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Is it Permissible to Drill Groundwater for Business on Gili Trawangan Islands

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ABSTRACT

The pros and cons of groundwater drilling in the main tourism area of Gili Trawangan, North Lombok Regency have caused the government to revoke the groundwater extraction permits of several companies in 2022. Then there was a freshwater crisis in Gili until now in 2025. The purpose of this study was to analyze the potential of groundwater and the alleged impact of seawater intrusion in Gili as well as recommendations for groundwater business licensing policies on the island of Gili. The research method used geohydrological analysis and water balance analysis. The results showed that there are 5 (five) rock layers in Gili, namely coastal alluvial, reef, fine sand, coarse sand/reef and fine sand. Hydrogeological Borehole Log and Recovery for the aquifer layer are free or Unconfined Aquifer. In the pumping test with a capacity of 61.6 and 16.6 liters / second for 2 x 24 hours resulted in a decrease in the groundwater level of 0.5 meters and a relapse rate of only 2 minutes causing the groundwater level to return to normal height. Observations on the water quality revealed an alkaline pH and low salinity of 5 grams per liter, necessitating distillation techniques to obtain fresh water.

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A. INTRODUCTION

Gili Trawangan Island in North Lombok Regency is one of the small islands in North Lombok Regency, West Nusa Tenggara Province. Gili Trawangan has an area of 340 hectares and is a major tourist destination after Bali Island. Tourist visits reach an average of 3,000 people per day. The water demand in Gili Trawangan reaches 1,500,000 cubic meters per year. This demand is sourced from groundwater treatment using the SWRO system. The water is mainly used to meet the raw water needs of hotels and households. According to Astjario and Astawa (2016), Gili Trawangan, Meno, and Air are atoll islands that expose volcanic seabed rocks in the form of pillow lava, covered by volcanic material from the Rinjani volcano and coral reef debris.

These conditions make these three islands have high marine tourism value. Freshwater sources in Gili Trawangan are not available (Yasa et al., 2016). Some hotels meet their raw water needs by processing brackish water into fresh water using the SWRO system (Lokajaya, 2016). The groundwater in Gili Trawangan is only brackish water, but drilling and utilization permits are prohibited by the local government due to environmental risk concerns. The island has no rivers, only surface flow channels during the rainy season. The average annual rainfall is 1,540 mm. Currently, water is supplied from a seawater treatment unit by PT. Berkat Air Laut in collaboration with PT. Gerbang NTB Emas since 2012, and its groundwater extraction permit was revoked in 2022. From 2022 to 2024, water supply in Gili Trawangan was provided by PT. Tiara Cipta Nirwana in collaboration with PDAM Kab. Lombok Utara, but the seawater extraction permit was also revoked by the Ministry of Marine Affairs and Fisheries in 2024. To meet the water needs of the local population and tourism businesses, they buy water from the mainland using wooden boats at an average price of 3 to 5 million per cubic meter.

Currently, Gili Trawangan Island is experiencing a freshwater crisis, creating significant challenges for both local communities and tourism activities. The role of the government is essential in providing sustainable solutions for water supply systems on small islands. The PDAM water pipeline network has only reached Gili Air, while Gili Meno and Gili Trawangan continue to face difficulties in fulfilling freshwater demands. Although previous studies have discussed the geological characteristics and groundwater conditions of small islands, limited evidence is available regarding the integration of hydrogeological characteristics, aquifer behavior, groundwater recovery capacity, and seawater intrusion risk as a basis for groundwater management decisions in tourism-dependent islands. Consequently, scientific evaluation is required to determine whether groundwater extraction can be implemented without causing adverse environmental impacts and long-term degradation of water resources. Therefore, this study investigates the groundwater potential, hydrogeological characteristics, and possible seawater intrusion impacts on Gili Trawangan, while also providing a scientific basis for groundwater drilling and utilization policies for commercial purposes through Groundwater Drilling Permits (SIPA) and Groundwater Utilization Permits (SIP), particularly in supporting sustainable and equitable access to clean water resources.

B. METHODS

This research was conducted in January and June 2024. The research location was in Gili Trawangan Hamlet, Gili Indah Village, Pemenang District, North Lombok Regency, West Nusa Tenggara Province, as shown in Figure 1, which is the research location map below.

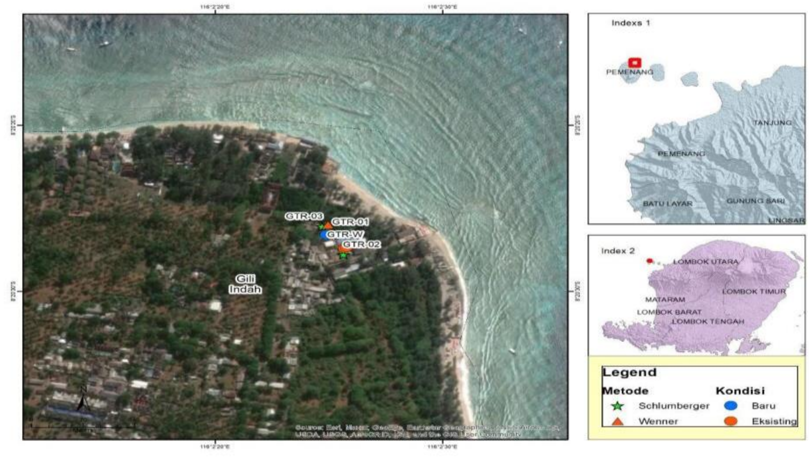


Figure 1. Research Location Map of Gili Trawangan

The materials used are chemicals for salinity testing in the laboratory. The tools used in this research are Neo Resist and Naniura geoelectric devices, EC Meter, pH meter, TDS salinity meter, geological compass, digital camera, battery, stakes, electrodes and electrode cables, toolbox, and Motorola handy talkie.

The research method used is natural observation, with descriptive quantitative analysis (Ahmad Fathoni, Erni Romansyah, 2025) in the form of geohydrological analysis and groundwater analysis. Data collection is carried out using survey methods and field observation (Hasanuddin Molo, 2025). Statistical data analysis is conducted through geohydrological studies with geological analysis and geoelectric testing (Shinta Werorilangi, 2025). Groundwater analysis is carried out through groundwater pumping analysis and physical-chemical testing of groundwater. Geoelectric estimation analysis is conducted through resistivity testing, while pumping tests are performed on existing bore wells and physical-chemical tests on bore well samples, residents' wells and surrounding seawater.

Geological mapping is basically depicting data on a base topographic map which produces a reflection of geological conditions at the desired scale. The geological conditions encountered in the field consist of the distribution of rocks, geological structures, and landscape morphology features. Observations of geological conditions in the field are conducted to understand what actually happened at that location several million years ago so that we can reconstruct what truly happened in the past, in accordance with the motto 'the present is the key to the past'.

One of the methods used in groundwater geophysical exploration is the geoelectric resistivity method. Geoelectric resistivity utilizes the electrical resistivity properties of rocks to detect and map subsurface formations. This method is carried out by measuring the potential difference caused by injecting electric current into the ground. The properties of a formation can be described by three basic parameters, namely electrical conductivity, magnetic permeability, and dielectric permittivity. The conductivity properties of porous rocks result from the conductivity properties of the fluid filling the pores, the interconnection of the pore space, and the conductivity properties of the interface between grains and pore fluid. Based on the value of electrical resistivity, the materials composing a subsurface structure can be identified. The geoelectric method is quite simple, inexpensive, and very sensitive to disturbances, making it suitable for shallow exploration (Yolantari et al., 2023).

A pumping test is a method of measuring water discharge that consists of observing the continuity of the water source and the availability of water from the source itself. The pumping test is conducted to determine the residual drawdown capacity of the aquifer to replenish after the well is pumped. The pumping test also aims to determine the effect of pumping a production well on the groundwater level conditions of nearby wells. The method used in this pumping test is the Theis Recovery method. This method is easy to perform because it does not require a monitoring well during the pumping test (Septiardi et al., 2019).

Some possibilities of flow rate measurement conditions using a pumping test include: (1) If the ratio of these two conditions (the rate of water level decline during pumping to the rate of water level rise during recovery) is 1, then the source flow rate = the water flow discharged by the pump (pump output); (2) If the rate of water level decline during pumping is greater than the rate of water level rise during recovery, it means the source flow rate is smaller than the pump flow rate (output); (3) If the rate of water level decline during pumping is smaller than the rate of water level rise during recovery, it means the source flow rate is greater than the pump flow rate (output). To obtain the actual flow rate of the source, it can be determined by multiplying the area of the source by the average water level rise during recovery..

The method of groundwater sampling was carried out using stratified random sampling based on formation units on the geological map. The water samples taken were from dug wells and bore wells (Panggabean, 2023). Laboratory chemical testing of groundwater was conducted to determine the content of major ions (Ca2+, Na+, Mg2+, K+, HCO3-, SO4 2-, and Cl-) using the Standard Method Evaluation for Water and Waste Water (SMEWW) by The American Public Health Association (APHA). The chemical analysis results were verified using the ion balance method with equation 1 before further analysis and interpretation were performed. The ion balance error limit was set at 10%; groundwater test samples with a cation/anion balance greater than 10% were retested. $[(\Sigma \text{ cations} - \Sigma \text{ anions}) / (\Sigma \text{ cations} + \Sigma \text{ anions})] \times 100\%$ Equation 1. Laboratory test results were analyzed and classified, interpreted, and grouped by the origin of groundwater using classification techniques based on physical properties, The results of water chemical tests, using either graphic methods or multivariate statistics, are: "Piper Diagram, Cluster Analysis, and Principal Component Analysis". The combination of graphic and statistical analysis can produce consistent and mutually supportive sample classifications. For statistical analysis, Minitab version 16 by Minitab Inc., and Statistical Product and Service Solution (SPSS) version 20 by IBM were used. Some physical properties of groundwater measured in the field include: temperature (T), Total Dissolved Solids (TDS), acidity (pH), elevation, discharge, Eh, Ec.

C. RESULT AND DISCUSSION

1. Geology of Gili Trawangan Island

The geological condition of North Lombok Regency, based on the regional geological map, consists of the Lekopiko Formation, Kalibabak Formation, Kalipalung Formation, alluvial deposits, and the tuff breccia lava deposits of Mount Rinjani. The Lekopiko Formation is composed of Quaternary volcanic rocks consisting of pumice tuff, lahar breccia, and lava deposits. The pumice tuff is characterized by a yellowish-white color, low compaction, fine to coarse grain sizes, and high permeability. Lahar breccia is characterized by dark gray rock with angular andesitic igneous fragments and relatively low compaction. Meanwhile, the lava deposits are light to dark gray in color, vesicular, and characterized by compact and hard flow structures. Geological research conducted by Lestari et al. (2023) in Malaka Village, North Lombok Regency, revealed that the subsurface stratigraphy is predominantly composed of soft soil layers consisting of three main lithological units, namely sandstone in the first layer, alluvial deposits in the second layer, and saline water-bearing rock layers associated with clay deposits in the third layer.

The geological conditions in the western part of North Lombok Regency, particularly within Pemenang District, are composed mainly of the Kalibabak Formation, which originated from volcanic activities during the Plio–Pleistocene and Oligo–Miocene periods. The Kalibabak Formation consists primarily of breccia and lava deposits. The breccia is characterized by brownish-gray coloration, angular andesitic igneous fragments ranging from gravel to boulder sizes, poor sorting, and compact, hard textures. The lava deposits are dark gray, andesitic–basaltic in composition, and exhibit hard and compact characteristics. Weathered soil materials consist of silty clay, sandy clay, and silty sand to sand deposits. The silty clay and sandy clay layers are gray in color, fine-grained, cohesive, soft to moderately stiff, and exhibit high plasticity, with thicknesses ranging from 3–4 m. The silty sand to sand deposits are dark gray to brownish-black in color, ranging from fine to coarse grain sizes, soft to moderately loose, with moderate to high porosity and thicknesses ranging from 1.50–3.50 m. Geological hazards and engineering geological constraints that require attention in the study area include ground movement or landslides, coastal abrasion, surface erosion, and flooding.

Coastal observations conducted along the Gili Trawangan shoreline based on geomorphological characteristics and sedimentary materials indicate that the coast is predominantly sandy. The surrounding marine environment also contains living coral reefs that continue to grow and function as marine conservation areas. Based on the geological setting, it can be preliminarily inferred that coral reefs developed around submarine volcanic lava structures, forming atoll systems that later emerged above sea level and eventually formed Gili Air, Gili Meno, and Gili Trawangan Islands. The existence of these three islands may have resulted from uplift processes associated with volcanic activity, as well as coral reef emergence followed by reworking due to wave action and sea-level fluctuations, leading to the accumulation of alluvial and coastal deposits on the island surfaces.

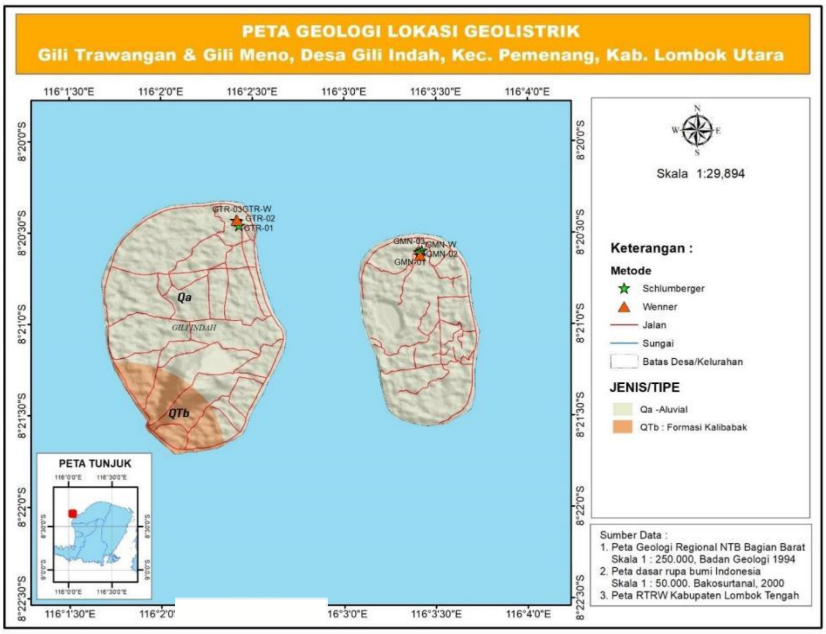


Figure 2. Geological Map of Gili Trawangan and Gili Meno

2. Hydrogeology of Gili Trawangan Island

Gili Trawangan is a small island covering an area of approximately ±3.497 km^2. The island morphology is predominantly flat, with only a small portion in the southern area characterized by hilly terrain reaching a maximum elevation of 62.5 m. The coastal base consists mainly of fringing coral reefs, while the island surface is covered by coastal alluvial deposits composed of unconsolidated fine- to very coarse-grained sand.

Regionally, the investigation area is classified as an aquifer system with groundwater flow occurring through intergranular pore spaces and characterized by moderate aquifer productivity. Sandy layers possess high permeability properties, resulting in considerable groundwater storage potential. In contrast, layers interpreted as non-aquifer units (aquicludes) consist mainly of clay and lava deposits (Darmansyah et al., 2020).

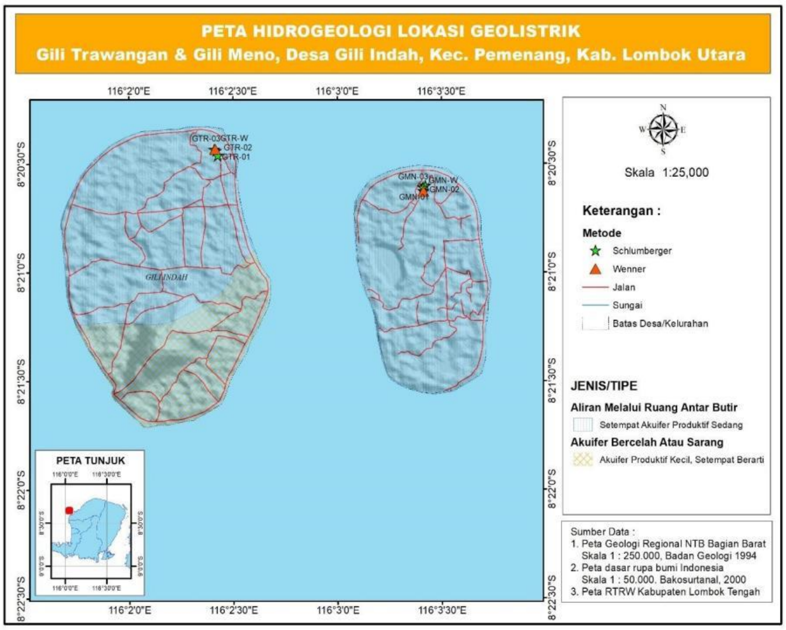


Figure 3. Hydrogeological Map of Gili Meno and Gili Trawangan

3. Schlumberger Resistivity Geoelectric Method

Resistivity measurements using the Schlumberger method were conducted by injecting electrical current into the subsurface through two current electrodes, while the resulting potential difference was measured using two potential electrodes. When electrical current is injected into a medium and the potential difference (voltage) is measured, the resistivity value of the medium can be estimated (Baso Usman et al., 2017). Geoelectrical measurements were conducted at three observation points (Figure 1), namely:

a. GTR-01 located at coordinates 116° 2′ 25.18″ E and 8° 20′ 26.44″ S
b. GTR-02 located at coordinates 116° 2′ 25.65″ E and 8° 20′ 27.80″ S
c. GTR-03 located at coordinates 116° 2′ 24.71″ E and 8° 20′ 26.10″ S

The results obtained from the Schlumberger resistivity measurements were subsequently processed using the geophysical software IP2Win, which performs inversion modeling by adjusting an ideal subsurface model to approximate the field data curve (field data curves are provided in the appendix). Variations in resistivity values were used to interpret potential aquifer locations. This approach can be applied because different subsurface materials exhibit distinct resistivity characteristics (Table 1). Igneous and metamorphic rocks generally possess high resistivity values, which are strongly influenced by the presence and density of fractures filled with groundwater. Sedimentary rocks typically contain abundant pore spaces, resulting in higher water content and lower resistivity values. Wet soils and groundwater generally exhibit low resistivity, while clay tends to have lower resistivity values than sandy soils.

Table 1. Resistivity Ranges of Several Rock and Soil Types

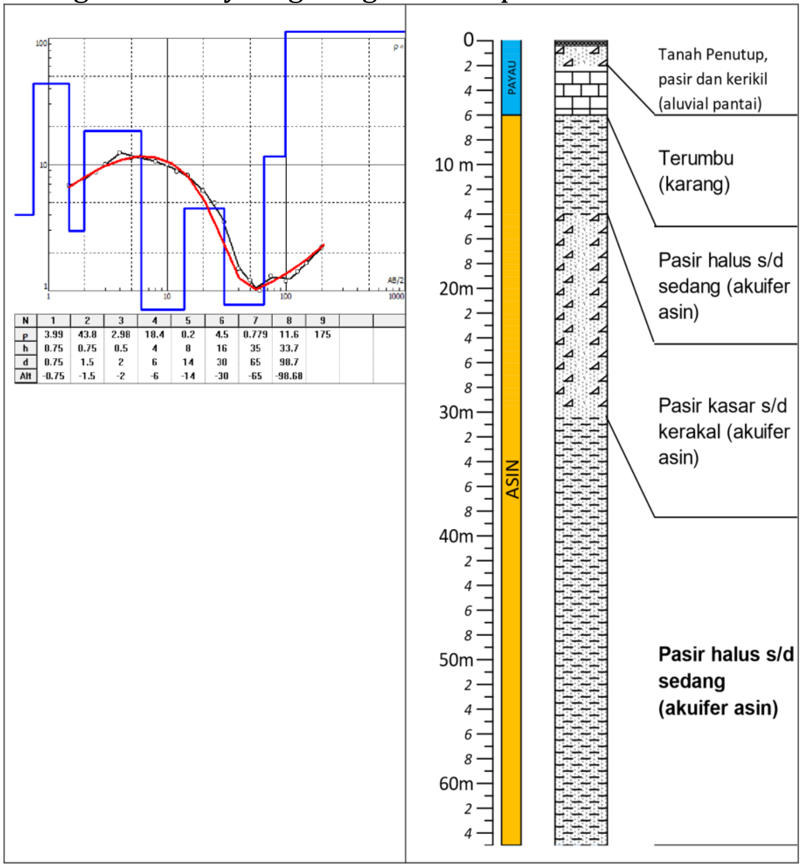
Material	Resistivity (Ωm)
Igneous and Metamorphic Rocks	
Granite	$5 \times 10^3 - 10^6$
Basalt	$10^3 - 10^6$
Slate	$6 \times 10^2 - 4 \times 10^7$
Marble	$10^2 - 2.5 \times 10^8$
Quartzite	$10^2 - 2 \times 10^8$
Sedimentary Rocks	
Sandstone	$8 - 4 \times 10^3$
Shale	$20 - 2 \times 10^3$
Limestone	$50 - 4 \times 10^2$
Soils and Waters	
Clay	1 – 100
Alluvium	10 – 800
Groundwater (fresh)	10 – 100
Seawater	0.2

The processed and correlated data from the geophysical software produced resistivity values used to interpret lithological characteristics and groundwater-bearing layers. The distribution of subsurface layers was represented through apparent resistivity sections and resistivity contrast sections.

Subsequently, the processed data were interpreted and correlated with geological and hydrogeological conditions to determine aquifer potential. The analysis results at observation points GTR–01, GTR–02, and GTR–03 revealed five lithological layers (Table 2), namely:

1. A thin surface layer interbedded with sand and gravel deposits originating from coastal sediments, with a thickness of 2–3 m and resistivity values ranging from 2.51–43.8 Ωm;
2. The second layer was interpreted as a coral reef layer characterized by relatively higher resistivity values ranging from 17.3–18.4 Ωm, occurring at depths of 2–6 m with thicknesses of 3–4 m;
3. The third layer indicated fine- to medium-grained sand deposits occurring at depths of 6–17 m, characterized by very low resistivity values ranging from 0.200–0.205 Ωm, suggesting saline groundwater conditions;
4. The fourth layer was interpreted as coarser deposits consisting of coarse sand to gravel at depths ranging from 14–30.5 m, with resistivity values between 4.5–9.61 Ωm;
5. The fifth layer indicated fine- to medium-grained sand deposits at depths ranging from 30–65 m, characterized by low resistivity values of 0.619–0.779 Ωm, indicating saline groundwater conditions.

Table 2. Lithological and Hydrogeological Interpretation at Measurement Points



N	1	2	3	4	5	6	7	8	9		
ρ	3.99	43.8	2.98	18.4	0.2	4.5	0.779	11.6	175		
h	0.75	0.75	0.5	4	8	16	35	33.7			
d	0.75	1.5	2	6	14	30	65	98.7			
Alt	-0.75	-1.5	-2	-6	-14	-30	-65	-98.68			

4. Wenner Resistivity Geoelectric Method

The Wenner configuration is a resistivity survey arrangement characterized by constant electrode spacing, where the factor n represents the ratio between the distance of electrodes C1–P1 (or C2–P2) and the spacing between P1 and P2, as illustrated in Figure 3. If the spacing between potential electrodes (P1 and P2) is represented by a, then the spacing between current electrodes (C1 and C2) becomes 2na + a. The resistivity determination process employs four electrodes positioned in a straight line. The Wenner configuration (Kamur et al., 2024) is widely used in geoelectrical exploration due to its uniform electrode spacing arrangement ($r1 = r4 = a$ and $r2 = r3 = 2a$). During field data acquisition, potential and current electrodes were arranged symmetrically around the sounding point.

Field data obtained using the Wenner method were subsequently processed using Res2DInv software to determine subsurface resistivity distributions along the survey line.

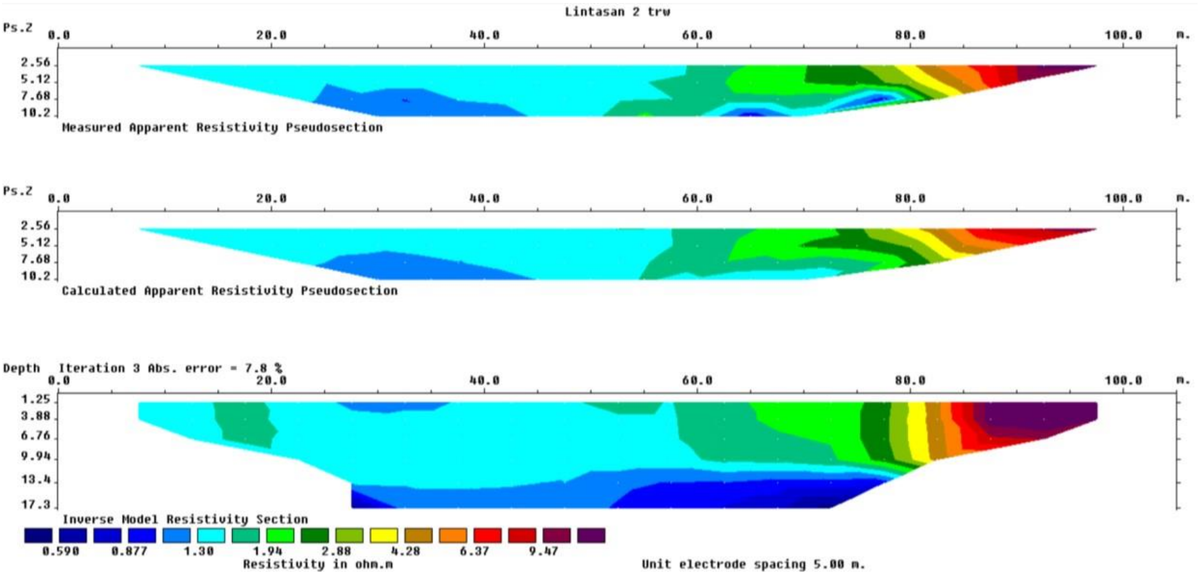


Figure 4. Results of Data Processing Using the Wenner Method with Res2DInv

The results of the Schlumberger resistivity analysis indicated that the upper part of the investigation area consists of a brackish aquifer layer, whereas saline aquifer layers were identified below a depth of approximately 6 m.

Correlation among the three Schlumberger measurement points, confirmed by Wenner analysis, revealed similar subsurface layering models (Figure 5). Surface layers were predominantly composed of coastal deposits consisting of sand and coral fragments, while coral reef layers were identified at depths ranging from 2–6 m. Brackish groundwater was interpreted to occur within coastal alluvial deposits at depths of approximately 1–2 m.

Beneath the coral reef layers, saline groundwater-bearing formations composed of fine- to coarse-grained sand deposits were identified. The coarse sand layer at depths ranging from 14–30 m may also represent coral reef materials, although this interpretation requires confirmation through drilling results. At depths between 30–65 m, another fine sand layer was encountered, indicating possible coastal or paleo-volcanic sediment deposits.

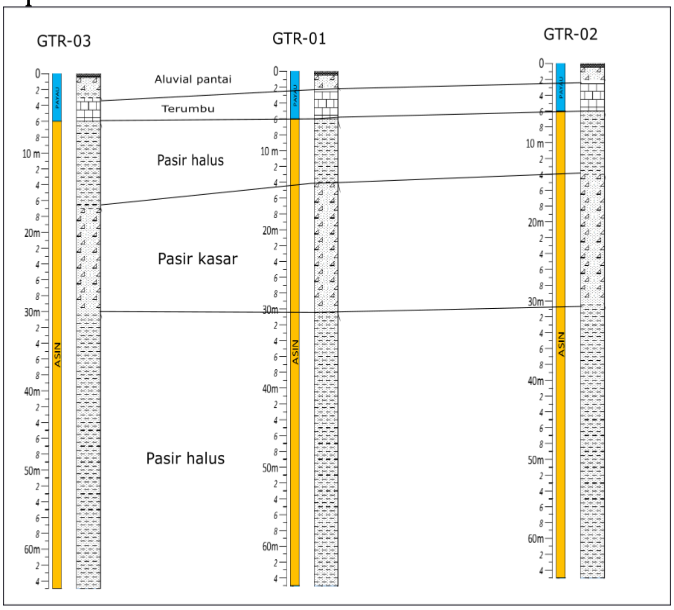


Figure 5. Correlation of the Three Geoelectrical Measurement Points

Based on the lithological characteristics and layer thicknesses, the investigation area demonstrates considerable groundwater potential and relatively low susceptibility to geological hazards such as land subsidence. These findings suggest that groundwater extraction in Gili Trawangan may be considered for domestic and commercial purposes, provided that sustainable groundwater management and environmental monitoring are implemented.

5. Groundwater Potential

Based on groundwater drilling data obtained from Gili Trawangan, the groundwater table was identified at approximately 1 m below the ground surface (Table 3).

Table 3. Groundwater Table Conditions in Gili Trawangan

Location	X Coordinate	Y Coordinate	Elevation (m)	Production Well	Well Depth (m)	Groundwater Level (-m)	Discharge (L/s)
Gili Trawangan	116°02′25.7″	08°20′27.5″	13	GT 01	15	1	22.22
	116°02′25.6″	08°20′27.5″	13	GT 02	20	1	41.67

Shallow groundwater was encountered at depths of approximately 1–2 m and was identified as a brackish aquifer associated with coastal alluvial deposits. At depths ranging from 2–6 m, a relatively compact coral reef layer with limited pore spaces was identified. This layer exhibits low groundwater storage potential and is therefore interpreted as a low-productivity aquifer layer.

Saline groundwater-bearing formations were identified at depths ranging from 6–65 m, consisting of alternating sandy volcanic sediment layers and coral reef deposits with an approximate thickness of 59 m. The aquifer system was classified into an unconfined aquifer at depths of 6–15 m and a confined aquifer at depths of 30–65 m.

6. Pumping Test

Groundwater level fluctuations have not yet been determined precisely; therefore, an estimated groundwater level variation of approximately 5 m was adopted for fluid mechanics calculations. The influence drawdown effect under an average pumping rate of 20 L/s at a distance of 125 m resulted in groundwater level depletion of approximately 0.5 m.

The constant-rate pumping test (Long Duration Pumping Test) is an aquifer test conducted under a fixed discharge rate within a specified period. In the constant-rate pumping analysis, a linear relationship between drawdown and discharge was plotted on semi-logarithmic paper. When $t/t_0 = 10$ and $\log(t/t_0) = 1$, the parameter S can be replaced by the drawdown difference over one logarithmic cycle of observation time.

7. Recovery Test

Following the completion of the constant-rate pumping test, the pump was turned off and a recovery test was conducted simultaneously. The calculation procedures for the recovery test were identical to those used in the pumping test analysis.

Aquifer parameters were estimated through semi-logarithmic plotting between pumping time (minutes) on the logarithmic scale and groundwater drawdown (meters) on the linear scale using the Jacob method developed by Cooper and Jacob (1946). The transmissivity values for wells GT–01 and GT–02 were calculated as

925.14 m^2/day and 1734.96 m^2/day, respectively, while permeability values were estimated as 308.38 m/day and 578.32 m/day. The aquifer type was classified as an unconfined aquifer.

Table 4. Constant-Rate Pumping Test Results

No.	Production Well	Transmissivity (m^2/day)	Permeability (m/day)
1	GT 01	925.14	308.38
2	GT 02	1734.96	578.32

The rapid recovery of groundwater levels to their initial conditions indicates that the aquifer system in the study area exhibits characteristics of an unconfined aquifer.

8. Water Quality

Groundwater quality assessment was conducted based on groundwater quality criteria established by the Decree of the Ministry of Energy and Mineral Resources No. 1451 K/10/MEM/2000 dated November 3, 2000. Groundwater quality in Gili Trawangan was generally classified as good, except for salinity parameters. Groundwater wells in the study area commonly exhibited relatively shallow groundwater levels ranging from approximately 0.5–2.5 m below the ground surface.

D. CONCLUSION AND SUGGESTIONS

The geoelectrical results indicated the presence of five subsurface lithological layers arranged sequentially from the surface, namely coastal alluvium, coral reef deposits, fine sand (volcanic sediments), coarse sand/coral reef deposits, and fine sand (volcanic sediments). The constant-rate pumping test analysis yielded transmissivity values ranging from 925–1,734 m^2/day and permeability values ranging from 308–578 m/day. Hydrogeological Borehole Log and recovery test analyses indicated that the aquifer system is predominantly characterized as an unconfined aquifer. Pumping activities with capacities of 61.6 L/s and 16.6 L/s at the two bore wells resulted in only a 0.5 m decline in groundwater levels, while recovery to the initial groundwater level occurred within approximately two minutes. Water quality observations indicated that groundwater in the study area was predominantly characterized by alkaline pH conditions and relatively high electrical conductivity values. Based on groundwater potential and recovery test results, groundwater extraction in Gili Trawangan may be considered feasible, provided that appropriate groundwater management and environmental monitoring measures are implemented.

To ensure the sustainable utilization of groundwater resources, appropriate groundwater well management based on hydrogeological analyses should be implemented as follows: (1.) The safe discharge (*optimum flow rate*) for each groundwater well is estimated at approximately 50 L/s, with a maximum pumping water level of 1–2 m below the top reference level; (2) Simultaneous pumping operations may be conducted continuously for up to 7 × 24 hours, followed by a recovery period of approximately 12 hours; (3) Each groundwater well on Gili Trawangan should undergo re-evaluation after one year of operation, or at a maximum interval of two years, to determine the coefficient of well loss, coefficient of aquifer loss, and drawdown characteristics. This evaluation is also necessary to assess well performance and identify potential clogging along the well screen using borehole camera inspections before determining appropriate schedules for well development or maintenance procedures.

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