# Analysis of Flood Discharge Changes in the Watershed of the Bendung Area, Palembang City

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**Abstract.** Changes in land use inevitably influence flood discharge, and the balance of the watershed ecosystem is significantly affected by land use and land cover alterations. Both land use and climate change play crucial roles in shaping the hydrological cycle, and modifications in land use can notably impact flood discharge patterns within a given area. This is due to the decreased water absorption into the soil resulting from increased development. In addition to changes in land use, there are several factors that contribute to flooding in Palembang City, including the loss of tributaries due to land filling and construction, insufficient drainage functionality, massive filling of wetlands every year, and the area's topography, which has several low-lying points. One of the areas most frequently affected by flooding in Palembang City is sub-district Kemuning, sub-district Ilir Timur Satu, and sub-district Ilir Timur Tiga, which are traversed by the Bendung watershed. Therefore, a study was conducted to analyze changes in flood discharge based on rainfall data from 2005 and 2024, in relation to land use changes within the study area. The analysis found that the average flood discharge increased by 24 m³/s in 2005, and by 2024, the average discharge had risen to 70 m³/s. This increase was primarily caused by land use changes in the Bendung Watershed area.

**Keywords:** Flood, land use, discharge, topography, watershed.

## 1 Introduction

A watershed is an area bounded by mountain ridges where rainfall falls in that area and is then channeled into rivers. This watershed also serves as a water catchment area, a storage facility, and a distribution system for water (Halim, 2014).

Palembang City has an area of 352.51 km² as of 2022, with a population of 1,729,546 people (BPS Kota Palembang, 2024). The increasing population will impact the development of construction in Palembang City. The increase in development certainly requires new land, leading to construction on wetlands by filling in the existing marshes in Palembang City. Many tributaries have been lost due to this filling. With the increase in development, there will be an impact on the characteristics of the watershed, resulting in a decrease in the infiltration process, which is the absorption of water into the soil, causing an increase in runoff volume that leads to flooding (Handayani, Jayadi, & Triatmodjo, 2005).

With this background, a calculation of flood discharge was conducted in the Bendung watershed, comparing flood discharge in 2005 with that in 2024. Climatic


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data was obtained from the Kenten climatological station, along with maximum rainfall data over 10 years.

## 2 Literature Review

Land use planning, also known as land use management, refers to the planning process for the utilization or use of land in a specific area. Changes in land use due to increased development impact the characteristics of river basins. A river basin is defined by (Kodoatie & Sugiyanto, 2010) as a natural unit of area/region/watershed where water catchment from rainfall flows within that area towards a river.

The reduction of infiltration areas with high rainfall will result in increased runoff, leading to water accumulation, commonly referred to as flooding. To prevent flooding, it is necessary to analyze rainfall and flood discharge based on recurrence intervals.

From the climatology station, rainfall data for the region is obtained, and then the maximum rainfall for the area over a 10-year period is calculated using the arithmetic method. Next, a planned rainfall distribution analysis is conducted using the Gumbel method for return periods of 2, 5, 10, 25, 50, and 100 years with the following equation :

$$X_T = X_r + K_{Tr}S$$

The value of Ktr can be determined using the following equation:

$$K_{tr} = \frac{Yt-Yn}{Sn}$$

$$Yt = -\ln\left[-\ln\ln\frac{Tr-1}{Tr}\right] \quad (1)$$

Where:

| | |
|---|---|
| XT | : Annual Rain Plan |
| Xr | : Average maximum rainfall |
| Ktr | : Frequency factor |
| S | : Standard deviation |
| Yt | : Reduce variated |
| Yn | : Average price of reduce variate |
| Sn | : Reduce standar deviasi |

The analysis of rainfall intensity was then carried out using the Mononobe method, with the aim of determining the amount of rainfall over the specified concentration period (Marlina & Andayani, 2018), Can be calculated using the equation:

$$I = \frac{R24}{24}\left[\frac{24}{t}\right]^{2/3} \quad (2)$$

Where:

| | |
|---|---|
| I | = Rainfall intensity (mm/hour) |
| $R_{24}$ | = Maximum daily rainfall (mm) |
| T | = Duration of rainfall (hours) |

The calculation can be further extended by analyzing the design flood discharge using the Rational Method, as given by the following equation:

$$Q = C \times I \times A \quad (3)$$

Where:

Q = Discharge of surface ($m^3/s$)
C = Runoff coefficient
I = Rainfall intensity (mm/hour)
A = Catchment area ($km^2$)

## 3 Research Objectives and Benefits

Several studies have examined the effects of land use changes on flooding discharge. Rachmayanti, Musa, and Mallombasi (2022) investigated land use impacted alterations on flood discharge using HEC-HMS software, with a case study focused on the Saddang Watershed. Similarly, Ismoyojati, Sujono, and Jayadi (2018) studied the influence of land use changes on flood characteristics in Bima City. In Palembang City, Hidayat (2024) utilized GIS technology to map and analyze flood distribution by district, providing valuable insights into the spatial variability of flood risks across the city. Furthermore, Sudarmadji (2024) concentrated on identifying and evaluating retention ponds as part of flood management strategies in Palembang. Lastly, Indrayani (2024) conducted an analysis of inundation and flooding distributed throughout Palembang City, examining both the extent and causes of flood occurrences in different areas.

On previous research, this study aims to compare flood discharge in the Bendung Watershed of Palembang City to determine the design flood discharge for the years 2005 and 2024, considering return periods of 2, 5, 10, 25, 50, and 100 years. By calculating the flood discharge for these return periods, this research will contribute to the planning of flood control structures in Palembang City, with the goal of mitigating flooding, particularly in the Bendung Watershed. The primary objective of this study is to analyze the flood discharge for the years 2005 and 2024 and to assess the impact of land use changes on flood discharge in the watershed. The outcomes of this research are expected to provide valuable insights and recommendations for effective flood control measures in Palembang City, especially in the Bendung Watershed area.

## 4 Research Methodology

### 4.1 Study Region

The research was conducted in Palembang City, focusing on the Bendung Watershed with an area of 15.4 $km^2$, which includes several sub-districts, among others 10 Ilir, 11 Ilir, 13 Ilir, 14 Ilir, 15 Ilir, 18 Ilir, 20 Ilir DIV I, 20 Ilir DIV II, 9 Ilir, 8 Ilir, Ario Kemuning, Dukuh, Kepandean Baru, Kuto Batu, Sekip Jaya, Talang Aman. The

Bendung Watershed was analyzed using DEMSTRM maps, followed by data processing and analysis, resulting in a map of the sub-districts within the Bendung Watershed, as shown in Figure 1.

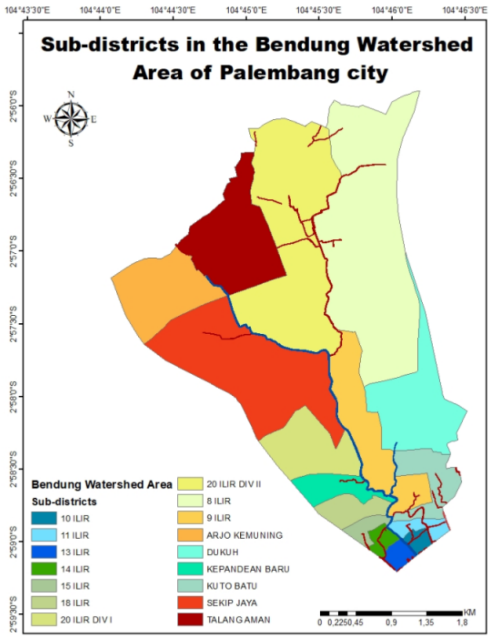


**Fig. 1.** The Map of Sub-Districts in the Bendung Watershed

## 4.2 Method of Collecting Data

To conduct this research, primary and secondary data are required as shown in Table 1.

**Table 1.** Required data

| Data Primary | Explanation |
|---|---|
| - Field observations and documentation of each land use<br>- Analysis of land use change using the NDVI method | Data processing using GIS |
| **Data Seconds** | **Institution** |
| - Rainfall data<br>- Regional spatial planning map<br>Land use data for the years 2005 and 2024<br>- Land use change data<br>- Topographic map<br>- River mapPeta DEM SRTM | PSDA Palembang City<br>Interpretation from Google Earth |

### 4.3 Research Stages

This study first collects primary and secondary data. The rainfall data obtained from the Kenten rain gauge station for the years 1995–2005 and 2014–2014 underwent analysis of rainfall distribution using the Gumbel distribution based on return periods. Next, the rainfall intensity was calculated using the Mononobe method. The design flood discharge can then be determined using the Rational Method. However, before proceeding with this calculation, it is essential to classify the land cover types in the area to calculate the land cover area, which will subsequently be used to determine the runoff coefficient.

## 5 Research Results and Discussion

### 5.1 Rainfall distribution analysis

To determine the planned flood discharge, hydrological analysis is required. From the maximum rainfall data at the Kenten station, a planned rainfall distribution analysis is performed using the Gumbel method, as shown in Table 2 for the years 1995–2005 and Table 3 for the years 2014–2024.

Table 2. Calculation of planned rainfall for the year 1995-2005

| No | Year | X | (X-Xi)2 |
|---|---|---|---|
| 1 | 1995 | 413,00 | 9 |
| 2 | 1996 | 307,00 | 10609 |
| 3 | 1997 | 314,00 | 9216 |
| 4 | 1998 | 391,00 | 361 |
| 5 | 1999 | 418,00 | 64 |
| 6 | 2000 | 453,00 | 1849 |
| 7 | 2001 | 521,00 | 12321 |
| 8 | 2002 | 378,00 | 1024 |
| 9 | 2003 | 492,00 | 6724 |
| 10 | 2005 | 413,00 | 9 |
| Total | | 4100,00 | 42186 |
| Average | | 410,00 | |
| Standard deviation | | 68,46 | |

Table 3. Calculation of planned rainfall for the year 2014-2024

| No | Year | X | (X-Xi)2 |
|---|---|---|---|
| 1 | 2014 | 214,11 | 9350,89 |
| 2 | 2015 | 115,60 | 38106,94 |
| 3 | 2016 | 172,40 | 19157,33 |
| 4 | 2017 | 113,90 | 38773,55 |

| | | | |
|---|---|---|---|
| 5 | 2018 | 97,00 | 45714,72 |
| 6 | 2019 | 487,00 | 31042,92 |
| 7 | 2020 | 399,00 | 7777,48 |
| 8 | 2021 | 588,00 | 76834,30 |
| 9 | 2022 | 554,00 | 59141,38 |
| 10 | 2023 | 332,00 | 449,02 |
| 11 | 2024 | 345,90 | 1231,31 |
| Total | | 3418,91 | 327579,82 |
| Average | | 310,81 | |
| Standard deviation | | 180,99 | |

Calculating planned rainfall for return periods of 2, 5, 10, 25, 50, and 100 years as shown in Table 4 for the year 2005 and Table 5 for the year 2024.

Table 4. Calculation of Maximum Daily Rainfall for the Year 2005 Based on Return Periods

| Tr (Year) | Ktr | $X_{Tr}$ (mm) |
|---|---|---|
| 2 | 0,3668 | 353,56 |
| 5 | 1,5004 | 517,16 |
| 10 | 2,2510 | 625,49 |
| 25 | 3,1993 | 762,35 |
| 50 | 3,9028 | 863,88 |
| 100 | 4,6012 | 964,67 |

Table 5. Calculation of Maximum Daily Rainfall for the Year 2024 Based on Return Periods

| Tr (Year) | Ktr | $X_{Tr}$ (mm) |
|---|---|---|
| 2 | 0,3668 | 285,97 |
| 5 | 1,5004 | 498,01 |
| 10 | 2,2510 | 638,41 |
| 25 | 3,1993 | 815,79 |
| 50 | 3,9028 | 947,39 |
| 100 | 4,6012 | 1.078,02 |

## 5.2 Rainfall Intensity

Calculation of rainfall intensity using the Mononobe method with a river length of 12.371 km and a river slope of 0.0161. The results of the rainfall intensity calculations for the year 2005 can be seen in Table 6, and for the year 2024 in Table 7.

Table 6. Rainfall Intensity 2005 Based on Return Periods

| **Tr** | **$R_{24}$ (mm)** | **I (mm/hour)** | **I (m/s)** |
|---|---|---|---|
| 2 | 400,74 | 80,780 | 0,000022439 |
| 5 | 482,47 | 97,255 | 0,000027015 |
| 10 | 536,59 | 108,163 | 0,000030045 |
| 25 | 604,96 | 121,945 | 0,000033874 |

| | | | |
|---|---|---|---|
| 50 | 655,68 | 132,169 | 0,000036714 |
| 100 | 706,03 | 142,319 | 0,000039533 |

Table 7. Rainfall Intensity 2024 Based on Return Periods

| **Tr** | **$R_{24}$ (mm)** | **I (mm/hour)** | **I (m/s)** |
|---|---|---|---|
| 2 | 285,969 | 57,644 | 0,000016012 |
| 5 | 498,012 | 100,387 | 0,000027885 |
| 10 | 638,413 | 128,688 | 0,000035747 |
| 25 | 815,795 | 164,444 | 0,000045679 |
| 50 | 947,386 | 190,970 | 0,000053047 |
| 100 | 1078,023 | 217,303 | 0,000060362 |

### 5.3 Land Use Data Analysis

Based on the land cover map derived from the interpretation for the years 2005 and 2024, with an area of 15.4 km², the land is divided into three classifications: built-up land, open space, and bodies of water. From this classification, the runoff coefficients can be seen in Table 8 for the year 2005 and Table 9 for the year 2024.

Table 8. Calculation of the runoff coefficient for the year 2005

| No | *Landcover* | Area (m2) | Area (km2) | Area (Ha) | Coefficient C | Area (Ha) x Coefficient c |
|---|---|---|---|---|---|---|
| 1 | Open Space | 4098600 | 4,0986 | 409,86 | 0,2 | 81,97 |
| 2 | Built-Up Land | 10066500 | 10,0665 | 1006,65 | 0,6 | 603,99 |
| 3 | Bodies of Water | 1224900 | 1,2249 | 122,49 | 0,05 | 6,12 |
| | | value of c | | | | 0,45 |

Table 9. Calculation of the runoff coefficient for the year 2024

| No | *Landcover* | Area (m2) | Area (km2) | Area (Ha) | Coefficient C | Area (Ha) x Coefficient c |
|---|---|---|---|---|---|---|
| 1 | Open Space | 2425500 | 2,4255 | 242,55 | 0,2 | 48,51 |
| 2 | Built-Up Land | 12199500 | 12,1995 | 1219,95 | 0,6 | 731,97 |
| 3 | Bodies of Water | 766800 | 0,7668 | 76,68 | 0,05 | 3,83 |
| | | value of c | | | | 0,51 |

## 5.4 Analysis of Planned Flood Discharge

The planned flood discharge calculations with return periods are calculated using the rational method. The results for the planned flood discharge in 2005 can be seen in Table 10, and Table 11 shows the results for the planned flood discharge for the year 2024.

Table 10. Calculation of the planned flood discharge for the year 2005

| **Tr** | I (m/s) | Area (m2) | runoff coefficient. C | Q (m3/s) |
|---|---|---|---|---|
| 2 | 0,000022439 | 15390000 | 0,45 | 155,296 |
| 5 | 0,000027015 | 15390000 | 0,45 | 186,968 |
| 10 | 0,000030045 | 15390000 | 0,45 | 207,940 |
| 25 | 0,000033874 | 15390000 | 0,45 | 234,434 |
| 50 | 0,000036714 | 15390000 | 0,45 | 254,090 |
| 100 | 0,000039533 | 15390000 | 0,45 | 273,603 |

Table 11. Calculation of the planned flood discharge for the year 2024

| **Tr** | I (m/s) | Area (m2) | runoff coefficient. C | Q (m3/s) |
|---|---|---|---|---|
| 2 | 0,000016012 | 15391800 | 0,51 | 125,587 |
| 5 | 0,000027885 | 15391800 | 0,51 | 218,708 |
| 10 | 0,000035747 | 15391800 | 0,51 | 280,367 |
| 25 | 0,000045679 | 15391800 | 0,51 | 358,266 |
| 50 | 0,000053047 | 15391800 | 0,51 | 416,056 |
| 100 | 0,000060362 | 15391800 | 0,51 | 473,427 |

According to the results of the planned flood discharge calculations for the years 2005 and 2024, a comparison graph of the flood discharge was created, as shown in Figure 2.

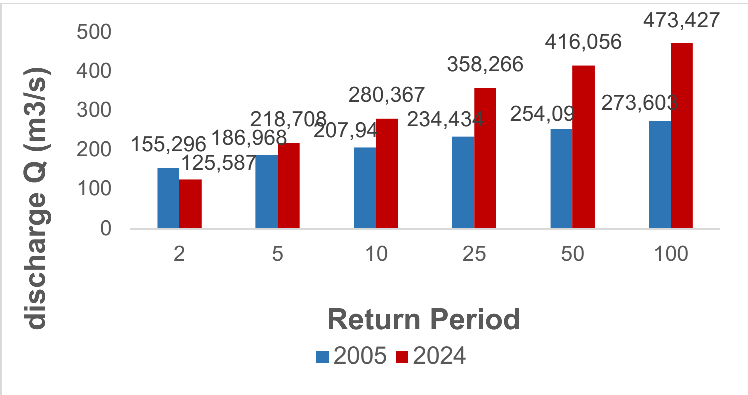


**Fig. 2.** Comparison of Flood Discharge Based on Return Periods for the Years 2005 dan 2024

## 6 Conclusion

The flood discharge for the year 2005 in the Bendung Watershed is as follows: 155.296 $m^3/s$ for a 2-year return period, 186.968 $m^3/s$ for a 5-year return period, 207.940 $m^3/s$ for a 10-year return period, 234.434 $m^3/s$ for a 25-year return period, 254.090 $m^3/s$ for a 50-year return period, and 273.603 $m^3/s$ for a 100-year return period. For the year 2024, the flood discharge values are 125.587 $m^3/s$ for a 2-year return period, 218.708 $m^3/s$ for a 5-year return period, 280.367 $m^3/s$ for a 10-year return period, 358.266 $m^3/s$ for a 25-year return period, 416.056 $m^3/s$ for a 50-year return period, and 473.427 $m^3/s$ for a 100-year return period. Land use impacted changes on flood discharge in the Bendung Watershed results in an average increase of 24 $m^3/s$ in flood discharge for 2005, and an average increase of 70 $m^3/s$ for 2024.

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