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EFFECTIVENESS OF ABSORPTION WELLS USING THE SUNJOTO METHOD TO CONTROL FLOODING IN THE VILLAGE OF NGRASEH BOJONEGORO

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ABSTRACT

Infiltration wells are a form of hydrological infrastructure used to manage rainwater. Infiltration wells are usually built as part of a rainwater management system to soak rainwater into the ground and reduce surface waterlogging as well as slow down surface runoff and allow rainwater to seep into the ground to renew aquifers or prevent waterlogging. Maintaining groundwater levels is an important step in sustainable water resource management. The aim of this research is to plan effective infiltration wells to replace rainwater catchment areas lost due to building construction. The planning of this infiltration well uses the Sunjoto method. From the research results, it was found that an effective infiltration well design was calculated using the Sunjoto method. With the data, each roof area of the house has an optimum number of infiltration wells with a planned infiltration well diameter of 1 m with a depth of 2.5 m with an effective depth according to the calculations is as follows: 60 m2 number of 1 unit of absorption well with an optimum depth of 2.82 m, 80 m2 number of 2 units of absorption well with an optimum depth of 3.76 m, 100 m2 number of 2 units of absorption well with an optimum depth of 4.7 m, 120 m2 number of 2 units of infiltration wells with an optimum depth of 5.64 m, 140 m2 number of 3 units of absorption wells with an optimum depth of 6.58 m, 160 m2 number of 3 units of absorption wells with an optimum depth of 7.52 m, 180 m2 number of 3 units of absorption wells with an optimum depth of 8.46 m, 200 m2 total of 4 units of infiltration wells with an optimum depth of 9.4 m.

***Keyword:** Infiltration wells, sunjoto method, optimum depth, number of infiltration wells.*

1. INTRODUCTION

Bojonegoro is a district in East Java Province, Indonesia, which is located in the southwest part of Java Island. Bojonegoro has 31 sub-districts, among these sub-districts is Dander Sub-district. Ngraseh Village is one of the villages in Dander District, Bojonegoro Regency. According to data from the Ngraseh Village website, Ngraseh Village consists of 135 families and a population of 4383 people with an area of 400.04 Ha consisting of rice fields and dry land. Ngraseh Village consists of 2 hamlets, namely Ngraseh Hamlet and Ngrawan Hamlet. As the population increases, the need for housing also increases, resulting in changes in land use from open land that became rainwater catchment areas to built-up land. [1][2].

So far, Ngraseh Village has implemented conventional drainage so that water will flow into the river without seeping into the ground first, so that every rainy season the river will receive a load that is more than its capacity [3] and resulting in flooding around residential areas [4]. As an effort that can be made to reduce inundation as a result of reducing water catchment areas [5][6] The result of the construction of buildings is to create environmentally friendly drainage (ecodrainage). [7][8][9] one of them with an absorption well [10].

Inundations that often occur due to rainfall can be caused by several factors, including high rainfall intensity, poor drainage systems [11] [12], inappropriate land use [13], and flat or basin topography. To reduce the risk of inundation caused by rainfall [14], It is important to pay attention to wise urban spatial planning, build an adequate drainage system, maintain environmental sustainability, and increase public awareness about the importance of maintaining the environment and a good drainage system. One good method for dealing with inundation or flooding is the ecodrainage method [15].
High rainfall is one of the main factors that can cause various problems, including floods, landslides, erosion and infrastructure damage [16]. High rainfall can occur naturally or be caused by climate change and human activities [17]. Some of the impacts of high rainfall include: floods, landslides, soil erosion, economic losses, disruption to public services.
To overcome the impact of high rainfall, mitigation and adaptation measures need to be taken, including improving drainage infrastructure [18], good watershed management, wise spatial planning, implementation of an early warning system [19], and increasing community capacity in dealing with disasters [20][21]. In connection with the importance of infiltration wells, this research was conducted with the aim of planning effective infiltration wells to overcome flooding and replace rainwater catchment areas lost due to the construction of buildings.

2. LITERATURE REVIEW

Collection of relevant information and literature on a particular topic from books, scientific journals, articles and official publications. Literature study refers to the collection and analysis of pre-existing sources of information, such as books, journals, reports, and websites. This step allows users to obtain further and in-depth information about the topic being researched or studied. Literature study also allows users to understand more advanced concepts, theories and practices in the field being researched or studied.

2.1 Infiltration wells

Infiltration wells are structures or facilities designed to collect and absorb rainwater into the ground [22], typically used to control surface water and allow rainwater to soak into the ground to renew aquifers or prevent waterlogging. Maintain groundwater levels [23] is an important step in the sustainable management of water resources. Groundwater levels can be affected by various factors, including rainfall, land use, and human activities [24]. Infiltration wells are a simple but effective technology that can be used to manage rainwater [25], prevent environmental damage [26], and increasing environmental resilience in areas vulnerable to flooding and erosion [27]. Maintaining groundwater levels by using infiltration wells [9] has many important benefits [28], including:

1. Recharge the aquifer
2. Prevent flooding
3. Reduces Soil Erosion
4. Improved Water Quality
5. Resource Conservation
6. Clean Water Savings

Thus, maintaining groundwater levels with infiltration wells is an important step in sustainable water resource management, protecting the environment, and building resilience to climate change. Infiltration wells can also be used as a replacement for rainwater catchment areas lost due to the erection of a building to maintain groundwater levels.

2.2 Rainwater Catchment Area

Rainwater catchment areas are areas where rainwater is absorbed into the ground, seeped into aquifers, or stored in groundwater bodies [29]. This is a natural process where rainwater that falls on the ground is absorbed by the soil and rocks beneath it. Some of the characteristics and importance of rainwater catchment areas include::

a. Infiltration: Rainwater catchment areas facilitate the infiltration of rainwater into the soil. This is important for fertilizing the soil, providing water for plants, and renewing groundwater sources.

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b. Water Storage: Rainwater catchment areas act as natural reservoirs to store rainwater. This helps maintain sustainable water supplies in dry seasons and reduces the risk of drought [14].
c. Flood Protection: The rainwater absorption process can reduce the volume of surface water flowing into rivers and waterways, thereby reducing the risk of flooding.
d. Improved Water Quality: When rainwater soaks into the ground, it passes through layers of soil that act as natural filters. This helps remove pollutants and improves water quality in aquifers and other underground water sources.
e. Aquifer Formation: Rainwater catchment areas are one of the important mechanisms in the formation and maintenance of aquifers or groundwater layers below the ground surface. It provides an important water source for society and the environment [21].
f. Soil and Water Conservation: Maintaining the health of rainwater catchment areas is an important part of soil and water conservation efforts. Conservation practices such as reforestation, wise land use management, and protection of natural vegetation help maintain water catchment functions.

Protecting and maintaining rainwater catchment areas is very important to maintain water availability, prevent environmental damage, and ensure the sustainability of groundwater ecosystems. This requires cooperation between government, communities and other stakeholders to implement sustainable water resource management practices.

2.3 Rain Intensity

To calculate rainfall intensity, we need two main factors: the amount of rainfall and the duration of the rainfall. Rain intensity is calculated as the amount of rainfall that falls per certain unit of time [30]. The general formula for calculating rain intensity is :

$$I = \frac{C}{T} \qquad (1)$$

Information:
I is the amount of rainfall (mm/hour)
C is rainfall (mm)
T is the length of time it rains (hours)

2.4 Sunjoto Method 1988

The assumption made by Sunjoto in 1988 was that the amount of water entering the well was constant and equal to Q, which is the symbol for water discharge. The equation used to calculate the incoming water discharge is the equation below [31].

$$Q_0 = F.\ K.\ H \qquad (2)$$

Information :
Q_0 = incoming water discharge (m^3/sec)
F = geometric factor for various cases (m)
K = Water absorption coefficient in the soil (soil permeability) (m/sec)
H = water depth in the absorption well (m)

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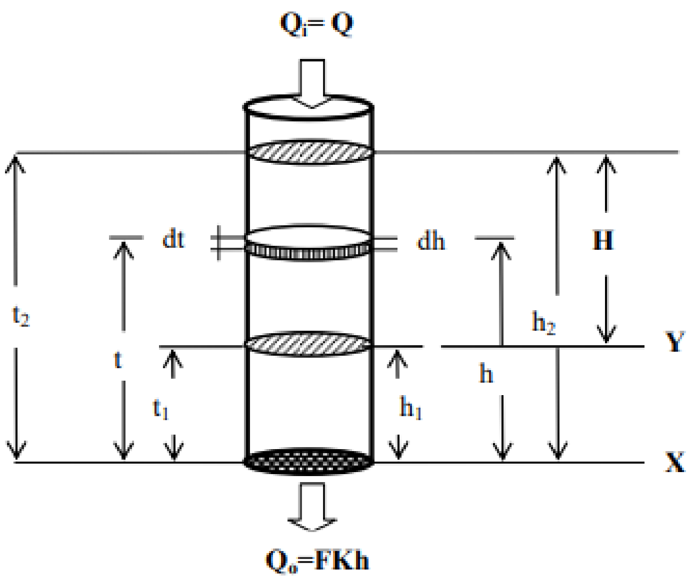

Figure.1 Flow Scheme in a well [32]

Calculating the depth of water in the well (H), according to the Sunjoto method [33]:

$$H = \frac{Q_i}{F.K}\left\{1 - e\left(\frac{-FKT}{\pi R^2}\right)\right\} \quad (3)$$

Information :
H = Depth (m)
Q_i = Incoming discharge (m^3/sec)
F = Well geometry factor (m)
K = Soil infiltration coefficient (soil permeability) (cm/sec)
T = Duration of dominant rain
R = Well cross-sectional radius (m)

To calculate the incoming water discharge, use the formula :
Q = C. I. A (4)

Information :
Q = Water discharge entering from the roof (m^3/hour)
C = Runoff coefficient on the roof
I = Amount of rainfall (m/hour)
A = roof area (m^2)

To calculate the infiltration discharge in a well, use the following formula [34] :

$$Q_{sumur} = F.\,K.\,H \quad (5)$$

Dimana :
Q_{sumur} = Discharge entering the infiltration well (m3/hour)
F = Well geometry factor (m)
K = Soil infiltration coefficient (permeability)(m/hour)
H = Height of the well (m)

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2.5 Sunjoto Method Infiltration Well Parameters [22]

The following are the parameters used in the Sunjoto method calculation formula [32] :
- Roof surface flow coefficient (Runoff coefficient) with a value of C = 0.95
- Rainfall in units of time (T)
- The area of the observation area in this case is the area of the roof which is assumed to be flat
- Duration of rain
- Well Geometric Factor (F)

Determination of the geometric factor (F) is based on the shape of the soil infiltration well and the bottom of the infiltration well. The following are examples of geometric factor (F) values for various cases [32]. Meanwhile, to calculate the number of infiltration wells, the following formula is used [35] :

$$n = \left(\frac{H\ total}{H\ rencana}\right) \quad (6)$$

2.6 Effectiveness of Infiltration Wells

To manage rainwater in terms of the effectiveness of infiltration wells depends on several factors, such as the capacity of the infiltration well, the rate of groundwater absorption (permeability), and groundwater levels. However, its effectiveness is also influenced by soil conditions, rainfall and the location of absorption wells. Several studies show that infiltration wells can reduce the volume of runoff water by up to 77%, and have other benefits such as groundwater conservation and suppressing erosion. Therefore, the effectiveness of infiltration wells also depends on soil conditions, depth of the groundwater table, and soil permeability at the location where they are applied. The effectiveness of infiltration wells is not always the same in every location and must be carefully considered based on local conditions before being implemented and can be calculated using the following equation [36] :

$$Q\ absorbed = Q\ before - Q\ after \quad (7)$$

$$E_{eff} = \frac{Q\ absorbed}{Q\ before} \times 100\% \quad (8)$$

Information :
Eeff = effectiveness of infiltration wells
Q before = discharge before the infiltration well/runoff discharge (m^3/s)
Q absorbed = discharge absorbed in absorption wells (m^3/s)

3. RESEARCH METHOD

The study location in this research was in Ngraseh Village, Dander District, Bojonegoro Regency, East Java by analyzing soil type, rain data and roof area. Study locations can be seen at (Figure-2).

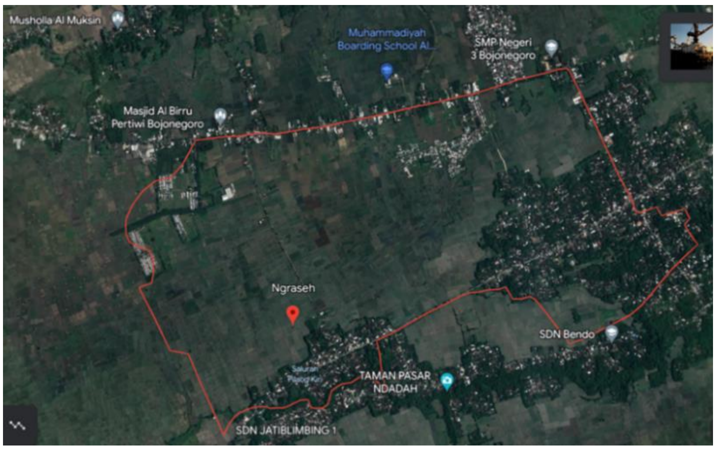

Figure.2 Research Area

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3.2. Data Collection

The data collected for the purposes of this research include the data below and the flow of the research carried out can be seen in (figure-3):

1. Rainfall
2. Population
3. Number of houses
4. Land area
5. Roof/building area
6. Soil type

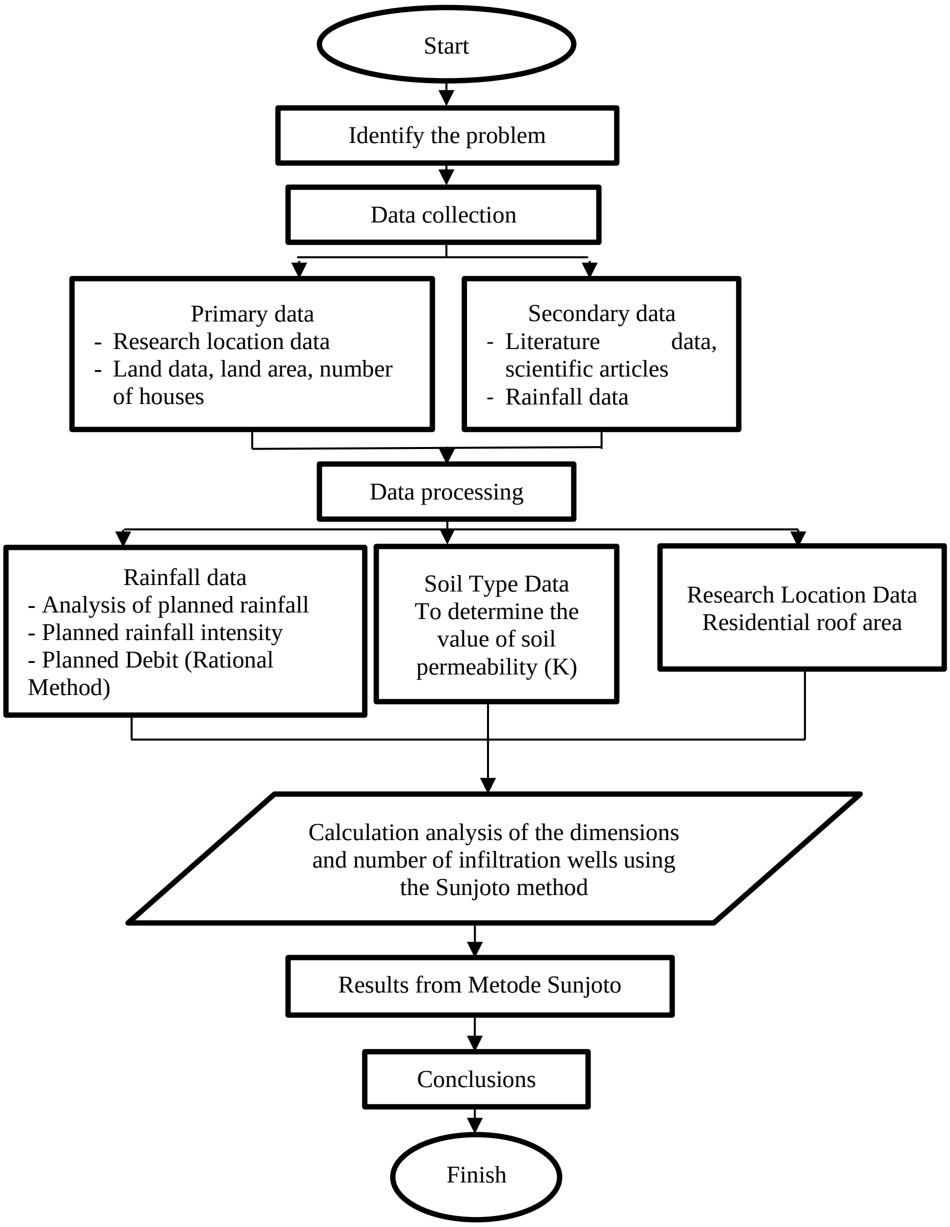

Figure.3 Research Flow

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4. RESULTS OF ANALYSIS AND DISCUSSION

4.1 Rainfall Intensity

The rainfall given is for a 2-year return period, which means that rainfall can be expected to occur once in every 2 year period.

$$I = \left(\frac{96,7}{24}\right)\left[\frac{24}{2}\right]^{\frac{2}{3}}$$

I = 21,11 mm/jam

4.2 Infiltration Wells Using the Sunjoto Method

The sample calculates the total H value for buildings that have a roof area 80 m^2

$$H = \frac{Q_i}{F.K}\left\{1 - e\left(\frac{-FKT}{\pi R^2}\right)\right\}$$

$$= \frac{C\ I\ A}{F.K}\left\{1 - e\left(\frac{-FKT}{\pi R^2}\right)\right\}$$

$$= \frac{0.95\ x\ 0.02111\ x\ 80}{2.75\ x\ 0.0244}\left\{1 - e\left(\frac{-2.75\ x\ 0.0244\ x\ 2}{\pi\ x\ 0.5^2}\right)\right\}$$

= 3.76 m

4.3 Effectiveness of Sunjoto Method Infiltration Wells

The sample calculates the effectiveness of infiltration wells for a roof area of 80 m^2 :

Q well = F x K x H
= 2.75 x 0.0244 x 3.76
= 0.253638 m^3/ jam

Q absorbed = Q runoff – Q well
= 1.21 – 0.253638
= 1.36 m^3/ jam

Effectiveness $= \frac{Q\ absorbed}{Q\ runoff}$ x 100%
$= \frac{1.36}{1.21}$ x 100%
= 84.48 %

Table 1. Recapitulation of Sunjoto Method Infiltration Well Effectiveness Calculations

Roof area (m^2)	Q runoff (m^3/hours)	F	K	H (meter)	Q well (m^3/jam)	Q absorbed (m^3/jam)	Efektiveness (%)
60	1.21	2.75	0.0244	2.84	0.190564	1.02	84.3 %
80	1.61	2.75	0.0244	3.78	0.253638	1.36	84.48 %
100	2.01	2.75	0.0244	4.71	0.316041	1.7	84.58 %
120	2.41	2.75	0.0244	5.65	0.379115	2.04	84.65 %
140	2.81	2.75	0.0244	6.59	0.442189	2.37	84.35 %
160	3.21	2.75	0.0244	7.52	0.504592	2.71	84.43 %
180	3.61	2.75	0.0244	8.46	0.567666	3.05	84.49 %
200	4.02	2.75	0.0244	9.42	0.632082	3.39	84.33 %

Tabel 2 Summarizing each roof area (A), the optimum depth of infiltration wells (H Tot.) is obtained when planning an infiltration well with a diameter of 1 meter so that the number of infiltration well units (n) can be obtained for each different roof area.

Table 2. Recapitulation of Infiltration Well Calculations Using the Sunjoto Method

A (m^2)	Q (m^3/jam)	F 5.5 R	K	F x K	Q/ (f x k)	T (hour)	Ø (m)	(-FKT)	π x R^2	H total (meter)	n
60	1.20327	2.75	0.0244	0.0671	17.9325	2	1	-0.1342	0.785	2.82	1
80	1.60436	2.75	0.0244	0.0671	23.91	2	1	-0.1342	0.785	3.76	2
100	2.00545	2.75	0.0244	0.0671	29.8875	2	1	-0.1342	0.785	4.7	2
120	2.40654	2.75	0.0244	0.0671	35.865	2	1	-0.1342	0.785	5.64	2
140	2.80763	2.75	0.0244	0.0671	41.8425	2	1	-0.1342	0.785	6.58	3
160	3.20872	2.75	0.0244	0.0671	47.82	2	1	-0.1342	0.785	7.52	3
180	3.60981	2.75	0.0244	0.0671	53.7975	2	1	-0.1342	0.785	8.46	3
200	4.0109	2.75	0.0244	0.0671	59.775	2	1	-0.1342	0.785	9.4	4

5. CONCLUSION

From the research results, an effective infiltration well design was obtained according to calculations using the Sunjoto method. With data, each roof area of the house has an optimum number of infiltration wells with a planned infiltration well diameter of 1 m with an effective depth as follows:

- 60 m^2 total of 1 infiltration well unit with an optimum depth of 2.82 m
- 80 m^2 total of 2 units of infiltration wells with an optimum depth of 3.76 m
- 100 m^2 total of 2 units of infiltration wells with an optimum depth of 4.7 m
- 120 m^2 total of 2 infiltration wells with an optimum depth of 5.64 m
- 140 m^2 total of 3 infiltration wells with an optimum depth of 6.58 m
- 160 m^2 total of 3 infiltration wells with an optimum depth of 7.52 m
- 180 m^2 total of 3 infiltration wells with an optimum depth of 8.46 m
- 200 m^2 total of 4 infiltration wells with an optimum depth of 9.4 m

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