P. ISSN 2527-9629, E. ISSN 2548-6675
JOURNAL OF ENVIRONMENTAL ENGINEERING AND WASTE MANAGEMENT
In Collaboration With:
Managed by Environmental Engineering Undergraduate Program, School of Engineering, President University, Jl. Ki Hajar Dewantara. Kota Jababeka, Cikarang Baru, Bekasi 17550 – Indonesia.

The Study of Rainwater Harvesting System for Supporting Green Campus

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Manuscript History

Received
04-08-2022
Revised
26-09-2022
Accepted
03-10-2022
Available online
14-04-2023

Keywords

Green Campus Concept;
Rainwater Harvesting;
Rain Intensity;
Water Demand

Abstract. Water is one of the most important elements for humans but nowadays, the growing demand for clean water and increasing of water scarcity are a serious issue that must be addressed. As an alternative solution, optimizing the use of high-intensity rain in Indonesia through the use of a Rainwater Harvesting system can help and also support the water conservation efforts that are also conducted in the green campus concept. **Objectives.** The purpose of this final project is to calculate the cost and saving possibility through applying the rainwater harvesting system both in water saving possibility and economic saving and provide the design of a rainwater harvesting system unit that is suitable for the Building A of President University. **Method.** Observation method was used in this final project to find out what is the water quality of the rainwater harvested and also used the documentation method for processing the secondary data. **Results.** Using the given rainfall data, the rainwater supply, in a year water saving through the use of rainwater harvesting system can reach around 148.8 – 154 m^3/year and saving around Rp. 208,320 over year for water cost. The storage tank capacity of the system was in the size of 840 liter with gutter is 9 inch in diameter and distribution pipe diameter is 8 inch.

1 Introduction

Water is one of the essential elements for human survival. Every activity in human daily life, such as cooking, washing, and other important activities, usually necessitates the use of water. Nowadays, the growing demand for clean water in major greater areas has been a serious issue that must be addressed. Around 5% up to 20% of the global society was predicted to live in absolute water scarcity ($500m^3$/C/Y) and expected to increase in the future [1].

In recent years, floods and droughts have hit various regions in Indonesia, where during the dry season, drought and water scarcity occur in many places, while when the rainy season comes, floods hit. The impact of climate change is unavoidable and must begin to be addressed. Based on the summary of BNPB's hydrometeorological disasters, throughout 2020 there have been 726 flood events. In August 2020 BNPB stated that flooding was the deadliest and dominant natural disaster that occurred from early January 2020 to August 2020 and it was recorded that more than 100 people died and 17 others were missing due to this disaster. Not only casualties, the flood disaster also caused losses to the housing sector, education, damaged public facilities, health facilities, educational facilities, and offices due to floods in 2020 [2]. The following is a graph of the intensity of flood events since 2011-2020, it can be seen that the highest flood intensity occurred in 2019 and sloping back in 2020. However, even though it looks sloping, the flood disaster is still detrimental.

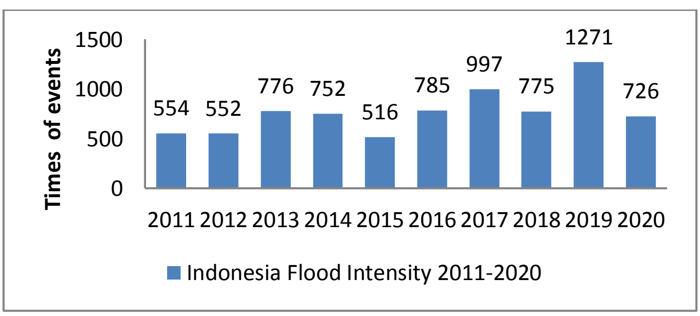

Fig. 1. Indonesia flood intensity 2011-2020
Source: Badan Nasional Penanggulangan Bencana

Land use change that does not pay attention to the possibility of environmental and disaster aspects also contributes to the increasing intensity of this disaster. Increased development that reduces water catchment areas causes the volume of runoff to burden the river bodies and results in over capacity and increased potential for flooding. The reduction in the catchment area also affects the availability of ground water which is generally used by the community as the main water source and ends with the problem of water scarcity and drought that hit various areas due to lack of ground water availability. It was recorded that in 2017, the Karawang district experienced a drought which affected 33 villages and resulted in as many as 20,325 people having difficulty getting access to clean water due to dry water sources [3]. At the end of 2020, BNPB recorded 29 drought events in the country [4]. In 2021, where September to November was the the rainy season but in some areas actually experienced drought with alert status. [5].

In the year of 2009, data from *Badan* Geology shown that around 40% of ground water was exploited which is exceed the recommendation of ground water exploited around 20%. The high percentage of ground water use will cause the land subsidence. Seeing the growing of population nowadays cause the continious development and change the land use purpose where its before was the water absorption area, now was covered by concreate. The decreasing of water absorption area make the rainwater that might be infiltrate to the soil and recharge the ground water become the surface water and flow to the lowland and it can cause a flooding [6]. If those problem was continuing and not tackle well, it will impact the water cycle.

Several anticipation and alternative solutions are needed to overcome those issues to reduce the negative impact that will face in the future also it is need to undertake the water conservation effort to also recharge the ground water. Several ways such as retention pond, installation of biopores and recycle water could be an alternative. By seeing the average rainfall rate in Indonesia, which around 2000 mm/year and such a high intensity, the utilization of rainwater can be made by maximizing the use of high-intensity rain in Indonesia through the use of a Rainwater Harvesting system [7]. Harvesting rainwater can save the potential of water resources that are wasted when water can no longer be accommodated in existing water bodies in drainage channels, rivers, weirs, lakes, and others. [8].

The solutions to tackle those issues can delivers in a huge or small scale. On of it is in the scale of education/university. In 2002, United Nation adopted the 52/54 resolution that state United Nations Decade of Education for Sustainable Development (2005-2014) that discuss how global plan to use the educational sector as a tool to discuss obstacle in the 21st century regarding the social, environment, economy and cultural issues.

In this era where the climate change has been a serious issue, many universities are starting to compete to have the prestige of a green campus. Many agencies have issued assessments/indicators related to this green campus, one of it, is the University of Indonesia through the UI Green Metrix. One of the assessment indicators is a water indicator.

President University is a private university located in the Bekasi district, North Cikarang. So far, domestic water needs for university buildings are fulfilled by the water supply distributed by the Jababeka Water Treatment Plant. North Cikarang itself is one of the areas with a fairly short rainy season but has a high rainfall intensity. The potential for rainwater itself can be utilized by applying a rainwater harvesting system (RWH System). Utilization of this system can save expenses for clean water and also hope the system could support the university to join and implemented the Green Campus Concept and do a water conservation efforts.

2 Method

2.1 Framework

Conducting this work, there were steps needed to be done, as shown in **Fig.2.** bellow:

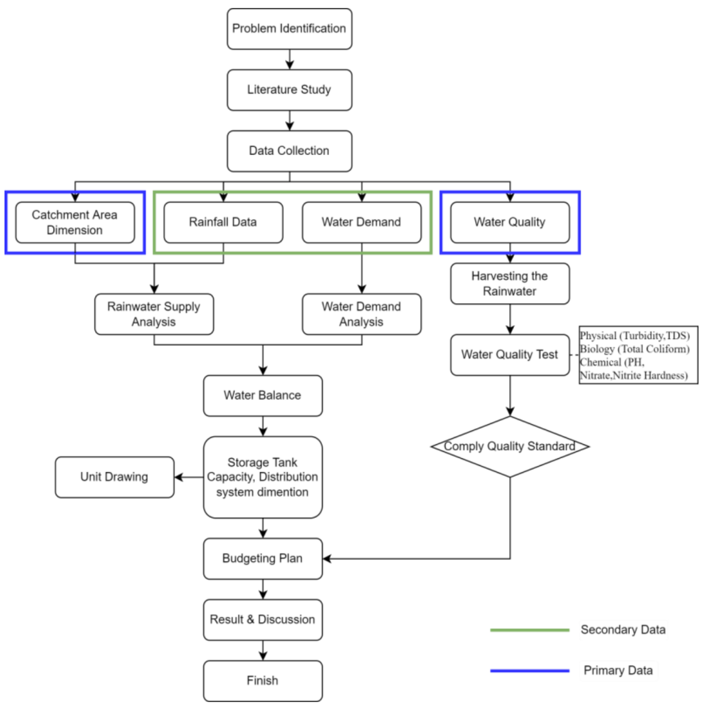

Fig. 2. Project Framework
Source: Personal Data (2022)

2.2 Data Collection Method

The observation and documentation method used to collecting the data. There is an experimental process needed to provide the rainwater quality. The observation method was done during the experimental process. The secondary data was collect through the documentation method from several sources.

2.2.1 Primary Data

- **Catchment area**, the catchment area was the rooftop of building A president University, the total area was measured using Google Earth application because there is no data provided by the University. Total catchment area was756 m^2 , with catchment area runoff coeficient is 0.8 by assume 20% of the rainwater isn't able to harvested.

- Rainwater Quality, the data collected from the laboratory experiment from the rainwater sample. The water quality was obtained from several experimental process such; Turbidity Test; Total Dissolve Solid Test; Total Colli form Test; PH Test; Hardness Test; Nitrate Test; and Nitrite test.

2.2.2 Secondary Data

- Rainfall Data, Rainfall data used was two years data of rainfall from the year of 2019 to 2020. The data was a secondary data get from the WWTP II station located at Sekolah Hijau Street, Simpangan, North Cikarang District, Bekasi Regency, West Java, Indonesia. The data taken from the WWTP II station because it is located around 1.2 km from the final project area and the closest one, its assume that the rainfall data will be de same as in the final project location.
- Water Demand, the data get from the calculation of the water demand of each person per day times by the amount of people that will used the water. The water demand used here was 20 l/person/day because it is for the toilet used only.

2.3 Data Analysis Method

2.3.1 Potential Rainwater Supply

The amount of available rainwater depends on the amount of rainfall, the area of the catchment, and its run-off coefficient. The run-off coefficient (RC) takes into account any losses due to evaporation, leakage, overflow and transportation [9]. In general, the amount of rainwater that can be accommodated is 80%, with the remaining 20% assumed to evaporate in the air or cannot be caught completely. As a result, the runoff coefficient being used is 0.80.[10].

$$S = R \times A \times C_r \tag{1}$$

Where: S = Mean annual rainwater supply (m^3), R = Mean annual rainfall (m), A = Catchment area (m^2), C_r = Run-off coefficient.

2.3.2 Water Demand

The need for rainwater is the volume of rainwater that will be used by residents for daily needs for one month.

$$Demand\ (m3)\ = Water\ Use\ (m3) \times Number\ of\ Users \times Time \tag{2}$$

2.3.3 Storage Tank Capacity

The size of the storage tank is adjusted to the required water [11]. Also the capacity of storage tank and the system performance was influence by the rainfall [12].

$$V_{Storage} = \frac{Highest\ rainwater\ supply}{Number\ of\ month} \tag{3}$$

2.3.4 Water Debit

Calculating raw water discharge aims to determine how much the average rainwater discharge enters the rainwater harvesting system (PAH). The results of this discharge calculation will also determine the dimensions of the upright gutters and gutters as rainwater diverters to the storage tank later. The following is the equation used to calculate the average rainwater discharge [13]:

$$Q = \frac{I \times A}{T} \tag{4}$$

$$I = \left(\frac{R_{24}}{24}\right) \times \left(\frac{24}{T}\right)^{\frac{2}{3}} \tag{5}$$

$$Tc = 0.0195 \times \left(\frac{L}{\sqrt{S}}\right)^{0.77} \tag{6}$$

Where: Q = Average rainwater discharge (m^3/s), I = Average rainfall intensity (m), T = Rain duration/dominant duration of precipitation (s), A =

Catchment Area (m^2), R_{24} = Maximum rainfall with return period (mm), S = Channel mean slope, L = Length of slope (m), T_c = Concentration time.

2.3.5 Gutter Dimension

a. Gutter sign

Gutters are gutters that collect rainwater that falls directly from the roof, which then from this gutter signs, will be flowed to the gutters upright. The calculation as follow [13]:

$$A = \frac{Q}{v} \quad (7)$$

$$A = \frac{1}{2} \times \pi \times r^2 \quad (8)$$

Where: Q = Average rainwater discharge (m^3/s), v = Velocity in gutters (m/s), r = Radius (m), A = Gutter Area (m).

b. Upright Gutters

Upright gutters are gutters that collect rainwater after going through gutters and then drain it into a storage tank [13]. The calculation as follows:

$$v = \sqrt{2 \times g \times h} \quad (9)$$

Where: v = velocity upright gutters (m/s), g = gravity 9.8 (m/s^2), h = high (m). After knowing the velocity of water in the upright gutters, the dimension of the upright gutter can defined by the value of the gutter radius, with formula :

$$d = 2 \times r \quad (10)$$

Based on module for socialization and dissemination of rainwater catchment standards and manuals for 2014 by Balidbang PU, by considering the safety factor, the dimension of gutter should be times with 3.5 and the minimum diameter for the upright gutter is 5.1 cm [13].

2.3.6 Gumbel Distribution

The rainwater supply value was got form the calculation of the rainfall rate with the water demand. This calculation was used the Gumbel distribution method [10].

$$X_{Tr} = \bar{X} + \frac{Y_{Tr} - Y_n}{S_n} \times S \quad (11)$$

Where: X_{Tr} = Variable with T return year, $\bar{X} = Average\ Value$, S= Standard Deviation, K = Frequncy factor from gumbel, Y_n = Reduce mean depend on sample amount, S_n= Reduce standard deviation, Y_{Tr} = Reduced variate.

$$Sd = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{n-1}} \quad (12)$$

Where Sd is standard deviation.

3 Results and Discussion

3.1 Water Demand & Rainwater Supply

Using the eq.2 to calculate the water demand and based on the previous study in 2016 and seeing the purpose of rainwater use as the toilet use, the water demand used was **20 l/person/day** with number of person used in a day was **200 person/day.** For calculating the rainwater supply, it used the eq. 1. The result of water demand and rainwater supply can see on **table. 1** and **table. 2** bellow:

Table 1. Water Balance Calculation In 2019

Month	*Days*	*Rainfall Rate (m)*	*Catchment (m^2)*	*RW Supply (m^3)*	*Water Demand (m^3)*
Jan	31	0.0603	756	36	124
Feb	29	0.0178	756	11	116
March	31	0.021	756	13	124
April	30	0.0241	756	15	120
May	31	0.0268	756	16	124
June	30	0.0095	756	6	120
July	31	0.0025	756	2	124
Aug	31	0	756	0	124
Sep	30	0.0115	756	7	120
Oct	31	0.025	756	15	124
Nov	30	0.0226	756	14	120
Dec	31	0.0249	756	15	124
Total	366	0.246		**149**	**1464**

Table 2. Water Balance Calculation In 2020

Month	*Days*	*Rainfall Rate (m)*	*Catchment (m^2)*	*RW Supply (m^3)*	*Water Demand (m^3)*
Jan	31	0.0384	756	23	124
Feb	28	0.032	756	19	112
March	31	0.0311	756	19	124
April	30	0.0335	756	20	120
May	31	0.0161	756	10	124
June	30	0	756	0	120
July	31	0	756	0	124
Aug	31	0	756	0	124
Sep	30	0	756	0	120
Oct	31	0	756	0	124
Nov	30	0.0726	756	44	120
Dec	31	0.0308	756	19	124
Total	365	0.2545		**154**	**1460**

From the calculation table above, the total rainwater supply was **149 m^3/year** in 2020 and **154 m^3/year** in 2019. By using the result of water demand and supply above, it also get that the average of water demand is **112 m^3/month** and the average of rainwater supply is just **12 m^3/month**, the average result was conducted by divide the total rainwater supply and demand with the total month in year. As can see on the table above, the rainwater supply was not fulfill the water demand and there are a huge amount of shortage water if use the rainwater as the main water supply.

3.2 Rainwater Quality Result

Table 3. Water Quality Result

No.	*Name*	*Standard*	*Result*	*Unit*
1.	Turbidity	25	1.91 - 1.97	NTU
2.	Total Dissolved Solid (TDS)	1000	0.671	mg/l
3.	Total Coliform	50	0	CFU/100ml
4.	PH	6.5-8.5	6.78 - 6.80	mg/l
5.	Hardness (CaCO3)	500	1.6 - 2.5	mg/l
6.	Nitrate	10	0	mg/l
7.	Nitrite	1	0	mg/l

The rainwater quality was used the standard of clean water for sanitary used, based on the Ministry of Health Regulation No. 32 Year of 2017 about the environmental health quality standards and water health requirements for sanitation hygiene purposes, swimming pools, per aqua solutions, and public bathing. Refers to the standard and comparing to the result of water quality parameter used, the quality of rainwater wasn't exceed the existing standard gave.

3.3 Detail Engineering Drawing

3.3.1 Storage Tank

Using calculation from the eq.3, the storage tank capacity volime was 18.5 m^3/6month or 770 l/week. Choosing for carrying the water supply for a weeks because if using the capacity for a month, the dimension is to big with the available land is less and also the water harvested predicted to be in the storage tank in a short time. Storage tank will used was the available water tank in the market with capacity of 840 l, which is the closest size with the storage tank calculation result.

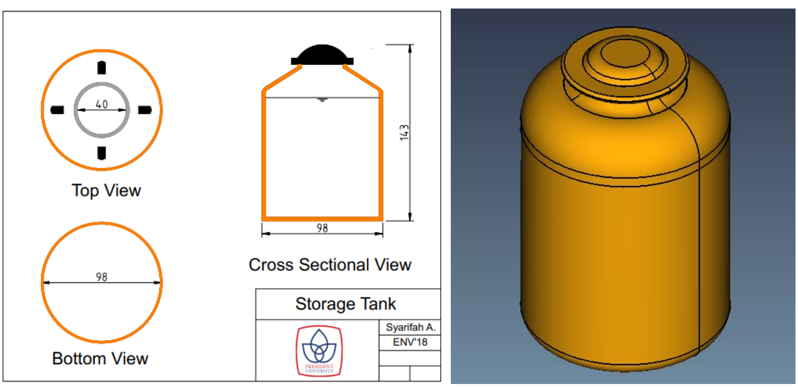

Fig. 3. 2D & 3D Storage Tank Design

3.3.2 Catchment Area

Based on the measurement via Google Earth, the catchment area total was 756 m^2 and as attach on the second pictures, the figure when the gutter was installed.

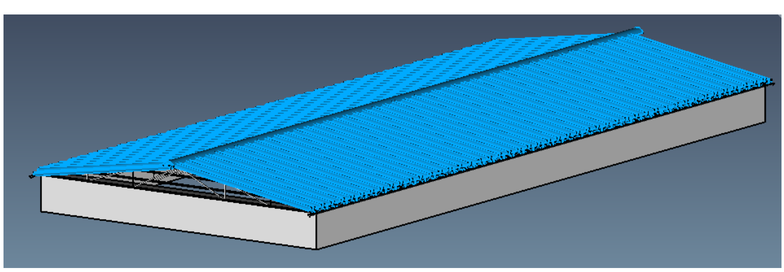

Fig. 4. *3D Catchment Area Design*

3.3.3 Pipe & Gutter

Rainfall Intensity

The rainfall data used was 2 year of rainfall data within 2019-2020, refers to the table of variance reduction value (Y_t), average variance reduction value (Y_n) and standard deviation (S_n), the value for 2 years return period are as bellow and the other value for different return period can see on the appendix C:

***Table 4**. Y_t, Y_n & S_n Value*

No	*Name*	*Value*
1	N	2
2	Yn	0.5035
3	Sn	0.9833
4	Yt	0.3665
5	Xt	*Curah Hujan Rencana*

Maximum daily rainfall:

Known from the main rainfall data, the maximum daily rainfall data for each year was 160 mm/d for year 2019 on 21/11/19 and 291 mm/d for year 2020 on 1/1/20.

$$\bar{X} = \frac{160\ mm/d + 291\ mm/d}{2}$$

$$\bar{X} = 225.5\ mm/d$$

By the calculation, its get the value of average maximum daily rainfall as 225.5 mm/d. By using the gumbel distribution

Table 5. Maximum daily rainfall

Maximum Daily Rainfall (mm/d)			
Year	XI	(XI-Average)^2	Unit
2019	160	4290	mm/d
2020	291	4290	mm/d
Average	225.5	8581	mm/d
Standard Deviation (S)		93	

The value of maximum daily rainfall rate on 2 years return period is as bellow:

$$X_{Tr} = \bar{X} + \frac{Y_{Tr} - Y_n}{s_n} \times S$$

$$X_{Tr} = 225.5 + \frac{0.3665 - 0.5035}{0.9833} \times 93$$

$$X_{Tr} = 212.59\ mm$$

From the calculation, the maximum rainfall data was 212.59 mm/d

For rainwater intensity calculation:

Given:

- Roof Length = 42m
- Roof Width = 18m
- Roof High = 2m

$$Roof\ slope\ length\ (L0) = \sqrt{2^2 \times 18^2} = 36m$$

$$Roof\ Slope = \frac{High}{Width} = 0.1m$$

$$Tc = 0.0195 \times \left(\frac{L}{\sqrt{s}}\right)^{0.77}$$

$$Tc = 0.0195 \times \left(\frac{42}{\sqrt{0.1}}\right)^{0.77}$$

$$Tc = 0.81\ minute$$

$$I = \left(\frac{R_{24}}{24}\right) \times \left(\frac{24}{T}\right)^{\frac{2}{3}}$$

$$I = \left(\frac{212.59mm/d}{24}\right) \times \left(\frac{24}{60}\right)^{\frac{2}{3}}$$

$$I = 4.81\ mm/h$$

Gutter

Average Rainwater Discharge :

$$Q = \frac{I \times A}{T}$$

$$Q = \frac{0.00481m \times 756m2}{48.6\ s}$$

$$Q = 0.0748\ \text{m3/s}$$

$$v = \sqrt{2 \times g \times h}$$

$$v = \sqrt{2 \times 9.81 \times 0.5}$$

$$= 2.21 m/s$$

$$A = \frac{Q}{v}$$

$$A = \frac{0.0748\ m2/s}{2.21\ m/s} = 0.033 m2$$

$$A = \frac{1}{2} \times \pi \times r^2$$

$$0.033 m2 = \frac{1}{2} \times 3.14 \times r^2$$

$$r = 0.11 m = 11\ cm$$

Velocity in upright gutter

$$v = \sqrt{2 \times g \times h}$$

$$v = \sqrt{2 \times 9.81 \times 0.5}$$

$$= 2.21 m/s$$

$$upright\ gutter = 2 \times r = 2 \times 11 = 22\ cm$$

From the calculation get the debit of rainwater is 0.0748 m^3/s with velocity of water is 2.21 m/s and the **gutter** diameter is 22 cm.

Pipe Dimension

$$Q = V \times \frac{\pi \times D^2}{4}$$

$$0.0748\ m^3/s = 2.21\ m/s \times \frac{3.14 \times D^2}{4}$$

$$\mathbf{D^2} = \frac{0.0748\ m^3/s}{1.7348\ m/s}$$

$$D = 0.20\ m = 7.87\ inch = 19.98\ cm$$

From the calculation get that the distribution pipe have a diameter of 19.98 cm and the pipe size used was pipe with dimension of 8 inch/20 cm pipe diameter, which is the closest size to the calculated pipe diameter.

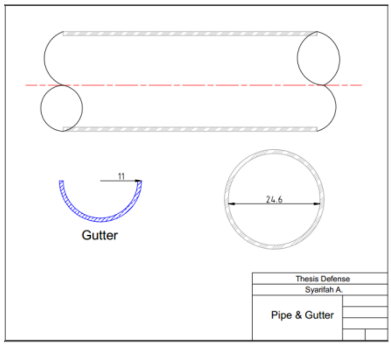

Fig. 5. Pipe & Gutter Design

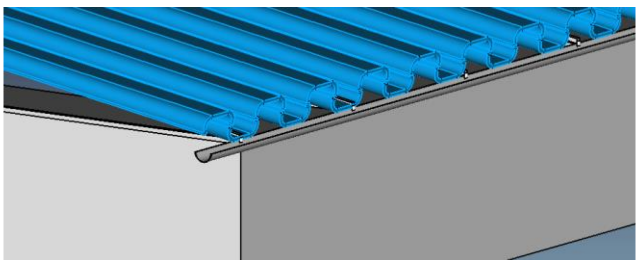

Fig. 6. Gutter Installation On The Roof

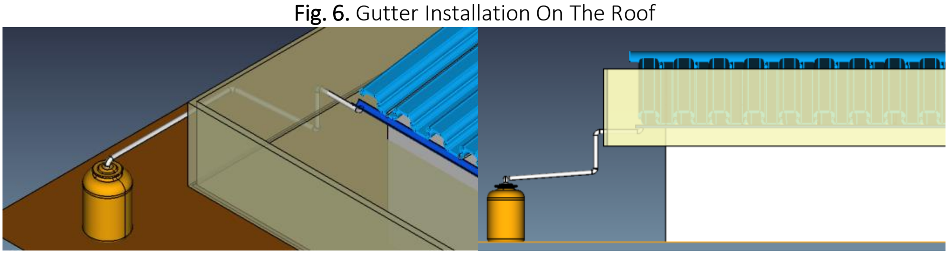

Fig. 7. The Rainwater Harvesting System

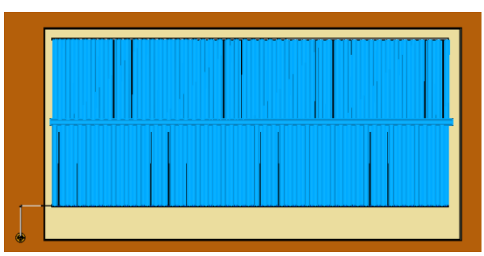

Fig. 8. Top View Of The Rainwater Harvesting System

The figure above illustrates how the entire rainwater harvesting system is planned. The catchment area is the roof of the Building A President University, which is the roof of the auditorium located on the 5th floor. For the planned placement of the storage tank, it will be placed on the top of the 4th floor of an empty spot, 3 m below the roof/rainwater catchment area. As can be seen in the picture above, the yellowish green part is the wall that surrounds the roof of the building so that if the system is going to be installed as shown in the figure, construction work will be needed to connect the roof and the storage tank.

3.3.4 Budgeting Plan

1. The cost of clean water that must be paid by the university is Rp. 1,400 /m^3 when the water usage more than 10m^3 in 2021 and according to the water usage data obtained from the university in the year of 2021, total cost for water that has been paid was around Rp. 22,835,400/year for the water consumption in 2021 based on the actual data of water usage in the university for building A.
2. By using the data from rainwater supply in 2020, the water supply was 149 m3. By this amount of water supply by the RWH system, the university can save around Rp. 208,320 in a year.

Table 6. Cost Estimation

No.	*Name*	*Size*	*Quantity*	*Cost*	*Total*	*Source*
1	Storage Tank	840 L	1 Piece	Rp. 1,610,000	Rp. 1,610,000	*Nirwana Bahan Bangunan (Tokopedia)*
2	Distribution Pipe	8 inch in diameter	6.5 m	Rp. 218,075	Rp. 1,417,486	*Toko Bintang Teknik (Shopee)*
3	Gutter	9 inch in diameter	42 m	Rp. 22,500	Rp. 945,000	*Aula Pipa Shop (Ecommerce-Shopee)*
4	Gutter Joint		20	Rp. 6,500	Rp. 130,000	*Aula Pipa Shop (Shopee)*
5	Gutter Hanger		10	Rp. 13,500	Rp. 135,000	*Aula Pipa Shop (Shopee)*
6	Gutter Cover	8 inch	4	Rp. 5,500	Rp. 22,000	*Aula Pipa Shop (Shopee)*
Total					**Rp. 4,256,486**	

4 Conclusions

1. Based on the result and looking on the amount of water demand and rainwater supply, by applying the rainwater harvesting system in building A, President University, could save around Rp. 208,320 over year for water cost. Applying the RWH system couldn't fulfil the water demand of the building, which the amount of rainwater supply just around 148.8-154

m^3/year while the water demand is 1460-1464 m^3/year and the average of water demand is 112 m^3/month and the average of rainwater supply is just 12 m^3/month or the RWH system could just comply 10.8% of the water demand. Even in a number is a small value both in cost saving and water saving, but with this movement/instalment of the system, the university already make a move to become better and it will also supporting the green campus concept and the water conservation efforts.

2. The design of the Rainwater Harvesting system that planned to be installed was shown in the 4th chapter and resulting in the dimension of storage tank is 840 L, the gutter dimension is 22 cm in diameter and distribution pipe was 20 cm in diameter, and the catchment area was the existing roof with total area 756m^2. By considering and referring to the water supply and demand that have been previously calculated, and considering the results of the water quality test, a design like this is obtained.

By installing the Rainwater Harvesting system, the system was help to improve President University in fulfilling one of UI Green Metric categories which is the water category in improving the water conservation program and use the recycle water as the water source.

5 Aknowledgement

First of all, I would like to express the highest gratitude to Allah SWT for the chance and all the gifts in my life. Special thanks to my parents, siblings and family for all the love and support. Without the help and support of God and family, I would not be able to get to where I am now. I also want to express my deepest gratitude to Dr. Ir. Yunita Ismail Masjud, M.Si., as my advisor, for the continuous support, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writing.

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