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# Estimating the Need for Infiltration Wells to Support Groundwater Conservation and Surface Runoff Control in Enggal Subdistrict

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**ABSTRACT**

Urban areas frequently encounter environmental challenges such as the reduction of green open spaces, water shortages during the dry season, and water ponding during the rainy season. These problems are mainly caused by rapid urbanization and the expansion of impervious surfaces, which reduce natural infiltration capacity and increase surface runoff. As a result, groundwater recharge decreases while the potential for urban flooding becomes higher. Similar conditions are observed in Enggal District, located in the central area of Bandar Lampung City, Indonesia. Therefore, effective stormwater management strategies are required to mitigate surface runoff while improving groundwater conservation. This study aims to estimate the required number of infiltration wells needed to achieve zero run-off conditions in Enggal District. The study area covered approximately 2.80 km² and consists of six urban villages with a population of 24,611 in 2025 based on the Enggal District Report. Land-use analysis indicates that the area has a surface runoff coefficient of 0.55. Hydrological analysis was conducted using 20 years of rainfall data (2005–2024) to determine rainfall characteristics and runoff potential. The rainfall intensity analysis for a 10-year return period produced a peak discharge of 15.88 m³/s with a rainfall intensity of 37.23 mm/h. Several designs with 2 scenarios were developed by considering variations in infiltration well dimensions and land availability within the study area.

## INTRODUCTION

The phenomenon of a deficit of groundwater sources as raw water in the dry season and the difficulty of handling surface water runoff control during the rainy season indicate an imbalance in the hydrological cycle. Infrastructure growth and high urbanization cause the waterproofing surface to increase, resulting in a significant reduction in infiltration and high surface runoff. (Pratama et al., 2018).

The city center is one of the areas that is under great pressure due to the limitations of Green Open Space (RTH). The natural function of the soil as a water catchment area is decreasing. Rainwater that falls on the surface of the land is mostly directly drained into the drainage system so that the available drainage is often unable to accommodate peak discharges. Enggal District, the capital of Bandar Lampung City, has minimal RTH and is dominated by a large amount of built land causing overload of available drainage. Of the 24,611 people, 11,223 people were affected by floods in January 2025 and there were 37 inundation points in March 2026 (Pratama et al., 2018; Siswanto, 2019).

Various approaches have been developed to overcome the problem of waterlogging, such as the concept of sustainable urban drainage system (Aditya Dwi & Cundaningsih, 2025). However, the conventional drainage approach (quick drainage) is not able to solve the problem, because this system does not accommodate groundwater conservation efforts (Wahyuni et al., 2021). More comprehensive efforts and the concept of zero runoff are needed by integrating aspects of runoff control and efforts to increase groundwater infiltration. one of them is with infiltration wells, (Rifai et al., 2015).

The urgent nature of the research problem stems from escalating urban water challenges. With climate change altering precipitation regimes and urban expansion continuing, sustainable stormwater management strategies are critical for preventing groundwater depletion and reducing urban flooding. At the same time, urban runoff often carries contaminants that threaten groundwater quality, necessitating careful consideration of infiltration practices to protect aquifers. Hence, research that refines infiltration well strategies integrates both water quantity and quality dimensions in rapidly urbanizing regions.

This study's novelty lies in its integrated analytical framework, combining hydrological simulation, field measurements, and design optimization to establish evidence-based guidelines for infiltration well deployment. Unlike previous research that predominantly relies on singular case observations or modeling alone, this approach assesses performance across multiple variables including soil permeability, rainfall intensity, well design parameters, and urban context. This enables a refined understanding of how infiltration wells can be optimized as part of urban water infrastructure.

The primary purpose of the research is to quantify the effectiveness of different infiltration well designs in reducing surface runoff and enhancing groundwater recharge under realistic urban conditions. Through systematic evaluation and comparative analysis, the study intends to inform design criteria that maximize recharge while ensuring functionality during varying storm events. This purpose addresses the broader need to reconcile stormwater management with aquifer sustainability in urban planning.

This research's contribution extends to practitioners and policymakers by offering empirically-validated strategies for integrating infiltration wells within urban stormwater systems. By providing a framework that quantifies the trade-offs between well design, land use constraints, and hydrologic response, the study supports evidence-based decisions that can improve water security and resilience in urban catchments.

Finally, the objectives and benefits of the research include developing predictive models that can guide infiltration well placement, optimizing design parameters to suit local hydrological conditions, and estimating potential reductions in runoff volumes. The benefits include enhanced groundwater recharge, reduced flood risk, and improved urban water management practices that support long-term sustainability especially in regions vulnerable to water scarcity and urban flooding pressures.

## METHOD

### Research Location

The research location was located in Enggal District which is part of the central administrative area of Bandar Lampung City, Lampung Province. Based on data from the Central Statistics Agency, (2025), Enggal District is located at the coordinates of 5°20'–5°30' S and 105°28'–105°37' E. This area has an area of about 280 ha which is divided into six villages, with the center of government being in Enggal Village. The location of the research is presented in Figure 1, while the administrative details of the Enggal District area are shown in Table 1.

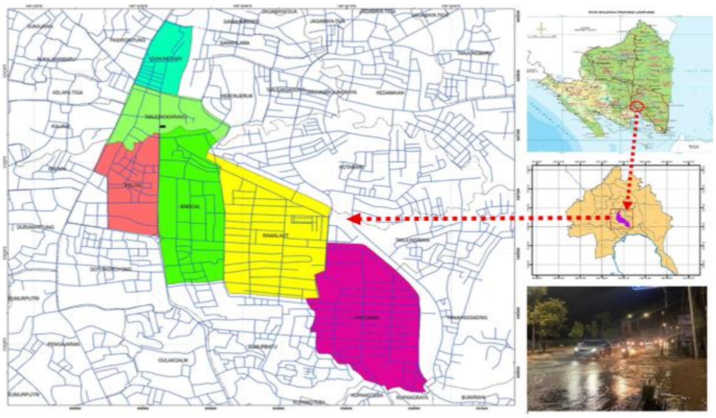

**Figure 1.** Research Location

**Table 1.** Enggal District Administration Data 2025

| Village | Area (km2) | Percentage (%) of the total area |
|---|---|---|
| Gunung Sari | 0,19 | 6,79 |
| Tanjung Karang | 0,23 | 8,21 |
| Lamp | 0,27 | 9,64 |
| Quick | 0,60 | 21,43 |
| Sea Swamp | 0,72 | 25,71 |
| Pahoman | 0,79 | 28,21 |
|  | 2,80 | 100,00 |

Source: Enggal District in 2025 Figures

### Data Source

Data collection in this study was carried out using secondary data obtained from related agencies and relevant literature sources. The data includes:

1. Secondary data in the form of hydrological data from 20 years from 3 (three) Rain Posts (PH), namely PH-001 (Pahoman), PH-004 (Sumur Putri), and PH-005 (Sumber Rejo) are sourced from the Mesuji Sekampung River Regional Office.
2. Spatial data in the form of slope slope maps, land use maps, and topographic maps are sourced from the Lampung Province BAPPEDA.
3. Other supporting data such as permeability maps, groundwater table maps, hydrological maps, were obtained from the results of relevant previous research.

### Stages of Data Analysis

The stages of data analysis are carried out on the parameters of hydrological, hydrogeological and other supporting data. The stages of data analysis, include:

1. Rainfall (CH) data analysis.
2. Runoff analysis prior to the application of infiltration wells, including:
    a. Composite runoff coefficient ($C_{composite}$),
    b. Intensity of rain (I),
    c. Runoff discharge (Q),
    d. Volume limpasan (V).

3. Analysis of peak discharge at the research site ($Q_{peak}$).
4. Analysis of infiltration well dimensions based on groundwater level conditions.
5. Analysis of the total capacity of the well.
6. Scenario analysis of the dimensions and number of infiltration wells to achieve *zero runoff conditions*.
7. Analysis of runoff volume in various infiltration well installation scenarios.
8. Analysis of runoff volume reduction prior to SR installation and subsequent SR installation to achieve *zero runoff conditions*.

## RESULT AND DISCUSSION

### Rainfall Plan

The results of statistical analysis of the planned rainfall showed a Cv value of 0.33, Cs of 0.51, and Ck of 4.16. Based on these parameters, the distribution of rain data at the location in the value meets the type of Gumbel and Pearson Log Type III method (Table 2).

**Table 2.** Requirements for Rain Slope Type

| Distribution Type | Requirements | Results | Remarks |
|---|---|---|---|
| Normal Method | Cs ≈ 0 | 0,51 | Not Compliant |
| | Ck ≈ 3 | 4,16 | Not Compliant |
| Normal Log Method | Cs = Cv3 +3.Cv | 0,51 | Not Compliant |
| | 1,00 | | |
| | Ck = Cv8 + 6.$Cv^6$ + 15Cv4 + 16Cv2 + 3 | 4,16 | Not Compliant |
| | 3,00 | | |
| Gumbel Method | Cs ≤ 1,1396 | 0,51 | Meet |
| | Ck ≤ 5.4002 | 4,16 | Meet |
| Method Log Pearson III | Cs ≠ 0 | 0,51 | Meet |

The most effective rain occurs in the first hour. The intensity of rain in the first hour is used because it represents the most critical rainy conditions that contribute to the formation of maximum runoff, in line with the characteristics of the rain and the concentration time of the catchment area. In this study, the intensity of rain was calculated using the Van Breen method based on daily rainfall data due to the limitation of short-duration data. This approach is used as the basis for conservative and relevant infiltration well planning to optimize early runoff handling and water permeation as quickly as possible.

**Table 3.** Effective Rain Intensity per Hour

| **Repeat Time (T)** | **R (mm)** | **90%. R (mm)** | **Rain Intensity (mm/h)** | | | |
|---|---|---|---|---|---|---|
| | | | **1st hour** | **2nd hour** | **3rd hour** | **4th Hour** |
| **2** | 61,05 | 54,95 | 21,98 | 21,98 | 8,24 | 2,75 |
| **5** | 85,10 | 76,59 | 30,64 | 30,64 | 11,49 | 3,83 |
| **10** | 103,40 | 93,06 | 37,22 | 37,22 | 13,96 | 4,65 |
| **25** | 128,66 | 115,80 | 46,32 | 46,32 | 17,37 | 5,79 |
| **50** | 150,25 | 135,23 | 54,09 | 54,09 | 20,28 | 6,76 |
| **100** | 173,46 | 156,11 | 62,44 | 62,44 | 23,42 | 7,81 |
| **200** | 198,67 | 178,80 | 71,52 | 71,52 | 26,82 | 8,94 |

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Based on the results of the analysis of the re-period, the effective rainfall intensity in the first hour for the 10-year re-period was 37.22 mm/hour. Meanwhile, the relationship of daily rainfall (R(24)) based on the Mononobe method is presented in Figure 2.

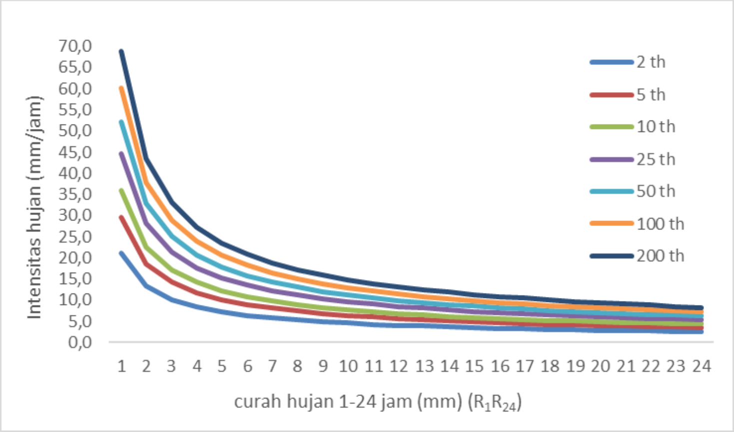

**Figure 2.** Rainfall Intensity Graph for 2 years – 200 years

## Coefazine Limpasan

The land cover of Enggal District in 2025 will be dominated by settlements of 58.11% of the total area. Meanwhile, the remaining vacant land is only 0.29% Based on the composition of land use, a composite runoff coefficient value (C) of 0.55 is obtained. This value indicates that more than half of the rainfall that falls in the study area has the potential to be surface runoff. Details of the runoff coefficient for each type of land use are presented in Table 4.

**Table 4.** Land Runoff Coefficient of Enggal District 2025

| No | Types of Land Use | Area (A) (ha) | Percentage (%) | Coefazine Limpasan (C) |
|---|---|---|---|---|
| 1 | Villages/Settlements | 162,72 | 58,11 | 105,77 |
| 2 | Agriculture | 85,01 | 30,36 | 25,50 |
| 3 | Forest | 4,95 | 1,77 | 2,47 |
| 4 | Material | 0,05 | 0,02 | 0,01 |
| 5 | Company | 3,59 | 1,28 | 2,87 |
| 6 | Industry | 6,12 | 2,19 | 4,28 |
| 7 | Services | 7,62 | 2,72 | 6,09 |
| 8 | Others and roads | 9,13 | 3,26 | 6,39 |
| 9 | Vacant Land | 0,82 | 0,29 | 0,16 |
| | | 280,00 | 100,00 | 153,56 |
| | | | | 0,55 |

## Runoff Discharge Analysis Before Infiltration Wells Are Installed

The runoff discharge before the installation of the infiltration well (SR) is calculated as a basis for comparison with the conditions after the application of the infiltration well. Based on calculations using the Rational Method, the runoff discharge value of 1.588 $m^3/s$ was obtained. So that the volume before the SR was installed was 5,716.76 $m^3$.

**Effectiveness of Infiltration Wells**

Based on the results of the analysis, 2 scenarios for the implementation of infiltration wells (SR) are planned in each sub-district of Enggal District, namely if 50% and 100& are installed. The number of SR placements is based on the consideration of the available land area in each village. The results of the analysis show that efforts to achieve *zero runoff* conditions are greatly influenced by the dimensions and number of SRs applied. At a peak discharge of 1,588 m³/s, the total SR capacity shows an increase as the well dimensions increase.

**Table 5.** Infiltration Well Planning Scenario in Enggal District for Each Village

| **Placement Location** | | **Well Dimensions** | | **Number of Potential SRs** | | **Qpuncak** | **Qsumur** | **Qtotal $_{well}$** | | **Discharge Reduction** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Ø** | **H** | **100 %** | **50%** | **m3/dt** | | **100 %** | **50 %** | | |
| | Village | (m) | (m) | Fruit | Fruit | | m3/dt | m3/dt | m3/dt | % | % |
| **Well Dimension D = 0.8 m; H = 2 m, Installed 934 pieces** | | | | | | | | | | | |
| **1** | Gunung Sari | 0,8 | 2 | 63 | 32 | 1,588 | 0,0017 | 0,108 | 0,054 | 6,8% | 3,4% |
| **2** | Tanjung Karang | 0,8 | 2 | 78 | 39 | 1,588 | 0,0017 | 0,132 | 0,066 | 8,3% | 4,2% |
| **3** | Lamp | 0,8 | 2 | 91 | 46 | 1,588 | 0,0017 | 0,155 | 0,077 | 9,7% | 4,9% |
| **4** | Enggal | 0,8 | 2 | 198 | 99 | 1,588 | 0,0017 | 0,336 | 0,168 | 21,2% | 10,6% |
| **5** | Sea Swamp | 0,8 | 2 | 240 | 120 | 1,588 | 0,0017 | 0,408 | 0,204 | 25,7% | 12,9% |
| **6** | Pahoman | 0,8 | 2 | 264 | 132 | 1,588 | 0,0017 | 0,448 | 0,224 | 28,2% | 14,1% |
| | | **0,8** | **2** | **934** | **467** | **1,588** | **0,0017** | **1,5877** | **0,79** | **100,0%** | **50,0%** |
| **Well Dimension D = 1.2 m; H = 3 m, Installed 612 pieces** | | | | | | | | | | | |
| **1** | Gunung Sari | 1,2 | 3 | 42 | 21 | 1,588 | 0,0026 | 0,109 | 0,054 | 6,9% | 3,4% |
| **2** | Tanjung Karang | 1,2 | 3 | 50 | 25 | 1,588 | 0,0026 | 0,130 | 0,065 | 8,2% | 4,1% |
| **3** | Lamp | 1,2 | 3 | 59 | 29 | 1,588 | 0,0026 | 0,153 | 0,077 | 9,6% | 4,8% |
| **4** | Enggal | 1,2 | 3 | 131 | 65 | 1,588 | 0,0026 | 0,340 | 0,170 | 21,4% | 10,7% |
| **5** | Sea Swamp | 1,2 | 3 | 157 | 79 | 1,588 | 0,0026 | 0,408 | 0,204 | 25,7% | 12,8% |
| **6** | Pahoman | 1,2 | 3 | 172 | 86 | 1,588 | 0,0026 | 0,448 | 0,224 | 28,2% | 14,1% |
| | | **1,2** | **3** | **612** | **305,75** | **1,588** | **0,0026** | **1,5884** | **0,79** | **100,0%** | **50,0%** |
| **Well Dimension D = 1.5 m; H = 4m, installed 454 pieces** | | | | | | | | | | | |
| **1** | Gunung Sari | 1,5 | 4 | 33 | 16 | 1,588 | 0,0035 | 0,115 | 0,056 | 7,3% | 3,5% |
| **2** | Tanjung Karang | 1,5 | 4 | 42 | 22 | 1,588 | 0,0035 | 0,147 | 0,077 | 9,2% | 4,8% |

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| | Placement Location | Well Dimensions | | Number of Potential SRs | | Qpuncak | Qsumur | Qtotal $_{\text{well}}$ | | Discharge Reduction | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Ø** | **H** | **100 %** | **50%** | **m3/dt** | | **100 %** | **50 %** | | |
| | Village | (m) | (m) | Fruit | Fruit | | m3/dt | m3/dt | m3/dt | % | % |
| **3** | Lamp | 1,5 | 4 | 48 | 24 | 1,588 | 0,0035 | 0,168 | 0,084 | 10,6% | 5,3% |
| **4** | Enggal | 1,5 | 4 | 95 | 48 | 1,588 | 0,0035 | 0,332 | 0,168 | 20,9% | 10,6% |
| **5** | Sea Swamp | 1,5 | 4 | 115 | 57 | 1,588 | 0,0035 | 0,402 | 0,199 | 25,3% | 12,6% |
| **6** | Pahoman | 1,5 | 4 | 121 | 60 | 1,588 | 0,0035 | 0,423 | 0,210 | 26,6% | 13,2% |
| | | **1,5** | **4** | **454** | **227** | **1,588** | **0,0035** | **1,588** | **0,794** | **100,0%** | **50,0%** |

Based on Table 5 with a 100% *zero runoff* scenario, the dimensions of the well with a diameter of 0.8 m and a depth of 2 m, as many as 934 well units are needed to reduce runoff by 100%. Meanwhile, in the larger dimensions, which are 1.2 m in diameter with a depth of 3 m, the number of wells needed is reduced to 612 units. Furthermore, at a diameter of 1.5 m and a depth of 4 m, the number of wells required is further reduced to 454 units to achieve a run-off condition.

The results show that increasing the dimensions of the infiltration well significantly increases the infiltration capacity, resulting in fewer units needed to achieve *zero runoff*. Thus, there is an inverse relationship between the dimensions of the infiltration well and the number of units required to reduce surface runoff.

## CONCLUSION

The study on the need for infiltration wells in Enggal District aims to address the persistent issues of surface runoff and groundwater conservation exacerbated by urbanization. The results confirm that infiltration wells are an effective solution for mitigating surface runoff by facilitating groundwater recharge. By analyzing multiple scenarios based on well dimensions and available land, the research demonstrates that a strategic installation of infiltration wells can achieve zero runoff conditions. The most efficient design involved larger wells with diameters of 1.5 m and depths of 4.0 m, significantly reducing the number of wells required for effective runoff management. The implementation of these systems is expected to play a vital role in improving urban water management and enhancing groundwater sustainability in highly urbanized areas like Enggal District. Future research could explore the long-term effectiveness of infiltration wells in various urban settings, including the impacts of soil composition and other local hydrological factors. Additionally, studies could focus on the integration of infiltration wells with other stormwater management strategies, such as green infrastructure or permeable surfaces, to enhance overall water conservation efforts. Future research should also investigate the cost-effectiveness and maintenance requirements of infiltration well systems, particularly in densely populated urban areas, to determine their viability as a sustainable urban water management solution. Further exploration into the potential scalability of this approach in other regions facing similar challenges would provide valuable insights for broader implementation.

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