Water Availability Analysis at Empat Lawang Dam's Left Latitude in Empat Lawang Regency

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Abstract. The main objective of water resistance development is to support the Nawacita program of the Indonesia Government in terms of food sovereignty through the rehabilitation of 3 million Hectare of irrigation networks and the construction of 1 million Hectare Irrigation Networks as well as Operations and Maintenance (OPs) that include surface irrigations networks, slopes irrigation network and groundwater irrigating networks. The Integrated Participatory Irrigation Development and Management Program is expected to encourage reforms in the governance of the irrigated sector as an effort to ensure continued improvement of irrigation network infrastructure and OPs and improvements in management. The concept of 5 pillars of irrigation modernization is: Improving the reliability of irrigation water supply; Improving the means and facilities of Irrigation; Improving the irrigation management system; Strengthening the institutions of irrigation managers; Empowerment of the human resources of Irrigation managers. In this writing, the author only analyses the availability of water at the Left Latitude side of Empat Lawang Dam in Empat Lawang Regency which is the first pillar of the concept of irrigation modernization. In the discussion of this writing, the volume of the available debit is obtained at the head of the dam which is then arranged through the water gate (intake) to flow Sawah on a potential area of 3.037 hectares.

Keywords: Analysis of Water Availability, Left Latitude side of Empat Lawang Dam, irrigation management system.

1 Introduction

Water is a vital resource for for sustaining life and supporting ecological systems. In terms of the irrigation sector, water is critically needed for the sustainable growth of plants in support of food sustainability. In the context of Empat Lawang Regency, the availability of water resources plays a pivotal role in the socio-economic development and environmental sustainability of the region.

The Empat Lawang Dam, situated at the left latitude side of the regency, serves as a critical infrastructure for managing water supply for various uses, including

A. Zakaria et al. (eds.), *Proceedings of the 1st International Conference on Industry Science Technology and Sustainability (IConISTS 2023)*, Advances in Engineering Research 235,
https://doi.org/10.2991/978-94-6463-475-4_23

agriculture, domestic consumption, and industrial activities. However, the reliability of the current irrigation water supply is a growing concern. Especially on the water supply system that comes from the river runoff fluctuates enormously. This is because the function of the River Stream Area (RSA) as a water storage is declining as forest vegetation is decreasing. The river is the source of irrigation water in the rainy season.

To ensure the viability of rice cultivation, it is necessary to take into account the availability of water on the front part. Through the concept of irrigation by making (long storage) or padding, or by raising the surface of water through the setting of a measured door, so it is allowing for the even distribution of water across the fields.

This study proposes an alternative method for estimating water availability using a hydrological model based on the "rainfall-runoff" approach. The purpose of this calculation is to count up the yield (Q80). The HEC-HMS model is employed to calculate the river's natural yield using meteorological data, including rainfall figures derived from TRMM satellite data, which have been corrected for Indonesia[1]. The utilization of satellite rainfall data is essential to provide a continuous representation of half-monthly conditions, especially when ground-station data is inadequate. This satellite data has been calibrated against ground-station data, ensuring the correlation and error assessment meet the necessary standards for accurate hydrological modeling.

2 Methodology

The research methods used by the authors in this research are qualitative methods in which the author tends to use analysis and based on previous studies. The analysis is based on primary data of instant observations of field conditions and secondary data by studying and digging information from previous studies.

The location of this research at Empat Lawang Dam's Left Latitude in Empat Lawang Regency, South Sumatra Province, Indonesia.

3 Result and Discussion

3.1 Rainfall Runoff Approach Method with HEC-HMS model

The hydrological data required for the analysis of water availability are rain-fall data, discharge data, climatological data as well as other supporting data. Generally, in the estimation of water availability, can be seen from the type and length of the data, will then determine what method will be used. (refer to Table 1).

Table 1. Selection of methods used based on available data.

Design Parameters	Data Type and Length	Methods
Water availability	*Monthly or daily debit > 10 years*	Duration Curve Analysis *Direct simulation of reservoir water*
	Balance Monthly or daily debit <10 years	Rain and discharge relationship model *Duration Curve Analysis*
	No monthly or daily debit	Area analysis

In the analysis of the availability of surface water will be used as a reference is reliable dis-charge (dependable flow). A reliable discharge is a quantity of discharges at a control point in a river which the discharge is a combination of direct and base flows. This debit reflects a figure that can be expected to occur at a control point associated with time and reliability values with a particular risk of failure.

3.2 Rain-discharge modelling

To supplement or extend the flow data, if complete and long enough rainfall data are available, then rain-flow models, as depicted in Figure 1, can be used which calculate the flow based on rainfall, evapotranspiration data, and model parameters. Hydrological modelling is like this generally through two stages of calculation:

Calibration model. It carried out on a river flow area that has had daily observation outflow data. With the TRMM rain data input (1998-1999 and 2015-2016) and the observation debit data, the model parameters were searched with trial and error in such a way that the model output, the simulated debit, came close to the observed debit. At this stage, intensive verification is required to ensure that the resulting parameters are truly reliable. The calibration results can be applied to the RSA's left latitude to search for reliable discharge.

Generation model. The calibration result model parameters applied to the location of the left latitude RSA with the daily rain data input TRMM (1998-2016) thus producing simulation flow data that should be longer than the calibrating year.

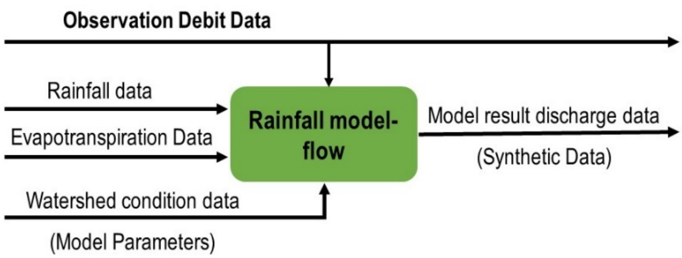

Fig.1. Stage modeling rain–flow to produce synthesis discharge.

The model used to analyze the water availability at this study site is with HEC-HMS software by dividing RSA into smaller sub-RSA. Based on the analysis of the GIS, the left latitude RSA with an area of 143 km2 is divided into nine smaller sub-RSA with the scheme as shown in Fig. 2.

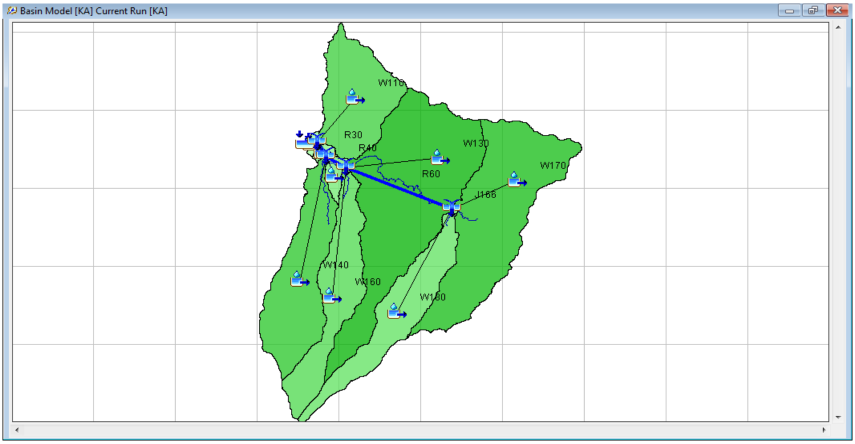

Fig. 2. HEC HMS DAS modelling scheme in left latitude.

Table 2. Sub-basin division on HEC-HMS modelling left width.

Sub RSA	Width (km^2)
W100	0.450
W110	16.162
W120	0.656
W130	41.587
W140	19.570
W150	1.484
W160	15.904
W170	32.116
W180	15.172

The selected model and the parameters contained therein and how to estimate each selected parameter can be seen in Table 3 below.

Table 3. Summary Sub Models, Methods, Parameters and Methods of Determination.

Model	Sub-model	Method	Parameters	Approaches	Notes
Rain-fall-Runoff	Losses (infiltra-tion)	Deficit con-stant	Initial deficit (mm)	Trial & error	
			Maximum storage (mm)	Estimated from SCS Equation	S=1000/CN=10
			Constant rate (mm/hour)	From HSG & trial-error	HSG: Hydro-logic soil group
		Simple cano-py	Initial storage (%)	Trial and error	
			Maximum storage (mm)	Based on field coverage	
		Simple sur-face	Initial storage (%)	Trial and error	
			Maximum storage (mm)	Based on slope	
	Transfor-mation	Unit hydro-graph SCS	Time lag (minute)	GIS (physical approach)	Program TR55
	base flow	Linear reser-voir	GW 1 coeffi-cient (hour)	Trial and error	
			GW 1 reser-voir	Trial and error	
			GW 2 coeffi-cient (hour)	Trial and error	
			GW 2 reser-voir	Trial and error	
Routing	River rout-ing	Muskingum-Cunge	Length & slope	GIS	
			Manning n	about 0.025-0.03	
	Reservoir routing	Storage indi-cation	Elevation storage	Given (measure-ment)	
			Elevation discharges	Given (rating curves)	
			Release dis-charges	given	

3.2.1 *Synthetic Hydrograph Unit*

As previously described, for the calculation of the precipitation model, the soil conservation service (SCS) synthetic unit hydrograph (HSS) is used [2, 3]. The HSS SCS of a RSA is explicitly determined by the parameter of lag time depending on its length, inclination, cross-section of the canal and river as well as its coefficient of solidity. The HSS SCS tide time can be estimated through calibration, for those who have observation data in the left latitude RSA. In cases where there is no data, the

SCS suggests the tide is estimated from the t_c concentration time through the formula $t_{lag} = 0.6\ t_c$ [4]. Whereas concentration time is estimated from the formula:

$$t_c = t_{sheet} + t_{shallow} + t_{channel} \tag{1}$$

Where t_{sheet} is the sum of the travel time of the segment of the stream of the layer or sheet on the surface of the ground, $t_{shallow}$ is the amount of the time travel of the shallow in the street, the well, the ground stream and the $t_{channel}$ is the number of the journey time from the canal or river. The river stream requires cross-sectional, latitude and speed estimates using Manning's *n*.

3.2.2 Loss Calculation Using Deficit-Constant

This loss method is capable of taking into account the loss of rain continuously especially at the time of no rain the ability of the soil to absorb water becomes greater (recovery). Thus, this method goes into a group of one layer of soil for a continuous change of flexibility. It should be used by applying a canopy method that would suck water from the soil in response to evapotranspiration from a meteorological model. The soil layer dried between rains because the canopy sucked water into the soil. Percolation outside of one layer of soil on top only occurs if the soil layer becomes saturated.

This method contains three parameters: the initial deficit in millimeter (mm), the maximum deficit of millimeter (mm), a constant rate in mm/h. The early deficit is the initial condition of the calculation indicating the amount of water needed to fill the soil layer to reach the maximum absorption.

The maximum deficit is defined as the amount of water from the soil layer that can be sustained and expressed in thickness. The upper limit is the thickness of the active soil layer multiplied by the porosity approached with the Soil Storage of the SCS Curve Number (SCS CN)[5]. However, in many ways it must be reduced by a permanent dew point and for other conditions that reduce the capacity of the water resisted.

The rate of constant infiltration occurring when the soil layer becomes saturated is estimated from saturated hydraulic conductivity.

3.2.3 Canopy Calculation

This method is used to count the canopy of plants. The falling rain is intercepted over the leaves until its exposure capacity is fulfilled. The canopy is affected by evapotranspiration until its capacity limit is met. Unfulfilled evaporation in the canopy will occur in the soil component. The canopy will fill the pad during the rain or empty the pads as long as there is no rain. There is no evapotranspiration while the rain falls.

The initial condition of the canopy in the model is estimated to be full and specified as a percentage of the full canopy mounting at the beginning of the calculation. The canopy mounting is the maximum amount of water that can be retained by a leaf before a trough-fall occurs, expressed in units of millimeter (mm) (source: HEC,2013).

3.2.4 Flood Routing or Flood Search (Source: HEC, 2013)

The Muskingum-Cunge model [6] is used to calculate the route of the river canal. Although popular and easy to use, the Muskingum model parameters are not physically measurable, so it is difficult to predict [7]. This model is based on the solution of the following form of the continuity equation, (inflow with lateral q_L):

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q_L \tag{2}$$

and the diffusion form of the momentum equation:

$$S_f=S_o-\frac{\partial y}{\partial x} \tag{3}$$

Combining both of these equations and using a linear approached results in convective diffusion equations [8].

$$\frac{\partial Q}{\partial t}+c\frac{\partial Q}{\partial x}=\mu\frac{\partial^2 Q}{\partial x^2}+cq_L \tag{4}$$

with:
c = wave speed;
μ = hydraulic diffusivity.

The wave speed and hydraulic diffusivity are expressed as follows:

$$c=\frac{\partial Q}{\partial A} \tag{5}$$

and

$$\mu=\frac{Q}{2BS_o} \tag{6}$$

with:
B = width above water surface.

A limited approach difference from a partial derivative, combined with the Muskingum equation, results in:

$$O_t=C_1I_{t-1}+C_2I_t+C_3O_{t-1}+C_4(q_L\Delta x) \tag{7}$$

Coefficient used:

$$C_1=\frac{\frac{\Delta t}{K}+2X}{\frac{\Delta t}{K}+2(1-X)} \tag{8}$$

$$C_2=\frac{\frac{\Delta t}{K}-2X}{\frac{\Delta t}{K}+2(1-X)} \tag{9}$$

$$C_3=\frac{2(1-X)-\frac{\Delta t}{K}}{\frac{\Delta t}{K}+2(1-X)} \tag{10}$$

$$C_3=\frac{2\frac{\Delta t}{K}}{\frac{\Delta t}{K}+2(1\text{-}X)} \quad (11)$$

For the *K* and *X* parameters are [9, 10]:

$$K=\frac{\Delta x}{c} \quad (11)$$

$$X=\frac{1}{2}\left(1\text{-}\frac{Q}{BS_0c\Delta x}\right) \quad (12)$$

But *c*, *Q*, and *B* change over time, so *C1, C2, C3*, and *C4* coefficients have to change too. The program recomputes at every time and step, Δt and Δx using the algorithm proposed by Ponce [11].

Once again, the choice of measurements of time and distance is very important. The steps selected to ensure accuracy and stability. Δt is chosen as a minimum, following: the user step time of the control specification, the time passed through the section of the river; or 1/20 time to rise from the entrance of the steep peak ascending, rounded to the nearest number or divider of the particular time step. After Δt is selected, Δx is counted as:

$$\Delta x=c\Delta t \quad (13)$$

Such values are limited to:

$$\Delta x<\frac{1}{2}\left(\frac{Q_o}{BS_oc}\right) \quad (14)$$

Here's the Q_o flow = the reference flow, calculated from the inflow hydrograph as:

$$Q_o=Q_B+\frac{1}{2}\left(Q_{peak}\text{-}Q_B\right) \quad (15)$$

With:
Q_B = basic flow;
Q_{peak} = peak inflow flow.

The parameters of this method are mostly measured such as the length and inclination of river sections, the perpendicular crossing of the estimated breadth of the base of the river and the slope of the cliff as well as the coefficient of rigidity or the magnitude of the Manning *n* [12] of the basement.

3.2.5 Rise Debit

One way to estimate the discharge is with the help of the Deficit Constant rain-discharge model combined with the SCS synthetic unit hydrograph, Muskingum-Cunge routing, and the linear reservoir for the baseflow so that a decent and accountable reliable discharges are obtained.

For the study of water availability, continuous infiltration can be estimated using the Deficit Constant method using the Initial Deficit parameter in millimeter (mm), Maximum Deficit or Maximum Storage in millimeter (mm), Constant Rate in mm/hour and percentage impervious. Maximum storage is estimated from soil storage from the Curve Number and Constant Rates formula and the hydraulic permeability or conductivity depends on the Hydrologic Soil Group (HSG) as in the previous chapter.

Based on SCS of NRCS [13] saturated hydraulic conductivity values for each type of HSG: HSG type B saturated. Hydraulic conductivity is 0.57-1.42 inches/hour, HSG C is 0.06-0.57 inches /hour and HSG D is less than 0.06 inches per hour. The limits of such parameters and the value of the selected or calibrated Constant Rate can be found in **Table 4**.

Based on the CN and t_{lag} values already calculated at each sub-RSA, the rainfall is converted into a direct runoff as well as the estimated baseflow from the Baseflow Model is summed up and routed by Muskingum-Cunge with data obtained from the HEC-Geo HMS.

Table 4. Basic determination of constant infiltration speed parameters (Constant Rate).

Saturated hydra conductivity	**Hydrologic soil group (HSG)**			
	Group A	Group B	Group C	Group D
Inch/hour	>1.42	0.57-1.42	0.06-0.57	<0.06
Mm/hour	>36.1	14.5-36.1	1.5-14.5	<1.5
Selected (mm/h)				0.2

Table 5. Basic Determination of Maximum Storage Parameters.

Sub-basin	**Deficit and constant**			
	Initial Deficit (mm)	Max storage	Constant rate (mm/h)	Impervious (%)
W100	4	199.57	9	0
W110	4	117.82	9	0
W120	4	199.57	9	0
W130	4	148.56	9	0
W140	4	178.18	9	0
W150	4	150.46	9	0
W160	4	186.44	9	0
W170	4	125.38	9	0
W180	4	163.10	9	0

(Source: Analysis result, 2021)

The HSS SCS parameters are calculated through a digital map and processed by the TR 20 program to the time of dew as seen in Table 6 below,

Table 6. HSS SCS parameters.

Subbasin	Time lag (minute)
W100	8.70
W110	47.70
W120	10.90
W130	132.95
W140	58.38
W150	26.42
W160	69.66
W170	115.01
W180	80.77

(Source: Analysis result, 2021)

Based on the parameters that have been obtained, the next step is to generate debit data using TRMM rainfall data from 2003-2019, thus obtaining a debit value of Q80% per month. The results of each month's debit analysis can be seen in **Table 7** below.

Table 7. Monthly generated debit data in the left width.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	7.52	10.06	8.19	8.78	9.85	6.08	5.76	5.85	8.25	9.41	8.48	12.06
2004	10.21	9.00	9.68	8.82	9.30	6.60	6.60	6.05	5.45	5.12	5.72	8.57
2005	11.10	9.06	11.57	11.17	12.37	11.06	8.75	8.65	8.43	8.15	10.33	8.77
2006	12.31	11.64	10.85	10.79	10.35	9.42	6.74	5.49	4.64	3.35	4.72	6.68
2007	7.24	10.30	8.32	10.59	10.94	8.65	7.94	6.57	6.65	5.41	6.18	7.30
2008	6.62	6.76	8.42	11.00	7.50	6.69	5.24	6.20	6.86	5.28	7.88	9.44
2009	8.68	9.90	9.67	11.51	9.95	7.82	7.24	5.91	5.32	6.83	5.29	8.69
2010	8.06	9.41	11.56	11.12	10.30	9.90	8.98	9.53	9.55	8.58	10.45	8.89
2011	7.10	9.75	7.65	7.10	9.22	7.15	6.65	4.81	3.91	4.16	5.32	6.46
2012	6.24	6.20	8.66	8.16	8.33	6.20	5.07	3.90	4.13	4.52	6.14	10.41
2013	9.54	12.53	9.65	10.92	9.64	7.92	7.89	7.59	8.15	7.55	8.49	10.61
2014	8.94	7.30	8.55	8.76	9.81	6.98	6.41	6.77	5.67	3.61	6.60	7.78
2015	6.31	10.29	8.83	10.06	8.95	6.62	5.27	4.37	2.27	2.09	3.47	6.07
2016	7.54	9.10	10.45	11.67	11.06	9.08	7.72	8.06	7.73	7.70	8.50	8.97
2017	7.54	7.63	11.10	9.93	11.19	7.83	7.29	6.29	5.20	9.30	8.01	8.33
2018	8.25	6.21	10.29	9.33	6.99	7.13	5.49	4.37	5.56	3.81	6.49	9.63
2019	7.96	8.73	9.46	10.34	9.17	7.00	6.93	4.46	3.77	2.63	3.16	5.23
Q90	6.22	6.21	8.08	7.95	7.40	6.18	5.20	4.28	3.56	2.52	3.41	5.91
Q80	6.91	7.08	8.38	8.77	8.70	6.61	5.40	4.42	4.04	3.50	5.06	6.60

(Source: Analysis result, 2021)

4 Conclusion

From the analysis carried out was obtained the monthly reliable discharge (Q80) on the Lintang Left Bend DAS with the highest discharges occurred in April with the discharging 8.77m3/dt while the lowest was in October with the discharge 3.50 m3/dt.

Acknowledgement. The authors would like to thank DIPA Faculty of Engineering University of Lampung for funding the research Analysis of Water Availability at the Left Latitude side of Empat Lawang Dam in Empat Lawang Regency. Thanks also to the Empat Lawang Dam for providing the place, equipment, and assistance during the research activity. And thanks also to the team for our best effort so the research can be useful for the public and for the future.

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