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Housing Design with Rainwater Harvesting System for Housing Type 36 And Type 48 Environmentally Friendly

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Abstract

Procurement of housing for low to middle income people in the city of Palembang is carried out by the government and developers with the direction of building housing on the outskirts of the city. One of the development directions is the Talang Kepuh area, Ilir Barat District 1. Housing development in this area is carried out on landfill swamp land, so that in its construction it must have its own characteristics. In addition, the problem of housing development is the difficulty of providing clean water. So that it takes a housing design that pays attention to environmental aspects, one of which is the rainwater harvesting system as an alternative solution to the problem of providing clean water to meet the needs of the community. The rainwater harvesting system is the use of rainwater harvesting, where rainwater from the roof of the house will be channeled into distribution pipes which will then be forwarded and accommodated in a holding tank. The analytical method used is descriptive qualitative. The results of the discussion are outlined in the form of a simple concept of planning and designing an environmentally friendly house.

Keywords : Rainwater Harvesrting, Water Needs, Rainfall

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1. Introduction

Palembang is located in the lowlands which has an area of 36,484.94 Ha of which 54% is swamp [1]. The swamp in Palembang was originally intended as a water catchment area. However, along with the development of the city of Palembang and the increasing need for development in the residential sector, swampland has shifted its function into a built-up area. Changes in land use in Palembang cannot be separated from the influence of population movement and urban policies. The population of the city of Palembang amounted to 1,674,243 people in 2019 with an average growth of around 5% annually, so it is predicted that in 2025 it will increase to 1,802,350 people [2].

The problem of development in the housing and settlement sector is inseparable from the dynamics that develop, both from government policies and developments in people's lives because the need for space and land continues to increase. Several areas in Palembang have experienced a large-scale conversion of swampland, for example, the Jakabaring area, the area around the Musi II bridge, and the Ilir Barat 1 area which currently has a lot of hoarding of swampland for housing and settlements. Housing development on swampland should have its housing characteristics so that a review of the housing pattern built by developers on land that is experiencing hoarding is needed [3]. People who can't afford to own a house on dry land use swampland as a place to live. This is what causes the conversion of swamps in Palembang as a fast-growing residential area. The tendency of people who want a permanent house shape because it is influenced by modern life triggers housing developers by hoarding swamps to become permanent housing land. In addition to the problem of land availability for housing, developers are also faced with the problem of the need for clean water, and water that was previously stored in swamps after stockpiling will shift to lower areas and can cause flooding, this is also supported by the flat topography of Palembang which can cause puddles [4].

The application of environmentally friendly housing and settlement designs requires several supporting theories, for example, the theory of spatial patterns, regional images, and rainwater treatment installation systems as one of the regional water management systems. The spatial pattern is a pattern of building mass in one area which includes a centralized, linear, radial cluster, and grid pattern [5]. While the regional image contains components that can affect the appearance of an area such as nodes, landmarks, districts, paths, and edges [5]. In the design of buildings, the harmony of design with nature is not given much attention, because, in the utilization of natural resources and the use of technology, it is often not friendly to nature. Therefore, approach and understanding in the application of building design must better understand the natural conditions. The concept of environmentally friendly housing is not only identified with tree planting and the existence of green open space requirements, which assumes that this concept can withstand the rate of global warming and is environmentally friendly [6].

However, the problem of the need for clean water is a concept of housing and settlement development that has occurred in the city of Palembang. This condition occurs in almost every housing development, especially development in the suburbs of Palembang. The need for clean water is generally sourced from the provision of water from local water company and by utilizing groundwater. Not all of the clean water supply from local water company is obtained every day and groundwater quality in housing tends to be cloudy, sticky, and smelly so that the use of clean water is obtained from mobile water sellers who require a higher cost per unit volume than local water company supply.

In an effort to optimize the need for clean water, developers must have special criteria in water management, namely by means of water use efficiency, water replacement, water reuse, recycling, and harvesting [7]. Rainwater harvesting is a system that utilizes to be used as a second change for daily non-consumable clean water needs.

If it is seen from the intensity of rainfall which is quite high in the city of Palembang, rainwater harvesting can be applied to houses whose supply from the local water company is not obtained every day.

In addition, water resources through water conservation with the rainwater harvesting system have been widely applied internationally and have become a global environmental water resources management agenda in the context of overcoming water inequality in the rainy and dry seasons (lack of water) and as a water countermeasure.

The housing and settlement planning approach with a rainwater harvesting system is another alternative to the use of water resources other than local water company water and groundwater. Rainwater harvesting is a rainwater harvesting system with the concept of reducing groundwater use, where the stored rainwater can be used for non-potable water use, this system prioritizes environmental sustainability and can be integrated with other water resource management systems [3]. From some of the studies above, this research emphasizes the design of simple housing development by looking at the existing environmental aspects. Based on these considerations, housing design with the application of a rainwater harvesting system is expected to be a solution for the availability of clean water.

2. Materials and Methods

2.1 Time and Location

The object study was carried out in the swamp area of Bukit Baru Village, Ilir Barat 1 Palembang District which was carried out in February 2020. The site location selection was based on several factors in the form of existing data obtained from field observations, interviews, and location mapping. From the existing data, it can be analyzed as a consideration to determine the design of housing in swampland that is environmentally sound based on typology, spatial planning patterns, and regional image conditions. The data analysis was carried out using a qualitative descriptive method by processing field data and then tabulation was carried out to determine the pattern of housing being built and referring to 3 (three) housing patterns, namely, the conventional pattern, cluster and Planned Unit Development (PUD). The analytical variable used is the housing pattern. Maps are used to determine the location and placement of housing zones, land use data is used as a reference in planning. The analyzed data will be the main reference in the development of environmentally friendly housing designs.

Figure 1. Location of study

Figure 2. The appearance of low land as the study area

Geographically Jl. Talang Kapuh is located in the Ilir Barat 1 District, part of which is located on the edge of the Musi River with an area of ± 19.77 km2 or 1.977 Ha, located about 10 Kilometers from Palembang City Center. The topographical conditions of this area are located at an altitude of 4 m - 20 m above sea level and there is no steep topography, thus when viewed from the topographical aspect there is no limiting factor for the development of space, either in the form of a large slope or slope. The general climatological conditions of this area are not much different from the city of Palembang which has an average temperature ranging from 24-32 C, and rainfall intensity ranging from 91 mm – 541 mm. [4].

2.2 Characteristics of Housing Design.

The concept of an environmentally friendly housing area in Law No. 4 of 1992 Chapter 1 article 1 is a group of houses that function as a residential environment or residential environment equipped with environmental facilities and infrastructure, which reflect the standard of living, welfare, personality, and human civilization of its inhabitants. According to the World Health Organization for health and the environment, the house is a physical structure or building as a shelter, environmental conditions can be useful for physical and spiritual health and social conditions both for the health of families and individuals. The concept involves a sociological and technical approach to risk factor management and is oriented towards the location, building, qualification, adaptation, management, use, and maintenance of the house and the surrounding environment, which also includes the element of whether the house has adequate drinking water supply and cooking facilities. washing, storing food, and disposing of human waste and other waste[8].

The Decree of the Minister of Health of the Republic of Indonesia Number 829/Menkes/SK /VII/1999 concerning environmental health requirements based on the technical guidelines for the assessment of healthy homes by the Directorate General of Disease Control and Environmental Health of the Ministry of Health of the Republic of Indonesia in 2007 is:

1. The ceiling, as for the requirements for a good ceiling, should be easy to clean, not prone to accidents, light in color, and must cover the roof frame evenly.
2. The wall, the condition is that the wall must be perpendicular so that it can carry the weight of the wall itself, the load of wind pressure and if as a bearing wall it must be able to carry the load on it, the wall must be separated from the foundation by a waterproof layer so that groundwater does not seep up so that the wall is protected from getting wet, damp and looks clean, not mossy.
3. Floor, the condition of the floor must be strong to withstand the load on it, flat, not slippery, stable when stepped on, the floor surface is easy to clean and waterproof. To prevent the entry of water into the house, for houses not on stilts, the floor height should be ± 10 cm from the yard and 25 cm from the road.

4. Ventilation, a healthy home must have ventilation as air circulation, maintaining optimum humidity. The area of ventilation holes is a minimum of 5% of the room area and incidental ventilation holes (can be opened and closed) a minimum of 5%.
5. The division of the room/layout, the condition of a healthy house must have a part of the room that is by its function, such as having a room for rest (bedroom) which is quite spacious with a room of at least 8 m2, kitchen room, bathroom, and family toilet.
6. Lighting, a healthy home requires sufficient lighting, not too little and not too much, sanitation facilities group, including clean water facilities, sewage disposal, wastewater disposal, waste disposal facilities. Resident behavior groups, including opening windows in the room at home, cleaning the house and yard, throwing feces into the latrine, throwing garbage in the trash can.

An environmentally friendly residential area is an area with an RT/RW scale and has a contribution to the environment, especially around the area. Analysis of the application of the area is carried out based on the existing problems, namely in a qualitative way, and then used as a design in the preparation of planning and design concepts. The process of qualitative analysis includes:

1. Site Analysis

Site analysis is carried out on the condition and layout of the site to determine the site program to be designed. The site conditions in this area are adjusted to land use, namely residential areas, shape and dimensions of the site, accessibility analysis, noise analysis, view analysis, circulation analysis, analysis of sun orientation, wind, and vegetation.

2. Structural Analysis

The structural analysis includes the structural requirements of the foundation, building body, and roof structure by considering the function of space, security, sturdiness, durability, image, and aesthetic demands of a building adapted to environmental conditions.

3. Utility Analysis

Utility analysis is designed to support residential area buildings so that they can function properly based on space requirements and comfort factors for their users. The utilities needed are lighting systems, ventilation, waste networks, and clean water management.

3. Results and Discussion

3.1. Site Analysis and Building Concept

The basic concept of housing design in this area is to meet the needs of middle-income people in creating livable houses. To overcome the problem of people's income, it is necessary to provide cheap and livable housing that optimizes natural conditions, such as natural lighting and natural air circulation. When viewed from the climatic conditions of Palembang City, the application of simple house design in this area refers to the theme "Tropical Modern Architecture Approach". Tropical modern architecture is a building designed with a design concept that adapts to the tropical environment but does not forget the aesthetic side, for example, the use of materials, air circulation, and natural lighting, this is because the tropical environment has a climate with quite scorching heat.

Figure 3. Site Plan Area

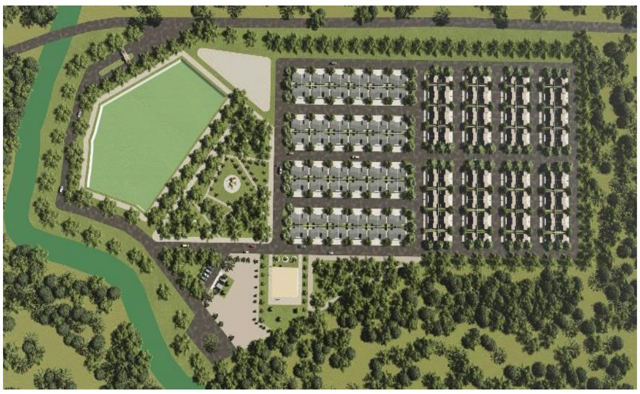
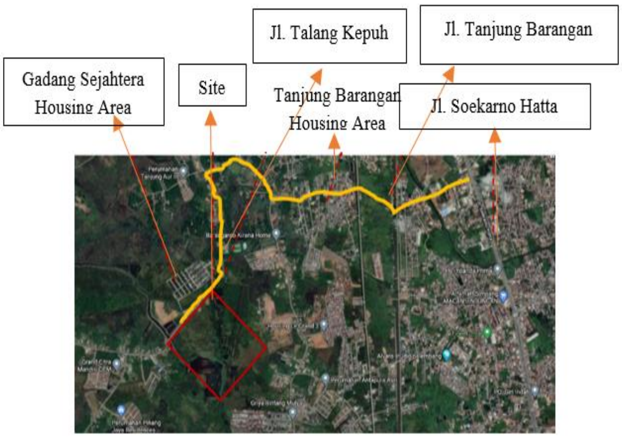


Figure 4. Layout Plan

3.2. Concept of Achievement and Layout of Building Mass

The initial stage that needs to be considered in determining the concept of achievement and the location of the building mass is to pay attention to the regulations regarding the concept of achievement and building layout with adjustments to the location of building boundaries. Based on the analysis of the achievements to the site area can be accessed using private vehicles (motorcycles, cars) or public transportation. Meanwhile, the concept of building mass layout results in the need for building orientation and building form, so that it can create a semi-private communal space (figure 5).



a

b

Figure 5. Concept of Achievement (a) and Layout of Building Mass (b)

3.3. Building Structure Concept

The application of the building concept is to maximize buildings with natural conditions in the area through natural ventilation, increase the intensity of light in the room so that it can control the use of lights, and increase greenery. In addition, the analysis of the concept of the building structure must be by the design characteristics by considering the function, form of expression, and physical factors. The design concept in this area uses a landed house structure design with a height of 50 cm^2. The type of substructure used is a treaded house foundation with continuously shaped bricks, this foundation is used as a pedestal. The roof structure of the building used in this plan is light steel which can be used as a gutter that is passed through a pipe to a rainwater reservoir. The wall structure used in the design is made of concrete, with a wall thickness applied of 12 cm by 30 cm and 40 cm in the vertical direction and 60 cm in the horizontal direction.

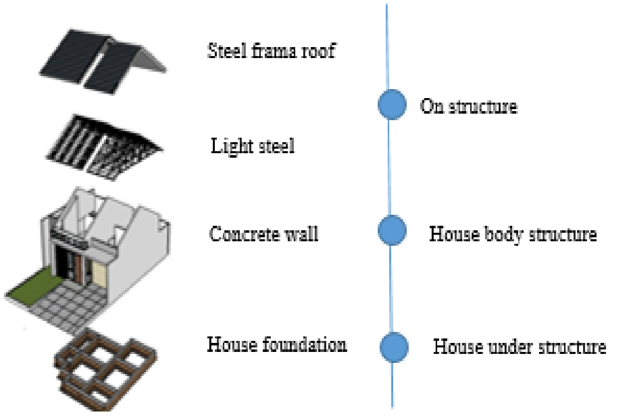


Figure 6. Concept of Building Structure

Figure 7. Natural Air Conditioning and Natural Lighting of Buildings

The concept of an environmentally friendly house must have clean air circulation openings. In addition to improving natural air quality, housing design with this design can save energy because of the reduction in air conditioning energy consumption. In addition, the use of sunlight for lighting can maximize the use of lights during the day, therefore every part of the house gets sufficient exposure to sunlight. To deal with the sun's rays can be tricked by making a canopy on each window.

Figure 8. Skylights as an Alternative to Building Wall Openings

3.4 Utility Concepts and Building Waste Management

The utility system used to support the planning of this area is the creation of green open spaces and retention ponds. The purpose of making a retention pond is to accommodate rainwater and household wastewater. In addition, the application of making rainwater harvesting as water conservation. Rainwater harvesting can be used to meet daily clean water needs, such as toilets, kitchens, washing clothes, and others. The distribution system for the clean water network uses a Down Feed System with pump power from the water reservoir to the distribution pipes. The clean water supply system can be used to standardize the provision of clean water quality.

Figure 9. Green Open Space Area

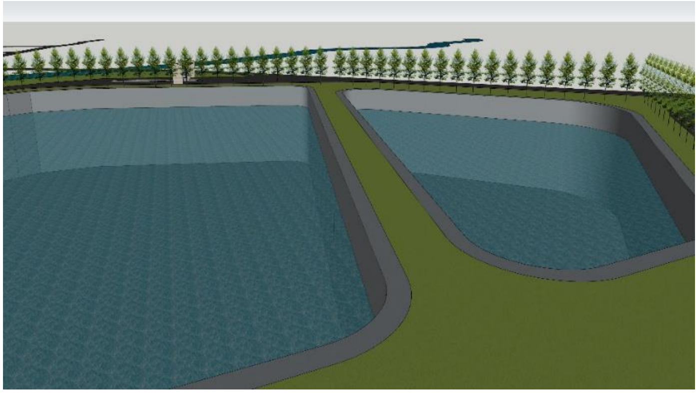


Figure 10. Retention Pond Site Plan

Rainwater harvesting system is collecting, storing, and utilizing rainwater (Figure 10). The use of rainwater harvesting is as the main source of clean water, an additional source of clean water for the use of clean water, and an additional source of water for the use of non-clean water. [9]. The advantages of using rainwater as an alternative to using clean water are to minimize environmental impacts, absorb excess rainwater into the ground, reduce dependence on the supply system, and as a conservation effort.

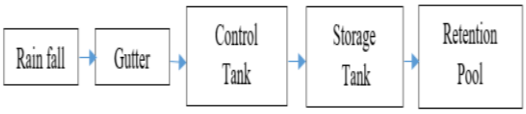


Figure 11. Rainwater Utilization Process

The application of the rainwater harvesting system serves to store rainwater captured from the catchment area, then flowed through pipes and is stored in storage tanks. The schematic of a simple rainwater harvesting system that can generally be applied to household needs can be seen in Figure 11 below.

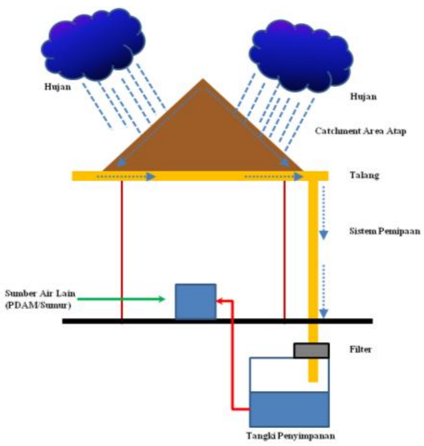


Figure 12. Rainwater Harvesting Site Plan

Domestic waste management within the scope of the area can create a clean and conducive environment, and the management of household sewage systems can be managed properly so that it does not pollute the environment either. Garbage is an important part, especially for urban settlements that are densely populated. The concept of waste management must be planned so that problems do not occur in the future. The house is the starting point in a series of waste management, starting with sorting organic, inorganic, and B3 waste.

Figure 13. Residential Waste Management

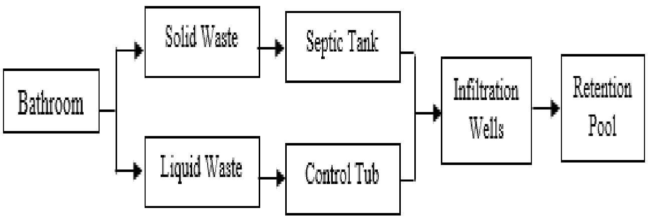


Figure 14. Toilet Disposal Scheme

Figure 15. Shower to save water usage and the bathroom does not require a large space.

3.5 Rainwater Harvesting Potential and Techniques.

1. Building roof area

To get good quality rainwater, the roof surface should be coated with aluminum or a roof made of cement (cast). The design of the house to get good water quality can be designed in such a way that the quality of the water that is accommodated is suitable for use to meet daily needs. Water that falls on the precarious surface will be channeled to the reservoir through a pipe. The pipe is first made a filter, this is useful as a precaution against the possibility of water pollution due to the inclusion of various impurities (tree branches, leaves, or garbage) that enter along with rainwater. The random or reservoir must be provided with a drain pipe at the bottom to facilitate the cleaning process.

2. Calculation of Raw Water Needs

To calculate the need for raw water in residential homes, SNI 03-7065-2005 can be used as much as 120 liters/day according to the function of the building. Aspects of water availability and quality are odorless water, and not cloudy in color. In this study the use of clean water is only used for bathing, washing and several other needs. For residential houses have the following specifications for Cluster Area 1 (House type 36) is 53.25 m^2 and Cluster Area 2 (House type 48) is 58.1 m^2.

Table 1. The need for raw water, not drinking water.

Necessities	Water Used (Liters/Person/Day)
Bath. Outhouse	20.0
Wash clothes	12.0
Wudhu water	15.0
Miscellaneous needs	20.0
Total	67.0

In the table above, the need for clean water that is not consumed as drink water is 67 liters/person/day. Calculation of clean water needs assuming family members for each type of house with water needs for bathing, washing clothes, ablution water, house cleaning, watering plants, and other purposes are:

Qd = Number of family members x Water usage per person per day
Qd = 5 x 120 liters/day
= 600 liters/day = 0.6 m^3/day

Table 2. Water needs by house type

House Type	Number of Occupants (Persons)	Water Needs (Liters/Person/Day)	Water Needs (Liters/day)	Water requirement (m^3/day)
36 type	5	67	335	0.335
Type48	6	67	402	0.402

3.6. Mainstay Discharge Probability Analysis

The mainstay discharge calculation aims to analyze the availability of water, which is better known as the lowest flow rate. Mainstay discharge is a predetermined minimum discharge that can meet water needs. Reliable debt analysis requires monthly debit data with a period of more than 10 years or a minimum of 10 years. For better accuracy, data with a longer period is needed. The rainfall used in this study is rainfall data using 15 daily rainfall in 2011-2020. The following table is a recapitulation of semi-monthly rainfall data for 10 years (2011-2020) based on data obtained from Indonesia Agency for Meteorology, Climatology, and Geophysics, Kenten Station, Palembang, South Sumatera (BMKG). Semi-monthly rainfall data with a period of 10 years, then calculated the probability value with a probability of being fulfilled by 80%. The probability value (P) is calculated using the method of Weibull. Here's how to calculate the probability value.

$$P = \frac{m}{(n\ total) + 1}\ x\ 100\%$$

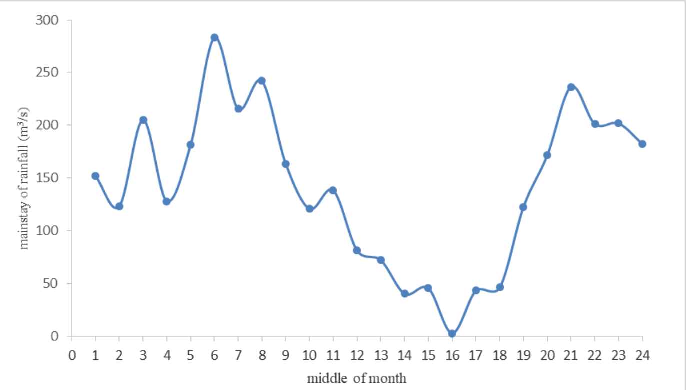


Figure 16. Featured Rainfall Graph

From the graph, it can be seen the value of rain fall mainstay each month is fluctuating or not fixed. The value of the lowest rainfall intensity starts in June to the end of September, which ranges from 46.05 mm/month - 81.15 mm/month. The highest rainfall intensity occurs in January, February, March, April, May, June, November, and December, which is above 100 mm/month. The occurrence of changes in the mainstay discharge is influenced by the high and low rainfall in the Palembang City area.

3.7. Analysis of Water Availability and Demand.

According to [10] to get the volume of rainwater availability, what must be done is the amount of rainfall multiplied by the roof area and the runoff coefficient. The roof runoff coefficient value is 0.8. The method of meeting water needs is done by adjusting the capacity of the rainwater catcher tank. Determination of the volume of this tank using the water balance method, namely adjusting to the conditions of the rainy and dry seasons. So that the water obtained can be supplied in the rainy season to meet the water needs in the dry season which makes the water balance balanced. The following is the calculation of water availability and needs per 15 days.

For the calculation of water availability can be calculated with the following equation:

$$V = ARC$$

Where:
V = Volume of water availability (m^3)
R = 80% reliable rainfall (mm)
C = Coefficient *runoff*
A = roof area (m^2)

From the above equation, the values for the availability of water for house type 36 and house type 48 are obtained. The balance of water availability and demand is done by comparing the mainstay rainfall discharge that must be available to meet daily raw water needs. Thus, by comparing the two, an idea will be obtained whether the availability of water is sufficient or not to meet the daily needs of clean water. The results of the calculation of meeting water needs in the middle of the month can be seen in Tables 2 and 3 and Figures 17 and 18.

From Figures 17 and 18, the results of the calculation of water availability show varying and fluctuating values according to the seasons, while the domestic water requirement does not change with the seasons so that it is considered constant throughout the year. The comparison of the two discharges shows that the surplus of water occurs in the 1st January, 1st February, March, April, May, 1st June, 2nd half month of October, November, and December. The high availability of water during this period was due to the high intensity of rainfall in these months. Meanwhile, in the 2nd month of June, July, August, September, and the 1st half of October, the availability of water could not meet the raw water needs, because during that period the intensity of rainfall was low or more precisely, the dry month period. Thus, to meet the needs of raw water in that month using clean water sources from local water company.

Table 2. Calculation of Water Needs Fulfillment Type 36 House.

Month	Mainstay of Rainfall 80% (mm)	Clean Water Needs (m^3)	Availability of Rainwater (m^3) 36 House Type	Deficiency (m^3)	Surplus (m^3)
Jan-01	151,85	5,025	6,47	-	1,445
Jan-02	123,15	5,025	5,25	-	0,225
Feb-01	205,05	5,025	8,74	-	3,715
Feb-02	127,95	5,025	5,45	-	0,425
Mart-01	181,2	5,025	7,72	-	2,695
Mart-02	283,05	5,025	12,06	-	7,035
Apr-01	215,4	5,025	9,18	-	4,155
Apr-02	241,95	5,025	10,31	-	5,285
Mei-01	163,65	5,025	6,97	-	1,945
Mei-02	120,75	5,025	5,14	-	0,115
Jun-01	138,15	5,025	5,89	-	0,865
Jun-02	81,15	5,025	3,46	1,57	-
Jul-01	72	5,025	3,07	1,96	-
Jul-02	40,05	5,025	1,71	3,32	-
Agust-01	45,3	5,025	1,93	3,10	-
Agust-02	2,73	5,025	0,12	4,91	-
Sep-01	43,2	5,025	1,84	3,19	-
Sep-02	46,05	5,025	1,96	3,07	-
Okt-01	122,55	5,025	5,22	-	0,195
Okt-02	171,6	5,025	7,31	-	2,285
Nov-01	236,55	5,025	10,08	-	5,055
Nov-02	201,15	5,025	8,57	-	3,545
Des 1	201,75	5,025	8,59	-	3,565
Des2	182,25	5,025	7,76	-	2,735
Total	**3398,48**	**120,6**	**144,8**	**21,085**	**45,285**

Table 3. Calculation of Water Needs Fulfillment Type 48 House.

Month	Mainstay of Rainfall 80% 80% (mm)	Clean Water Needs (m^3)	Availability of Rainwater (m^3) 36 House Type	Deficiency (m^3)	Surplus (m^3)
Jan-01	151,85	6,03	7,06	-	1,03
Jan-02	123,15	6,03	5,72	0,31	-
Feb-01	205,05	6,03	9,53	-	3,5
Feb-02	127,95	6,03	5,95	0,08	-
March-01	181,2	6,03	8,42	-	2,39
March-02	283,05	6,03	13,16	-	7,13
Apr-01	215,4	6,03	10,01	-	3,98
Apr-02	241,95	6,03	11,25	-	5,22
Mei-01	163,65	6,03	7,61	-	1,58
Mei-02	120,75	6,03	5,61	0,42	-
Jun-01	138,15	6,03	6,42	-	0,39
Jun-02	81,15	6,03	3,77	2,26	-
Jul-01	72	6,03	3,35	2,68	-
Jul-02	40,05	6,03	1,86	4,17	-
Agust-01	45,3	6,03	2,11	3,92	-
Agust-02	2,73	6,03	0,13	5,90	-
Sep-01	43,2	6,03	2,01	4,02	-
Sep-02	46,05	6,03	2,14	3,89	-
Okt-01	122,55	6,03	5,7	0,33	-
Okt-02	171,6	6,03	7,98	-	1,95
Nov-01	236,55	6,03	10,99	-	4,96
Nov-02	201,15	6,03	9,35	-	3,32
Des 1	201,75	6,03	9,38	-	3,35
Des2	182,25	6,03	8,47	-	2,44
Total	**3398,48**	**144,72**	**157,98**	**27,98**	**41,24**

Check the calculation results:
Σ Water Availability Volume – Σ Water demand = Σ Excess water – Σ Water shortage
36 type house : 144.8 – 120.6 = 45.285 – 21.085
48 type house : 157.98– 144.72 = 41.24 – 27.98.

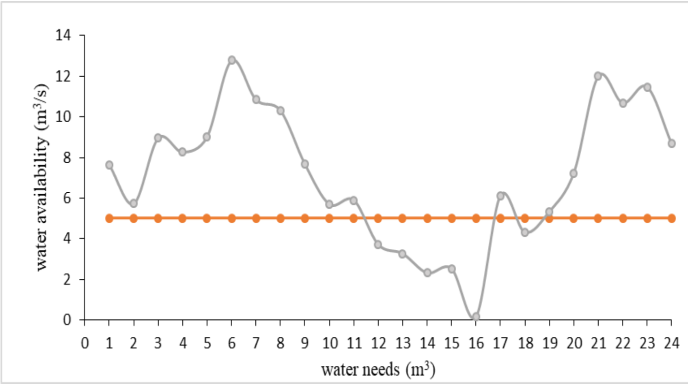


Figure 17. Comparison Graph of Water Supply and Demand for House Type 36.

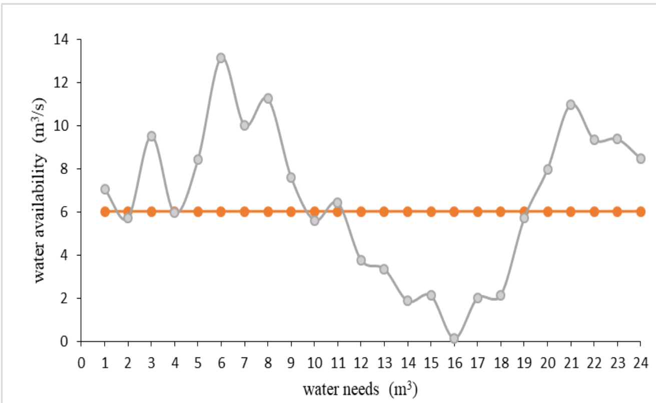


Figure 18. Comparative Graph of Water Supply and Demand for House Types 48.

4. Conclusion

1. Ilir Barat 1 district has good potential to implement rainwater harvesting, with an average maximum monthly rainfall of 535.4 mm and the highest daily rainfall rate of is172.4mm in September 2016 for the last 10 years. Based on the amount or quantity of

rainfall, the mainstay discharge is 80% with the lowest rainfall intensity value occur-ring in June to the end of September, which is around 46.05 mm/month - 81.15 mm/month and the highest oc-curs in March, April, May, November and Decem-ber which ranged > 100 mm/month.

2. The design of the rainwater harvesting system with the highest main-stay rainfall value obtained a dis-charge of 9.83 m3/month for house type 36 and 10.72 m3/month house type 48. When viewed from the magnitude of the discharge value obtained and the limited land used to build Rainfall storage tanks/tanks in large quantities, so for each type of house has a reservoir of 10 m3 for type 36 and type 48 with a depth of 120 cm below the ground and given a concrete slab cover with a thickness of 125 mm. The size of the reservoir is 250 cm x 250 cm x 120 cm for types 36 and 48 or 4 m3.

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