FLOOD ANALYSIS ON THE TAILING DAM AT WAY LINGGO, LAMPUNG PROVINCE

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I. Introduction

Due to the absence of an automatic water level recorder in the project site , another recorder in neighbouring catchment, which is the smallest catchment area in the Way Seputih Sekampung River basin, had to be selected. Observation at the gauging station produces several flood hydrographs that will be considered in the selection of methodology, especially the establishment of the Hydrological Soil Group. The Way Linggo-Tailing project site is situated almost adjacent to the Way Humarabalak-Banjar Agung with a catchment area of 140 km2 (see Figure 1). Catchment area of the Tailing Dam, less the weir inundated area (5,875 ha), ranges approximately 20.78 ha.

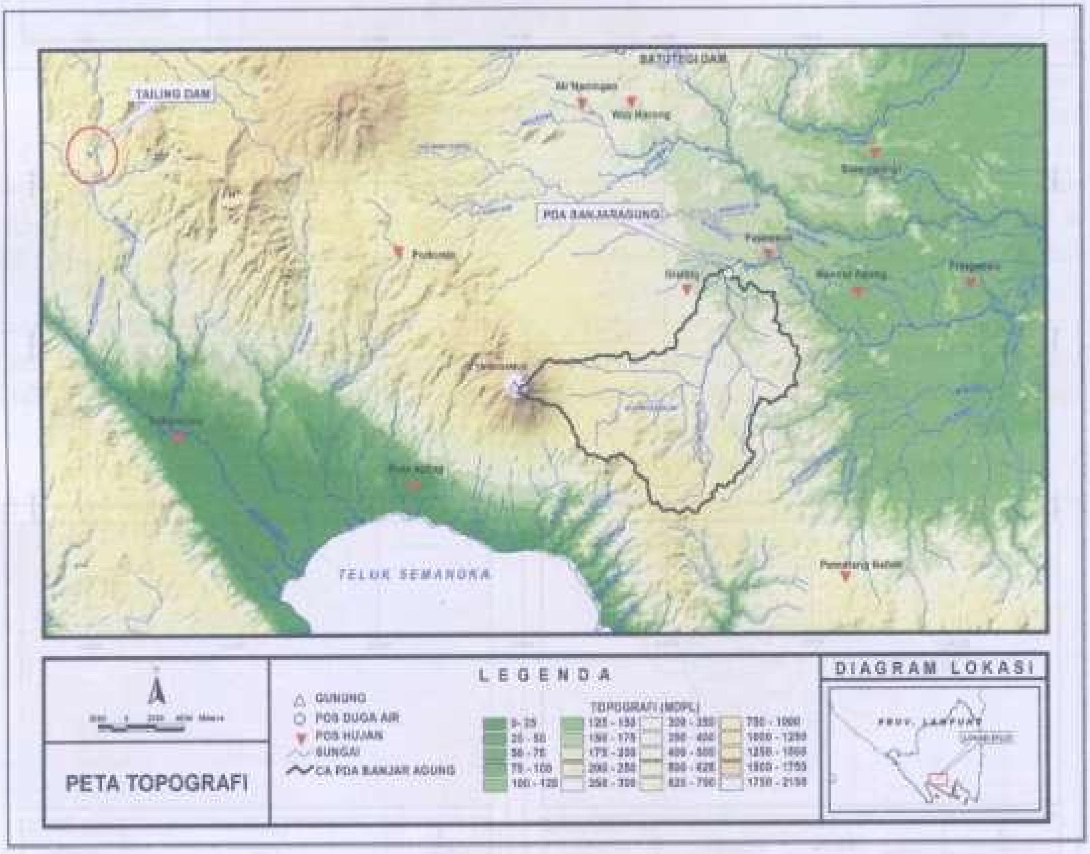

Figure 1.Location of Project Site (Tailing Dam) and Banjaragung Catchment Area

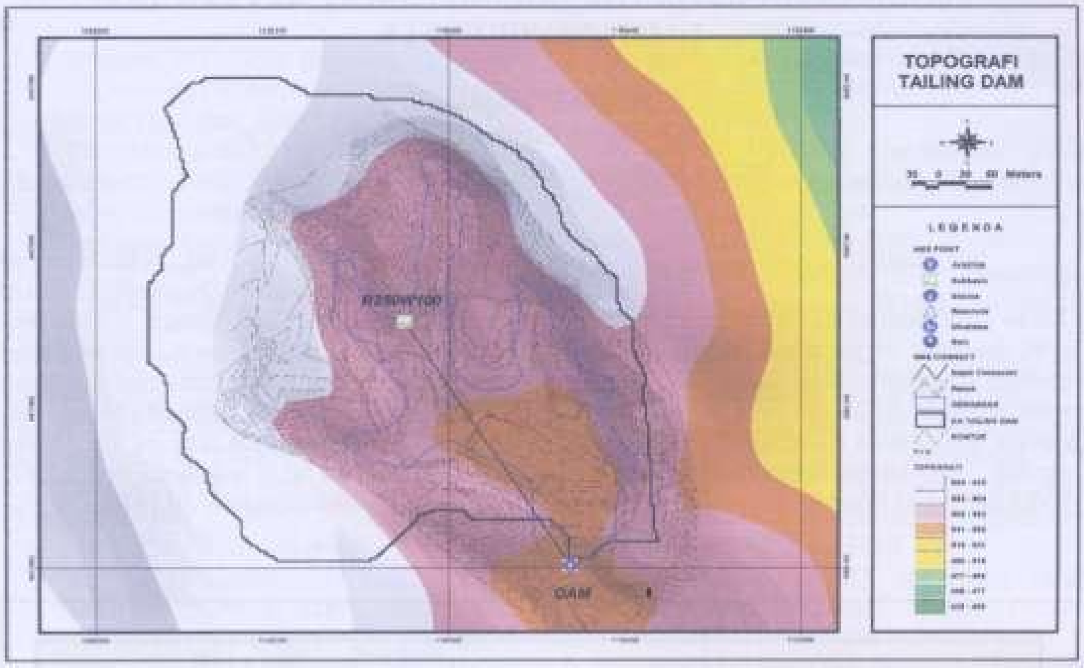

Figure 2. Topographical Map of the Tailing Dam Catchment Area

The Hydrological data shall involve:

a. Calibration phase : re-constitution of hydrograph 2 flood event (May 81 and Feb 82) at Banjaragung needs:
   i. Daily rainfall of some manual rainfall stations as depicted on the figure below, i.e. Srikuncoro, Podoredjo, Kota Agung, Air Naningan, Way Harong, Gisting, Pajaresuk, Banyuwangi,Pringsewu, and Pematang Nebak (see Figure 4).
   ii. Topographical map (Figure 1), Land-use map, 2009 (Figure 3), Topographical Map of Bakosurtanal (Figure 2), Hydro-geological map from Direktorat Geologi Tata Lingkungan (Figure 5).

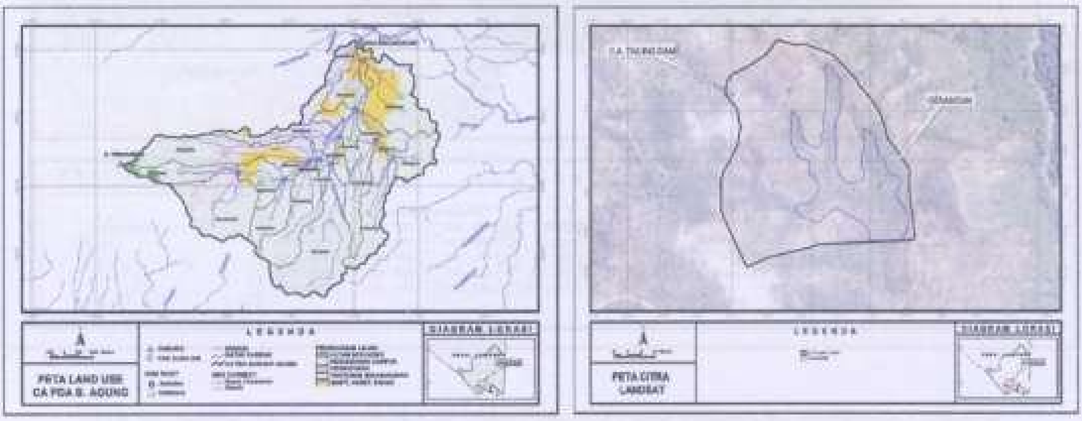

Figure 3. Land Use Map of BanjarAgung and Tailing Dam Catchment

Figure 16 shows that reconstitution results are sufficient for conclusion that parameters are representing actual hydrological conditions for losses composed in Curve Numbers, Baseflow parameters and unit hydrograph of Soil Conservation Service (SCS) parameters (time lag depending on river length) or in other words, the Curve Number can also be applied in the Tailing Dam catchment.

Conclusion

This Interim Report addresses the following subjects:

1. Collected data
2. Calculation of Design Rainfall
3. Topographical Analysis
4. Analysis for the Estimation of Losses by use of the Curve Number
5. Calibration of model parameters for Banjaragung catchment to validate the Curve Number method for use at the Tailing location.

The Draft Report shall explain on:

1. Flood Model for Tailing Dam
2. Condition of reservoir (water level, storage, outflow) when inflow with various return periods occurs i.e.
   a. Scenario 0: Existing condition (4 culverts)
   b. Scenario 1: Using 5 culverts (existing land-use)
   c. Scenario 2: Finding total number of culverts accommodate the Probable Maximum Flood (PMF), using existing land-use.
   d. Scenario 3: Impact of land-use change to inflow, storage and water level in the reservoir a.
   e. Scenario 4: Scenario 0 with increasing dam height in order to accommodate the Probable Maximum Flood (PMF).

4.1 Scenario 0 (Existing Condition, 4 culverts)

Two years to thousand years inflow can be stored in a reservoir without overspill at dam crest. Highest water level in dam, + 1170.1 for 100-year inflow, is still below the top of culvert which is situated at 1170.4. The 1000-year inflow causes a water level a little above the dam crest, that is + 1171.51, so that overspill is resulting a discharge of 0.093 m^3/s, as shown in Figure 17. Probable Maximum Flood (PMF) as result of the Probable Maximum Precipitation (PMP) shall indicate a maximum water level of + 1170.68 or 0.18 m above dam crest and a peak spill discharge of 24.38 m^3/s (see Figure 18).

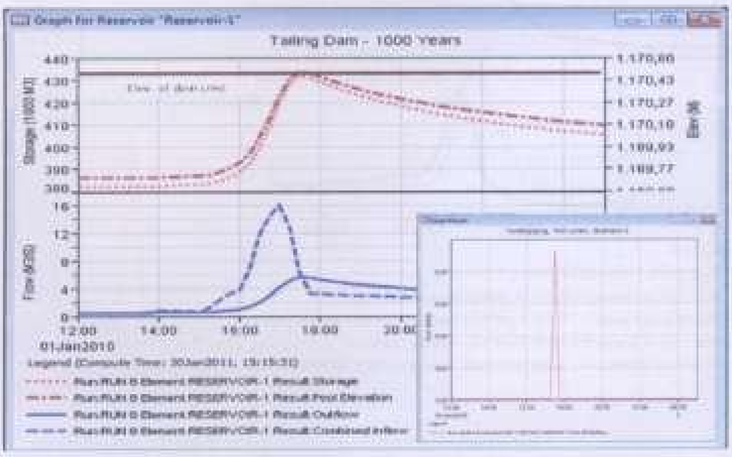

Figure 17. Reservoir Condition When 1000 Year Inflow (overspill), Scenario 0

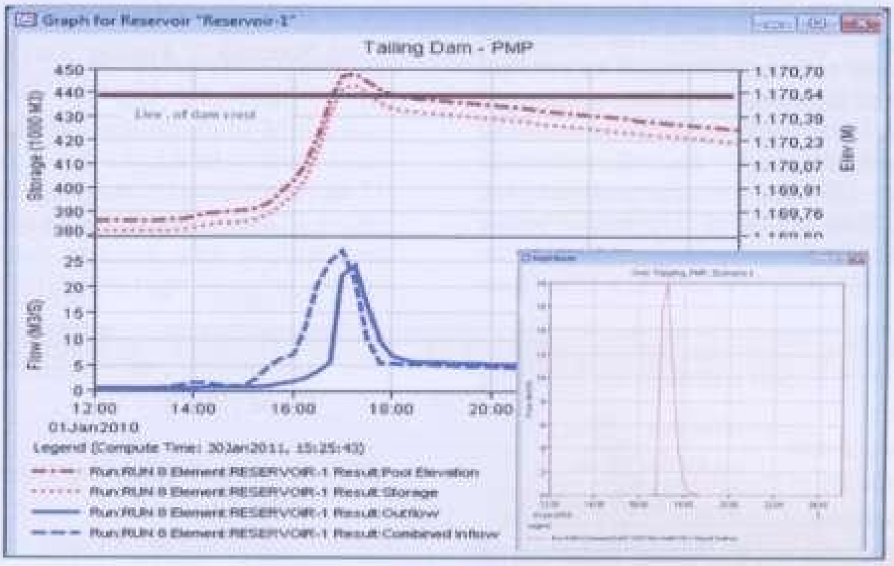

Figure 18. Reservoir Condition at Probable Maximum Flood / PMF (overspill), Scenario 0

4.2 Scenario 1

This scenario shall measure the outlow of 5 culverts with the expectation that water level in the reservoir will be lower than previous water level. For 1000-year inflow there will be no overspill at dam crest, whereas at Probable Maximum Flood/PMF, maximum water level will be + 1170.66 or 0.16m above the dam crest resulting a peak spill discharge of 15.8 m3/s as depicted in Figure 19. The role of storage is less significant because peak of outflow is slightly different than the inflow peak.

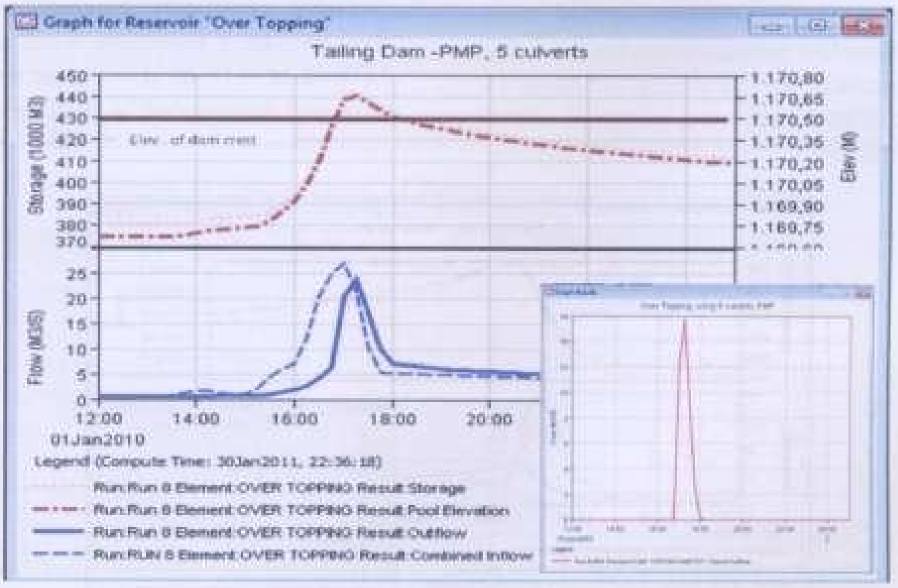

Figure 19. Reservoir Condition at Probable Maximum Flood / PMF (overspill), Scenario 1

4.3 Scenario 2

This scenario shall set-up a model of dam condition according to the Probable Maximum Flood/PMF by adding the number of culverts so that overspill shall not occur at the dam crest. Results of the scenario estimate that if 14 culverts are being applied, maximum water level will reach 1170.48 or 2 cm below the dam crest. The number of culverts needed is much larger when compared to the previous number of only 4 culverts.

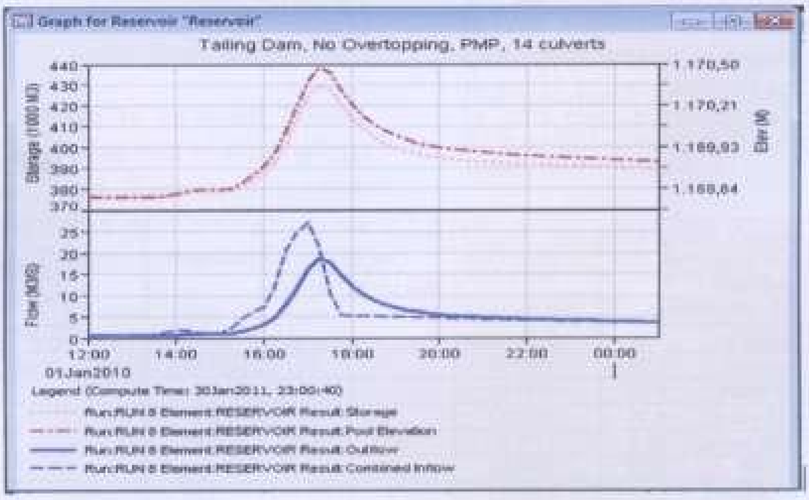

Figure 20. Reservoir Condition at Probable Maximum Flood / PMF (no overspill), Scenario 2

4.4 Scenario 3

Objective of this scenario is to change the land-use from brush of bad hydrological condition into brush of good hydrological conditions (less than 25% of open space) or woods of good hydrological conditions, see Table 4. By adapting scenario 2 (14 culverts), inflow (Probable Maximum Flood) is changed because of the change of land-use. The curve number of 77 is changed to 65 for brush and 70 for woods. By increasing the hydrological conditions of brush, maximum water level will be 1170.41 or decreasing 7 cm before the change of land-use.

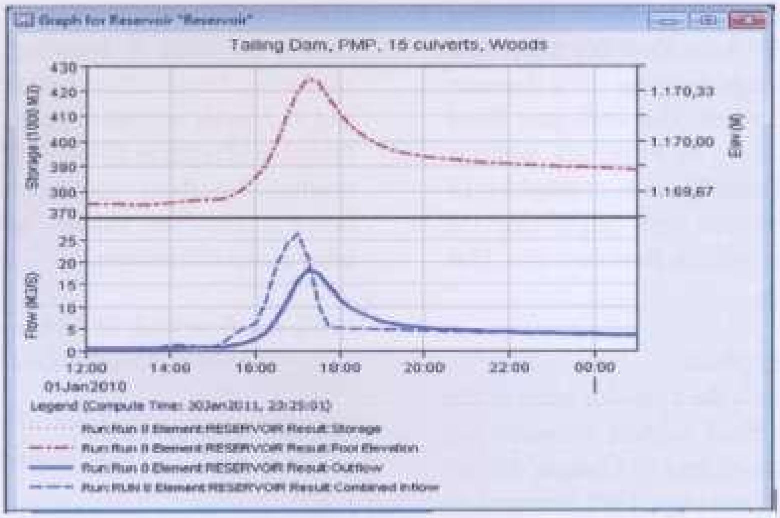

Figure 21. Reservoir Condition at Probable Maximum Flood / PMF (no overspill), Scenario

4.5 Scenario 4

If outflow is maintained to flow through 4 culverts, dam crest is to be heighten in order to prevent overspill. From the trial and error test can be concluded that elevation of the dam crest has to be 1171.2 so that the Probable Maximum Flood/PMF can be stored in the reservoir at maximum level of 1171.12 indicating an increase of height of 62 cm not including the freeboard of 75 cm. If the freeboard is considered, dam crest of 1171.12 + 0.75 will be similar with 1171.87 or increasing 1171.87 1170.5 = 1.37m.

4.6 Summary

Table 5 summarizes that all hydrological parameters in the reservoir (inflow, outflow, water level and volume storage) at critical point will be the maximum or peak.

Table 5 Summary of the Rainfall-Runoff model results for various scenarios

	Return Period (Rainfall)	Peak Inflow	Reservoir			Peak Outflow	Notes
			Max Water Level	Overtopping			
				Max Level	Peak Disc.		
		m3/s	m	m	m3/s	m3/s	
Scenario 0	2 years	1.59	1169.735			0.62	4 culverts
	5 years	2.55	1169.79			0.69	
	20 years	4.98	1169.93			1.51	
	100 years	8,48	1170.12			2.78	
	1000 years	16.1	1170.51	0.022	0.01	5.65	
	PMP	27.2	1170.68	0.18	18	24.38	
Scenario 1	1000 years	16.1	1170.42			6.28	5 culverts
	PMP	27.2	1170.66	0.16	15.8	23.81	
Scenario 2	PMP	27.2	1170.48			18.7	14 culverts
Scenario 3	PMP	27.2	1170.38			17.9	14 culverts +brush
			1170.41			18	14 culverts + woods
Scenario 4	PMP	27.2	1171.12			8.45	dam crest inceases to 1171.2

The large difference between outflow and inflow shows a significant role of flood storage, resulting a small outflow. For a better illustration see Scenario 0 for the flood of 2-year return period to 1000-year return period. With the Probable Maximum Flood/PMF, storage function will decrease and outflow increase. The 1000-year flood can only be avoided by 5 culverts, whereas Probable Maximum Flood is avoided by 14 culverts or 4 culverts with heightening the dam crest 62cm without freeboard or 1.37m with freeboard.

V. Verification phase

This phase shall provide input of the most probable flood highest elevation for other areas as developed by Creager, Meyer or Herschy & Fairbridge, 1998 (referred to Liongson, 2003). Creager is the most known compared to the others, but this source is not suitable to be applied in small catchment areas (less than 1km2) like Tailing Dams. Thus, the other two sources were applied. These various approaches were measured as shown on Table 6 resulting a Probable Maximum Flood inflow between 18.2 m3/s and 43.6 m3/s with average 30.5 m3/s. The Probable Maximum Flood/PMF , 27.2 m3/s, resulted by these measurements ranges between these two values and thus, with other words still acceptable.

Table 6 Inflow Peak of Probable Maximum Flood in Penjalin Reservoir

PMF (m^3/s)	Constant (C)	Source
18,2		Q = 90*A (Harshy and Fairbridge)
43,6	97	C*A^0.5 (Modified Meyer)

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Figure 4. Hydrological Map of Tailing Dam and Surroundings

Figure 5. Hydro-geological Map

a. Prediction phase:
   i. Yearly maximum daily rainfall series of several rainfall stations for the calculation of design rainfall of various return periods of rainfall stations in the surroundings of the Tailing Dam
   ii. Design rainfall isohyetal map of various periods in compliance with the structure design specification (2 years; 5 years; 20 years; 100 years; 1000 years and Probable Maximum Precipitation or PMP)

II. Rainfall Analysis

2.1 Rainfall Data Collection

Rainfall data available consist of the yearly maximum daily rainfall data collected from some rainfall stations in the surroundings of proposed Tailing Dam. Badan Meteorologi, Klimatologi dan Geofisika (BMKG)/ Meteorological, Climatologic and Geo-physical Agency collected for the Lampung province 11 (eleven) rainfall stations for the recording of yearly maximum daily rainfall from 1964 to 2008. One station (Kota Agung) had collected data of only 14 (fourteen) years, on the contrary another station (Pringsewu) collected data for a period of 45 (forty-five) years. The rainfall station Sri Kuncoro is not sufficient enough to represent the actual rainfall at the Tailing Dam, and some other stations like Podorejo and Air Naningan showed also an influence on the rainfall in the area.

Data availability is depicted on Table 1 below.

Table 1 Data Availability

Name	No Sta.	Location		Data Availability	Availability of data (year)	Yearly rainfall (mm)
		Latitude	Longitudinal			
Air Naningan	R067	5.12.42	104.36.39	1975 - 2008; 2003-2005 not filled	32	2416
Banyuwangi	R018	5.16.34	104.53.23	1972 - 2008	37	1827
Pematang Nebak	R040	5.31.02	104.52.03	1974 - 2008	35	1497
Pringsewu	R006	5.21.09	104.57.46	1964 - 2008	45	1746
Srikuncoro	R042			1975 - 2003	29	2432
Kota agung	232	5.48	104.61	1956 - 1984; 1965-1977 not filled	14	2424
Way Harong	R072	5.15	104.45	1976 - 2008	33	2338
Banjar Agung	R011	5.22.02	104.49.06	1969 - 2008	40	1554
Podorejo	230B	5.35	105.83	1980 - 2008	29	1701
Pajaresuk	230E	5.35	104.60	1980 - 2008	29	1717
Gisting	231A	5.37	104.78	1986 - 2008	22	2636

2.2 Frequency Analysis

Frequency analysis done by GEV (Generalized Extreme Value) method based on results of a previous study shows that GEV is the most appropriate method to be applied in Indonesia (Fransisca Mulyantari, Dr, Ir, M.Eng).

Results of the frequency analysis are shown on table 2.

Table 2 Design rainfall of various return periods

Return period (year)	Design Rainfall (mm)										
	Name of Station										
	Air Nan.	Banyu wangi	Pmtang Nebak	Pring sewu	Srikun coro	Kota agung	Way Harong	Bandjar agung	Podo rejo	Paja resuk	Gisting
PMP	456.40	465.72	632.81	539.60	658.67	467.53	436.61	668.91	446.64	567.63	683.22
1000	279.65	175.98	308.45	152.96	432.28	210.94	212.87	216.78	147.86	205.53	291.9
100	191.92	143.51	209.89	142.83	261.88	187.83	163.81	174.85	133.51	168.22	224.7
20	145.16	118.95	153.57	130.03	181.77	167.66	131.92	140.22	119.02	139.28	179.15
5	111.33	95.57	110.56	111.69	129.20	146.14	104.97	104.86	101.66	111.18	139.38
2	89.66	76.71	81.72	90.87	98.19	127.05	85.30	74.83	84.69	88.13	109.55

Kota Agung station shall further not be used because of its short data availability which may cause a deviation of data particularly for 2 and 5 years return period.

2.3 Basin Rainfall

Basin rainfall refers to the average rainfall in study area obtained from point rainfall Table 2 by approach of an Isohyetal map shown on Figure 6 to Figure 11.

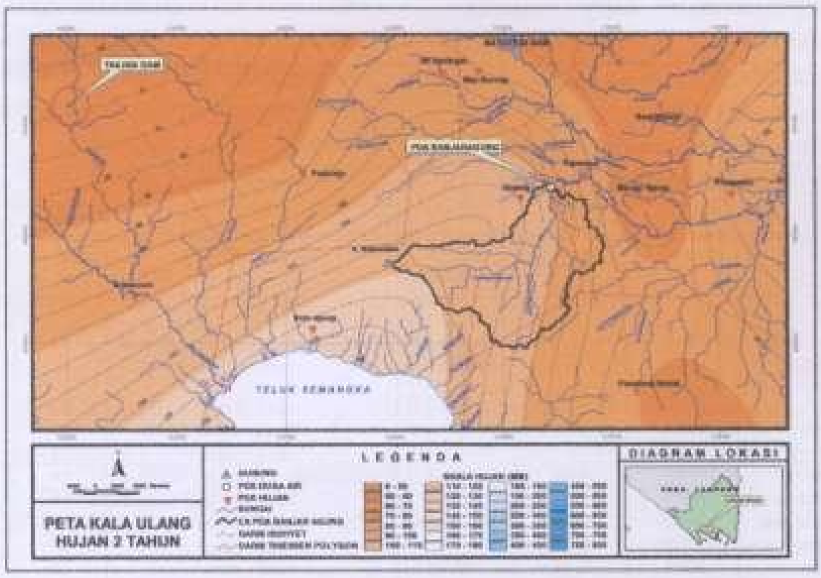

Figure 6 . Isohyetal Map for 2 Years Design Rainfall

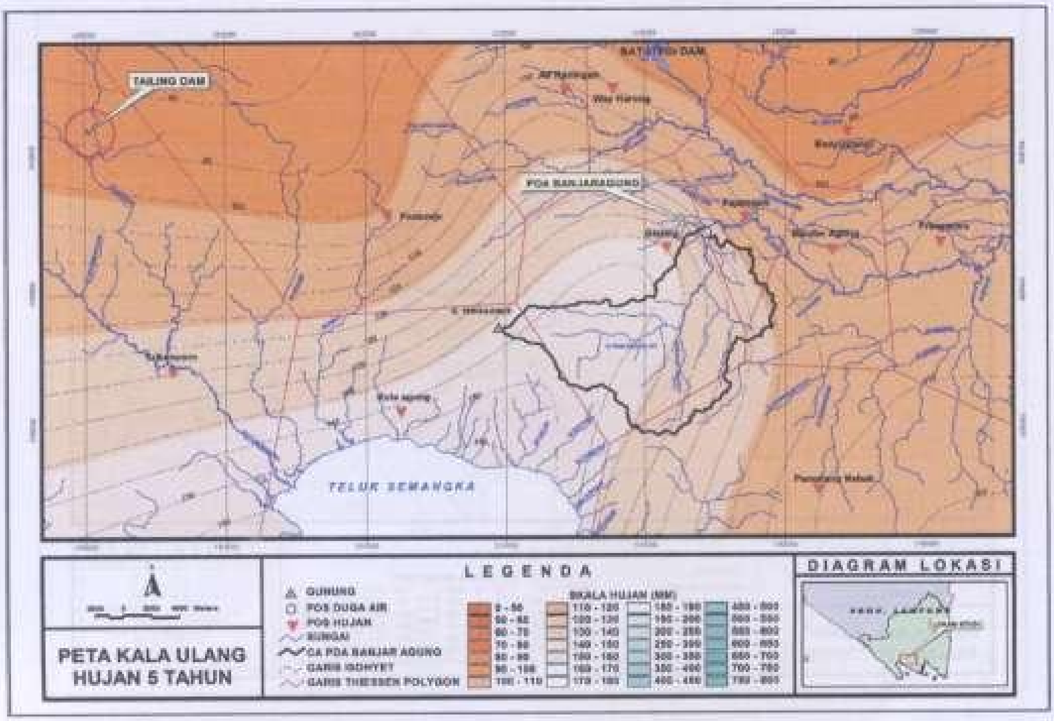

Figure 7. Isohyetal Map for 5 Years Design Rainfall

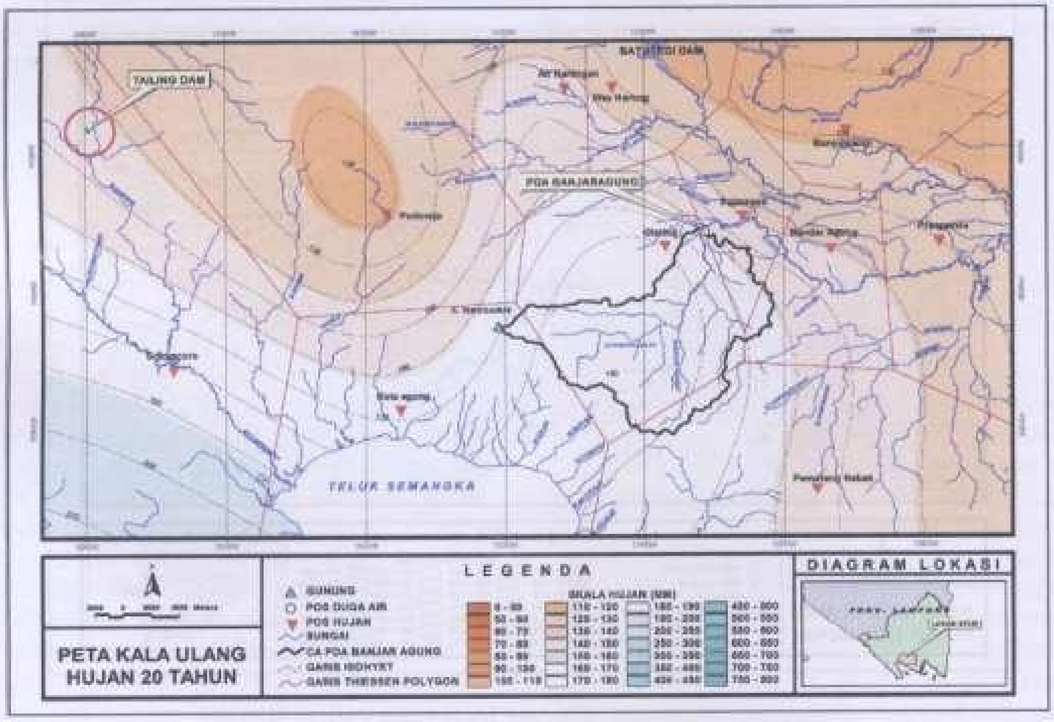

Figure 8 . Isohyetal Map for 20 Years Design Rainfall

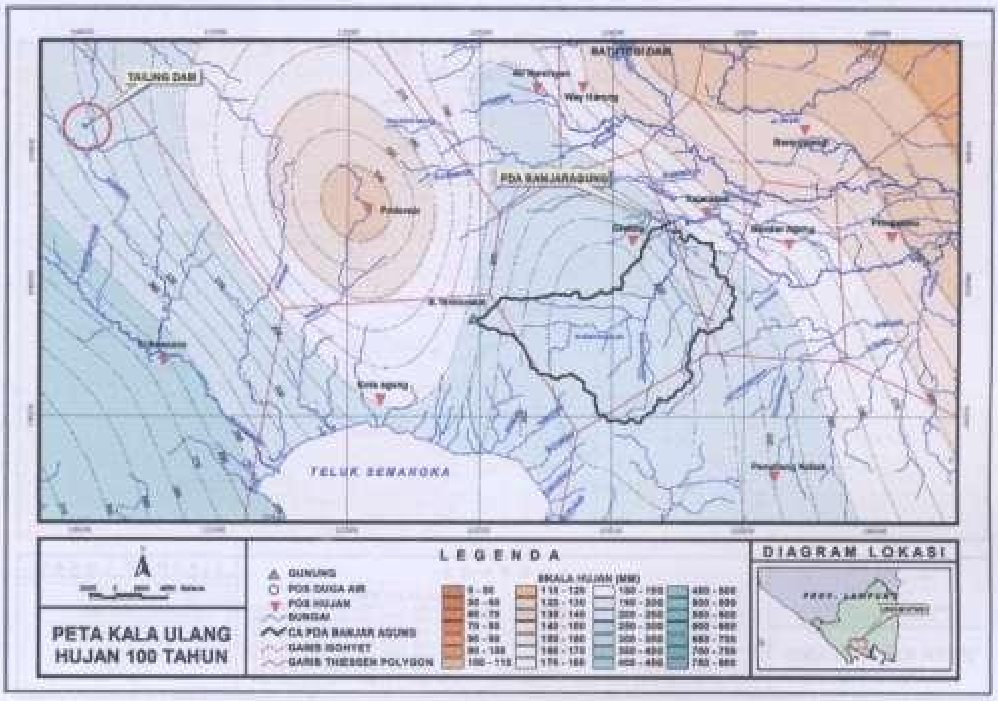

Figure 9 . Isohyetal Map for 100 Years Design Rainfall

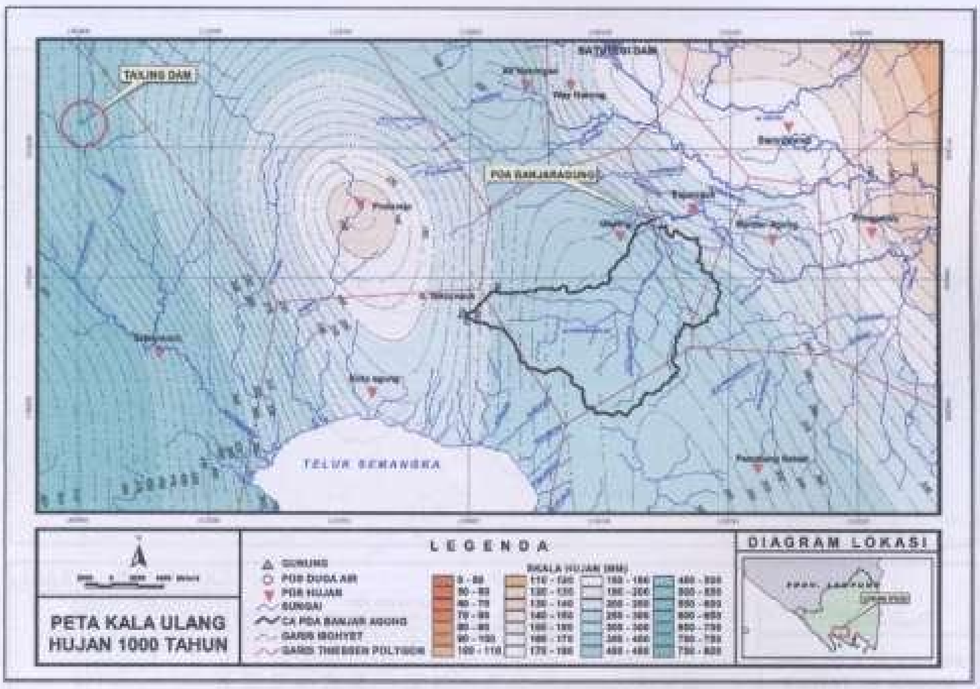

Figure 10. Isohyetal Map for 1000 Years Design Rainfall

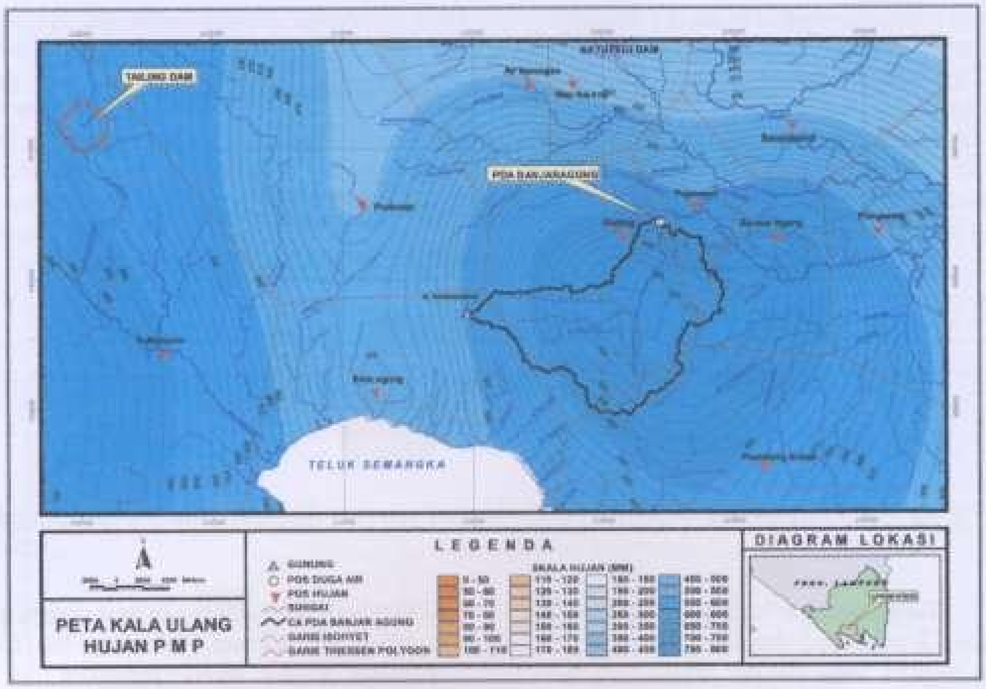

Figure 11. Isohyetal Map for Probable Maximum Precipitation (PMP)

Thus, based on above isohyetal maps, a series of design rainfall in Tailing Dam were obtained, as shown on Table 3.

Table 3 Basin Rainfall for Tailing Dam

Design Rainfall (mm/day)					
2 year	5 year	20 year	100 year	1000 year	PMP
64.1	93.7	144.3	222.5	391.8	641.1

2.4 Temporal Distribution

Daily rainfall is to be distributed into hourly rainfall, and even for very small catchment areas like the Tailing Dam, it is to be distributed into quarterly hour/15 minutes rainfall. If automatic rainfall stations are available, distribution is commonly carried out by Intensity Duration Frequency/IDF curve. Unfortunately, an automatic rainfall station was not found in the study area and therefore the empiric equation (Adidarma, 2008) was used to draw the IDF curve representing the function of average rainfall and a 10-year design rainfall calculated from yearly maximum daily rainfall data series.

I. Model Parameters

3.1 Topographical Analysis

Topographical analysis is the most important part of the HEC HMS (Hydrologic Engineering Centre-Hydrologic Modelling System) Model because flow condition is influenced by land slope and elevation in such way that ridge points can be determined and boundaries of sub-catchments delineated . The role of topographical analysis involving ARC VIEW and Geo-HMS is very substantial for the support of catchment parameter reading i.e. catchment area, river length, land slope even average rainfall, land cover, and soil type of each grid or sub-catchment can be detected by this soft ware.

Framework of the topographical analysis can be seen on Figure 12 below.

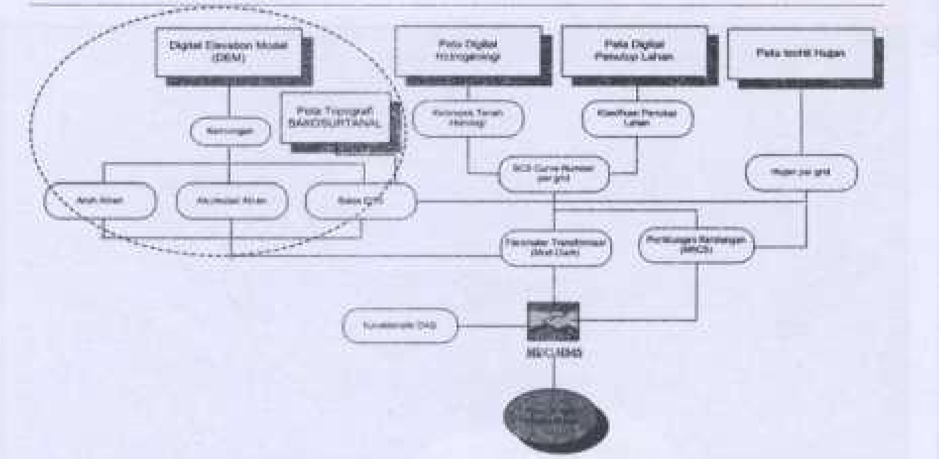

Figure 12. Framework of HEC-HMS Model (circles illustrate the topographical analysis)

Topographical analysis results on Figure 12 produced the topographical and slope map as basis for the division of sub-catchments, and run as an overall cathment formation. Each sub-catchment consists of 30m x 30m grids which are the main elements for the reading of sub-catchment topographical characteristics.

3.2 Curve Number

Floods are very much influenced by direct runoff representing the total of surface and sub-surface flow resulted by the deduction of total rainfall and infiltration. The infiltration rate depends also the soil type and land cover so that both parameters can be converted into numbers or indexes, therefore the Curve Number (CN) shall function as the combination of soil type and land cover (see Figure 13). The Hydrological Soil Group is divided into 4 (four) groups: soil type A (high infiltration), B (moderate infiltration), C (small infiltration), and D (very small infiltration). These soil types were derived from the Hydro-geological map where description about lithological composition and its permeability is re-classified into Hydrological Soil Group.

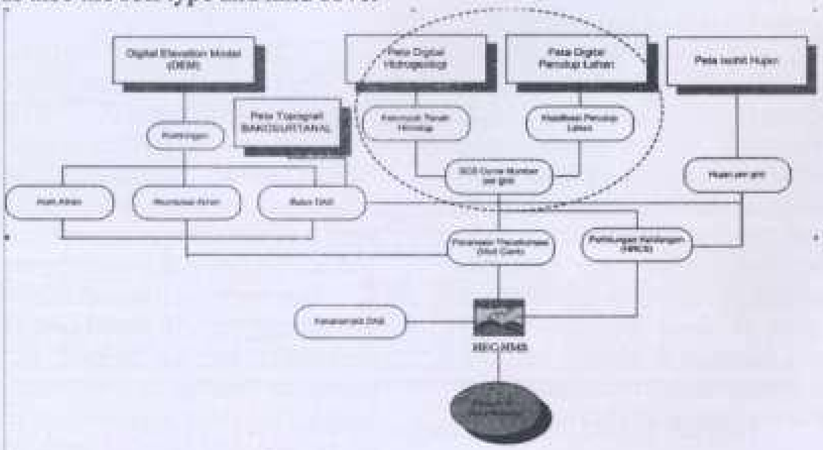

Figure 13. Framework of HEC-HMS Model (circles illustrate the Curve Number analysis)

The Curve Number is a substantial element to illustrate the flood runoff volume if land cover had changed. In a sub-catchment, the type of soil and land cover is very heterogeneous and both boundaries are not similar, and the average Curve Number is to be calculated from each grid. This can only be done by application of GIS software such as Arc View and HEC GeoHMS. Calibration is done on the CN analysis results of 21 sub-catchments of the Banjaragung catchment (Figure 14) so that these procedures can be applied to the Tailing Dam which comprises only one sub-catchment. Lithology of the Tailing Dam , see Figure 5, including low to moderate permeability, if transferred to the Hydrological Soil Group inclusive Group C which is combined with brush land cover (poor hydrological conditions) will result a Curve Number of 77, see Table 4.

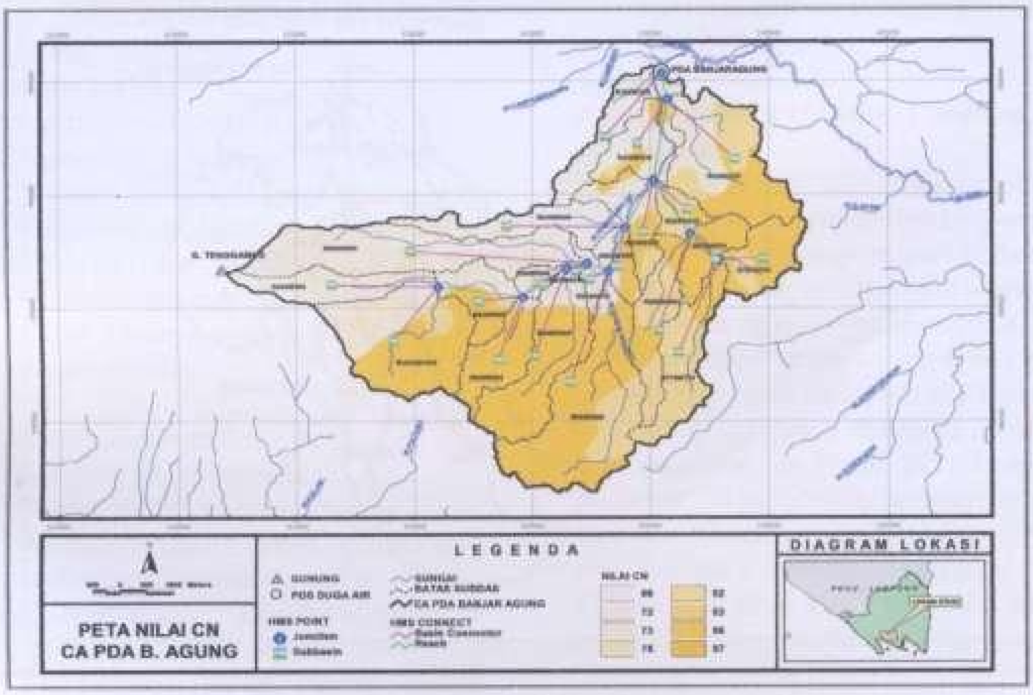

Figure 14. Map of Curve Number for Banjaragung Catchment Area

Table 4 Table of Curve Number for Tailing Dam

Cover type	Hydrological Condition	Hydrological Group			
		A	B	C	D
Brush brush-weed-grass mixture, with brush the major element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77

IV. Calibration Results

Reliability of calibration results is determined by the availability of hydrological data and details of land cover, topographical and Digital Elevation Model maps. The Banjaragung catchment with 21 (twenty-one) sub-catchments has CN values in accordance with soil type, land-use and various precipitation rates as shown on the Isohyetal map on Figure 6 and 11. Configuration of the catchment system is depicted on Figure 15. Baseflow parameters comprising Initial Abstraction, Recession Constant and Ratio to Peak are the same for all sub-catchments. Reconstitution of 2 Flood Hydrographs for the 1981 and 1982 events are shown by graphs on Figure 16 with 15 minutes interval considering the small catchment area.

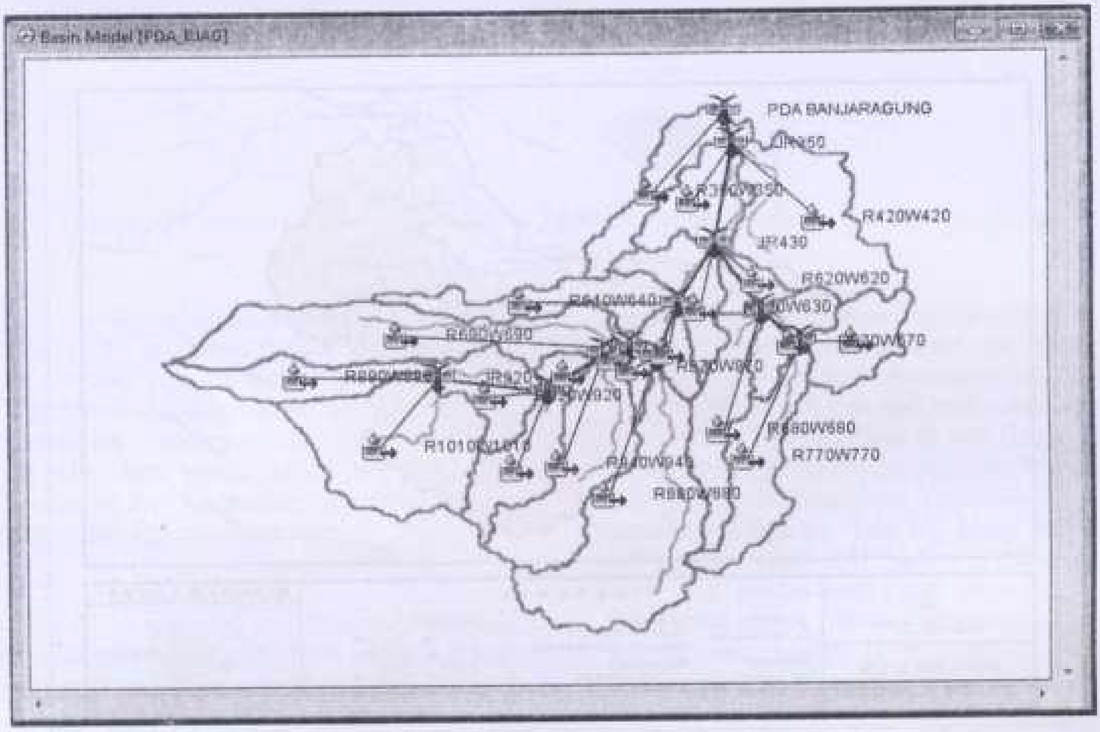

Figure 15. Basin Model of Banjaragung using HEC-HMS

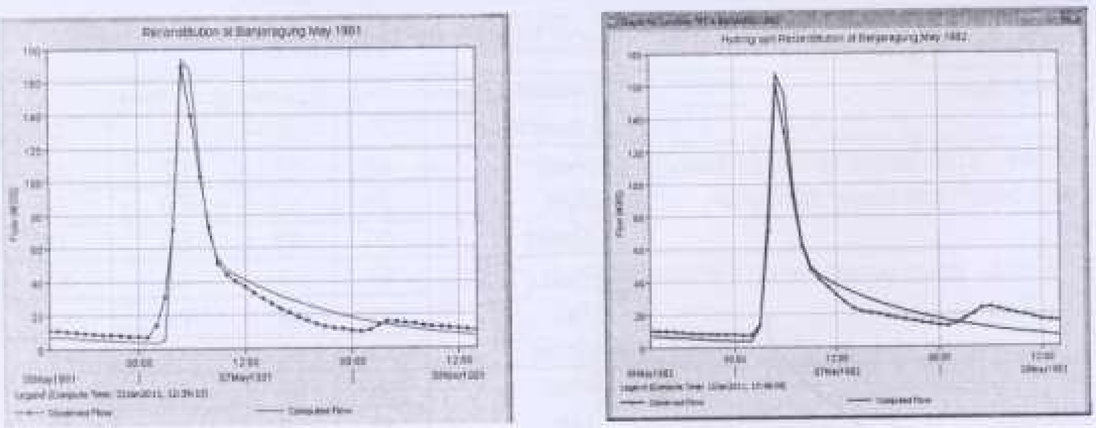

Figure 16. Reconstitution of Flood Hydrograph at Banjaragung for May 1981 and May 1982