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River flood risk quantification using reliability index method's safety factor (Level I) and first order second moment (Level II), a case study of Plumbon River, Semarang city, Central Java

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Abstract: This paper presents a case study on flood risk assessment using reliability as the analysis system's framework. The objectives of this study are to describe a flood event condition through quantitative analysis of how a river acts as the reliable hydraulic resistance and serves as an improvement from past studies' calculations to study flood resistances for rivers using sections' factual shapes. The study refers to the Performance Indices Ten, Safety Factor (SF) or Level I, which uses the exceedance probability as the performance index, and First Order Second Moment (FOSM) or Level II, which uses the probability for failure as the performance index that assumes all probability densities to be convertible to Gaussian distributions. Study in Plumbon River is analyzed with two methods: (a) Analyzing the river as a whole single unit to produce a single quantification; (b) Analyzing the river as separated units based on stream locations (upstream & downstream) classified by its slope level, and scored based on its rank compared to the other units. The results show that: (a) Level I and II results in similar trend and particular defined numbers for reliability; (b) River classification analyzes each section better, showing slope level is directly proportional to reliability; and (c) Trapezium-shaped assumption is not suitable for river with complex morphology.
Keywords: *First order second moment, Flood risk analysis, Risk quantification, Safety factor.*

1. Introduction

Flood is considered a failure phenomenon and has been a concern for a long time by hydraulic, hydrologic, and water resources engineers. The failure event, or E, is one of the major concerns that indicates the probability of the failure event's occurrence. Hydraulic design follows standard structural practice based on a design load concept that incorporates statistical aspects [1]. The quantifying of load-based design with "n-year design flood" such as shown in Figure 1 might imply a probability measure for the safety, but not directly related to the potential of its failure probability (Table 1).

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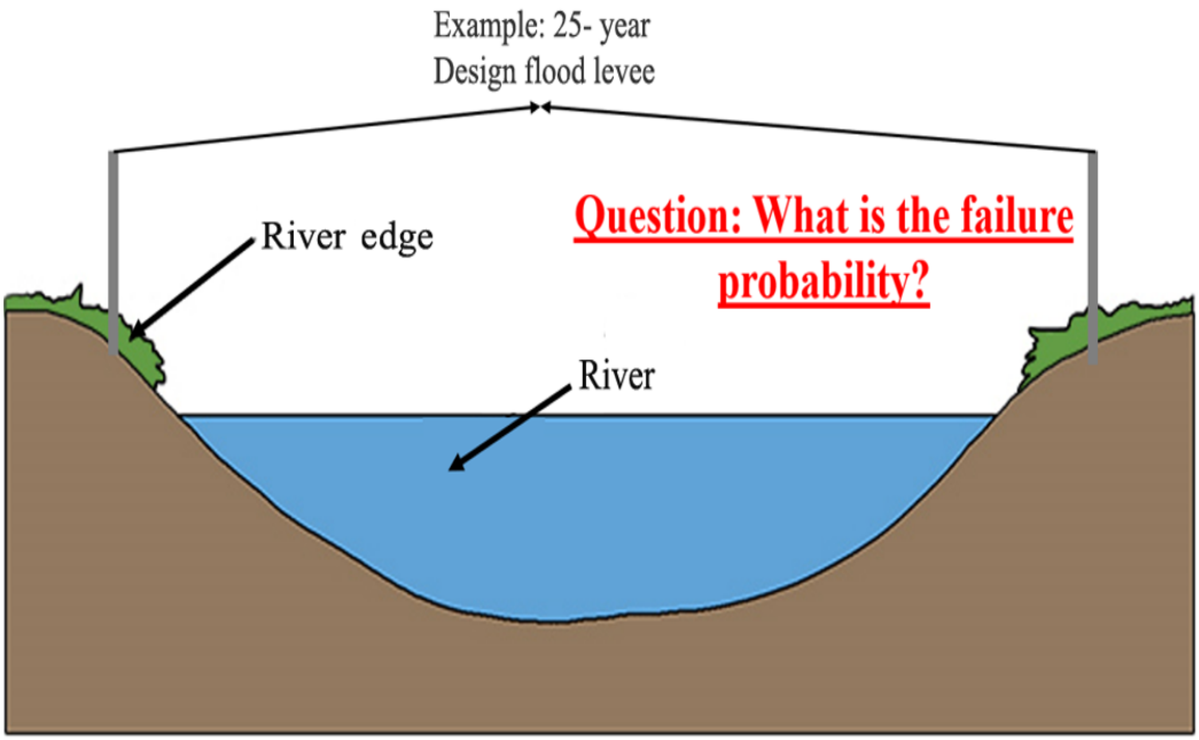

Figure 1.
Illustration of hydraulic design with n-year design flood.

The other reason to reconsider or add a new theoretical basis is the consideration of common flood hazard analysis. Flood hazard has always been analyzed by only the definition of overtopped cross sections, but never a quantified number that can summarize the whole situation [2]. By serving a new definition of a flood event, a generally known standard number is expected to create a more valid statement and quicker understanding for analysis as illustrated in Figure 2.

Duckstein and Plate [3] suggests a theorem that measures how well a system performs called performance indices (PI). Ten incident-related PI's are used to assess the desirability of an input/output trajectory pair defined, and this paper follows the PI4 named "reliability". The reliability performance indice is defined as an estimation of the relative frequency that the system is not in mode during the experiment. This definition will then represent either structural reliability or target-related reliability.

Plumbon River located in Semarang City, Central Java, Indonesia, is a river with a total length around 19.8 km and has been experiencing flood in almost every year recorded. This study is intended to compare the existing capacity resistance of Plumbon River against the loads given, then aims to analyze the river's reliability as a whole while producing a risk quantification index using the first two levels of the reliability analysis, which are Safety Factor (Level I) and First Order Second Moment (II). As flood risk quantification method had ever been analyzed earlier by Ferdiansyah, et al. [4], this study also intends to analyze a river's resistance with higher accuracy by not assuming rivers' cross sections as trapezium-shaped, but as its factual shape.

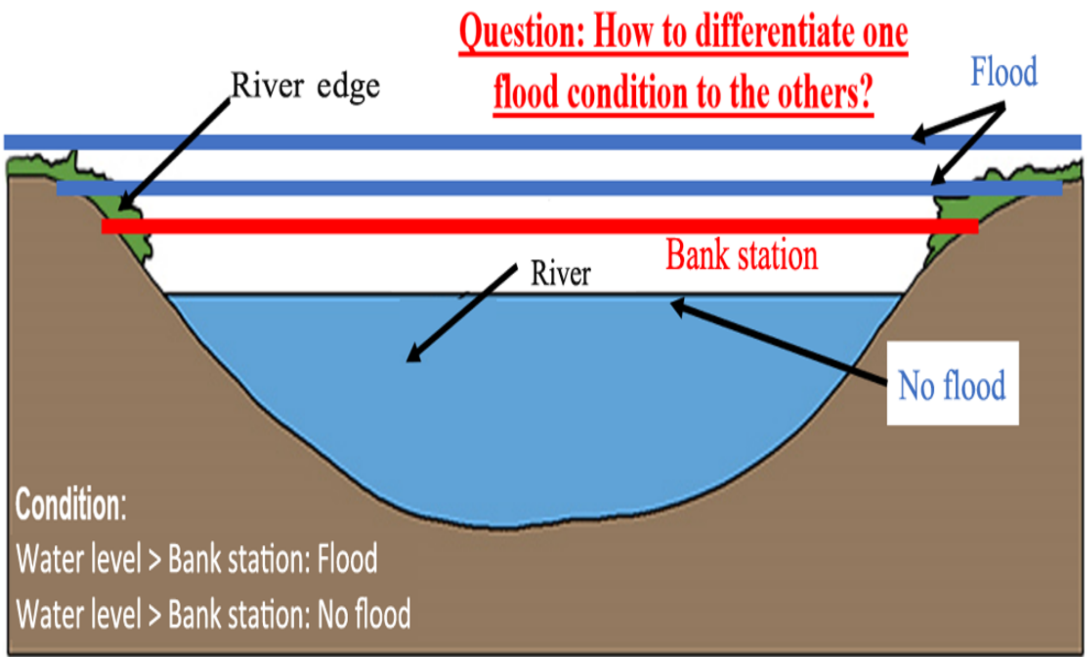

Figure 2.
Illustration of the problem in flood event qualitative description.

Table 1.
General comparison of risk calculation methods.

Method	Return period	Reliability index
Capability to account for different factors	Very limited	Yes
Information needed on probability distribution for factors	Indirectly	First two statistical moments
Complexity in application	Simple	Moderate
Amount of computation	Simple	Moderate to simple
Capability to estimate total risk	No	No
Result adaptable for risk cost analysis	Partial	No

Source: Duckstein and Plate [3].

2. Conceptual Method

2.1. Reliability Analysis

Reliability is considered to be the criterion that rated the performance of a system and the value to its performance, thus becomes the figure merit of the design.

Based on the definition of PI4, reliability is expressed through a conversed formula of frequencies of failures to the total events ratio. To simplify, reliability is the possibility of non-failure where the level of resistance of the system exceeds the load it receives and is related to the probability of succeeding to threats comparison [3].

There are two main parameters/variables in the reliability analysis: (a)Load, calculated through the extreme discharges based on return period from the hydrologic analysis and is averaged to be a nominal load; and (b)Resistance, calculated from the river's bankfull capacity and is influenced by its geometries' variables, such as cross depth (h), cross width (b), river slope

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(s), river longitudinal slope (i), and is calculated with Manning's Formula as it also needs Manning's roughness value (n) that is obtained by calibration.

The resistance will also be analyzed to produce a nominal resistance.

Figure 3 illustrates the definition of failure probabilities based on join probability density function of load and resistance.

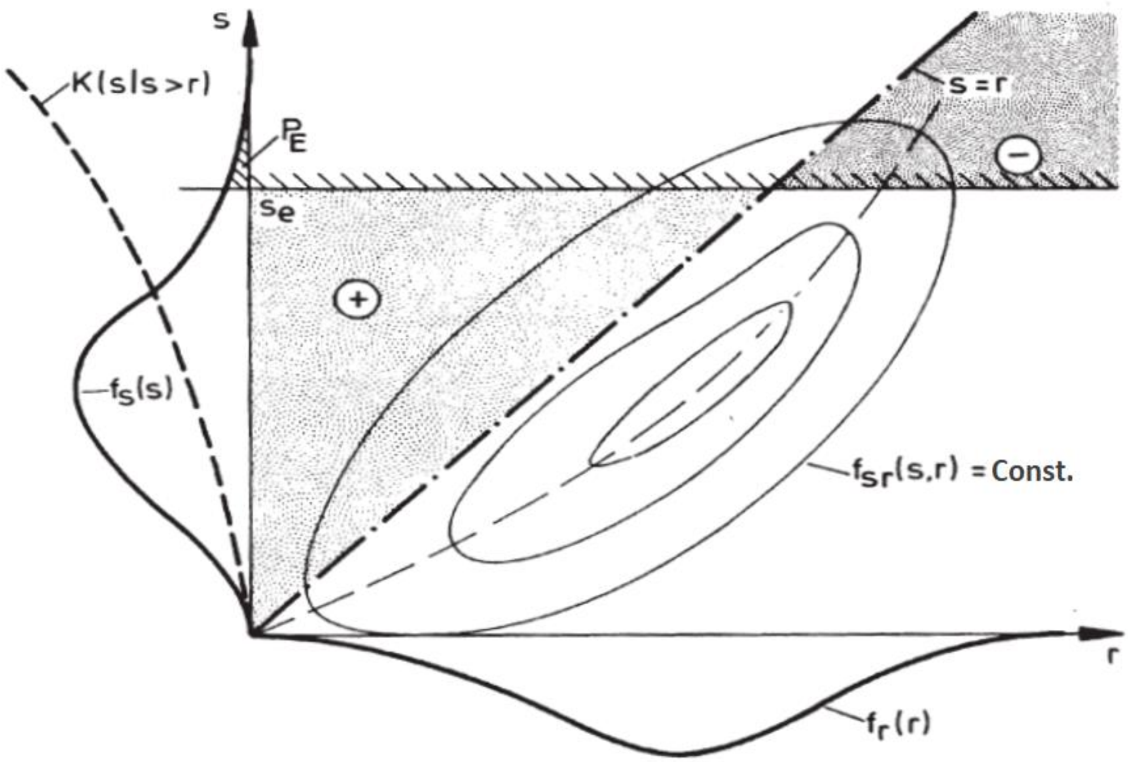

Figure 3.
Definition of failure probabilities based on join probability density function of load and resistance
Source: Duckstein and Plate [3].

2.2. Level I: Safety Factor

The first level of design in hydraulic using reliability method is based on the concept of Safety Factor. Level I use the probability of exceedance as the performance index. By referring to Equation 1, safety factor is defined as a comparison or ratio of the nominal resistance (Rn) to its nominal load (Ln) Duckstein and Plate [3].

$$SF = \frac{R_n}{L_n} \quad (1)$$

Where,

Rn = Nominal Resistance.
Ln = Nominal Load.
SF = Safety Factor.

$$L_n = \overline{L} + (WL \times L \times f^{-1}(1\text{-}aL)) \quad (2)$$
$$R_n = \overline{R} + (WR \times R \times f^{-1}(1\text{-}aR)) \quad (3)$$

Where,

L = Averaged Load.

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R = Averaged Resistance.
W = Coefficient of Variation = (St. deviation)/Average.
aL = Designed Load Failure = 2% - 50%.
aR = Designed Resistance Failure = 5% - 10%.

2.3. Level II: First Order Second Moment

The second level of design in hydraulic using reliability method is based on the concept of First Order Second Moment. Level II uses the probability of failure as the performance index while assuming that all probability densities to be Gaussian (or to be convertible to Gaussian distributions).

To simplify, the First Order Second Moment concept is to make or approximate & transform the determining loads and resistances into a normal distribution, thus makes the probability of the failure of the hydraulics be determined from the normal distribution. This method is fully specified by mean value and standard deviation.

By referring to Equation 4, the average load and resistance equation, standard deviation, and coefficient of variation will be obtained from the estimation of Taylor' series expansion of first order [3] as illustrated in Figure 4.

$$P_R = f\left(\frac{\bar{R}-\bar{L}}{\sqrt{(\bar{R}W_R)^2+(\bar{L}W_L)^2}}\right) \quad (4)$$

Where,
P_R = Reliability Probability.
F = Function returning normal distribution for stated mean and distribution.

2.4. Flood Risk Identification

As what has been mentioned in introduction, Kurniawan [2] study sets as one of many examples that identify and describe a flood risk event just as a qualitative description (overtopped or not).

Reliability index method is studied as a new way to describe flood risk event in updating the old conventional method. Figure 5 as follows shows broad outline of the differences in some inputs and outputs. As for what this paper studied, Level I and II out of four levels defined by Duckstein and Plate [3] as explained before (Sub-unit 2.2 and 2.3) are used to change the old qualitative description to new quantitative description (Figure 6).

Level I as in Safety Factor will directly serve a ratio of resistance to load that can be used to compare on flood event to the others. Level II will result in reliability and failure probability percentage as to fill n-year design's weakness in not only serving a rate of safety, but also its probability to fail.

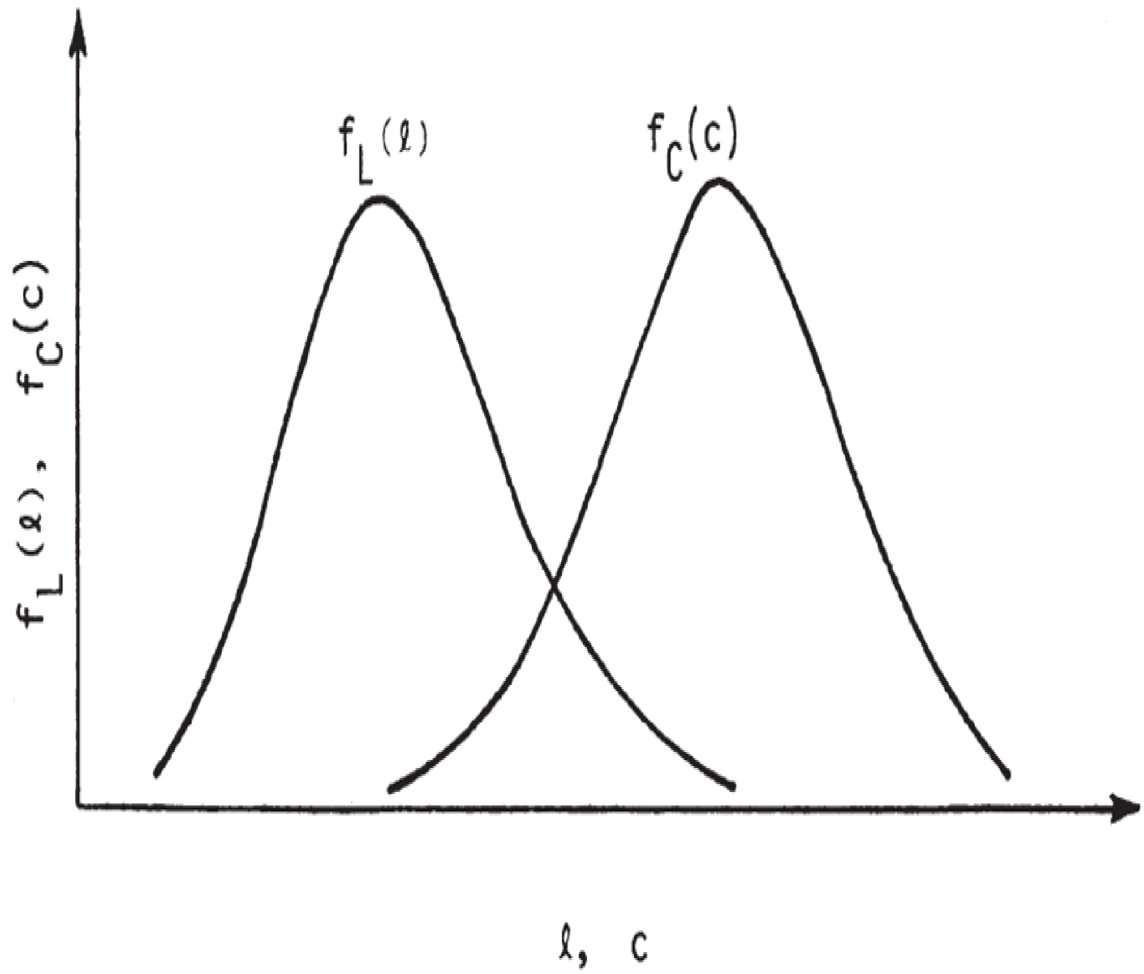

Figure 4.
Probability density functions for load and resistance.
Source: Duckstein and Plate [3].

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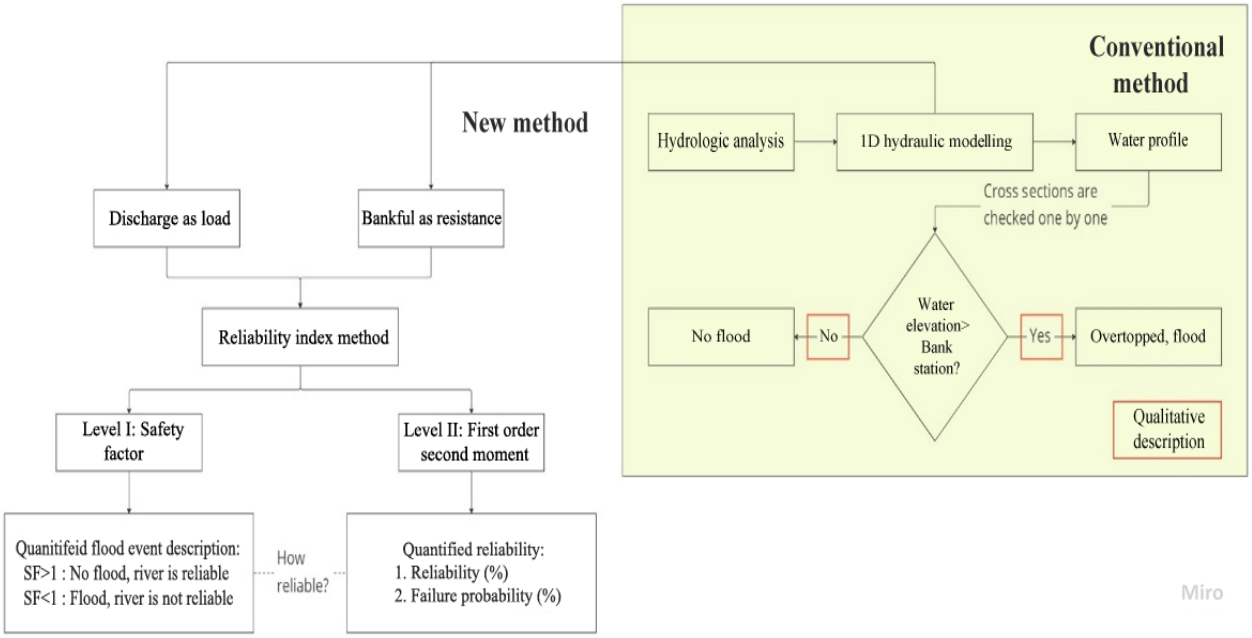

Figure 5.
Flowchart of flood risk identification's conventional and new method.

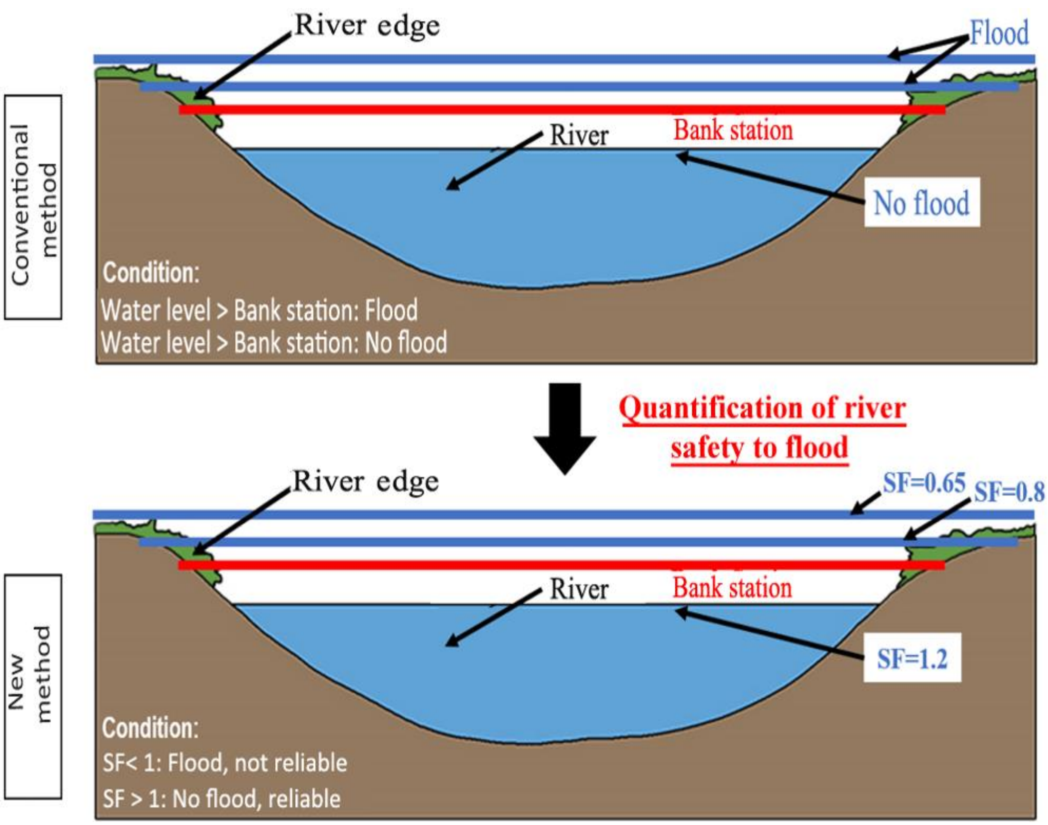

Figure 6.
Illustration of flood risk identification's conventional and new method.

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3. Data and Methodology

3.1. Data Collection

The data used in this study are:

1. Yearly Maximum Daily Precipitation for 14 years from Meteorology, Climatology, and Geophysical Agency Indonesia.
2. Land Use and Soil Type Data from Ministry of Environment and Forestry of The Republic of Indonesia, 2019.
3. River's Geometries Data, measured on August, 2022, and Data Elevation Model (DEM) Data from Indonesia National DEM.
4. Hourly Tidal Data for 15 days from NAOTide.
5. Open Street Map Data using Google Satellite.

3.2. Hydrologic Analysis

The hydrological analysis in this study including some steps as follows:

1. Hourly Tidal Data Prediction using Least Square and Admiralty Method to obtain its harmonical components, predicted hourly tidal data, and important sea's elevation.
2. Rainfall data' test such as Outlier, Spearman's Independency, Stationery and Uniformity Test (F-Test & T-Test), Persistency Test, and RAPS' (Rescaled Adjusted Partial Sums) Consistency Test.
3. Rainfall frequency analysis using Gumbel Distribution, Normal Distribution, Log Normal Distribution, and Log Pearson III Distribution.
4. Rainfall Frequency tests such as Parameters Test, Mean Absolute Percentage Error Test, Regression Test, Chi-Squared Test, and Smirnov-Kolmogorov Test.
5. Watershed Delineation
6. Rainfall Abstraction analysis using Soil Conservation Service (SCS) Method by defining curve numbers using the land use and soil type data.
7. Hourly Rainfall Distribution analysis from effective rainfall using the standardized distribution from The Indonesian National Standard (SNI) 2415:2016, PSA (Precipitation System Approach)-007 Distribution.
8. Synthetic Unit Hydrograph analysis using the hourly rainfall distribution and watershed's data, and is analyzed using Nakayasu SUH (Syntetheic Unit Hydrograph), SCS SUH, and ITB (Institut Teknologi Bandung) SUH for return periods of 2, 5, 10, 25, and 50 years.

3.3. Hydraulic Analysis

The hydraulic analysis in this study was done using HEC-RAS (Hydrologic Engineering Center River Analysis System) [5] and was carried out with a 1-Dimensional modelling and an unsteady flow simulation. The inputs of the model include:

1. River's geometries data.
2. Synthetic Unit Hydrograph for each return periods for upstream's boundary condition.
3. Predicted Hourly Tidal Data from Least-Square Analysis for down-stream's boundary condition.

The outputs of the model include:

1. Bankfull Flow Area for each cross section to calculate the resistances.
2. Extreme Discharge based on return periods for each cross section to calculate the loads.
3. Longitudinal Cross graphic to visualize the modelling result.

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3.4. Load and Resistance Analysis

Load and resistance data are obtained from the outputs of hydraulic analysis using HEC-RAS. As mentioned previously, the loads are extreme discharge based on return periods for each cross section and will be calculated using Equation 3, while the resistances are the bankfull capacity for reach cross section and will be calculated using Equation 2. Figure 7 as follows shows the illustration of how resistance's wetted area is taken from HEC-RAS models.

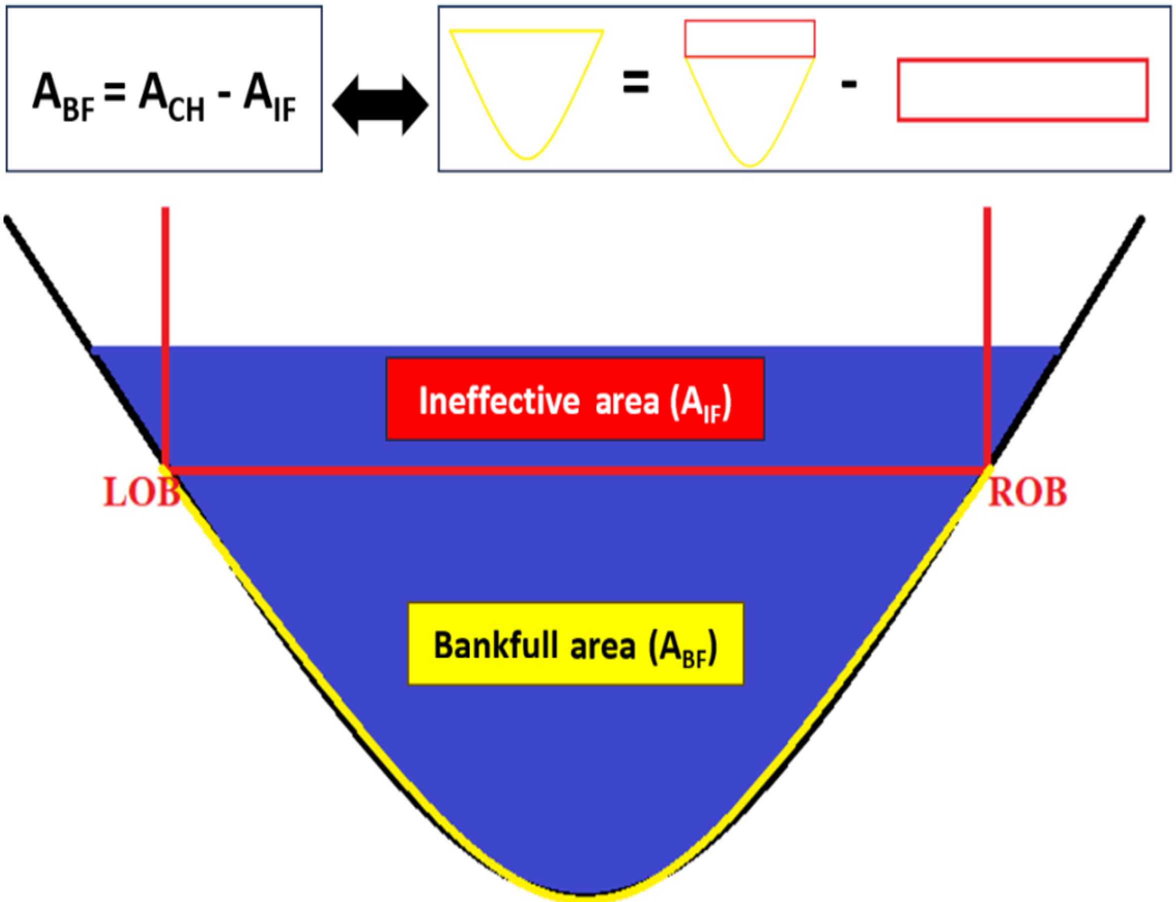

Figure 7.
Illustration of bankfull area output from hydraulic analysis.

With HEC-RAS, the outputs are channel's area, wetted perimeter, inverted slope, and Manning's roughness number. The problem here lies in the channel's area where it does not represent only the flow bounded by the set bank stations. In order to produce the wetted area intended, further steps are needed with equations such as follow:

$$A_{BF} = A_{CH} - A_{IF} \quad (5)$$

$$A_{IF} = Sta(ROB-LOB) \times El(WSE-min(LOB:ROB)) \quad (6)$$

Where,

A_{BF} = Bankfull area (m2).
A_{CH} = Channel's flow area (m2).
A_{IF} = Ineffective flow area (m2).

LOB_{STA} = Left bank station (m).
ROB_{STA} = Right bank station (m).
WSE = Water elevation (m).
LOB_{El} = Left bank elevation (m).
ROB_{El} = Right bank elevation (m).

Additional analysis is also done to compare reliability with channels' factual shape to the assumption of channels in the shape of trapezium [4]. The formulas used in this trapezium-shaped resistance assumption is as follows:

$$\bar{Q}_R = \frac{[(\bar{b}+\bar{m}\bar{h})\bar{h}]^{5/3}}{(\bar{b}+2\bar{h}\sqrt{1+m^{-2}})}\frac{\sqrt{\bar{i}}}{\bar{n}} \quad (7)$$

Where,
Q_R = Bankfull discharge (m^3/s).
b = Width (m).
m = Channel trapezium side slope.
h = Depth (m).
i = Channel longitudinal slope.
n = Manning's coefficient.

3.5. Reliability Analysis

The river's risk quantification index is obtained by using the first two levels of reliability analyses, which are Safety Factor (Level I) and First Order Second Moment (Level II). The first level with Safety Factor will compare the nominal resistance and the nominal load (Equation 1), and produce a single number that can be analyzed as follows:

1. When the number obtained is smaller than 1 (SF<1), it indicates that the analyzed hydraulic has a tendency to fail as the load is greater than the resistance, thus the river is estimated to not be able to flow the discharge safely.
2. When the number obtained is larger than 1 (SF>1), it indicates that the analyzed hydraulic has a tendency to succeed as the resistance is greater than the load, thus the river is estimated to be able to flow the discharge safely.

The calculations done within the paper analysis assumes the level of probability of acceptable failure (aL & aR) with the value of 5% and 25% respectively. The second level with First Order Second Moment method will calculate the reliability probability by dividing the average load and resistance with its standard deviation, and approximate the result and transform them to the normal distribution function (Equation 4).

4. Result and Discussion

4.1. Hydrologic Analysis

The rainfall data analyzed are from 2006-2020, and have been tested by numerous methods as mentioned before to validate its validity (Table 2). Frequency analysis is then done and results in Log Pearson III as the chosen distribution method (Table 3).

Table 2.
Rainfall data and tests' results.

No.	Tests method	Result
1	Outlier	v
2	Independency	v
3	Stationarity and uniformity	v
4	Persistency	v
5	Consistency	v

Table 3.
Frequency analysis tests' results.

Tests	Normal	Log normal	Log pearson III	Gumbel
Parameter	Ok	Not ok	Ok	Not ok
MAPE	Not ok	Not ok	Ok	Not ok
Regression	Not ok	Not ok	Not ok	Ok
Smirnov - Kolmogorov	Ok	Ok	Ok	Ok
Chi square	Not ok	Not ok	Not ok	Ok
Total	2	1	3	3

Plumbon's river watershed delineation is calculated using GIS (Geographic Information System) Software and result shows that the area has a value of 55.93 km^2 at the most downstream outlet point. For the reason that the upstream's outlet point has a small watershed area and is expected to not meet the actual river's load, the watershed is divided into six sections (R1 to R6) based on the river's slope from downstream to upstream to prevail the load along the river (Table 4 and Figure 8).

Table 4.
Watershed classification based on river's slope.

No	Code	Slope (%)	Area (km^2)
1	R1	6.58	55.93
2	R2	0.90	22.98
3	R3	4.32	18.63
4	R4	1.41	17.89
5	R5	0.37	0.81
6	R6	0.05	0.72

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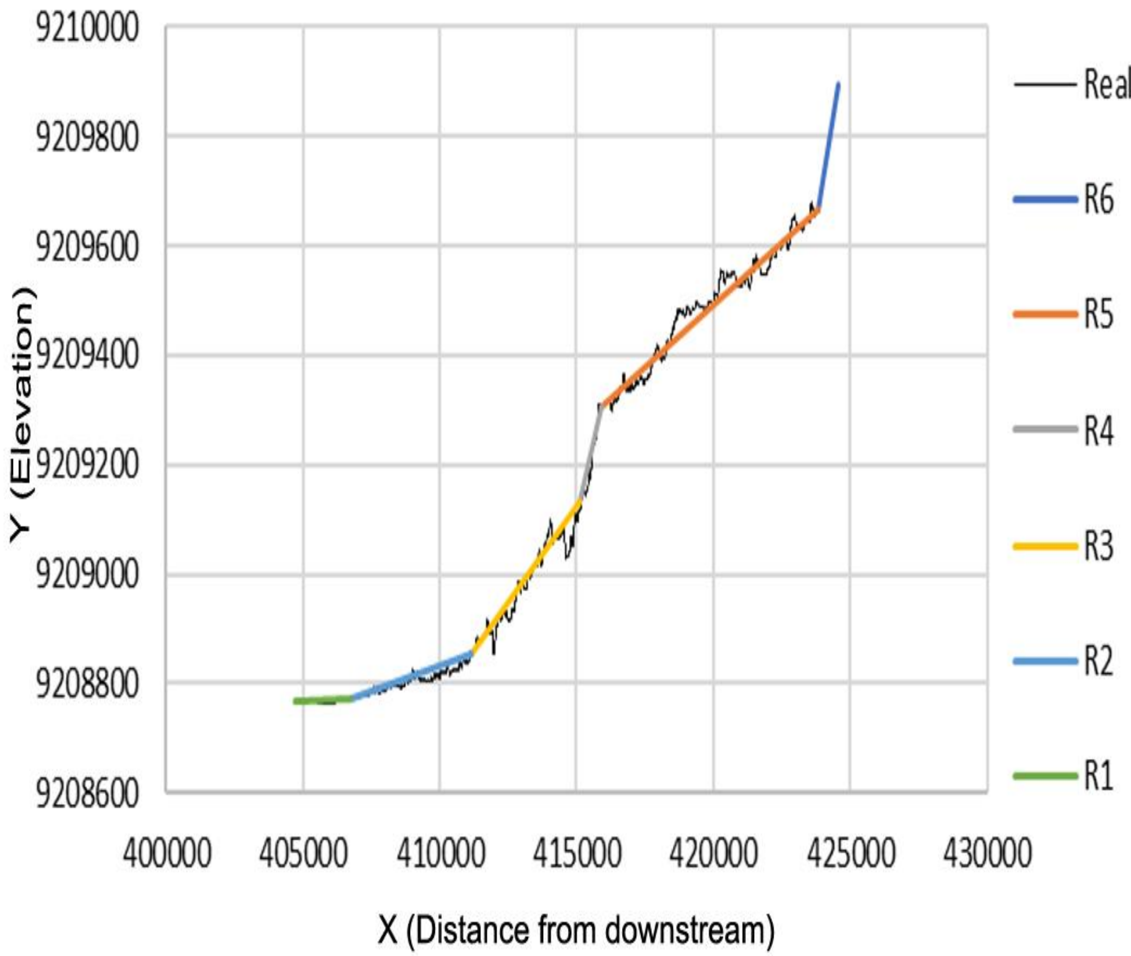

Figure 8.
River's long section slope classification.

Synthetic Unit Hydrograph method is chosen as the method to calculate load discharges based on the available data [6] and is analyzed for return periods of 2, 5, 10, 25, and 50 years. The inputs of the calculation are hourly distributed effective rainfall and has results as shown in Table 5. SUH Method chosen is ITB1-b SUH using Creager Curve as the validity test [7].

Table 5.
Synthetic unit hydrograph based on return periods.

No.	Watershed	Peak discharge based on return periods (m^3/s)				
		2	5	10	25	50
1	R1	120.6	164.3	232.5	297.1	317.3
2	R2	22.7	32.6	36.6	40.9	43.7
3	R3	6.5	9.5	10.6	11.7	12.3
4	R4	66.9	95.2	107.4	120.8	129.1
5	R5	1.1	1.6	1.7	1.9	2.0
6	R6	5.6	8.2	9.1	10.1	10.6

Hourly tidal data analyzed are from the measurement on December 2022 in the span of fifteen days. The calculation to obtain its harmonical components, predicted hourly tidal data, and important elevation is done using Least Square Modelling and Admiralty Modelling. The comparison is shown in Figure 9, while Table 6 shows the error test compared to field data with Least Square becomes the chosen method.

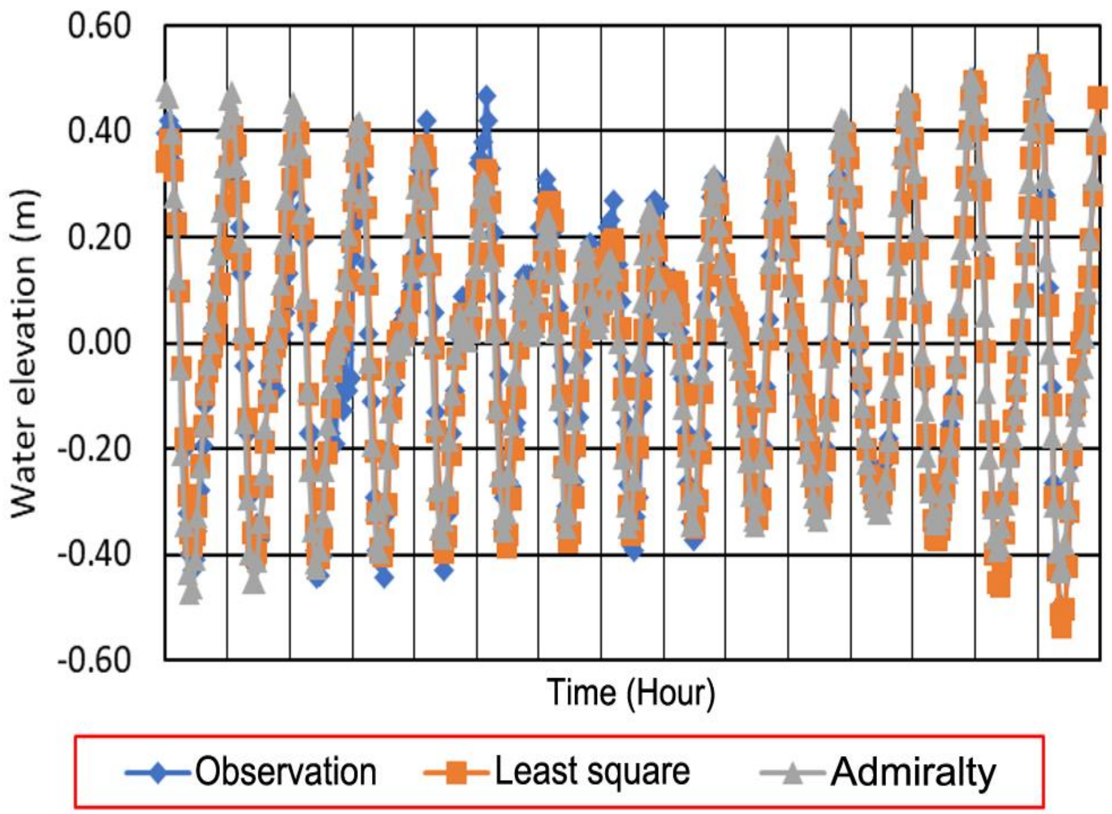

Figure 9.
Hourly tidal data comparison between observations and predictions.

Table 6.
Tidal data error tests' results.

Method	Least square	Admiralty
RMSE (Root mean squared error)	0.048	0.064
MAD (Mean absolute deviation)	0.033	0.049
MAPE (Mean absolute percentage error)	39.20%	64.97%

4.2. Hydraulic Analysis

Hydraulic analysis with HEC-RAS is done in 1-dimension modeling with Synthetic Unit Hydrograph as the upstream boundary conditions and predicted hourly tidal data as the downstream boundary condition. Based on the river's geometries data that act as the DEM input, the 1D modeling shows results as Table 7 shows.

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It summarizes the percentage of failed cross-sections at each return period-based simulation. As analyzed from the result, most failure happens at river's downstream where loads are at its highest but the resistances are at its lowest.

Table 8 shows the comparison of loads and resistances for each river's sections based on its slope level for an example of 2-year return period.

Table 7.
Percentage of failed cross sections.

No.	Return period (Years)	Failure percentage (%)
1	2	38.86
2	5	45.07
3	10	47.15
4	25	52.33
5	50	53.36

Table 8.
Load and resistance comparison (Example of 2-year return period).

No.	Data	Watershed load and resistance (m3/s)											
		R1		R2		R3		R4		R5		R6	
		L	R	L	R	L	R	L	R	L	R	L	R
1	Max.	225.6	15.5	94.4	200.0	135.7	200.1	77.9	200.0	7.1	200.0	5.6	200.0
2	Avg.	218.7	5.6	91.7	30.3	74.8	106.1	66.2	176.3	5.5	79.7	5.5	200.0
3	St. dev.	28.2	4.2	3.4	45.5	10.4	72.0	24.4	44.0	0.6	71.9	0.0	0.0
4	Var.	0.1	0.7	0.0	1.5	0.1	0.7	0.4	0.2	0.1	0.9	0.0	0.0

4.3. Reliability Index Analysis

Reliability index analysis is analyzed with two methods:

1. First, analyze the river as a single unit to produce a single quantification result. This approach will be called the "River Generalization Method".
2. Second, analyzing the river as separated units based on stream location (Upstream & downstream) classified by its slope level. This approach will be called the "River Classification Method".

4.3.1. River Generalization Method

Weighting for each slope's segment is done using an AHP (Analytical Hierarchy Process) method, scored based on its rank compared to the other units.

The first approach will analyze the whole loads and resistances data as a single whole, calculating the statistics data such as average, maximum, standard deviation, and coefficient of variation (Table 9).

The graph inserted will compare the relation between the average load and the risk quantification, either its Safety Factor (with the blue line) or Reliability Index (with the orange line), and the relation between indexes produced by both levels (Figure 10-11). In this approach, the optimal load that can give the balance between load, safety factor, and failure is in the value of 96 m3/s load, 2.8 safety factor, and 50% failure.

Table 9.
River generalization method reliability index.

Return periods	River's loads (m^3/s)			River's resistances (m^3/s)			SF	Pɣ	Pf
	Average	Nominal (Ln)	Ω_{L1}	Average	Nominal (Ln)	Ω_R			
2.33	66.60	112.53	1.023	70.86	192.60	1.04	1.71	51.69%	48.31%
5	80.86	128.47	0.873				1.50	46.11%	53.89%
10	107.21	178.57	0.987				1.08	38.92%	61.08%
25	134.33	229.29	1.048				0.84	34.49%	65.51%
50	152.20	263.90	1.088				0.73	32.69%	67.31%

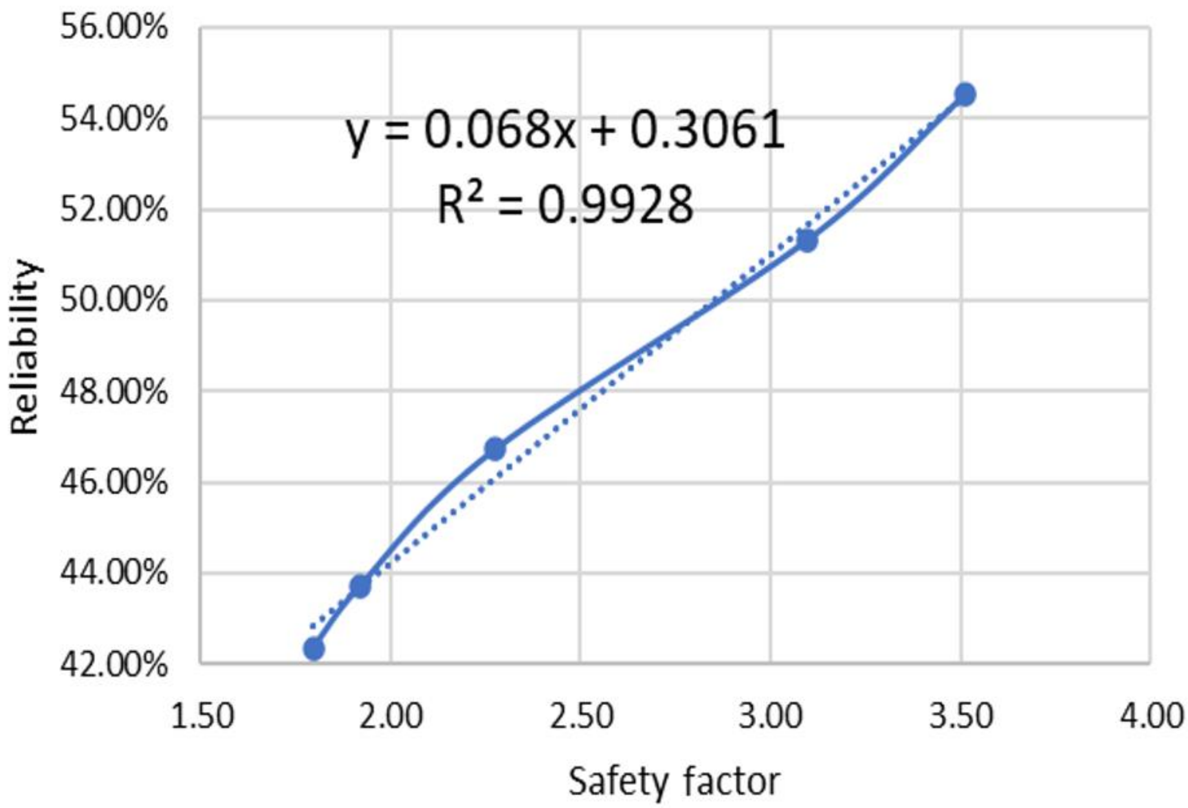

Figure 11.
River generalization method safety factor and reliability correlation.
Note: Solid blue: Safety factor and reliability correlation line, dotted blue: Linear trendline.

4.3.2. River Classification Method

The second approach will analyze the loads and resistances given from the hydraulic analysis into groups based on the previous slope classification. Figure 9 as follows shows the Failure Probability comparison for all sections. A clear difference is shown as sections located upstream have lower failure probability, even close to 0%, and sections located downstream have higher and increasing failure probability. Table 10 as follows shows the recapitulation of the

Safety Factor and Failure Probability for each section and helps emphasize the explanation for Figure 12.

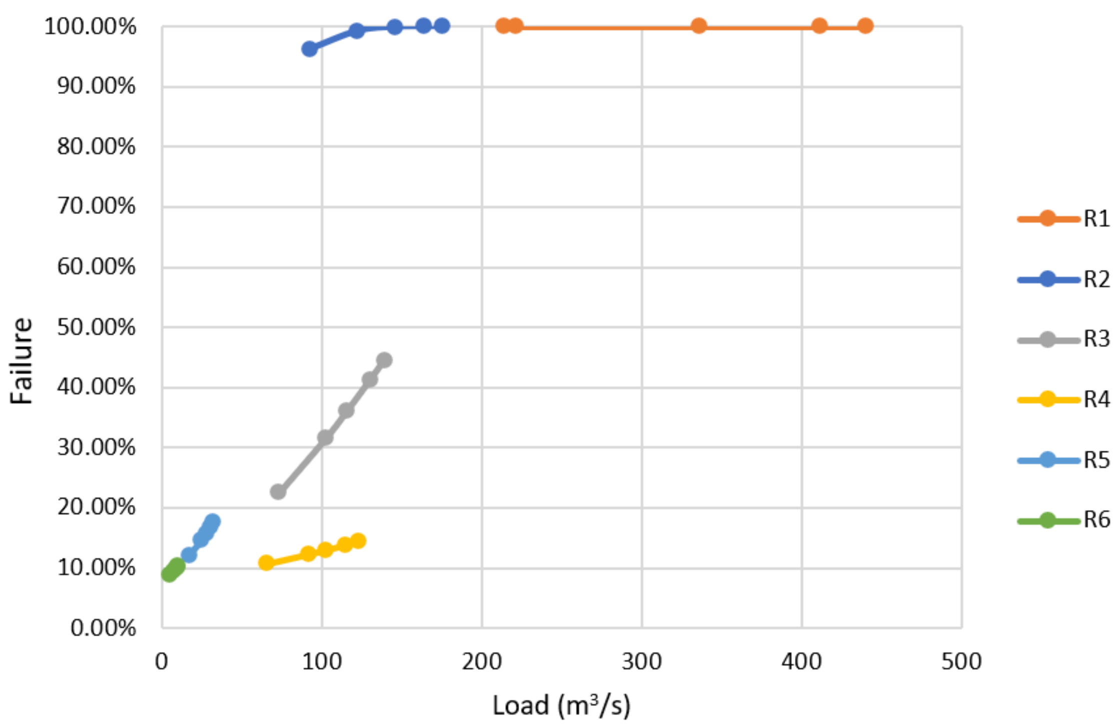

Figure 12.
Failure probability comparison for all sections.

Table 10.
Recapitulation of safety factor and failure probability for all sections.

Return periods	**R1**		**R2**		**R3**		**R4**		**R5**			**R6**
	SF	**Pf**	**SF**	**Pf**	**SF**	**Pf**	**SF**	**Pf**	**SF**	**Pf**	**SF**	**Pf**
2.33	0.05	100.00%	1.12	91.08%	2.74	0.14%	3.01	0.00%	33.15	0.00%	35.93	0.00%
5	0.05	100.00%	0.80	97.56%	2.18	0.00%	2.21	0.46%	21.33	0.00%	24.61	0.00%
10	0.03	100.00%	0.70	99.44%	1.67	82.38%	1.39	26.19%	19.06	0.00%	22.13	0.00%
25	0.03	100.00%	0.62	99.83%	1.12	73.48%	0.58	81.51%	17.09	0.00%	19.94	0.00%
50	0.03	100.00%	0.58	99.93%	1.01	79.31%	0.38	93.52%	16.44	0.00%	18.94	0.00%

After knowing each section's risk quantification, recombining the river back as a whole is analyzed using weighting for each slope class. Scoring and indexing are done using an Analytical Hierarchy Process (AHP) by classifying parameters such as:

1. Average Load and Resistance differences.
2. Slope value (steeper slope has greater reliability in flood resistance [8].

By those AHP parameters, R1 (downstream) will have a greater score percentage compared to R6 (upstream). Table 11 shows the impact percentage for each section, and Table 12 and Figure 13-14 will show the risk quantification number for the second approach. In this approach, the optimal load that can give the balance between load, safety factor, and failure is in the value of 155 m3/s load, 2.2 safety factor, and 59% failure.

Table 11.
Sections' impact percentages for second approach.

Section	Slope	Score	Impact percentages
R6	6.58%	1	5%
R4	4.32%	2	10%
R3	1.41%	3	14%
R5	0.90%	4	19%
R2	0.37%	5	24%
R1	0.05%	6	29%

Table 12.
River classification method reliability index.

Return periods	River's loads (m3/s)			River's resistances (m3/s)			SF	Pɣ	Pf
	Average	Nominal (Ln)	Ω_{L1}	Average	Nominal (Ln)	Ω_R			
2.33	108.80	118.80	0.14	71.31	167.78	0.82	1.41	26.77%	73.23%
5	124.18	134.49	0.12				1.25	19.15%	80.85%
10	175.77	192.81	0.14				0.87	5.09%	94.91%
25	233.52	268.22	0.22				0.63	1.88%	98.12%
50	275.43	313.38	0.20				0.54	0.60%	99.40%

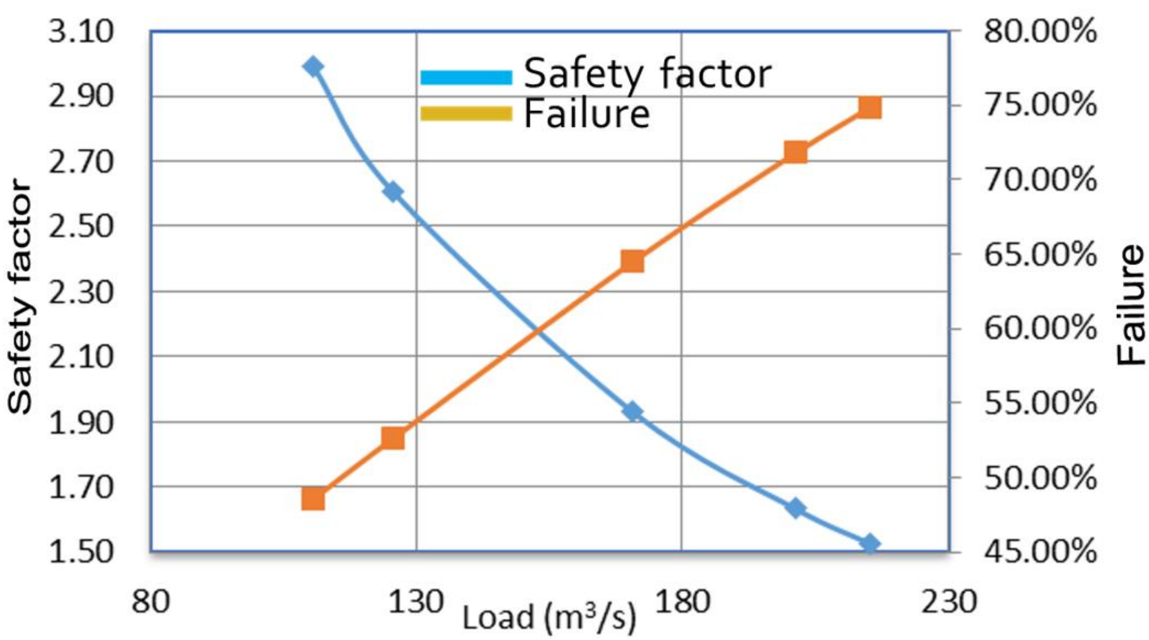

Figure 13.
River classification method safety factor and failure probability to load.
Note: Orange: Failure line, blue: Safety factor line.

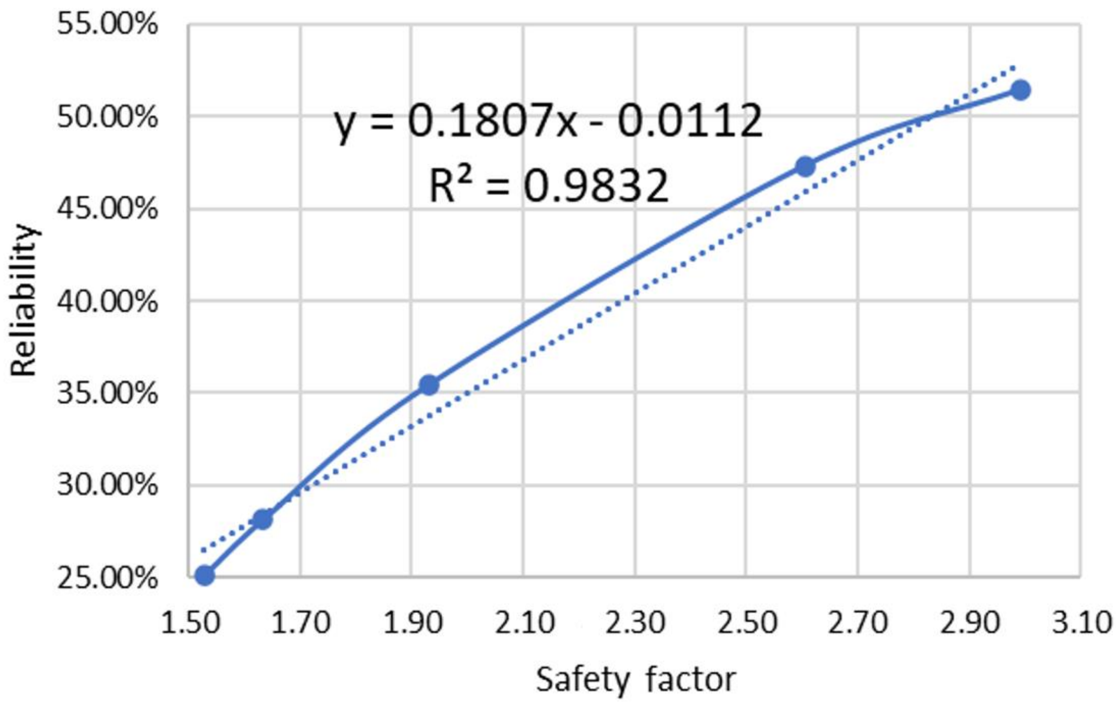

Figure 14.
River classification method safety factor and reliability correlation.
Note: Solid blue: Safety factor and reliability correlation line, dotted blue: Linear trendline.

4.3.3. Comparison

The comparison between the two methods set in the analysis is shown in Table 13. Though the Safety Factor as Level I's Reliability Index between the two methods do not show a great difference ($\bar{\Delta}$=0.23), but the First Order Second Moment as Level II's Reliability Index analysis shows a massive difference averaging about $\bar{\Delta}$=30% difference. To conclude, the second approach will be proposed to be the best way in quantifying a flood risk number using reliability index method and the higher the level used, the better the result.

Table 13.
First and second approach reliability index comparison.

Return periods	River's loads		River's resistances		SF		Pγ		Pf	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
2.33	71.5	110.6	94.2	116.0	3.5	3.0	54.5%	51.4%	45.4%	48.5%
5	71.5	125.8			3.1	2.6	51.3%	47.3%	48.6%	52.6%
10	71.5	170.7			2.3	1.9	46.7%	35.4%	53.2%	64.5%
25	71.5	201.4			1.9	1.6	43.7%	28.1%	56.2%	71.8%
50	71.5	215.3			1.8	1.5	42.3%	25.1%	57.6%	74.9%

4.3.4. Trapezium and Factual Shape Comparison

As a comparison to what has been mentioned in the introduction, the result shows that river's resistance method that was analyzed by Ferdiansyah, et al. [4] by assuming trapezium-shaped sections will result in an overestimated number, thus resulting in a higher reliability number that doesn't match the flood outspreads (Table 14).

Table 14.
Trapezium and factual shape reliability index comparison.

Return periods	SF		Pɣ		Pf	
	Trapezium channel	Factual channel	Trapezium channel	Factual channel	Trapezium channel	Factual channel
2.33	7.5	3.00	75.4%	51.5%	24.6%	48.5%
5	6.5	2.6	73.9%	47.3%	26.1%	52.7%
10	4.9	1.9	69.4%	35.5%	30.6%	64.5%
25	4.1	1.6	66.1%	28.1%	33.9%	71.9%
50	3.8	1.5	64.5%	25.1%	35.4%	74.9%

5. Conclusion and Recommendation

Based on the results, the final analysis concludes that:

1. Safety Factor (Level I) and First Order Second Moment (Level II) will have a similar trend with each other in a way to quantify the risk number as both show a valid and particular defined number for the river's reliability.
2. The generalization approach will result in an overestimated reliability thus classifying rivers with slope parameters is done to analyze each special section, resulting in the upstream section with a higher slope level having greater flood reliability (or slope level is directly proportional to reliability).
3. The assumption of trapezium-shaped sections will result in an over-estimated flood reliability number as rivers have a complex morphology that varies from one section to another.

As recommendations, the higher level reliability method will produce numbers that define more meaning with greater accuracy, thus it is recommended to study Level III and IV as a comparison to the limited Level II used in this paper. Secondly, wetted areas obtained from its factual shape using HEC-RAS 1D's outputs is recommended to be studied even further to increase its accuracy and validity by understanding the finite difference used in its calculation and recalibrating the results using software specialized in geometries drawing.

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Transparency:

The authors confirm that the manuscript is an honest, accurate and transparent account of the study that no vital features of the study have been omitted and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Competing Interests:

The authors declare that they have no competing interests.

Authors' Contributions:
All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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