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Evaluation of Drainage System Performance in Flood Control Efforts in Benua Melayu Darat Subdistrict, Pontianak City

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Abstract: Benua Melayu Darat, located in South Pontianak Regency, relies heavily on artificial drainage systems to control surface runoff and flooding. However, the area still frequently experiences flooding during high rainfall intensity. Therefore, this study was conducted to evaluate the performance of the drainage system in Benua Melayu Darat District from a hydraulic and non-technical perspective, and to identify the dominant factors contributing to channel dysfunction. The evaluation began with hydrological and domestic wastewater analyses to determine the total water volume to be accommodated by the existing channels. A hydraulic analysis was then conducted to determine the channel's design discharge. Direct field measurements were performed to assess channel dimensions and flow velocity, and non-technical analyses were conducted of sedimentation, waste, and land cover. The results showed that 45% of channels in Benua Melayu Darat District had inadequate capacity to accommodate rainfall and domestic wastewater. Non-technical factors, such as uncontrolled sedimentation rates and garbage blockages, also significantly disrupted channel function. This study shows the need to normalise dimensions and channels, implement Low Impact Development systems, such as retention ponds, strengthen maintenance programs to ensure adequate drainage, and provide public education on how to maintain or protect the environment to prevent flooding.

Keywords: Drainage, Evaluation, Flood, Hydraulics, Urban

1. Introduction

Pontianak City, which is in the Kapuas River Delta, has unique geographic features. Relative topographic contours are flat with a height surface range between 0.1 and 1.5 meters above the surface sea level. The land in Pontianak city is greatly affected by the river's ebb and flow. The average surface water level in urban areas at the time of flooding reached 50 cm. Tidal measurements in Pontianak show that the highest water level (HWL) reaches 2.42 meters, the lowest water level (LWL) reaches 0.07 meters, and the mean sea level (MSL) is 0.89 meters. [1]. This results in large areas of the city being highly dependent on the system's artificial drainage to control surface runoff, minimising the occurrence of floods and inundation.

Benua Melayu Darat (BMD) is in the South Pontianak

District. It has an area of 2.67 km^2 and the number of residents is as many as 25,683 people, with a population density of 9,619 people/km^2, as well as 35 pillar residents (RW) and 154 neighbourhood associations (RT) [2]. This area is one of the city's central commercial and economic areas, with a high risk of waterlogging and tidal flooding. Waterlogging often occurs after rainfall, especially during high tide (rob) of the Kapuas River. Drainage functional artificial control runoff surface considered experience failure due to inability to drain water, resulting in rapid water accumulation and puddles. This is also reinforced by the results of interviews with the sub-district heads from the BMD who stated the same thing. Based on the description above, this research has several objectives as follows:

1. Analyse the flood discharge comparison plan with the existing capacity channel.
2. Identify the factors that cause drainage channels in BMD sub-district to not function optimally.
3. Give a technical recommendation for improving the performance of the drainage system in the BMD Subdistrict.

2. Literature Review

As an effort to find a position study on this, conduct a search for previous ones with similar discussions, including research written by previous researchers. First, Rahardjo states that high rainfall and the lack of planning and maintenance of drainage systems in densely populated urban areas are among the seven general causes of flooding [3]. Next, the Study of the Analysis of Flood Management Concepts Drainage for the Serok River Area, West Pontianak District, Pontianak City, proposed building a sluice gate leading to the Kapuas River as a drainage solution, ensuring the channel would function as a water reservoir and be unaffected by tidal fluctuations [4]. Third, Arianti et al. in [5] offer a basic manufacturing system and an early warning system (EWS) created to utilise the Internet of Things (IoT) to monitor vulnerable areas to flooding as a disaster solution. Fourth, the research entitled "Analysis Study of Drainage Management Concepts to Support Water Management in Settlements on the Kapuas Riverbanks in Pontianak" discusses drainage management in the Benua Melayu Laut sub-district of Pontianak City [6]. Finally, the Study titled "Identification of Damage Type of Side Ditch Drainage at Benua Melayu Laut Village, Pontianak City, West Borneo, Indonesia" identifies drainage damage that needs to be repaired and renewed due to frequent flooding caused by Rain or the ebb and flow of the Kapuas River [7]. Several studies on flooding in urban areas and drainage systems show that research on the effectiveness of drainage systems in the sub-district of Pontianak City has not been conducted and is worth pursuing, given its dense population and the supporting economy of Pontianak City.

3. Methodology

3.1. Data and Location

A study was conducted in the Kelurahan area of Benua Melayu Darat, South Pontianak District. Data used includes:

1. Primary Data: Survey results field in the form of dimensions, drainage existing, speed, channel layout, drainage in BMD sub-district, slope channel, depth sediment, and conditions of blockage in the duct drainage.
2. Secondary Data: Rainfall data, daily rainfall maximum from the BWSK 1 station in West Kalimantan for 14 years, population data, and the number of facilities.

3.2. Analysis of Hydrology

Flood discharge (Q_{flood}) is calculated using the Rational Method with a period of 5 years (return period), which is often used for planning urban drainage [8][9][10].

$$Q_{flood} = 0.00278 \cdot C \cdot I \cdot A \quad (1)$$

Where Q_{flood} denotes discharge plan (m^3/s); C denotes coefficient of runoff (based on land use); I denotes rainfall intensity (mm/h); A denotes catchment area (km^2).

3.3. Analysis of Hyrdarulics

Capacity channel existing (Q_{design}) is calculated using Manning's Equation, considering the dimensions of the channel existing and the coefficient of roughness (n):

$$V = \frac{1}{n} \cdot R^{\frac{2}{3}} \cdot S^{\frac{1}{2}} \quad (2)$$

$$Q_{design} = A \cdot V \quad (3)$$

Where V describes flow velocity (m/s); n describes Manning's roughness coefficient; R describes hydraulic radius (m); S describes bed slopes.

Drainage performance is assessed by comparing Q_{flood} and Q_{design}. Channel is considered to function optimally if $Q_{flood} \leq Q_{design}$.

For the count of residents in settlements, using the geometric formula as follows:

$$P_n = P_0 \times (1 + r)^n \quad (4)$$

In the equation, P_n is the amount of resident after n years, P_0 is the initial total resident, r is the percentage rate of growth, and n is the number of years.

For calculating waste discharge, use several stages as follows:

1. Determine Q_domestic

$$Q_{domestic} = \frac{total\ population \times water\ needs \times 10^{-3}}{86400} \quad (5)$$

2. Determine $Q_{non\ domestic}$

$$Q_{non\ domestic} = \frac{facilities \times water\ needs \times 10^{-3}}{86400} \quad (6)$$

3. Determine Q_{input}

$$Q_{input} = Q_{domestic} + Q_{non\ domestic} \quad (7)$$

4. Determine $Q_{reserve}$

$$Q_{reserve} = Q_{input} \times 20\% \quad (8)$$

5. Determine Q_{need}

$$Q_{needs} = Q_{input} + Q_{reserve} \quad (9)$$

6. Determine Q_{waste}

$$Q_{waste} = Q_{needs} \times 80\% \quad (10)$$

4. Result and Discussion

Based on hydrological calculations using a rational method for over 5 years, with rainfall data spanning 14 years from 2011 to 2024 and post-BWSK I West Kalimantan rainfall, the rainfall discharge in BMD Village is 192,438 m^3/s.

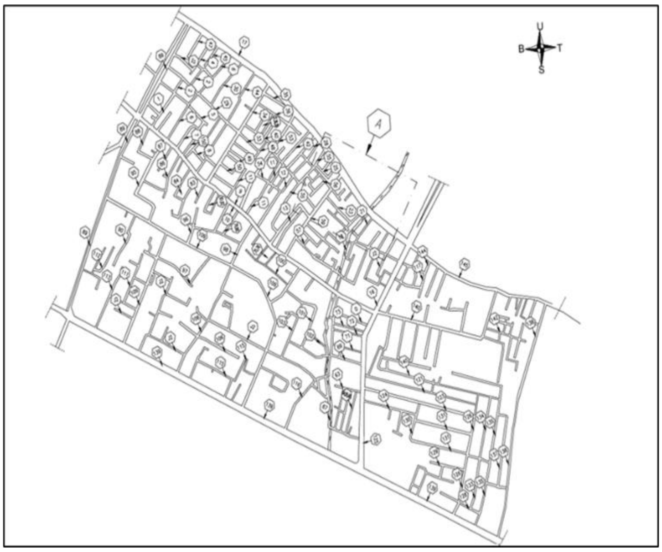

Figure 1. *Layout BMD Drainage System*

Figure 2. *Condition of Several Existing Channels at the Research Location*

Of the 148 points in the BMD sub-district's catchment area, the obtained location is not. There is channel drainage at as many as 41 points (28%), and channel drainage with a capacity channel existing smaller than flood discharge at as many as 29 points (20%). Suppose added up, 28% + 20% = 48%. Shows that 48% of the total length of the surveyed channels is not capable of accommodating the flood discharge and wastewater in the BMD sub-district during the control flood. It can also be seen in Table 1.

The survey results show that there are 41 points where location conditions the channel filled with rubbish, sedimentation, and almost overall part on channel drainage, closed concrete or the iron in question. For the expansion of parking areas, trade, and so on, it is difficult for officers to control the water flow underneath. A comparison of existing and designed channels revealed that 45% of the total length of the surveyed channels was unable to accommodate floodwater and wastewater discharge.

Channel drainage that exceeds the water capacity. Lots found in the area are congested with resident activities, such as around Gajah Mada Street. The advantages of this water capacity are caused by two main factors, namely the dimension factor of channels and the elevation factor, with descriptions as follows:

1. Dimensions: Of all the data found, there are 28% of points that do not have channel drainage in the BMD sub-district and 20% of points with capacity discharge channel existing smaller from the flood discharge so that if added up, there are a total of 48% points location channels that are not can accommodate the flood discharge and wastewater in the BMD output. This causes several channel drainages that have uniform or too small (around 0.4 - 0.5m), no comparable with increasing the watertight area (building/road), asphalt, which has an increased coefficient of runoff (C).
2. Elevation: A condition with very flat topography causes the slope channel (S) to become very small and slows down the speed of flow (V) significantly. This is also made worse by much waste and sediment that settles, which reduces the capacity of the flow.

Malfunction channel exacerbated by non-technical factors that affect drainage capacity:

1. Sedimentation: Channel drainage experiences an average shallowing of 30-50% of normal depth due to sedimentation, especially at low-flow locations.
2. Blockage Garbage: Accumulation of rubbish, House stairs, and solid waste in the channel drainage becomes an inhibitor of the most critical flow, causing instant overflow (puddle) when it rains heavily.
3. Effect of Tidal Flow (Rob): When the Kapuas River has high tide, the tide seeps in, or even flows back into the channel, reducing the channel's capacity until it approaches zero, and increasing the duration of the puddle.

In a way, overall performance drainage in the sub-district Benua Melayu Darat is classified as "Less Effective". This matter was reviewed from the indicator stated effectiveness in PU Regulation No. 12/2014, which has not been achieved, with information as follows:

1. Effectiveness: Channels fail to flow as planned, resulting in a puddle.
2. Efficiency and Adequacy: Suboptimal maintenance (related to waste and sedimentation) results in a constant reduction in efficiency in limited channels.

Table 1. *Comparison of Design and Flood Discharge in The BMD Sub-District.*

Location	Qdesign (m^3/s)	Qflood (m^3/s)	Location	Qdesign (m^3/s)	Qflood (m^3/s)	Location	Qdesign (m^3/s)	Qflood (m^3/s)	Location	Qdesign (m^3/s)	Qflood (m^3/s)	Location	Qdesign (m^3/s)	Qflood (m^3/s)
Gg.GAJAH MADA 1	7.38	0.26	GG.HAJI ABBAS 2	18.44	0.28	GG.HIJAS 2	0.00	0.26	GG.WARU 5	0.25	0.25	JL.UNTUNG SURAPATI	0.00	0.26
Gg.SIAM DALAM	1.68	0.23	GG.KLANTAN 2	0.00	0.27	GG.RAJA WALI	0.00	0.23	GG.WARU 3	0.00	0.21	GG.BUDI	0.15	0.30
JL. SIAM DALAM	1.21	0.27	JL.SETIA BUDI	0.00	0.48	GG.STRUKTUR 6	1.29	0.24	GG.WARU 1	0.00	0.21	JL.TRUNOJOYO	0.10	0.39
GG. DELI ACEH	0.59	0.27	GG.SETIA BUDI 1	0.00	0.26	GG.ILHAM	0.13	0.24	GG.WARU 2	0.04	0.21	JL.KARVIN	0.10	0.25
GG.KELANTAN 4	0.20	0.25	GG. SETIA BUDI 2	0.00	0.28	GG.BERKAH	0.00	0.27	JL.WR SUPPRATMAN	10.69	0.33	JL.VETERAN	0.17	0.36
JL. SIAM	2.36	0.30	GG.SUKADANA B2	0.00	0.28	GG.WAHYU	0.16	0.29	JL.ISMAIL MARZUKI	0.00	0.32	JL.PALAPA 1	0.00	0.33
GG.GAJAH MADA 5	0.02	0.27	GG. SUKADANA B1	0.00	0.25	GG.BERKAH II	0.03	0.28	JL. CHAIRIL ANWAR	1.92	0.09	JL.PALAPA 2	0.06	0.50
GG.GAJAH MADA 9	0.00	0.24	GG.SUKADANA	0.00	0.28	JL.ARIS MARGONO	0.00	0.26	GG.SWADAYA	2.71	0.30	JL.PALAPA 3A	0.00	0.53
JL.GAJAH MADA	0.09	0.43	GG.SETIA BUDI 3	0.00	0.35	GG.SYUKUR 5	0.00	0.27	JL.DEWI SANTIKA	1.06	0.31	JL.PALAPA 3B	0.00	0.24
GG.GAJAH MADA 15	0.23	0.26	GG.BADDURI 1/2	0.00	0.29	GG.DUNGUN	0.00	0.29	JL.LETJEND SUPRAPTO	0.13	0.51	JL.PALAPA 3D	0.00	0.28
GG.GAJAH MADA 17	3.76	0.24	GG.BADDURI 1	0.00	0.28	GG.SYUKUR 4	0.59	0.26	JL.LETJEND SUPRAPTO 1	0.21	0.32	JL.PALAPA 3C	0.00	0.36
GG.GAJAH MADA 19	0.03	0.39	GG. 17	0.00	0.31	GG.SYUKUR 3	0.36	0.26	JL.LETJEND SUPRAPTO 2	0.37	0.33	JL.PALAPA 2B	0.00	0.42
JL.TERMINAL HIJAS	0.20	0.29	GG.IRMA	0.00	0.36	GG.SYUKUR 2	0.06	0.26	JL.SUPRAPTO DALAM	0.13	0.27	JL.PALAPA 2A	0.00	0.33
GG.GAJAH MADA 21	0.09	0.26	GG.BUNTU	0.00	0.34	GG.SUPRAPTO	0.00	0.27	JL.SUPRAPTO 3	0.66	0.29	JL.PALAPA 3	0.26	0.24
JL.PAHLAWAN PLAMBOYAN	1.90	0.29	GG.DELI ACEH	0.00	0.36	GG.GAJAH MADA 28	0.30	0.25	JL.SUPRAPTO 4	0.62	0.33	KOMPLEK TENTARA 1	0.00	0.29
JL.TANJUNG PURA	0.45	0.60	GG.MANDOR	0.00	0.30	GG.GAJAH MADA 26	0.00	0.26	JL.SUPRAPTO 5	0.16	0.37	KOMPLEK TENTARA 2	0.00	0.29
GG.HIDAYAT 11	1.48	0.34	GG.4	0.00	0.38	GG.GAJAH MADA 24	0.00	0.23	JL.ADEK IRMA SURYANI 1	0.33	0.31	JL.MEDIA & TANJUNG HARAPAN	0.00	0.34
GG HIDAYAT 11' (YANG BESAR)	0.00	0.23	GG. 5	0.00	0.26	GG.GAJAH MADA 22	0.00	0.22	JL.SURYANI 2	1.42	0.29	JL.AYANI 1	0.00	0.29
GG.PAGAR ALAM	0.05	0.34	GG. 6	0.00	0.24	GG.GAJAH MADA 20	0.00	0.27	JL.SURYANI 3	0.26	0.26	JL.BUDI KARYA	0.00	0.34
GG 30 AGUSTUS	0.00	0.23	GG.9	2.03	0.26	GG.GAJAH MADA 18	0.00	0.26	JL.S SUPRATMAN	0.28	0.42	JL.GRAHA MAZEMUT	0.00	0.77
GG.SUES	0.17	0.38	GG.8	0.00	0.22	GG.GAJAH MADA 16	0.00	0.26	GG.III	0.23	0.24	KOMLEK WADUK PERMAI	0.00	1.24
GG.MURNI	0.06	0.22	JL.KETAPANG	6.08	0.32	GG.GAJAH MADA 14	4.98	0.22	JL.S PARMAN DALAM	0.38	0.30	GG.SAKURA	0.00	0.41
GG.ELEKTRO	0.03	0.25	GG,KETAPANG 7	0.00	0.23	GG.GAJAH MADA 12	0.30	0.26	GG.DAMAI	0.23	0.29	GG.PALEMBANG	0.00	0.30
GG.KELANTAN	0.00	0.24	JL.KEDAH	0.53	0.30	GG.GAJAH MADA 10	0.10	0.24	JL.PANJAITAN	0.00	0.34	JL.IMAM BONJOL	0.00	0.25
GG.KETAPANG 5	0.00	0.27	GG.MASA	4.65	0.26	GG.GAJAH MADA 8	0.05	0.23	GG.NIRMALA	0.04	0.23	JL. SUPRAPTO 6	0.00	0.25
GG.BADDURI 2	0.00	0.32	GG.SUES PERMAI	0.00	0.27	GG.GAJAH MADA 6	2.61	0.25	JL.KATAMSO	0.10	0.50	GG.GAJAH MADA 11	0.00	0.29
JL.H.ABBAS 1	0.00	0.46	GG.DB AGUNG	0.00	0.24	GG.GAJAH MADA 4	0.00	0.23	GG.MENTOK	0.45	0.70	GG. 7	0.00	0.89
JL.MELIAU	0.00	0.34	JL.HIJAS	1.72	0.33	GG.GAJAH MADA 2	0.00	0.24	GG.TENAGA BARU	0.28	0.27	GG.GAJAH MADA 7	0.00	2.04
GG.KELANTAN 1	0.00	0.31	GG.SUES INDAH	0.00	0.29	JL.AGUS SALIM & GUSTI SULUNG	0.00	0.35	JL.SURAU NURUL HUDA	0.00	0.20	GG. MASSA 1	0.00	0.31

5. Conclusion

An evaluation of the drainage system performance in Benua Melayu Darat District has been conducted. The results indicate that 48% of existing channels lack sufficient capacity to control runoff from both rainfall and wastewater. This inadequate channel capacity can contribute to frequent inundations or flooding in the area. Based on field observations, the channels are experiencing capacity degradation. Several factors contributing to this degradation include damage to channel sections, sedimentation-induced silting, and garbage blockages. These factors contribute to the functional failure of the drainage system and to flooding during high-intensity rainfall. Several measures to address these problems include restoring channel capacity to its original condition, implementing the Low Impact Development (LID) concept through the development of retention ponds that can reduce the volume of incoming runoff and channel it to the channels during rainfall, and increasing community participation in maintaining and reducing the volume of garbage in the channels. Finally, this study is expected to serve as a reference for stakeholders and practitioners in addressing flooding problems in the Benua Melayu Darat area.

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