Handling of The Environmental Drainage System In Jembrana District, Bali Province

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Abstract. The rapid growth of the urban population should be followed by the provision of basic infrastructure and facilities in inadequate residential areas. One of them is the facilities and infrastructure for the environmental drainage system in residential areas to be free from standing water, especially during the rainy season. In Jembrana Regency, especially in Negara city and its surroundings, there are fourteen inundation points spread over 3 (three) districts. Drainage treatment is carried out by ranking priority scales based on inundation parameters. The parameters are inundation of height, length, frequency, and also the loss parameters due to inundation of economic facilities, public facilities, transportation facilities, housing, and casualties. With limited funds available, detailed planning is carried out on three inundation points with the highest priority score. The analysis shows that three inundation points receive priority for handling, namely Baler Bale Agung village’s environmental drainage system, Dauh Waru village, and environmental drainage Loloan Timur village. The drainage construction system uses an open channel with a U-ditch type and a box culvert with freecast concrete’s quality value of K-350.

keywords: concrete channel, environmental drainage system, U-ditch precast

1. Introduction
Urban flooding often disturbs the livelihood in an urban area, which most likely happens in the lowland urban area [1]. The availability of suitable facilities and infrastructure is one of the parameters of comfortable living. Urban drainage systems are essential for a city infrastructure that has grown public attention due to some severe flooding of the urban environment [2]. The rapid population growth in Jembrana Regency should be followed by the provision of basic infrastructure and facilities. Limited funds and development programs can hamper the provision of such basic infrastructure and facilities. Generally, the need exceeds the condition. At that time, there was an imbalance between significant needs and limited supply. The planned infrastructure and facilities can no longer meet the requirements. As a result, traffic jams, floods, puddles, garbage is not managed correctly. Wastewater discharges are not appropriate, and people find it difficult to get clean water services and others. One of the basic infrastructure and facilities that are considered quite important is environmental drainage. A good environment needs to pay attention to the condition of the drainage channels because if a settlement is flooded, it will significantly impact the life of the domain. Buildings become easily damaged, the environment becomes unhealthy, and the accommodations become a slum. Drainage channels function to dry surface water, whether sourced from rainwater, high tide, floods, stagnant water, and others. Sustainable urban drainage systems (SUDS) were almost unknown in Indonesia.
already noticed. Urban drainage in some countries' progress is transitioning towards more sustainable management where green open space policies are implemented [3].

The drainage that will be handled is environmental in Kota Negara and its surroundings. Bali Province is a residential area. The speed of growth in this area must be balanced with the provision of ecological infrastructure and facilities. The condition of drainage channels in this area has generally been strived to organize appropriately. Still, some locations have drainage problems, such as unavailability of channels, inadequate channels, stagnant water, etc.

This study aims to improve the effectiveness of the drainage system in this area and make infrastructure improvements and facilities to reduce the inundation.

2. Materials and Methods

2.1. Study Location

The research area is Kota Negara, Jembrana Regency, Bali Province. The inundation of residential areas in Jembrana Regency is spread over 13 points of location of residential areas as follows:

Spread over 6 inundation points in the Negara District:
1. MTS Banyubiru
2. Perumnas BBA
3. Kaliakah Village
4. Jalan Bonsai - Jln. Sandat
5. Banjar Tengah - SMA PGRI
6. Area of Jalan Mangga - Mujahidin Mosque - Loloan Barat Sub District

Spread over 6 inundation points in the Jembrana district:
1. LC Dauh Waru
2. Mertasari Environment – Loloan Timur
3. Banjar Tegalasih
4. Jl. Kutai (Tukad Sebual) - Dangin Tukad Daya Village
5. Jl. Irian Island - Budeng Village
6. SMA TP 45 Pangkung Lampah

Spread over 2 inundation points in the Mendoyo District:
1. Tegalcangkring
2. West Community Health Center Yeh Embang

![Figure 1. Map of the Study Location](image)
The inundation problems in the district of Jembrana is:
1. A change in land use significantly.
2. The settlement development system with the Land Consolidation (LC) system from paddy fields has caused a change in the direction of channel use from irrigation to drainage channels.
3. There is a narrowing of the river, especially in the middle and downstream parts, which often causes flooding.
4. The condition of the sewer building many household culverts are clogged (not connected) and have tiny dimensions.
5. Most of the village roads do not have adequate drainage channels.
6. Disposal of garbage into river/canal bodies.

Figure 2. Relationship Scheme of Drainage System Problems in the Field

Figure 3. General drainage problem

This study requires data to support this study, and the following are the required data:
1. Rain data analysis:
   - Rainfall analysis by frequency analysis, maximum annual daily rainfall data > 10 years.
   - Frequency analysis: Normal distribution method, Log-Normal, Log Pearson Type III, and Gumbel.
   - Rain data test: outliers, trends, RAPS, multiple mass curve methods, or as appropriate.
• Rain intensity calculation: Mononobe, Hasper, Weduwen method.

2. Flood Discharge Analysis:
• The design discharge is calculated using a modified rational method.
• Runoff coefficient: based on catchment land use

3. Land Use Map
   The map was used to determine the runoff coefficient in the catchment area.

4. Topography Map
   The map was used to determine the flow direction in the drainage channel outlet.

5. Population Data
   The population data were used to calculate the wastewater needs of Kota Negara

2.2. Hydrology of Drainage System

A. Average Area Rainfall
   The maximum average areal rainfall data is obtained using the Thiessen Polygon method [4]. The calculation formula is:
   \[ \bar{d} = \frac{A_1d_1 + A_2d_2 + \ldots + A_nd_n}{A} \]  
   Where:
   \( \bar{d} \) = average area rainfall height (mm)
   \( d_1, d_2, \ldots, d_n \) = height of rainfall in rainfall stations 1, 2, ..., n (mm).
   \( A_1, A_2, \ldots, A_n \) = area of influence of rain station 1, 2, ..., n (mm).
   \( A \) = area of a watershed (km\(^2\))

B. Design Rainfall
   Design rainfall is the most significant annual rainfall with a certain probability of occurring in a certain area. The design rainfall can be calculated using the Log Pearson Type III method equation [5]:
   \[ \log X_T = \log X + G \cdot S \]  
   Where:
   \( \log X_T \) = logarithmic value of the design rainfall with the return period T year,
   \( \log X \) = logarithmic value of the average rainfall data.
   \( G \) = magnitude of the slope coefficient function from time to time.
   \( S \) = logarithmic standard deviation of rainfall data.

C. Rainfall Intensity
   The selected intensity has a simple equation form. The equations that will be used later are those of Talbot, Sherman, and Ishiguro.

   a. Talbot formula:
   \[ I = \frac{a}{t + b} \]  
   \[ a = \frac{\sum t \cdot I}{n} - \frac{\sum t^2 \cdot \sum I}{n \sum t^2} \]  
   \[ b = \frac{\sum t \cdot I - n \sum t^2 \cdot \sum I}{n \sum t^2 - (\sum t)^2} \]  

   b. Sherman’s formula
   \[ I = \frac{a}{t^2} \]
\[ \log a = \frac{\sum (\log I) \sum (\log t^2) - \sum (\log t) \sum \log t}{n \sum (\log t^2) - (\sum \log t)^2} \]  
\[ y = \frac{\sum (\log I) \sum (\log t) - n \sum (\log I \log t)}{n \sum (\log t^2) - (\sum \log t)^2} \]  
\[ c. \text{ Ishiguro formula} \]
\[ l = \frac{a}{\sqrt{t+b}} \]
\[ a = \frac{\sum (l \sqrt{t}) \sum (l^2 \sqrt{t}) \sum t}{n \sum (l^2) - (\sum l)^2} \]
\[ b = \frac{\sum (l \sqrt{t}) \sum (l^2 \sqrt{t})}{n \sum (l^2) - (\sum l)^2} \]

Concentration Time
The concentration-time (Tc) is divided into two, namely (t₁) the time to reach the beginning of the channel (inlet time), and (t₂) the flow time [6]. According to JICA, road surface drainage is used (t₁), while for canals or culverts it is used (t₁ + t₂).

Inlet time is influenced by factors such as conditions and slope of the surface, area, and other forms of the catchment area.

\[ t_1 = \left( \frac{L_t}{3 \times 3.28 \times L_t \times \frac{n_d}{\sqrt{s}}} \right)^{0.167} \]

Where:
- \( t_1 \) = inlet time, in (minutes)
- \( L_t \) = length from the farthest point to the drainage facility, in (m)
- \( s \) = slope of the surface
- \( n_d \) = drag coefficient (effect of surface conditions through which the flow passes).

Drainage Plan Discharge
The Haspers, Der Weduwen, and Melchior methods are empirical methods developed for situations in Indonesia and based on the Rational method's concept to determine the relationship between rainfall and river flooding. The three empirical methods above have the following general equation [7]:

\[ Q = C \times \beta \times I \times A \]

Where:
- \( Q \) = runoff discharge (m³/s)
- \( C \) = runoff coefficient
- \( \beta \) = coefficient of rain distribution.
- \( I \) = rain intensity (mm / hour)
- \( A \) = catchment area of flow (km²)

2.3. Hydraulic Analysis
A steady flow, the wet surface area, does not change for a certain time, or it can be said that the flow rate does not change. The calculation principles for channel design are based on the uniform flow principle. The flow equation is:

\[ Q = A \times V \]

Where \( Q \) = channel discharge (m³/s); \( A \) = wet cross-sectional area (m²); and \( V \) = flow velocity (m/s).

For drainage channel design using the Strickler method with the following equation:

\[ V = K \times R^{2/3} \times S^{1/2} \]
Where \( V \) = flow velocity (m/s); \( R \) = hydraulic radius (m); \( S \) = slope of the bottom channel; and \( K \) = Strickler roughness coefficient.

3. Results and Discussion

3.1. Hydrological Analysis

The rainfall intensity duration frequency (IDF) curves are representations of the probability graphical that a given average rainfall intensity will occur within a given period of time [8]. Rainfall intensity was calculated using the Talbot, Ishiguro da Sherman method. However, Talbot provides the best scores as below.

| Duration (minutes) | 2     | 5     | 10    | 25    | 50     |
|-------------------|-------|-------|-------|-------|--------|
| 5                 | 355.54| 416.73| 437.83| 505.83| 540.69 |
| 10                | 322.18| 355.57| 390.57| 439.11| 476.75 |
| 20                | 288.82| 322.21| 348.87| 380.73| 410.03 |
| 40                | 216.54| 247.15| 273.81| 297.33| 326.63 |
| 60                | 174.84| 208.23| 232.11| 258.41| 287.71 |
| 120               | 105.34| 130.39| 148.71| 166.67| 184.85 |
| 240               | 63.64 | 80.35 | 90.33 | 102.73| 120.91 |

From the analysis result above, rainfall intensity at the study location average is 120 mm/minutes with return periods of 5 years.

3.2. Handling Priority Scale

Priority scale is needed to facilitate programming if funds are limited and handling cannot be done simultaneously. The priority scale referred to in this discussion is several inundation cases that have occurred in recent years and require immediate handling in the next 1 or 2 years [9]. So to compile a funding program, it is necessary to make a ranking order. Parameters for determining the priority of reducing inundation are inundation depth, economy sector, social disruption, and government facilities, transportation, and residential. The priority of handling inundation reduction in Kota Negara is shown in table 2 below.
### Table 2. Handling Priority Scale

| Inundation Area                                                                 | Scoring | Rank |
|--------------------------------------------------------------------------------|---------|------|
| Perumnas BBA– Baler Bale Agung Village                                         | 745     | 1    |
| LC Dauh Waru – Dauh Waru Village                                               | 710     | 2    |
| Lingkungan Mertasari – Loloan Timur Village                                    | 640     | 3    |
| Kaliakah Village                                                               | 615     | 4    |
| Jl. Pulau Irian - Budeng Village                                               | 555     | 5    |
| MTS Banyubiru – Banyubiru Village                                              | 515     | 6    |
| Jl. Mangga – Majahiddin Mosque – Loloan Barat Sub District                     | 505     | 7    |
| Tegalangkring Village                                                          | 480     | 8    |
| West Community Health Center Yeh Embang – Yeh Embang Village                   | 420     | 9    |
| SMA PGRI – Banjar Tengah Sub District                                          | 390     | 10   |
| Banjar Tegalasih – Batuagung Village                                           | 355     | 11   |
| Jl. Bonsai, Jl. Sandat – Lelateng Sub District                                 | 335     | 12   |
| Jl. Kutai (Tukad Sebual) – Dangin Tukad Daya Village                           | 335     | 13   |
| SMA TP.45 (Pangkung Lampah) – Pendem Sub District                              | 290     | 14   |

Based on the calculation of the priority scale above, the current management plan is focused on the reducing inundation management at the Baler Bale Agung (BBA) Village, Dauh Waru Village, Loloan Timur Village

3.3. Flow Direction Analysis

In planning for an environmental drainage system, the direction of the flow is very important to be studied in detail both through topographic maps and based on direct field surveys [10]. This is intended to ensure that water and puddles can be flowed by gravity. Below is a picture of the direction of drainage flow at the study site.

![Figure 5. Schematic of Flow Direction and Existing Inundation Conditions](image)

From the calculations for evaluating the drainage channel, there are several schemes for reducing inundation at Bale-bale Agung Village and Dauh Waru Village with construction precast U-ditch, culvert, and existing drainage maintenance in Figure 6-8 below. The type of precast drainage channel is shown in Figure 9.
Figure 6. Existing and scheme of reducing inundation at Baler Bale Agung Village

Figure 7. Existing and scheme of reducing inundation at Dauh Waru Village

Figure 8. Existing and scheme of reducing inundation at Loloan Timur Village
4. Conclusion
The 3 (three) inundation points receive priority for handling, namely the Baler Bale Agung village's environmental drainage system, Dauh Waru village, and environmental drainage in Loloan Timur village. Refers to a stronger type of construction, a longer design life, and easier and efficient implementation then:

- The channel construction type is selected U-ditch from freecast concrete with K 350 quality for the open channel.
- The type of channel construction is selected box culvert from freecast concrete with K 350 quality for closed channels.

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