



## Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author: I Gusti Agung Putu Eryani  
Assignment title: Article  
Submission title: Model Calibration Parameter Using Optimization Trial in HE...  
File name: meter\_Using\_Optimization\_Trial\_in\_HEC-HMS\_for\_Unda\_Wat...  
File size: 1.35M  
Page count: 10  
Word count: 4,252  
Character count: 21,211  
Submission date: 23-Jan-2022 11:59AM (UTC+0700)  
Submission ID: 1746204267

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Model Calibration Parameter Using Optimization Trial in HEC-HMS for Unda Watershed

To cite this article: G A P Eryani et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 930 012040

View the [article online](#) for updates and enhancements.

The Electrochemical Society  
**241st ECS Meeting**  
May 29 – June 2, 2022 Vancouver • BC • Canada  
Extended abstract submission deadline: Dec 17, 2021  
Connect. Engage. Champion. Empower. Accelerate.  
Move science forward

Submit your abstract

This content was downloaded from IP address 38.85.192.48 on 15/12/2021 at 03:31

# Model Calibration Parameter Using Optimization Trial in HEC- HMS for Unda Watershed

*by I Gusti Agung Putu Eryani*

---

**Submission date:** 23-Jan-2022 11:59AM (UTC+0700)

**Submission ID:** 1746204267

**File name:** meter\_Using\_Optimization\_Trial\_in\_HEC-HMS\_for\_Unda\_Watershed.pdf (1.35M)

**Word count:** 4252

**Character count:** 21211

**PAPER · OPEN ACCESS**

## Model Calibration Parameter Using Optimization Trial in HEC-HMS for Unda Watershed

To cite this article: G A P Eryani *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **930** 012040

10

View the [article online](#) for updates and enhancements.



The Electrochemical Society  
Advancing solid state & electrochemical science & technology

### 241st ECS Meeting

May 29 – June 2, 2022 Vancouver • BC • Canada

Extended abstract submission deadline: Dec 17, 2021

Connect. Engage. Champion. Empower. Accelerate.  
Move science forward



Submit your abstract



## Model Calibration Parameter Using Optimization Trial in HEC-HMS for Unda Watershed

I G A P Eryani<sup>1,\*</sup>, I M S Amerta<sup>2</sup> and M W Jayantari<sup>3</sup>

<sup>1</sup>Civil Engineering Department, Warmadewa University, Denpasar, 80239, Indonesia

<sup>2</sup>Management Department, Warmadewa University, Denpasar, 80239, Indonesia

<sup>3</sup>Civil Engineering Department, Undiknas University, Denpasar, 80224, Indonesia

\*Corresponding Author: eryaniagung@gmail.com

**Abstract.** In water resource planning, information on water availability is needed. Nowadays, data on water availability is still difficult to obtain. With technology in the form of a rainfall-runoff simulation model that can predict water availability in the Unda watershed. It can add information about the potential for water in the Unda watershed. It can be used to prepare water resources management in the Unda watershed so that the existing potential can be used sustainably. Based on the rainfall simulation model results in the Unda watershed, it can be concluded that after running the initial model and calibration. The results are obtained R<sup>2</sup> value was 0.68 and increased by 9.81% to 0.754. Both the initial model and the calibration model show an efficient R<sup>2</sup> value, NASH value increases by 49.93% to 0.713, which includes satisfactory criteria, RMSE value of 1.135 and decreased by 49.47% to 0.758, and the PBIAS value was 44.70% which was classified as unsatisfactory and decreased from 80.24% to 24.80% at the time of calibration which was classified as satisfactory. In general, the overall simulation results are quite good for representing the watershed's efficient hydrological process.

Keywords: Calibration, HEC-HMS, Unda watershed

### 1. Introduction

The issue of sustainable management of water resources is a major challenge and very important for society worldwide. Failure to manage water resources effectively will harm society and the country's economy. In planning the allocation of water resources in a river area, it requires an understanding of the dynamics of the water potential of the watershed and an assessment of the availability of the river area to determine the appropriate and sustainable use of water [1]. The Unda Watershed is one of the second largest watersheds in Bali Province. The Unda River is a river that has water potential every year or what is commonly called the Perennial river flow type with a total area of 222.85 km<sup>2</sup>. There is still around 91.361 liters/second in one year the potential of surface water that has not been used in the Unda watershed is wasted [2].

Although it has many water sources, it turns out that the land is critical in the Unda watershed. Volcanic formations dominate the Unda watershed. 79.59% of the land use in the study area is dry land. The type of Regosol soil that is very vulnerable in the study area is 68.41%. Meanwhile, 45.64% are undulating areas (hilly to mountainous) and illegal C excavation sites. Currently, the watershed function is starting to decline because there are some problems in watershed management [3].



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd

The Unda watershed is one of the critical watersheds that is considered an urgent target for an integrated watershed management plan. The difference between the minimum and maximum discharges, which is quite significant, recorded during the 2016-2013 period, the maximum discharge of 53.4 m<sup>3</sup>/s and the lowest discharge of 0.17 m<sup>3</sup>/s, can indicate poor watershed performance. The Unda watershed has a large enough critical land [4].

Integrated water resources management in the Unda watershed needs to be done. Therefore, it can be used optimally for all types of needs. However, nowadays, water availability data is still difficult to obtain [5][6][7].

Hydrological modelling can estimate the hydrological response of a watershed due to precipitation. Various types of hydrological models, from black-box models that require fewer watershed data to physically-based models that require large amounts of watershed data have been developed. The selection of the model depends on the needs of the analysis and the results to be obtained. HEC-HMS is one of the hydrological models developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. This model can support rainfall-runoff simulation with several hydrological parameters to approach the simulation results to the actual event [8].

Rainfall-runoff hydrological studies have been carried out in many areas around the world to meet various desired needs. It is necessary to carry out the use effectively and appropriately, both now and in the future. So with technological advances in the form of a rain-runoff simulation model that can predict the availability of water in the Unda watershed, it can add information about the water potential in the Unda watershed. So that it can be used as a basis for preparing water resource management in the Unda watershed so that the existing potential can be used sustainably.

In making a model, a calibration process is needed to minimize the difference between the simulation discharge results and the observed discharge [9].

Previously, in determining the optimal parameters that produce good model reliability in the HEC HMS model, the calibration process requires a sensitivity analysis process to obtain optimal parameter values [10][11]. In the latest version of HEC HMS, an Optimization Trial Simulation tool has been provided, making it easier to determine the optimum value for each calibrated parameter [12]. For this reason, this study will simulate the HEC HMS model for the Unda watershed with the Optimization Trial Simulation tool to obtain optimum model reliability.

## 2. Research Methods

### 2.1. Research Location

The Unda Watershed is one of the second largest watersheds in Bali Province. The Unda River is a river that has water potential every year or what is commonly called the Perennial river flow type with a total area of 222.85 km<sup>2</sup>. The Unda watershed is currently used to meet the needs of raw water and irrigation water in the area around the watershed. The water potential is large enough to make the Unda watershed one of the potential rivers in the Bali Province. However, some of the problems still being experienced by the Unda watershed make the potential that exists cannot be utilized effectively. The Unda watershed has two main rivers, namely the Telagawaja River and the Unda River. Using the HEC-HMS software's GIS menu, the Unda watershed is delineated into several sub-watersheds to obtain discharge data in several locations.

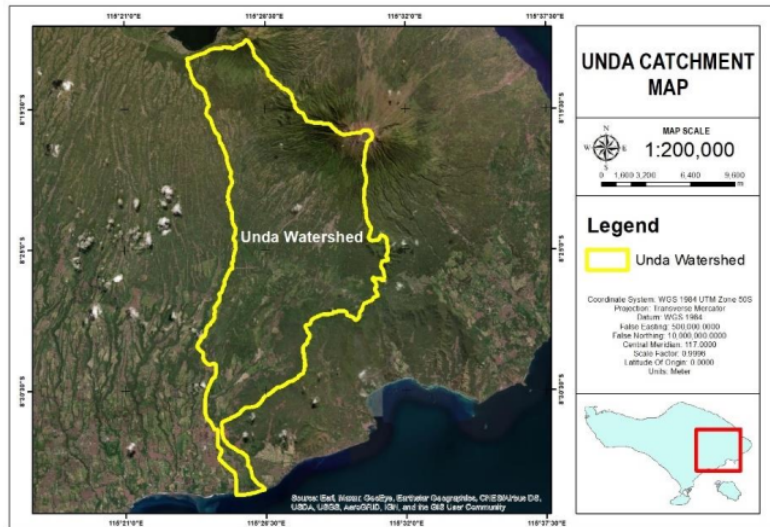


Figure 1. Unda Watershed

1

2.2. Research Tools and Materials

The tools used in data processing in this research are Microsoft Excel, Microsoft Word, and HEC-HMS 4.6.1. As for the research materials needed in this study in the form of primary data and secondary data. Primary data in the form of a survey of the existing condition of the Unda watershed for making assumptions in modelling, while secondary data in the form of digital elevation model (DEM) data of the Unda watershed, rain data, discharge data, as well as maps of land use and Unda soil types obtained from relevant agencies and literature studies in determining the assumptions in the modelling.

16

2.3. Preparation of Rainfall-Runoff Model Using HEC-HMS

The structure of the model development using HEC-HMS consists of five components that have several methods. This study uses the method that can be seen in Table 1 below.

Table 1. Method Used

Model	Method
Precipitation	Specified Hyetograph
Runoff-Volume Models	SCS CN
Direct runoff Models	SCS UH
Channel Routing Models	Lag
Base flow Models	Constant monthly

Source: Analysis Results

2.4. Basin Model Processing

The preparation of the basin model is one of the important stages in analyzing the hydrological system using the HEC-HMS model. At this stage, it consists of arranging elements that represent the physical watershed in nature. The elements that make up the watershed include sub-basin, reach, reservoir, junction, diversion, source, and sink. The Unda watershed model basin is divided into seven sub-basins based on the watershed topography. The delineation process into several sub-basins is done automatically with the help of the GIS menu in the HEC-HMS software.



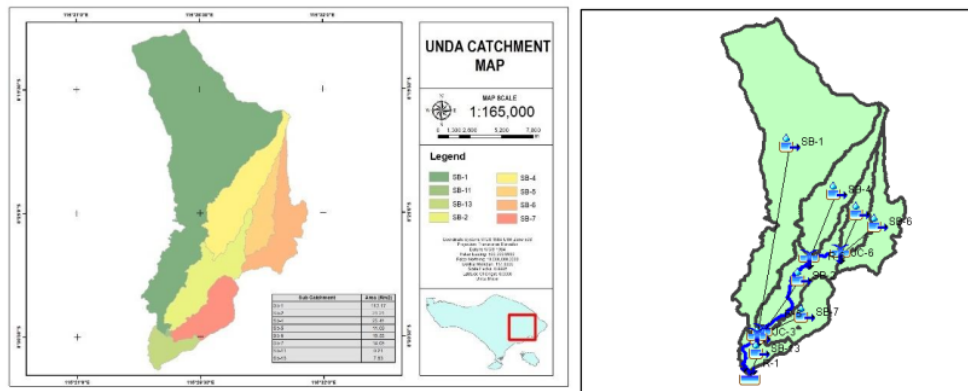


Figure 2. Basin Model Unda Watershed

35

2.5. Parameters Used in the HEC-HMS Model

The sub-basin element in HEC-HMS has only inflow and only one outflow. Outflow from the sub-basin is obtained based on rain data that has been processed in the watershed by converting excess rain into a flow (transform). While the reach element is an element with one or more inflows originating from other elements in the model. Outflow is derived from total inflow and channel calculations based on simulation of open flow in a channel or river. The parameters used in this study are listed in Table 2.

Table 2. Parameters Used in the HEC-HMS Model

Element	Component	Method	Parameter
Sub-basin	Surface	Simple Surface	Initial Storage Max storage
	Loss	SCS CN	Initial Abstraction Curve Number Impervious
	Transform	SCS UH	Time Lag SCS
	Base flow models	Constant Monthly	Base Flow
Reach	Reach routing method	Lag	Lag Time

Source: Analysis Results

2.5.1. Surface Method

The surface method in the sub-basin represents the ability of the land surface in the watershed to store water. Rain that falls directly on the ground surface will experience infiltration if the surface is only soil like rice fields. Suppose waterfalls are on closed surfaces such as roads and parking lots, the ability to store groundwater is 0.

The surface runoff will occur if the rate of precipitation exceeds the infiltration rate. Initial Storage is the percentage of ground surface storage at the beginning of the simulation. Initial Storage in this study is assumed to 0 because the start of the simulation coincides with the dry month. At the same time, Storage is the maximum amount of water that can be accommodated on the soil surface before surface runoff occurs. Maximum Storage in the initial simulation of this study is assumed to be 50.8 mm based on the slope of the Unda watershed, which ranges from 0-5%.

**Table 3.** Surface Depression Storage

Description	Slope (%)	Surface Storage (mm)
Flat	0-5	50,8
Medium	5-30	6,35-12,7
Steep	>30	1,02

Source: Ouédraogo et al [13]

### 2.5.2. Loss Method

The loss method simulates water loss in the watershed from rain to surface runoff. The model will simulate the process of rainwater loss due to land use and soil type through filtration and evapotranspiration processes before finally becoming direct runoff. This study uses the SCS CN method. The SCS CN method uses the initial Abstraction, CN, and impervious parameters. Calculation of initial Abstraction, CN, and impervious values. The composite CN calculation should not include a watertight area. Calculation of the composite CN uses the curve number value based on the land cover and soil type. The value of the curve number indicates the amount of runoff that will occur, if the value of the curve number of 100 indicates that the rainwater will become full runoff and the watershed condition is bad. Rainfall loss, which occurs through the runoff/infiltration process is determined using the SCS Curve Number method. This method calculates the effective precipitation of a hydrological event based on empirically derived relationships between location, soil type, land use, previous moisture conditions and runoff [14].

**Table 4.** Loss Parameter for Unda Watershed Model

Subbasin	Initial Abstraction (mm)	Curve Number	Impervious (%)
SB-1	52.55	49.15	65
SB-2	38.54	56.86	65
SB-4	44.95	53.06	65
SB-5	43.94	53.62	65
SB-6	45.16	52.94	65
SB-7	46.92	51.98	65
SB-11	28.36	64.18	65
SB-13	37.32	57.65	65

### 2.5.3. Transform method

The transform method in the sub-basin simulates the process from rain to flow hydrograph. This study uses the SCS UH method using the lag time parameter. Lag time is the time interval between the center of mass of rain and the time of peak discharge. Lag time calculation of each sub-basin.

**Table 5.** Transform parameter for Unda Watershed Model

Subbasin	Graph Type	Lag Time (min)
SB-1	Standard	8357.25
SB-2	Standard	7243.42
SB-4	Standard	2846.8
SB-5	Standard	649.35
SB-6	Standard	2016
SB-7	Standard	2878.85
SB-11	Standard	463.61
SB-13	Standard	7516.62



#### 2.5.4. Base flow Method

28

Conceptually, sub-basin elements represent infiltration, surface runoff, and subsurface processes that interact together. Subsurface processes are calculated through surface base flow or base flow. In this study, the base flow calculation uses the constant monthly method. The base flow value in each month is held constant at the beginning of the simulation using the lowest measured discharge value during the measurement from secondary data in the simulation period. The lowest discharge in the simulation period.

**Table 6.** Baseflow parameter for Unda Watershed Model

Sub basin	Jan BF <sup>+</sup> (m <sup>3</sup> /s)	Feb BF <sup>+</sup> (m <sup>3</sup> /s)	March BF <sup>+</sup> (m <sup>3</sup> /s)	April BF <sup>+</sup> (m <sup>3</sup> /s)	May BF <sup>+</sup> (m <sup>3</sup> /s)	June BF <sup>+</sup> (m <sup>3</sup> /s)	July BF <sup>+</sup> (m <sup>3</sup> /s)	Aug BF <sup>+</sup> (m <sup>3</sup> /s)	Sept BF <sup>+</sup> (m <sup>3</sup> /s)	Oct BF <sup>+</sup> (m <sup>3</sup> /s)	Nov BF <sup>+</sup> (m <sup>3</sup> /s)	Dec BF <sup>+</sup> (m <sup>3</sup> /s)
9 SB-1	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-2	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-4	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-5	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-6	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-7	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-11	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02
SB-13	0.12	0.05	0.02	0.22	0.02	0.02	0.05	1	0.6	0.11	0	0.02

BF: Baseflow

#### 2.5.5. Reach Routing Method

The reach routing method conceptually represents the condition of the river channel in the watershed. This study uses the Lag method. This method is the simplest of the included routing models. With that said, the outflow hydrograph is just the inflow hydrograph, but with all coordinates translated (lag in time) with a defined duration. The flow is not leveled, so the shape does not change [15].

**Table 7.** Reach Routing Parameter for Unda Watershed Model

Reach	Initial Type	Lag Time (min)
R-1	Discharge = Inflow	4283.84
R-3	Discharge = Inflow	463.61
R-5	Discharge = Inflow	5645.75
R-6	Discharge = Inflow	2504.22

#### 2.5.6. Time Series Data

The time-series data used in this study are daily rainfall data and daily discharge. Daily rainfall data is obtained from daily regional rain, which will be simulated into discharge using HEC-HMS. In contrast, daily discharge data is obtained from measurements of the Unda-Cegeng discharge station used for calibration on the sink element on the HEC-HMS Unda Watershed model.

#### 2.6. Model Calibration

Calibration will be carried out from January 1, 2014, to October 31, 2014; this time was chosen from selecting matches between the rainfall pattern and the observed discharge. The HEC-HMS 4.6.1 has been equipped with automatic calibration with an optimization trial manager.

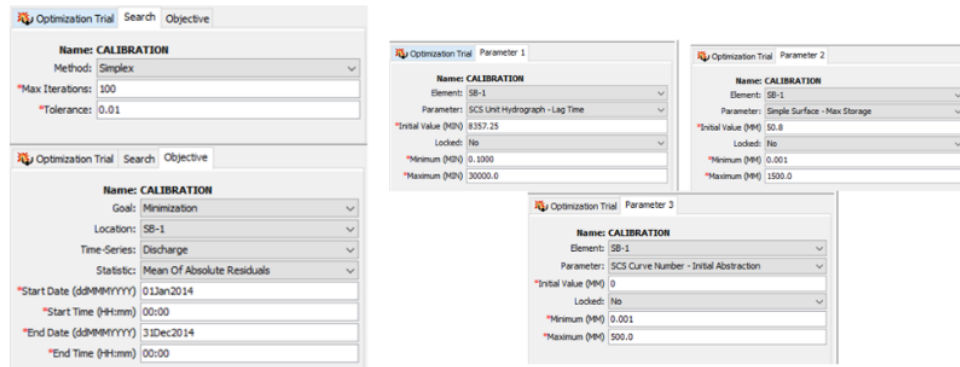
**3. Result and Discussion**

Based on the basin model, meteorological model, time-series data, and control specifications, then run to observe the simulated discharge hydrograph and observation discharge. After seeing the level of match between the simulation discharge and the observed discharge, the overall fit of the initial model is still quite good. But still not good enough to represent the watershed. Although the model with the initial parameters still has a poor model reliability value, the results are quite satisfactory after being calibrated.

**Table 8.** Result Value of Unda Watershed Model

Simulation	NASH	RMSE	PBIAS	R <sup>2</sup>
Initial Model	0.357	1.135	44.70%	0.68
Calibration	0.713	0.758	24.80%	0.754
Value change	49.93%	-49.74%	-80.24%	9.81%

Source: Analysis Results



**Figure 3.** Model Calibration Parameter Using Optimization Trial in HEC-HMS

**Table 9.** Optimized Parameter for Unda Watershed Model Calibration

Element	Parameter	Unit	Initial Value	Optimized Value
SB-1	SCS Unit Hydrograph - Lag Time	Min	8357.25	29715
SB-1	Simple Surface - Max Storage	mm	50.8	158.04
SB-1	SCS Curve Number - Initial Abstraction	mm	52.55	52.777

Source: Analysis Results

The R<sup>2</sup> (correlation coefficient) value shows the strength of the relationship between the two variables that you want to know. The correlation coefficient values ranged between -1.0 and 1.0. A correlation of -1.0 indicates a perfect but negative correlation, which is an inversely proportional relationship. In contrast, a correlation with a value of 1.0 indicates a perfect positive correlation that is directly proportional [12]. The correlation with a value of 0 indicates that the two variables do not show a relationship. In the initial model obtained, the value of R<sup>2</sup> is 0.68, while after calibrating the parameters, the R<sup>2</sup> value is 0.754. From this value, it can be seen that after calibration, the relationship between variables increased by 9.81%, which means that the simulation value is closer to the results in the field.

Nash Sutcliffe model efficiency coefficient is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance (Nash and Sutcliffe, 1970). The Nash-Sutcliffe efficiency indicates how well the observed and simulated data plots fit the 1:1 line.

NSE = 1, corresponding to a perfect fit of the model to the observed data. NSE = 0, indicating that the predictive model is as accurate as the observed data mean,  $INF < NSE < 0$ , indicating that the observed mean is a better predictor than the model. In the initial model, the NASH value is 0.357, which is still unsatisfactory. In contrast, after calibration, the NASH value increases by 49.93% to 0.713, which includes satisfactory criteria [16].

Understanding Root Mean Square Error (RMSE) is a method of measuring the difference in the value of a model's prediction as an estimate of the observed value. The Root Mean Square Error is the result of the square root of the Mean Square Error. The accuracy of the measurement error estimation method is indicated by the presence of a small RMSE value. The estimation method that has a smaller Root Mean Square Error (RMSE) is said to be more accurate than the estimation method that has a larger Root Mean Square Error (RMSE). The method of calculating the Root Mean Square Error (RMSE) is by subtracting the actual value from the forecast value, then squared, and the total results are then divided by the number of data. The initial model obtained the RMSE value of 1.135 and decreased by 49.47% to 0.758.

Percent bias is expressed in relative terms so that it is possible to evaluate the size of the bias due to under coverage for the parameters that are not known to be estimated. In the initial model, the PBIAS value was 44.70%, classified as unsatisfactory and decreased from 80.24% to 24.80% at calibration, classified as satisfactory [17]. Several parameter values have changed; namely, the lag time value for SB-1 changed from 8357.25 minutes to 29715 minutes. The Max Storage parameter changed from 50.8 to 158.04 mm, and the Initial Abstraction value was originally 52.55 to 52.777.

#### 33 4. Conclusion

Based on the rainfall simulation model results in the Unda watershed, it can be concluded that after running the initial model and calibration, the results are obtained  $R^2$  value was 0.68 and increased by 9.81% to 0.754. Both the initial model and the calibration model show an efficient  $R^2$  value, NASH value increases by 49.93% to 0.713, which includes satisfactory criteria, RMSE value of 1.135 and decreased by 49.47% to 0.758, and the PBIAS value was 44.70% which was classified as unsatisfactory and decreased from 80.24% to 24.80% at the time of calibration which was classified as satisfactory. And overall fit of the model is quite good, indicating that the model represents the hydrological process in the watershed is efficient.

#### Acknowledgments

The authors express gratitude to the Acknowledgments submitted to Warmadewa University who have supported the completion of this paper, and all parties who helped the completion of this paper

#### References

- [1] K. Sok and C. Oeumg 2016 Application of HEC- HMS Model to Assess Streamflow and Water Resources Availability in Stung Sangker Catchment of Mekong Tonle Sap Lake Basin in Cambodia
- [2] G. A. Bawantu, I. G. B. Siladharna, and N. N. Pujianiki 2018 Potensi Air Permukaan DAS Unda untuk Memenuhi Kebutuhan Air Domestik dan Non Domestik di Kabupaten Karangasem *J. Spektran* vol 6 no 1 p 38:49
- [3] E. W. Toban, I. N. Sunarta, and N. M. Trigunasih 2016 Analisis Kinerja Daerah Aliran Sungai Berdasarkan Indikator Penggunaan Lahan dan Debit Air pada DAS Unda *E-Jurnal Agroekoteknologi Trop.* vol 5 no 4
- [4] Pemerintah Provinsi Bali 2015 Status Lingkungan Hidup Daerah Provinsi Bali
- [5] N. I. Ihimekpen, I. R. Ilaboya, and O. F. Onyecholem 2018 Modelling and Simulation of Rainfall-Ruoff Relations for Sustainable Water Resources management in Ethiopie Watershed using SCS-CN, ARC-GIS, ARC -HYDRO, HEC-GEOHMS and HEC-HMS *Trends Civ. Eng. its Archit.* vol 2 no 3
- [6] M. Msaddek, G. Kimbowa, and A. El Garouani 2020 Hydrological Modeling of Upper

- OumErRabia Basin (Morocco), Comparative Study of the Event-Based and Continuous-Process HEC-HMS Model Methods *Comput. Water, Energy, Environ. Eng.* vol **09** no 04 pp 159–184 doi: 10.4236/cweee.2020.94011
- [7] S. Ramly, W. Tahir, J. Abdullah, J. Jani, S. Ramli, and A. Asmat, "Flood Estimation for SMART Control Operation Using Integrated Radar Rainfall Input with the HEC-HMS Model 2020" *Water Resour. Manag.* vol **34** no 10 pp 3113–3127 doi: 10.1007/s11269-020-02595-4
- [8] D. S. Sampath, S. B. Weerakoon, and S. Herath HEC-HMS Model for Runoff Simulation in a Tropical Catchment with intra-basin Diversion 2015 (Case Study: Deduru Oya River Basin, Sri Lanka) *Engineer* vol **XLVIII** no 1 pp 1–9
- [9] B. Winarta, P. T. Juwono, and N. A. A. Ghani 2019 Rainfall Runoff Model Evaluation for Lebir River, Kelantan, Malaysia *IOP Conf. Ser. Earth Environ. Sci.* vol **366** no 1 doi: 10.1088/1755-1315/366/1/012037.
- [10] CFCAS project 2004 Calibration, verification and sensitivity analysis of HEC-HMS Model *Computer (Long. Beach. Calif)*
- [11] D. Roy, S. Begam, S. Ghosh, and S. Jana 2013 Calibration and validation of HEC-HMS model for a river basin in eastern India *ARPJ. Eng. Appl. Sci.* vol **8** no 1 pp 40–56
- [12] USACE Hydrologic Engineering Center 2021 Applying the Optimization Trial Simulation Type," *HEC-HMS Tutorial and Guide* <https://www.hec.usace.army.mil/confluence/hmsdocs/hmsguides/applying-the-optimization-trial-simulation-type> (accessed July 28, 2021)
- [13] W. A. A. Ouédraogo, J. M. Raude, and J. M. Gathenya 2018 Continuous modeling of the Mkurumudzi River catchment in Kenya using the HEC-HMS conceptual model: Calibration, validation, model performance evaluation and sensitivity analysis *Hydrology* vol **5** no 44 doi: 10.3390/hydrology5030044.
- [14] USACE 2000 *Hydrologic Modelling System HEC HMS Technical Reference Manual*
- [15] D. H. Pilgrim and I. Cordery 1993 Flood Runoff in *Handbook of Hydrology*, D. R. Maidment, Ed. McGraw-Hill, New York, USA: McGraw-Hill Publishing
- [16] Y. G. Motovilov, L. Gottschalk, K. Engeland, and A. Rodhe 1999 Validation of a Distributed Hydrological Model Against Spatial Observations *Elsevier Agric. For. Meteorol.* vol **98** pp 257–277
- [17] B. JHS, F. ALT, L. AD, and A. LC 2019 The influence of spatial discretization on HEC-HMS modelling: a case study *Int. J. Hydrol.* vol **3** no 5 pp 442–449 doi: 10.15406/ijh.2019.03.00209

# Model Calibration Parameter Using Optimization Trial in HEC-HMS for Unda Watershed

## ORIGINALITY REPORT

20%

SIMILARITY INDEX

15%

INTERNET SOURCES

13%

PUBLICATIONS

9%

STUDENT PAPERS

## PRIMARY SOURCES

1	<a href="http://civense.ub.ac.id">civense.ub.ac.id</a> Internet Source	2%
2	Habtamu Nega, Yilma Seleshi. "Regionalization of mean annual flow for ungauged catchments in case of Abbay River Basin, Ethiopia", Modeling Earth Systems and Environment, 2020 Publication	2%
3	Submitted to Institut Pertanian Bogor Student Paper	2%
4	Barbosa JHS, Fernandes ALT, Lima AD, Assis LC. "The influence of spatial discretization on HEC-HMS modelling: a case study", International Journal of Hydrology, 2019 Publication	1%
5	<a href="http://backend.orbit.dtu.dk">backend.orbit.dtu.dk</a> Internet Source	1%
6	D. S. Sampath, S. B. Weerakoon, Srikantha Herath. "HEC-HMS model for runoff	1%

simulation in a tropical catchment with intra-basin diversions – case study of the Deduru Oya river basin, Sri Lanka", Engineer: Journal of the Institution of Engineers, Sri Lanka, 2015  
Publication

---

7	<a href="http://www.atlantis-press.com">www.atlantis-press.com</a> Internet Source	1 %
8	Submitted to Asia Pacific University College of Technology and Innovation (UCTI) Student Paper	1 %
9	<a href="http://repository.its.ac.id">repository.its.ac.id</a> Internet Source	1 %
10	<a href="http://repository.ung.ac.id">repository.ung.ac.id</a> Internet Source	1 %
11	<a href="http://ebin.pub">ebin.pub</a> Internet Source	<1 %
12	<a href="http://swat.tamu.edu">swat.tamu.edu</a> Internet Source	<1 %
13	Submitted to Coventry University Student Paper	<1 %
14	Waikhom Rahul Singh, Manoj K Jain. "Continuous Hydrological Modeling using Soil Moisture Accounting Algorithm in Vamsadhara River Basin, India", Journal of Water Resource and Hydraulic Engineering, 2015	<1 %



15 [ikee.lib.auth.gr](http://ikee.lib.auth.gr) <1 %  
Internet Source

---

16 M. GHARIB. "EVALUATION OF MODCLARK MODEL FOR SIMULATING RAINFALL-RUNOFF IN TANGRAH WATERSHED, IRAN", Applied Ecology and Environmental Research, 2018 <1 %  
Publication

---

17 [www.wrc.org.za](http://www.wrc.org.za) <1 %  
Internet Source

---

18 Submitted to University Der Es Salaam <1 %  
Student Paper

---

19 Submitted to Swinburne University of Technology <1 %  
Student Paper

---

20 [opinvisindi.is](http://opinvisindi.is) <1 %  
Internet Source

---

21 [studylib.net](http://studylib.net) <1 %  
Internet Source

---

22 Ismaeil Fazel, Alireza Ahmadi. "On the Relationship between Writing Proficiency and Instrumental/Integrative Motivation among Iranian IELTS Candidates", Theory and Practice in Language Studies, 2011 <1 %  
Publication

---

23

Internet Source

<1 %

---

24

[pakjas.com.pk](http://pakjas.com.pk)

Internet Source

<1 %

---

25

[repository.ipb.ac.id:8080](http://repository.ipb.ac.id:8080)

Internet Source

<1 %

---

26

Surendar Natarajan, Nisha Radhakrishnan. "Simulation of extreme event-based rainfall-runoff process of an urban catchment area using HEC-HMS", Modeling Earth Systems and Environment, 2019

Publication

<1 %

---

27

[coweeta.uga.edu](http://coweeta.uga.edu)

Internet Source

<1 %

---

28

Halwatura, D., and M.M.M. Najim. "Application of the HEC-HMS model for runoff simulation in a tropical catchment", Environmental Modelling & Software, 2013.

Publication

<1 %

---

29

João Pedro Nunes. "Vulnerability of water resources, vegetation productivity and soil erosion to climate change in Mediterranean watersheds", Hydrological Processes, 07/30/2008

Publication

<1 %

---

30 Rathnayake U. "Importance of Hydrologic Simulation for Lids and BMPs Design Using HEC-HMS: A Case Demonstration", International Journal of Hydrology, 2017  
Publication <1 %

---

31 d.researchbib.com  
Internet Source <1 %

---

32 ir.lib.uwo.ca  
Internet Source <1 %

---

33 trijurnal.lemlit.trisakti.ac.id  
Internet Source <1 %

---

34 vdoc.pub  
Internet Source <1 %

---

35 I. Popescu, A. Jonoski, S. J. Van Andel, E. Onyari, V. G. Moya Quiroga. "Integrated modelling for flood risk mitigation in Romania: case study of the Timis-Bega river basin", International Journal of River Basin Management, 2010  
Publication <1 %

---

36 civilejournal.org  
Internet Source <1 %

---

Exclude quotes On

Exclude matches Off

Exclude bibliography On