Flood Control Analysis at the Confluence of Cikeas River and Cileungsi River in Bekasi City

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Abstract

Bekasi City often experiences flooding, especially at the confluence of Cikeas River and Cileungsi River, due to high rainfall intensity and poor drainage infrastructure. This study aims to analyze the total discharge at the confluence point of the river and propose appropriate flood control measures. This research uses a quantitative descriptive method, combining manual calculations and software-based hydrological modeling. Rainfall and river discharge data were collected and processed to determine the peak discharge for a given return period. The river confluence area was identified as a highly vulnerable area, especially during extreme weather events. The analysis showed that the combined flow significantly increases the flood risk in the surrounding area. The results of the analysis were compared with existing flood control strategies from various literature sources. Based on the findings, recommendations include river normalization, levee repair, and drainage system improvement. This study emphasizes the need for integrated flood management in rapidly urbanizing areas. The proposed approach contributes to disaster risk reduction and sustainable urban planning in Bekasi.

1. INTRODUCTION (TITLE 1)

Bekasi City is one of the areas experiencing rapid growth in terms of population and infrastructure development. As part of the Jabodetabek region, Bekasi faces various challenges, one of which is flooding. Flooding in Bekasi often occurs due to high rainfall, suboptimal drainage management, and unplanned land use change. One critical point that often causes flooding is the confluence of two rivers, whose combined flow can cause a significant increase in water discharge.

The Cileungsi River and Cikeas River are two important rivers that flow through Bekasi and its surroundings. These rivers play an important role in local ecosystems, water resource management and the daily lives of local residents. However, the confluence of these two rivers is also a flood-prone area, especially during the rainy season.

The confluence of the Cileungsi and Cikeas Rivers occurs in Bekasi City, where the two streams merge to form a larger flow towards the Citarum River. This confluence point is highly prone to flooding, especially during periods of heavy rainfall. Increased water discharge from both rivers can cause overflows and impact the surrounding areas.

Flooding not only disrupts people's daily activities, but also impacts infrastructure, public health, and the local economy. Losses caused by flooding often reach billions of rupiah and can have long-term impacts. Therefore, analyzing flood control at the confluence of these two rivers is very important.

Flood control requires a comprehensive approach that includes technical, social and environmental aspects. Various control methods, such as levee construction, river normalization, and efficient drainage systems, must be evaluated and implemented effectively.

To overcome flooding in the Bekasi area, a comprehensive flood control analysis is needed. Therefore, the author proposes the title: "ANALYSIS OF FLOOD CONTROL AT THE GATHERING OF CIKEAS RIVER AND CILEUNGSI RIVER IN BEKASI CITY".

2. METHODS

This research uses a quantitative descriptive method. This research focuses on flood control analysis. This method describes events in the form of numerical data and data interpretation, along with the resulting output. The collected data is then processed using manual analysis and software-based analysis. The results are then correlated with relevant theories found in various literature sources to obtain conclusions on appropriate flood control measures.

2.1. Research Time and Location

The location of the case study is the confluence of two rivers, the Cileungsi River and the Cikeas River. These two rivers meet at the southern border of Bekasi City and Gunung Putri, Bogor, precisely in Jatiasih area, Bekasi City, which then forms Bekasi River. Geographically, this location is located at 6°18'15.14 "S - 106°58'19.09 "E.

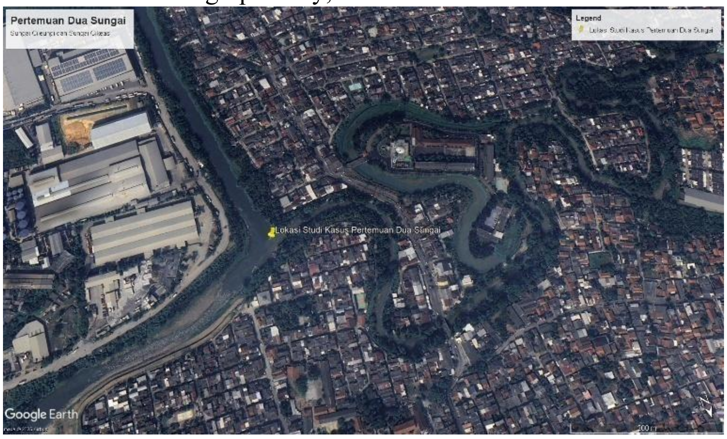

Figure 1. Research Location

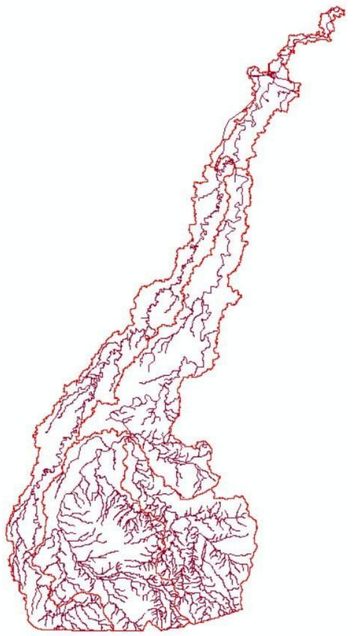

Figure 2. Watershed Map

2.2. Data Collection

To obtain relevant and accurate data for this research, several data collection techniques were carried out as follows:

2.2.1. Literature Study

The literature study used in this research includes research journals, theses, academic publications, and official documents from the Ministry of Public Works and Housing (PUPR). This study focuses on flood control efforts.

2.2.2. Hydrological Data

Data is a form of collected information obtained through observation, either orally or in writing. Data is useful in supporting this research. The data collection technique used in this study is secondary data. Secondary data refers to information that has been processed and is available from pre-existing sources. The following is the secondary data used in this study.

Table 1. Data Used in Research

No	Type of Data	Data Source
1	Rainfall Data	Meteorology, Climatology, and Geophysics Agency (BMKG) https://dataonline.bmkg.go.id/dataonline-home
2	Topography Data	Global Mapper
3	Topographic Map	*Digital Elevation Modeling* Map (DEM) https://tanahair.indonesia.go.id/portal-web/
4	Flood Inundation Map	https://gis.bnpb.go.id/

2.3. Data Analysis

2.3.1. Hydrological Analysis

Hydrological analysis is the study of the elements of the hydrological cycle, particularly with regard to the movement, distribution, and availability of water on the earth's surface, which aims to understand the behavior of water, especially in the form of rainfall, surface runoff, and river discharge. The following are the steps of the hydrological analysis conducted in this study:

a) Determining the area of the watershed (DAS)
b) Creating a rainfall distribution map using the Thiessen Polygon Method
c) Calculating the maximum rainfall at each station
d) Calculating rainfall distribution
e) Testing the consistency of rainfall data using the RAPS (Rescaled Adjusted Partial Sums) Method f) Calculating statistical parameters
g) Calculating design rainfall for various return periods
h) Conducting a frequency distribution fit test using the Chi-Quadrat, Smirnov-Kolmogorov, and Least Squares methods
i) Calculating the design rainfall distribution
j) Calculating Unit Hydrograph (UH) using HEC-HMS software
k) Modeling existing conditions using HEC-RAS software to simulate flood events
l) Obtain output from the simulation to determine appropriate flood control measures at the river confluence.
m) The rainfall data used includes three stations: Soekarno-Hatta Station (Tangerang), Halim Perdanakusuma Station (East Jakarta), and Pondok Betung Station.

2.3.2. Flood Control Analysis

The flood control analysis in this study is supported by the use of HEC-HMS and HEC-RAS software. HEC-HMS is used for hydrological modeling, particularly in simulating surface runoff, river discharge, and hydrological response to rainfall. Meanwhile, HEC-RAS is used to analyze how flow moves through river systems and its impact on flooding.

1. HEC-HMS Modeling

The following are the steps in using HEC-HMS software to obtain synthetic unit hydrograph data:

a. Create a new project by selecting the "File" menu, then "New", enter the project name, and set the default unit system to Metric.

b. Create a new watershed model by selecting "Components" → "Basin Model Manager" → "New" and entering the watershed name.

c. On the "Components" toolbar, select "Terrain Data Manager" → "New", then enter a name for the terrain, select a DEM (Digital Elevation Model) file, and click "Finish".

d. Define the coordinate system by selecting the "GIS" toolbar → "Coordinate System" → "Explore"
→ enter a projection file → "Set" → "Close."
e. On the watershed model, click the (+) icon, select the watershed name, and on the left panel, enter the terrain data name and save the project to display the DEM.
f. On the "GIS" toolbar, select "Preprocessing Sinks," then continue with "Preprocess Drainage."
g. Continue by selecting "Identify Stream" and enter the area to define the stream.
h. Use the "Break Point Manager" to define an intake point (for example, to a pond or retention pond).
i. Use the "Delineate Element" option to create a sub-watershed. In the Delineate Element option, enter a name for the Subwatershed, Reach, and enable "Insert Junction," then convert the breakpoint.
j. Enter the simulation time in the Control Specifications Manager.
k. Enter the design rainfall data at 1-hour intervals in the Time Series Data Manager.

Before running the simulation, the parameters in the sub-basin must be specified. The parameters entered into HEC-HMS include:

a) Loss (SCS Curve Number Method): Required data includes:
- Initial Abstraction (mm), using the formula:
  $Ia = 0.2\ x\ S$

Ia = Initial Abstraction
S = Basin Slope = (1000 / Total Basin Area) = 10

b) Transformation (SCS Unit Hydrograph Method):
Required data: Lag Time in minutes, calculated using:
- Initial Abstraction (mm), using the formula:
  $Ia = 0.2\ x\ S$

Ia = Initial Abstraction
S = Basin Slope = (1000 / Total Basin Area) = 10

3. Results and Discussion

After conducting hydrological analysis, the effective rainfall of each return period is obtained. The following are the results of the calculation of effective rain per return period.

Table 3. Results of Effective Rain Calculation

Hour	Effective Rain						
	Q2	Q5	Q10	Q20	Q25	Q50	Q100
1	5.03	8.73	11.18	13.53	10.15	16.57	18.85
2	9.88	15.55	19.30	22.90	23.03	27.57	31.06
3	5.09	9.49	12.40	15.19	15.82	18.80	21.51
4	1.82	5.29	7.58	9.78	10.42	12.63	14.77
5	0.00	0.00	0.00	0.73	1.09	2.27	3.43
6	0.00	0.00	0.00	0.00	0.00	0.00	0.60
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Calculation of the SCS hydrograph using HEC-HMS software. The results of running using HEC-HMS software are as follows:

Table 4. Base Flow SCS Hydrograph

Sub waters hed	Subwate rshe d Area (Km^2)	Leng th of Long est Flow Path (km)	Slop e of Lon ges t Flo w Path	Lengt h of Centr oida l Flowp ath (km)	Slope of CentroidalFl owpat h	10-85 Flow Path Leng th (km)	10-85 Flo w Pat h Slo pe	Basi n Slop e	Basin Relief (M)	Reli ef Rati o	Elong atio n Ratio	Drain age Densit y (km/k m2)	Base Flow (m3/s)
Sub-basin1	22.078	24.15 12 4	0.00 14 6	12.24 807	0.00085	18.11 34 3	0.00 07 3	0.09 08 9	43.61 849	0.00 18 1	0.219 53	1.030 7	3.59100 8359
Subba sin-2	87.922	59.65 98 3	0.00 81 2	27.29 342	0.00275	44.74 48 8	0.00 41 1	0.07 81	484.2 254	0.00 81 2	0.177 35	0.268 15	2.45765 9789
Subba sin-3	85.319	49.6 568	0.00 96 5	27.52 318	0.00162	37.2 426	0.00 26 2	0.11 07 1	495.8 023 9	0.00 99 8	0.209 89	0.473 94	4.12437 4076
Subba sin-4	91.897	25.68 90 7	0.02 96 5	14.77 861	0.00662	19.2 668	0.01 37 7	0.14 37 4	763.6 204 1	0.02 97 3	0.421 07	0.094 51	0.94582 7508
Subba sin-5	61.976	22.45 85 1	0.02 86 1	14.37 475	0.00856	16.84 38 8	0.01 80 3	0.19 11	783.0 760 5	0.03 48 7	0.395 53	0.138 42	1.05158 5023
Total	349.19												

Table 5. Routing- Muskingum Method

Reach	Length (m)	Slope (M/M)	Relief (M)	Sinusi ty	Tc (jam)	Tc (hour)	h (m)	c(m/s)	K (hour)	B (m)	Q (m3/s)	x
Range -1	22750.1	0.00059	13.4663	1.674 68	2627.92 31	17948.29 54	2.13	4.57 11	1.3825	36.2	3.5910	0.4991 92
Range -2	40440.2 8	0.00203	82.0006 4	1.953 54	2543.16 45	21767.90 55	8.64	9.20 64	1.2202	72.4	4.1244	0.4999 62

Table 6. Time lag

Sub-Basin	A (Km2)	L (Km)	Slop e	Bransby-Williams Method			Kirpich			Australian Rainfall-Runoff		
				tc (Hou r)	T (lag) (hours)	T (lag) (minutes)	tc (Hou r)	T(lag) (Hours)	T(lag) (minutes)	tc (Hou r)	T(lag) (hours)	T(lag) (minutes)
Subwaters hed-1	22.07 8	24.15 124	0.00 146	15.89 6	9.537	572.245	2.841	1.705	102.284	2.463	1.478	88.679
Sub watershed -2	87.92 2	59.65 983	0.00 812	24.26 4	14.559	873.514	4.045	2.427	145.606	4.165	2.499	149.925
Subbasin3	85.31 9	49.65 68	0.00 965	19.56 9	11.742	704.494	3.392	2.035	122.128	4.117	2.470	148.222
Sub watershed -4	91.89 7	25.68 907	0.02 965	8.028	4.817	289.016	1.632	0.979	58.738	4.235	2.541	152.465
Sub watershed -5	61.97 6	22.45 851	0.02 861	7.353	4.412	264.706	1.482	0.889	53.343	3.646	2.188	131.269
Total	349.1 9											

To calculate CN, Impervious Mean, and initial Abstraction (la). The land cover area (.shp) was obtained from the website https://tanahair.indonesia.go.id/portal-web. The following are the results of calculations per subwatershed.

Table 7. Calculation results per subwatershed Calculation Subwatershed 1

Sub watershed
1 22.078 km ^{2}

No	Land Cover Type	A (km^2)	CN	A x CN	% Impermeable	A x % Impermeable	CN Composite	% Average Impermeability	Max retention S (mm)	Initial Abstraction (Ia) mm
1	Plantation/Garden	0.642590059	43	27.63	5	3.212950294	56.83	28.84	192.983	38.597
2	Settlements and Places of Activity	20.11253195	57	1146.41	30	603.3759585				
3	Rice Field	0.036939529	63	2.33	5	0.184697644				
4	Shrubs	0.189039796	74	13.99	5	0.94519898				
5	Empty/Bare Land	0.110509217	74	8.18	5	0.552546087				
Total		21.09		1198.54		608.27				

Table 8. Subwatershed 1 Calculation Subwatershed 2 Calculation

Sub watershed
2 87.922 km ^{2}

No	Land Cover Type	A (km^2)	CN	A x CN	% Impermeable	A x % Impermeable	CN Composite	% Average Impermeability	Max retention S (mm)	Initial Abstraction (Ia) mm
1	Building	0.20586105	57	11.73	30	6.175831498	58.57	18.62	179.693	35.939
2	Plantation/Garden	5.25098764	43	225.79	5	26.2549382				
3	Settlements and Places of Activity	46.85725762	57	2670.86	30	1405.717729				
4	paddy field	11.66204309	63	734.71	5	58.31021543				
5	Shrubs	0.13918027	74	10.30	5	0.695901352				
6	Empty/Bare Land	3.253331664	74	240.7465432	5	16.26665832				
7	Mixed Crops	11.20388427	74	829.0874357	5	56.01942133				
8	Farm/Field	7.804459462	43	335.5917569	5	39.02229731				
Total		86.38		5058.82		1608.46				

Table 9. Calculation of Subwatershed 3 Calculation of Subwatershed 3

Sub watershed 3 85.319

No	Land Cover Type	A (km^2)	CN	A x CN	% Impermeable	A x % Impermeable	CN Composite	% Average Impermeability	Max retention S (mm)	Initial Abstraction (Ia) mm
1	Building	0.011956591	57	0.68	30	0.358697718	59.86	19.63	170.354	34.071
2	Jungle	1.642131883	30	49.26	5	8.210659417				
3	Plantation/Garden Settlements and Places	8.304968753	43	357.11	5	41.52484377				
4	of Activity paddy field	49.66313131	57	2830.80	30	1489.893939				
5	Scrub	2.367339685	63	149.14	5	11.83669843				
6	Empty/Bare Land	9.812961414	74	726.16	5	49.06480707				
7	Mixed Crops	10.66229189	74	789.01	5	53.31145946				
8	Farm/Field	2.396113497	74	177.31	5	11.98056748				
9		0.004145864	43	0.18	5	0.020729322				
Total		84.87		5079.66		1666.20				

Table 10. Calculation of Subwatershed 4 Calculation of Subwatershed 4

Sub watershed 4 91.897 km^2

No	Land Cover Type	A (km^2)	CN	A x CN	% Impermeable	A x % Impermeable	CN Composite	% Average Impermeability	Max retention S (mm)	Initial Abstraction (Ia) mm
1		0.817130131	57	46.58	30	24.51390392	53.29	11.28	222.636	44.527
2		0.022285324	30	0.67	5	0.111426622				
3		20.59625023	43	885.64	5	102.9812512				
4	Building	21.92738288	57	1249.86	30	657.8214864				
5	Jungle	5.056528881	63	318.56	5	25.2826444				
6	Plantation/Garden Settlements and Places	9.146708421	74	676.8564232	5	45.73354211				
7	of Activity paddy field	7.228285984	74	534.8931628	5	36.14142992				
8	Scrub	0.139641438	74	10.3334664	5	0.698207189				
9	Empty/Bare Land	25.56222299	43	1099.175589	5	127.8111149				
	Mixed Crops Farm/Field Total	90.50		4822.56		1021.10				

Table 11. Calculation of Subwatershed 5 Calculation of Subwatershed 5

Sub watershed
5 61.976 km ^{2}

No	Land Cover Type	A (km^2)	CN	A x CN	% Impermeable	A x % Impermeable	CN Composite	% Average Impermeability	Max retention S (mm)	Initial Abstraction (Ia) mm
1	Building	0.028538201	57	1.63	30	0.856146036	58.25	6.87	182.019	36.404
2	Jungle	4.408465713	30	132.25	5	22.04232856				
3	Plantation/Garden	11.09084847	43	476.91	5	55.45424233				
4	Settlements and Places of Activity	4.544039984	57	259.01	30	136.3211995				
5	paddy field	10.21579757	63	643.60	5	51.07898783				
6	Scrub	22.87956627	74	1693.087904	5	114.3978314				
7	Empty/Bare Land	0.423950655	74	31.37234845	5	2.119753274				
8	Mixed Crops	0.010514411	74	0.778066444	5	0.052572057				
9	Farm/Field	7.610589864	43	327.2553641	5	38.05294932				
Total		61.21		3565.89		420.38				

After doing the CN calculation, running the HEC-HMS software is carried out to get the results of the discharge per reset time. the following are the running results of the HEC-HMS software.

Table 12. Running Results of HEC-HMS Software Running Results of HEC-HMS Software

Time	**Total Incoming Discharge (m3/s)**						
	Q2	**Q5**	**Q10**	**Q20**	**Q25**	**Q50**	**Q100**
1	12.20	12.20	12.20	12.20	12.20	12.20	12.20
2	12.90	13.50	13.90	14.20	13.70	14.60	14.90
3	16.30	19.10	21.00	23.00	21.00	25.70	27.80
4	35.60	52.20	63.00	73.60	61.90	88.10	99.20
5	72.20	111.40	137.80	163.60	149.00	201.30	235.10
6	90.8	144.8	185	234.6	221.5	319.5	397.4
7	79.6	135.7	189.3	265.6	255.9	396.2	512.7
8	55.7	98.2	144.9	218.3	215.1	347	460.8
9	36	60.8	88.9	136.3	137	223.3	307.3
10	24.6	37.5	52.1	77.3	78.2	124.1	174.8
11	18.6	25.3	32.9	45.7	46.2	69.2	95.9
12	15.6	19.1	23.1	29.6	29.9	41.5	55
13	14	15.9	18	21.4	21.5	27.5	34.3

14	13.2	14.2	15.3	17.1	17.2	20.3	23.9
15	12.7	13.3	13.9	14.8	14.9	16.6	18.5
16	12.4	12.7	13.1	13.6	13.6	14.5	15.5
17	12.3	12.4	12.6	12.9	12.9	13.4	13.9
18	12.2	12.3	12.3	12.5	12.5	12.7	13
19	12.2	12.2	12.2	12.3	12.3	12.4	12.5
20	12.2	12.2	12.2	12.2	12.2	12.2	12.3
21	12.2	12.2	12.2	12.2	12.2	12.2	12.2
22	12.2	12.2	12.2	12.2	12.2	12.2	12.2
23	12.2	12.2	12.2	12.2	12.2	12.2	12.2
24	12.2	12.2	12.2	12.2	12.2	12.2	12.2

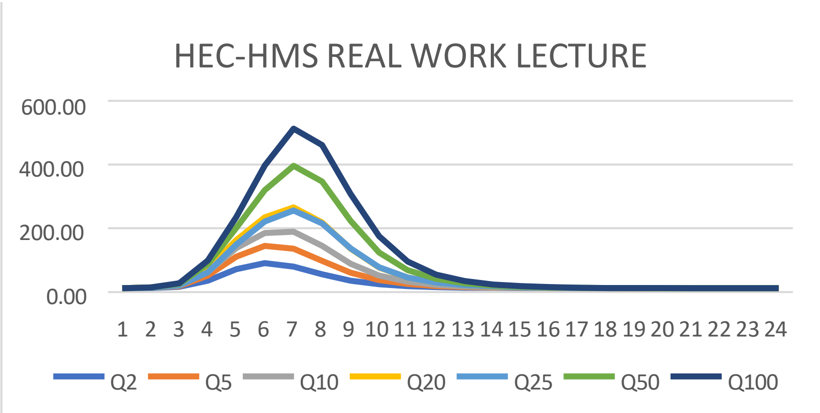

Figure 3. HEC-HMS SCS Hydrograph Discharge Chart

4. Conclusion

Prior to using the HEC-HMS software, a hydrological analysis was conducted to determine the effective rainfall for each return period. This analysis involves processing rainfall data using methods such as rainfall-runoff transformation and abstraction loss calculation. The effective rainfall obtained serves as the main input for the hydrograph simulation. Each return period (Q2, Q5, Q10, etc.) produces a different effective rainfall depth, which significantly affects the resulting peak discharge. These values are then used in HEC-HMS to model the surface runoff response. The resulting inflow hydrographs reflect the impact of different rainfall intensities at different return periods.

The hydrograph data generated using the SCS method in HEC-HMS showed a clear increase in peak discharge as the return period increased. The peak discharge for the Q100 event reached about 512.7 m^3/s at the 7th hour, much higher than the constant base discharge of 12.2 m^3/s observed at lower return periods such as Q2. The upper part of the hydrograph shows a rapid increase in flow from hour 3 to hour 7, followed by a sharp decrease. The hydrograph shows a distinctive asymmetric shape, consistent with the characteristics of the SCS unit hydrograph. This behavior highlights the sensitivity of the system to extreme rainfall events, where flood magnitudes increase exponentially. Overall, these data support the importance of considering higher return periods in flood risk assessment and mitigation planning.

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