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Comparison of Rainfall -Runoff Models with F.J. Mock and NRECA to Determine Water Availability of Rukoh Reservoir, Aceh

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Abstract

Rukoh Reservoir is located in the upper part of Krueng (Kr.) Rukoh River Watershed, Pidie Regency, Aceh Province with a catchment area of 19.63 Km^2. This reservoir has a storage capacity of 124.42 million m^3 and is used for irrigation, drinking water and hydropower. The condition of Kr. Rukoh there is no discharge recording device, so to obtain discharge data it is necessary to convert rainfall data into discharge in the form of Rainfall-Runoff Model. The purpose of this research is to calculate the amount of flow discharge and the suitability of the two rainfall-runoff models using the F.J. Mock method and NRECA method with observed discharge. Furthermore, determining the amount of reliable discharge as inflow availability of Rukoh reservoir. This research begins with the collection of rainfall data, evapotranspiration and condition parameters of the Rukoh Reservoir catchment area. The parameters in both models are optimized to obtain the optimal model discharge that is close to the observed discharge data (Qobs). The results of the model suitability test showed that the NRECA model discharge is better compared to the F.J. Mock discharge model, the NSE test value = 0.64 and the correlation test value R = 0.83. Based on the selected discharge model, the calculation obtained the average flow discharge as Rukoh reservoir inflow of 1.13 m^3 / sec and 80% water availability of Rukoh Reservoir by 0.58 m^3/sec and 90% water availability obtained at 0.43 m^3/sec.

Keywords: *FJ. Mock; NRECA; Rainfall-Runoff Model; water availability; calibration; engineering.*

1. Introduction

In planning a dam/reservoir, a discharge analysis is needed to estimate the amount of reservoir storage to meet water demand. The amount of inflow can be obtained by recording the discharge of water gauging stations installed in river channels and the discharge generated from the Rainfall-Runoff Model.

Most of the watersheds in Indonesia do not have discharge data recording posts, but the number of rainfall recording posts is quite large. These rainfall data can be used to generate discharge with the rainfall-runoff model. Rainfall data can be obtained from rainfall stations (manual/automatic), weather radar or satellite.

The Rukoh Reservoir is located on the Krueng (Kr) Rukoh Stream in Pidie District, Aceh Province, and has the function of providing irrigation water, raw water supply, and hydropower. The location of the reservoir was once a conflict area, which has affected the availability of hydrological data, especially very limited discharge data. Therefore, it is necessary to calculate the discharge using the Rainfall-Runoff Model. This model converts rainfall data into discharge data using climatological data parameters and watershed characteristic.

In this research discharge data will be obtained by converting rainfall data into discharge data in the form of a Rainfall-Runoff Model. This discharge model uses two methods, namely the F.J. Mock Model and NRECA (Natural Rural Electrical Cooperation Agency), because these two models are often used in Indonesia. (Alby & Suhartanto, 2018).

In addition to F.J. Mock and NRECA, many other models can be used for flow discharge analysis, such as HEC-HMS, SWAT, ANN, and MIKE. Model selection should consider the research objectives, data availability, and watershed characteristics. The selection of a model that is commonly used as an example for flood purposes is HEC-HMS. The study area (Rukoh Reservoir Catchment Area) has limited data for suitable models are F.J. Mock and NRECA when compared to models such as SWAT and MIKE SHE which require more complete data. Furthermore, testing of the two models is carried out; the best model will be used to determine the magnitude of the water availability of Rukoh Reservoir. Discharge data is needed in reservoir planning, one of which is to determine the amount of the discharge as a

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basis for the availability of inflow into the reservoir area to meet water demands with a calculated risk of failure.

The objectives of this research are as follows: (1) to calculate the amount of discharge using the F.J. Mock and NRECA models, (2) to know the suitability of two models, namely F.J. Mock and NRECA with the observed discharge; and (3) to determine the amount of inflow reliable discharge to Rukoh reservoir as reservoir water availability.

2. Research Materials and Method

2.1. Location

The research site at Rukoh Reservoir is located in Pidie District, Aceh Province (Figure 1). Geographically located at 05^{o}11’55” – 05^{o}12’28’’ North dan 95^{o}20’20” – 95^{o}53’59” East. Rukoh Reservoir has 2 (two) inflow streams, namely from Krueng (Kr.) Rukoh, with a reservoir catchment area of 19.63 km^2, and Krueng (Kr.) Inong as a supply to the reservoir. This research focuses on the catchment area of the Rukoh Reservoir, which

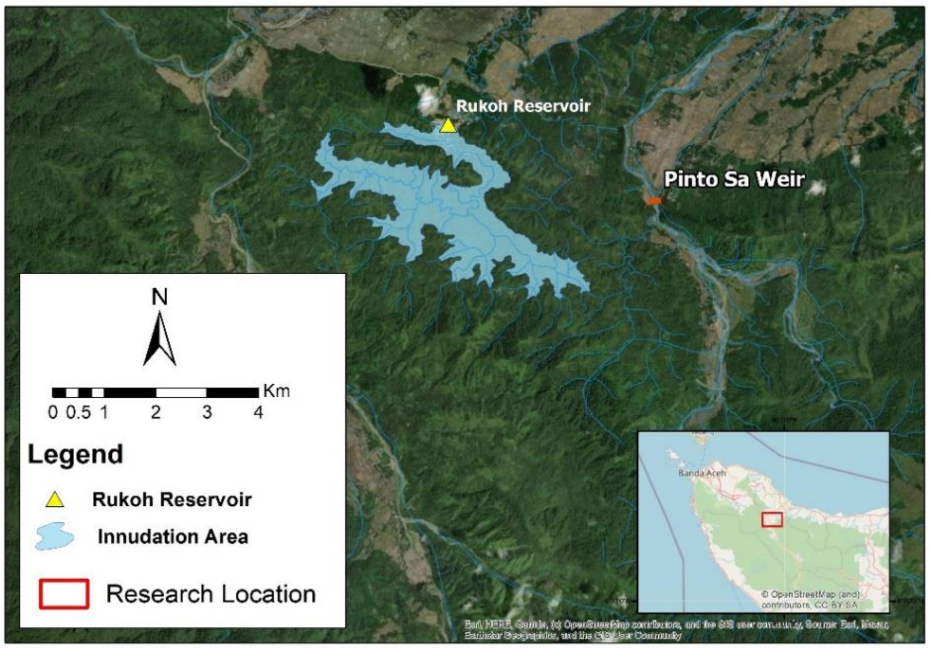

Figure 1. Research location map of Rukoh Reservoir catchment area

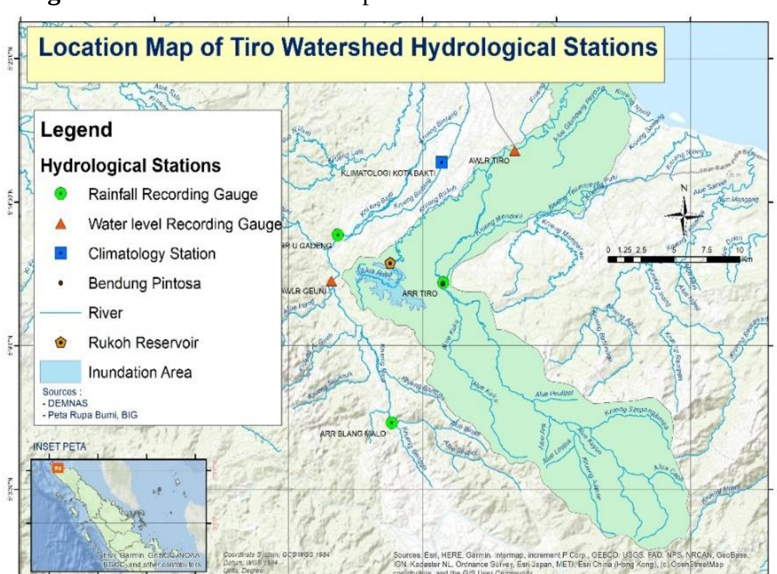

Figure 2. Location map of the hydrological gauging stations in the Tiro watershed

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comes from Krueng (Kr.) Rukoh, where Kr. Rukoh is part of the Tiro watershed, as shown in Figure 1.

2.2. Data Requirements

The required hydrological data consists of daily rainfall and discharge data. The data is obtained from hydrological stations managed by the Sumatera 1 River Basin Organization (BWS) of the Ministry of PUPR. Based on Figure 2. there are 3 (three) rainfall stations, 1 (one) climatology station and 1 (one) water level/discharge station located on the main river Krueng (Kr.) Tiro.

The required climatic data consisted of temperature, wind speed, humidity, and sunshine duration. These data were obtained from the Kota Bakti Climatology Post and are presented in Table 1. :

Digital Elevation Model (DEM) is a digital model in the form of a group of geometric data consisting of X and Y coordinate points with algorithms that shape

Table 1. Average climate data of Kota Bakti Climate Station (2015-2023)

Month	Temp (t) (^{0}C)	Relative Humidity (Rh) (%)	Wind Speed (u) (m/dt)	Sunshine (n/N) (%)
Jan	25.96	97.25	3.207	42.21
Feb	25.91	96.92	3.695	51.24
Mar	26.91	96.60	2.675	56.38
Apr	27.24	96.92	2.499	47.91
Mei	27.57	97.02	2.645	40.97
Jun	27.27	95.37	2.776	46.37
Jul	26.94	96.60	3.013	42.85
Ags	27.63	96.41	3.349	46.27
Sep	27.21	96.70	3.047	37.17
Oct	27.04	96.78	3.047	35.35
Nov	26.26	97.25	2.581	33.49
Des	25.76	97.38	3.131	32.20

Source : (BWS Sumatera I, 2023)

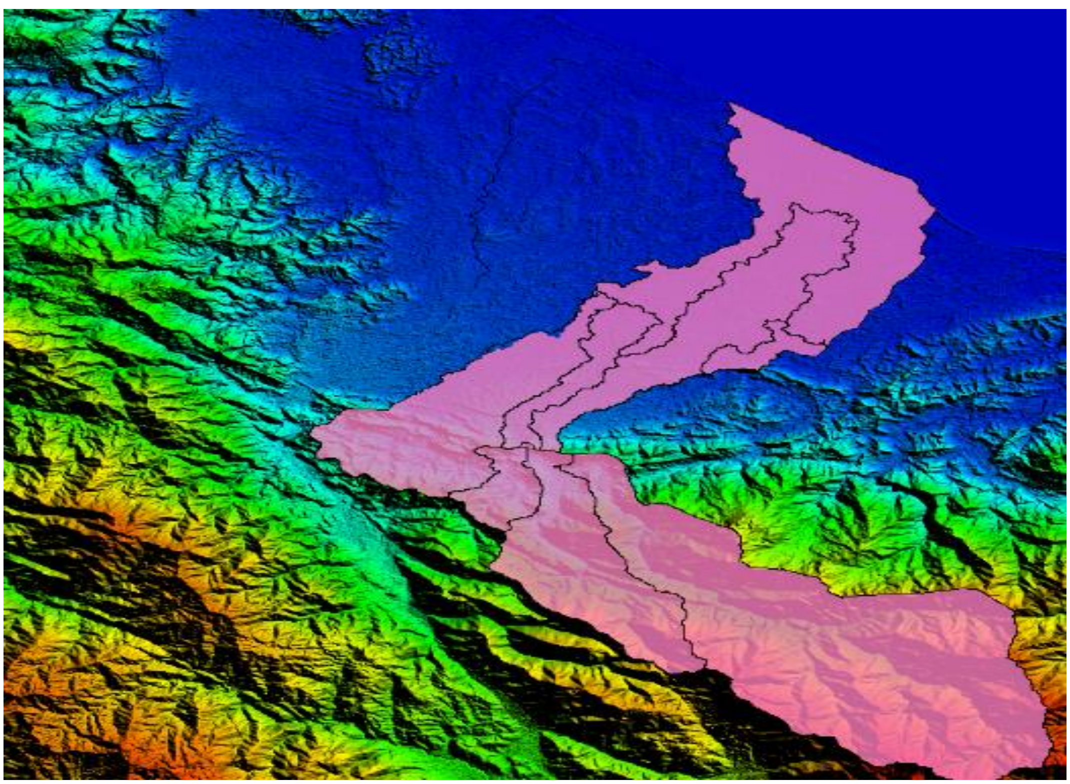

Figure 3. DEM map of Tiro Watershed

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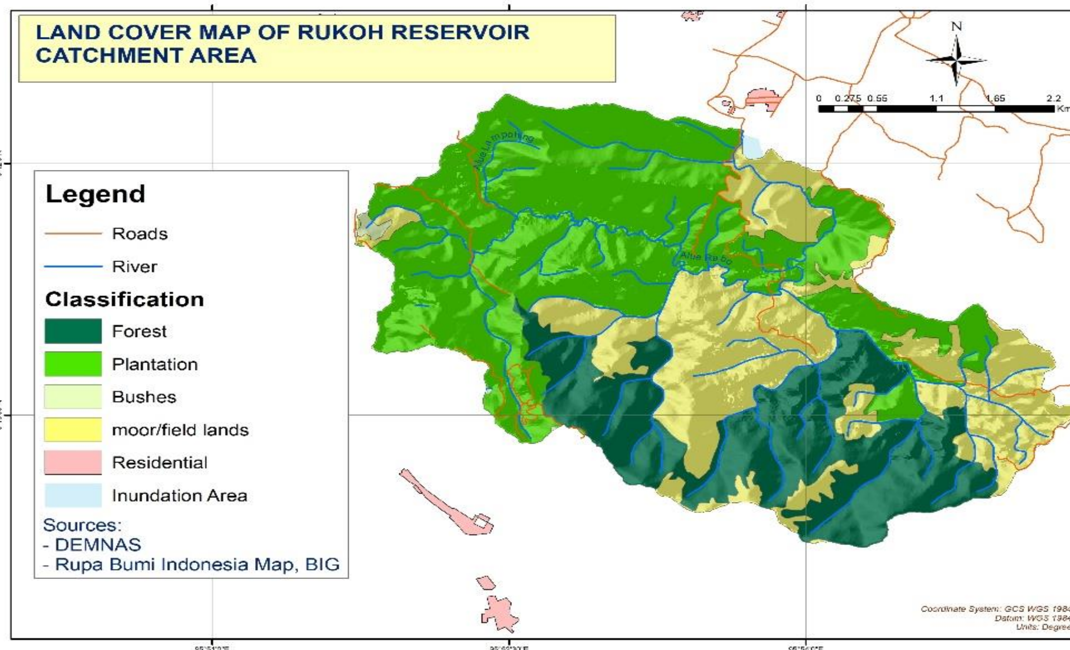

Figure 4. Rukoh Reservoir catchment land use map

topography or landforms into the Z coordinate system (Purwono et al., 2018). The DEM data used are from the National DEM with a resolution of 11.25 m - 5 m (Geospatial Information Agency, 2024). The DEM map display is shown in Figure 3.

The land use map of the research area was obtained from the Rupa Bumi Indonesia (RBI) map published by the Geospatial Information Agency, with a scale of 1:25,000. This map consists of RBI maps No. 0521-12 and No. 0520-443. The land use patterns within the research area, specifically in the Krueng Rukoh stream (Rukoh Reservoir DTA), are predominantly characterized by forests, plantations, and shrubs, as illustrated in Figure 4.

2.3. Research Methods

The research stages are arranged systematically to obtain research results that are in accordance with the predetermined objectives. The research stages to determine the discharge model by comparing two discharge model methods, namely F.J. Mock and NRECA, which then obtained the amount of discharge (inflow) as the availability of Rukoh Reservoir water, is illustrated in the flow chart in Figure 5.

Based on the flow chart in Figure 5, the outline of the research stages performed consists of hydrological data collection with an initial check in the form of completeness of hydrological data consisting of rainfall data length of at least 10 (ten) years, discharge data for 3 years (2020-2022) and climate data (temperature, humidity, wind speed and sunshine) with a data length of 10 years. Based on the results of the initial screening, there are 2 (two) rainfall stations, 1 (one) climatology station and one water estimation station that have daily discharge data that will be used. A summary of the results of the initial data screening is presented in Table 2.

Rainfall data testing uses a statistical approach to ensure that the available rainfall data is consistent and stable and describes the appropriate hydrological conditions in the field without being affected by measurement or data collection errors. Data that pass the test can be used for further analysis, while data that does not pass the test is reviewed with the original data from the table or graph from the data collection at the rain post and discussed with the provider/data manager. Rainfall data testing (series data) is performed using several tests, namely the RAPS (Rescaled Adjusted Partial Sums) consistency test, the outlier test, and the F and T stability tests.

Before analyzing the rainfall in a watershed, it is necessary to know the boundaries and area of the watershed through the delineation stage. Delineation watershed is the process of forming an area as a container to drain rainwater runoff into the river network to a certain point outside (outlet). Watershed components include hillsides, river networks, waterways, water bodies, floodplains, and groundwater (Dumont & Rowney, 2017). In this study, the delineation is done automatically by extracting the digital elevation model (DEM) into the topography by considering the value of hydrological parameters (flow direction - flow accumulation - stream order - basin/watershed) (Purwono et al., 2018).

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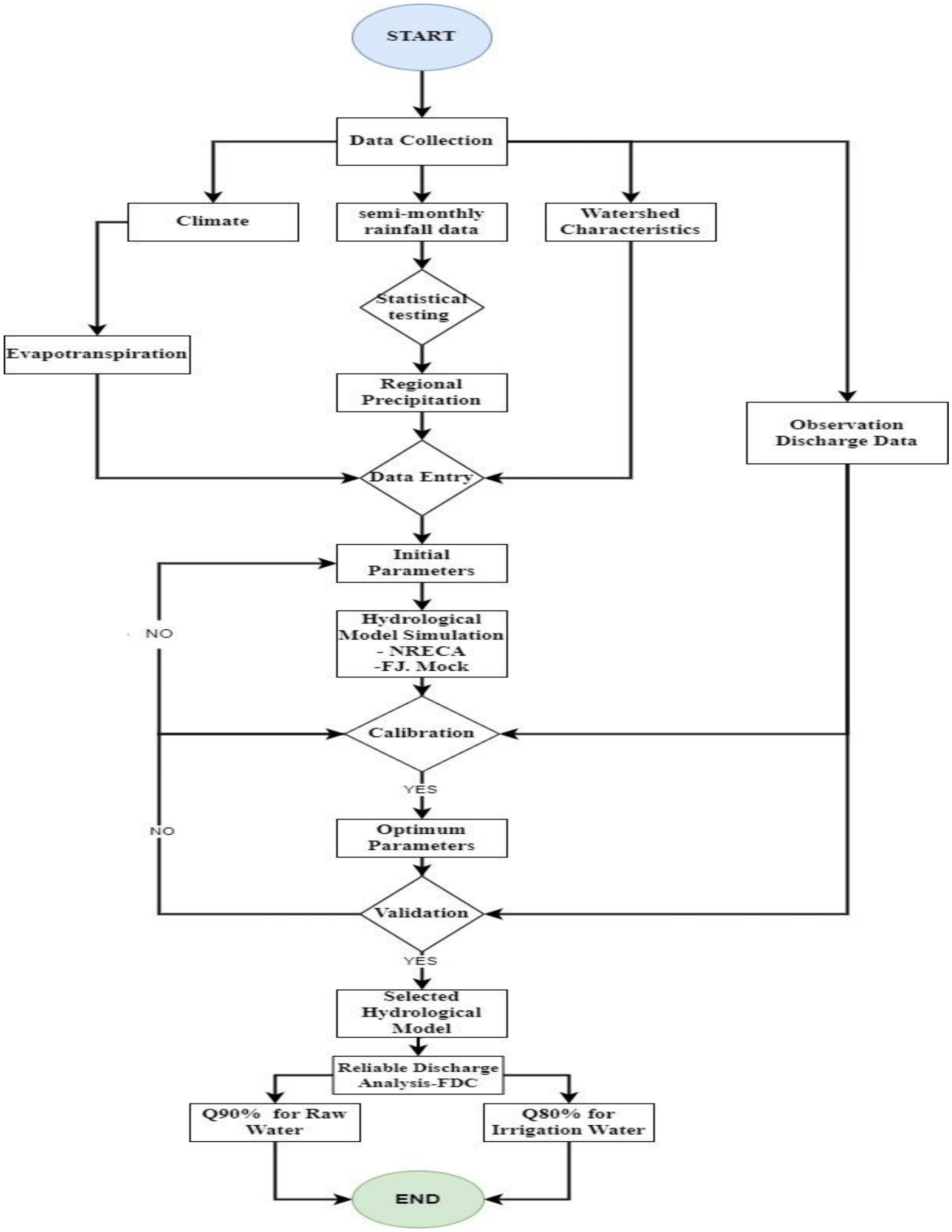

Figure 5. Research flow chart of the comparison of the F.J. Mock and NRECA Rainfall-Runoff Models for water availability in Rukoh Reservoir.

Analysis of regional rainfall using the Thiessen polygon method. The shape and area of the Thiessen polygon in this research is supported by using Arc Map 10.3 software. There are three influential rainfall stations connected by a perpendicular line axis to each rainfall station, forming a polygon as the Thiessen polygon is illustrated in Figure 6. (Dumont & Rowney, 2017).

Analyzing regional rainfall using the Thiessen Polygon Method is calculated using Equation 1 as follows (Subramanya, 2013) .

$$P_{average} = \frac{A_1P_1 + A_2P_2 + \cdots + A_nP_n}{A_1 + A_2 + \cdots + A_n} \quad (1)$$

where A is the area of the Thiessen influence zone, P is the mean rainfall/precipitation of the region P1, P2, ..., Pn

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Table 2. Hydrological Data Type and Length Conditions

No	Stations	Data Type	Data Length
1.	Blang Malo	daily rainfall	2014-2023
2.	U Gadeng	daily rainfall	2014-2023
3.	Kota Bakti	daily rainfall and climate data	2014-2023
4.	AWLR Tiro	daily discharge	2020-2022

Source :(BWS Sumatera I, 2023)

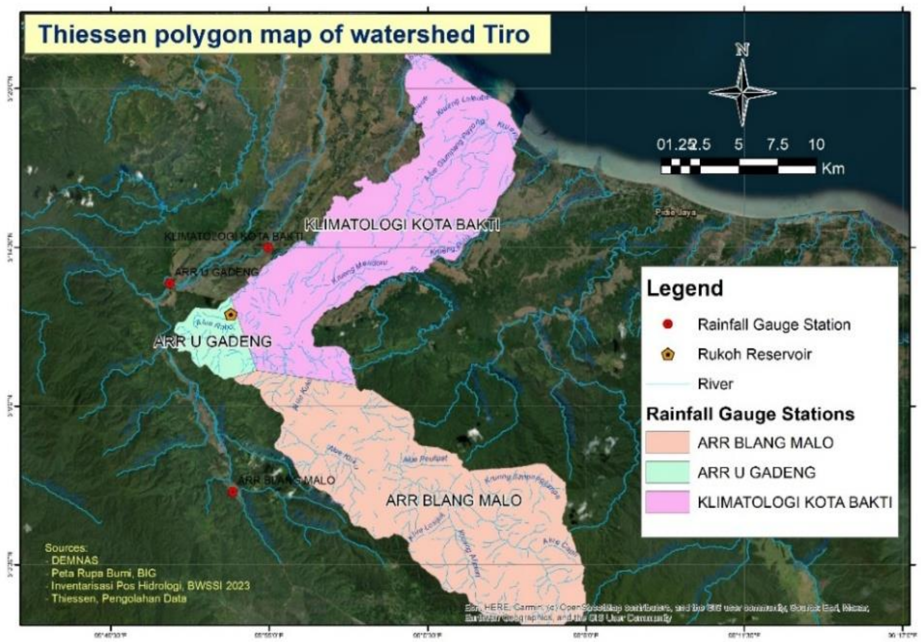

Figure 1. *Polygon Thiessen* DAS Kr. Tiro

is the rainfall at each station A1, A2, ..., and An is the area at each rain station.

Evapotranspiration is the water loss due to evaporation from the soil surface and transpiration from vegetation (Rasyid & Afdhaliah, 2021). evapotranspiration analysis uses the calculation of the modified Penman method, where this method has been adapted to the conditions of the Indonesian region (Hadisusanto, 2010). The Penman-modified evapotranspiration calculation method was developed from the Penman equation by the Food and Agriculture Organization of the United Nations (FAO) in 1977 (Baskoro et al., 2024). The Penman-modified evapotranspiration equation is shown in Equations 2 and 3.

$$Eto = c \times Eto^{*} \quad (2)$$

$$Eto^{*} = W(0{,}75\ Rs - Rn1) + (1 - W)f(u)(ea - ed) \quad (3)$$

with ET0 as evapotranspiration (mm/day), W as a factor related to air temperature (t) and elevation, Rs as shortwave radiation (mm/day), Rn1 as net longwave radiation (mm/day), f (U) as wind speed with a height of 2 meters from the ground (m/sec), (ea-ed) is the difference between saturated vapour pressure and actual

Table 3. Classification of correlation coefficient evaluation

R-value	Evaluation class
0 – 0.19	very low
0.20 – 0.39	low
0.40 – 0.59	moderate
0.60 – 0.79	strong
0.8 -1	very strong

(Sugiyono, 2007)

Table 4. Interpretation of NSE (Nash-Sutcliffe Efficiency) value

NSE	Interpretation
NSE > 0.75	Good
0.36 < NSE < 0.75	Satisfactory
NSE < 0.36	Poor

(Moriasi et al., 2007)

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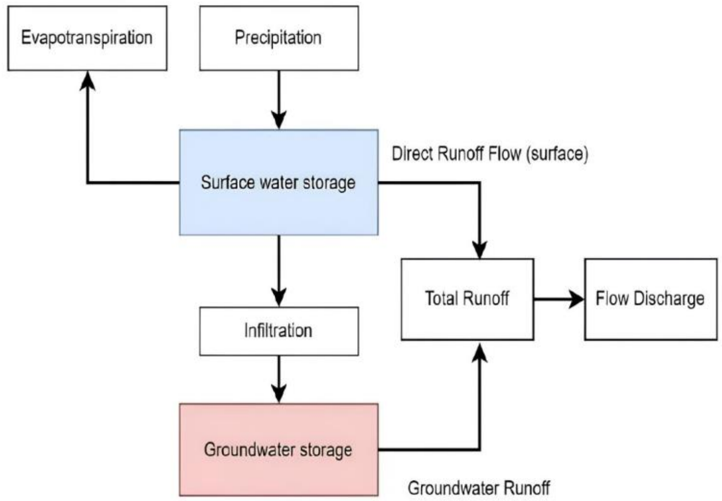

Figure 6 . F.J. Mock Model Calculation Scheme (Jayanti et al., 2023)

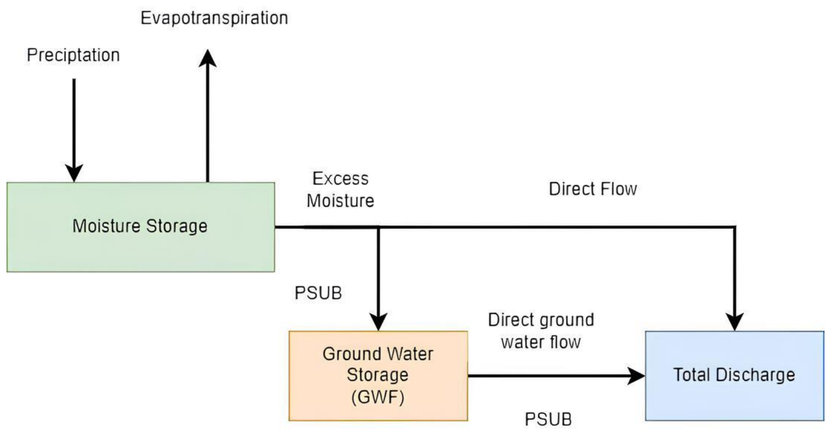

Figure 7. NRECA Model Calculation Scheme (Krisnayanti et al., 2022)

vapour (mbar), c is Penman correction based on the day and night conditions.

The rainfall-runoff model introduced by Dr. F.J. Mock (1973) is a simple model of monthly water balance simulation with rainfall data parameters, evapotranspiration and hydrological characteristics of the river basin or catchment area (Adiningrum, 2016). Figure 7 shows the analysis of discharge calculations based on the transformation of rainfall data, evapotranspiration, soil moisture, and groundwater storage.

In general, the F.J. Mock model is a rainfall-runoff model, and the parameters for calculating discharge with this model use the necessary data, including regional average rainfall (P), potential evapotranspiration (Eto), number of rainy days (n), groundwater infiltration flow factor (k), and infiltration coefficient (i), as well as the determination of evapotranspiration limit, amount of water on the soil surface (Ds), amount of soil moisture (SMC), infiltration (i) between 0 and 1, excess water in the soil (surplus water); soil water content (Vn), changes in soil water content (DVn), base flow and direct flow, and the discharge that can be accommodated by the river. The FJ. Mock discharge model can be formulated based on Equation 4.

$$Q = \big((WS - I) + (i - V)\big)\, A \quad (4)$$

Where Q is the available water discharge (m3/sec), WS (water surplus) is the water surplus, V is the change in groundwater flow volume (m^3), (i-V) is the base flow, i is the infiltration (mm), (WS-I) is the direct runoff (mm), and A is the catchment area (Km^2).

The NRECA method rainfall-runoff model is one of the simple rainfall-runoff models shown in Figure 8. It divides the flow into two runoffs: direct runoff (surface

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runoff) and base flow. Storage is divided into two, moisture storage and groundwater storage.

In this model, the water equilibrium is applied to a watershed as formulated in Equation 5.

$$Q = (DRo + GF) \quad (5)$$

Q is the discharge of runoff entering the river (m^3/sec), DRO indicates direct runoff, GF is the groundwater flow leading to the river, and A is the area of the das. The NRECA model uses 15 (fifteen) daily or semi-monthly rainfall data to index soil moisture storage capacity (nominal), Percent Sub Surface (PSUB), Ground Water Flow (GWF), and crop coefficient (kc). Soil moisture storage capacity (NOMINAL) with Equation 6.

$$Nominal = 100 + 0{,}2 \times avg.rainfall \quad (6)$$

Runoff that leaves the catchment area at the sub-surface (PSUB). PSUB values are between 0.3 and 0.9. PSUB is 0.5 for watersheds with normal/usual rainfall. A value of 0.5 < PSUB ≤ 0.9 is for watersheds with large permeable aquifers. A value of 0.3 ≤ PSUB < 0.5 is for watersheds with limited aquifers and thin soil layers (Ginting, 2018). The percentage of groundwater storage runoff to the river (GWF) is between 0.2 - 0.8. Initial values of soil moisture storage (SMSTOR) and groundwater storage (GWSTOR).

This model suitability evaluation analysis is carried out by comparing the modelled discharge with the

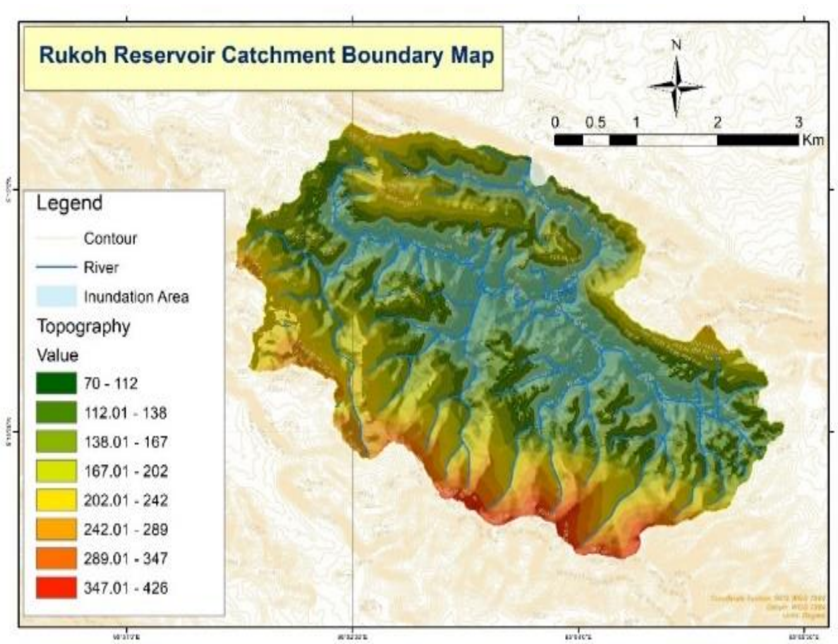

Figure 8. Catchment area map of Rukoh Reservoir

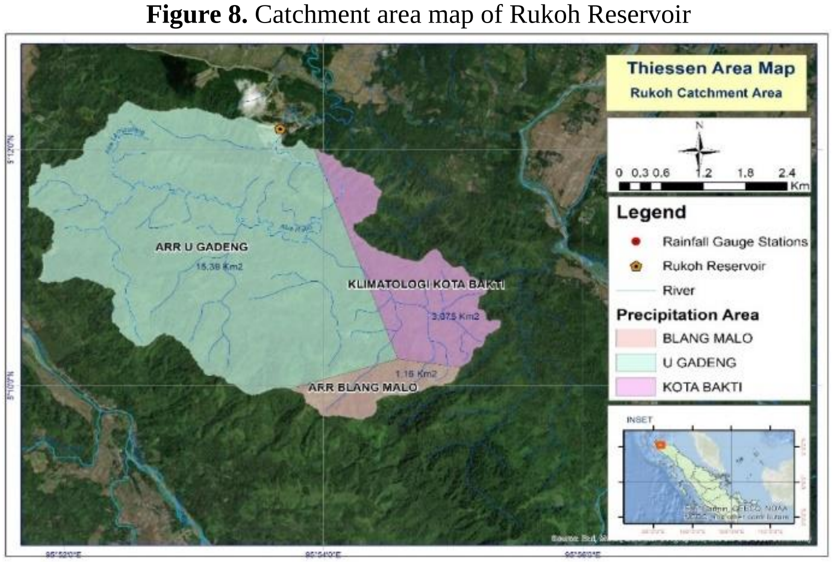

Figure 9. Thiessen Polygon of Kr. Rukoh (Rukoh Reservoir Catchment Area)

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Table 5. Statistical testing of rainfall data 2014-2023

Testing Type	Rainfall Station		
	U Gadeng	Kt. Bakti	Blang Maloe
Consistency test RAPS	Accepted	Accepted	Accepted
Outlier	Accepted	Accepted	Accepted
F Test	Consistent	Consistent	Consistent
T Test	Consistent	Consistent	Consistent
Result	**Valid**	**Valid**	**Valid**

Table 6. Thiessen Polygon Influence Area Ratio in the Rukoh Reservoir Catchment

Rainfall Stations	Area Km^2	Rasio Luas Thiessen
U gadeng	15.39	0.78
Blang Malo	1.17	0.06
Kota Bakti	3.08	0.16

Table 7. Potential Evapotranspiration (Eto) Modified Penman Method at Rukoh Reservoir (mm/day)

Description	Month											
	Jan	Peb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Oct	Nov	Dec
Potential Evapotranspiration (Et_0)	3.46	4.15	4.36	4.09	3.77	3.99	3.99	4.26	4.12	4.25	3.94	3.82

observed discharge (Chandrasasi et al., 2020). Pengujian yang dilakukan dua metode yaitu uji korelasi dan uji efisiensi (*Nash-Sutcliffe Efficiency*). This Correlation Test aims to see the relationship between the model and the observations in Equation 7. (Adiningrum, 2016) :

$$R = \frac{n\sum Q_{mo}Q_{ob} - \sum Q_{mo}\sum Q_{ob}}{\sqrt{\{(n\sum Q_{mo}^2 - (\sum Q_{mo})^2)(n\sum Q_{ob}^2 - (\sum Q_{ob})^2)\}}} \quad (7)$$

with R as the correlation value between the variables Qobs and Qmod, Qob as the value of field observation discharge (m^3/sec), Qmo as the value of modelling discharge (m^3/sec), and n as the amount of data. The classification of the correlation coefficient assessment can be seen in Table 3.

The Nash-Sutcliffe Efficiency test aims to evaluate the level of accuracy and validity of the model

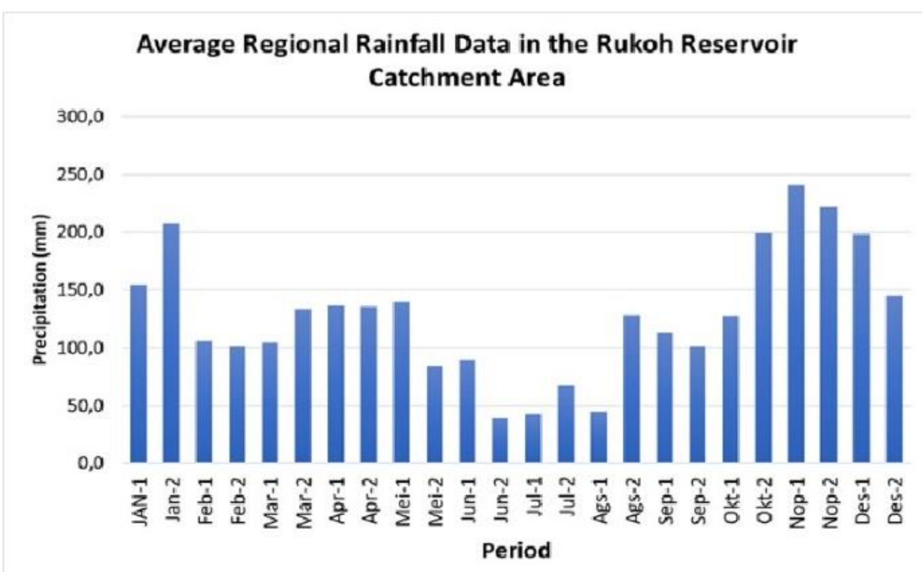

Figure 10. Rainfall Average Half Monthly Graph for Rukoh Catchment Area

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(Nurviana et al., 2023). The Nash-Sutcliffe efficiency test is performed using the criteria in Equation 8.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Qobs - Qmo)^2}{\sum_{i=1}^{n}\left(Qobs - \overline{Qobs}\right)^2} \qquad (8)$$

Q*obs* is the observed discharge, Q*mo* is the modelled/simulated discharge, $\overline{Qobs}$ i is the average observed discharge. The classification of the assessment of NSE is presented in Table 4.

The level of reliability of a model is tested by the RMSE (Root Mean Square Error) statistic; the formula in Equation 9 can be used (Halik et al., 2023). his RMSE (Root Mean Square Error) value indicates how much a model deviates from the measured data. The closer the RMSE value is to 0 (zero), the better the results of a model.

$$RMSE = \sqrt{\frac{\sum(Qobs - Qmod)^2}{n}} \qquad (9)$$

w where RMSE is the root mean square error, Qobs is the observed discharge data, Qmod is the resulting model discharge, and n is the number of data.

The last stage of this research analyzes the reliable discharge in Rukoh Reservoir. The reliable discharge is a discharge that is always available in the river to be used to meet the water demand in reservoirs that have calculated the risk of failure. The reliable discharge is an inflow to the reservoir with the objective of operating to meet the needs of irrigation water, raw water and hydropower. The level of discharge reliability is calculated based on the probability of occurrence by referring to the Weibull formula in Equation 10. (Subramanya, 2013)

$$P = \frac{m}{n+1} \qquad (10)$$

with P is the probability of discharge data and n is the amount of discharge data. Calculation of reliable discharge data is used in accordance with the requirements in planning(Badan Standarisasi Nasional, 2004): (1) discharge of raw water needs planning / drinking with a probability of 90%; (2) discharge of irrigation planning with a probability of 80%; and (3) discharge of environmental planning in the form of maintenance flow with a probability of 95%.

3. Results and Discussion

3.1. Boundary of Rukoh Reservoir Catchment Area

Based on the delineation of catchment boundaries with DEM, the catchment area (DTA) of Rukoh Reservoir is approximately 19.63 Km^2, as shown in Figure 9.

3.2. Statistical Testing of Rainfall Data

Statistical testing of rain data was carried out on three rain stations for 10 (ten) years, namely 2014-2023, with the results shown in Table 5. Based on the results of testing the rain data in Table 5, it is found that the rain data is valid and can be used for further analysis.

3.3. Regional Rainfall Analysis

The Rukoh Reservoir catchment area is supplied by the flow of Krueng (Kr.) Rukoh. As shown in Figure 10, three rainfall gauge stations significantly influence this region. The results of the Thiessen polygon analysis define the influence area of each rainfall gauge station, as shown in Table 6. The total catchment area of Rukoh Reservoir spans 19.63 km² and is divided into three rainfall influence zones: U Gadeng, Blang Malo, and Kota Bakti Rainfall Stations. The proportional area of each zone was then calculated relative to the total catchment area.

Additionally, using Equation 1, the average semi-monthly rainfall at each rainfall station is calculated in relation to the area ratio. Thiessen Figure 11 shows the semi-monthly average rainfall in the Rukoh Reservoir catchment area. Figure 11 illustrates how the research area's hydrological conditions are often wet due to its tropical environment, which has two distinct seasons: the rainy season and the dry season. The months of January and November mark the height of the rainy season.

Table 7. Observation discharge (Qobs) at Rukoh Reservoir DTA (m^3/sec)

Month	Year		
	2020	**2021**	**2022**
Jan I	1.23	1.56	1.81
Jan II	1.07	2.04	1.28
Feb I	1.14	1.55	1.22
Feb II	1.34	1.24	1.22
Mar I	1.26	0.87	1.35
Mar II	1.48	0.98	1.54
Apr I	1.66	1.18	1.91
Apr II	1.52	1.09	1.64
Mei I	2.80	1.07	1.12
Mei II	1.70	0.94	0.79
Jun I	1.46	0.90	0.74
Jun II	1.00	0.67	0.78
Jul I	1.01	0.76	0.74
Jul II	1.14	0.50	0.83
Aug I	1.01	0.72	0.61
Aug II	1.01	1.02	0.74
Sep I	0.66	0.61	0.69
Sep II	0.62	0.71	0.69
Oct I	0.68	0.61	0.74
Oct II	0.61	1.07	0.80
Nov I	1.29	1.65	2.09
Nov II	1.52	1.78	1.52
Dec I	1.64	1.40	1.33
Dec II	1.55	1.75	1.55

Source :(BWS Sumatera I, 2023)

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Table 8. Exposed surface value (m%) based on land cover

Land Cover	*Exposed surface (m)*
Forest	0%
Secondary land	0%; increased by 10% at the end of the rainy season
Eroded Land	10-40%
Agriculture land	30-50%

Source : (Mock, 1973)

Table 9. NSE Value for Discharge Model

Discharge Model	**NSE Value**
F.J. Mock	0.38
NRECA	0.51

Table 10. Model Validation Assessment Results

Model	**Validation**			
	Correlation Coefficient (R)	Criteria	NSE	Criteria
FJ. Mock	0.66	Strong	0.32	Poor
NRECA	0.83	Very Strong	0.64	Satisfactory

Table 11. Summary of statistical tests of the NSE model and correlation test of the Rukoh reservoir watershed

Model	**2020-2022**		**2022**	
	NSE	**Coef. Correlation**	**NSE**	**Coef. Correlation**
FJ Mock	0.33	0.64	0.32	0.66
NRECA	0.51	0.75	0.64	0.83

Table 12. Results of RMSE Evaluation of F.J. Mock and NRECA models in the Rukoh Reservoir catchment area

Model	**2020-2022**	**2022**
	RMSE	**RMSE**
F.J. Mock	0.36	0.33
NRECA	0.26	0.31

Typically, the rainy season lasts from April or May to September or October.

3.4. Potential Evapotranspiration (Eto)

Evapotranspiration is calculated based on Equation 3 using climate record data at the Kota Bakti climatology station 5,268925º North dan 95,929619ºEast. The results of the potential evapotranspiration analysis are presented in Table 7.

3.5. Measurement of Discharge Data

Observation discharge data is obtained from the Tiro automatic discharge post (AWLR) managed by BWS Sumatera 1 for 3 years consisting of 2020 to 2022. Discharge data on Kr. Rukoh is obtained based on the area ratio between the Tiro watershed and the Rukoh sub-watershed, as shown in Table 8.

3.6. Optimization of model parameters

Optimization of model parameters is done by comparing (testing) the observed discharge with the modelled discharge. Testing the dischage model using the Nash-Sutcliffe Efficiency (NSE) statistical test and the correlation coefficient is discussed in the next step. Testing in the form of calibration using observed discharge data by conducting trials (trial and error) of different parameter values until they approach the optimal value or the observed discharge value. The optimization process was performed repeatedly using a solver in Excel 2019 that aims to optimize the fit of parameter values between the model and the measured data (Syaakiroh et al., 2024). Optimization was performed on the FJ. Mock and NRECA model parameters with the following results:

a. F.J. Mock Model

Calculation of discharge with the F.J. Mock rainfall-runoff model based on Equation 4-1 by entering rainfall and evapotranspiration. The condition of the catchment area will affect the Exposed surface (m%) value based on the land cover map or with the assumptions in Table 9. (Anindya et al., 2022).

Soil Moisture Capacity (SMC) is the maximum amount of water that can be held in the top layer of soil. In this calculation, the SMC value is between 50 and 200

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millimetres (mm) (Widyaningsih et al., 2021). The Rukoh watershed has the following parameters: an open land surface of m = 0%, increasing by 10% in the dry season, with conditions still in the form of forests and plantations, an initial soil moisture of 200 mm/month based on soil types and plants in general (Sachro et al., 2014) and an infiltration coefficient, IF = 0.8. The groundwater recession constant (k) is 0.87.

b. NRECA Model

Optimization of the calculation of discharge using the NRECA model obtained model parameters consisting of the index of soil moisture storage capacity (nominal) of 713.09, the value of Percent Sub Surface (PSUB) is 0.9, which indicates that the study area has a large permeable aquifer. The value of the crop factor obtained is 0.87. The value of initial moisture storage (Wo-i) is 135.0.

3.7. Model Evaluation

Model suitability evaluation is carried out using the correlation test method, Nash-Sutcliffe Efficiency (NSE) test and Root Mean Square Error (RMSE). Model suitability testing in the form of calibration of observed discharge data for 2020-2021 and validation using observed discharge data in 2022. Based on Figure 12, the results of the correlation test between the F.J. Mock model and the observation data obtained the coefficient of determination R2 = 0.41 or the correlation coefficient (R) = 0.64 is strong.

The correlation test on the NRECA discharge model with the observation discharge (Qob) is based on the graph Figure 13. obtained the Coefficient of Determination R2 = 0.56 or R = 0.75 is strong.

This NSE (Nash-Sutcliffe Efficiency) test was also carried out on the model discharge (FJ. Mock and NRECA) with the observed discharge obtained the NSE value as shown in Table. 10. Furthermore, the F.J. Mock and NRECA models are validated against discharge data in 2022, the results of the calculation of model discharge and observation data in 2022 can be seen in Figure 14. A comparison of model validation test results between F.J. Mock and NRECA is shown in Table 11. Based on Table 12, it can be tested in the form of model calibration using observation data for 3 years (2020-2022). The NSE test value and the NRECA Model Correlation Coefficient are better than the F.J. Mock model as well as the validation test for 1 year (2022).

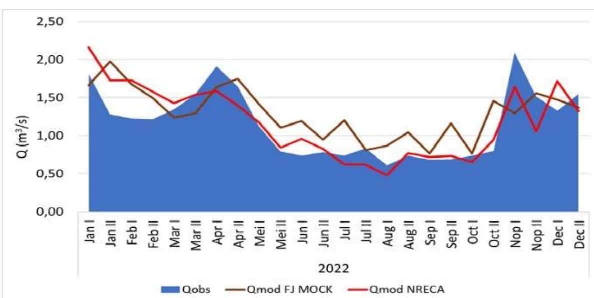

Figure 11. Validation Graph of F.J. Mock, NRECA Model Discharge with Observation Discharge

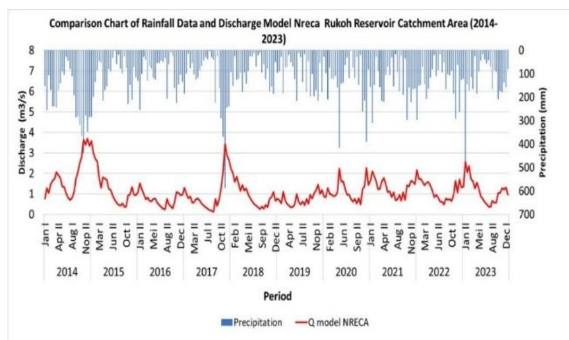

Figure 12. Comparison of the NRECA Kr. Rukoh discharge model with rainfall data for the years 2014-2023

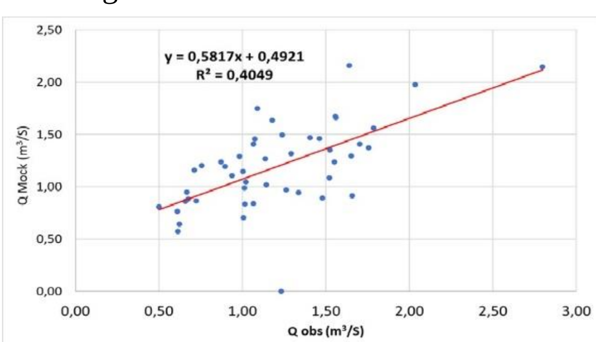

Figure 13. Graph of correlation coefficient between FJ Mock and observed discharge

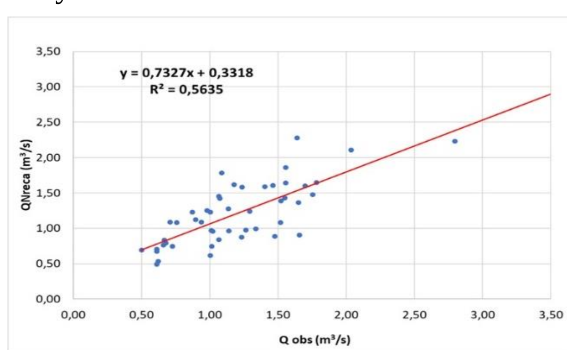

Figure 14. Graph of NRECA and Observation discharge correlation coefficient

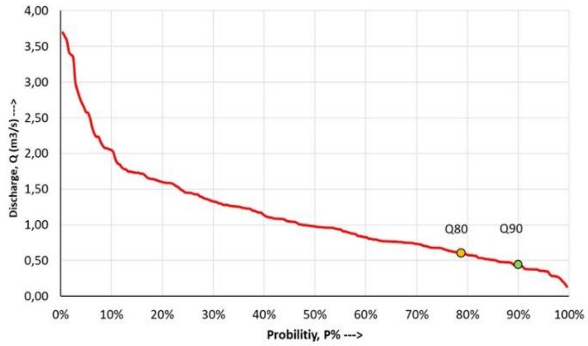

Figure 15. Flow duration curve (FDC) of Rukoh Reservoir Catchment Area

Based on the evaluation of the RMSE (Root Mean Square Error) value that the NRECA model discharge is slightly better (close to the value of 0) than the FJ. Mock Model. Based on the results of the overall model testing in the form of correlation, NSE and RMSE tests, it is concluded that the rainfall-flow model analysis suitable for the analysis of flow discharge calculations in the Rukoh Reservoir catchment area is the NRECA discharge model as shown in Table. 13. Based on the results of the comparison of these two models, it can be briefly explained that the F.J. Mock Model and NRECA are two methods used for discharge and surface flow analysis based on rainfall data and watershed characteristics. Although both are often used because of their simplicity and ease of implementation, there are some weaknesses that need to be considered. The F.J. Mock model is considered too simple because it only relies on a few parameters without taking into account more detailed temporal variations of rainfall (e.g. intensity and duration of rainfall), and the validity for small areas is less accurate.

The NRECA model also has weaknesses in accuracy due to its simplicity and reliance on the runoff coefficient (C), which is often difficult to determine accurately without sufficient field data. This coefficient varies greatly depending on soil type, land use, and topographic conditions, which can lead to inaccuracies in the calculation of discharge.

The advantages of the NRECA Model are relatively more accurate than F.J. Mock in various topographic conditions, soil types, and land uses, especially in more heterogeneous areas. Besides, the NRECA Model can integrate more variables in flow calculations, such as land use changes, human water use (for agriculture or raw water demands), and various physical factors that affect river discharge and flow.

The NRECA method discharge model is then analyzed to calculate the flow discharge to determine the amount of Rukoh Reservoir inflow discharge.

3.8. Simulation of Rukoh Reservoir DTA Flow Discharge

The flow discharge model was simulated over a ten-year period (2014–2023), with the minimum discharge (Qmin) occurring in August–II, 2017, at 0.13 m3/second and the maximum discharge value (Qmax) occurring in December–I, 2014, at 3.7 m3/second. Figure 15 illustrates the connection between the amount of rainfall and the NRECA model discharge.

3.9. Rukoh Reservoir Water Availability

The availability of water in the Rukoh reservoir is obtained by calculating reliable discharge based on Equation 16. in the form of the Weibull formula. Discharge data for 10 years is sorted from the largest data to the smallest data, and then 80% and 90% probability are calculated.

In terms of reservoir water availability for irrigation and raw water, the probabilities used are Q_{80} and $Q_{90}$with the discharge magnitude presented in the flow duration curve in Figure 16.

4. Conclusions

The conclusion of this study is that the F.J. Mock Model discharge has an average annual discharge of 1.19 m3 / second. The NRECA model obtained an average flow discharge of 1.13 m^3 /second. Testing the suitability of the two models against observational data shows that the NRECA discharge model is better when compared to the F.J. Mock model with a validation test value of NSE = 0.64 and correlation test R = 0.83 The amount of reliable discharge at the Rukoh Reservoir DTA for irrigation is (Q80) = 0.58 m^3 / second while for raw water needs using the rel (Q90) = 0.43 m^3 / second.

The discharge data generated from the analysis of the rainfall-runoff model in this study has problems in accuracy. Improving the accuracy of the model is done by increasing the data density of several rainfall stations around the watershed to reduce errors due to spatial variability of rainfall. If there is no use of high-resolution satellite data, calibration of the model should use measured river discharge data in good quality with historical that has a long enough time span (more than 10 years). Accurate and long discharge data can easily be used to analyze reservoir operation patterns in accordance with plans to fulfil water needs (raw water, irrigation and hydropower).

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