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PROBLEMS OF LOCAL FLOODS AND THEIR RELATION TO BOGOR CITY DRAINAGE INFRASTRUCTURE SYSTEM

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ABSTRACT

Highland areas are not necessarily without flood problems, especially local flooding. The problem of poor drainage can be the cause of a local flood, as happened in Bogor City, West Java. Development analysis related to local flooding in a city is an exciting topic to study further. The purpose of this analysis is to answer the need for public information about the philosophy of flooding in the highlands, existing policies, and factors causing local flooding in Bogor City. The benefits of this analysis can also provide policymakers with input on strategic steps in the planning of urban drainage infrastructure systems, both in terms of physical channels, social approaches, and aspects of land carrying capacity within the ecological framework. The method used in this paper is a literature review and direct field observations of Bogor City's drainage infrastructure at specific points. The recommendation for the Bogor City government is to carry out comprehensive data collection and re-topography, namely by collecting data on buildings and drainage, determining the slope and height of the channel, and implementing risk management at each stage of its implementation. In addition, strict supervision and community participation in overseeing the development process and reducing waste disposal in the river supports the improvement of drainage development.

1. INTRODUCTION

Floods are one of the environmental problems that often occur in Indonesia, especially during the rainy season. This problem happens almost every year and increases in frequency, area, depth, and duration. The root of the floods problem in urban areas begins with a very

high population increase above the national average growth due to urbanization. When a flood occurs, it not only destroys homes but can injure humans, which is very crucial to rescue (Afiah, 2018; Batu & Fibriani, 2017; Atmodjo et al., 2015). Floods can cause physical and material losses. Floods are natural disasters caused by high rainfall but are imbalanced with the ability of drainage channels to accommodate excess runoff (Rahman & Wardhani, 2020).

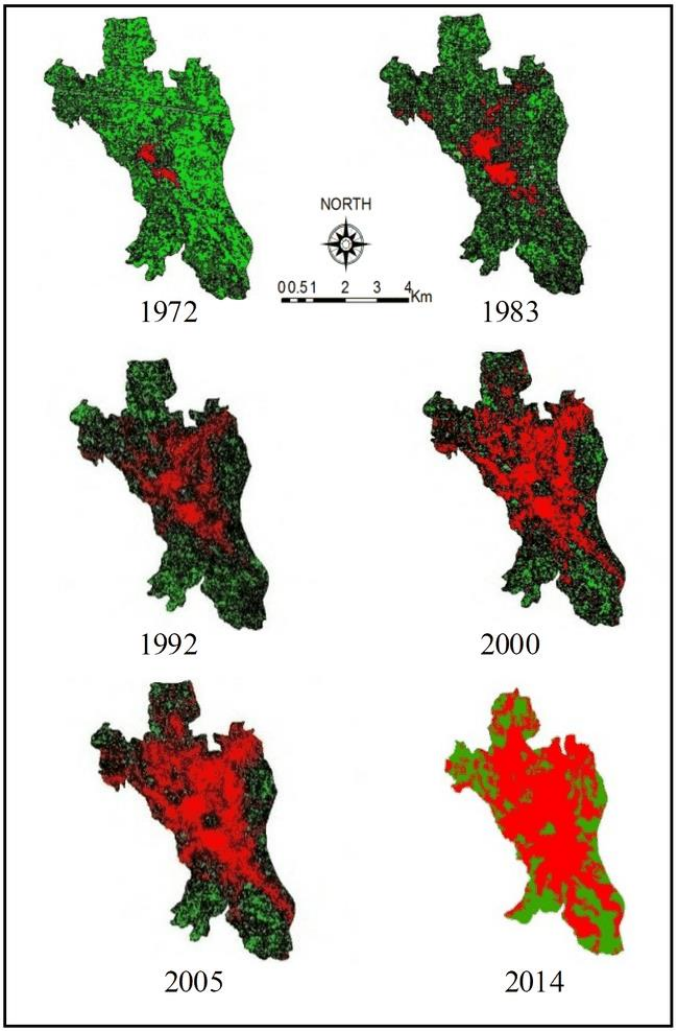


Figure 1 Built-up area (red) and open or vegetated area (green) in Bogor City
Source: Ramdhan et al., 2018

Bogor city is a rainy city. Bogor City has relatively high rainfall every year, ranging from 3,500-4,000 mm with an area of 4,992.30 ha, between 4,000-4,500 mm with an area of 6,424.65 ha, and between 4,500-5,000 mm with an area of 433.05 ha in a year. The administrative area of Bogor City has a large area of 11,850 hectares consisting of 6 sub-districts, namely North, East, South, Central, West, and Tanah Sereal Districts, and consists of 68 sub-districts. In general, the topography of this city is wavy, or the ground surface is uneven. Bogor is a city that is also prone to landslides. In the case of landslides, the prone areas are generally around river flows (Permadi et al., 2018). The rapid growth and land conversion led to land use with steep slopes on riverbanks for settlement and economic activities. Ironically, this city is imbalanced with good catchment areas, and the existing drainage system is not optimal. The city of Bogor has two large rivers, namely the Ciliwung River in the east and the Cisadane River in the west. The development of Bogor city converts the vegetated land cover area quite significantly to a built area (Ramdhan et al., 2018). The

coefficient of rainwater runoff on built-up land is greater than that of vegetated land so that the ability of the soil to absorb water is lower. It causes Bogor city to experience water flooding problems in the rainy season and the difficulty of clean water in the dry season.

Urban areas such as Bogor City have a high population growth that encourages many changes in the function of land use into facilities and infrastructure such as housing, infrastructure, buildings, and others (Pambudi, 2020). It does not rule out the possibility of adding new problems, especially environmental problems (Pambudi, 2021a; Pujiastuti, 2017). With the position of Bogor City, located in the upper reaches of the Ciliwung River, potentially this city should be safer from flooding than the middle or downstream part of the watershed such as Jakarta. In reality, there are still local (a specific region) flooding cases. It is closely related to the problem of water disposal/drainage infrastructure.

According to Hasmar (2002), drainage defines as the study of efforts to drain excess water in the context of specific uses. Urban drainage/applied drainage is a drainage science specializing in urban areas closely related to urban socio-cultural environmental conditions. Urban drainage/applied drainage is a system of draining and rinsing water in urban areas, including 1. Settlements, 2. Industrial and commercial areas, 3. Campuses and schools, 4. Hospitals and public facilities, 5. Sports fields, 6. Parking lots, 7. Installation of military, electricity, telecommunications, 8. Airport. Drainage is one of the elements of public infrastructure needed by urban communities to lead a safe, comfortable, clean, and healthy city life. The drainage infrastructure here serves to drain surface water into water bodies (surface and subsurface water sources) and or infiltration buildings. In addition, it also functions as a controller for surface water needs with actions to improve muddy areas, puddles, and floods. The use of these drainage channels is to dry up inundated areas so that there is no accumulation of groundwater, lower the groundwater level to an ideal level, control soil erosion and damage to existing roads and buildings, control excessive rainwater so that floods do not occur (Hasmar, 2002).

Based on the identification results, to solve the problem of local flooding, the existing drainage system tends to direct final disposal to the two rivers whose riverbeds are much lower than the city plain. In Bogor city, as other undergoing development cities, there have been many changes in the function of the waterway, from an irrigation waterway to a drainage waterway.

The drainage system of the Bogor City area consists of a macro drainage system and a micro drainage system. The macro drainage system includes the main river, tributaries, central waterways, and irrigation. And the micro drainage system is an artificial channel that generally follows the road network pattern (left and right). In addition, the widespread conversion of agricultural land into housing and commercial areas (housing, shops, toll roads, etc.) impacts agricultural land in Bogor City, which continues to shrink every year. One of the development points of Bogor City that has a significant impact on water absorption is in the northern area. Currently, in the North Bogor area, the Bogor Outer Ring Road (BORR) toll road is being built. The new toll road has cut down hundreds of trees along the associated road. If it rains, it will cause water runoff to increase. This water runoff flows into the drainage system, which causes flooding due to poor drainage infrastructure in North Bogor City.

The problem of local flooding does require serious attention from various parties because this can be anticipated with a scientific approach in terms of drainage science. The purpose of analysis of local flooding and its relationship to the drainage infrastructure system of Bogor City is to answer the need for public information about the philosophy of flooding in the highlands, existing policies and factors causing local flooding in Bogor City.

2. METHODS

This research draws from journals, report, and regulations related to drainage, floods and urban area planning in Bogor City. There are in the table below

Table 1 Source of literature review

Kind of Literature	Title
Journal	1. Afiah, L.M., Dewi, I.K., & Fadholie,N. (2018). Flood Disaster Risk on Space Utilization in Tanah Sareal District, Bogor City (Risiko Bencana Banjir Terhadap Pemanfaatan Ruang Di Kecamatan Tanah Sareal Kota Bogor). *Jurnal Online Mahasiswa (JOM) Bidang Perencanaan Wilayah & Kota. 1(1), 1-8*
	2. Pambudi, A.S. (2021a). Overview of Sustainable Urban Lakes/"Situ" Management In Bogor. *Indonesian Journal of Applied Research (IJAR), 2(2), 79-91*. DOI: https://doi.org/10.30997/ijar.v2i2.108
	3. Permadi, M.G., Tjahjono, B., & Baskoro, D.P.T. (2018). Identification of Landslide Risk in the City of Bogor (Identifikasi Daerah Risiko Bencana Longsor Di Kota Bogor). *J. Il. Tan. Lingk., 20 (2), 86-94.* http://dx.doi.org/10.29244/jitl.20.2.86-94
	4. Rahman, F.N. & Wardhani, E. (2020). *Selection of Priority for Flood Handling in Central Bogor District, Bogor City, Jawa Barat Province (*Pemilihan Prioritas Penanganan Banjir Di Kecamatan Bogor Tengah Kota Bogor Provinsi Jawa Barat). *Serambi Engineering, V (2), 1034 – 1042*. https://doi.org/10.32672/jse.v5i2.1931
	5. Ramdhan, M., Arifin, H.S., Suharnoto, Y., & Darma Tarigan, S. (2018). Towards Water Sensitive City: Lesson Learned From Bogor Flood Hazard in 2017. *E3S Web of Conferences, 31, 09012*. doi:10.1051/e3sconf/20183109012
	6. Rufina, A., Wardhani, E. & Sulistyowati, L.A. (2019). *Analysis of Priority Determination of Inundation or Flooding in South Bogor District (*Analisis Penentuan Skala Prioritas Genangan atau Banjir di Kecamatan Bogor Selatan). *Jurnal Teknologi Lingkungan Lahan Basah, 7 (2). pp. 81-91*.
Report	1. *Updating the City Sanitation Strategy for the City of Bogor*
Regulation	1. Bogor Mayor Regulation Number 139 of 2019 concerning the Bogor City Drainage Master Plan
	2. Indonesia Minister Regulation of Publik Works Number 12 Year 2014 concerning the Urban Drainage System Operation
	3. Indonesia Law Number 24 Year 2007 concerning Disaster Management

The method used in this paper is a literature review (qualitative). In addition, it also uses direct field observations of drainage infrastructure at specific points in Bogor City start from 1 January to 15 February 2022. Direct observations were also conducted by interviewing residents directly with a purposive random sampling of 10 people from each sub-district to get conclusions about the routine problems of flooding in 6 sub-districts in Bogor City.

The final result of this paper is a recommendation regarding the drainage development plan in Bogor City as input for policymakers and other development actors. The benefits of this analysis can also provide input for policymakers regarding strategic steps in planning

urban drainage infrastructure systems, both in terms of physical channels, social approaches, also aspects of land carrying capacity within an ecological framework.

3. RESULTS AND DISCUSSION

3.1. Results

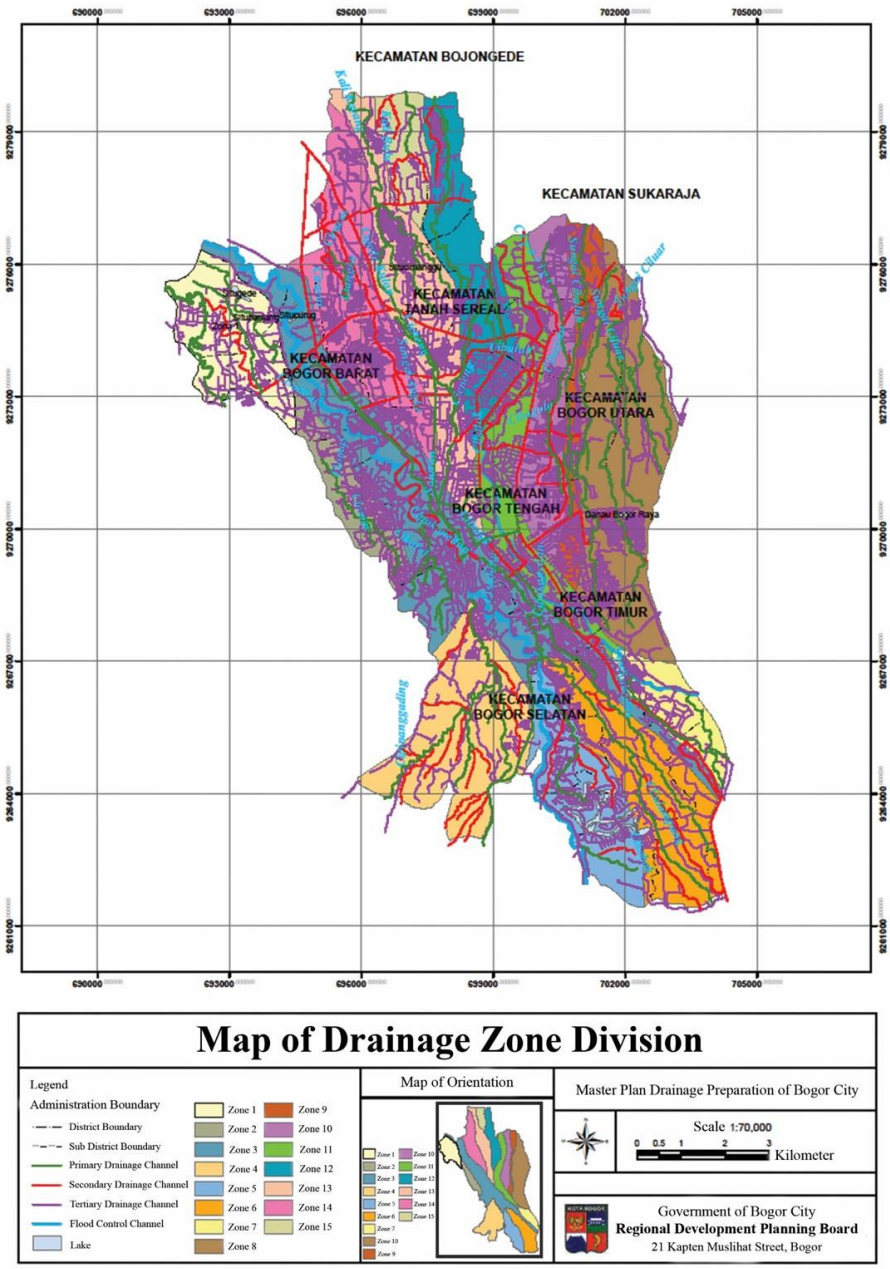
In general, the drainage system in Bogor City is divided into 2 (two) parts, namely macro drainage and micro drainage. Macro drainage are drainages that naturally already exist in the city of Bogor that consist of two large rivers, namely the Ciliwung and Cisadane rivers which flow from south to north, and several small rivers such as the Cipakancilan River, Cipinanggading River, Ciluar River, Cikalibaru River, Ciheuleut River, Ciapus River, Cisindangbarang River, Cigede Wetan River, Cigede Kulon River, Cileungsir River, Cipalayangan River, Cibeureum River, Cikaret River, Cigenteng River, Cinyangkokot River, Cileuwibangke River, Cipaku River, and Cijeruk River. Micro drainage is a waterway intentionally built to follow the road network pattern. Ultimately, these waterways lead to macro drainage close to microchannels. From the network density, the channels in Bogor City are pretty tight. The span of Bogor City from west to east is approximately 13 km, and there are 137 (one hundred and thirty-seven) waterways from south to north with a total length of ± 268 km. Of these, ± 80% are still in good physical condition. However, functionally only the channels in the South Bogor and East Bogor sub-districts can still accommodate waterways. The two sub-districts have the highest geographical position among other sub-districts. While the waterways in other sub-districts are shallow and narrow so that runoff floods often occur when it rains. The Bogor City area has a reasonably complex drainage network, which hydraulically stands alone. Still, there is an interconnected network of drainage channels. In addition to the complicated drainage network, there is still an irrigation network that functions as a drainage channel so that its capacity is not sufficient to withstand the rain load that occurs. In essence, every inundation area has local drainage waterways.

The increase in surface runoff and the reduced availability of water in big cities show how the upstream and downstream linkages in the water cycle have been neglected slightly by policymakers (Pambudi, 2021b). Several areas in Bogor City are included in flood-prone areas. The leading cause of problems related to this is the current condition of the drainage system in Bogor city. The current situation in this city is that the drainage system of one area has not integrated with other surrounding areas. The topographic characteristics of Bogor City are very varied, where almost ± 90% is plain land with a relatively gentle slope to a rather steep slope with limited capacity and flow rate of the existing drainage system. The current drainage system's limited micro-drainage infrastructure and the non-functioning indicated by the emergence of areas prone to flooding and landslide-prone problems. The bottom elevation of the drainage channel in the south eastern region and the northern part of Bogor cities is lower than the natural riverbed surface.

Table 2 Scientific analysis of the causes of local flooding in Bogor City

Reason	Explanation
The dimensions of the existing drainage channel are not wide enough.	The existing canal water body can no longer accommodate the increasing flow rate due to the rapid development and reduced green open space for water absorption. The new development is constrained by limited land and budget for constructing drainage channels (Bappeda City of Bogor, 2015).
Increased rainfall intensity	Climatic characteristics in Bogor City are relatively large annual rainfall ranging from 3,500 – 5,000 mm during increased rainfall (that is, between December and January), there is often an increase in surface runoff. The accumulation of surface runoff due to increased rainfall intensity

	originating from the upstream and central parts, directly concentrated in basin areas or natural waste reservoirs, often causes overflow and flood inundation in the basin area and relatively low land elevation downstream.
Shallowing and narrowing of the drainage network	The decrease in the capacity of natural drainage channels generally occurs due to increased surface erosion and sedimentation in relatively sloping river channels, causing silting problems. The narrowing occurs relatively quickly, causing shrinkage of the channel flow section. The capacity of the existing drainage network infrastructure is generally still not functioning effectively to accommodate and drain excess water temporarily. This condition is also caused by the lack of practical anticipatory operation and maintenance activities (O&M) of irrigation and drainage networks.
Changing the function of irrigation water channels into drainage water channels	Changes in land use are very significant, from agricultural areas to urban areas and settlements/housing, and have become increasingly massive in recent years. In this regard, usually, the topic of catchment area protection related to land use to support environmental sustainability and carrying capacity is an exciting topic to discuss scientifically (Pambudi, 2021b). The irrigation canals used as a water supply in the rice fields often turn into residential drainage channels and road drainage. The irrigation network system and drainage channels are interconnected. This condition reduces the effectiveness of the function and capacity of irrigation services and irrigation canals in the City and District of Bogor.
Mix Drain	Occurs due to irregularities in waste management behavior and the use of land that is mistaken in the city / densely populated residential area and the center of traditional trade/market activities, thus burdening the normal capacity of drainage channels so that it must serve as a waste container of rainwater runoff as well as domestic waste and solid waste. This condition encourages the transfer of the function of water supply buildings (such as water doors and irrigation canals) into drainage channels so that it tends to have an impact on the occurrence of problems decreasing the potential availability of mainstay discharges in surface water sources and groundwater, especially during the period of reduced rainfall (dry season).
Workers of drainage construction services do not pay enough attention to the technical aspects of making good drainage	The drainage technique does not adapt to the soil construction and topography area. The current drainage system uses the U-ditch system, which is ready-made concrete. With the U-ditch system, construction service workers only need to attach a concrete wall that has already been printed. This system is ineffective because of the same mold size, while the size of the existing drainage is not the same due to uneven topography.
Unbalanced grey infrastructure and green infrastructure policies	In urban water management, it is necessary to pay attention to the performance of each grey infrastructure and green infrastructure in a proportional portion (Nguyen et al., 2019). Drainage construction and maintenance in practice are related to physical infrastructure and need to pay attention to vegetative aspects to maintain the carrying capacity of the existing environment. The policy of clearing land covered with vegetation to develop drainage infrastructure that is carried out without caution will impact a significant increase in surface runoff (Yang & Zhang, 2021).
Land-use changes	One of the causes of flood problems in Bogor is uncontrolled land-use change. Changes in land use from land that can absorb water to the ground that cannot absorb water will affect the amount of flood discharge generated.



Gambar 2 Map of drainage zone of Bogor City
Source: Bappeda of Bogor City, 2015

Most of the drainage in Bogor City is not functioning correctly. The areas with the worst drainage quality are in the Central Bogor area, such as Pajajaran, Bogor Station, Pasar Anyar. Some are located in the West Bogor area, such as Jalan Sumeru, East Bogor, and Jalan Sholeh Iskandar. Based on this condition, the government must issue a policy to improve the drainage system. Otherwise, road damage and flooding in Bogor City will continue to occur. In some areas, the drainage system in Bogor City is not optimal to accommodate runoff water in the area due to intensive development. The Bogor City area consists of complex drainage networks. Some of them are drainage canal networks that are hydraulically stand-alone, but

there are interconnected drainage canal networks. Based on the problems above, the impact is local flooding (inundation) in 6 sub-districts in Bogor City.

Table 3 Local flood conditions (Puddles) related to drainage infrastructure in Bogor City

No.	Location of Puddles	Puddle Area					Infrastructure *	
		Broad	Elevation	Length	Frequency	Cause ***	Type	Information **
		Ha	meters	Hours/days	Times/years			
1	North Bogor Sub-district	19	0,3 – 0,4	1-2	>2	The overflow of the Ciparigi River, the Ciluar River, and the Cibuluh River	Primary waterways	Massive land conversion, reduced water infiltration, smaller water channel dimensions.
2	East Bogor Sub-district	2	0,3 – 0,4	1-2	>2	Ciliwung River Overflow	Primary waterways	Less large dimensions
3	South Bogor Sub-district	2	0,3 – 0,4	1-2	>2	Overflow of the Cisadane River. It is caused by excessive storage capacity and discharges in the waste channel	Primary waterways	Less large dimensions. South Bogor sub District has five inundation points that potentially cause flooding in drainage waterways that has a problem.
4	West Bogor Sub-district	6	0,3 – 0,4	1-2	>2	Overflow of the Cisadane River, surface water runoff of primary and secondary waterways	Primary and secondary waterways	Less large dimensions, the water catchment area is not adequate
5	Central Bogor Sub-district	4	0,3 – 0,4	1-2	>2	Overflow of the Cisadane River and the Ciranjang River	Primary waterways	Less large dimensions
6	Tanah Sereal Sub-district	19	0,3 – 0,4	1-2	>2	Primary, secondary, and tertiary waterways	Primary, secondary, and tertiary waterways	Less large dimensions

Source: Processed from the 2015-2020 Bogor City Sanitation Strategy (SSK) and field observations

Note:

*) Infrastructure can consist of drainage channels (primary and secondary) or complementary buildings. Infrastructure in the inundation area.

**) Can be in the form of information related to the length of the channel, pump capacity, the size of the retention pond, etc., contained in the inundation area.

***) It is an indication of the cause of the inundation. Indications can come from within or outside the area but still in the same drainage system.

Based on observations, the drainage network system, in general, is quite good because there are waterways on each road segment. Still, some channels require maintenance and repairs, such as sedimentation and damage to drainage buildings. Improvements need by analyzing the priority flood points on the waterways that require repair. The priority scale is determined based on the priority scale method by comparing the condition of the drainage system, namely the inundation or flood parameters, including inundation depth, inundation area, inundation duration, and inundation frequency regarding the Regulation of the Minister of Public Works and Public Housing Number 12 of 2014 concerning the Implementation of Urban Drainage Systems (Rufina et al., 2019; GoI, 2014).

3.2. Discussion

Disasters can be reduced or even prevented their impact on society, but it all depends on the community itself to act or not. Therefore, humans are responsible for identifying risks and factors that cause disasters then deciding on preventive or management activities to control their impacts. It is a fundamental principle in the theory of watershed management in Indonesia, namely that watershed management is a human effort to regulate the reciprocal relationship between natural resources and humans in watersheds and all their activities (Pambudi, 2019). Flood disaster is a common disaster in several places in Bogor City. The rainfall in Bogor City is high. Floods are an event where land that is usually dry becomes inundated by water, caused by high rain and the topographical conditions of lowland to sunken areas (Sebastian, 2008). Meanwhile, disaster risk is the potential loss caused by a disaster in a particular area and period (GoI, 2007).

Areas prone to flooding have high rainfall, flat slopes, thin soil, and low vegetation cover. A watershed with a forest cover area of less than 30% warns that conservation efforts must be carried out immediately based on the causal factors (Pambudi et al., 2021). In particular, the condition of drainage channels in Bogor City has dimensions that are not large enough so that it is no longer optimal to accommodate runoff when it rains, as shown in Table 2. Overcoming the vulnerability of the flood environment can be done by increasing water absorption, especially in the highlands, by planting trees and reducing building development, giving directions to the community not to build on river borders and shallow plains. Physical development can overcome flooding by increasing drainage density to drain water, clearing land for water catchment areas, reducing non-permanent buildings by reconstructing houses with more robust materials and increasing soil retaining dams to hold water in rivers.

Based on the existing drainage master plan, the Bogor City Government follows its authority through the relevant Regional Apparatus and its responsibilities to carry out efforts to secure urban drainage and its surroundings, which include: a. management of Urban Drainage area; b. water damage control; and c. control of urban drainage flows (GoI, 2019). The plan for the construction of the Bogor City drainage network must be able to overcome runoff/rainwater flows on the surface so as not to cause inundation, overflow, or flooding by considering the physical growth of the city, the balance of development between and within the city, as well as public awareness of environmental sanitation.

Table 4 Bogor City drainage infrastructure development plan

District	Drainage Infrastructure Issues	Development Recommendations	Necessary Support
North Bogor Sub-district	Diversion of land functions, reduced water absorption, smaller dimensions.	Increase the depth (dimensions) of the existing drainage waterways, make infiltration wells	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management. c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.
East Bogor Sub-district	Less large dimensions	Increase the depth (dimensions) of existing drainage waterways	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management. c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.
South Bogor Sub-district	The dimensions are less considerable. South Bogor Subdistrict has five inundation points that can cause flooding in problematic drainage waterways	Increase the depth (dimensions) of existing drainage waterways, conserving water resources through Biopore. This recommendation must also be equipped with environmental education to all parties so that the problem does not reoccur.	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management. c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.

District	Drainage Infrastructure Issues	Development Recommendations	Necessary Support
West Bogor Sub-district	Dimensions are less extensive, and the water catchment area is inadequate	Increase the depth (dimensions) of existing drainage waterways, make infiltration wells	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.
Central Bogor Sub-district	Less large dimensions	Increase the depth (dimensions) of existing drainage waterways	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management. c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.
Tanah Sereal Sub-district	Less large dimensions	Increasing the depth (dimensions) of existing drainage waterways and the delay of new permits for housing development can reduce natural water catchment areas.	a) Latest flood discharge calculation data (hydrological analysis) and spatial. b) Risk management. c) Budget support and Political/Policy support for the Mayor, Sub-district head, and village head around the location. d) Strict law enforcement. e) Active community participation in maintenance.

Source: Analysis Results

Notes:

They are not suggested/recommended in the form of channel widening, considering that most drainage canals are located very close to public facilities such as roads and housing. Channel deepening activities do not require land acquisition but effectively accommodate runoff water that enters the canal infrastructure.

4. CONCLUSION

Floods are one of the environmental problems that often occur in Indonesia, especially during the rainy season. Floods can cause physical and material losses. The problem of local flooding does require serious attention from various parties because this can be anticipated with a scientific approach in terms of drainage science. The recommendation for the Bogor City government is to re-topography, namely by collecting data on buildings and drainage to determine the slope and height of the channel. Furthermore, the government must have standard data as a reference for developers, and people who want to build must adapt to the existing data. In addition, strict supervision and community participation in overseeing the development process and reducing waste disposal in the river supports the improvement of drainage development in Bogor City. If the government has the standard data, then there will be a good development arrangement to resolve the problems of flooding and road damage. The drainage infrastructure development is needed considering the rapid development of Bogor City development so that the dimensions of the existing drainage channels are no longer relevant to the city's development.

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