Enviromental housing planning with rainwater harvesting system as clean water resources using 3D in Sumenep regency

S Fansuri\textsuperscript{1} and N Zainah\textsuperscript{1}

\textsuperscript{1}Civil Engineering Department of Engineering Faculty of Wiraraja University, Sumenep, Indonesia.

E-mail: subaidillah.sd@gmail.com, ina.zainahnor@gmail.com

Abstract. Todays, so many housing developments in Sumenep, but not in accordance with the existing Indonesian National Standards. The purpose of environmentally housing is complying with the Indonesian national standard stipulations concerning various aspects of housing planning, plumbing plans which reuse rainwater as clean water. The requirements of data required for basic residential environment research are primary and secondary data. Location planned in Pangarangan Village, Kab. Sumenep. Secondary data is data obtained from the agency concerned. Based on data analysis techniques used in this study is quantitative data analysis, and the calculations are done by Design House using AutoCAD and 3D Sketchup applications, and Plumbing Installation Analysis. The total land area to be planned for housing is 3,400 m\textsuperscript{2}, the land utilized for the house is 1,800 m\textsuperscript{2}, and the land for public facilities and social facilities is 1,600 m\textsuperscript{2}. Every house that is planned in this housing, is given rainwater storage to be reused into clean water. The results of the analysis and calculation of clean water for type 65 as many as 10 units of houses and type 85 of 4 units of houses in 2019 amounted to 6.72 m\textsuperscript{3} / day, which sufficient for daily needs.

1. Introduction
The house is a place for everyone to live which give them a comfort, safe and secure. The need for decent housing for the community is increasing due to population increase every year. Currently in Sumenep Regency has a lot of housing, but not environmentally friendly. Housing continues to be built to meet community demand without thinking about environmental impacts. Descreeing of soil absorption for rainwater because housing made rainwater flew directly into the river then into the sea without any chance to seep into the ground. [1,8,10]. In other side, the need of clan water and the use of ground water are increasing. This will creat problems when the needs and availability are not appropriate. Rainwater harvesting is one of the solution taht can we use to meet the demand of clean water daily needs. Many authors have proposed rainwater harvesting system as daily clean water resources. Dani et al [5] assessed the potential for rainwater harvesting in the Klunggen village Slogohimo ditrict Wonogiri regency. Faisal et al [11] also assessed the potential for rainwater harvesting system in public facilities such as university or schools.

With rainwater harvesting system, it is expected to creat the environmentally friendly housing planning. The planning also including the plumbing system for the utilization of rainwater into clean
water in order to reduce the available clean water. With this plumbing system, users can save water from drilled wells or form Regional Water Utility Company [7]. For designing we use AutoCAD application to draw 2D buildings and 3D images with Google SketchUp application. This case study takes place in Rampak Housing Pangarangan Village, Kota District, Sumenep Regency. The purpose of this study is to plan an environmentally friendly housing with a plan that is in accordance with the wishes and has good quality.

2. Methods
This research involves some data collection both primary and secondary data. Primary data in the form of a survey of residential locations to be built and secondary data in the form of rainfall data that researchers obtained from the Sumenep district Department of Public Works Water Resources. For more details can be seen in flow further explanation and the picture of flow chart research below.

### INTRODUCTION

**Basic of study**
1. The large number of housing developments in Sumenep without regard to environmental effects
2. Puddles often occurs when it is raining because soil absorption is decreasing

**Urgency**
1. Design an environmentally friendly housing by taking into account the criteria of a healthy home.
2. Utilization of rainwater harvesting to helps the application of zero run off.

**Originality**
1. Planning an environmentally friendly housing design by taking into account the standards of a healthy home and the use of rain water as a source of clean water.

| Primary Data - (Survey) | Secondary Data |
|------------------------|----------------|
| Field overview is in the form of large residential area | 1. Rainfall data from the Sumenep district Water Resources Public Works Department |
|                        | 2. Literature studies in the form of theoretical basic and previous research |

**Data Analysis**
1. Planning the type of house design in accordance with the criteria for a healthy home using AutoCad for 2D and SketchUp for 3D.
2. Calculation of average daily rainfall, reliable rainfall, availability of rainwater, clean water requirements for housing and calculation of rainwater storage.

**Conclusion**
2D and 3D design of environmentally friendly housing with rainwater utilization system as a source of clean water fulfillment

*Figure 1. Research flow chart*

2.1. Livable Housing Criteria
Housing is a land that is converted into a group of buildings in the form of livable houses and equipped with adequate facilities and infrastructure [6]. Housing is divided into two. The first is residential housing and the second is cluster housing [1]. Livable housing criteria according to SNI 03-1733-2004, every house must have good air circulation; adequate lighting; fulfilled clean water for
drinking, coking, washing, etc; waste water disposal; residential health and green open space. House type will be design and concern with these criteria.

2.2. Pumbing Installation
Domestic (household) water needs are calculated based on population and per capita water needs. The criteria for determining the domestic water needs issued by the Center for Irrigation of the Ministry of Public Works uses the parameter of population as a determination of the amount of water needed each capita each day. And the standard of domestic water needs for household is 120 liter/person/day [2].

2.3. Rainwater Harvesting
Rainwater harvesting is an old-fashioned method that was popularized again by storing rainwater for later re-use. The consideration for using rainwater is the pH of rainwater which is near neutral and relatively free of pollutants. Rainwater harvesting is the process of utilizing rainwater by being accommodated and can be used for various purposes. Rainwater is usually collected or harvested from rooftops, concrete floors in houses, roads and other waterproof surfaces. Rainwater flows along the road (gutter) and enters a collection tank. Rain harvesting is very helpful in reducing runoff from rain.Rainwater harvesting is intended to utilize runoff. Runoff can be caught and collected from the roof runoff or the land surface or seasonal rivers. A water harvesting system that harvests runoff from the roof of a building or the land surface is included in the category of rainwater harvesting [7,8,9].

Calculate rain intensity using a formula

\[ I = \frac{R_{24}^2}{24} \left( \frac{24}{T} \right)^{2/3} \]  
(1)

\[ I \]  = Rain Intensity (mm/hour)
\[ R_{24} \]  = Maximum Rainfall for 24 hours (mm)
\[ T \]  = The duration of rain (hour)

The mainstay rainfall calculation is done through the processing of the existing annual rainfall discharge data by ranking the annual average discharge data ranking from the highest value to the lowest value based on the average annual rainfall. Then each opportunity is calculated with this formula:

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

\[ m \]  = sequence number
\[ n \]  = amount of data
\[ P \]  = opportunity

To find out how much the percentage (%) of rainwater that is accommodated to the water needs within a certain time period is used this formula:

\[ \text{Rasio Persentase (\%)} = \left( \frac{\Sigma Q}{C} \right) \times 100\% \]  
(3)

\[ \Sigma Q \]  = Amount of rainwater discharge in a reservoir (m³)
\[ C \]  = Total one month water requirement (m³)

Rainwater basin discharge is the volume of rainwater that is accommodated from several houses in the housing that are chosen as rainwater collectors. The formula for obtaining the inflow is as follows:

\[ V = R \times A \times C \]  
(4)

\[ V \]  = Amount of collected water volume (m³)
\[ R = \text{Average rainfall that occurs during one day (mm)} \]
\[ A = \text{Area of house roof / catchment area (m}^2\text{)} \]
\[ C = \text{Runoff coefficient (} f = 0.75 - 0.95\text{)} \]

2.4. 3D SketchUp
Sketchup is an application for 3D images, this application is usually used by architects to present the results of the picture. With this application, we can pour creative ideas in the form of 3D images in the form of rough sketches or realistic final drawings. Google sketchup is a 3D graphic design application that is usually used to create houses and other applications. The benefits of google sketchup are many, including creating several interior and exterior designs. 3D sketchup is indeed very easy for us to learn. We can use Google Sketchup to describe a 3D object that is very detailed and with very satisfying results even the same as the original when it has gone through rendering [3,4,12].

3. Main Results
3.1. Liveable House Planning
According to SNI 03-1733-2004 every houses for liveable living must have good air circulation; adequate lighting; fulfilled clean water for drinking, coking, washing, etc; waste water disposal; residential health and green open space. Based on this, we planned houses with two types, type 65 and type 85. In each type is planned to use maximum ventilation as a medium of air circulation and the entry of sunlight during the day. It also planned an effective plumbing pipe to supply clean water and remove dirty water.

![Figure 2. Plan of house type 65 (left) and type 85 (right)](image)

3.2. Plumbing System Planning
Calculating the raw water needs of residential houses using Indonesian National Standardization, SNI 03-7065-2005 for water needs according to building functions. And according this standard, the average water demand for house is 120 litre/person/day. From this value, we can calculate the total raw water requirements according to the population. From two types of house (type 65 and type 85)
the total population is 56 people (40 people for houses type 65 and 16 people for houses type 85). The result of calculation of water requiremnt can be seen in table 1 below:

| No. | House Type | Population (people) | Average water demand liter/person/day | Total raw water requirements (liter/day) | Total raw water requirements (m3/day) |
|-----|------------|---------------------|--------------------------------------|-----------------------------------------|--------------------------------------|
| 1   | 65         | 40                  | 120                                  | 4800                                    | 4.8                                  |
| 2   | 85         | 16                  | 120                                  | 1920                                    | 1.92                                 |
| Total | 56         | 120                 |                                      | 6720                                    | 6.72                                 |

In this study, the rainwater data station that is used has the longest and most complete data is Sumenep Irrigation rain station. Rain data used is from 2008 - 2017 (10 years). Example calculation to get the probability of rainfall mainstay no. 1 (one) as follows:

\[ P(\%) = \left( \frac{m}{n+1} \right) \times 100\% = \left( \frac{1}{10+1} \right) \times 100\% = 9.09\% \]

The calculation of the next mainstay rain probability can be seen in table 2 below,

Figure 3. Rainfall mainstay probability

Mainstay rainfall can be obtained by taking the average value in a year that has a probability value more than 80%, so the mainstay rainfall value is chosen based on a value close to the average rainfall value. From table 2 the chance of rainfall is chosen 81.82%, and 90.91% is the data for 2009 and 2015.
Table 2. Stipulation of mainstay rainfall

| Year | Month | Jan | Feb | March | Apr | May | Jun | Jul | August | Sept | Oct | Nov | Des | Total |
|------|-------|-----|-----|-------|-----|-----|-----|-----|--------|------|-----|-----|-----|-------|
| 2009 |       | 137 | 87  | 51    | 89  | 187 | 27  | 0   | 0      | 0    | 0   | 125 | 101 | 804  |
| 2015 |       | 175 | 301 | 67    | 161 | 59  | 0   | 0   | 0      | 0    | 0   | 77  | 840 |      |
|      | Average Rainfall | 156 | 194 | 59    | 125 | 123 | 13.5| 0   | 0      | 0    | 0   | 62.5| 89  | 822  |
|      | Mainstay Rainfall | 137 | 87  | 67    | 89  | 187 | 27  | 0   | 0      | 0    | 0   | 125 | 101 | 820  |

From table 2 it shows that rainfall in June, July, August, September and October is very small at <50 mm/month which tends to experience the dry season. Furthermore, from the calculation of the mainstay rainfall is calculated the volume of water supply that can be accommodated for each month. With the roof area data for each area, the result of mapping the area can be calculated the volume of rainwater availability. The rainwater availability volume for November to October are shown in figure 4.

POTENTIALS OF RAIN WATER SUPPLY

![Graphic of potentials of rain water supply](image)

**Figure 4.** Graphic of potentials of rain water supply

Based on the calculation of rainwater supply and raw water demand, the volume of rain water supply is sufficient for raw water needs. So that the percentage (%) is calculated to at least meet the overall raw water needs of the average residential occupant. From the results of the study obtained a comparison between raw water needs and rainwater supply is to combine the data as in figure 5.
Based on the comparison between rainwater supply and raw water requirements, $V_{\text{supply}} > V_{\text{demand}}$ is obtained. This is main, the rainwater supply is sufficient to meet the overall raw water needs of the average householder. So the calculation of tank volume is based on the mainstay supply in January, February, April, May, November, and December which tends to supply high rainwater as shown in figure 1 with quantities of 187, 119, 121, 255, 255 and 138 $\text{m}^3/\text{month}$ for type 65 and 62, 40, 40, 85, 57 and 46 $\text{m}^3/\text{month}$ for type 86. And for other months, to fulfill the water needs can use water sources from the Local Water Company or ground water that drilled and managed privately in each home.

**Figure 5.** Comparison of rainwater availability to raw water needs

**Figure 6.** Top view of rainwater shelter for house type 65
The drainage system in Rainwater Harvesting is using a pump system. In this system the water that is collected in the rainwater reservoirs will be distributed by Pumping System through distribution pipes to the house channel. Where the rain water that is received by the roof of the house is flowed through the gutter to the rainwater reservoir, after the shelter is filled then the homeowner can use it again for clean water unless it is not used for drinking water. This rainwater harvesting for water resources is useful to reduce expenses for the fulfillment of clean water. Besides that, this system also can help for reduces the amount of rain water that flows directly into rivers to the sea without any absorption (zero run off).

3.3. 3D Design by Sketchup

3D design is used to facilitate prospective housing buyers in describing the house they will occupy later. 2-dimensional depiction of the design is done using the help of autocad software which is then visualized into 3d using the help of a sketchup program. 3D images consist of layouts, type 65 and type 85 houses, places of worship (mosques) and green open spaces. With the help of 3D housing design it looks more alive. clients can see clearly, the house they will buy and occupy. 3D design follows 2D design (by AutoCAD) that regarding with healthy home criteria. Mosque area for worship for residents of housing and playgrounds to relax and enjoy the fresh air around housing.

Some 3d design drawings based on housing plans with the rainwater harvesting system as one source of meeting the needs of clean water can be seen in the following pictures.

**Figure 7.** Top view of rainwater shelter for house type 85
Figure 8. 3D Design of housing plan by sketchup

4. Conclusions
Based on the discussion carried out on the subject of the previous discussion and the analysis results, the following conclusions are obtained:
1. Based on the comparison between rainwater supply and raw water requirements, $V_{supply}>V_{demand}$ is obtained. This means the rainwater supply is sufficient to meet the overall raw water needs of the average household.
2. The calculation of tank volume is based on the mainstay supply in January, February, April, May, November, and December which tends to supply high rainwater as shown in figure 1 with quantities of 187, 119, 121, 255, 255 and 138 m$^3$/month for type 65 and 62,40,40,85,57 and 46 m$^3$/month for type 86.

To fulfill needs for clean water in the months other than the six months mentioned, housing residents can use water Regional Water Supply Company or from ground water that is drilled and managed privately in each home. For further research it is expected to be able to use rainwater as a source of clean water for one year not only in certain months.

Acknowledgment
The authors would like to thank to Water Resource Public Works Agency in Sumenep Regency, which has provided the data what the authors needs in this research process and authors also would like to the Institute for Research and Community Services of Wiraraja University for funding to this research publication in the academic year of 2019. Recomendation for the further research, it is expected to be able to use rainwater as a source of clean water for one year not only in certain months.
References
[1] Indonesian National Standardization 2004 *Procedure for planning a housing environment in urban* Jakarta, Indonesia : National Standardization Agency
[2] Indonesian National Standardization 2005 *plumbing system planning procedures* Jakarta, Indonesia : National Standardization Agency
[3] Bhirawa W T 2012 *Google SketchUp Software Usage in Designing Flans Couplings* Jakarta, Indonesia : Suryadarma University
[4] Chandra H 2012 *80 Autocad's Hidden Tricks* Palembang : Maxikom
[5] Dani A 2012 *The Potential of Rainwater Harvesting For household Needs In The Klunggen Village Slogohimo District Wonogiri Regency* Surakarta, Indonesia : University of Muhammadiyah Surakarta
[6] Harjanto T 2016 Strategy for housing development in urban areas *J. Economic* 5 (2) pp 47 – 48
[7] Indah A B, Yohanna L H, and Imam S 2016 Study of rainwater utilization as fulfillment of clean water needs in small island (case study: conceng tengah village conceng district) *J. Eng* 3 (1) pp 1 – 10
[8] Fairus N and Mas A M 2016 *J. Eng. ITS* 5 (2) pp D241-D242
[9] Nugro R P 2000 Technology to meet the water needs of the seribu islands community through optimization of rainwater reservoir utilization *J. Environmental Eng.* 1 (3) 195 – 205
[10] Rofil and Maryono 2017 *Proc.Biology Education Conf.* Vol 14 (1) pp 247-251
[11] Faisal N, Satria W E P, Sri S S 2014 and Sugiyanto *J. MKTS* 20 (2) pp 189-196
[12] Rio M 2019 *Home Facade Design Techniques with AutoCAD & Google SketchUp* Jakarta, Indonesia : PT Alex Media Komputindo