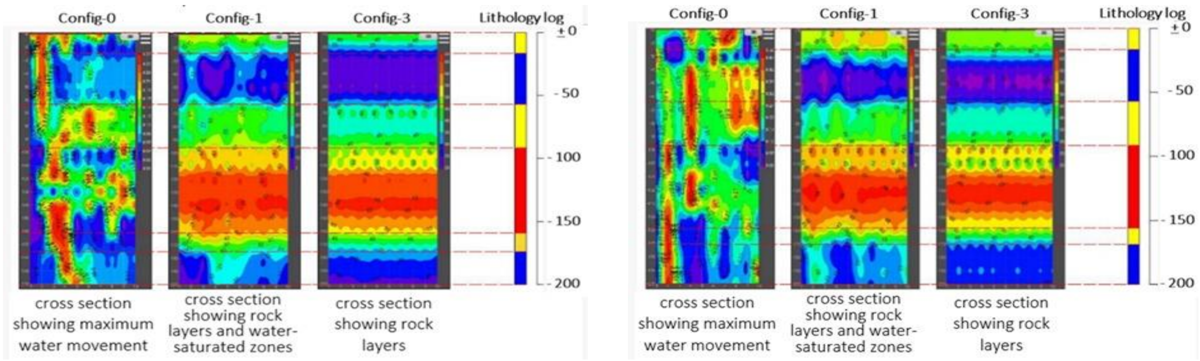
(a) (b)

Gambar 4. Location of drilled well 1 (a), and location of drilled well 2 (b)

The location of drilled well 1 [WL-1] is at 112°35'15.2''E and 7°55'56.1''S with an elevation of 604 masl, and the planned drilled well 2 [WL-2] is located at 112°34'38.75''E and 7°55'56.41''S, with an elevation of 676 masl. Implementation of groundwater potential estimation in both wells with predicted depths of up to 300 m with configurations 0, 1, 2, and 3. Configuration 0 has the sensitivity to maximum water movement, and configuration 2 is for investigating aquifer discharge (Q) data and is also sensitive to rock layers and zones of saturated water (Dita Aprilia et al., 2015; Mikael Erlström & Daniel Sopher, 2019; Wahyuddin et al., 2023).

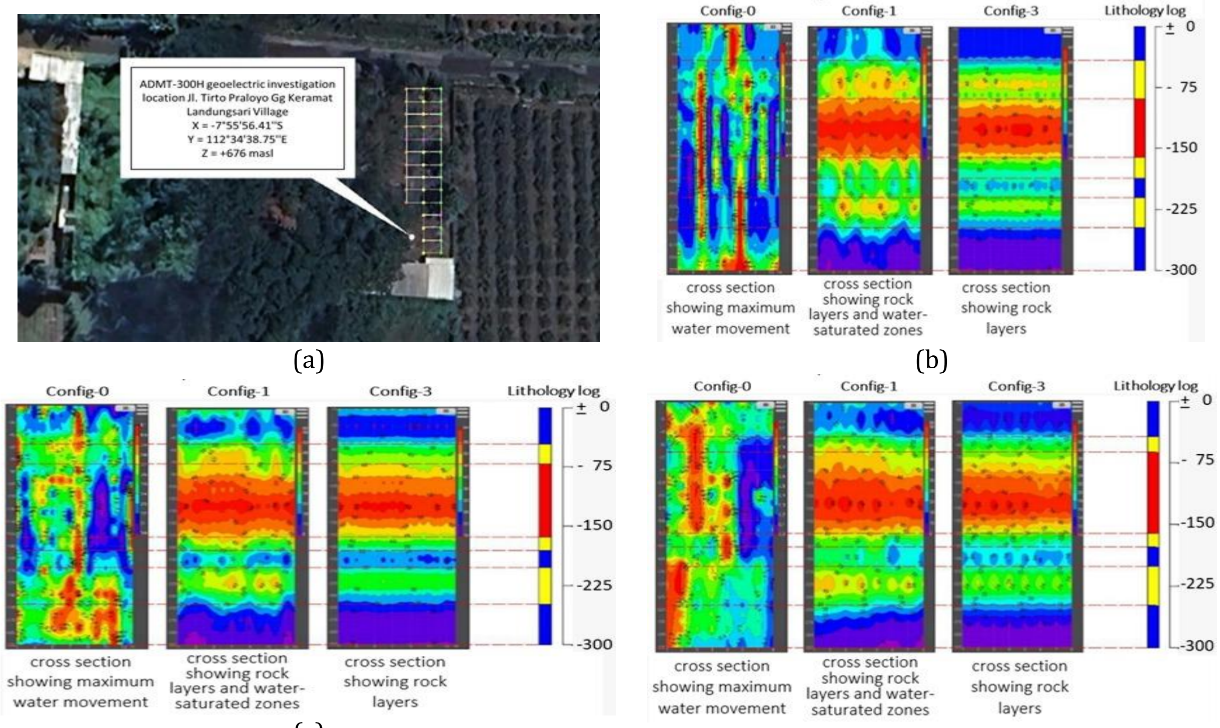


(a) (b)



(c) (d)

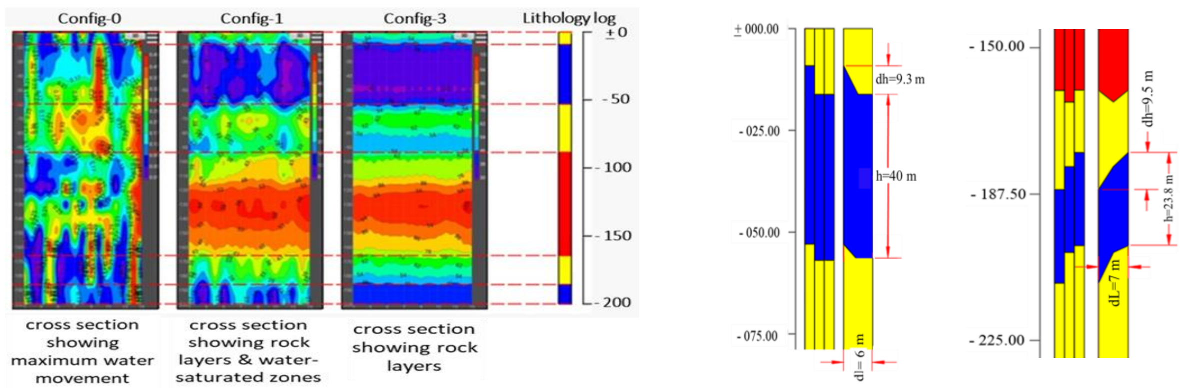
Figure 5. Location of well 1 [*WL-1*] investigation (a), results of aquifer investigation track A (b), results of aquifer investigation track B (c), results of aquifer investigation track C (d).



(a) (b) (c) (d)

Figure 6. Location of well 2 [*WL-2*] investigation (a), results of aquifer investigation track A (b), results of aquifer investigation track B (c), results of aquifer investigation track C (d)

The results of the aquifer investigation using ADMT-300H were subsequently projected onto configurations 1 and 3 to determine the type and inclination of the lithology composing the aquifer. By categorizing the type of medium based on its resistivity values and projecting it into a lithology log, and then combining the lithology logs of cross-sections into one, the inclination of the lithology can be observed (Dita Aprilia et al., 2015; M. Liu et al., 2023; Ren et al., 2019; Tri Wulan Sari & Sujito, 2019; Worapop Thongsame et al., 2018; Wu, 2022).



(a) (b) (c)

Figure 7 Depiction of Lithology Log (a), lithology of well 1 (b), lithology of well 2 (c)

To determine the groundwater potential at the study site, the basic concept used by ADMT-300H refers to Darcy's Law. According to Darcy (1856), groundwater movement is caused by differences in hydraulic gradient (dh/dL). Groundwater flows from high h (hydraulic head) to low h, where h reflects the potential energy of the groundwater **(Suresh Kumar Govindarajan, 2019)**. The velocity in the soil and the continuity of the flow depend on the passability coefficient of the rocks in the soil layer **(Dita Aprilia et al., 2015; Song et al., 2023; Wahyuddin et al., 2023; Wang et al., 2023)**.

Based on the results of the groundwater estimation in Figures 6, 7, and 8, the aim is to determine the flow rate in the ground related to Transmissivity (T) and Hydraulic Conductivity (K), as well as the hydraulic gradient (dh) of groundwater flow. The Transmissivity value (T) = 1.55 R (resistivity), and hydraulic conductivity (K) is length per time. The magnitude of the hydraulic conductivity (K) = Transmissivity value divided by the aquifer thickness. The results of the soil hydrogeology analysis, groundwater flow behavior, and the potential yielded are presented in the following table.

Table 2. Results of the analysis of geohydrological data calculations and soil lithological layers.

No.	Description	Symbol	Well 1 [C2, C3]	Well 2 [A3]
1	Aquifer depth	H	30.00	170.00
2	Height difference [m]	dh	9.30	9.50
3	Height difference distance [m]	dL	6.00	7.00
4	Aquifer thickness [m]	h	40.00	23.80
5	Resistivity value [ohm.m]	R	23.00	23.00
6	Transivicity [m]	T	35.65	35.65
7	Conductivity [m/day]	K	0.89125	1.4979
8	Available discharge [m3/day; l/s]	Qd	**331.54**; 3.84	**338.67**; 3.92
9	Optimum discharge [l/s]	Qt	3.07	3.14

Source: Analysis result

Table 3. Projection of the need and availability of clean water in the Landungsari village area in 2034

No	Description of area	Population		Clean water needs [Qd]			Qt	Notes
				Rate	Max	Peak		
		Block	Person	[l/s]	[l/s]	[l/s]	[l/s]	
1	Rambakan & Bendungan Village	1 – 14	2.738	2.24	2.68	3.80	-	well plan 3
2	Puri Landungsari Cluster	15 – 21	1.071	0.87	1.05	1.49	-	well plan 3
3	Klandungan Village	22 – 35	2.825	2.31	2.77	3.92	3.07	well 1
4	Oma Campus Cluster	36 – 41	1.224	1.00	1.20	1.70	-	independent
5	Pondok Bestari Cluster	42 – 43	554	0.45	0.54	0.77	3.14	well 2
6	South side of West Clusters	44 – 51	1.162	0.95	1.14	1.61	3.14	well 2
	Total Projection 2034		9.574	7.82	9.38	13.28		

Source: Analysis result [Water needs with a service level of 70% and an assumption of 30% using shallow wells, and some are self-service].

Groundwater investigation particularly with the ADMT-300H system, has proven effective in delineating potential groundwater resources. Studies have shown that the tool can provide high-resolution data on subsurface resistivity structures, identifying water-bearing zones like pegmatite and migmatite gneiss at depths of around 200m. Additionally, stable isotope technology has been utilized to evaluate groundwater flow and recharge sources, emphasizing the importance of groundwater in sustainable development (Bogdevich et al., 2022). Furthermore, research in Indonesia highlighted the significance of detailed information on groundwater quantity and quality for sustainable resource management, showcasing the potential of sand and clayey sand aquifers (Kalo et al., 2024). This shows that the electrical resistivity method has been successfully used in determining groundwater potential in certain areas, showing varying results and aquifer thickness (Coker et al., 2020).

Figures 5 and 6 show the results of soil layer investigations for wells 1 and 2 according to the configurations used. Based on these gradient maps, the values of transmissivity, hydraulic conductivity, and the hydraulic gradient of groundwater flow are interpreted. These gradient maps also indicate the estimated depth and thickness of potential groundwater layers to predict the aquifer discharge. The gradient map in Figure 7 shows the investigation results that depict the lithology of the soil layers, including the hydraulic gradient of groundwater flow. The apparent depth and thickness of the groundwater layers are predictions of groundwater conditions. The result of the analysis and calculations get, as shown in Table 2 above.

Based on the projected population growth, the maximum clean water discharge needed by the residents of each hamlet. By comparing the clean water needs with the available discharge capacity from the groundwater survey result (ADMT-300H), a plan for developing clean water supply in the study location can be formulated, as shown in Table 3 above. These groundwater survey results provide more reliable information and can be scientifically justified, making them a reference and recommendation for determining the location and depth of groundwater drilling.

CONCLUSION

The population of Landungsari Village is 9,330 people, projected to reach 9,574 in the next 10 years. The peak water demand is estimated at 13.28 liters per second. Currently, the water supply is still supported by shallow wells and the limited supply from the Regional Drinking Water Company (PDAM). Several hamlets in the southern part of the village tend to have difficulty accessing water because the groundwater surface is quite deep (more than 40 meters).

The availability of clean water needs to be increased according to the demand. Effective methods are required in planning groundwater exploration, as it is the only potential source that can be developed. Various exploration methods have been widely used, such as geoelectric. The geoelectric method operates on the principle of electrical resistivity in subsurface rocks. The ADMT-300H is based on Darcy's Law, emitting electromagnetic waves and measuring soil resistivity to identify aquifer layers and determine their depth and thickness.

Estimation using the ADMT-300H provides more detailed information on groundwater potential and subsurface structure for water resource management and well drilling planning. It has good accuracy, as validated by existing wells where the results are highly relevant. The development of water resources in Landungsari Village includes assessing groundwater potential using the ADMT-300H. The optimum discharge is 3.07 l/s for well 1 (WL-1) and 3.14 l/s for well 2 (WL-2). Optimum discharge represents the sustainable utilization limit of groundwater flow.

As a preventive measure, in addition to utilizing groundwater potential by exploring it for clean water, the community needs to preserve the environment and ensure sustainable water availability. This can be achieved by collaborating with the government to raise awareness about land conservation and protecting catchment areas to replenish groundwater.

ACKNOWLEDGEMENT

The project team conveys their gratitude to the Dean of Engineering Faculty University of Muhammadiyah Malang with grant Number: 1/P2M-HDL/FT-UMM/VII/2023 for the support and funding that this community service is successfully implemented. Also, we would like to express our thanks to the Landungsari Village Government, the Landungsari Village BUMDes Director, and his staff who have supported the running of this activity, and our students who are involved in this activity.

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