TEKNIKA: JURNAL SAINS DAN TEKNOLOGI

Journal homepage: http://jurnal.untirta.ac.id/index.php/ju-tek/

Rainwater harvesting system planning and design (Case study: Female dormitory building, Campus E, Untirta Sindangsari)

Restu Wigati [a,1], ***Rama Indera Kusuma*** [a], ***Fahrus Sabri*** [a]

[a]*Department of Civil Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Jl. Jenderal Sudirman Km.3, Cilegon 42435, Indonesia*

[1]*E-mail: restu.wigati@untirta.ac.id*

ARTICLE INFO

Article history:
Submitted 15 September 2021
Reviewed 23 October 2021
Received 30 October 2021
Accepted 1 November 2021
Available online on 2 November 2021

Keywords:
Rainwater harvesting system, ground reservoir, water saving.

Kata kunci:
Rainwater harvesting system, ground reservoir, penghematan air.

ABSTRACT

The female dormitory building on the campus E Sindangsari Untirta, which has 161 inhabitants, needs a relatively large amount of clean water. The need is a potential application of rainwater harvesting systems (RWHS) to save water usage. Moreover, in the rainy season, the excess volume of water causes runoff to increase, while there is a lack of water in the dry season. Thus, planning this system is necessary to collect water to prevent rainwater from being wasted and used in the dry season. This study uses area calculation data with arithmetic methods and uses 90% reliable rainfall data with the F.J. Mock method, then regarding the intensity of rain, the Mononobe theory is used. In planning the volume and design of the ground reservoir, the standard provisions of the Minister of Public Works concerning the Implementation of Non-Piping Network SPAM Development are used. 01/PRT/M2009. The overall water consumption for dormitory structures is 7,051.8 m^3/year, with a harvestable volume of rainwater of 3,124.447 m^3/year. The RWHS in the Women's Dormitory Building consists of a ground reservoir with a capacity of 324 m^3, a circle gutter with a diameter of 250 mm on the roof of the building, and a 100 mm PVC standpipe and 150 mm diameter PVC flat pipe. Based on this plan, water can be saved by an average of 41.12% per month. The calculation of the RAB of this system obtained a value of Rp. 288,471,000.

ABSTRAK

Gedung asrama putri di kampus E Sindangsari Untirta yang berpenghuni 161 jiwa membutuhkan air bersih yang relatif cukup banyak. Kebutuhan tersebut menjadi suatu potensi penerapan *rainwater harvesting system* (RWHS) untuk menghemat penggunaan air. Terlebih lagi, pada musim penghujan volume air berlebih menyebabkan limpasan air permukaan meningkat sedangkan pada musim kemarau terjadi kekurangan air. Dengan demikian, merencanakan sistem ini sangat diperlukan untuk menampung air sehingga air hujan tidak terbuang sia-sia dan dapat digunakan pada musim kemarau. Penelitian ini menggunakan data perhitungan kawasan dengan metode aritmatika serta menggunakan data curah hujan andalan 90% dengan metode F. J. Mock, kemudian mengenai intensitas hujan digunakan teori *Mononobe*. Dalam perencanaan volume dan desain *ground reservoir* digunakan standar ketentuan dari Permen PU Tentang Penyelenggaraan Pengembangan SPAM Bukan Jaringan Perpipaan No. 01/PRT/M2009. Hasil penelitian ini menunjukan volume suplai air hujan dapat dipanen sebesar 3124,447m^3/tahun, dan total kebutuhan air gedung asrama sebesar 7051,8 m^3/tahun. RWHS pada gedung asrama putri ini terdiri dari *ground reservoir* berkapasitas 324 m^3, talang ½ lingkaran berdiameter 250 mm pada atap gedung, dan pipa tegak PVC 100 mm serta pipa datar PVC berdiameter 150 mm. Berdasarkan perencanaan ini, penggunaan air dapat dihemat rata-rata sebesari 41,12% per bulan. Perhitungan RAB sistem ini didapatkan nilai sebesar Rp. 288.471.000.

Available online at http://dx.doi.org/10.36055/tjst.v17i2.12407

1. Introduction

Water is something that is needed by all living things. The balance of water use is important and very much needed through integrated water management. The smart & green campus concept is a concept where building construction, management, scientific research, and cultural planting are based on sustainable development. As one of the state universities, Universitas Sultan Ageng Tirtayasa (Untirta) also applies this concept as campus development and concern for the environment. Water resources conservation efforts continue to be realized to meet the needs of living things that are always available and sustainable in sufficient quantity and quality at present and in the future [1]. Pemanenan air hujan merupakan salah satu solusi dengan potensi besar, diterapkan secara universal untuk memenuhi kebutuhan air yang meningkat dan mengendalikan dampak dari penggunaan air tanah yang berlebihan dan upaya pencegahan banjir [2]. The implementation of the rainwater harvesting system (RWHS) and the choice of technology are influenced by economic conditions and local regulations to save groundwater use. Challenges in the future use of RHWS need to pay attention to aspects of maintenance, increasing efficiency of rainwater utilization, and community acceptance [3].

Many studies have been carried out related to RWHS and have been applied with modern techniques in many developed countries [4]. Provision of clean water that is effective and promising in overcoming the problem of scarcity which is functioned as flushing toilets, watering gardens [5]. Rainwater harvesting systems can be applied individually in urban areas and planned for small or large commercial buildings. The research results in Johor Bahru Malaysia, commercial buildings located at AEON Taman University and AEON Bukit Indah, which are categorized as small-scale and large-scale buildings, have a reliability percentage of 93% and 100% [6]. The topography of an area determines the percentage level of reliability from the use of RWHS. For example, in Islamabad, which has a subtropical climate, water-saving efficiency reaches 84%-88% for watering plants. For the Larkana area, water-saving efficiency for toilet flushing reaches 32%-33% [7]. Apart from being applied in urban areas, Rainwater harvesting can also be used individually on a residential scale. Based on the study results, two large cities (Sylhet and Chittagong) in Bangladesh have a high potential for rainwater harvesting, where maximum reliability of 40% can be achieved, around 500-800 m3 of water can be saved annually [8].

The benefits obtained by harvesting rainwater are a means of supporting sustainable development by carrying out the concept of environmentally friendly buildings with design, accurate location selection, and proper maintenance [9]. The campus environment is a small part of global life that must tackle the impacts of climate change [10-11]. Through the smart & green campus concept, the development of campus building construction, campus management, scientific research, and cultural cultivation based on sustainable development emphasizes efforts to use energy efficiently, recycling existing resources in the campus environment [12]. Based on the UI Green Metric International Accreditation, the use of water on campus is an important indicator in assessing a green campus. The goal is to encourage campuses to reduce water use, enhance conservation programs, and protect habitats. Water conservation programs, water recycling programs, water use efficiency programs, and the use of treated water are the criteria for assessment [13].

Several studies have been conducted, the application of a rainwater harvesting system can meet the needs of 70% of the total water demand in Building IV, Faculty of Engineering, Universitas Sebelas Maret [14]. Using non-potable water for toilet purposes and watering plants in the ITS dormitory building requires more than 3700 m^3/month using water from harvesting rainwater, and based on the rainwater quality test. It shows a pH value of 6.75, hardness level 35.71 mg/L, and Total Dissolved Solids (TDS) 336 mg/L. These values indicate that rainwater is suitable for use as clean water according to the standard reference of Minister of Health Regulation No. 492 of 2010 [15]. Analysis of the potential for rainwater harvesting on the northern side of the campus I area of Ekasakti University with a roof size of 3034 m^2, the total water harvested for a year is 10941 m^3.

Research [16] shows that the rainwater harvesting process using groundwater tanks to meet raw water at the campus 3 lecture building of the University of Muhamadiyah Purworejo has a potential volume of rainwater supply obtained of 976.99 m^3/year and water savings of 0. 76% of the total water requirement of the lecture hall is 86400 m^3/year [16]. In comparison, the water requirement is 10427.6 m^3 [17]. In line with Untirta's vision as a smart and green campus in Indonesia to realize an integrated smart and green university (It'S Green) that is superior, has character and is competitive in the ASEAN region by 2030 [18]. This effort aims to continue improving the ranking of the UI Green Metric, which in 2020 is ranked 30 [19], so real action is needed to realize this concept, one of which is through planning and designing RWHS.

2. Research Methodology

2.1. Research Location

Research location Figure 1 is located in the female dormitory building on the Sindangsari campus E, Universitas Sultan Ageng Tirtayasa (Untirta), Sindangsari Village, Pabuaran District, Serang Regency, Banten at coordinates 6°11'28.2"S 106°07'21.7"E [20] consists of 4 floors with a building area of 2,640 m^2.

2.2. Data Collection

Rainfall data, in Table 1, is used in data processing, namely monthly rainfall data from the five closest rain posts in the study location in Figure 2 in 2010-2019. The data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) Serang Regency, South Tangerang City, and the Central River Basin (BBWS) Ciujung, Cidanau, Cidurian.

Table 1. Rain post stations and location coordinates.

Nama Stasiun / Pos Hujan	Lokasi	Koordinat		Jarak
		Lintang	Bujur	
Ragas Hilir	Serang	-06°04'08" LS	106°18'14" BT	19.8 m
Pamarayan	Serang	-06°15'33" LS	106°17'03" BT	19.9 m
Pipitan	Serang	-06°08'37" LS	106°13'39" BT	9.4 m
BMKG Serang	Serang	-06°11'85" LS	106°11'00" BT	6.2 m
Cadasari	Pandeglang	-06°22'36" LS	106°55'14" BT	10.8 m

In planning a rainwater harvesting system for a dormitory building, it is necessary to have supporting data obtained based on project working drawings. The roof of the female dormitory building consists of two types of roof, namely tile roof and non-concrete roof, with a total roof floor area of 1,083 m^2 as a catchment area. The number of toilets is 41 units, and the garden area around the building is 770.85 m^2 planter box which planted with plants on the 4th floor covering an area of 100.81 m^2. Building occupants 161 female students, with details on the 1st floor with a capacity of 16 people, the 2nd and 3rd floors each have a capacity of 45 people, and the 4th floor has a capacity of 28 people. The estimated number of employees working is 20%.

Figure 1. (a) Research location; (b) Campus map; (c) Girls dormitory building; (d) Roof floor E Sindangsari campus, Universitas Sultan Ageng Tirtayasa.

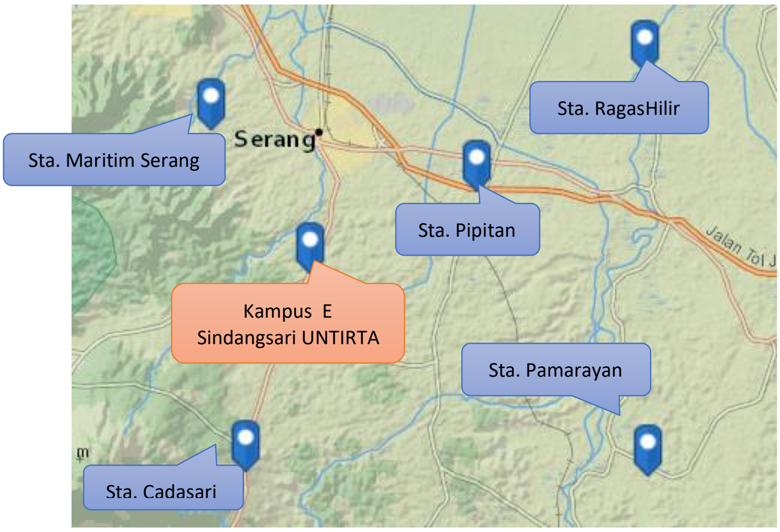

Figure 2. Research locations and rain post stations.

2.3. Rain Water Harvesting

As a water supply system, a rainwater harvesting system (RWHS) is a method or technology used to supply clean water by collecting rainwater from building roofs, ground surfaces, roads, or roads rock hills to be used. The main components of RWHS are the catchment area, conveyance system, storage device, distribution system [21].

2.4. Rain Plan

The mainstay rain calculation uses the F. J. Mock method to estimate the amount of discharge in a watershed-based on water balance [22]. The mainstay rainfall calculation is based on the nth order of the smallest 10-year rainfall price [23]. The following are the equations in the mainstay rain analysis.

$$P(\%) = \left(\frac{m}{n+1}\right) \times 100\% \quad (1)$$

2.5. Rainwater Supply & Clean Water Demand

The volume of rainwater supply is needed to determine the amount of rainwater harvested. The coefficient is defined as the ratio between peak runoff and rainfall intensity [24]. For cases with rainwater catchment areas in the form of roofs, the runoff coefficient is 0.75 – 0.95 [25]. Rainwater requirement is the volume of water used for daily needs for one month.

2.6. Budget Plan

The cost budget plan (RAB) is the number of costs needed, either wages or materials, in a construction project containing the volume, unit price, and the total price of various materials and required labor wages. In the building cost budget plan, there is an analysis of the unit price of work (AHSP), which analyzes materials and wages to make a unit of a certain type of work. Everything is regulated in the BOW (burgeslijke openbare werken) and SNI (Indonesian national standard) rules.

3. Result and Discussion

3.1. Rainwater Quality

Rainwater quality testing was carried out at the Water and Waste Treatment Laboratory (PAL) Department of Chemical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa. The rainwater samples used were sourced from 4 locations with test parameters (Table 2) consisting of pH (acidity level) and TDS (total dissolved solid). Based on the test results, the quality of rainwater in the E Sindangsari Untirta campus area meets the requirements of the physical parameters of water quality for sanitation hygiene purposes as stipulated in the Minister of Health Regulation No. 32 of 2017 [26].

Table 2. Rainwater quality test results in the E Sindangsari Untirta campus area.

Test	Unit	Result	Standard	Description
pH	-	7.196	6.5 – 8.5	Fulfilled
TDS	mg/L	10.25	< 1000	Fulfilled

3.2. Clean Water Demand

The demand for clean water is calculated using the number of occupants method. The use of water for this type of dormitory activity is 120 liters/person/day based on SNI 03-7065-2005 concerning planning plumbing systems for buildings [27]. The percentage of water used for non-potable water needs per person per day is shown in Table 3, with a recapitulation of water needs per day and per month in Table 4.

Table 3. Estimated demand for non-potable water**.**

Non-potable water needs	Result	
	%	Liter
Bath	66.42	79.704
Washing clothes	13.06	15.672
Washing kitchen utensils	2.840	3.408
Washing floor	0.760	0.912
Wudu	13.45	16.14
Washing the vehicle	0.830	0.996
Water plants	2.180	2.616
Other	0.460	0.552
Total	**100**	**120**

Table 4. Daily and monthly water requirements.

Month	Number of days	Daily water needs (m^3/day)	Monthly water needs (m^3)
January	31	19.32	598.92
February	28	19.32	540.96
March	31	19.32	598.92
April	30	19.32	579.60
May	31	19.32	598.92
June	30	19.32	579.60
July	31	19.32	598.92
August	31	19.32	598.92
September	30	19.32	579.60
October	31	19.32	598.92
November	30	19.32	579.60
December	31	19.32	598.92
	Total		**7,051.8**

3.3. RWHS Design

Mainstay rain is the monthly rainfall that occurs at a certain time with a chance of occurrence approaching 90% using the F. J. Mock method. The mainstay rain is obtained from processing the existing monthly rainfall data by sorting the ranking of the rainfall data based on the monthly average rainfall. Indonesia has two seasons, namely the rainy and dry seasons, with significant differences in monthly rainfall values, so that the mainstay rain cannot use the annual average rainfall data. Figure 3 shows the order of probability of the smallest to the largest mainstay rain percentage. In 2017 the highest rainfall values were in February, May, November, and December.

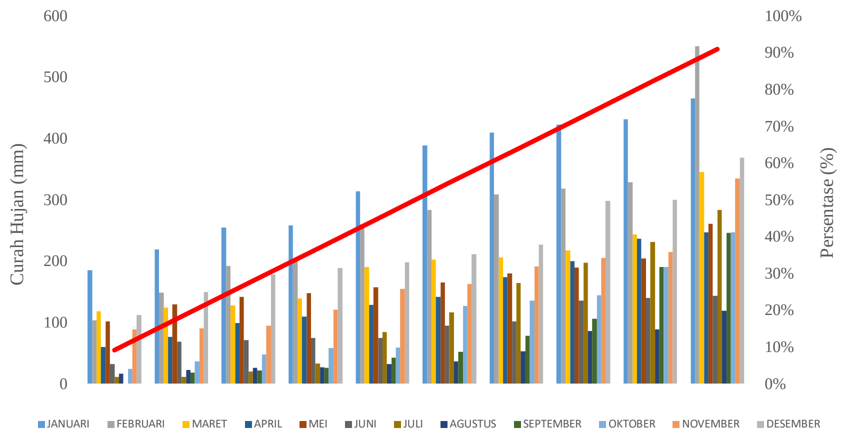

Figure 3. Mainstay rainfall sequence.

Figure 4 and Table 5 are the mainstay rain recapitulation of 90%, the highest is in February with rainfall of 550.22 mm, and the lowest is in August of 118.4 mm. The rainfall value becomes a reference in calculating water availability and planning for the RWHS component. The maximum monthly rainfall value fluctuates during the rainy season, usually from November to May. The rainfall value used to analyze potential savings is the result of the mainstay rain analysis. This amount of rainfall affects the amount of savings estimated each month. The higher the value of rainfall, the bigger the opportunity for savings. This potential savings analysis aims to determine the estimated percentage of water needs met each month.

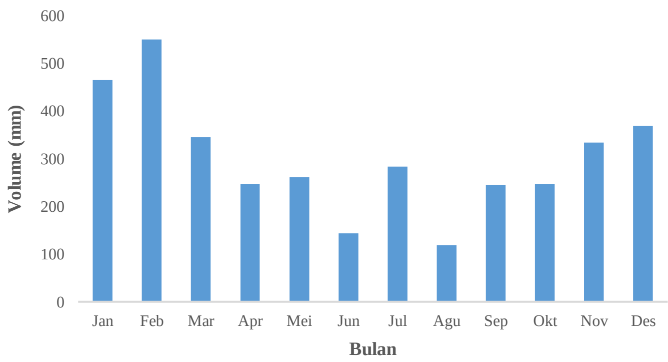

Figure 4. 90.91% mainstay rain.

Table 5. Recapitulation of 90.91% mainstay rain analysis.

Month	Year	Rainfall (mm)
January	2014	465.02
February	2017	550.22
March	2019	344.68
April	2019	246.44
May	2017	260.56
June	2016	142.99
July	2013	282.92
August	2010	118.40
September	2010	245.60
October	2016	246.69
November	2017	334.10
December	2017	368.62

3.4. Water Availability and Ground Reservoir Capacity

The way to fulfill needs is to store and accommodate rainwater to meet water needs. The volume of rainwater that is accommodated in the female dormitory building of the E Sindangsari Untirta campus is water accommodated in the catchment area, then flows through the gutter channel down through the pipe and stored in the holding tank. The regulation of the accommodated rainwater supply is carried out by adjusting the soil storage capacity to meet the needs of clean water. This method will also adjust to conditions in two seasons, namely the rainy and dry seasons. Perhitungan ketersediaan air hujan dan kapasitas tampungan tanah didasarkan pada akumulasi kekurangan air hujan sesuai dengan Peraturan Menteri Pekerjaan Umum tentang Penyelenggaraan Pembangunan SPAM Non Perpipaan No. 01/PRT/M 2009 [28]. Peraturan tersebut dijelaskan lebih lanjut dalam modul sosialisasi dan diseminasi standar dan pedoman pengumpulan air hujan yang dikeluarkan oleh Balitbang Kementerian Pekerjaan Umum [29]. The calculation of soil storage capacity is analyzed based on the difference between the accumulated rainwater supply and the maximum accumulation of clean water needs per month [30]. Based on the two methods, which will produce the most efficient ground reservoir volume.

Concerning the Regulation of the Minister of Public Works No. 01/PRT/M of 2009 concerning the volume of soil storage required for the utilization of rainwater is 3,927.35 m^3/year, so the supply of rainwater obtained is less than the need for clean water per month so that groundwater is still used. Calculation analysis will be carried out again to determine sufficient supply and appropriate demand based on land availability and aspects of efficiency and economy. The ground reservoir capacity also produces very large dimensions, so that it will cost a large budget. The calculation of the water supply ratio for the female dormitory building on the campus E Sindangsari Untirta is only 40% fulfilled. The following is Table 6 calculation of ground reservoir capacity to save groundwater use.

Table 6. Calculation of water availability (40% of monthly water needs).

Month	Number of days	Rainfall (mm)	Roof area (m^2)	Coef. run off	Rainwater supply (m^3)	Daily water needs (m^3)	Monthly Water Needs (m^3)	Water shortage (m^3)	Excess water (m^3)
Jan	31	465.02	1083	0.8	402.89	19.32	239.57		163.32
Feb	28	550.22	1083	0.8	476.71	19.32	216.38		260.33
Mar	31	344.68	1083	0.8	298.63	19.32	239.57		59.06
Apr	30	246.44	1083	0.8	213.52	19.32	231.84	-18.32	
May	31	260.56	1083	0.8	225.75	19.32	239.57	-13.82	
Jun	30	142.99	1083	0.8	123.88	19.32	231.84	-107.95	
Jul	31	282.92	1083	0.8	245.12	19.32	239.57		5.55
Aug	31	118.40	1083	0.8	102.58	19.32	239.57	-136.99	
Sep	30	245.60	1083	0.8	212.79	19.32	231.84	-19.05	
Oct	31	246.69	1083	0.8	213.73	19.32	239.57	-25.83	
Nov	30	334.10	1083	0.8	289.46	19.32	231.84		57.62
Dec	31	368.62	1083	0.8	319.37	19.32	239.57		79.80
Jml	**365**	**3,606.24**			**3,124.45**		**2,820.72**	**-321.97**	**625.69**

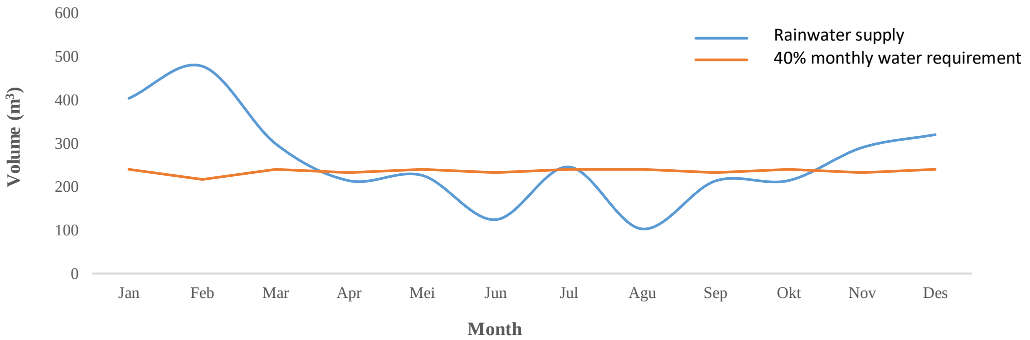

Figure 5. Supply and demand of water needs.

In Figure 5, a comparison chart of rainwater supply and 40% of clean water needs in January – March, July, and November – December. The rainwater supply is above the monthly water demand line, which indicates that the rainwater supply has a surplus. The water volume is Excess rain will be stored in the ground reservoir to be used as an alternative to clean water in months that experience a deficit, namely April – June and August – October. According to the ground reservoir capacity calculation based on the Minister of Public Works Regulation No. 01/PRT/M2009 above, the volume is 322 m^3 which can accommodate maximum rainfall and meet the needs of ±40% clean water needs. The water balance calculation is based on the relationship between the water supply (input) and an area's output (output) within a certain period. The water balance can identify water sources and water use in an area over a certain period [31]. After obtaining the ground reservoir volume, the monthly water balance can be calculated in Table 7 and Figure 6 to determine the volume of rainwater that can be accommodated and used every month. This study used analysis in the first two years.

The water balance in the first year of January, namely in the rainy season, fills the ground reservoir with a volume of 0 m^3 at the beginning of the month. Then at the end of January, the ground reservoir volume has been filled following the ground reservoir capacity minus the building's raw water requirement for one month. In February - March of the first and second years, the volume of water in the ground reservoir exceeds capacity. This month, the rainwater supply overflows and must be drained into the sewer or sewn into the ground.

Table 7. Calculation of monthly water balance.

Month	Rainwater supply (m^3)	Ground reservoir capacity (m^3)	First year			Second year		
			Initial (m^3)	Need (m^3)	Last (m^3)	Initial (m^3)	Need (m^3)	Last (m^3)
Jan	402.89	324	0	239.57	163.32	145.01	239.57	308.34
Feb	476.71	324	163.32	216.38	324.00	308.34	216.38	324.00
Mar	298.63	324	324.00	239.57	324.00	324.00	239.57	324.00
Apr	213.52	324	324.00	231.84	305.67	324.00	231.84	305.68
May	225.75	324	305.67	239.57	291.86	305.68	239.57	291.86
Jun	123.88	324	291.86	231.84	183.90	291.86	231.84	183.90
Jul	245.12	324	183.90	239.57	189.45	183.90	239.57	189.45
Aug	102.58	324	189.45	239.57	52.47	189.45	239.57	52.47
Sep	212.79	324	52.47	231.84	33.42	52.47	231.84	33.42
Oct	213.74	324	33.42	239.57	7.58	33.42	239.57	7.58
Nov	289.46	324	7.58	231.84	65.20	7.58	231.84	65.20
Dec	319.37	324	65.20	239.57	145.01	65.20	239.57	145.01
Total	**3,124.45**			**2,820.72**			**2,820.72**	

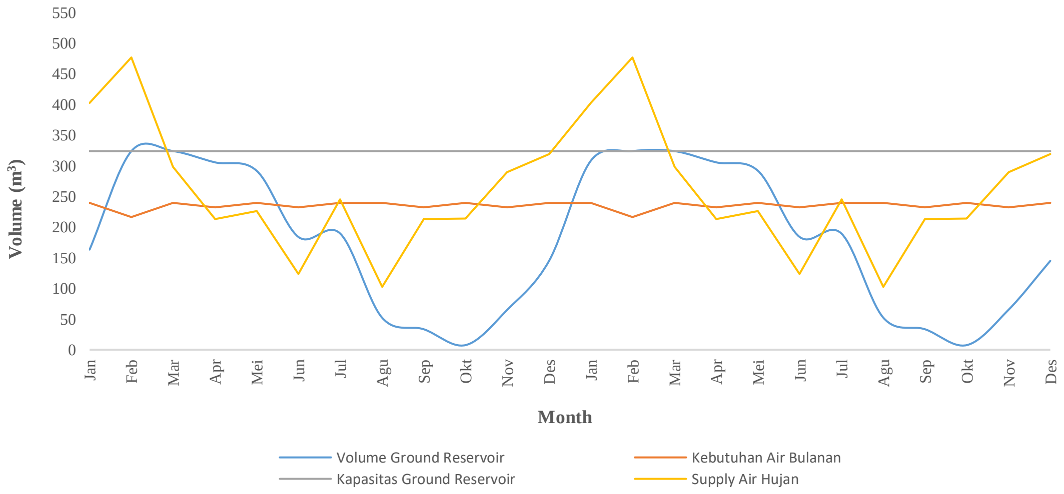

Figure 6. Rainwater harvesting system water balance.

3.5. RWHS Component Planning

The ground reservoir planning for the female dormitory building uses the main material of masonry in the form of a beam, in contrast to previous research in the Faculty of Social and Political Sciences building which was designed using a fiberglass panel tank [32]. The material is easy to obtain, the price is quite economical, and it is not tied to a certain volume of soil reservoir, which is the reason for choosing masonry material. However, this masonry must be reinforced by concrete construction on columns, beams, sloof, and slabs. This ground reservoir is also supported by a stone foundation with a minimum of 108 m^2 built underground to the west of the female dormitory building, as shown in Figure 7.

The factor influencing the dimensions of this standpipe is the roof area. With the roof area as shown in Figure 8 above and the design slope, the diameter of the open roof gutters for all segments is 200 mm or 8 inches. The dimensions of this 200 mm gutter are in the form of a semicircular cross-section. The larger the roof area, the larger the pipe dimensions will be because the load of rainwater that must drain is also getting bigger. Based on the measurement results, the dimensions of the roof segment used are determined using a minimum slope of 1% and a flat pipe diameter of 125 mm or 5 inches in diameter.

The filtration system used in the RWHS planning is based on a filtration system/artificial aquifer that is applied to ABSAH (artificial aquifer for rainwater storage). This filtration system filters rainwater from fine and coarse impurities contained in the rain to the flow process using pipes. This filtration system consists of 7 segments containing filtration material, in the following order: sand, gravel & limestone, crushed red brick, charcoal, gravel, sand, and palm fiber, as shown in Figure 9, as well as a series of components based on the RWHS analysis so that it can be summarized as follows: make a design and design as shown in Figure 10. The dimensions of the gutters are planned based on the catchment area (roof) with a rainfall intensity of 100 mm/hour.

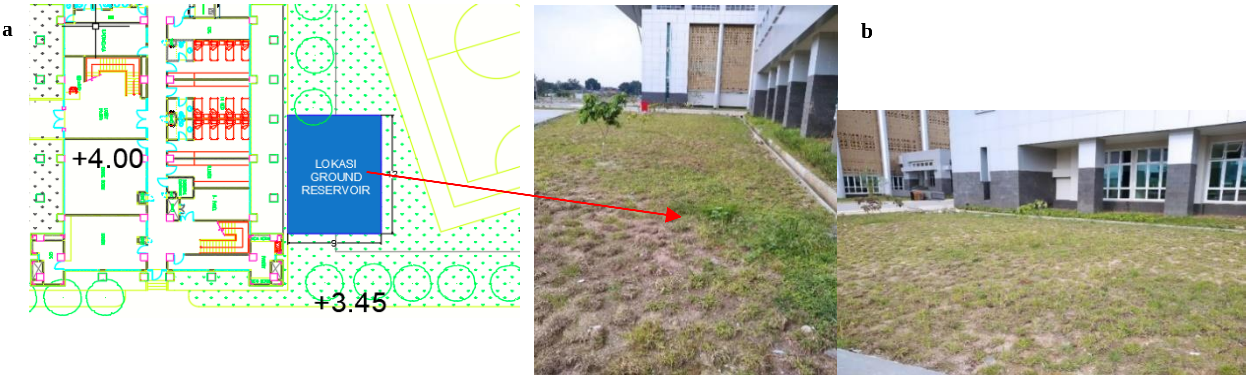

Figure 7. (a) Floor plan; (b) Location of ground reservoir layout.

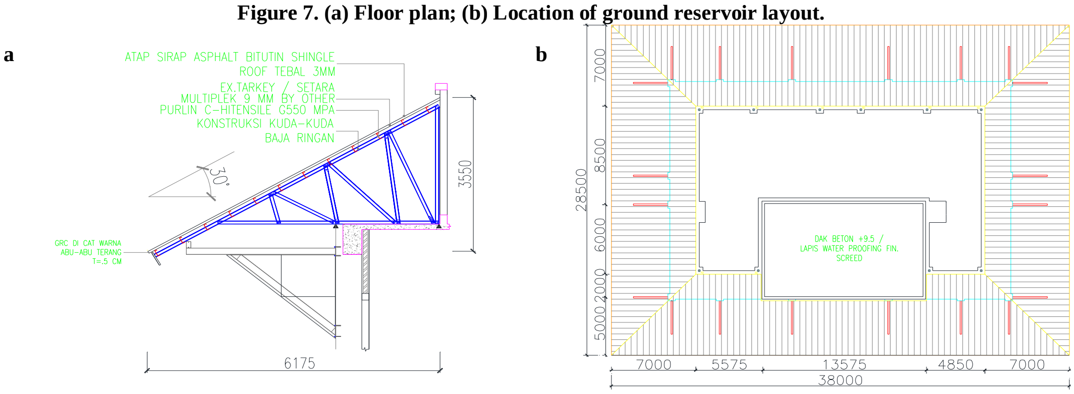

Figure 8. (a) Details of roof size (b) Division of roof segments.

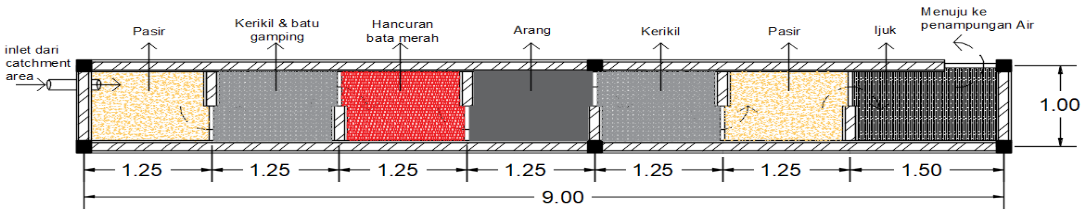

Figure 9. The RWHS filtration system for the female dormitory building on the campus E Sindangsari Untirta.

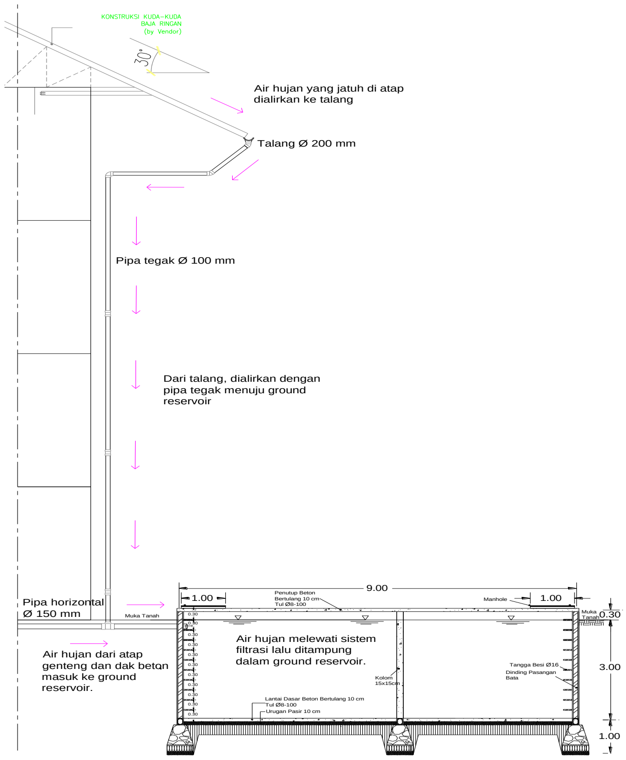

Figure 10. Schematic of the rainwater harvesting system of the female dormitory building for the campus E Sindangsari Untirta.

3.6. Budget Plan

The Work Unit Price Analysis (AHSP) carried out in this study refers to the Regulation of the Minister of Public Works and Public Housing Number 28/PRT/M/2016. The regulation regulates all costs, including overhead costs, which consist of field overhead (warehouse facilities, material transportation, building permits) and office overhead (office facility rental, employee salaries) total price per job. The budget plan for planning the RWHS system for the E Sindangsari Untirta female dormitory building is calculated based on the price of the latest system components and the Standard Unit Price for the Fiscal Year 2021 Banten Province. Based on the bill of quantity analysis results, the RAB is then compiled, which is listed in Table 8.

Table 8. Recapitulation of the RWHS budget plan for the female dormitory building.

No	Job	Total price	
1	Prepatory work	Rp	4,726,540
2	Work on soil and foundation	Rp	67,453,596
3	Concrete works	Rp	90,322,029
4	Wall work	Rp	63,501,343
5	Gutter and piping installation	Rp	36,242,539
	Total cost	**Rp**	**262,246,047**
	VAT (10%)	**Rp**	**26,224,605**
	Total cost + VAT	**Rp**	**288,470,652**
	Rounding	**Rp**	**288,471,000**

4. Conclusion

Within one year, the female dormitory building of the E Sindangsari Untirta campus with a population of 161 people requires 7,051.8 m^3 of clean water with a roof area of 1,083 m^2 which can only accommodate a rainwater supply of 3,124.45 m^3. The design of a rainwater harvesting system consists of 3 main components, namely the catchment area, pipeline network, and ground reservoir. The catchment area on the roof does not take advantage of the existing conditions, and on the tile roof can be added a circle gutter with a diameter of 250 mm. A 100 mm diameter PVC standpipe and a 150 mm diameter PVC flat pipe flow to the ground reservoir from the roof. The ground reservoir volume obtained is 324 m^3 equipped with a filtration system in 7 filtration stages. The water stored in the ground reservoir is good for non-potable water needs. Usage savings reach 41.12% per month. In making this rainwater harvesting system, the total budget plan that must be prepared is Rp. 288,471,000.

Acknowledgements

The authors would like to thank the Institute for Research and Community Service (LPPM) of Sultan Ageng Tirtayasa University, which has allowed us to carry out research activities, the 2021 intermediate lecturer research scheme with a research contract Number: B/177/UN.43.3/PT .01.03/2021.

REFERENCES

[1] Republik Indonesia. (2019). *Undang-Undang Republik Indonesia No. 17 Tahun 2019 tentang Sumber Daya Air*. Jakarta: Kementerian Pekerjaan Umum Republik Indonesia.

[2] Qi, Q., Marwa, J., Mwamila, T. B., Gwenzi, W., & Noubactep, C. (2019). Making rainwater harvesting a key solution for water management: The universality of the Kilimanjaro Concept. *Sustainability*, vol. 11, no. 20, pp, 5606-1-15.

[3] Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusk, K., ... & Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. *Water research*, vol. 115, pp. 195-209.

[4] Maryono, A. (2020). *Memanen Air Hujan*. Yogyakarta: UGM Press.

[5] Notaro, V., Liuzzo, L., & Freni, G. (2016). Reliability analysis of rainwater harvesting systems in southern Italy. *Procedia engineering*, vol. 162, pp. 373-380.

[6] Lani, N. H. M., Syafiuddin, A., Yusop, Z., & bin Mat Amin, M. Z. (2018). Performance of small and large scales rainwater harvesting systems in commercial buildings under different reliability and future water tariff scenarios. *Science of the total Environment*, vol. 636, pp. 1171-1179.

[7] Ali, S., Zhang, S., & Yue, T. (2020). Environmental and economic assessment of rainwater harvesting systems under five climatic conditions of Pakistan. *Journal of Cleaner Production*, vol. 259, no. 120829, pp. 1-13.

[8] Bashar, M. Z. I., Karim, M. R., & Imteaz, M. A. (2018). Reliability and economic analysis of urban rainwater harvesting: A comparative study within six major cities of Bangladesh. *Resources, Conservation and Recycling*, vol. 133, pp. 146-154.

[9] GhaffarianHoseini, A., Tookey, J., GhaffarianHoseini, A., Yusoff, S. M., & Hassan, N. B. (2016). State of the art of rainwater harvesting systems towards promoting green built environments: a review. *Desalination and Water Treatment*, vol. 57, no. 1, pp. 95-104.

[10] Tim Penyusun Konsep Green Campus. (2019). *Naskah Akademik dan Perencanaan Implementasi Green Campus IPB 2019-2023*. Bogor: Institut Pertanian Bogor.

[11] Kucukkaya, E., Kelesoglu, A., Gunaydin, H., Kilic, G. A., & Unver, U. (2021). Design of a passive rainwater harvesting system with green building approach. *International Journal of Sustainable Energy*, vol. 40, no. 2, pp. 175-187.

[12] Santoso, N. D., Akmalah, E., & Irawati, I. R. A. (2017). Implementasi konsep green campus di Kampus Itenas Bandung berdasarkan kategori tata letak dan infrastruktur. *RekaRacana: Jurnal Teknil Sipil*, vol. 3, no. 4, pp. 139-150.

[13] UI Green Metric Team. (2020). Guideline of UI GreenMetric World University Rangkings 2020. Jakarta: Universitas Indonesia.

[14] Qomariyah, S., Solichin, S., & Putri, A. (2016). Analisis pemanfaatan air hujan dengan metode penampungan air hujan untuk kebutuhan pertamanan dan toilet Gedung IV Fakultas Teknik Universitas Sebelas Maret, Surakarta (Studi kasus: Gedung IV Fakultas Teknik Universitas Sebelas Maret, Surakarta). *Matriks Teknik Sipil*, vol. 4, no. 2, pp. 434-441.

[15] Quaresvita, C. (2016). Perencanaan sistem pemanenan air hujan sebagai alternatif penyediaan air bersih (Studi kasus asrama ITS). [*Dissertation*]. Surabaya: Institut Teknologi Sepuluh Nopember.

[16] Riyanto, E., & Setiawan, A. (2020). Pemanenan air hujan menggunakan ground water tank untuk pemenuhan air baku di lokasi bangunan perkuliahan (Lokasi penelitian: Kampus 3, UM Purworejo). *Semesta Teknika*, vol. 23, no. 1, pp. 54-62.

[17] Marni, E. (2019). Analisis potensi pemanenan air hujan sebagai salah satu alternatif penghematan pemakaian air tanah pada Kawasan Universitas Ekasakti. *Journal Of Scientech Research*, vol. 1, no. 1, pp. 52-60.

[18] Tim Penyusun Pedoman Akademik Untirta. (2021). Pedoman Akademik Universitas Sultan Ageng Tirtayasa. Serang: Universitas Sultan Ageng Tirtayasa.

[19] Dwi, R. (2020). *UI Green Metric World University Rankings, Untirta Raih The Best New Participating University*. Accessed at 30 December 2020. Available online on https://untirta.ac.id/2020/12/07/ui-green-metric-world-university-rankings-untirta-raih-the-best-new-participating-university/.

[20] Google Inc. (2020). *Map of Female Dormitory Building, Campus E, Untirta Sindangsari*. Accessed at 13 September 2020. Available online on https://www.google.co.id/maps/@-6.9264558,106.2404471,15z.

[21] Barron, J. (2009). *Rainwater Harvesting: A Lifeline For Human Well-Being*. Geneva: UNEP/Earthprint.

[22] Indra, Z., Jasin, M. I., Binilang, A., & Mamoto, J. D. (2012). Analisis debit sungai Munte dengan metode Mock dan metode Nreca untuk kebutuhan pembangkit listrik tenaga air. *Jurnal Sipil Statik*, vol. 1, no. 1, pp. 34-38.

[23] Lestari, E., & Pamuji, B. (2017). Perencanaan teknologi pemanenan air hujan sebagai sumber air bersih pada Masjid Agung Banjarbaru Kalimantan Selatan. *Jurnal Muara Sains, Teknologi, Kedokteran dan Ilmu Kesehatan*, vol. 1, no. 2, pp. 1-12.

[24] Kamiana, I. M. (2016). *Teknik Perhitungan Debit Rencana Bangunan Air*. Yogyakarta: Graha Ilmu.

[25] Suripin. (2004). *Sistem Drainase Perkotaan yang Berkelanjutan*. Yogyakarta: Penerbit Andi.

[26] Republik Indonesia. (2017). *Peraturan Menteri Kesehatan Republik Indonesia Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua dan Pemandian Umum*. Jakarta: Kementerian Pekerjaan Umum.

[27] Badan Standardisasi Nasional. (2015). *Tata Cara Perencanaan Sistem Plambing, SNI-03-7065-2005*. Jakarta: Badan Standardisasi Nasional.

[28] Republik Indonesia. (2019). *Peraturan Menteri Pekerjaan Umum No. 01/PRT/M/2009 tentang Penyelenggaraan Pengembangan Sistem Penyediaan Air Minum Bukan Jaringan Perpipaan*.Jakarta: Kementerian Pekerjaan Umum.

[29] Darwati, S. (2014). Penampungan Air Hujan, in *Modul Sosialisasi dan Diseminasi Standar Dan Manual*. Bandung: Balitbang Pekerjaan Umum.

[30] Darmadi. (2020). Artificial aquifer of rain water deposit (ABSAH) to provide a cleanwater for dry season in Karangmoncol District , Purbalingga Regency. *Jurnal Teknik Sipil-Arsitektur*, vol. 13, no. 1, pp. 1-8.

[31] Hartanto, P. (2017). Perhitungan Neraca Air DAS Cidanau Menggunakan Metode Thornthwaite. *RISET Geologi dan Pertambangan*, vol. 27, no. 2, pp. 213-223.

[32] Ulfa, A., Wigati, R., & Kusuma, R. I. (2021). Perencanaan rainwater harvesting system sebagai implementasi konsep smart & green campus (Studi kasus: Gedung Fakultas Ilmu Sosial Politik, Universitas Sultan Ageng Tirtayasa, Kampus Sindangsari). *Fondasi: Jurnal Teknik Sipil*, vol. 10, no. 2, pp. 123-133.