HYDROLOGICAL ASPECT OF BATANG ALAI WEIR WATERSHED DUE TO LAND USE CHANGES INTO MINING AREAS

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ABSTRACT

The policy of the Ministry of Energy and Mineral Resources that provides permits for mining production activities for PT. MCM in the Batang Alai River area has an impact on the hydrology of the area. This study will discuss the changes in land use in the Batang Alai River area, Batang Alai Timur District, Hulu Sungai Tengah to the aspects of high flow and low flow hydrology.

The research method used is manual calculation with rational methods for high flow hydrology and calculations using the ArcSWAT 2012.10.1.18 for low flow hydrology. The data needed in the processing are rainfall data, DEM data, daily discharge data, climatology data, land use data, land use change data, and Batang Alai watershed data.

The results of the study were that the ratio of peak discharge of land use was changed to the mining area and land use was not converted into a mining area for high flow hydrology calculations. There is an increase in plan flood discharge in the Batang Alai River if there is a change in land use into a mining area, the design flood discharge always increases in each period. Whereas for low flow hydrology is the comparison between the daily use of land use converted into a mining area and land use is not converted into a mining area, then the daily discharge results are calculated for the availability of water. The results of low-flow hydrological modeling are categorized as good and have high influence based on the Nash-Sutcliffe efficiency value grouping and the coefficient of determination, and water availability decreases if land use is converted into a mining area.

Keywords: Batang Alai River, Hydrology, Water Availability

I. Introduction

The policy of the Ministry of Energy and Mineral Resources (ESDM) which issued a decision number 441.K / 30 / DJB / 2017 concerning Adjustment of the Phase of Activity of the Work Agreement on Coal Mining Exploitation (PKP2B) PT. Mantimin Coal Mining (MCM), dated December 4, 2017, has a direct and indirect impact on the environmental ecosystem in the upstream of the Batang Alai Weir, Batang Alai Timur District, Hulu Sungai Tengah.

Changes in land use patterns (mining activities) can cause changes in ecosystems, especially in upstream areas, can have an impact on downstream areas in the form of changes in fluctuations in water discharge and sediment content and have an impact on decreasing regional water availability due to increased seasonal fluctuations with symptoms of flooding and drought. Increasingly extreme, and the size of the watershed as well as the capacity of watershed storage systems, both on the surface (plants, rice fields, swamps, lakes/reservoirs, and rivers) and subsurface (soil and water).

This research was conducted to assess the impact of changes in land use into mining areas and to analyze their effects on the hydrological conditions that occur. The hydrological model was examined for aspects of high flow and low flow hydrology. For high flow hydrology using the maximum rainfall plan calculation with the calculation of the rational method, the results of the calculation are in the form of flood discharge according to each period. Whereas for low flow hydrology applying SWAT model in Batang Alai watershed with output in the form of daily discharge and surface runoff, the SWAT model results can be used to analyze groundwater availability in the watershed if there is a change in land use into a mining area.

1.1 Formulation of the Problem

The things discussed in this study are as follows:

1. What is the impact if there is a change in land use (being a mining area) in the upper reaches of the Batang Alai Weir against the hydrological aspects of the area's high flow?

2. What is the impact if there is a change in land use (being a mining area) in the upper reaches of the Batang Alai Weir against the hydrological aspects of the area's low flow?

1.2 Research Purposes

The objectives of this study are:

1. Knowing the impact of land use change (being a mining area) in the upper reaches of the Batang Alai Weir on the hydrological aspects of the area's high flow (design flood discharge with return period).

2. Knowing the impact if there is a change in land use (to become a mining area) in the upper reaches of the Batang Alai Weir to the hydrological aspects of the area's low flow (dependable flow).

1.3 Scope of the Problem

The problem limits in this study are as follows:

1. River data collection points are in Batang Alai Timur District, Hulu Sungai Tengah (HST).
2. It doesn't count the capacity of the Batang Alai River.
3. Data collection is done by collecting hydrological data and spatial data.
4. It doesn't load the effects of erosion and sedimentation.

II. Literature Review

2.1 Definition of Hydrological Cycle

The hydrological cycle or cycle is the journey of water from the sea surface to the atmosphere than to the surface of the land, and back to the sea which never stops, the water will be temporarily held in rivers, lakes or reservoirs, and so that it can be used by humans or living things others (Asdak, 2004).

2.2 High Flow Hydrological Analysis

High flow hydrological analysis aims to determine the designed flood discharge in a watershed. Flood discharge plans can be interpreted as maximum discharge during maximum rainfall if there is not enough discharge data for analysis. Rational methods are the method most widely used for flow analysis from small watersheds. This method has a special application in urban drainage planning where peak flow calculations are used for rainwater discharge designs and small drainage structures.

2.3 Maximum Rainfall Analysis

Analysis of rainfall data is intended to determine the amount of rainfall design. This analysis includes several phases of calculation, including the rain count of the watershed area followed by an analysis of the frequency and curve of rain intensity. By calculating statistical parameters such as average values, standard deviations, the coefficient of variation, and skewness

coefficients from existing data and followed by statistical tests, the appropriate probability of rain distribution can be determined. There are several distributions in the hydrological analysis including Normal distribution, Log-Normal, Extreme value Type I (Gumbel), and Log-Pearson III.

2.4 Design Rainfall Analysis with Rational Methods

Rational methods are widely used to estimate peak discharge caused by heavy rainfall in small catchments. A watershed is called small if the distribution of rain can be considered uniform in space and time, and usually, the duration of rain exceeds the time of concentration. The rational method is based on the following equation:

$$Q = 0.2778 \, CIA \qquad\qquad (2.1)$$

With:

Q   = Discharge (m^3 / sec)

C   = Runoff Coefficient (without dimensions)

I   = Rainfall Intensity with T Year Return Period (mm / hour)

A   = Area of drainage area (km^2)

2.5 Low Flow Hydrological Analysis

Low flow hydrological analysis is a model that can simulate rain-flow transformations over a long period, rather than the period used for flood analysis. Specific models are needed in the study of low flow characteristics with an approach to the complexity of systems that exist in a watershed, then the models that are suitable for use are Even Models and Continuous Models.

2.6 Analysis of Water Availability

Changes in the relatively broad land use in the watershed area can disrupt the hydrological cycle. One method that is used to be able to find out the availability of groundwater in a watershed by comparing the value of Q_{max} / Q_{min} per period or also called the calculation of the Q_{max} / Q_{min} ratio. Therefore to develop a comprehensive watershed management strategy that takes into account the parameters of a watershed, a hydrological model is needed that can present the hydrological cycle of a watershed.

2.7 SWAT (Soil Water and Assessment Tool)

One GIS-based software that can be used to analyze hydrological conditions is SWAT (Soil and Water Assessment Tools). The SWAT model is an agro-hydrological watershed scale model developed by the Agricultural Research Services of the United States Department of Agriculture (USDA). SWAT is a hydrological model that is widely used to evaluate the effects of climate change, land use, and land management on hydrological characteristics.

The hydrological cycle at the land phase simulated by SWAT is based on the water balance equation (Equation 2.2):

$$SW_t = SW_0 + \sum_{t=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \qquad (2.2)$$

Information:

SW_t = Final soil water content (mm).

SW_0 = Initial groundwater content on day i (mm).

R_{day} = Amount of precipitation on day i (mm).

Q_{surf} = Amount of surface flow on day i (mm).

E_a = Amount of evapotranspiration on day i (mm).

W_{seep} = The amount of water entering the vadose zone on the soil profile of day i (mm).

Q_{gw} = Amount of water returning to groundwater on day i (mm).

III. Research Methods

3.1 General

The study was carried out for approximately 6 (six) months (January-June) in the Batang Alai watershed, which included Batang Alai Timur District, with an area of the watershed is 323,303 km^2.

This study uses primary and secondary data derived from several government agencies and related institutions including:

1. Rainfall data.

2. DEM data.

3. Daily discharge data.

4. Climatology data.

5. Land use data.

6. Land use changes data.

3.2 Research Procedures

The steps taken in this research procedure are:

1. Research procedure for regional high flow hydrology:

➢ Prepare data to be processed

➢ Determine the watershed boundaries.

➢ Calculate the hydrological analysis. This analysis is done to get the plan discharged.

➢ Determine runoff discharge using rational methods. Perform calculation of peak discharge with watershed without any changes in land use into mining areas with watersheds with changes in land use into mining areas.

➢ Conclude from the results of the comparison of the discharge calculation.

2. Research procedures for regional low-flow hydrology:

➢ Prepare data to be processed

➢ Modeling with SWAT software (Soil and Water Assessment Tool):

✓ Preparation of input data:

land data, land use, climate, and DEM prepared in a database format.

✓ Delineate the watersheds.

✓ Establishment of HRU (Hydrology Response Unit Analysis) with input data on land use maps, topographic maps, and maps as well as data on the physical properties of soil.

✓ Climate database, by making climate generator data (weather data generator).

✓ Unification of HRU with climate data, this process is carried out after the analysis is formed.

✓ SWAT simulation is done by selecting the time to be simulated in Run SWAT mode.

➢ Calibration and validation of the SWAT model using daily discharge data.

➢ Analysis of water availability.

➢ Calculating water availability between watersheds that have not undergone land use change to become mines with watersheds that have experienced land use change into mining areas.

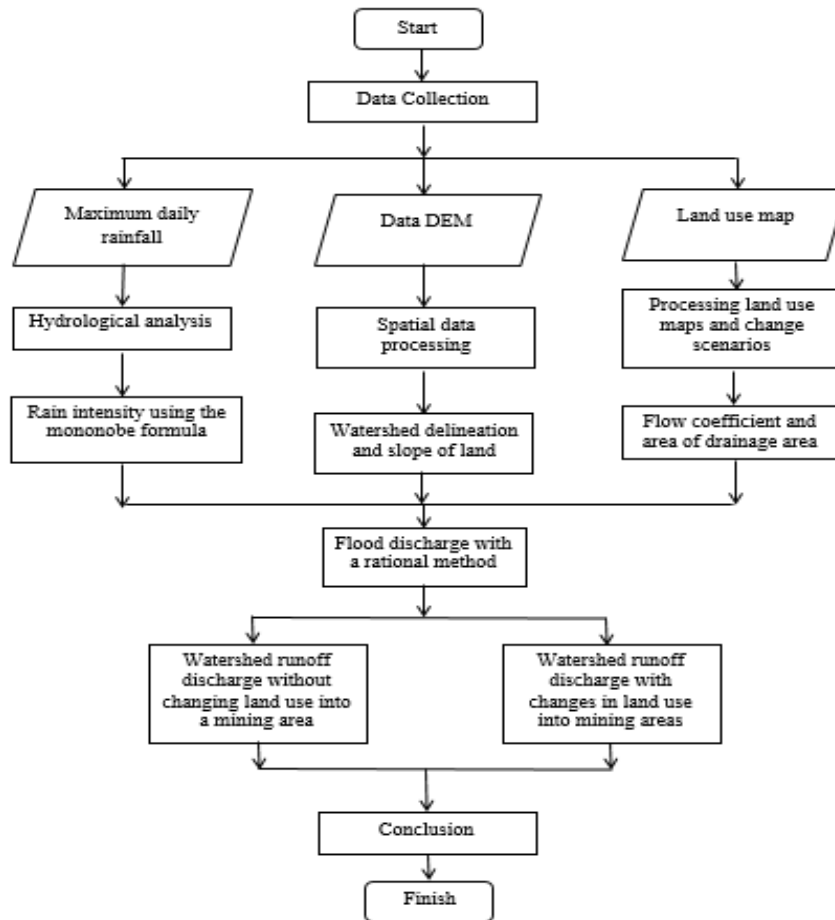➢ Conclude from the results of the comparison of the analysis of water availability.

Figure 3.1 Flow Chart of High Flow Hydrology
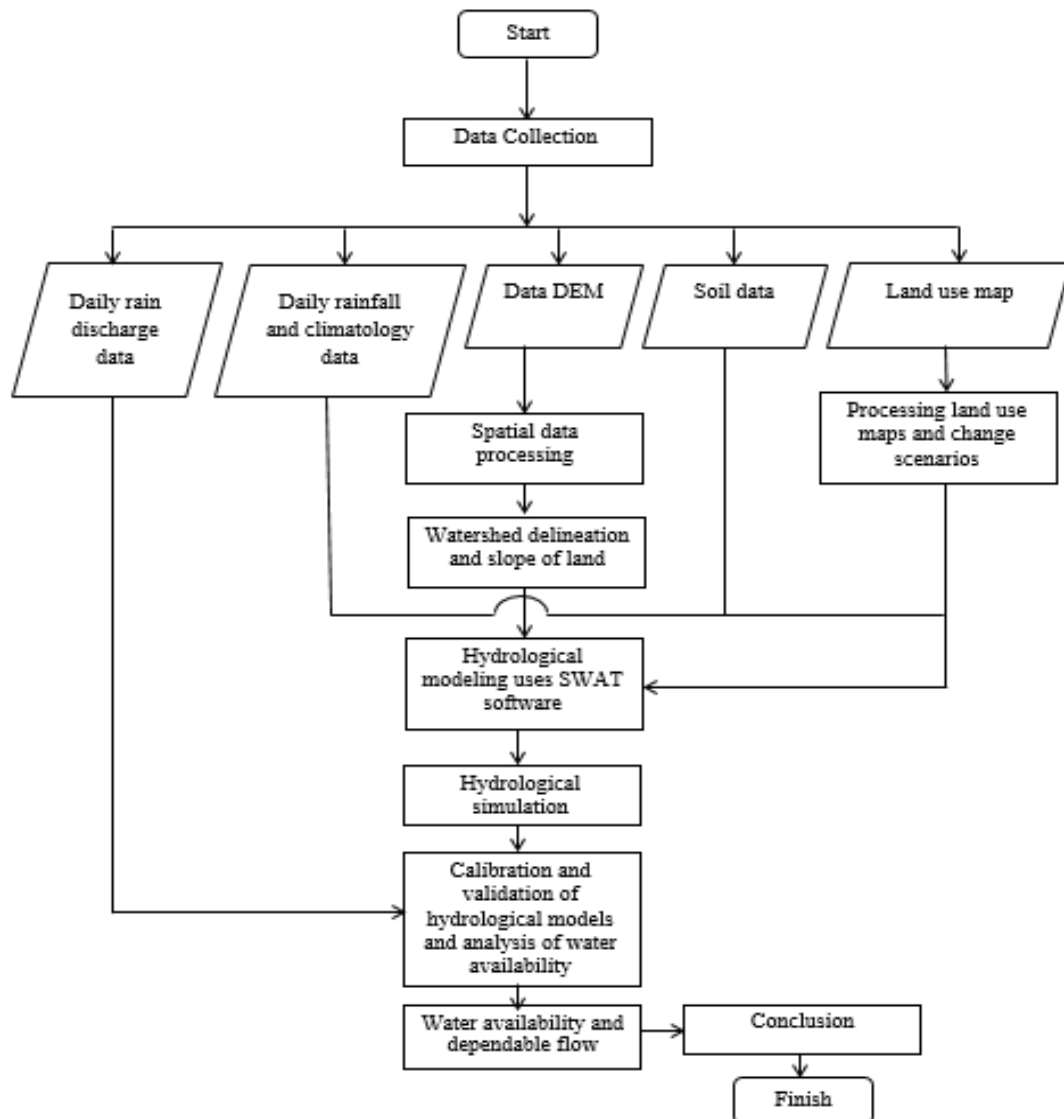
Figure 3.2 Flow Chart of Low Flow Hydrology

IV. RESULTS AND DISCUSSION

4.1 High Flow Hydrology Analysis

4.1.1 Frequency Analysis

This frequency analysis is done using the probability distribution theory – rainfall data obtained in the form of maximum daily rainfall data for 17 years (2000-2016).

- Maximum Rainfall Calculation

The analytical methods used in this analysis are the Normal Distribution Method, Gumbel, Log-Normal, and Log Pearson Type III.

Table 4.1 Results of Maximum Rainfall Analysis (mm) Calculation

X	Normal	Gumbel	Log-Normal	Log Pearson Type III
2	114,3882	108,3661	108,3270	101,2618
5	149,1966	153,4665	143,0299	125,7235
10	167,4295	203,9601	165,4419	147,4208
20	182,3474	211,9883	186,3673	168,7368
25	185,1790	218,1696	190,6285	180,5242
50	199,3372	249,0724	213,4411	203,9445
100	210,9400	276,8626	234,1575	247,4252

Source: Calculation Results

- **Probability Distribution Test (Distribution Type Testing)**

  To strengthen the selection of the type of distribution to be used and deemed more suitable for a series of data, testing is carried out, which is commonly called: "Matching Test" ("Testing of the goodness of fit"). The test is carried out after describing the probability line on probability paper. The types of testing methods that are often carried out are the Chi-Square test and the Smirnov-Kolmogorov test.

Table 4.2 Recapitulation of Chi-Square Test for 4 Probability Distributions

Probability Distributions	X^2	X^2_{cr}	Explanation
Normal	5,2353	7,8147	accepted
Log-Normal	5,2353	7,8147	accepted
Gumbel	3,8235	7,8147	accepted
Log Pearson Type III	37,7059	7,8147	not accepted

Source: Calculation Results

Table 4.3 Recapitulation of the Smirnov-Kolmogorov Test

Probability Distributions	ΔP maximum	ΔP critical	Explanation
Normal	0,20	0,32	accepted
Log-Normal	0,17	0,32	accepted
Gumbel	0,14	0,32	accepted
Log Pearson Type III	0,17	0,32	accepted

Source: Calculation Results

From the calculations above, then in the calculation of rainfall frequency, the Normal Probability Distribution method is used because it can be accepted by statistical parameters, Chi-Square test, and Smirnov-Kolmogorov test.

4.1.2 Design flood discharge Calculation

It was carried out twice the calculation of peak discharge, first with a watershed with no changes in land use to become a mining area. And the second calculation with the watershed that has been converted into a mining area.

- **Calculation of Concentration Time**

  Concentration-time (tc) is the length of rain that will cause flood discharge, and t is calculated by Kirpich formula (I Made Kamiana, 2010).

$$\text{tc} = \left(\frac{0{,}87 \text{ x } L^2}{1000 \text{ x } S}\right)^{0{,}385} \qquad (4.1)$$

  Information:

  Tc   = Time of concentration (hours).

  L   = The length of the trajectory of the water from the farthest point to the point being reviewed (km).

  S   = The slope of the average area of water trajectory.

- **Calculation of Rainfall Plan Intensity**

  Rainfall plan intensity is obtained from the method using the Mononobe Equation. In this calculation, the maximum rainfall used is the maximum rainfall from the Normal Distribution Method with a 2-year return period.

$$I = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{2/3} \qquad (4.2)$$

  Information:

  I   = Rain intensity (mm / hour).

  R_{24} = Daily rainfall (mm).

  t   = Time of concentration (hours).

- **Runoff Coefficient**

  Before calculating the discharge, first, determine the runoff coefficient (C) in the Batang Alai watershed. From Bing 2016 image processing, land use and area are obtained. The data can be described as the following table:

Table 4.4 Land Use of Batang Alai Watershed

No.	Land Use	Area Ai (km^2)
1	Forest	321,91
2	Settlements	0,294
3	Rice Field	0,53
4	Productive Land	0,569
	Total	323,303

Source: Calculation Results

- **Maximum Design Discharge Calculation**

In calculating the design discharge for the 2-year return period, the following results are obtained:

$$Q = 0,2778 \ CIA \qquad (4.3)$$

With:

Q = Discharge (m^3 / second)

C = runoff coefficient (without dimension)

I = Rainfall Intensity with Year T Return Period (mm / hour)

A = Area of Flow (km^2)

1. **Watershed without mining area**

Table 4.5 Design flood discharge Results with Rational Method

No.	Return Period (year)	$\sum$ Ai x Ci	It (mm/hour)	Discharge Q (m^3/second)
1	2	129,3565	12,7203	457,3165
2	5	129,3565	16,5912	596,4780
3	10	129,3565	18,6187	669,3721
4	20	129,3565	20,2776	729,0128
5	25	129,3565	20,5925	740,3334
6	50	129,3565	22,1670	796,9368
7	100	129,3565	23,4572	843,3240

Source: Calculation Results

2. Watershed with mining area

Table 4.6 Design flood discharge Results with Rational Method

No.	Return Period (year)	$\sum$ Ai x Ci	It (mm/hour)	Discharge Q (m^3/second)
1	2	139,169	12,7203	491,9183
2	5	139,169	16,5912	641,6091
3	10	139,169	18,6187	720,0186
4	20	139,169	20,2776	784,1718
5	25	139,169	20,5925	796,3490
6	50	139,169	22,1670	857,2352
7	100	139,169	23,4572	907,1321

Source: Calculation Results

4.2 Low Flow Hydrological Analysis

### 4.2.1 General Description of Batang Alai Watershed

Batang Alai watershed is located in Batang Alai Timur District, Hulu Sungai Tengah, and is included in the WGS 1984 UTM Zone 50S zone. The Batang Alai watershed area is 323,303 km², and the main river length is 48,816 km, where the topography is dominated by mountains in the southern and lowlands in the north. Batang Alai Weir is used as an outlet of this watershed.

4.2.2 Land Conditions

Based on the FAO soil map with a scale of 1: 5,000,000 in 1974, the type of soil found in the Batang Alai watershed consists of 2 types, namely:

Table 4.7 Classification of Batang Alai watershed soil types

Type of soil	Area (km^2)	Percentage of watershed %
Humic Acrisols	183,403	56,728
Humic Acrisols Lithic	139,900	43,272
Total	323,303	100
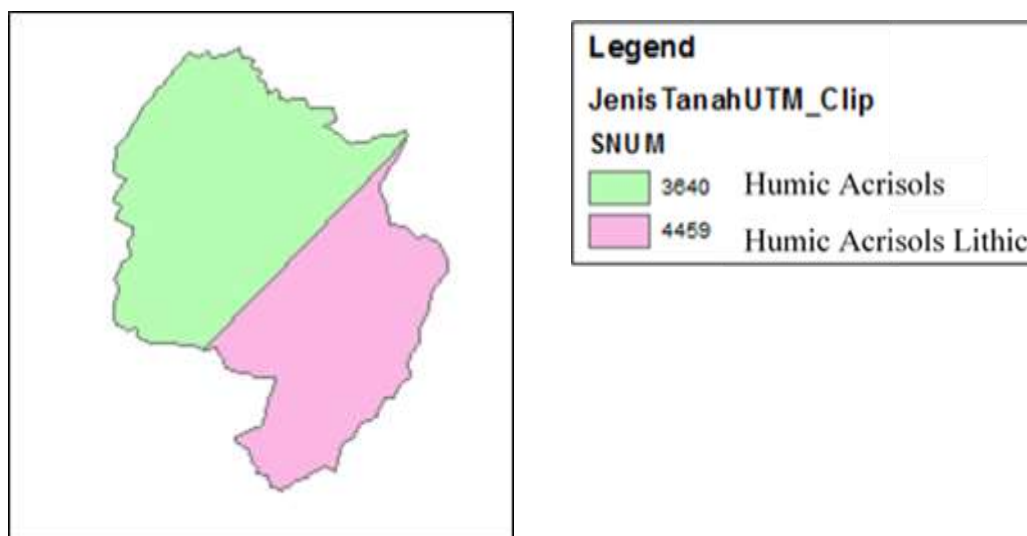
Source: FAO Soil Map 1974

Figure 4.1 Map of Soil Types

4.2.3 Land Use

In this research, Bing 2016 imagery was used as a source of land use information. Image data is classified by dividing into several types of land use for watershed conditions without/with mining areas, forests, settlements, rice fields, and productive land.

Table 4.8 Watershed Conditions without Mining Areas (Existing)

No.	Land Use	Area Ai (km^2)	Percentage of watershed %
1	Forest	321,91	99,569
2	Settlements	0,294	0,091
3	Rice Field	0,53	0,164
4	Productive Land	0,569	0,176
	Total	323,303	100

Source: Calculation Results

Table 4.9 Watershed Conditions with Mining Areas

No.	Land Use	Area Ai (km^2)	Percentage of watershed %
1	Forest	302,734	93,638
2	Settlements	0,191	0,059
3	Rice Field	0,312	0,096
4	Productive Land	0,514	0,159
5	Mines (Land without Plant)	19,551	6,047
	Total	323,303	100

Source: Calculation Results

4.2.4 Climate Data

The climate data of the research area is in the form of secondary climate data based on data records from the Global Weather Data for SWAT in 1995.

4.2.5 SWAT Analysis

In this research, a SWAT analysis using ArcSWAT 2012.10.1.18 was conducted. In this SWAT simulation, four processes were carried out, including those are:

1. the watershed delineation process,

2. establishment of a hydrological response unit (HRU),

3. SWAT data processing,

4. and the simulation process.

4.2.6 SWAT Simulation Results

Results from SWAT simulations can be displayed using SWAT Plot and Graph. Simulation output data used in this study is the surface flow and daily discharge data of the Batang Alai watershed in 1995. SWAT Plot and Graph applications can also be used to compare the discharge of simulation results with the discharge of measurement results in the field so that the model validity value can be obtained.
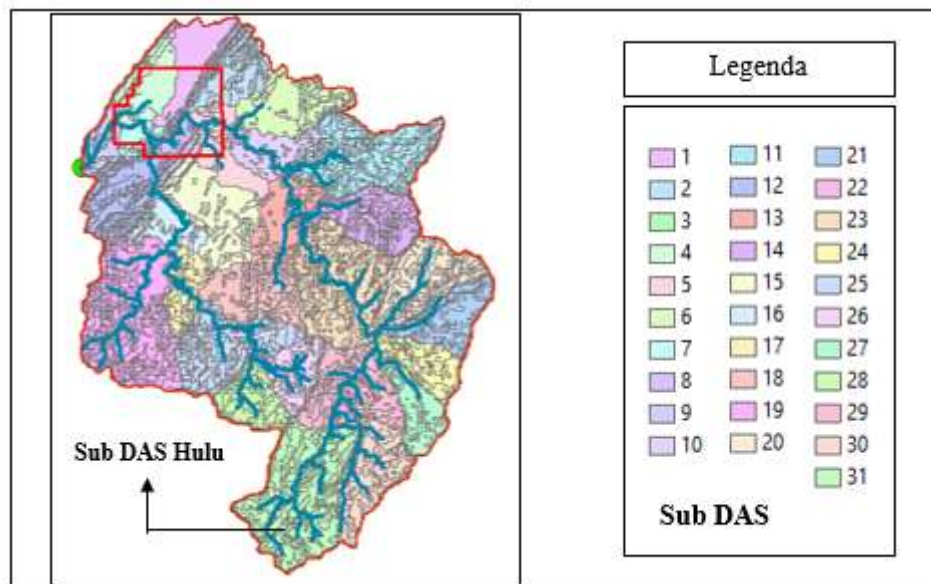

Figure 4.2 Distribution map of the Sub-watersheds in the Batang Alai watershed

Table 4.10 Alteration in surface flow accumulation (Q_{surf}) without mines and with mines in each Sub-watershed

Sub-Watershed	Surface Flow (mm)		Alteration (mm)	Alteration (%)
	without mines	with mines		
1	26.80	41.10	14.30	53.3582
2	28.40	38.30	9.90	34.8592
3	29.30	67.50	38.20	130.3754
4	28.10	50.30	22.20	79.0036
5	26.40	43.00	16.60	62.8788
6	27.90	28.00	0.10	0.3584
7	31.20	57.00	25.80	82.6923
8	29.30	59.80	30.50	104.0956
9	31.40	34.90	3.50	11.1465
10	28.50	28.60	0.10	0.3509
11	29.40	29.50	0.10	0.3401
12	29.10	31.00	1.90	6.5292
13	28.20	28.30	0.10	0.3546
14	29.50	29.60	0.10	0.3390
15	27.20	27.40	0.20	0.7353
16	27.80	27.90	0.10	0.3597
17	28.50	28.60	0.10	0.3509
18	29.00	29.10	0.10	0.3448
19	29.10	29.20	0.10	0.3436
20	29.40	29.50	0.10	0.3401
21	29.50	29.60	0.10	0.3390
22	29.40	29.50	0.10	0.3401
23	29.50	29.60	0.10	0.3390
24	29.40	29.50	0.10	0.3401
25	29.50	29.60	0.10	0.3390
26	29.40	29.60	0.20	0.6803
27	29.40	29.50	0.10	0.3401
28	29.50	29.60	0.10	0.3390
29	29.40	29.60	0.20	0.6803
30	29.40	29.50	0.10	0.3401
31	29.40	29.50	0.10	0.3401
Total	898.30	1063.70		
Average	28.9774	34.3129		

Source: Calculation Results

Table 4.11 Changes in flow discharges without mines and with mines in each
Sub-watershed

Sub-Watershed	Discharge Flow (m^3/second)		Alteration (m^3/second)	Alteration (%)
	without mines	with mines		
1	5.187	6.388	1.201	23.15
2	5.931	6.653	0.722	12.17
3	0.01581	0.0233	0.00749	47.38
4	4.572	6.244	1.672	36.57
5	156.2	157.8	1.6	1.02
6	7.006	7.019	0.013	0.19
7	246.4	251.6	5.2	2.11
8	169.7	173.8	4.1	2.42
9	254.5	261.5	7	2.75
10	144.7	145	0.3	0.21
11	15.54	15.58	0.04	0.26
12	74.78	75.1	0.32	0.43
13	125	125.3	0.3	0.24
14	10.61	10.63	0.02	0.19
15	8.018	8.034	0.016	0.20
16	58.65	58.78	0.13	0.22
17	37.01	37.09	0.08	0.22
18	7.491	7.506	0.015	0.20
19	18.14	18.18	0.04	0.22
20	11.87	11.9	0.03	0.25
21	9.481	9.501	0.02	0.21
22	21.41	21.46	0.05	0.23
23	108.5	108.7	0.2	0.18
24	66.4	66.54	0.14	0.21
25	25.7	25.75	0.05	0.19
26	6.822	6.836	0.014	0.21
27	7.445	7.46	0.015	0.20
28	6.645	6.659	0.014	0.21
29	52.08	52.19	0.11	0.21
30	12.65	12.68	0.03	0.24
31	25.22	25.27	0.05	0.20
Total	1703.6738	1727.1733		
Average	54.9572	55.7153		

Source: Calculation Results

4.2.7 SWAT Model Calibration and Validation

The calibration and validation process is carried out by comparing the daily data of the observation discharge with the simulated daily discharge data for a

certain period. The statistical method used in conducting calibration and validation is the determination coefficient model (R^2) and Nash-Sutcliffe efficiency model (E_{NS}).

$$R^2 = \left[\frac{\sum_{i=1}^{n}(Q_{Mi} - \bar{Q}_{Mi})\,(Q_{Si} - \bar{Q}_{Si})}{\sqrt{\sum_{i=1}^{n}(Q_{Mi} - \bar{Q}_{Mi})^2 \sum_{i=1}^{n} Q_{Si} - \bar{Q}_{Si}^2}}\right]^2 \qquad (4.4)$$

$$E_{NS} = 1 - \left[\frac{\sum_{i=1}^{n}(Q_{Mi} - Q_{Si})^2}{\sum_{i=1}^{n}(Q_{Mi} - \bar{Q}_{Mi})^2}\right] \qquad (4.5)$$

Information:

R^2 = Coefficient of Determination

E_{NS} = Nash-Sutcliffe Efficiency

Q_{Si} = Model simulation value

Q_{Mi} = Observation value

$\bar{Q}_{Mi}$ = Average observation value

$\bar{Q}_{Si}$ = Average Simulation value

n = Amount of data

From the calculation results obtained for watershed without mine which has been calibrated and validated, the coefficient of determination (R^2) 0,94, with $0,7 < R^2 < 1$, and Nash-Sutcliffe efficiency value 0,57, with E_{NS} $0,36 < E_{NS} < 0,75$, while for watershed with mine, the coefficient of determination (R^2) 0,91, with $0,7 < R2 < 1$, and Nash-Sutcliffe efficiency value 0.41, with $0,36 < E_{NS} < 0,75$.

So, it can be concluded that the prediction of the model is categorized as fulfilling and has a high effect based on the grouping of Nash-Sutcliffe efficiency values and the coefficient of determination. So the model can be used to simulate the desired scenario.

4.2.8 Water Availability Analysis

The method for estimating groundwater availability is by comparing the Q_{max} / Q_{min} value for each period or also called the Q_{max} / Q_{min} ratio calculation. The Q_{max} and Q_{min} values used are the output of the SWAT model. Q_{max} / Q_{min} ratio values can identify a watershed to go through critical changes. Q_{max} and Q_{min} ratio values for a watershed, are calculated by calculating the comparison value of Q_{max} and Q_{min} from the average daily debit data, then the average Q_{max} / Q_{min} ratio is calculated annually. If the Q_{max} / Q_{min} ratio is getting big, then the watershed is

increasingly critical, and it can be concluded that there is a tendency for water to experience a decrease in availability.

Table 4.12 Calculation Results of the Ratio Value

Year	Watershed Condition	Q_{max} (m^3/second)	Q_{min} (m^3/second)	Ratio Calculation (Q_{maks}/Q_{min})
1995	without mines	51.7153	1.6155	32.0112
	with mines	55.7153	1.5659	35.5805

Source: Calculation Results

Although there was an increase in the Q_{max} / Q_{min} ratio from the watershed without mine and with mine, the Q_{max} / Q_{min} ratio of the Batang Alai watershed was still categorized as good because the ratio was less than 50. If the Q_{max} / Q_{min} ratio was less than 50, then the watershed was categorized as good (Asdak, 1995).

V. Conclusion

5.1 Conclusion

Based on the analysis and discussion that has been done, conclusions can be drawn, including:

1. There is an increase in design flood discharge in the Batang Alai River if there is a change in land use to become a mining area. The design flood discharge is always increasing in each period. The design flood discharge 2-year return period for watershed without mines (Q_2 = 457,3165 m^3 / second), while the design flood discharge 2-year return period for the watershed with mines (Q_2 = 491,9183 m^3 / second) and so on. Increased the peak discharge due to changes in land use into mining areas, which also means increasing the risk of flooding in the area.

2. The calibrated model is categorized as fulfilling and having a high influence based on the grouping of Nash-Sutcliffe efficiency values and coefficient of determination. So the model can be used to simulate the desired scenario. In the period of research without mine watershed with the watershed with mining, the ratio has increased from 32,0112 to 35,5805, which means that there is a decrease in the availability of water in the watershed if there is a change in land use. But the Qmax / Qmin ratio of the Batang Alai Watershed is still categorized as good because the ratio is still less than 50.

5.2 Suggestions

The suggestions that writers can give to those who wish to continue this research or conduct similar research as follows:

1. In planning the regional spatial plan, it is necessary to review the conditions of land use more thoroughly within a certain period, so as not to cause hydrological damage to the watershed and the impact on the surrounding environment.

2. It is necessary to calculate the capacity of the Batang Alai River to find out whether or not it can accommodate flooding.

3. Study of changes in land use, runoff coefficient, runoff discharge in this study has not been supported by drainage system research. This can be continued for the next research.

4. Further studies are needed to determine the water quality in the Batang Alai watershed. This can be continued for the next research.

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