RWH Plan

by Ika Meicahayanti

Rainwater Harvesting Planning as an Alternative for Clean Water Supply in Public Facilities in Sepaku District: A Study of Supply Potential Using Probability Methods

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Abstract

The clean water supply in Sepaku District covers only 15.27% of the total water demand. Efforts to utilise rainwater as an alternative source are necessary due to this region has high rainfall. The study aims to analyse the potential of rainwater discharge and design a Rainwater Harvesting (RWH) system to support clean water provision. The analysis was conducted on rainfall data using probability methods, calculations of potential rainwater discharge, and sizing of the RWH system components. The rainwater potential was calculated based on reliable rainfall, roof area, runoff coefficient, and first-flush volume. The RWH system design included determining suitable storage tank capacity, gutter specifications, and first-flush pipe dimensions. The rainwater potential discharge varies accross locations, ranging from 109.3 to 434 m^3/year, influenced by differences in roof area as catchment area. The RWH system planned consists of storage tank capacities of 2.2, 3.2, and 7.5 m^3, horizontal pipes of 100–150 mm, vertical pipes of 75–125 mm, and first-flush pipes of 6 inches or 10 inches with a height of 1.45–3.38 m. This design is adjusted to the rainwater potential that can be applied in each building and is expected to become an alternative clean water supply.

Keywords: Clean water; Design; Probability; Rainwater potential; Rainwater harvesting plan.

1. INTRODUCTION

The provision of clean water is the responsibility of local governments to support the availability and quality of clean water (Sriwati et al., 2024). Sepaku District, North Penajam Paser Regency, is a district supplied with clean water by Perumda Air Minum Danum Taka. Based on the data, Sepaku District is only served by 15.27% clean water (Perumdam Danum Taka, 2025) and does not yet meet the requirements for quality, quantity, and continuity. Clean water demand can be met by utilising nearby water sources (Ayatri et al., 2021). The supply of clean water can be reduced if its use is not properly regulated, so it is necessary to conserve water resources by maintaining water availability, saving water resources, and utilising rainwater as an alternative water source (Murda et al., 2024).

Rainwater is a high-quality water source and can reduce the use of clean water sources (Sudinda, 2022). Rainwater quality varies depending on environmental conditions and rainwater harvesting media (Rizky et al., 2022). Based on research conducted on the application of the concept of rainwater harvesting as an alternative source of clean water, rainwater can meet up to 82.3% of clean water demand (Cahyani & Helda, 2022; Djalle et al., 2022). Other studies related to the implementation of rainwater harvesting system planning have produced results in the form of simple rainwater storage designs that can be used at local research sites (Dharmawan & Pranoto, 2023; Dirgawati et al., 2024).

Based on rainfall data for the Sepaku District, the intensity of rainfall over the last 10 years, namely data from 2015 to 2024, was 1334–3152 mm/year or 111–263 mm/month (BMKG, 2025). This data shows that rainfall in the Sepaku District has a high intensity and can produce abundant rainwater supplies. High rainfall has benefits for life, including restoring groundwater reserves, maintaining ecosystem balance, and being a source of clean water in addition to surface water and groundwater. Therefore, this study analysed the potential of rainwater discharge and planned a rainwater harvesting system as an alternative source of clean water in the Sepaku District.

2. METHODOLOGY

2.1 Analysis Method of Rainwater Discharge Potential

Rainwater harvesting requires a well-designed system in order to maximise the amount of rainwater collected. The design of a rainwater harvesting system is influenced by the amount of rainwater that can be collected, the amount of clean water required, the capacity of the storage tank, and so on. Calculating the potential rainfall is very important in the process of planning a rainwater harvesting installation. The potential rainfall discharge is used as the basis for calculating the design of rainwater harvesting, including water tank capacity, gutter size, pipe dimensions, and the required pipe length (Pamungkas et al., 2023). The potential rainfall supply can be calculated using Equation 1.

$$Q_{supply} = A \times C \times h \tag{1}$$

where Q_{supply} is the potential rainwater discharge (L/month or m^3/year), A is the roof area of the building (m^2), C is the runoff coefficient, and h is the rainfall (mm/month)

Reliable rainfall calculations can provide estimates of the amount of rainfall available for use in the planning process. Reliable rainfall is analysed by sorting data based on rainfall magnitude, then calculating the probability through column plotting to select rainfall that is close to 80% (Suhardi, 2020). Reliable rainfall is calculated using Equation 2.

$$P\% = = \frac{m}{n+1} \times 100\% \qquad (2)$$

where P% is the probability, m is the serial number, and n is the amount of data.

The catchment area will affect the amount of rainwater available. Roofs are commonly used as catchment areas. The catchment area can be assumed to be equal to the floor area of the building. The catchment area of a rectangle is calculated using the formula for the area of a rectangle, which is the multiplication of the length and width, while roofs with multiple sections are calculated by the sum of the roof area of each section (Juliana, 2019).

The runoff coefficient is needed to calculate the potential rainwater that can be harvested for each building. The runoff coefficient value is determined by the shape and type of roofing material used (Herdiaprila & Hartati, 2023). The runoff coefficient for roofs with two types of materials is calculated using the runoff coefficient value and the roof area of each material, as well as the total roof area, to obtain an average value as the combined roof runoff coefficient value.

The first rainwater that falls on the roof is of poor quality due to the accumulation of pollutants trapped on the roof. Therefore, this water is drained into the drainage system to maintain the quality of the harvested water (Ayatri et al., 2021). The first flush volume is calculated using Equation 3.

$$V_{ff} = H_d \times A \qquad (3)$$

where V_{ff} is the first flush volume (m^3), H_d is the diverter height (0.5–1.5) mm, and A is the roof area (m^2).

Total water demand is calculated by multiplying the number of occupants (persons) in a building by the standard water demand (L/person.day) according to the type of building at the research location (Suheri et al., 2019). The standard clean water demand for public facilities in mosques is 3000 L/unit.day and for public facilities in offices is 50 L/person.day (BSN, 2005; Kementerian PU, 2007).

2.2 Method of Rainwater Harvesting System Plan

Rainwater harvesting system planning includes determining the capacity of tanks, gutters, and pipe dimensions. Tank capacity is determined by calculating the potential rainfall and number of rainy days, thereby obtaining the maximum rainfall in litres per day. Gutters are determined in accordance with SNI 03-7065-2005, which stipulates a minimum slope of 2% (BSN, 2005). The dimensions of the gutters and pipes are then determined based on the average rainfall to obtain the maximum roof area. The maximum roof area is calculated using Equation 4 based on SNI 8153:2015 concerning the size of horizontal and vertical rainwater pipes for a roof slope of 2% (BSN, 2015; Komala & Maisuara, 2021).

$$Y = Y_1 + \left(\frac{X - X_1}{X_2 - X_1}\right) \times (Y_2 - Y_1) \tag{4}$$

where Y is the maximum roof area (m²), Y_1 is the roof area in column 1 (m²), Y_2 is the roof area in column 2 (m²), X is the local rainfall value (mm), X_1 is the rainfall value in column 1 (mm), and X_2 is the rainfall value in column 1 (mm).

3. RESULTS AND DISCUSSION

3.1 Result of Rainwater Discharge Potential Analysis

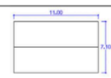
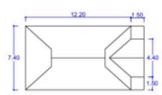
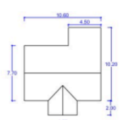
3.1.1 Analysis of Reliable Rainfall

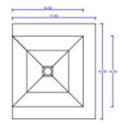
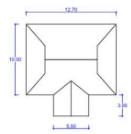
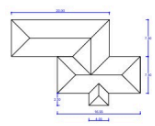
Rainfall data was processed into reliable rainfall by sorting the data from largest to smallest. Then, reliable rainfall with a probability of approximately 80% will be determined (Suhardi, 2020). The result of the calculation of the reliable rainfall approaching 80% was obtained in 2015 with a probability of 81.82% and rainfall of 1813 mm/year.

3.1.2 Analysis of Roof Area

The roof area was obtained from processing the length and width data, which is found in Table 1. The results of the roof area calculation were used in calculating rainwater supply and first-flush volume. The roof area will affect the amount of rainwater that can be harvested; the larger the area, the more water will be obtained (Juliana, 2019).

Table 1. Roof Area

Location of Rainwater Harvesting Plan	Type of Roof	Roof Area (m²)
1 Karang Jinawi BPD Secretariat Office		78.10
2 Bukit Raya Village Office		101.38
3 Tengin Baru BPD Secretariat Office		100.87

4	Argo Mulyo Village Office		93.24
5	Raudhatul Jannah Suko Mulyo Mosque		331.50
6	Semoi Dua Village Multipurpose Building		142.00
7	Wonosari Village Office		286.75

3.1.3 Analysis of Runoff Coefficient Determination

The runoff coefficient was determined by the shape and type of the catchment area. The runoff coefficient value for zinc roofs is 0.8 (Murda et al., 2024). The runoff coefficient for roofs with a combination of zinc and cement is determined through average calculations (Herdiaprila & Hartati, 2023). The runoff coefficient value used for zinc roofs is 0.8, while for cement roofs it is 0.65 (Heryani, 2013). The runoff coefficient for the Karang Jinawi BPD Secretariat Office, Bukit Raya Village Office, Tengin Baru BPD Secretariat Office, Semoi Dua Village Multipurpose Building, and Wonosari Village Office, which have zinc roofs, is 0.8. The runoff coefficient for the Argo Mulyo Village Office, which has a zinc and slab roof, is 0.77, and for the Raudhatul Jannah Suko Mulyo Mosque, which has a zinc and clay roof, is 0.75.

3.1.4 Analysis of First Flush

The first flush volume is calculated based on the roof area and diverter height. The diverter height used is 0.5 mm (Widiantoni et al., 2022). The first flush volume can be influenced by the diverter height used and the roof area at the research location. The results of the first flush volume calculation are shown in Table 2.

Table 2. First Flush Calculations

	Location of Rainwater Harvesting Plan	Roof Area[1] (m^2)	*Diverter Height*[2] (mm)	*First Flush*[3] (m^3)	*First Flush*[3] (L)
1	Karang Jinawi BPD Secretariat Office	78.10	0.5	0.039	39
2	Bukit Raya Village Office	101.38	0.5	0.051	51
3	Tengin Baru BPD Secretariat Office	100.87	0.5	0.050	50
4	Argo Mulyo Village Office	93.24	0.5	0.046	46
5	Raudhatul Jannah Suko Mulyo Mosque	331,5	0.5	0.166	166
6	Semoi Dua Village Multipurpose Building	142.00	0.5	0.071	71
7	Wonosari Village Office	286.75	0.5	0.143	143

Description: [1]Table 1; [2](Ayatri et al., 2021); [3]Calculation Result

3.1.5 Analysis of Rainwater Potential Discharge

The results of the rainfall supply potential calculations using Equation 3 will then be subtracted from the first flush value. The results are shown in Table 3.

Table 3. Rainwater Potential Discharge Calculations

	Location of Rainwater Harvesting Plan	Q_{max} Rainwater (L/month)	Q_{max} Rainwater (L/day)	$Q_{average}$ Rainwater (L/month)	Q_{total} Rainwater (m^3/year)
1	Karang Jinawi BPD Secretariat Office	26453.3	1693.40	9111.4	109.3
2	Bukit Raya Village Office	34332.1	2197.79	11824.2	141.9
3	Tengin Baru BPD Secretariat Office	34172.1	2187.48	11771.0	141.3
4	Argo Mulyo Village Office	30359.9	1944.67	10451.4	125.4
5	Raudhatul Jannah Suko Mulyo Mosque	105081.3	6727.69	36165.9	434.0
6	Semoi Dua Village Multipurpose Building	48095.4	3078.82	16565.5	198.8
7	Wonosari Village Office	97128.6	6217.64	33454.9	401.5

Based on Table 3, it can be seen that rainwater in the Sepaku District has a sufficient quantity to be utilised as an additional water source or an alternative source of raw water. The minimum potential rainwater discharge at all research locations was obtained in September, which was 0.0 L/month, where the rainfall in that month was 0 mm/month. Meanwhile, the maximum potential rainfall discharge in all research locations was obtained in April, with varying values, where the rainfall in that month was 434 mm/month, which was the highest rainfall in 2015. Factors that influence rainfall discharge include high rainfall, catchment area, runoff coefficient, and first flush amount. Rainwater flow is proportional to the catchment area; the larger the catchment area, the more abundant the rainwater obtained (Dharmawan & Pranoto, 2023).

3.1.6 Water Demand Analysis

The results in Table 4 show that the highest total water requirement is at the Raudhatul Jannah Suko Mulyo Mosque at 1,095.00 m^3/year, while the lowest is at the Karang Jinawi BPD Secretariat Office at 127.75 m^3/year. The standard water requirement for mosques is 3,000 litres/unit.day, while for offices it is 50 litres/person.day (Larasati et al., 2021; Putra et al., 2020).

Table 4. Water Demand Calculations

Location of Rainwater Harvesting Plan		Number of Occupants (person)	Standard of Water Demand		Q_{total} Water Demand[3]	
					L/day	(m^3/year)
1	Karang Jinawi BPD Secretariat Office	7	50[1]	L/person.day	350	127.8
2	Bukit Raya Village Office	8	50[1]	L/person.day	400	146.0
3	Tengin Baru BPD Secretariat Office	8	50[1]	L/person.day	400	146.0
4	Argo Mulyo Village Office	22	50[1]	L/person.day	1100	401.5
5	Raudhatul Jannah Suko Mulyo Mosque	-	3,000[2]	L/unit.day	3000	1,095.0
6	Semoi Dua Village Multipurpose Building	19	50[1]	L/person.day	950	346.8
7	Wonosari Village Office	18	50[1]	L/person.day	900	328.5

Description: [1](Kementerian PU, 2007); [2](BSN, 2005); [3]Calculation Result

The results of the calculations can be compared between the rainfall discharge values (Table 3) and the clean water demand at each research location (Table 4). This aims to determine whether the harvested rainwater can meet water requirements. The comparison results are shown in Table 5. Based on the analysis results, it was found that out of the seven locations, only the Wonosari Village Office had a higher rainfall supply than water demand. This indicates that the rainfall catchment area is not yet sufficient to meet general water demand. Planning on a communal scale needs to be considered so that the supply from all buildings can be collected to support water shortages in certain buildings.

Table 5. Comparison of Rainwater Potential and Clean Water Demand

Location of Rainwater Harvesting Plan		Q_{total} Rainwater[1] (m^3/year)	Q_{total} Water Demand[2] (m^3/year)
1	Karang Jinawi BPD Secretariat Office	109.3	127.8
2	Bukit Raya Village Office	141.9	146.0
3	Tengin Baru BPD Secretariat Office	141.3	146.0
4	Argo Mulyo Village Office	125.4	401.5
5	Raudhatul Jannah Suko Mulyo Mosque	434.0	1,095.0
6	Semoi Dua Village Multipurpose Building	198.8	346.8
7	Wonosari Village Office	401.5	328.5

Description: [1]Table 3; [2]Tabel 4

3.2 Rainwater Harvesting Plan

3.2.1 Determine the Capacity of The Water Tank

The capacity of rainwater harvesting tanks can be determined using the highest daily rainfall discharge based on Table 3. The storage tank capacity is then determined based on the highest daily rainfall discharge and the capacity of water tanks sold on the market. The water tank capacity values at the research location are shown in Table 6.

Table 6. Water Capacity Tank Calculations

Location of Rainwater Harvesting Plan		Q_{max} Rainwater[1] (L/day)	Capacity of Tank[2] (m^3)
1	Karang Jinawi BPD Secretariat Office	1693.40	2.2
2	Bukit Raya Village Office	2197.79	2.2
3	Tengin Baru BPD Secretariat Office	2187.48	2.2
4	Argo Mulyo Village Office	1944.67	2.2
5	Raudhatul Jannah Suko Mulyo Mosque	6727.69	7.5
6	Semoi Dua Village Multipurpose Building	3078.82	3.2
7	Wonosari Village Office	6217.64	7.5

Description: [1]Table 3; [2]Calculation Result

3.2.2 Determine Gutter and Pipe Dimensions

The slope criteria for rainwater gutters use a minimum slope of 2% (BSN, 2005). Rainwater collected in the gutters will be drained into a storage tank through a vertical pipe (Arsyadi et al., 2018). The dimensions of the rainwater pipes are calculated based on the maximum roof area, as shown in Table 7 to 9.

Table 7. Gutter or Horizontal Pipe Based on Maximum Roof Area

Horizontal Pipe Dimension		Maximum Roof Area (m^2)
inch	mm	
4	100	175
5	125	311
6	150	498

Table 8. Vertical Pipe Based on Maximum Roof Area

Vertical Pipe Dimension		Maximum Roof Area (m^2)
inch	mm	
3	75	146
4	100	303
5	125	570

Table 9. Pipe Dimennsion Calculations

Location of Rainwater Harvesting Plan		Roof Area [1] (m^2)	Pipe Dimension [2] (mm)	
			Horizontal	Vertical
1	Karang Jinawi BPD Secretariat Office	78.10	100	75
2	Bukit Raya Village Office	101.38	100	75
3	Tengin Baru BPD Secretariat Office	100.87	100	75
4	Argo Mulyo Village Office	93.24	100	75
5	Raudhatul Jannah Suko Mulyo Mosque	331.50	150	125
6	Semoi Dua Village Multipurpose Building	142.00	100	75
7	Wonosari Village Office	286.75	125	100

Description: [1] Table 1; [2] Calculation Result

3.2.3 Rainwater Harvesting System Design

The detailed design of rainwater harvesting at all research locations is shown in Table 10. Rainwater harvesting planning includes tank capacity, gutter size, horizontal pipe dimensions, vertical pipe dimensions, first flush diverter pipe diameter, and first flush diverter height. The first flush volume obtained ranged from 0.039 m^3 to 0.143 m^3. Therefore, a 6-inch first flush diverter pipe was used (Maryono, 2017). The size of the first flush diverter pipe can be increased if the first flush volume discharged is greater (Budiman et al., 2023).

Table 10. Detail Design of Rain Water Harvesting System

	Location of Rainwater Harvesting Plan	Capacity of Tank [1] (m^3)	Gutter Size [2] (inch)	Horizontal Pipe Diameter [3] (mm)	Vertical Pipe Diameter [3] (mm)	First Flush Diverter Pipe Diameter [4] (inch)	First Flush Diverter Height [4] (m)
1	Karang Jinawi BPD Secretariat Office	2.2	4	100	75	6	2,21
2	Bukit Raya Village Office	2.2	4	100	75	6	2,87
3	Tengin Baru BPD Secretariat Office	2.2	4	100	75	6	2,86
4	Argo Mulyo Village Office	2.2	4	100	75	6	2,64
5	Raudhatul Jannah Suko Mulyo Mosque	7.5	6	150	125	10	3,38
6	Semoi Dua Village Multipurpose Building	3.2	4	100	75	10	1,45
7	Wonosari Village Office	7.5	5	125	100	10	2,92

Description: [1]Table 6; [2] (BSN, 2005); [3] Table 9; [4] Calculation Result

The design used is adjusted to the results of calculations at each research location. The rainwater harvesting design that has been implemented is expected to obtain abundant rainwater availability so that it can be used as an alternative/additional water source at all research locations. The rainwater harvesting plan is shown in Figures 1 to 7.

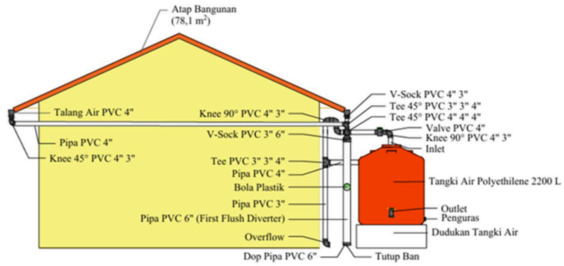
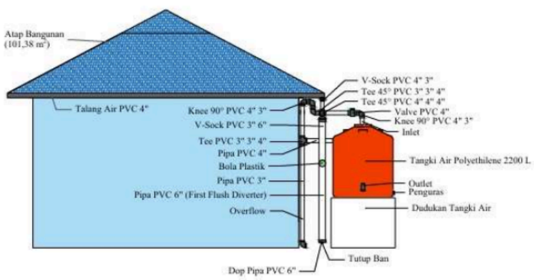
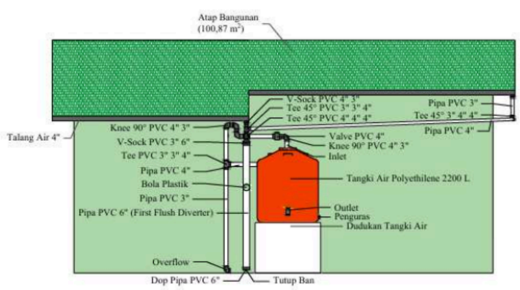


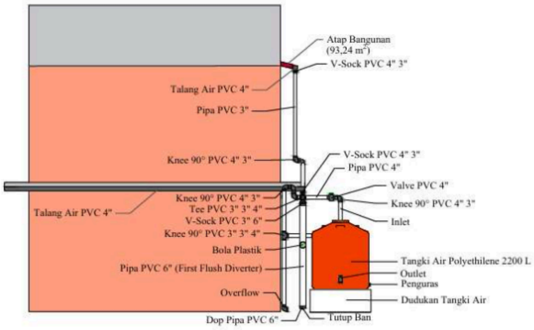
Figure 1. Details of Rainwater Harvesting Design at the Karang Jinawi BPD Secretariat Office



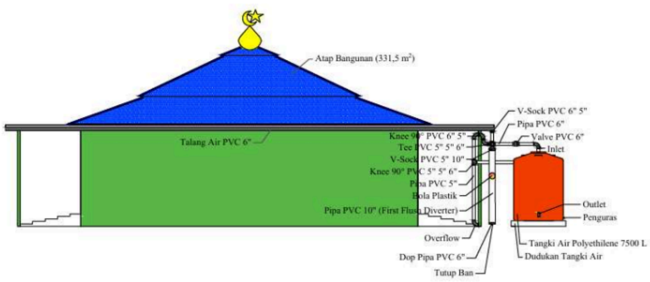
Gambar 2. Details of Rainwater Harvesting Design at the Bukit Raya Village Office



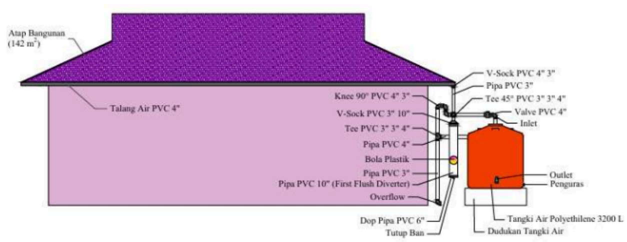
Gambar 3. Details of Rainwater Harvesting Design at the Tengin Baru BPD Secretariat Office



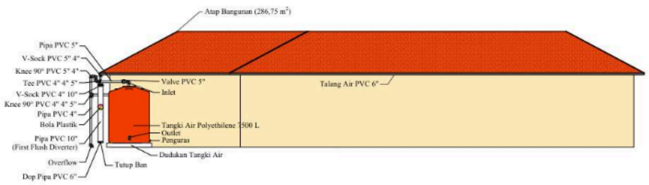
Gambar 4. Details of Rainwater Harvesting Design at the Argo Mulyo Village Office



Gambar 5. Details of Rainwater Harvesting Design at the Raudhatul Jannah Suko Mulyo Mosque



Gambar 6. Details of Rainwater Harvesting Design at the Semoi Dua Village Multipurpose Building



Gambar 7. Details of Rainwater Harvesting Design at the Wonosari Village Office

4. CONCLUSIONS

The study shows that the average of potential rainfall discharge is 221.7 m^3/year and at each planning location varies between 109.3 and 434 m^3/year. This is influenced by the roof area as the catchment area, where the larger the catchment area, the more abundant the rainfall will be. The highest potential discharge was at the Raudhatul Jannah Suko Mulyo Mosque at 434 m^3/year, and the lowest discharge was at the Karang Jinawi BPD Secretariat Office at 109.3 m^3/year.

The planned rainwater harvesting system consists of gutters, horizontal pipes, vertical pipes, first flush pipes, and storage tanks. These components are influenced by the potential rainwater discharge that can be collected. The tank capacity is planned to be 2.2 m^3, except for the Raudhatul Jannah Suko Mulyo Mosque, Semoi Dua Village Multipurpose Building, and the Wonosari Village Office, which will use tank capacities of 7.5, 3.2 and 7.5 m^3, respectively. The gutter size is 4 inch, but Raudhatul Jannah Suko Mulyo Mosque use 6 inch, and Wonosari Village Office use 5 inch. The planned diameters of the horizontal and vertical pipes is 100 mm and 75 mm. Due to the significant difference in potential discharge, the Raudhatul Jannah Suko Mulyo Mosque is planned to use 150 mm horizontal pipes and 125 mm vertical pipes, while the Wonosari Village Office will use 125 mm horizontal pipes and 100 mm vertical pipes. At four locations, namely the Karang Jinawi BPD Secretariat Office, Bukit Raya Village Office, Tengin Baru BPD Secretariat Office, and Argo Mulyo Village Office, it is planned to use 6-inch first-flush pipes with pipe heights of 2.21 m, 2.87 m, 2.86 m, and 2.64 m, respectively. At three other locations, namely the Raudhatul Jannah Suko Mulyo Mosque, the Semoi Dua Village Multipurpose Building, and the Wonosari Village Office, it is planned to use 10-inch first flush pipes with pipe heights of 3.38 m, 1.45 m, and 2.92 m, respectively.

The results of the study indicate that the planned rainwater harvesting system can be used as an alternative source of clean water for the research sites, both those that are already connected to the piped water network and those that are not. Further analysis of rainfall data using other methods and planning of communal systems is needed, given the shortfall in rainwater supply in some locations.

5. ACKNOWLEDGEMENTS

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