INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2023, Vol. 4, No. 11, 4031 – 4044
http://dx.doi.org/10.11594/ijmaber.04.11.23

Research Article

Spatial Modeling of Flood Affected Areas of Krukut River in Pela-Mampang Segment, South Jakarta, Indonesia

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Article history:
Submission August 2023
Revised November 2023
Accepted November 2023

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ABSTRACT

Flooding is one of the most common natural disasters in Indonesia, and the capital city of DKI Jakarta is no exception. Every year, there are always areas that experience flooding, mainly triggered by the overflow of flowing rivers. Jakarta itself is located in a downstream area consisting of swampy areas that are floodplains. One of the river basins that most often experiences flooding is the Krukut River. This is mainly triggered by the high value of rainfall which can reach more than 200 mm in a day. Massive development along the riverbanks has exacerbated the flooding, especially in the Pela Mampang segment which includes Pela Mampang Village, Mampang Prapatan Subdistrict and Petogogan Village, Kebayoran Baru Subdistrict. This research models two-dimensional flood inundation using the HEC-RAS program to describe the distribution of potential floods for return periods of 2, 5, 10, 25, 50 and 100 years. In addition, a spatial analysis of the affected infrastructure up to the RT level was also conducted to provide an overview of the extent of inundation using 4 types of classifications (low, medium, high and extreme). The results showed that 19 out of 150 RTs in Pela Mampang urban village and 33 out of 79 RTs in Petogogan urban village were flooded with a total inundation area of 100-year flood reaching 39.58 ha. The affected infrastructure reached 1,903 units with the area of inundated roads reaching 3.27 ha. It is hoped that this research can provide input for future infrastructure planning and river management in order to anticipate and mitigate disasters better.

Keywords: *Flooding, Krukut Watershed, Pela-Mampang Segment, Spatial Modeling*

How to cite:
Sugandhi, N., Supriatna, Kusratmoko, E., & Rakuasa, H. (2023). Spatial Modeling of Flood Affected Areas of Krukut River in Pela-Mampang Segment, South Jakarta, Indonesia. *International Journal of Multidisciplinary: Applied Business and Education Research. 4*(11), 4031 – 4044. doi: 10.11594/ijmaber.04.11.23

Introduction

Flooding events are not a new occurrence in an urban area (BNPB, 2021). Flooding occurs almost every year in Jakarta during the rainy season and is considered alarming because the scale of flood impacts has increased rapidly in recent decades (Amira et al., 2020). DKI Jakarta is an urban area that has an annual flood cycle caused by high rainfall and poor river conditions (Priambodo et al., 2018; Riyanto et al., 2019), and not balanced with good water absorption so that water overflows causing flood disasters (Tambunan, 2018)

Floods that occur in densely populated settlements and are then associated with social impacts and risks that occur as a result of flooding are one of the interesting subjects to study (Rahman et al., 2019). The National Disaster Management Agency (BNPB) formulated a social vulnerability calculation that is generally applicable and can be used for all types of natural disasters in Indonesia so that it can be implemented into flood analysis of the social vulnerability of residents in affected areas. Several rivers in Jakarta are known to be affected by extreme events (Klipper et al., 2021). one of them is the Krukut River, which is an example of a river in DKI Jakarta that always overflows and causes flooding within the scope of its watershed.

The Krukut watershed is a river flowing in the northwest region of Java Island that has a tropical rainforest climate with an average temperature of about 27°C. The average annual rainfall is 3674 mm. The month with the highest rainfall is December with an average of 456 mm. and the lowest is September with an average of 87 mm. The Krukut watershed has an area of 88.98 km2 and a main river length of 31.3 km with an average daily rainfall of 129 mm. and a peak discharge of 135 m^3/second (Hambali, 2018)

Based on historical data of flood events since 1890 until now DKI Jakarta and Depok City often experience flood disasters, one of which is due to the overflow of the Krukut watershed (Kadri et al., 2021). This is a problem in this research so that with the advancement of geospatial technology, it is hoped that it will be able to help model flood inundation in the Krukut River Pela Mampang Segment of DKI Jakarta to be able to provide information about mapping vulnerable areas and the impact on flooding using a spatial-based geographic information system as a flood mitigation effort.

Spatial modeling used to predict fluvial flooding is hydrological modeling and hydraulic modeling that aims to predict flooding (Riza Inanda Siregar, 2016). Spatial modeling of flood inundation is one of the important aspects in disaster risk reduction for current and future events (Rakuasa et al., 2022). This research uses Hydraulic modeling is one of the ways used to evaluate important elements of free surface fluid flow such as for flood forecasting and inundation map generation.

Spatial modeling in this study will use hydrological analysis and river hydraulics analyzed using HEC-RAS software. using DEM (Digital Elevation Model) obtained from LiDAR (Light Detection and Ranging) drones whose results are better than previous studies that only use Digital Elevation Models (DEM). so that the output of this inundation spatial model will produce a map of inundation depth variations along the affected area with more detailed accuracy with units of analysis up to the RT level.

Based on historical data of flood events in Jakarta. Krukut River is one of the causes of flooding in DKI Jakarta this is due to a very significant land use change in the watershed (Kurniyaningrum et al., 2019). Hambali, (2018), also added that the increase in population and the development of residential land on the banks of the Krukut river caused rainwater that fell could not absorb into the ground anymore and immediately became surface flow (runoof) and entered the river body. As a result, every rainy season. The city of Jakarta and its surroundings are inundated by rainwater and overflow from the Krukut River.

Hydraulic modeling to spatially analyze flood inundation areas has been carried out by many previous researchers in Indonesia such as Riyanto et al., 2019), who mapped flood potential in the Pesanggrahan watershed in South and West Jakarta with LiDAR data segmentation. Putriasri et al., (2020), who conducted hydraulic model ing by utilizing LiDAR data in flood risk management in the Wai Ruhu Ambon watershed, and Kurniyaningrum et al., (2019), who also conducted research on Sensitivity of Flow Depth Inundation Based on the Micro-Scale Topography in Krukut River. Jakarta. Indonesia and many other studies use hydraulic modeling and utilize LiDAR data and in general these studies only analyze and predict the extent of flood inundation without analyzing the impact or exposure caused by the flood. This research not only analyzes the spatial distribution of flood inundation areas for 2, 5, 10, 25, 50 and 100-year return periods but also maps the affected areas consisting of exposed road infrastructure and exposed building types up to the RT (Rukun Tetangga) level.

This modeling is expected to help the DKI Jakarta Provincial government in an effort to minimize the risks and impacts caused by flooding. especially the Krukut Watershed Pela Mampang Segment. This study aims to determine the spatial distribution of flood inundation areas for return periods of 2, 5, 10, 25, 50 and 100 years in the Pela Mampang Segment of the Krukut River and the spatial distribution of flood affected/exposed for periods of 2, 5, 10, 25, 50 and 100 years.

Methods

Research Location

This research was geographically conducted in the Pela Mampang Segment of the Krukut River. The research area is a catchment area of 40.79 km2. The length of the main river in the Krukut Sub-watershed is estimated to be 32.5 km. while with the river outlet in the Pela Mampang segment, the main river length is 30.60 km2. Administratively, the research location (Pela Mampang Segment) covers Kebayoran Baru Sub-district and Mampang Prapatan Sub-district. Kebayoran Baru sub-district consists of Petogogan urban village and Mampang Prapatan sub-district consists of Petogogan urban village. This research was conducted in RTs in both Petogogan and Mampang Prapatan urban villages that often experience flooding due to Krukut River overflow. The spatial location of the research can be seen in Figure 1.

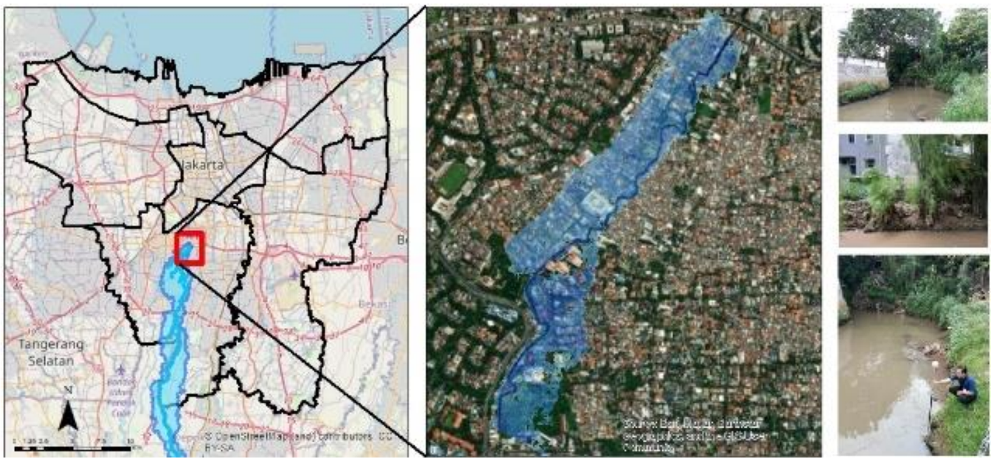

Figure 1. Research Locations

Data Source

This research uses digital elevation model (DEM) data obtained from LIDAR data processing, daily maximum rainfall data from 2012-2021 obtained from BMKG, land use data, administrative boundaries, road networks and building types obtained from the DKI Jakarta Provincial Cipta Karya Spatial Planning and Land Office, soil type data obtained from the Food and Agriculture Organization (FAO).

Data processing

This research was conducted in four stages. namely the preparation stage. data collection, data processing and data analysis. The preparation stage contains literature studies from books, journals, or the internet. The literature study was conducted to understand the basic theories related to flood inundation modeling and the impact of flooding. After the preparation stage, the next stage is data collection. The data collected consists of primary data and secondary data, where this research uses a lot of secondary data. Primary data used include Digital Elevation Model (DEM) data sourced from LiDAR, monthly maximum rainfall data from 2012-2021. river morphology data and observation of flood inundation areas while secondary data used include administrative boundary data, land use data, soil type data, topographic data, building data and road networks.

Data processing and data analysis began with the management of annual maximum daily rainfall data (2012-2021). land cover data of the Krukut Sub-watershed Pela Mampang Segment to obtain the planned flood discharge after that the DEM data obtained from LiDAR was recorded using an Unmanned Aerial Vehicle (UAV). The results of the LiDAR data recording are in point cloud format (*las). Point cloud data that has been recorded is then classified into two types, non-ground and ground point. The non-ground and ground point data then became input for the extraction of a digital terrain model (DTM) at a resolution of 0.2 meters analyzed with the results of the calculation of the planned flood discharge in the HEC-RAS software to produce a planned flood model at return periods of 5, 10, 25, 50 and 100 years in the Pela Mampang Segment, Krukut River South Jakarta. The existing planned flood model is then validated with the inundation map for 2021/2022 obtained from the DKI Jakarta Water Resources Agency at the neighborhood level and the results of observations and interviews to find out how much inundation depth has been experienced by residents in the area. The validated planned flood model is then overlaid with road and building network data to find out which road and building networks are affected by flooding, the complete research workflow can be seen in Figure 2.

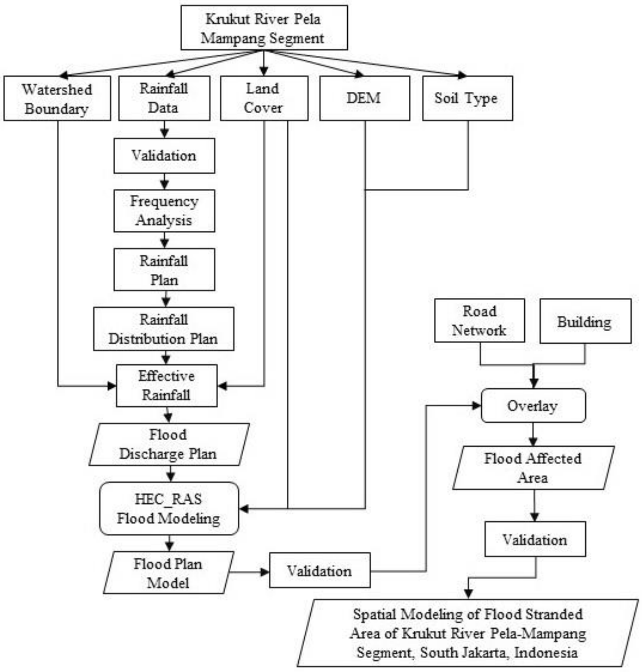

Figure 2. Workflow

Result and Discussion

Plan Flood Model for Various Return Periods

The plan flood modeling (flood hydraulic modeling) of return period Q2, Q5, Q10, Q25, Q50, Q100 was carried out in the Krukut River Pela Mampang Segment which is administratively located in Kebayoran Baru Sub-district, Petogogan Urban Village, RW 001 (RT 002, 003, 004, 005, 006, 013), RW 002 (RT 001, 002, 003, 004, 005, 006, 007, 010, 013, 014, 015), RW (RT 001, 002, 003, 004, 005, 006, 007, 008, 009, 010, 011, 013, 014, 015), RW 004 (RT 007) and Mampang Prapatan sub-district, Pela Mampang Urban Village RW 005 (RT 002, 003, 005, 007, 008, 015) RW 007 (RT 005, 006, 007, 008, 009), RW 008 (RT 001), RW 011 (RT 003, 004, 006, 009, 014, 015), RW 014 (RT 004). This research location was chosen based on data on the incidence of flood inundation due to the overflow of the Krukut River obtained from the Water Resources Office of the DKI Jakarta Provincial Government, where these RTs often experience flooding every rainy season.

Floodplain modeling or hydraulic modeling and prediction of affected areas (Buildings and Roads) in the Pela Mampang Segment are very useful in future flood disaster risk management. Furthermore, inundation mapping will also accelerate policy makers and planners in developing flood mitigation measures (structural and nonstructural). The plan flood modeling was conducted after the plan flood discharge was calculated and inputted in hydraulic modeling using HEC-RAS software, flood inundation maps were generated according to different return periods from 2 years (Q2), 5 years return period (Q5), 10 years return period (Q10), 25 years return period (Q25), 50 years return period (Q50) and 100 years return period (Q100). Vector data (shp) of buildings and roads obtained from the Office of Cipta Karya. Spatial Planning and Land of DKI Jakarta Province are used to determine the affected areas. The return period flood inundation height values obtained based on the results of the Log-Pearson III calculation are 3.18, 3.42, 3.57, 3.76, 3.9, 4.04 for 2 years, 5 years, 10 years, 25 years, 50 years, and 100 years, and the flood inundation area is different for each return period. Details can be seen in Table 1 below.

Table 1. Height and Area of Flood Inundation for Return Periods

No	Return Period	Inundation Height			Runoff Area (ha)
		Average	Min	Max	
1	Q2	1.45	0	3.18	21.1
2	Q5	1.48	0	3.42	26.83
3	Q10	1.51	0	3.57	31.14
4	Q25	1.54	0	3.76	36.01
5	Q50	1.57	0	3.90	38.42
6	Q100	1.6	0	4.04	39.58

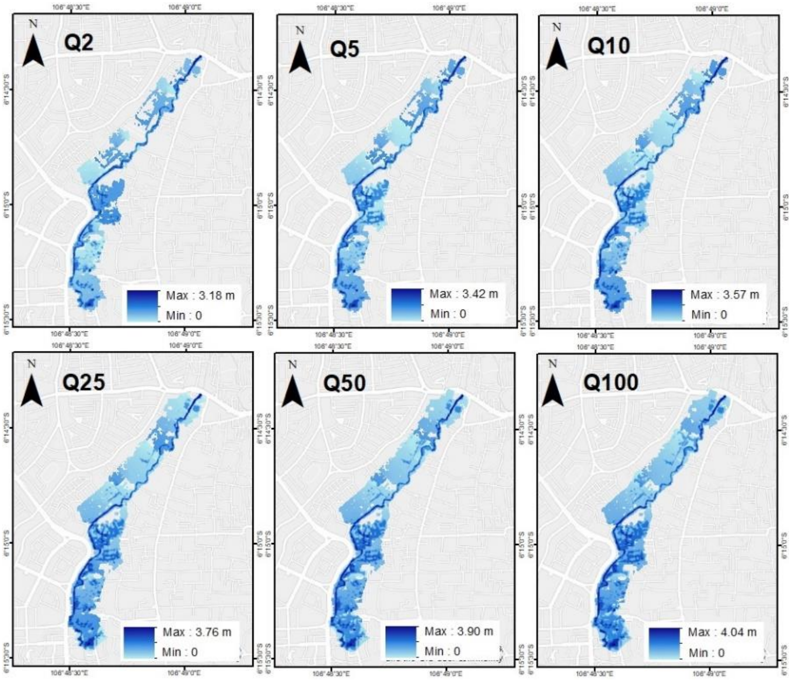

Figure 3: Return period flood inundation model

Based on the calculation of the height and area of flood inundation in Table 5.1, it is known that there is a very significant difference in each return period, this is influenced by rainfall discharge data, LIDAR data accuracy and land cover, which are used. According to Islam et al. (2016), in general, floods that occur in Indonesia are caused by high rainfall above normal, then causing water drainage systems including rivers, natural tributaries and artificial channel systems to be unable to accommodate the accumulation of rainwater that comes so that it overflows and causes flooding, Kusumo & Nursari, (2016), added that the slope affects the direction, rate, and also the concentration of rainwater, areas with relatively flat slopes will make the area always inundated and flooded during the rainy season. Land cover variable is one of the important variables for flood vulnerability analysis (Teng et al., 2017). The volume of standing water and the time it takes to recede are problems that often occur during floods (Kodoatie, 2021). This happens because the quantity of infiltration becomes small due to the fact that the land that used to be able to absorb water is now turned into permanent buildings that are impermeable to water. The 2-year return period (Q2) has a smaller maximum flood height and runoff area than the other periods. The spatial model of the 2-year return period (Q2), 5-year return period (Q5), 10-year return period (Q10), 25-year return period (Q25), 50-year return period (Q50) and 100-year return period (Q100) can be seen in Figure 3.

Figure 4. Residents' settlements on the banks of the Krukut River

Based on the results of modeling the 2-year return period (Q2), 5-year return period (Q5), 10-year return period (Q10), 25-year return period (Q25), 50-year return period (Q50) and 100-year return period (Q100) in Figure 5.1 - Figure 5.6, it is known that areas that are often flooded and have high flood inundation heights are areas that are >100 meters from the river. According to Aziza et al., (2021) areas close to the river are the areas with the most potential for flooding Figure 4. One of the factors that cause flooding in the South Jakarta area is high rainfall that overflows the Krukut River and based on data on flood disasters as of December 2021, there were 21 RTs in Petogogan Village and Pela Mampang Village.

Based on the calculation of the inundation area of the return period plan flood in Krukut River, Pela Mampang Segment, it is known that RT 015, 002 Pela Mampang Village, Mampang Prapatan Sub-district has the largest inundation area in each return period (Q2): 3.98 ha, (Q5): 4.63 ha, (Q10): 4.07 ha, 25 years (Q25): 4.63 ha, 50 years (Q50): 4.91 ha and 100-year return period (Q100): 4.93. RT 012 RW.007 is the RT that has the largest flood inundation area in each return period Q2 of 4.25 ha, Q10 of 4.81 ha, Q25 of 4.64, Q50 of 4.84 and Q100 of 4.92. Details of the return period flood inundation areas can be seen in Figure 5.

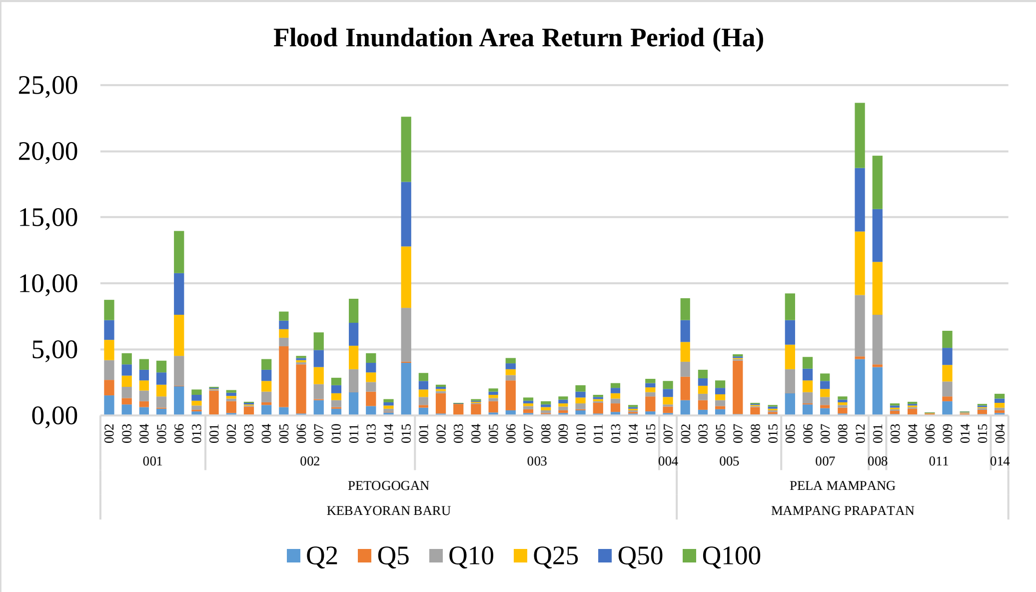

Figure 5. Flood Inundation Area of Return Period

Flood Affected Areas for Various Return Periods

Based on data obtained from the Regional Disaster Management Agency (BPBD) as of July 13, 2022 dozens of houses in Pondok Karya Complex, Mampang Prapatan, South Jakarta, were flooded again with varying heights, from 20 cm to 50 cm. Based on the flood disaster risk assessment matrix per regency/city prepared by BNPB in 2022, the city of South Jakarta is at a very high flood hazard intensity so that flood natural disasters become a top priority threat to be anticipated so that the adverse effects of both casualties and building damage can be minimized (BNPB, 2021).

Flood risk reduction is part of river basin (WS)-based water resources management that must be planned and implemented in an integrated manner within a WS. Therefore, flood risk reduction must be part of each river basin's natural resources management, which needs to be regulated in a river basin management plan (Tingsanchali, 2012; Taufik et al., 2022). Strategies and policies must be in line with the existing regulations in Law. No. 7, Year 2004 in the form of physical and non-physical disaster prevention, disaster management, and post-disaster recovery. Various strategies in the form of physical and non-physical efforts are applied to overcome flood and drought problems in the form of land conservation, construction of water reservoirs (reservoirs and reservoirs), river rehabilitation and polder construction. Flood disaster risk reduction is not only done by building and regulating facilities and infrastructure. In accordance with Law No. 26 of 2007 concerning Spatial Planning, the Unitary State of the Republic of Indonesia (NKRI) which is located in a disaster-prone area requires spatial planning based on disaster mitigation as an effort to improve the safety and comfort of life and preserve the environment.

According to Sarmah et al., (2020), an important part of flood disaster risk reduction is to predict how much built-up land/settlements are located in flood-prone areas. The utilization of GIS in mapping settlements and roads affected by flooding in this study is needed to provide information as an initial step in future flood disaster mitigation efforts. Identification of the level of flood vulnerability is carried out using Geographic Information Systems (GIS) to map and predict vulnerable areas and residential areas exposed to flooding in the Krukut River Pela Mampang Segment. According to Kadri et al., (2021), hydraulic modeling and utilization of Geographic Information Systems (GIS) to analyze flood-prone areas and flood-affected settlements in the Krukut River Pela Mampang Segment is very important, effective and efficient because this modeling uses DEM (Digital Elevation Model) obtained from LiDAR (Light Detection and Ranging) drones whose results are better when compared to previous studies that only used Digital Elevation Models (DEM) processed from SRTM and DEMNAS data, so that the output of this inundation spatial model will produce a map of inundation depth variations along the affected area with more detailed accuracy with the unit of analysis of affected settlements and roads up to the RT level.

Table 2. Flood Hazard Level by Return Period

No	Flood Hazard Level	Affected Area per Return Period (ha)					
		Q2	Q5	Q10	Q25	Q50	Q100
1	< 0,50 cm (Low)	3.28	4.37	5.35	5.75	5.11	9.26
2	0,50 m – 1,00 m (Medium)	15.67	11.18	7.39	5.04	4.66	21.14
3	1,00 m – 2,00 m (High)	12.41	14.76	17.97	21.20	21.87	8.73
4	>2,00 m (Extreme)	3.17	6.36	7.41	8.30	9.41	2.49

The flood inundation map of the flood inundation period is then classified into four classes. The Hazard Class of the affected area is classified based on Kusratmoko et al., (2016), which divides the height class of the flood depth into four heights, namely the height of <0.50 cm is classified as low, 0.50 m - 1.00 m is classified as Medium, the height of 1.00 m - 2.00 m is classified as High and the height of >2.00 m is classified as an Extreme situation.

Based on Table 2 and Figure 6, it is concluded that in the 2-year return period (Q2) the RT in Pela Mampang which is affected by flooding in the extreme class (>2 m) is RT 001 RW 008 as many as 17 building units and in Petagogan, RT 002 RW 001 as many as 6 building units. In the high class as many as 46 housing units in RT 001 RW 008 Pela Mampang are predicted to be affected by flooding as well as in Petagogan RT 013 RW 002 as many as 38 houses are predicted to be affected, this is because geographically these settlements are close to the Krukut river coupled with sloping topography making this area often flooded.

In the 5-year return period (Q5), the RT in Petagogan urban village that has the highest number of building units affected by flooding with an inundation height of >2 meters is RT 015 RW 002, namely 11 housing units and 43 housing units are predicted to be affected by flooding with the same height in RT 001 RW 008 Pela Mampang. At an elevation of 1-2 meters, 50 housing units are predicted to be affected by flooding in RT 001 RW 008 Kel. Pela Mampang and 34 units are inundated in RT 005 RW 005. At a height of 0.50-1 meter, 46 housing units in RT 015 RW 002 Kel. Petagogan are predicted to be affected.

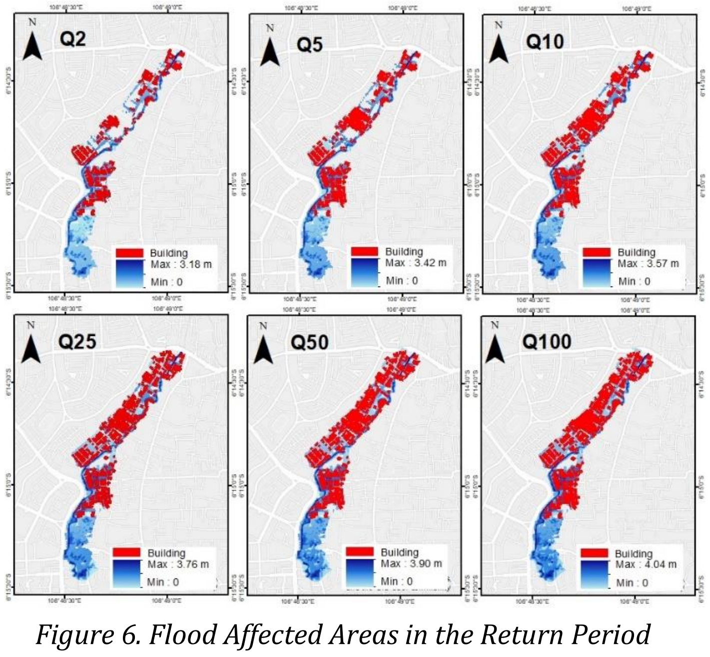

Figure 6. Flood Affected Areas in the Return Period

In the 10-year return period (Q10), the RT in Petagogan Urban Village that has the highest number of building units affected by flooding with an inundation height of >2 meters is RT 015 RW 002, with 11 housing units and 22 housing units predicted to be affected by flooding with the same height in RT 001 RW 006. RT 001 RW 008 Pela Mampang Kel. 46 housing units are predicted to be flooded with a height of >2 meters. At the same height in RT 005 and RT 007, 14 housing units are predicted to be affected by flooding. A total of 50 housing units in RT 001 RW 008 Pela Mampang are predicted to be affected by flooding at an inundation height of 1-2 meters, this RT is the RT with the highest number of building units affected by flooding. A total of 34 housing units in RT 005 RW 005 Pela Mampang are predicted to be affected by flooding at an inundation height of 1-2 meters. A total of 43 building units in RT 006 RW 001 Kel Petagogan are predicted to be affected by flooding at an inundation height of.

In the 25-year return period (Q25), the RT in Petagogan Urban Village that has the highest number of building units affected by flooding with an inundation height of >2 meters is RT 006 RW 001 with 27 housing units, and 13 housing units are predicted to be affected by flooding with the same height in RT 015 RW 002. RT 001 RW 008 is the RT with the most flooded buildings, namely 46 building units, and as many as 14 housing units are predicted to be affected by flooding with the same height in RT 007 RW 007 and RT 005 RW 007. A total of 50 building units are predicted to be flooded at a height of 1-2 meters in RT 001 TRW 008 and 35 units are also flooded at the same height in RT 005 RW 005. RT 01 RW 002 is the RT with the most flooded building units with 53 units and RT 006 RW 001 is predicted to have 45 flooded building units. RT 005 RW 005 is predicted to have 35 building units affected by flooding and RT 006 RW 003 is predicted to have 31 building units inundated. For the inundation height of 0.50 m - 1 m in Pela Mampang Urban Village, it is predicted that 32 building units will be flooded in RT 005 RW 005 and 44 building units are predicted to be flooded in RT 014 RW 002.

In the 50-year return period (Q50), 46 housing units are predicted to be flooded in RT 001 RW 008 at a height of >2 meters and 34 building units in RT 005 RW 005 are also affected by flooding. A total of 54 building units are predicted to be flooded at a height of 1-2 meters in RT 015 RW 002 and as many as 45 building units are flooded in RT 006 RW 001. A total of 50 buildings are predicted to be affected at a height of 1-2 meters in RT 001 RW 008 and 31 buildings are predicted in RT 005 RW 005 to be affected by flooding. A total of 54 buildings are predicted to be affected by flooding in RT 015 RW 002, 45 buildings are predicted to be affected in RT 006 RW 001, and 39 buildings are predicted to be affected by flooding in RT 010 RW 002. A total of 31 buildings are predicted to be affected by flooding at a height of 0.50-1 meter in RT 001 RW 008 and 30 buildings are affected by flooding in RT 005 RW 003. At this height (0.50-1 meter), 44 buildings are predicted to be affected in RT 013 RW and 25 buildings are predicted to be affected in RT 015 RW 012.

In the 100-year return period (Q100), it is predicted that 17 housing units will be flooded in RT 001 RW 008 Ke. Pela Mampang at an inundation height of >2 meters and as many as 12 building units in RT 005 RW 005 are also affected by flooding. A total of 10 buildings were affected by flooding in this return period in RT 015 RW 002. A total of 17 buildings in RT 001 RW 008 are predicted to be affected by flooding at this height and as many as 12 buildings in RT 005 RW 005 Pela Mampang Village are affected. At an inundation height of 1-2 meters, 50 buildings are predicted to be flooded in RT 001 RW 008 and 31 buildings in RT 005 RW 005 in Pela Mampang urban village. In Petagogan Urban Village, 58 buildings are predicted to be affected in RT 015 RW 002, 40 buildings in RT 013 RW 02, 43 buildings in RT 006 RW 001, 39 buildings in RT 010 RW 002 and 35 buildings in RT 011 RW 002.

Based on the results of the calculation of buildings and roads affected by flooding, the RTs affected by flooding in Pela Mampang urban village and Petagogan urban village per return period are classified. In Figure 5.21 it can be seen that the RTs affected by flooding in the 2-year return period in the high class are RT

002, 005, 001, 012 in Pela Mampang Kel. and RT 015, 007, 004, 002, 010, 015, 016, 007, 006, 001, 003 in Petagogan Kel. In Figure 5.22 it can be seen that the RTs affected by flooding in the 5-year return period in the high class are RT 005, 001, 012 in Pela Mampang Kel. and RT 005, 013, 006. 013, 007, 006, 008, 009, 002, 004, 001 in Petagogan Kel. In Figure 5.23, it can be seen that RTs affected by flooding in the 10-year return period in the high class are RT 005, 001, 012 in Pela Mampang Kel. and RT 013, 006, 015, 011, 004, 002, 008, 009, 001 in Petagogan Kel. RTs affected by flooding in the 25-year return period in the high class are RT 005, 001, 002, 012 in Pela Mampang Kel. and RT 003. 013, 006, 015, 011, 004, 002, 008, 009, 001 in Petagogan Kel.

In Figure 5.25 it can be seen that the RTs affected by flooding in the 50-year return period in the high class are RT 001, 012 in Pela Mampang Kel. and RT 002, 013, 006. 013, 007, 006, 008, 009, 002, 004, 001 in Petagogan Kel. In the 100-year return period (Figure 5.26), RTs 002, 005, 001, 012 in Pela Mampang are high risk and RTs 002, 013, 006. 013, 007, 006, 008, 009, 002, 004, 001 in Petagogan Kel. are also in the high risk class. Based on the results of the analysis and field survey, it is known that RTs in Pela Mampang and Petogogan Villages are most vulnerable to flooding due to high rainfall, where if there is rain that exceeds normal limits it can cause several RTs in Pela Mampang Village to be inundated, especially in basin areas that have lower elevations when compared to the surrounding area. Details of areas that are often flooded can be seen in Figure 7 and Figure 8.

Figure 7. Former Flood Inundation Area, Pela Mampang Village

Figure 8. Former Flooded Areas of Petogogan Village

Based on Figure 7 and Figure 8, it shows that the mapping of return period flood prone areas is very good and accurate. Mapping flood hazard areas using GIS is important for efforts to prevent and anticipate early flooding in the Krukut River area of the Pela Mampang segment and its surroundings. Its integration with the results of monitoring and analysis of rainfall conditions will greatly assist the community in providing early warning of the threat of flooding so as to reduce the resulting losses.

Based on the results of the return period flood modeling, it is known that building infrastructure and roads that are closer to the Krukut river, coupled with high rainfall, make the area have a high risk of being flooded. According to Tanwattana & Toyoda, (2018), residential areas that are close to the river, the greater the chance of an area for flooding, this is supported by the statement from Latue et al., (2023), where the area is > 100 m from the river This is an area with the most potential for flooding.

Based on Figure 9, it is known that the survey results for flood occurrence areas in 2020-2021 at 160 location points in the Jakarta, Bekasi and Tangerang areas which are plotted on the distribution map of flood hazard areas show that the locations of flood events are in 4 mapped areas including namely in Kel. Petogogan, Jl. Bank Kec. Mampang Prapatan, Jl. Kemang Raya in front of Khemchiks, Jl. Bangka XI Kel. Pela Mampang. Flood incident data for 2020-2021 shows that Petogogan Sub-District and Pela Mampang Sub-District coincide with flooding when the Krukut river overflows.

Figure 9. Flood-prone areas due to the overflow of the Krukut River

The results of this research have a number of significant benefits for spatial planning, disaster risk management and community empowerment in the affected areas. The following are the four main benefits of the research:

1) More Resilient Spatial Planning: Through spatial modeling of flood-affected areas of the Krukut River, this research can provide in-depth insights into how floodwater flows could potentially affect different areas in the Pela-Mampang Segment. This information can be integrated in urban spatial planning, enabling the selection of safer locations for infrastructure and settlement development (Taufik et al., 2022). Sustainability and flood resilience can be integrated in spatial design, which in turn will help reduce the impact of disasters (Kusumastuti et al., 2015).
2) More Effective Disaster Risk Management: An in-depth understanding of flood-affected areas helps in the development of disaster risk mitigation strategies. This research enables the identification of areas most vulnerable to flooding, which can help the government and relevant agencies allocate resources more effectively (Margatama et al., 2018). With accurate information, they can design better early warning systems, improve flood control infrastructure and develop more efficient evacuation plans (Samela et al., 2018).
3) Community Empowerment and Flood Awareness: This research can help raise community awareness about potential flood risks and their impact on their area (Hazarika et al., 2018). By having access to clear information about vulnerable areas, communities can be better prepared for

floods (Yodsuban & Nuntaboot, 2021). Education and training on how to act during a flood and what to do afterwards can also empower communities to reduce risks and negative impacts (Doeffinger & Rubinyi, 2023).

4) Database for Sustainable Decision Making: This research will generate valuable spatial data and information on flood patterns and impacts in the Pela-Mampang Segment. This data can form the basis for sustainable decisions on infrastructure development, flood control, and improving the region's capacity to cope with floods (Geravand et al., 2020). With a strong database, these decisions can be more informed and targeted, prioritizing the safety and welfare of residents (Rahman et al., 2021).

Overall, this research will contribute to mitigating the adverse impacts of flooding in the Pela-Mampang Segment, South Jakarta, through smarter planning, better risk management, as well as community empowerment and fact-based decision-making.

Conclusion

The results of analysis and modeling of the maximum flood inundation height show that in the 2-year return period it reaches 3.18 meters with a runoff area of 34.52 ha, for the 5-year return period the height reaches 3.42 meters with a runoff area of 33.67 ha, in the 10-year return period the height reaches 3. 57 meters with a runoff area of 38.12 ha, at the 25-year return period the height reached 3.76 meters with a runoff area of 40.29 ha, at the 50-year return period the height reached 3.90 meters with a runoff area of 41.05 ha, and at the 100-year return period the height reached 4.04 meters with a runoff area of 41.62 ha. The total affected buildings for the 2-year return period are 382 units, for the 5-year return period 557 units, for the 10-year return period 689 units, for the 25-year return period 814 units, for the 50-year return period 896 units and for the 100-year return period 967 units. The analysis results show that the area of the road affected by flooding in the 2-year return period is 1.91 ha, the 5-year return period is 2.33, the 10-year return period is 2.73, the 25-year return period is 3.14 ha, the 50-year return period is 3.24 ha and the 100-year return period is predicted to be 3.27 ha.

The results of this study are the basis for reconstructing the initial paradigm of flood inundation modeling in the Krukut River Pela Mampang Segment of DKI Jakarta, so that preventive steps can be taken as a risk reduction effort, and the results of this study are expected to help the DKI Jakarta Provincial Government in an effort to minimize the risks and impacts caused by flood inundation, especially the Krukut River Pela Mampang Segment area both physically in the future. The most realistic short- and medium-term solution in flood management in DKI Jakarta is to increase water storage capacity through river dredging and drainage programs and river normalization Normalization of rivers accompanied by the construction of inspection roads will help unravel congestion. Adding water storage capacity can also be done by normalizing lakes and reservoirs, building new reservoirs and conducting water storage programs.

Acknowledgement

The researcher would like to thank the Department of Geography, Faculty of Mathematics and Natural Sciences, University of Indonesia for facilitating us in conducting this research.

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