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# Analysis of Alternative Clean Water Supply in Bira Beach Tourism Area, Bulukumba Regency

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***Abstract*—** Clean water is used daily for drinking, sanitation, and other activities that support human life. Clean water has requirements in terms of quality and quantity. Clean water requirements include physical, chemical, and biological parameters with specific threshold values so that, it will not cause side effects when consumed. The quantity of clean water provided can be seen from the amount of raw water available to meet regional needs. This study aims to determine the potential for a clean water supply in the Bira Beach Tourism Area of Bulukumba. The alternatives include boreholes, Regional Drinking Water Company, rainwater harvesting, domestic wastewater reuse, and seawater desalination. The method used in this research is Break Event Point (BEP) to determine the economic price of each alternative water supply and the Analytical Hierarchy Process (AHP) method to choose the most suitable alternative to be used by calculating six criteria, namely quality, quantity, continuity, ecology, and technology. The results of this study indicate that the lowest BEP value is a borehole at IDR 302, then Regional Drinking Water Company at IDR 2,500, seawater desalination at IDR 4,022, domestic wastewater reuse at IDR 6,300 and rainwater harvesting at IDR 16,834, and the results of research using the AHP method rainwater harvesting and wastewater reuse get the highest value of 108.52 and 69.04 respectively.

***Keywords*—**Clean Water, Water Quantity, Water Supply, Water Treatment, Tourism Area.

## I. Introduction

Indonesia is a country with a coastline of 93,083 km. The transition between land and ocean forms a diverse and highly productive ecosystem that provides diverse and highly productive ecosystems that can provide economic value to humans. With the length of coastline owned by Indonesia, the management of coastal areas can be adjusted to their utilization, depending on the uniqueness potential, coastal physique, environmental impacts, and local communities (Sfarliana et al., 2021).

Coastal areas, in the context of landscape, are where land and ocean meet. Furthermore, coastal areas are essential from various planning and management perspectives (Kristian, 2021). The coastal area is a meeting point between two natural characteristics, land and water, and can be a potential tourist destination. Tourists are willing to pay a high price to enjoy the beach view, making the coastal area a tourist attraction that will not be timeless. Various forms of activity and development are carried out to improve and add value to tourism in coastal regions (Sfarliana et al., 2021).

Tourism is one of the sectors that aims to increase foreign exchange. As the largest archipelago country, it can utilize this capital to develop coastal area tourism, which aims to increase national income and improve the welfare and prosperity of the people (Prastika & Sunarta, 2018). Bira Beach is in Bulukumba Regency, one of South Sulawesi Province's tourist destinations. This ares is known as "Bumi Panrita Lopi", Phinisi ships are made, and several potential tourist attractions exist. Bira Beach has a stretch of fine white sand with a depth of 1-2 m. the absence of dangerous marine life makes this beach very safe as one of top tourist destinations. However more than the vast potential is needed to guarantee this beach to be a potential beach in a sustainable manner, one of causes is the problem of inadequate facilities and infrastructure, one of which is related to the availability of clean water. Every year, tourist visits also increase, so the need for clean water is also getting higher, so it is necessary to develop the right plan to choose an alternative clean water supply. The clean water source used by the Bira Beach Tourism Area community originally came from Regional Drinking Water Company. However, according to information obtained from local village officials, Regional Drinking Water Company water is currently insufficient for water needs because of its uneven distribution. It has yet to be distributed to the tourist area.

The local community then looks for alternatives by buying water outside the Tourist Area to meet their daily watter needs for IDR 25,000-35,000 for 1 m3 of water, including delivery costs to the Tourist Area. The dificully of clean water availability the impacts the high cost of lodging in the Tourist Area. According to residents, the making of boreholes is problematic because of the high salinity of the water near the shoreline and springs are found at depths above 35 meters underground. Some residents with drilled wells also sometimes buy water outside the Tourism Area to meet their daily water needs.

Problems with clean water availability often occur in coastal areas. Lack of public understanding of the utilization and management of clean water will impact the scarcity of clean water for daily needs (Sofyan A.P et al., 2023). The need for clean water continues to increase, especially in coastal or coastal residential areas, so a clean water treatment unit is needed. Due to limited groundwater sources, saltwater or seawater is another hope that can be used to meet water needs (Krisdiarto et al., 2020). The economic situation in coastal areas is limited because limited livelihood factors influence it due to low financial capital, low education, and limited skills (Huwaina et al., 2022).

Water treatment is manipulating water sources to obtain quality that meets specific objectives or standards (Putra & Zevi, 2021). Water supply is a sustainability issue, which can meet the needs of the current community without ignoring the needs of future generations (Mustikawati, 2022). The United Nations released a plan to implement sustainable development as the Sustainable Development Goals (SDGs), which also addresses the issue of access to clean water and sanitation. Many countries have implemented clean water and sanitation programs to achieve goal six of the SDGs (Fakhriyah et al., 2021).

Water is one of the supports in life, and it has a vital role in human life (Silangen et al., 2020). Clean water meets the requirements in terms of quality (physics, chemistry, biology) for daily use. The amount of water on earth is permanently fixed, but because the hydrological cycle and the conditions of each region vary, resulting in the amount of water available in an area at any given time is uneven, so sometimes there is a shortage of water (Aronggear et al., 2019).

The main problem regarding water resources is the quantity that can no longer meet the needs while the water demand continues to increase. To support the continuous availability of water, access to clean water, access to adequate sanitation, water quality, and management and conservation of water resources are required. To achieve these goals, government and non-governmental organizations can work together to translate them into concrete guidelines and action plans (Fakhriyah et al., 2021).

Several water sources, namely atmospheric water, fall to the earth's surface. However, please note that the composition of this water is only about 0.001% of the total amount of water on earth. Surface water comes from rainwater that flows on the earth's surfaces because it is not absorbed into the soil, so puddles will form and flow to the lower right. This water is called a river, groundwater, or water beneath the soil. It accounts for about 0.6% of all the water on Earth (Rolia et al., 2023). Several factors, including distance to the sea, groundwater depth, rock porosity, and human activities, influence groundwater in coastal areas. The season is also an influential factor, because in the dry season has greater potential for seawater intrusion than the rainy season (Febriarta, 2020).

In Indonesia, there is a rainy season and a dry season. The amount of water an area uses throughout the year depends on these two seasons. The rainy season brings a massive increase in water, while the dry season causes water shortages. The dry and rainy seasons present a dilemma for the people of Indonesia. These conditions take the form of disasters caused by water availability (Alfin et al., 2022).

Water availability based on its source is one of the primary capitals of development. Wise action is needed to maintain water availability according to quality, and quantity is maintained. In addition, a good water supply must serve adequate water needs and receive a positive response and support from the community (Aminuddin et al., 2023).

The hydrological cycle and the different conditions of each region result in an uneven amount of water in a place at a specific time. As a result, humans who need water at this particular place and time will experience water shortages. Clean water management consists of processing raw water sources and flowing and distributing clean water to the service area. An integrated water resources management system can provide water to consumers. The provision of clean water has a vital role, especially in the field of environmental or public health, which can reduce the number of people suffering from diseases, especially those related to water, and play a role in improving the quality of life of the community (Putri et al., 2023).

Quantity in the provision of clean water is reviewed based on the amount of raw water available; the raw water can be used to meet the needs according to the needs of the region and the number of inhabitants. Water quantity requirements can also be reviewed from the standard of clean water discharge that is flowed to the community according to the amount of clean water demand (Rolia et al., 2023).

The demand for clean water generally increases every year while its availability is increasingly limited. This is due to the narrowing of infiltration areas, the large number of developments that do not pay attention to the balance of water supply. Development that does not pay attention to the balance of nature and exploitation of raw water sources. To anticipate no water crisis, it is necessary to maintain and preserve existing water sources, be efficient in water use and find new alternative sources (Suheri et al., 2019).

## II. Methods

The location that is the object of this research is Bira Village, Bonto Bahari District, Bulukumba Regency, South Sulawesi Province.

### *A. Data Collection*

Respondent data and information were collected through interviews and questionnaires. Interviews were conducted to obtain information from respondents about the use and availability of clean water and alternative clean

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water supplies around the Bira Beach Area. The questionnaire consists of several written questions used to record information related to the respondents.

*B. Projected Water Demand*

This research projected clean water demand by considering tourists using the regional carrying capacity method. Area Carrying Capacity (ACC) is the maximum number of visitors who can physically be accommodated in the area at a certain time. The formula for calculating the area's carrying capacity can be seen in equation (1) (Retraubun et al., 2023).

$$AAC = K \times \frac{Lp}{Lt} \times \frac{Wt}{Wp} \quad (1)$$

Once the AAC is known, the water demand per person in the area is determined. Based on the Department of Public Works 1996, the water demand for tourism objects is 0.1 – 0.3 ltr/s/ha. Equations (2) – (8) show the formula for calculating the water demand.

Water use = 0.3 liters/s/ha x total tourist area (2)

Water demand/person = water use x ACC (3)

Then, calculate the total water demand on maximum days and weekdays:

Water usage/day (Max. day) = water demand org/day x number of tourist (4)

Water usage/year = tot. usage/day x nmb of max days (5)

Water consumption/day (Weekday) = water demand people/day x number of tourists (6)

Water usage/year = total usage/day x nmb of wkdays (7)

Total usage/year = water usage (max days)/year + water usage (Weekdays) (8)

In addition to water demand for visitors, calculations are carried out on water demand for employees. The formula for calculating the water demand for employees can be seen in equation (9)

Water demand = nmb of employees x water usage/day (9)

*C. Break Event Point (BEP)*

This research uses the Break Event Point (BEP) method to determine the economic price of each alternative water supply. BEP analysis helps in planning or decision-making. There are three cost components considered in BEP analysis, namely (Priskila Manuho, Zevania Makalare, Trixie Mamangkey, 2021):

1. Fixed costs are costs not affected by the volume of production. Some examples include building costs, land costs, machinery and equipment costs, etc.
2. Variable costs are costing whose amount depends (usually linearly) on production volume. Examples of variable costs include raw material costs and direct labor costs.
3. Total cost is the sum of fixed costs and variable costs.

There are two forms of break event point determination, which are as follows (Pelu et al., 2021):

1. Graph Method
   When determining BEP with a graph, it is necessary to describe the variables that determine BEP, such as total costs (fixed and variable costs) and total revenue. Firstly, draw a graph of the revenue function (TR) starting from the origin (zero point), and then this graph will rise from zero point to the upper right. Secondly, draw a fixed cost (FC) graph. This fixed cost graph parallels the quantity axis from left to right. Third, draw the total cost (TC), which starts from the intersection point between the FC graph and the vertical axis to the upper right intersecting the TR graph.

2. The Mathematical Method
   If using the mathematical method in Break Event Point, the formula used can be seen in equations (10) and (11).

$$BEP\ (Q) = \frac{FC}{P - V} \quad (10)$$

$$BEP\ (Price) = \frac{\text{Total } \textit{Coast}}{\text{Production Volume}} \quad (11)$$

*D. Analytical Hierarchy Process (AHP)*

AHP is a method for ranking alternative decisions and choosing the best based on several criteria. It develops a single numerical value to rank each alternative decision based on the extent to which each alternative meets the decision-making criteria. The first principle in the AHP method is the arrangement of hierarchies so that complex problems can be broken down into a more structured and systematic form of hierarchy (Permatasari, 2020).

Determination of clean water supply alternatives using the Analytical Hierarchy Process (AHP). The steps taken in the AHP method are as follows (Munthafa et al., 2017):

1. Define the problems and determine the desired solution.
2. Create a hierarchical structure that starts with the primary goal.

The advantages of the AHP method are hierarchical structure as a consequence of the criteria to be selected, down to the deepest sub-criteria, besides that it also takes into account the validity up to the tolerance limit of inconsistency as criteria and alternatives selected by decision makers by taking into account the durability of the output of decision-making sensitivity analysis.

In general, the hierarchical structure can be seen in Figure 1.


Figure. 1. Hierarchical Structure of the AHP Method

1. Create a pairwise comparison matrix that illustrates each element's relative contribution or influence to the objective or criterion above it. Can be seen in Table 1.
2.

Table 1. Pairwise Comparison Matrix

| | Criteria-1 | Criteria-2 | Criteria-3 | Criteria-n |
|---|---|---|---|---|
| Criteria-1 | C11 | C12 | C13 | C1n |
| Criteria-2 | C21 | C22 | C23 | C2n |
| Criteria-3 | C31 | C32 | C33 | C3n |
| Criteria-m | Cm1 | Cm2 | Cm3 | Cmn |

3. Define pairwise comparisons so that there are a total of n x [(n-1)/2] raters, with n is the number of elements being compared. Can be seen in Table 2.

Table 2. Pairwise Comparison Rating Scale

| Intensity of Interest | Description |
|---|---|
| 1 | Both elements are equally important. |
| 3 | One element is slightly more important than the other. |
| 5 | One element is more important than another. |
| 7 | One element is more important than the other. |
| 9 | One element is essential to the other. |
| 2,4,6,8 | Number value between two adjacent judgment values |
| Opposite | If activity i gets one number compared to activity j, then j has the opposite value compared to i. |

4. Calculate eigenvalues and test for consistency. If it is inconsistent, the data collection is repeated.
5. Repeating steps 3, 4, and 4 for the hierarchy level.
6. Calculating the eigenvector of each pairwise comparison matrix, which is the weight of each element for prioritizing elements at the lowest hierarchical level until it reaches the goal.

The calculation is done by summing the values of each column to obtain a normalized matrix, summing the values of each row, and dividing by the number of elements to get an average. If A is a pairwise comparison matrix, then the weight vector is of the form, the formula used can be seen in equation (12).

$$(A)(wT) = (n)(wT) \quad (12)$$

can be approached in a way:

a) Normalize each column j in matrix A, such that, the formula used can be seen in equation 13:
$$\sum a(i\,j)i = 1 \quad (13)$$
refer to as A'.
b) Calculate the average value for each row I in A' the formula used can be seen in equation 14:
$$Wi = 1\ n \sum a(i, j)\ I \quad (14)$$
With Wi is the I goal weight of the weight vector.

7. Checking the consistency of the hierarchy
Suppose A is a pairwise comparison matrix and w is a weight vector, then the consistency of the weight vector w can be tested as follows:

1. Count: $(A)(w)^T$
the formula used can be seen in equation 15:
$$t = \frac{1}{n} \sum \left(\frac{\text{element - i on } (A)(w^T)}{\text{element - i on } w^T}\right) \quad (15)$$
2. Calculate the consistency index with equation 16
$$CI = \frac{t - n}{n - 1} \quad (16)$$
3. Table 3 shows the random index Rin is the average value of selected Cis in A.

Table 3. Index RIn

| n | 2 | 3 | 4 | 5 | 6 | 7 | .... |
|---|---|---|---|---|---|---|---|
| RIn | 0 | 0 | 0 | 0 | 1 | 1 | .... |

4. Calculate the consistency ratio
Rasio consistency can use the formula in equation 17:
$$CR = \frac{CI}{RIn} \quad (17)$$
1. If CR < 0.1, then the hierarchy is moderately consistent.
2. If CR > 0.1, then the hierarchy is highly inconsistent.

## III. Results and Discussion

The Bira Beach Tourism Area is one of the areas experiencing a clean water crisis, even though every year there is an increase in the need for clean water due to the increasing number of tourist visits. Data from Regional Drinking Water Company Bulukumba Regency explains that the water supply to Bira Village and Darubiah Village will be 2500 m3/month from 2017-2023. This figure is estimated based on the volume of the water reservoir in Lahongka, whose capacity is 300 $m^3$, because the water matter usually used as a measuring device is no longer functioning (damaged).

Local people then look for alternatives by buying water outside the Tourist Area to meet their daily water needs for IDR 25,000-35,000 for 1 m3 of water, including the delivery cost to the Tourist Area. The difficulty of clean water availability then impacts the high cost of lodging in the Tourist Area.

According to residents, the construction of boreholes is problematic because of the water's high salinity near the shoreline, and the springs are found at a depth of more than 35 meters underground. Some residents with drilled wells also sometimes buy water outside the Tourism Area to fulfill their daily water needs. The analysis results show that the demand for clean water in the Bira Beach Tourism Area increases every year because there is a rapid increase in tourists.

The government should then be particularly concerned about immediately providing solutions for the provision of clean water sources. Table 4 shows the projection of clean water demand for the Bira Beach Tourism Area. Table 4 shows that the number of tourists has increased yearly except in 2021, when the number decreased somewhat due to the COVID-19 pandemic.

Table 4. The projection of clean water demand for the Bira Beach Tourism Area

| Year | Number of Tourists/Year | Requirement/year ($m^3$) |
|---|---|---|
| 2017 | 189181 | 15293.88864 |
| 2018 | 242367 | 19920.05136 |
| 2019 | 261034 | 21461.25456 |
| 2020 | 288384 | 23695.9992 |
| 2021 | 255962 | 21037.42368 |
| 2022 | 301260 | 24774.84144 |
| 2023 | 319218 | 26238.98448 |
| 2024 | 337176 | 27703.12752 |
| 2025 | 355133 | 29205.80064 |
| 2026 | 373091 | 30669.94368 |
| 2027 | 391049 | 32134.08672 |
| 2028 | 409007 | 33636.75984 |
| 2029 | 426965 | 35100.90288 |
| 2030 | 444923 | 36565.04592 |

In addition to projecting tourists' clean water needs, Table 5 calculates the projected clean water needs for managers/employees in the Bira Beach Tourism Area. Table 5 shows that managers/employees have increased even though the addition is only slightly yearly. This is directly proportional to the rising clean water needs in the Bira Beach Tourism Area.

Table 5. The Projected Clean Water for Managers/Employees

| Year | Number of Managers / Employees | Requirement/year ($m^3$) |
|---|---|---|
| 2017 | 89 | 1263.0168 |
| 2018 | 93 | 1319.7816 |
| 2019 | 94 | 1333.9728 |
| 2020 | 96 | 1362.3552 |
| 2021 | 98 | 1390.7376 |
| 2022 | 101 | 1433.3112 |
| 2023 | 103 | 1461.6936 |
| 2024 | 105 | 1490.076 |
| 2025 | 107 | 1518.4584 |
| 2026 | 109 | 1546.8408 |
| 2027 | 111 | 1575.2232 |
| 2028 | 113 | 1603.6056 |
| 2029 | 115 | 1631.988 |
| 2030 | 118 | 1674.5616 |

1. BEP Value

The economical price of alternative clean water supply in the Bira Beach Tourism Area is calculated using the equation using the Break Event Point (BEP) method. Table 6 and figure 3 shows the BEP value of each alternative source of clean water.

Table 6. BEP value of each Alternative Source of clean water

| No. | Alternative Source of Clean Water | BEP Value |
|---|---|---|
| 1 | Domestic Wastewater Reuse | IDR 6.300 |
| 2 | Seawater Desalination | IDR 4.022 |
| 3 | Communal Rainwater Catchment | IDR 16.835 |
| 4 | Regional Drinking Water Company | IDR 2.500 |
| 5 | Bore Wells | IDR 305 |

Based on the results of the analysis that has been carried out, the lowest BEP value is IDR 305, which is the BEP value of a borehole; the Regional Drinking Water Company with a BEP value of IDR 2,500, seawater desalination of IDR 4,022, domestic wastewater reuse of IDR 6,300 and rainwater harvesting of IDR 16,835. The high BEP value for the rainwater harvesting alternative is due to the large total cost required, while the production volume is relatively small.

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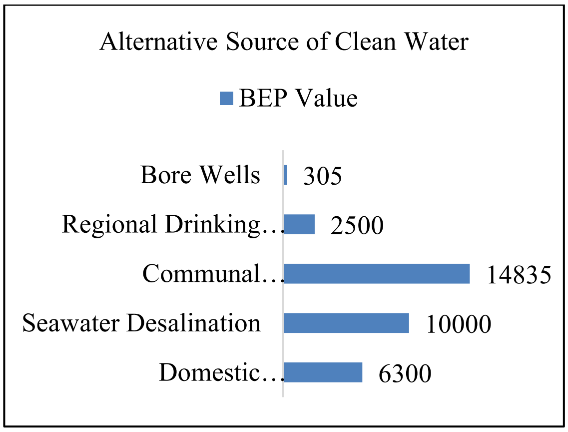


Figure. 2. BEP value of each Alternative Source of clean water

2. Alternative Clean Water Supply Strategy using the AHP Method

This research uses the AHP method to determine the right priority alternatives for strategies to fulfill clean water needs. Five criteria are considered when selecting water supply alternatives: quality, quantity, continuity, economy, ecology and technology availability. The resulting hierarchical structure can be seen in Figure 3.

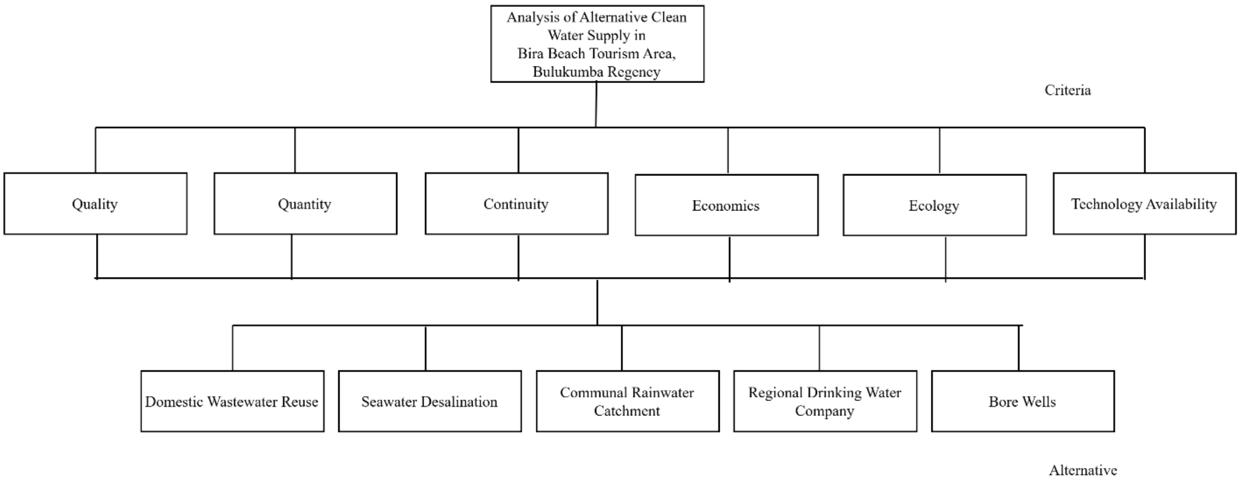


Figure. 3. Hierarchical Structure of Clean Water Fulfilment Strategies in the Bira Beach Tourism Area, Bulukumba Regency

Based on the observations made, it shows that clean water facilities are needed in the Bira Beach Tourism Area. For this reason, proper planning is needed to fulfill the need for clean water facilities and infrastructure in the area. Based on interviews conducted with local village officials, five alternatives can be used for clean water supply in the Bira Beach Tourism Area, namely domestic wastewater reuse, seawater desalination, Regional Drinking Water Company, rainwater harvesting (special distribution pipe for tourism area), and boreholes.

This study used the AHP method to determine the priority alternative strategies to fulfill clean water needs. The AHP results show that the combined assessment of the elements is consistent. This is indicated by the average consistency ratio (CR) value of 0.05, which fulfills the maximum allowed CR limit of 0.01.

Six criteria are considered in determining alternatives to fulfill clean water needs: quality, quantity, continuity, economics, technology, and ecology. The AHP results state that the main criterion in efforts to fulfill clean water needs in the Bira Beach Tourism Area is quality, with a score of 0.419, followed by economic criteria, quantity, continuity, ecology and technology, with scores of 0.2310; 0.1228; 0.1031; 0,0791 and 0.0445 respectively. Thus, each aspect must be considered when determining the strategy for fulfilling clean water needs in the Bira Beach Tourism Area.

The clean water alternatives analyzed in this study are domestic wastewater reuse, seawater desalination, communal rainwater harvesting, regional Drinking Water Company (special pipes for the Tourism Area), and boreholes. In terms of quality criteria for each alternative can be seen in Table 7 and the Table 8 shows the value of each criterion.

Table 7. Water Quality of each Alternative

| No. | Alternative Source of Clean Water | Water Quality |
|---|---|---|
| 1 | Domestic Wastewater Reuse | Good Quality |
| 2 | Seawater Desalination | Good Quality |
| 3 | Communal Rainwater Catchment | Medium Quality |
| 4 | Regional Drinking Water Company | Good Quality |
| 5 | Bore Wells | Poor Quality (Heavily polluted) |

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Table 8. AHP Value of Priority Alternatives on each Criterion

| | Domestic Wastewater Reuse | Seawater Desalination | Communal Rainwater Catchment | Regional Drinking Water Company | Bore Wells |
|---|---|---|---|---|---|
| Quality | 13.93 | 13.93 | 12.36 | 7.74 | 1.55 |
| Quantity | 7.41 | 7.41 | 6.59 | 5.76 | 2.47 |
| Continuity | 7.49 | 8.43 | 5.61 | 4.68 | 2.81 |
| Economics | 26.12 | 16.67 | 69.79 | 10.36 | 1.26 |
| Technology Availability | 3.96 | 2.64 | 5.28 | 10.56 | 11.88 |
| Ecology | 10.14 | 7.61 | 8.88 | 3.80 | 2.54 |
| Total | 69.04 | 56.68 | 108.52 | 42.90 | 22.50 |

Table 8 shows that the alternative of rainwater harvesting, and wastewater reuse gets the highest values of 108.52 and 69.04, respectively. Alternative recommendations for the fulfillment of clean water for Bira Beach Tourism Area can use a combination of alternative rainwater harvesting and wastewater reuse. The intended combination is that clean water sources can be obtained from rainwater harvesting in the rainy season. In contrast, clean water can be obtained from alternative wastewater reuse in the dry season.

## IV. CONCLUSION

Strategies to fulfill clean water needs in the Bira Beach Tourism Area can use a combination of alternative rainwater harvesting as a water source in the rainy season and reuse of domestic wastewater in the dry season.

The alternative of providing clean water by using rainwater harvesting is one of the environmentally friendly and sustainable alternatives. Still, this alternative can only be used during the rainy season. The production volume is relatively small, so it is necessary small, so it is necessary to combine it with alternative wastewater reuse, which is one of the sustainable strategies because it can support the sustainability of water resources by utilizing water efficiently, reducing environmental impacts and helping adapt to climate change.

Technological innovations such as the development of filtration technology and affordable water quality sensors and monitoring are needed for this alternative to ensure the treated water is safe to use and the need for public education to raise awareness about the benefits and how to use this alternative.

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