IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Flood risk mapping of the Sukamahi Dam failure with overtopping scenario

To cite this article: W G Prakoso *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **622** 012006

Flood risk mapping of the Sukamahi Dam failure with overtopping scenario

W G Prakoso[1*], B Rahman[1], H Purwanti[1], and P Irawan[2]

[1]Civil Engineering Department, Faculty of Engineering, Pakuan University, Bogor, Indonesia 16129
[2]Civil Engineering Department, Faculty of Engineering, Siliwangi UniversityTasikmalaya, Indonesia 46115

E-mail: wahyugendamprakoso@unpak.ac.id

Abstract. Sukamahi dam at Cisukabirus river, part of the upper Ciliwung watershed, located at Bogor regency. Sukamahi dam was designed for flood reduction purposes, especially for the downstream region, e.g., City of Bogor, Bogor regency, City of Depok, and Jakarta. Sukamahi dam will give flood reduction 13.53 m^3/s with probability exceeded 2 %, and time to concentration (tc) for peak discharge (Qp) at least 4 hours longer than existing condition. Despite providing the benefits of flood control, the construction of dams also has the potential to increase the risk, i. E if a dam fails due to overtopping. Based on the Sukamahi dam flood failure scenario, dam failure has the potential to occur if the bottom outlet (tunnel) and spillway fail when flood discharge with a 1000 year return period or more occur. Modeling of Sukamahi dam failure using 2 D HEC-RAS with unsteady flow analysis from sta 0 + 000 to STA 8 + 500 produces a map of inundation area of 36.89 Ha. The flood flow velocity is reaching 8.43 m/sec with a maximum flood flow depth of 69.72 m.

1. Introduction

Dams provide various benefits in human life. Some of those benefits than can be obtained include the provisions of water resources for drinking water, irrigation, and industrial water supply; they control floods, increase dry-weather flows in rivers and creeks, and give opportunities for various recreational activities. Sukamahi dry dam at Cisukabirus river, part of the upper Ciliwung Watershed, located at Bogor regency, was designed for flood reduction purposes . However,besides being a valuable resource, Sukamahi dam can also be a source of risk to downstream communities especially located at City of Bogor, Bogor regency, City of Depok, and Jakarta in the form of dam failure hazard. Dam Failure potentially resulting unacceptable damage to property and loss of life. One of the main causes of dam failure is the overtopping of dams because of inadequate flood carrying capacity.

In terms of safety, the traditional engineering approach has always been to specify the required flood discharge capacity for the dam at the design stage based on the relevant hydrological data and flood estimating and flood routing procedures. Hydrologic safety was considered separately from other risks, which resulted in the identification of inadequate spillway capacity as a major cause of dam failure[1]. This study aims to provide an inundation risk map on the Sukamahi dam failure with an overtopping scenario.

1.1. Objective

The primary objective of this study aims to provide an inundation risk map on the Sukamahi dam failure with an overtopping scenario.

1.2. Scope of study

The scope of study are limited to :

a. Sukamahi dam failure scenario limited to overtopping
b. dam failure occur on the Q_{1000}
c. the inundated area and the increase in the extreme discharge of the Cisukabirus and Ciliwung River will only cover the river segment from STA 0 + 000 (Sukamahi Dam) to STA 8 + 500 (Kalibaru Irrigation Channel), river cross section measured on 100 m spacing distances.

2. Methods

2.1. Location

Sukamahi dam located on the Cisukabirus Watershed, upper Ciliwung, West Java Indonesia

2.2. Data and Software

Data and Software which are used in the study

Tabel 1 Data and software

Data	Source	Note	Software	Version
DEM	SRTM		ArcGIS	10.1
River Polyline	SRTM, RBI		HEC-RAS	
River Cross Section	BBWS, field measurement	With 100 m spacing		
Discharge	BBWS		MS Excell	2016
River Profile	BBWS			

2.3. Prosedures

The working flow of the study follows flood hazard mapping procedure and practice as illustrated in Figure 1.

3. Results and discussion

3.1. flood risk Analysis on the Detailed Engineering Design and Operation Plan of Sukamahi Dam

The Sukamahi Dam is planned to control the Ciliwung River flood. The main obstacle in controlling floods is the relatively small volume of Sukamahi Dam reservoirs. Flood reduction by utilizing a reservoir above a spillway such as a dam is generally not possible because the resulting flood reduction will be very small. The engineering operation is carried out by applying the concept of a dry dam, where at the beginning of the rainy season, the reservoir water level is at a low elevation so that at the beginning of the flood, the flood discharge flows freely through the tunnel.

The Operational Plan for controlling the flood of the Ciliwung River in the Sukamahi Dam is as follows:

1) Changing the river flow pattern, which under existing conditions flows through the natural river channel with an average river width of 13-15 m, into a controlled flow by creating dams where water has flowed through the tunnel.
2) Discharge capacity through the tunnel will be smaller than the natural river, so the water flowing downstream to the Katulampa Dam will be decreased.
3) The function of the dam is to hold the rising water level due to the discharge outflow through the tunnel is smaller than the inflow discharge
4) The dam is equipped with a spillway, so if the flood discharge is large enough, then the reservoir surface rises, and the water flows through the spillway. The debit that comes downstream of the dam is the total discharge that flows through the tunnel and through the overflow.
5) For the safety of the dam, the height of the dam is determined based on the search for flood discharge of 1000 year return period, and the discharge is controlled by PMF discharge.

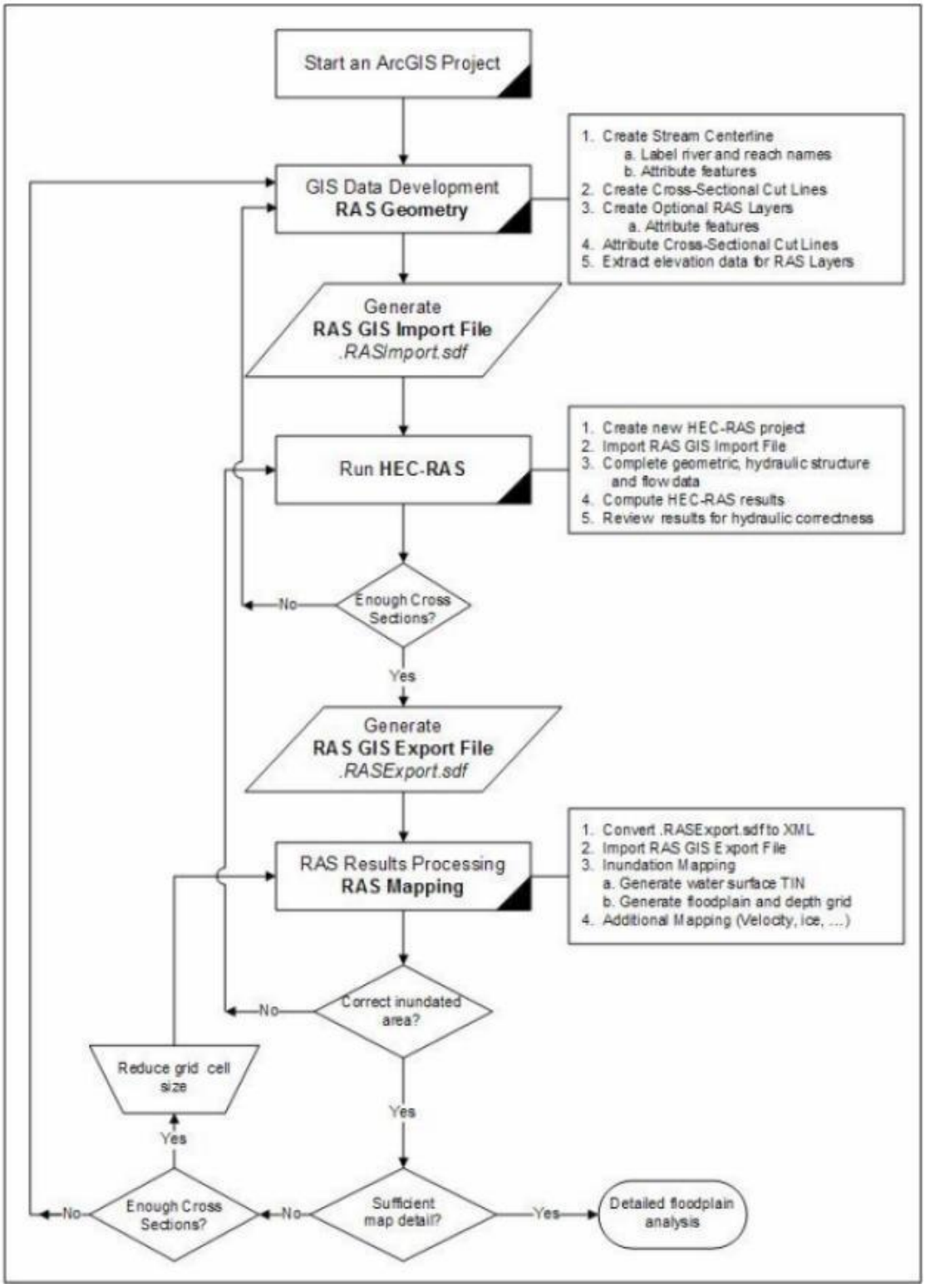
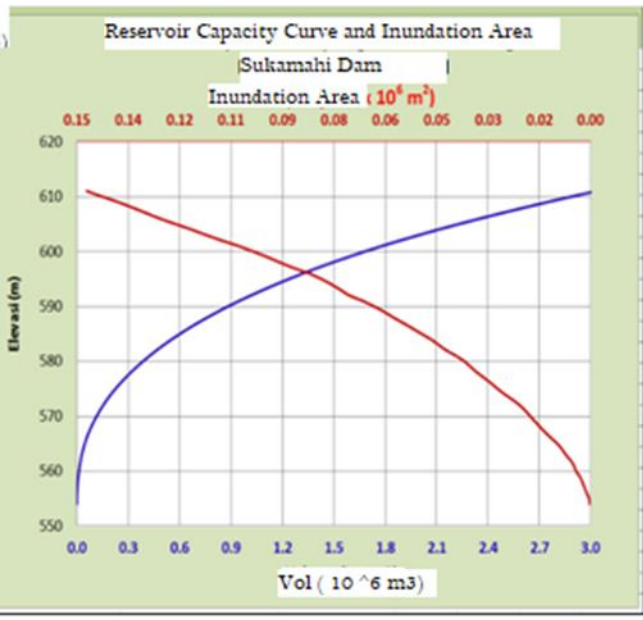


Figure 1. Research flow chart

Sukamahi Dam Located on the Cisukabirus river, which is a tributary of the Ciliwung River, the Sukamahi Dam watershed area is 15.86 km^2, the main river length is ± 15 km, with an average river slope of 0.037.

No	Heigh	elev	Area (ha)	Vol (10^6 m3)
1	0.00	554.00	0.03	0.00
2	1.00	555.00	0.05	0.00
3	2.00	556.00	0.12	0.00
4	3.00	557.00	0.19	0.00
5	4.00	558.00	0.25	0.00
6	5.00	559.00	0.32	0.01
7	6.00	560.00	0.44	0.01
8	7.00	561.00	0.50	0.02
9	8.00	562.00	0.60	0.02
10	9.00	563.00	0.74	0.03
11	10.00	564.00	0.84	0.04
12	11.00	565.00	0.98	0.05
13	12.00	566.00	1.16	0.06
14	13.00	567.00	1.33	0.07
15	14.00	568.00	1.48	0.08
16	15.00	569.00	1.63	0.10
17	16.00	570.00	1.77	0.11
18	17.00	571.00	1.91	0.13
19	18.00	572.00	2.08	0.15
20	19.00	573.00	2.29	0.18
21	20.00	574.00	2.52	0.20
22	21.00	575.00	2.72	0.23
23	22.00	576.00	2.91	0.25
24	23.00	577.00	3.12	0.28
25	24.00	578.00	3.33	0.32
26	25.00	579.00	3.51	0.35
27	26.00	580.00	3.69	0.39



No	Heigh	elev	Area (ha)	Vol (10^6 m3)
28	27	581	3.93	0.42
29	28	582	4.22	0.46
30	29	583	4.44	0.51
31	30	584	4.67	0.55
32	31	585	4.94	0.60
33	32	586	5.21	0.65
34	33	587	5.48	0.71
35	34	588	5.77	0.76
36	35	589	6.03	0.82
37	36	590	6.33	0.88
38	37	591	6.66	0.95
39	38	592	7.05	1.02
40	39	593	7.30	1.09
41	40	594	7.57	1.16
42	41	595	7.87	1.24
43	42	596	8.22	1.32
44	43	597	8.67	1.40
45	44	598	9.07	1.49
46	45	599	9.44	1.59
47	46	600	9.85	1.68
48	47	601	10.28	1.78
49	48	602	10.77	1.89
50	49	603	11.22	2.00
51	50	604	11.65	2.11
52	51	605	12.12	2.23
53	52	606	12.57	2.35
54	53	607	12.97	2.48

Figure 2. The Reservoir capacity curve and inundation area of the Sukamahi dam

Based on Sukamahi dam detailed engineering design the reservoir capacity reaching 2.48 X 10^6 m^3 with inundated area 12.97 Ha, on the highest water elevation + 607.00 m. There were several adjusment between data based on initial and revised design [2,3].

Sukamahi Tunnel Building has a diameter of 3 m with a horseshoe shape. Considering that the flood discharge in Sukamahi Dam is relatively small and in order to reduce it, the diameter of the tunnel is reduced to 1.6 m. The capacity of the Sukamahi Dam tunnel with variations in the upstream water level, as shown in Figure 3. [2,3].

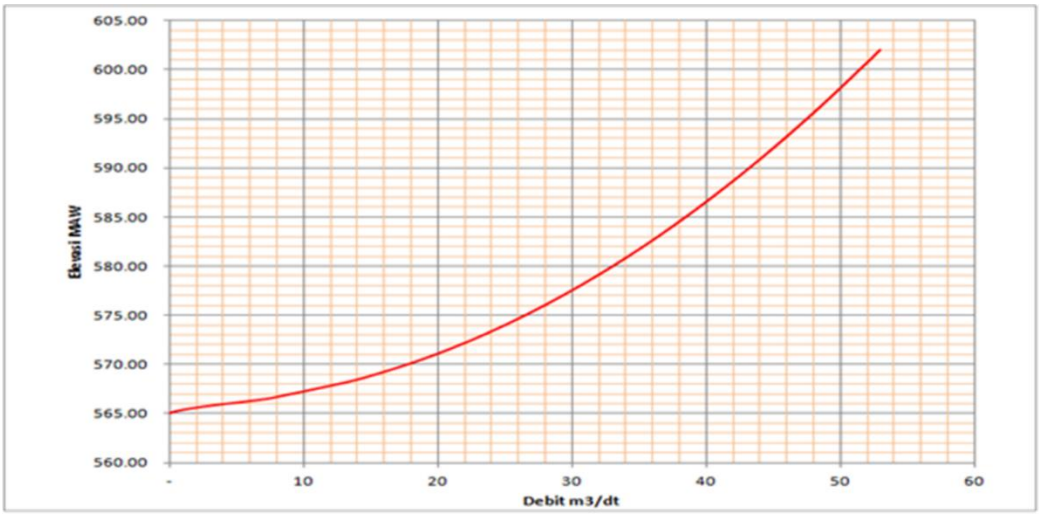


Figure 3. The discharge capacity of the Sukamahi dam tunnel

The overflow elevation at Sukamahi Dam is planned + 596 m, with a storage capacity of 1.32 million m^3. With an 80% probability inflow debit of 8.15 m^3 / sec, the Sukamahi Dam will be full in 1.87 days.

3.2. Sukamahi dam failure risk analysis due to excessive overflow capacity

Based on the flood design and sukamahi dam operation plan, it can be seen that the sukamahi dam has a high vulnerability to the danger of overflow capacity and dodging tunnels. If there is a failure in the tunnel when there is extreme rain that causes the flood peak discharge, which exceeds Q_{50}, it can potentially harm the sukamahi dam, especially from the aspect of failure due to overtopping.

The catchment area of Sukamahi Dam is 15.86 km^2 with AEP of 1 X 10^{-10} so that it is taken as the AEP (annual exceedance probability) norm.[4]

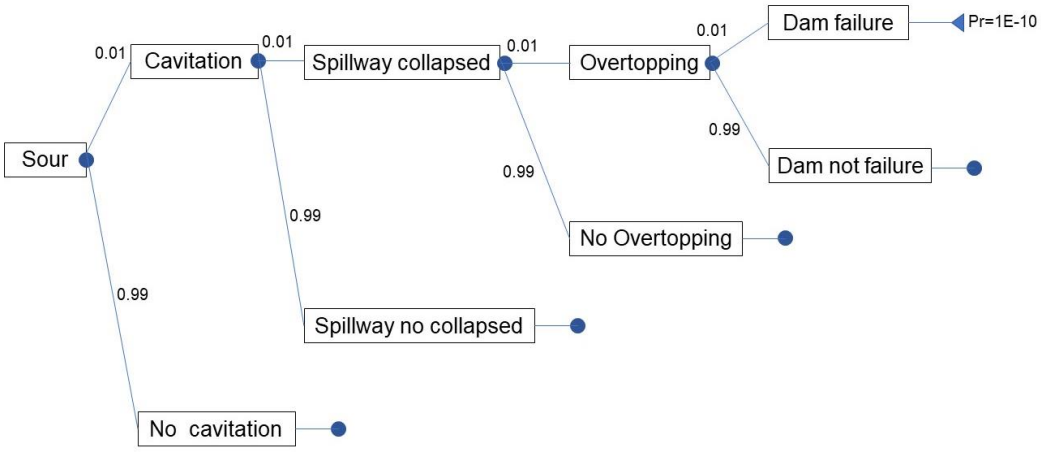


Figure 4. Tree Analysis of spillover events on the potential of overflow

3.3. Risk Analysis Inundated Area in the Sukamahi Dam failure scenario

Simulation results using 2D HEC RAS Software In the case of the Sukamahi Dam collapse due to overtopping, the maximum runoff discharge that occurs is 11867.172 m^3 / s at ± 0.29 hours or 1044 seconds when the process collapses (after dam break) [4]. From the analysis of Sukamahi Dam collapse simulation for overtopping case scenario for simulation time 0.29 hours, the total accumulation of inundation area from STA 0 + 000 to STA 8 + 500 is 38.69 Ha with a maximum flood depth 69.72 m. These results are smaller with similar studies on the analysis of flooded areas and flood behavior in Sukamahi dam failure with overtopping Scenario on Q_{PMF} [4,5] due to the limited river segment studied.

Figure 5. Inundation risk map on The Sukamahi Dam scenario STA 0 + 000 to STA 2 + 000

4. Conclusion

In conclusion, it was found that In the case of the Sukamahi Dam collapse due to overtopping, the total accumulation of inundation area from STA 0 + 000 to STA 8 + 500 is 38.69 Ha with maximum flood depth 69.72 m.

After the inundation map is created, the inundation polygon shall be verified with groundchek terrestrial survey data for its quality. The digital elevation model which is used in this study based on Google Earth and DEMNAS (SRTM). If the underlying terrain errors in the flood inundation polygon founded, it can be fixed in HEC-RAS geometry file. The refinement of flood inundation result to create a hydraulically correct output is an iterative process requiring several iteration process between GIS and HECRAS wich is not covered by this study.

References

[1] ICOLD 2012. Technical Guide on Dam Safety (Risk Analysis Applied to Management of Dam Safety). *SPANCOLD* : Spain.

[2] Balai Besar Wilayah Sungai Ciliwung Cisadane (BBWS). 2014. Revisi Detail Desain Bendungan Sukamahi Kabupaten Bogor Provinsi Jawa Barat.

[3] Indra Karya 2013 Studi Detail Desain Bendungan Ciawi dan Bendungan Sukamahi Kabupaten Bogor Provinsi Jawa Barat

[4] Prakoso W G, Mahfudz M, Irawan P 2018 Hydrological risk valuation on the design of Sukamahi dry dam Bogor, West Java. *The 6 th International Conference of Jabodetabek Study Conf, August 29-30 , 2018. P4W-IPB* (Bogor)

[5] Wirustyastuko D, Nugroho J 2013 Analisis Wilayah Tergenang dan Perilaku Banjir pada Simulasi Kegagalan Bendungan Ciawi *J. Teknik Sipil*. **20** 2 pp 121-131