Rainwater harvesting as an alternative of freshwater supply in Balikpapan city – a case study of Institut Teknologi Kalimantan

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Abstract. Currently, 73% of the water demand in Balikpapan was only supplied from Manggar Reservoir, and it will continue decreasing parallelly with the increasing population. Regarding the population issues and the government's planning for the new capital city of Indonesia, Balikpapan will be a buffer city facing serious risk in water supply issues in the future. Therefore, this study seeks to analyze an alternative of water supply. Following the concepts in Water Sensitive Urban Design (WSUD), The rainwater harvesting (RWH) method was chosen for preventive analysis, and Institut Teknologi Kalimantan (ITK) as one of the reputable's universities in Balikpapan will be taken as a study location. The results obtained that the monthly water demand in ITK was ranged from 3228.34 m³ to 16632.97 m³. Using RWH, water supply analysis was obtained from 3790.62 m³ to 10697.31 m³ in various rainfall durations (0.5 to 2 hours) and 20 years projections (2022 to 2042). Following the obtained water supply. This study also reveals that the savings of total water usage can be reached from 24% to 100%, and around IDR 14,082,002 to IDR 37,035,390 is converted to currency. The highest saving reached due to water supply meets the water demand.

1. Introduction
Balikpapan city is one of the cities in East Kalimantan, which is the main gateway for East Kalimantan Province at the location of the transfer of the new capital. However, according to the research, it is known that Balikpapan city only relies on Manggar Reservoir as the leading water supplier of 73% of the total water needs and to meet the remaining water needs using deep wells and other surface water sources. The study also edifice in 2035, Manggar Reservoir can only meet the water needs of 60.7% of the total water needs. This can happen because of the development of the city, which has an impact on increasing the population in the future. Therefore, Balikpapan city needs to prepare in the face of the risk of water resource limitations.

In providing freshwater, ITK Campus also relies on PDAM Balikpapan city to fulfill water needs in the ITK campus. Therefore, the risks experienced by the City of Balikpapan can also have an impact on the ITK Campus, coupled with an increase in water needs at the ITK Campus every year. With these problems, preventive measures need to be taken in dealing with the problem through the
alternative provision of new water sources using the Rainwater Harvesting method on the ITK Campus.

The Rainwater Harvesting method is defined as a means of collecting or sheltering rainwater or surface flow at times of high rainfall for further use at times of low rainfall [2]. This Rainwater Harvesting method is one of the technical elements of Water Sensitive Urban Design (WSUD). WSUD is one of the green infrastructure approaches that was initially motivated by the role of water in an area, which needs to be regulated in line with regional development and the need for water.

Looking at the risks that can occur in the future, it is necessary to anticipate preventive measures in dealing with the problem of limited water resources in Balikpapan city in general and increased water needs in the ITK Campus in particular with alternative freshwater supply. Therefore, a study of the potential of freshwater supply with rainwater management using rainwater harvesting method on ITK Campus to find out the number of water needs on ITK Campus, potential water supply and considerable savings obtained through the application of rainwater harvesting method by utilizing the roof of ITK Campus building as a rain catchment area.

2. Methodology
The research was conducted at the study site in 2021 by collecting secondary data from rainfall data, academic civitas, water usage, roof area dimensions of each building, and others through the parties concerned.

The research continued by calculating the significant water needs in the last three years as the basis for considering the application in the projections for the coming year. They were then compared to the extensive use of water with the supply of rainwater obtained. Projections are made in 2022-2042 by optimizing water needs, rainwater supply for a particular duration, and possible savings from the rainwater harvesting method. This study also calculates the potential of water supply through rainwater in the mainstay condition and the potential of each unit area on the roof of the building in supplying water.

2.1. Location
The research location is located at the ITK Campus located on Soekarno Hatta Street, KM.15, Karang Joang, North Balikpapan, Balikpapan City, East Kalimantan.

Figure 1. Location of study.
2.2. Rainfalls in Study Area
This study shows the average maximum rainfall data in Balikpapan within 10 years in the following table.

| No | Year | Maximum Rainfall (mm) |
|----|------|-----------------------|
| 1  | 2011 | 119.60                |
| 2  | 2012 | 148.00                |
| 3  | 2013 | 94.00                 |
| 4  | 2014 | 102.50                |
| 5  | 2015 | 108.10                |
| 6  | 2016 | 75.60                 |
| 7  | 2017 | 198.00                |
| 8  | 2018 | 161.40                |
| 9  | 2019 | 165.80                |
| 10 | 2020 | 120.80                |

2.3. Roof Area
ITK campus currently has 8 existing buildings. This study utilizes the roof area on each ITK campus building as a rain catchment area. This is because the size of the roof is quite wide felt to be used as a rain catchment area. The total area of the roof building of the ITK campus is 0.010574 km². Examples of roof areas are as follows.
Figure 2. Building Roof Plan A, B, Dormitory and Integrated Laboratory (ITK Planning Subsection).

3. Result

3.1. Potential application of rainwater harvesting method

3.1.1. Water demand. The amount of water needs to be obtained by stimulating academic civitas with a large amount of water usage per day using the reference SNI 03-7065-2015. The estimated amount of water usage per day ranges from 50-80 liters/person/day. The amount of water needs in a month is calculated using the following equation [4]:

\[ B = D \times P \times \text{day} \]  

Where \( B \) is the number of water needs (m\(^3\)), \( D \) is the number of people and \( P \) is the amount of water used in one day (m\(^3\)) with reference SNI 03-7065-2015.

3.1.2. Potential Water Supply in The Application of Rainwater Harvesting Method. The potential water supply through the roof area of each building is calculated using a rational discharge formula and then calculated the volume of water obtained each duration of rain based on the discharge. The formula used is as follows [5]:

\[ Q = 0.028 \times C \times I \times A \]  
\[ V = Q \times \text{duration of rain} \]

Where \( Q \) is rational discharge (m\(^3\)/sec); \( C \) is the runoff coefficient; \( I \) is the intensity of rain (mm/h), \( A \) is the area of rain catchment (m\(^2\)), and \( V \) is the large volume of water (m\(^3\)). Table 2 below shows the recommended coefficient values by type.

| Description Area | C    | Description Area | C    |
|------------------|------|------------------|------|
| Lawns            |      |                  |      |
| Sandy soil, flat, 2% | 0.10 | Light areas      | 0.70 |
| Sandy soil, average, 2-7% | 0.13 | Heavy areas      | 0.80 |
| Sandy soil, steep, >7% | 0.20 | Park, cemeteries | 0.25 |
| Clay soil, flat, 2% | 0.17 | Playgrounds      | 0.35 |
| Clay soil, average, 2-7% | 0.22 | Railroad yard areas | 0.40 |
| Clay soil, steep >7% | 0.35 | Streets          |      |
| Unimproved areas (forest) | 0.15 | Asphalt and concrete | 0.95 |
| Business         |      | Brick            | 0.85 |
3.1.3. Potential application of rainwater harvesting method in 2018-2020. The calculation is continued by calculating the conditions on the ITK Campus if applying the Rainwater Harvesting method in the last three years, namely 2018-2020. Using the data, assumptions, and calculations made, a significant result of comparing water needs, water use, and rainwater supply in 2018-2020 are as follows.

![Comparison of water needs, water usage, and rainwater supply in 2018-2020.](image)

**Figure 3.** Comparison of water needs, water usage, and rainwater supply in 2018-2020.

Based on Figure 3, it can be seen that the amount of water usage each year is less than the estimated water needs through calculations made. This is due to several factors such as the erratic presence of students in each month due to the schedule of lectures and water usage by the academic community of ITK, both students and employees, who do not consistently achieve the forecast of water usage per day according to SNI 03-7065-2005 which is 50-80 liters/person/day. Therefore, there is a considerable difference in Figure 3. The amount of water needed is 988,500 m³ – 4,501.72 m³ per month.

The amount of water supply depends on the intensity of Rainfall per month so that in certain months it can be seen to have a more excellent supply than other months. The amount of water supply obtained ranges from 18,547 m³ – 2448,042 m³ per month. Based on Figure 3, it can be known that the water supply can meet water needs based on the amount of water use in natural conditions. Therefore, it is known that rainwater has the potential to become an alternative water source provider. Therefore, there will be substantial savings if this method is implemented in 2018-2020, shown in Table 3 as follows.

| Description Area       | C  | Description Area       | C  |
|------------------------|----|------------------------|----|
| Downtown areas         | 0.95 | Drives walk, and roofs | 0.95 |
| Neighborhood areas     | 0.70 | Gravel areas           | 0.50 |
| Residential            |     | Graded or no plant cover|       |
| Single-family areas    | 0.50 | Sandy soil, flat, 0-5%  | 0.30 |
| Multi-units, detached  | 0.60 | Sandy soil, average, 5-10% | 0.40 |
| Multi-units, attached  | 0.75 | Clay soil, flat, 0-5%  | 0.50 |
| Suburban               | 0.40 | Clay soil, average, 5-10% | 0.60 |
| Apartment dwelling areas | 0.70 |                      |     |

*Georgia Stormwater Management, 2016*
Table 3. Percent savings with rwh method implementation in 2018-2020.

| Year   | Water Usage Savings per month | Surplus per month |
|--------|-------------------------------|-------------------|
| 2018   | 3.08% - 100%                  | 2.17% - 49.71%    |
| 2019   | 6.09% - 100%                  | 11.78% - 395.89%  |
| 2020   | 22.27% - 100%                 | 5.36% - 72.60%    |

3.1.4. Potential application of rainwater harvesting method in 2022-2042. The research continued by calculating the potential application of this method in the projection of 2022-2042. The calculation is done by calculating the projected number of academicians in the future each year, water needs, rainwater supply, and the significant savings obtained through the application of this method. With hydrological analysis calculations, 124,797 mm of Rainfall is obtained as Rainfall in future projections. Using data, assumptions, and calculations made, a significant result of comparing water needs and rainwater supply in 2022-2042 is as follows.

Figure 4. Comparison of water needs and water supply in 2022-2042.

Through Figure 4, it was obtained that the water supply with a duration of 2 hours can meet the estimated water needs at the ITK Campus in 2022-2042 up to more than 50%. The water needs in 2022-2042 obtained ranges from 3228.34 m$^3$ - 16632.97 m$^3$, with the water supply obtained based on the variation of rain duration of 30 minutes - 2 hours is ranging from 3790.62 m$^3$ - 10697.31 m$^3$ per month. Based on these calculations, the potential of rainwater obtained can save the estimated water usage in the future. The savings gained through the implementation of this method are shown in Table 4 below.

Table 4. Percent savings with rwh method implementation in 2022-2042.

| Types of Savings                                      | Year 2022 – 2042                          |
|-------------------------------------------------------|------------------------------------------|
| Water Usage Savings                                    | 24% - 100% with surplus 231%             |
| Cost Savings in The Rainy Month (Dec-Jun)              | IDR15,490,202 – IDR46,661,667            |
|                                                       | (38% - 100% with surplus 201%)           |
| Cost Savings in Dry Months (Jul-Nov)                  | IDR14,786,102 – IDR37,912,604            |
|                                                       | (24% - 100% with surplus 164%)           |

3.1.5. Potential application of rainwater harvesting method per unit area. The research continued by calculating the potential application of this method per unit area (m$^2$) of the roof of the building. This is done to know the enormous potential for development in the future, in order to know the ample
water supply that can be accommodated immediately—using formulations 2 and 3, an enormous potential water supply with a variety of rain durations of 30 minutes, 1 hour, 1.5 hours and 2 hours with a period of 2 - 25 years of rain ranging from 0.0329 m³ – 0.0868 m³ per rainy day. The calculation result is shown in Figure 5 as follows.

![Figure 5. Potential water supply per unit area.](image_url)

3.1.6. Potential application of rainwater harvesting method with mainstay debit. Mainstay debit is the minimum possible discharge that can be met with an 80% chance of discharge, so the chance of a lower discharge from the flagship debit is 20%. In calculating the reliability of Rainfall and discharge based on possible events, use measures according to SNI 6738:2015 regulations, with the following formula.

\[
P = \frac{m}{n + 1} \times 100\%
\]  

(4)

Where P is the probability of data (%); m is the ranking of the data of the entire data; n is the amount of data, in this study using daily Rainfall in the last 10 years, so that the precipitation with a probability of 80% is 1.5 mm rainfall, which is shown through Figure 6 as follows.

![Figure 6. Rainfall probability curve.](image_url)

They then calculated the mainstay discharge in the roof area of the ITK Campus building based on the mainstay rainfall with a variation in the duration of rain 30 minutes, 1 hour, 1.5 hours, and 2 hours with the formulation of 2. Therefore, the results of the calculation of flagship debit in all ITK campus buildings are shown in Table 5 as follows.
Table 5. Mainstay Debit on Existing Buildings in ITK Campus.

| Duration of Rain | R (mm) | A (km²) | C   | I (mm/h) | Q (m³/sec) | Water Supply (m³) |
|------------------|--------|---------|------|----------|------------|------------------|
| 30 minutes       | 1.5    | 0.012808| 0.95 | 0.825482 | 0.002812   | 5.062            |
| 1 hour           | 1.5    | 0.012808| 0.95 | 0.520021 | 0.001772   | 6.378            |
| 1.5 hour         | 1.5    | 0.012808| 0.95 | 0.39685  | 0.001352   | 7.301            |
| 2 hours          | 1.5    | 0.012808| 0.95 | 0.327593 | 0.001116   | 8.036            |

So based on the table, it is known that in the mainstay condition, all existing buildings on the ITK Campus can harvest rainwater ranging from 5,062 m³ – 8,036 m³.

4. Conclusion
In the projection of 2022-2042, ITK Campus is estimated to have water needs ranging from 3228.34 m³ - 16632.97 m³ per month. Therefore, a sufficient water source provider is required to meet the needs of the water. By knowing the vast potential of rainwater in the last three years, which ranges from 18,547 m³ – 2448,042 m³ per month, it is known that rainwater has sufficient potential as an alternative provider of additional water sources.

The application of the rainwater harvesting method is handy in overcoming the problem of water resource limitations. In addition to providing alternative water sources, this method helps reduce water consumption and spend enormous water costs if utilized optimally. In this study, if rainwater harvesting method is applied to ITK campus, it is known that the potential that can be utilized is water supply in the projection of 2022-2042 every month with a rain duration of 30 minutes - 2 hours ranging from 3790.62 m³ – 10697.31 m³ per month, with a percent savings of 24% - 100% with a surplus of 231% per month and able to save water expenditure costs of IDR14,786,102 – IDR46,661,667. Therefore, it is necessary to apply the optimal rainwater harvesting method in future planning so that the potential of rainwater can be appropriately used as an alternative provider of freshwater sources.

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