EVALUATION OF RAINFALL-RUNOFF MODELS APPLICATION ON SODONG WATERSHED, CENTRAL JAVA

THESIS

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WATER RESOURCES ENGINEERING MASTER DEGREE PROGRAM
PARAHYANGAN CATHOLIC UNIVERSITY
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VALIDATION PAGE

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ABSTRACT

Rainfall-runoff model is a model that cannot be separated with hydrology analysis. This model converts precipitation data into discharge and can be found in daily and monthly basis. Referring to several researches, “monthly basis model can simulate annual discharge better than annual model” and “certain model has advantages and limitations for a basin”. By considering watershed’s data capability, watershed location, watershed area, and watershed conditions this thesis aims to evaluate 3 selected models. Sodong watershed was chosen as study location.

Sodong watershed area is 44.87 Km^2. It is located in Central Java and a tributary of Paku River. More than 60% of the watershed is porus and its rainy season is normal with approximately 10 days late. The watershed has 1 climate post and 3 rainfall stations.

The analysis uses monthly data from year 2003 to year 2008. NRECA, HBV 96, and NAM model were chosen as the calculation model. The analysis consists of: sensitivity analysis, parameter calibration, verification, and evaluation. Sensitivity analysis was done by plotting the changes in parameters, calibrating was done by comparing simulated and observed discharge, verification was done by comparing parameter result with geological map, and evaluation was done by comparing each model duration curves. The research results are: the watershed porosity is high, models can simulate the watershed very well (NS>0.50), and duration curves comparison shows that overall HBV 96 model can simulate the watershed better. However in terms of simulating low flow, NAM model can simulate them better.

Key Words: Water Balance Model, Monthly Basis Model, Daily Basis Model, NAM Model, Sodong Watershed, Central Java.

EVALUASI APLIKASI MODEL HUJAN LIMPASAN PADA DAS SODONG, JAWA TENGAH

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ABSTRAK

Model hujan limpasan merupakan model yang tidak dapat dipisahkan dari analisis hidrologi. Model ini mengubah data hujan menjadi debit dan dapat ditemukan dalam basis harian dan bulanan. Mengacu pada beberapa penelitian, “model basis bulanan dapat mensimulasikan debit tahunan lebih baik dari model tahunan” dan “sebuah model memiliki kelebihan dan keterbatasan untuk bagi sebuah DAS”. Berdasarkan pertimbangan kemampuan data, lokasi DAS, luas DAS, dan kondisi DAS tesis ini bertujuan untuk mengevaluasi 3 model terpilih. DAS Sodong terpilih sebagai lokasi studi.

DAS Sodong memiliki luas sebesar 44,87 Km^2. DAS berlokasi di Jawa Tengah dan anak sungai dari Sungai Paku. Lebih dari 60% dari DAS merupakan tanah porus dan musim hujan “normal” dengan keterlambatan kurang-lebih 10 hari. DAS memiliki 1 pos iklim dengan 3 pos hujan.

Data yang digunakan dalam analisis adalah data tahun 2003 hingga tahun 2008. NRECA, HBV96, dan NAM merupakan model yang dipilih dalam analisis. Analisis yang dilakukan meliputi: analisis sensitifitas, kalibrasi parameter, verifikasi, dan evaluasi. Analisis sensitivitas dilakukan dengan plot perubahan parameter, kalibrasi dilakukan dengan membandingkan antara hasil kalibrasi dengan peta geologi, dan evaluasi dilakukan dengan membandingkankurva durasi tiap model. Hasil penelitian: DAS memiliki porositas tinggi, model-model dapat mensimulasikan dengan baik (NS>0.50), dan perbandingan kurva durasi menunjukkan bahwa secara keseluruhan HBV 96 dapat mensimulasikan DAS dengan baik, namun NAM dapat mensimulasikan debit rendah lebih baik.

Kata Kunci: Model Keseimbangan Air, Model Bulanan, Model Harian, NAM Model, DAS Sodong, Jawa Tengah.

PREFACE

The writer would like to thank Allah SWT for the blessing, health, and time that were given, so that the writer could finish a thesis entitled “Hydrology Characteristics Study of Sodong Watershed – Central Java by Using NRECA, NAM, HBV, and Sacramento Model” “Evaluation of Rainfall-Runoff Models Application on Sodong Watershed, Central Java “.This thesis was written to document the study result and fulfill the academics requirement in Parahyangan Catholic University. With the completion of this thesis, the writer would like to give gratitude to:

1. Mr. Doddi Yudianto, Ph.D and Ms. Dr. Ir. F. Mulyantari as thesis supervisor who always give time, idea and advices, help, and support so author can finish this thesis on time.
2. Prof. Wahyudi Triweko, Ph.D and Dr. Ir. Salahudin Gozali, M. Eng who gave author advices.
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4. Friends in “Water Resources Engineering” field who gave moral support and advices.
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7. Parahyangan Catholic University for giving author the chance of studying.
8. Last but not least, all of the parties that cannot be stated one by one who help the author during thesis making.

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NOTATION AND ABBREVIATION LIST

A	: area
CBFL	: groundwater flow coefficient
CFLUX	: capillary flux rate
CK2	: Time constant river flow
CKBFL	: time constant lower groundwater flow
CKBFU	: Time constant upper groundwater flow
CKI1	: time constant overland and interflow
CLG	: threshold value groundwater
CLIF	: threshold value interflow
Cmelt	: snow melt coeffiecient
CQIF	: Interflow runoff coefficient
CQOF	: overland flow runoff coefficient
D or Q	: debit
E	: evapotransporation
FC	: soil moisture storage
G	: water supply addition from groundwater
GWF	: groundwater fraction
Lmax	: lower zone storage capacity
LP	: limit for potential evaporation
M	: ground moisture addition
MAXBAS	: transformation function parameter
NS	: Nash-Sutcliffe

P	: precipitation
Pave	: average depth of rainfall over the area
PERC	: percolation rate
PET	: potential evapotranspiration
PSUB	: discharge to subbase
Qo	: observed discharge
Qs	: simulated discharge
RVE	: relative volume error
Umax	: Upper zone storage capacity

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CHAPTER 1
INTRODUCTION

1.1. General Background

Water is one of the basic necessities for living beings. Water flows systematically within a cycle called “Hydrological Cycle”. Hydrologic cycle can be described as water circulation which occurs continuously from atmosphere to earth through condensation, precipitation, evapotranspiration, and transpiration. This cycle happens continuously without end or beginning and is used as reference to formulate hydrologic interaction (Chow, 1988)..

Hydrology elements which take part in hydrology cycle are: atmosphere; vegetation; ground surface; ground; water flow, lake, and river; aquifer; and sea. In this cycle water that came from the sea and ground evaporate and turn into cloud then pour as rain. Even so, not all of the rain pours to the ground because some of the water evaporates. Some of them pour on the leafs as well. Rain that made their way to the ground infiltrate then some of them flow to the sea and rivers, some of them evaporate and some of them stored as ground water (Sosrodarsono et.al, 1999). Even though water can replenish itself, the increase of water demand leads to scarcity. The more needs variety within the area, the more water needs to be provided.

Rainfall-runoff models are used to describe the processes involved in the hydrology cycle and the links between the different components of the hydrology cycle. The ability of each model to present the cycles is different based on the parameter used.

This thesis uses three models in the analysis: NRECA, HBV 96, and NAM. The reasons are:

1. All of them are well known models,
2. NRECA was chosen as the monthly basis model comparison since it only has two parameters,
3. Considering parameter number, then there is a possibility that HBV 96, NAM, and Sacramento can picture the watershed better compared to NRECA. However, whether they are suitable for the selected watershed or not will be discussed in this thesis,
4. Both HBV 96 and NAM model have three simulation boxes. This means there is a possibility that their result will relatively close,
5. HBV96 is known for its good modeling result and NAM is part of MIKE 11.

Rainfall-runoff models have been researched throughout the time and cannot be parted from hydrology analysis needs. Alley et.al. (1984), Vandewiele et al. (1992), and Xu et. al. (1998) did a research comparison research on rainfall-runoff models. They were comparing monthly model to annual model which resulted, "Monthly basis model can simulate annual discharge better than annual model". Giakoumakis et. al. (2015) and Cilek et. al. (2016) did an evaluation research which resulted, "A certain model has advantages and limitations for a basin".

1.2. Research Objectives

The main objective of this thesis is to evaluate the performance of the three models (NRECA, HBV 96, and NAM) within the same data quality and continuing the previous studies. There are several objectives that also discussed alongside of the main objectives, like:

a. Sensitivity analysis for all models,
b. Calibrating the parameters,
c. Parameter verifications,
d. Evaluate the analysis result.

1.3. Scope of Study

These are the scope of study:

1. The watershed will only be analyzed by using three selected models: NRECA, NAM, and HBV 96;
2. Due to data availability, the calculation will use monthly data. This includes: rainfall, climate, and observed discharge. Also, verification will be done by comparing the result with geological map;
3. Sensitivity analysis will be done by using the data from one chosen year;
4. The analysis will only use monthly data from year 2003 – 2008 in both analysis and calibration process;
5. Watershed height and the influence of nearby watershed are excluded;
6. This study will not discuss about geological, social, and economical conditions in detail.

1.4. Research Methodology

Flowchart of this study can be seen on **Figure** 1.1 and the description can be seen below:

1. "Literature study" can be done by doing several activities like: reading papers, books, and previous studies as well as doing group discussion;
2. There are five kinds of data that need to be collected. Discharge station location is needed as the start and end of watershed draw point (watershed's outlet point). Rainfall and climate station location is needed to know which stations that affect the watershed analysis. Watershed area, rainfall data, and climate data are needed in the calculation. Observed stream flow data is needed in the process of calibration and verification;
3. The reason for doing "Sensitivity Analysis" is to know which parameters that give bigger impact (sensitive) compared to other parameters. Sensitive parameters are ones that well determined while the insensitive are ones that poorly determined (Sorooshian and Gupta et.al, 1995: 51). By knowing this, author can predict which parameters should be changed carefully and which can be changed freely;
4. "Rainfall-runoff model Construction" step will be done by using calculation tool and the formula in it will be taken from the literature study result;
5. "Rainfall-runoff model Calibration" is a step to find the right parameter for the model. The calibration will be done manually. The analysis will be advanced once the simulation discharge close to measured discharge (NS value is positive);

6. “Model Verification” will be done by comparing the calibration result with geological map;
7. “Model Analysis” will be done by looking at the result of the three models. The analysis will be based on their duration curves comparison, changes in parameters throughout the years, and result similarity between models;
8. “Conclusions and Recommendations” will be taken in the end of the analysis. This step includes what can be improved for further study;
9. “Report Writing” will be done in the end of analysis to document the study result.

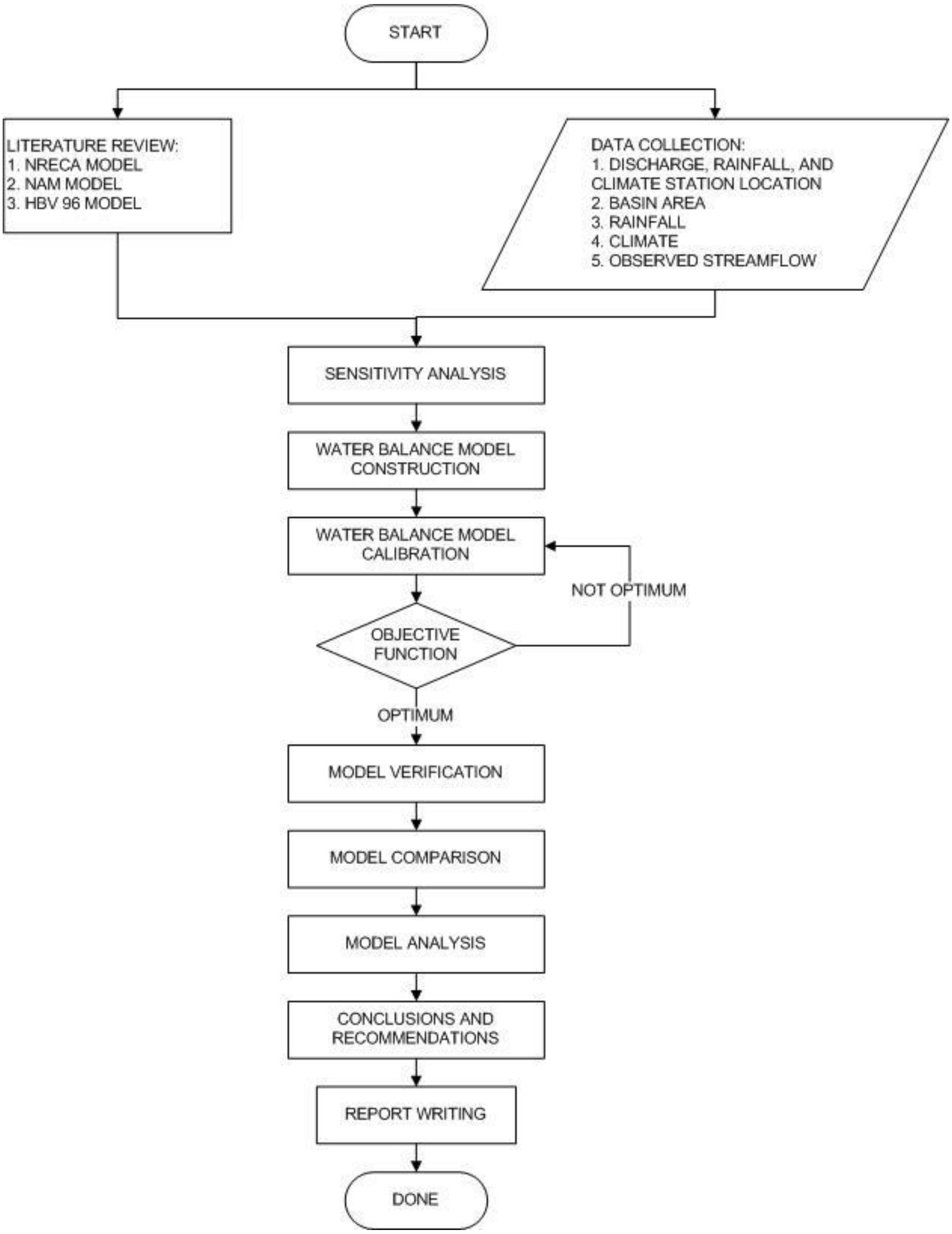

Figure 1.1. Thesis Flowchart