Groundwater Potential of Botubarani-Huangobotu Village for Groundwater Conservation Efforts in the Gorontalo Bay Geopark Development

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Abstract. Botubarani-Huangobotu Village, a coastal tourist area of Tomini Bay Beach, is part of a Geopark focused on conservation, education, and sustainable economic development. This study aims to assess groundwater availability and develop a conservation plan for the Tomini Bay Geopark. The research involved field data collection, data processing, and analysis to evaluate aquifer characteristics, topography, and groundwater flow direction. The geological conditions of the study area are rock contact between conglomerate of various materials and clastic limestone. Lithologic types are coastal deposits of Foalstone, volcanic breccia, diorite and andesite. Geomorphological units are volcanic hills, marine plains and structural hills. The Botubarani-Huangobotu area has high groundwater potential in coastal areas with high porosity reef limestone rock types. Depth to water table (MAT) is 1-13 meters. Groundwater flow moves towards the coast. Groundwater conservation strategies are mechanical and vegetative approaches with measures such as water monitoring, geo-conservation education, and community-based technology extension to encourage community participation in environmental conservation through tree planting.

Keywords: groundwater potential, water conservation, geopark development, hydrogeological

1 Introduction

Indonesia is known worldwide as a mega geodiversity country because it is rich in geological resources [1]. Geopark is a geographic area that has a geological heritage and geological diversity of high value, including biodiversity and cultural diversity that are integrated in it [2, 3]. This area is developed with three main pillars, namely conservation, education, and local economic development, as well as sustainable tourism [4]. Groundwater is a crucial natural resource for environmental sustainability and human life [5].

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In the midst of increasing challenges related to sustainability and environmental protection, groundwater conservation has become one of the main issues attracting attention in the context of geopark development [6]. One potential area of interest is Botubarani-Huangobotu Village, located in the coastal area of Tomini Bay, which is rich in geological, biological, cultural diversity and natural beauty. The biodiversity in this area provides significant added value, making it a strategic location for conservation efforts.

Botubarani Village has six geodiversity, including the Botubarani Geosite, Botubarani Foaltstone Cliff, Volcanic Breccia Cliff, Diorite Intrusion and Andesite Lava Mineralization. Currently, Botubarani Limestone is designated as a locally ranked geological heritage (Geoheritage) and a Geosite site that has the potential to become the Gorontalo Tomini Bay Geopark [7].

However, research on groundwater potential in the region is limited. These research gaps include the lack of comprehensive data on groundwater availability and movement, as well as effective conservation strategies that suit local geological and ecological conditions.

In the era of globalization and rapid climate change, the need for groundwater conservation efforts is becoming increasingly urgent [8]. The development of the Tomini Bay Geopark as part of Indonesia's environmental conservation efforts requires more in-depth research into the potential of groundwater in the region. Botubarani-Huangobotu Village, with its breathtaking natural landscape and rich geological heritage, has a strategic role to play in groundwater conservation efforts aimed at preserving the local ecosystem and supporting the sustainability of the Tomini Bay Geopark.

Understanding the importance of maintaining ecosystem balance and the urgent need to protect groundwater resources [9], this study aims to determine the availability of groundwater in Botubarani-Huangobotu Village and propose appropriate groundwater conservation strategies to support the sustainable development of the Tomini Bay Geopark.

This research seeks to answer specific questions about the role of aquifers, groundwater flow directions and critical recharge areas, and how conservation strategies can be effectively implemented in the local context.

2 Method

2.1 Description of Location

The research site is administratively located in Botubarani and Huangobotu Villages, Kabila Bone Sub-district, Bone Bolango Regency, Gorontalo Province, with coordinates of 0'28'38.42" LU and 123"5'38.79 "BT..

2.2 Data Collection

Geological and hydrogeological studies were conducted through field surveys to understand the geological conditions and hydrogeological characteristics in Botubarani-Huangobotu Village [10].

The research method consists of the preparation of tools and materials, field data collection including observation of outcrops and lithology description, measurement of rock contact and measurement of wells in settlements in Botubarani-Huangobotu Village to analyze water quality and physical condition of residents' wells.

2.3 Data Analysis

The data processing stage involved lithological analysis to identify rock types and lithological lineations on the study area map. Furthermore, based on the lithological analysis and literature study, historical reconstruction was conducted. Evaluation of rock units and geological structures aims to determine aquifer characteristics.

Aquifer characteristics, topography and groundwater flow direction were evaluated to determine groundwater accumulation and movement zones.

The results of the analysis and the resulting geological and hydrogeological maps will recommend a groundwater conservation plan in Botubarani-Huangobotu Village.

3 Result and Discussion

3.1 Geology of the Surrounding Area

Based on the results of the research, it is known that the research area has five types of lithology, as can be seen in the figure below (Figure 1).

Costal Sediment Coastal deposits are materials brought down by river water or floods from high altitude areas that are deposited on the beach which results in siltation of sea water.

Foalstone Foaltstone is a type of limestone characterized by grains consisting of organic skeletal fragments (¡10%) embedded in a carbonate matrix.

Volcanic breccia Volcanic breccia is a rock that consists mainly of angular fragments resulting from brecciation or emplacement due to volcanic action.

Diorite Diorite is one type of deep igneous rock (Plutonic Rock), feneric in texture, coarse to medium grained minerals, rather dark in color. Diorite rocks contain large amounts of calsiksodik plagioclase feldspar with many sodic types.

Andesite Andesite is a type of volcanic igneous rock, extrusive, medium composition, with afanitic to porphyritic texture.

The study area has 3 geomorphologic aspects as shown below (Figure 2).

The division of geomorphological units of the study area is based on the analysis of topographic maps by looking at contour patterns that reflect a form of landscape. In the division pay attention to the density and looseness of contours and typical contour

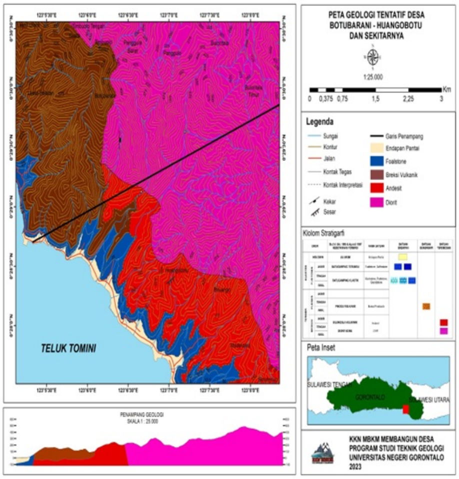

Fig. 1. Tentative Geological Map of Botubarani-Huangobotu Village and Its Surroundings

patterns such as circular patterns or forming a straightness, morphometry and morphogenesis. Based on the results of the calculation of height difference and morphometry, the research area consists of 3 types of morphology, namely: 1) Volcanic hills, 2) Marine plains, and 3) Structural hills. Volcanic hills are landforms derived from volcanic activity, both formed from volcanic material that has reached the earth's surface (extrusive) and frozen within the earth's surface (intrusive). Maritime plains are landforms found along the coast. The development process of coastal areas is strongly influenced by the depth of the sea. The shallower the sea, the easier the formation of landforms in coastal areas, while the deeper the sea, the slower the process of forming landforms in coastal areas. Structural hills are a process of land formation caused by endogenous processes. For example, the process of uplift, subsidence and folding of the earth's crust.

Observation of the topographic map is carried out by analyzing the symptoms of geological structures such as indications of the straightness of the bank or the straightness of the river. Based on the results of the analysis of the alignment pattern of mountains and rivers/valleys on the topographic map, the direction of the alignment pattern is northeast-southwest and southeast-west.

3.2 Groundwater Availability

Groundwater availability research was conducted using the well measurement method to determine the potential of groundwater in the study area and determine the direction of groundwater flow. The following is the well measurement data as shown in the table below:

Table 1. Botubarani Village Well Measurements

Code	Location	Elevation (m)	Depth (m)	Distance (m)	Head Loss (m)
B1	0°28’34.4”/123°5’58.9”	4	2.32	0	0.78
B2	0°28’34.7”/123°5’56.6”	4	2.51	35	0.73
B3	0°28’37.4” /123°5’56.5”	9	4.31	40	0.32
B4	0°28’37.9”/123°5’57.8”	18	3.6	20	0.66
B5	0°28’39.9”/123°5’54.4”	5	6.57	50	0.78
B6	0°28’35.5”/123°5’53.9”	4	2.6	60	0.7
B7	0°28’35.7”/123°5’52.3”	1	2.9	27	0.6
B8	0°28’37.8”/123°5’51.1”	10	4.43	43	0.73
B9	0°28’36.2”/123°5’49.2”	9	3.5	20	0.68
B10	0°28’36”/123°5’48.9”	10	3.33	7	0.81
B11	0°28’34”/123°5’49”	3	2.86	23	0.77
B12	0°28’33.2”/123°6’1.1”	3	3.64	100	0.58
B13	0°28’32.6”/123°6’1.9”	6	4.7	10	0.78
B14	0°28’32.7”/123°6’3”	12	5.6	6	0.74
B15	0°28’36.2”/123°6’6.7”	11	13.73	35	0.75
B16	0°28’26”/123°6’7.6”	18	5.8	100	0.7
B17	0°28’24.4”/123°6’7.8”	8	5.34	42	0.75
B18	0°28’23.5”/123°6’5.8”	4	3.48	30	0.84
B19	0°28’24.2”/123°6’4.7”	4	2.4	45	0.75
B20	0°28’25.5”/123°6’5”	4	3.7	20	0.81

3.3 Groundwater Potential of the Study Area

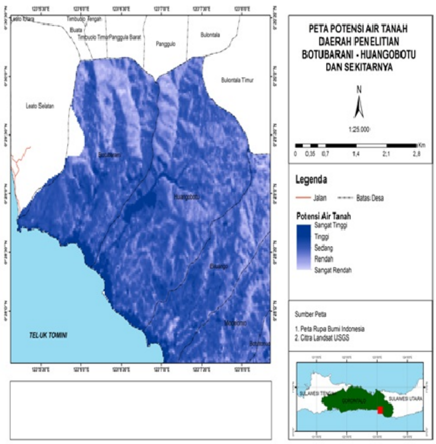

Fig. 2. Map of Groundwater Potential of Botubarani-Huangobotu Village and Its Surroundings

Table 2. Soil Water Content Measurement in Botubarani Village

Code	Location	Soil Depth (cm)	Water Content (%)	Soil Moisture (%)
S1	0°28’34.4”/123°5’58.9”	10	20.5	15.3
S2	0°28’34.7”/123°5’56.6”	20	18.7	14.8
S3	0°28’37.4”/123°5’56.5”	30	22.1	16.5
S4	0°28’37.9”/123°5’57.8”	40	19.3	12.7
S5	0°28’39.9”/123°5’54.4”	50	21.6	17.2
S6	0°28’35.5”/123°5’53.9”	60	23.4	18.0
S7	0°28’35.7”/123°5’52.3”	70	17.5	13.2
S8	0°28’37.8”/123°5’51.1”	80	24.2	19.5
S9	0°28’36.2”/123°5’49.2”	90	16.3	12.1
S10	0°28’36”/123°5’48.9”	100	25.1	20.7

Based on Landsat data from the United States Geological Survey (USGS), research into groundwater potential in this area shows that the area around the coastal edge, which can be identified by the dark blue color on the map (Figure 2), has high groundwater potential. This finding is reinforced by the 1:25,000 scale geological map for the study area (Figure 2), which shows that the area with high groundwater potential consists of reef limestone. Direct field observations show that the reef limestone has an adequate level of porosity, making it suitable as a groundwater aquifer [11].

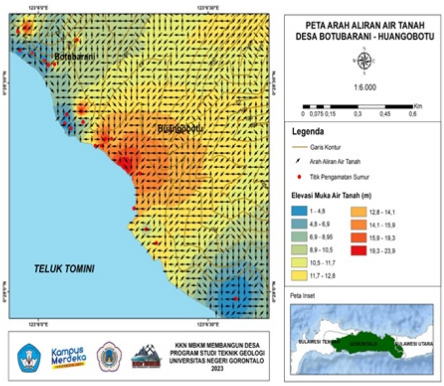

Fig. 3. Groundwater Flow Direction Map of Botubarani-Huangobotu Village

Based on field data, well data collection was conducted at 32 points located along the East-West direction in the study area. As a result, a groundwater flow direction map was obtained using ArcMap 10.8. From the visualization of the groundwater flow direction map, it can be seen that the water flow in the study area flows from higher to lower areas, indicated by arrows and color indices that reflect the elevation of the water table. It is clear that the flow of water in the study area is generally towards the coast. This finding is in line with the groundwater potential map prepared using Landsat imagery (Figure 3).

In comparison with previous studies, the findings in this research align with those reported by Herawati et al. [12], who identified reef limestone as a significant groundwater reservoir in coastal areas due to its high porosity and permeability. This consistency supports the current study's results showing high groundwater potential in reef limestone regions.

Additionally, the study by Susilowati et al. [13] emphasized the influence of geological formations on groundwater availability, highlighting volcanic breccia and diorite as less favorable for groundwater storage compared to limestone. This aligns with the current findings, where volcanic breccia and diorite areas show lower groundwater potential.

The methodology used in this research, which includes well measurements and Landsat data analysis, offers a comprehensive assessment of groundwater potential. This approach is more robust than relying solely on geological mapping or remote sensing data alone, as seen in earlier studies.

3.4 Groundwater Conservation Strategy

Groundwater conservation is an important requirement in maintaining and managing groundwater availability. Conservation approaches can be done mechanically and vegetatively.

Mechanical conservation, such as infiltration channels and rorak in terrace gulud system, emphasizes on technical approach in its management. Meanwhile, vegetative conservation involves the use of plants, such as Beringin, Bulu, Jambu Air, jati bongsor, mahogany, kayumanis, ulin wood, and sengon, to maintain soil moisture, prevent erosion, and reduce water evaporation.

Ground cover plants play an important role in lowering the risk of groundwater level decline by reducing evaporation, stabilizing the soil through their roots, and reducing water flow to prevent erosion.

Groundwater conservation measures also include groundwater monitoring, groundwater geo-conservation education, and community-based groundwater conservation technology extension to engage communities in environmental conservation and tree planting efforts [14, 15].

3.5 Practical Implications for Local Groundwater Management

The findings of this study have several practical implications for the management and conservation of groundwater resources in the Botubarani-Huangobotu area:

Resource Allocation High groundwater potential areas identified in this study, particularly those with reef limestone, should be prioritized for water extraction and development projects. This prioritization can help in planning sustainable groundwater use without overexploiting less productive areas.

Conservation Strategies Conservation strategies should focus on protecting the recharge zones of high potential areas. This includes preventing contamination and managing land use changes that could affect the permeability and porosity of the aquifer materials.

Community Planning The data can inform community and urban planning, ensuring that settlements and agricultural activities are aligned with areas of high groundwater potential to optimize water resource management and reduce the risk of water scarcity.

Future Research Directions Further research could explore the dynamic changes in groundwater levels in response to climatic variations and human activities. This would enhance the predictive capacity for groundwater management and ensure long-term sustainability.

The integration of geological, hydrological, and remote sensing data in this study provides a holistic view of groundwater potential, aiding in effective decision-making for groundwater resource management in the study area.

4 Conclusion

This study of the Botubarani-Huangobotu area revealed significant insights into its geological and groundwater conditions. The area's lithology consists of coastal sediment, foalstone, volcanic breccia, diorite, and andesite, with geomorphological features including volcanic hills, marine plains, and structural hills. Key geological structures align in northeast-southwest and southeast-west patterns.

Groundwater assessments indicated high potential in coastal areas with reef limestone due to its high porosity, with water tables ranging from 1 to 13 meters and flow predominantly towards the coast. Conservation strategies should prioritize mechanical and vegetative methods, groundwater monitoring, geo-conservation education, and community-based initiatives.

For future research, a focus on detailed hydrogeological modeling to better understand groundwater dynamics is recommended. Investigating the impacts of seasonal variations and climate change on groundwater levels, exploring and implementing innovative groundwater conservation technologies, and studying the effects of human activities on groundwater recharge and quality are also crucial. This study's comprehensive approach, integrating geological, hydrological, and remote sensing data, provides a solid foundation for effective groundwater management. The findings and recommendations offer valuable guidance for sustainable resource allocation, community planning, and conservation efforts, ensuring long-term water availability and protection in the Botubarani-Huangobotu area.

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