ESTIMATION OF LONG TERM STREAMFLOW GENERATION FOR SUNGAI YAP WITH CLIMATE ADAPTATION

FATIN NAQIYA BINTI ROSLAN

B. ENG (HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITY MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name	: FATIN NAQIYA ROSLAN
Date of Birth	: 31 MARCH 1993
Title	: ESTIMATON OF LONG TERM STREAMFLOW GENERATION FOR SUNGAI YAP WITH CLIMATE ADAPTATION
Academic Session	: 2017/2018

I declare that this thesis is classified as:

☐ CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐ RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑ OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

(Student's Signature)	(Supervisor's Signature)
930331-14-6946	**Dr Nurul Nadrah Aqilah Binti Tukimat**
New IC/Passport Number	Name of Supervisor
Date: 11 January 2018	Date: 11 January 2018

SUPERVISOR’s DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

____

(Supervisor’s Signature)

Full Name : Dr Nurul Nadrah Aqilah Binti Tukimat

Position : Senior Lecturer

Date : 11/01/2018

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : FATIN NAQIYA ROSLAN
ID Number : AA14015
Date : 11/01/2018

ESTIMATON OF LONG TERM STREAMFLOW GENERATION FOR SUNGAI YAP WITH CLIMATE ADAPTATION

FATIN NAQIYA ROSLAN

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JANUARY 2018

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Dr Nurul Nadrah Aqilah Binti Tukimat for her germinal idea, invaluable guidance, continuous encouragement and constant support in making this research possible. She has always impressed me with her belief that a degree program is only a start of lifelong learning experience. I appreciate her consistent support from first day I applied to graduate program to these concluding moments' am truly grateful for her progressive vision about my training in engineering, her tolerance of my naïve mistakes, and her commitment to my future career. I also sincere thanks for the time spent proofreading and correcting my many mistakes.

My sincere thanks to all my teammates, who helped me a lots in my ways and made my stay at university Malaysia Pahang pleasant and unforgettable. Many special thanks go to member water and hydrology research group for their excellent cooperation, inspirations and support during this study.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I cannot find the appropriate word that could properly describe my appreciation for their devotion, support and faith in my ability to attains my goals. Special thanks should be given to my committee members would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

ABSTRAK

Banjir berimpak tinggi telah menjadi pengalaman tahunan di Malaysia, namun insurans banjir kekal sebagai sebahagian besar daripada pengurusan risiko banjir yang bersepadu sepenuhnya. Untuk lebih cekap menggunakan jumlah air yang terhad di bawah dunia yang berubah-ubah atau dengan menyediakan masa yang mencukupi untuk amaran banjir, isu ini telah mencari teknik-teknik canggih untuk meningkatkan kecekapan aliran ramalan ramalan untuk jangka pendek dan jangka panjang. Kajian ini bertujuan untuk membangunkan persamaan aliran aliran untuk penjanaan aliran sungai jangka panjang di Sungai Yap dengan menggunakan Pengenalpastian Unit Hydrograph dan aliran Komponen dari model Hujan, Penyejatan dan Aliran (IHACRES). Keputusan penentukuran dan pengesahan menunjukkan nilai korelasi yang tinggi (0.921) dengan ARPE yang rendah (-0.102). Berdasarkan analisis ini, kira-kira 6 parameter kepentingan telah dikenal pasti dalam membangunkan aliran aliran sungai dengan mempertimbangkan penilaian iklim. Hasilnya sangat penting untuk pengurusan aliran sungai yang efisien pada tahun yang akan datang. Ia juga boleh sebagai input data penting yang perlu dipertimbangkan untuk perancangan jangka panjang bandar dan sumber air di kawasan ini.

ABSTRACT

High-impact floods have become a virtually annual experience in Malaysia, yet flood insurance has remained a grossly neglected part of comprehensive integrated flood risk management. To more efficiently use the limited amount of water under the changing world or to resourcefully provide adequate time for flood warning, this issue has seeking advanced techniques to improve an efficiency of streamflow forecasting for the short-term and long-term basis. This study is to develop the streamflow equation for the long-term streamflow generation at Sungai Yap using Identification of Unit Hydrograph and Component flow from Rainfall, Evaporation and Streamflow (IHACRES) model. The calibration and validation results show high correlation value (0.921) with low ARPE (-0.102). Based on this analysis, about 6 importance parameters have been identified in developing the streamflow generation with considered the climate assessment. The outcome is very significant for the efficient management of the river flow in the future year. It is also can be as a significant data input that must be considered for the long term urban planning and water resources at this area.

.

TABLE OF CONTENT

DECLARATION

TITLE PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of study

Water is significant sources in life routine that requires be protecting, defending and treating. It is also resources for the renewable energy generation and hydropower to meet energy demand for the development and economic growth. On the other hand, water uses for major welfare issues like irritation for food security and for household supply. However, most of the countries are facing with the water shortage, quality deterioration and flooding events, which need major awareness and action. Water is also crucial for the agricultural production, carbon budgets (and other biogeochemical cycles), biodiversity, energy generation, industrial production and human health. Extreme floods and droughts disasters are also contributed to the water scarcity and environmental damage (Halwatura & Najim, 2013; Harding, Weedon, van Lanen, & Clark, 2014).

Study by Manton et al., 2001 found that the annual rainfall was decreasing in the most countries of Southeast Asia region between 1961 and 1998. In the recent years, several extreme and drought events have been reported in Malaysia. For example, an extreme rainfall event from 9 to 11 December 2004 caused severe floods over the east coast of Peninsular Malaysia (Juneng et al. 2007). Due to the cold surges of the northeast monsoon, abnormal heavy rainfall occurred in the southern part of Peninsular Malaysia for several days in late December 2006 and in the middle of January 2007 which causing massive floods in the region (MMD, 2007)

In Malaysia, flood and drought are happened in every year causes by the monsoons. The strength of these monsoons will influencing the frequency and impact of the calamities. Based on the 100 years record, the worst flood disaster occurred at the district of Segamat, Johor, Malaysia on 12 January 2007 and since then the event occur at almost each year especially during monsoon season and this has caused lots of damages including death (Asmara & Ludin, 2014). Among all natural hazards, floods are the most frequent, destructive, and costly disasters in Malaysia. The east coast of Peninsular Malaysia have experienced floods regularly because of their geographical location that exposed to northeast monsoon that bring heavy rainfall and eventually contribute large volume of runoff to the relatively large catchment areas (Noor et al., 2016).The Department of Irrigation and Drainage (DID), Malaysia has estimated that more than 29000km^2 of land area and 4.82 million people affected by flooding annually. The damaged cause by flooding is in range about RM915 million. Two major types of flood that happened in Malaysia are monsoon floods and flash flood.

The sustainable of water resources is an important priority across the globe. While water scarcity limits the uses of water in many ways, floods may also result in property damages and the loss of life. To more efficiently use the limited amount of water under the changing world or to resourcefully provide adequate time for flood warning, this issue has seeking advanced techniques to improve an efficiency of streamflow forecasting for the short-term and long-term basis.

In this study, Identification of Unit Hydrograph and Component flow from Rainfall, Evaporation and Streamflow (IHACRES) has been applied. The model is classified as the metric based model. In the recent year, IHACRES has been successfully used as rainfall-runoff model. The advantage of this model compared to the physical and conceptual model, since it able to stimulate non-linearity in a system. Besides that, IHACRES is non-parametric techniques and does not require the assumptions of constraints. It is also effective to distinguish between relevant from irrelevant data characteristics.

1.2 Problem Statement

High-impact floods have become a virtually annual experience in Malaysia, yet flood insurance has remained a grossly neglected part of comprehensive integrated flood risk management (Aliagha, Jin, Choong, Jaafar, & Ali, 2014). The excessive water causes one of the main factor of the flood from the streamflow and rainfall. Streamflow is related to fresh water availability for human, animal, and plant populations, and to the incidences of natural hazards, such as flood and drought, that occur abruptly and may result in loss of human and animal life and damages to human properties. Flood alert systems hold the highest possibility or reducing the damages from the floods. On the other hand, drought analysis also counts on appropriate forecasts of stream flow. Stream flow prediction therefore provides crucial information for adaptive water resources management. Stream flow is also a best determinant of aquatic habitat conditions through the effects of peak or flood events. Stream flow or discharge is the volume of water that moves through a specific point in a stream during a given period of time. Discharge is usually measured in units of cubic feet per second (cfs). To determine discharge, a cross-sectional area of the stream or river is measured. Then, the velocity of the stream is measured using a Flow Rate Sensor.

Sungai Yap has been selected for this research area due to its historical data of flood recurrence, rainfall recorded and recent flood disaster. From the past two years, Pahang has been experiencing with the land development and economic growth rapidly. The increment of population of Pahang may causes the problem of water supply and water pollution in Pahang state causes the problem of water supply and water pollution from the industries (Tan el al.,2009).

The hydrological impacts change are analysed by using the conceptual based and physically based hydrological model. (Dibike and Coulibly, 2005). In this study, it will focus on metric based model, which has more accurate result than other model. This model has its expertise if the modeller with prior knowledge of the information input being modelled is the result in the IHACRES model. Sometimes, due to subjective factor involved the nonlinear result can produce uncertainty result. Therefore, this study is about to focus on developing an effective and efficient calibration procedure.

1.3 Scope of Study

The study is focused on the calibration and simulation of the streamflow models by using the IHACRES models. In flood forecasting, for the new hydrological model has been create to know the streamflow, rainfall and the temperature generation. IHACRES model has been used to study rainfall-runoff relationship and to obtain the streamflow characteristic at Sungai Yap with considered the climate change response. Sungai Yap has been selected it is because of rapid urbanization occurred in this area which affecting the trend of streamflow. This finding is only applicable for the Sungai Yap generation until year 2070.

1.4 Objective of the Study

The objective of this study are as follow:

I. To determine the reliability of the IHACRES model to generate the streamflow upstream Pahang river

II. To determine the best six parameters values for the long term streamflow estimation at Sungai Yap.

III. To develop a long term streamflow equations based on the six selected parameters

1.5 Significant of the study

This study is to develop the streamflow equation for the long-term streamflow generation. The outcome is very significant for the efficient management of the river flow in the future year. It is also can be as a significant data input that must be considered for the long term urban planning and water resources at this area.

CHAPTER 2

LITERARURE REVIEW

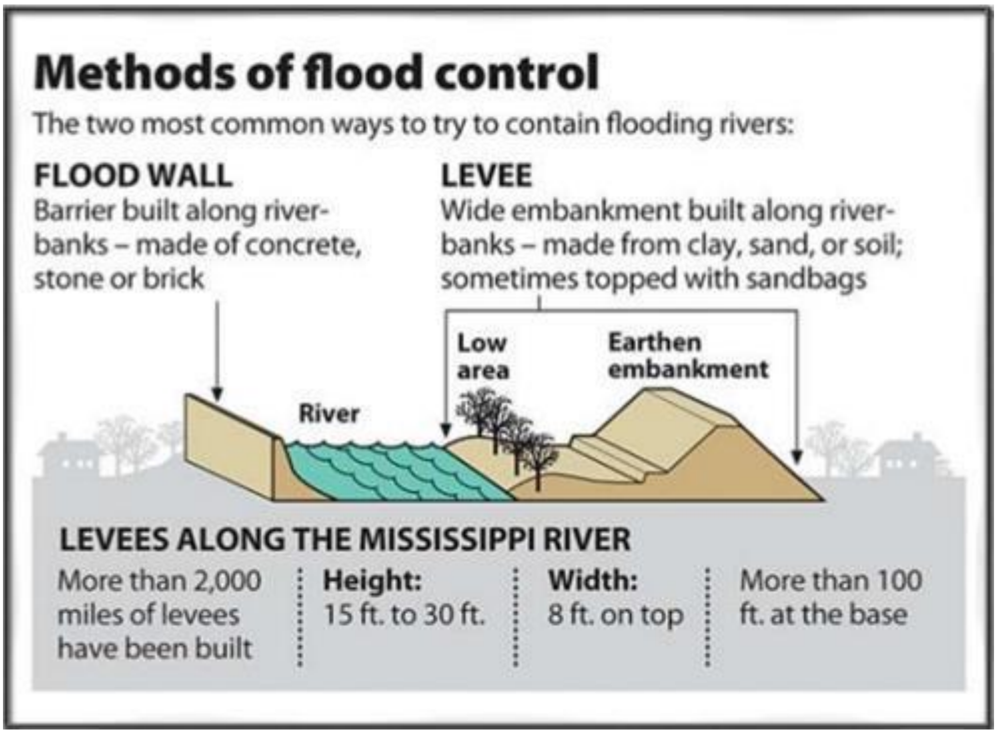
2.1 Introduction

Floods are the most frequently disaster occurred around the world not exception of Malaysia. It causes the extent of damages, natural disasters and immediate impact on the environment. For example, the worst flood in China occurred in year 1998, which causes disease spreading, electric disruption and water sources scarcity. About 3004 of peoples have been reported to dead, where 15 million were homeless and the economic loss was over US$ 23 billion. In Vietnam, the disaster flood in Cambodia and earthquakes in year 2000 causes 428 peoples reported to dead. About two major dangerous flood events there are monsoon flood and flash flood. Some of the countries provide flood insurance package as a tool for residual flood to manage their risk and as a support to non-structural approach. As a result, flood insurance has been incorporated as part of a comprehensive integrated flood risk management (Aliagha et al., 2014).

The temperature changes in Malaysia is varies from +0.7 ◦C to +2.6 ◦C and precipitation changes ranging from −30% to +30% due to the global climate change (NRE, 2005). The impact of climate change has been identified in several key sectors in Malaysia viz., agriculture, coastal resources, public health, water resources and forestry (Khailani & Perera, 2013). Furthermore, the flood event is the biggest hazard in Malaysia, especially in the eastern part of the Peninsular Malaysia. The heavy rainfall from November to January causes some devastation almost in every year. As much as 9% of the total land area in Malaysia (29,000 km2) and 23% of the total urban area are flood prone and as many as 2.7 million people have become victims during 1956–2007 (Khailani & Perera, 2013). The loss cost of the flood event was estimated to reach RM100 million annually (NRE, 2005). An argument for enhanced flood insurance penetrations an integral part of a comprehensive flood risk management in Malaysia could be established. Under the auspices of the Public Works and Irrigation Department, the government has over the years taken some significant structural and non-structural measures to address flood problems. Solutions to flooding problems have been introduced, with for example the structural solutions that attempt to eliminate flooding in specific areas using engineering work such as flood control dams, dikes, widening of river beds, etc. This could however often result in unwanted environmental, hydrologic, economic and ecological consequences. On the other hand, non-structural solutions aim at lowering the vulnerability of an area, and include land use regulation, flood warning systems and flood forecasting systems.

2.1.1 Structural Flood Risk Management

In structural techniques, one of the techniques is the reservoirs storage. The reservoir storage is one of the most reliable and effective methods of flood control. Ideally, in this method, a part of the storage in the reservoir is kept apart to absorb the incoming flood. Further, the stored water is released in a controlled way over an extended time so that downstream channels do not get flooded. As most of the present-day storage reservoirs have multipurpose commitments, the manipulation of reservoir levels to satisfy many conflicting demands is a very difficult and complicated task. It so happens that many storage reservoirs while reducing the floods and flood damages do not always aim at achieving optimum benefits in the flood-control aspect. To achieve complete flood control in the entire length of the river, a large number of reservoirs at strategic locations in the catchment will be necessary. In addition, Levees also known as dikes or flood embankments are earthen banks constructed parallel to the course of the river to confine it to a fixed course and limited cross-sectional width. The heights of levees will be higher than the design flood level with sufficient free board. Levees are one of the oldest and most common methods of flood-protection works adapted to the world. Also, they are probably the Cheapest of structural flood-control measures. While the protection offered by a levee against food damage is obvious, what is not often appreciated is the potential damage in the event of a levee failure. The levees, being earth embankments require considerable care and maintenance, In the event of being overtopped, they fail and the damage caused can be enormous. In fact, the sense of protection offered by a levee encourages economic activity along the embankment and if the levee is overtopped the loss would be more than what would have been if there were no levees. Confinement of flood banks of a river by levees to a narrower space leads to higher flood levels for a given discharge. Further, if the bed levels of the river also rise, as they do in aggrading rivers, the top of the levees have to be raised at frequent time intervals to keep up its safety margin. The design of a levee is a major task in which costs and economic benefits have to be considered. The cross section of a levee will have to be designed like an earth dam. Regular maintenance and contingency arrangements to fight floods are necessary to keep the levees functional. Masonry structures used to confine the river in a manner similar to levees are known as flood walls. These are used to protect important structures against floods, especially where the land is at a premium.



Methods of flood control

The two most common ways to try to contain flooding rivers:

FLOOD WALL
Barrier built along river-banks – made of concrete, stone or brick

LEVEE
Wide embankment built along river-banks – made from clay, sand, or soil; sometimes topped with sandbags

LEVEES ALONG THE MISSISSIPPI RIVER

More than 2,000 miles of levees have been built

Height: 15 ft. to 30 ft.

Width: 8 ft. on top

More than 100 ft. at the base

Figure 2.1 : Method of flood control
(Source : www.slideshare.net/bibhabasumohanty/flood-management-)

2.1.2 Non –structural Flood Risk management

Non-structural flood risk management measures are proven methods and techniques to reduce flood risk and flood damages incurred within floodplains. Thousands of structures across the nation are subject to reduced risk and damages or no risk and no damage due to implementation of non-structural measures. Besides being very effective for both short and long-term flood risk and flood damage reduction, non-structural measures can be very cost effective when compared to structural measures. A particular advantage of non-structural measures when compared to structural measures is the ability of non-structural measures to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement. There many non-structural method to reduce flood. This technique lifts an existing structure to an elevation which is at least equal to or greater than the 1% annual chance flood elevation. In many elevation scenarios, the cost of elevating a structure an extra foot or two is less expensive than the first foot, due to the cost incurred for mobilizing equipment. Elevation can be performed using fill material, on extended foundation walls, on piers, post, piles and columns. Elevation is also a very successful technique for slab on grade structures. Next method is fill basement with main floor Addition. This non-structural technique consists of filling in the existing basement without elevating the remainder of the structure. This could occur if the structure's first floor was located above the base flood elevation or above the design elevation, whichever is higher. With this measure, placing an addition on to the side of the structure could compensate for the lost basement space to the owner. If the addition could not be done because of limited space within the lot or because the owner did not want it, compensation for the lost basement space would be in order to the owner. This measure would only be applicable where the design flood depth is relatively small and the first floor elevation is already located above the design depth. Besides that the non-structural method is wet flood proofing. This non-structural technique is applicable either as a stand-alone measure or as a measure combined with other measures such as elevation. As a stand-alone measure, all construction materials and finishing materials need to be water resistant and all utilities must be elevated above the design flood elevation. Wet flood proofing is quite applicable to commercial and industrial structures when combined with a flood warning and flood preparedness plan.

This measure is generally not applicable to large flood depths and high velocity flows. In addition, flood forecasting also is one of the techniques that involved in non-structural techniques.

2.2 Forecasting of Water Streamflow

Streamflow forecasting is essential in many activities involving the operation and optimization of water resources. For this reason, the development of mathematical models able to provide more reliable long- term forecasting has attracted the attention of hydrologists through time (Santos & da Silva, 2014). Moreover, forecasting the river flow is the key for the hydrologists in proposing certain short or long-term planning and management for water resources system. Streamflow forecasting is a vital task for hydrologists in providing a sustainable conceptual design of water infrastructures, flood control measures and examining the river behaviour for operational purposes. Next, forecasting techniques based on statistical modelling are used when simplicity and robustness of the model implementation are more important than an accurate description of the various internal sub-processes (Lima, Cannon, & Hsieh, 2016). Besides that, streamflow forecasting also important information for hydrological applications including sustainable design of rural and urban water management systems, optimization of water resource allocations, water use, pricing and water quality assessment, and agriculture and irrigation operation (Yaseen et al., 2016). Other than that, Forecasting of streamflow is one of the many ways that can contribute to better decision making for water resource management. However, accurate stream-flow modelling and forecasting are important tools for sustainable water resources planning and management. Accurate multiple-scale stream-flow forecasts are important for the efficient operation and planning of reservoirs, sediment transport in rivers, hydropower generation, irrigation management decisions, scheduling reservoir releases and other hydrological applications (Yaseen et al., 2016). However, forecasting has always been somewhat of a challenge for researchers who acknowledge its fundamental role in real time operation of controls for efficient water management as well as in disaster management. Recent developments in wavelets have led to a renewed effort to design better forecasting frameworks for nonstationary hydrologic and other environmental systems (Maheswaran & Khosa, 2012). There are many ways of flood forecasting. There are two method that are classical forecasting and forecasting using rainfall run off model. Traditional techniques for design flood estimation include the rational method, empirical methods, flood frequency method, unit hydrograph techniques, and watershed models. The unit hydrograph techniques and watershed models can be used to estimate the design flood hydrograph in addition to the magnitude of the design flood peak (Halwatura & Najim, 2013)

2.2.1 Rational method

The rational method is a simple technique for estimating a design discharge from a small watershed. Kuichling (1889) developed it for small drainage basins in urban areas. Moreover, the rational method is appropriate for estimating peak discharges for small drainage areas of up to about 200 acres (80 hectares) with no significant flood storage. The method provides the designer with a peak discharge value, but does not provide a time series of flow nor flow volume. In addition, the Rational Method is widely publicised as a simple and effective method for use in hydrological calculations. Published data exist that cover a wide range of applicability and it appears as a published method in many guideline and regulatory documents. The Rational Method is a widely used technique in engineering hydrology; although it is known to, produce results that have large uncertainty (see McKerchar and Macky, 2001). It can be used as a screening tool in much the same way as described previously for TP108. Other similar models, such as the Modified Rational Method, can also be used as screening models.

2.2.2 Empirical method

Telvari (1382), evaluated the efficiency of some empirical methods such as Kreager, Horton and Fuller for estimating the peak of flood flow rate in Karkhe watershed and concluded Fuller method is the most proper method for estimating the highest amount of flood flow rate in most basins and sub-basins in study area due to considering ground traits, quantitative morphological, vegetation and climate. Besides that, empirical Modelling allows a better understanding on how the local hydrologic system works by relating a series of inputs to a series of outputs. This is an event-based modelling, usually at a catchment scale, without making many references to physical or hydrological process. Because of this, the model is also called as the black box modelling.

2.2.3 Unit hydrograph

The unit hydrograph is the unit pulse response function of a linear hydrologic system as shown in Figure 2.2. First proposed by Sherman (1932), the unit hydrograph (originally named unit-graph) of a watershed is defined as a direct runoff hydrograph (DRH) resulting from 1 in (usually taken as 1 cm in SI units) of excess rainfall generated uniformly over the drainage area at a constant rate for an effective duration. The unit hydrograph is a simple linear model that can be used to derive the hydrograph resulting from any amount of excess rainfall. It is a typical hydrograph of direct runoff, which is generate from one centimetre of effective rainfall falling at a uniform rate over the entire drainage basin uniformly during a specific duration. Effective rainfall is that portion of rainfall, which fully contributes towards direct runoff. Therefore, unit hydrograph can also be defined as the hydrograph of a drainage basin, which gives one centimetre of direct runoff from a rain storm of specific duration. This method involves building a graph in which the discharge generated by a rainstorm of a given size is plotted over time, usually hours or days. It is called the unit hydrograph method because it addresses only the runoff produced by a particular rainstorm in a specified period of time- the time taken for a river to rise, peak, and fall in response to a storm. Once rainfall-runoff relationship is established, then subsequent rainfall data can be used to forecast streamflow for selected storms, called standard storms. A standard rainstorm is a high intensity storm of some known magnitude and frequency. One method of unit hydrograph analysis involves expressing the hour by hour or day by day increase in streamflow as a percentage of total runoff. Plotted on a graph, these data from the unit hydrograph for that storm, which represents the runoff added to the pre storm base flow. To forecast the flows in a large drainage basin using the unit hydrograph method would be difficult because in a large basin geographic conditions may vary significantly from one part of the basin to another. This is especially so with the distribution of rainfall because an individual rainstorm rarely covers the basin evenly. As a result, the basin does not respond as a unit to a given storm, making it difficult to construct a reliable hydrograph.

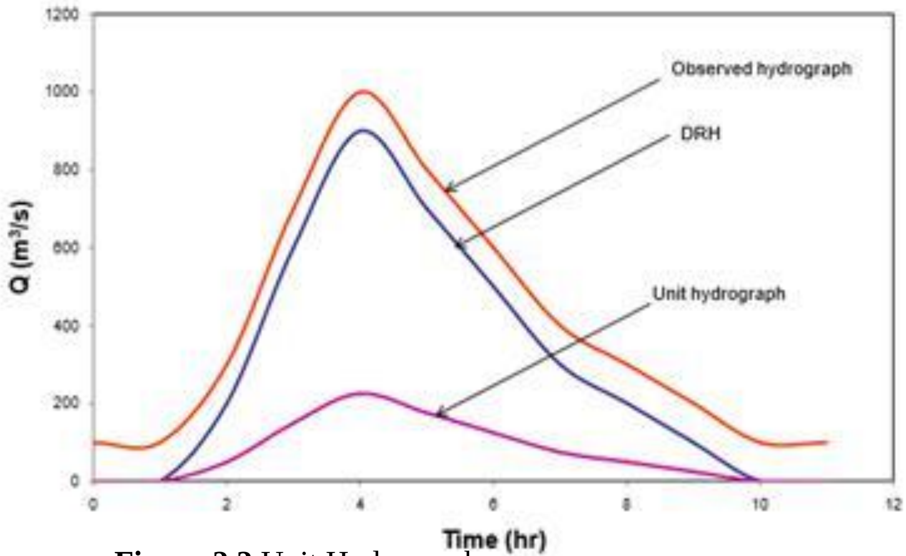


Figure 2.2 Unit Hydrograph

(Source- https://serc.carleton.edu/hydromodules/steps/derivation_unit.html)

2.2.4 Magnitude and frequency method

The magnitude and frequency method is used to calculate the probability of recurrence of large flows based on records of past years' flows. In United States, the Hydrological Division of the U.S. Geological Survey for most rivers and large streams maintains these records. For a basin with an area of 5000 square miles or more, the river system is typically gauged at five to ten places. The data from each gauging station apply to the part of the basin upstream that location. Given several decades of peak annual discharges for a river, limited projections can be made to estimate the size of some large flow that has not been experienced during the period of record. The technique involves projecting the curve (graph line) formed when peak annual discharges are plotted against their respective recurrence intervals. However, in most cases the curve bends strongly, making it difficult to plot a projection accurately. This problem can be overcome by plotting the discharge and/or recurrence interval data on logarithmic graph paper. Once the plot is straightened, a line can be ruled drawn through the points. A projection can then be made by extending the line beyond the points and then reading the appropriate discharge for the recurrence interval in question.

2.3 Rainfall-Runoff model

Hydrologic simulation employing computer models has advanced rapidly and computerized models have become essential tools for understanding human influences on river flows and designing ecologically sustainable water management approaches (Halwatura & Najim, 2013). Many different rainfall-runoff models has been developed and employed for hydrological field (Joo, Kjeldsen, Kim, & Lee, 2014). Besides that, Conceptual hydrologic models play a significant role in predicting a basin's response to different climatic and meteorological processes within natural systems however, these models require a number of estimated parameters (Mousavi, Abbaspour, Kamali, Amini, & Yang, 2012). Most of hydrological models available today reflect the diverse applications for which they were developed, such as operational forecasting of floods and streamflow in general, as planning tools in resource management, for impact assessment of past and proposed land use changes, and for assessing climate change effects (Bourdin, Fleming, & Stull, 2012). Several hydrological rainfall–runoff models have been developed to simulate the hydrological behaviour of watersheds. Their limits and their imperfections led modellers to progressively integrate the analysis of uncertainties in the modelling process (Lehbab-Boukezzi, Boukezzi, & Errih, 2016).

Rainfall-runoff model is the standard tools designed for hydrological investigations. It is used for many purposes such as for detecting climate change towards catchment response, design floods calculation, water resources management, flood forecasting, estimation of land use change impact, and stream flow prediction. Since various interacting processes that involve in the transformation of rainfall into runoff are complex, therefore stimulating the real-world relationship using rainfall runoff model is a difficult task. To overcome the difficulty on stimulation, rainfall runoff models have been classified into three types there are the physically-based model, conceptually-based model and metric-based model. Physically-based model and conceptual-based models describes the real system of hydrological system of the catchment based on physical equations. Both models require extreme data demand and large number of parameters. Therefore, these models are difficult to be calibrate and facing over parameterization. Another rainfall-runoff model that has been used widely is Metric-based model. This model is based on extracting information that is simplicity contained in the hydrological data without directly taking into the physical laws that underline the rainfall-runoff process. The model uses undemanding complex data and simple calculation that more suitable to apply at areas which have insufficient or very one of the most interesting modelling problems in hydrology is the characterisation of the nonlinear dynamic relationship between rainfall and runoff. This has received considerable attention over the past thirty years, with mathematical and computer-based models ranging from simple 'black-box' representations to complex, physically-based catchment models.

2.3.1 Physically based model

Physically based model the component processes within the models are represented in a more classical, mathematical-physics form, based on continuum mechanics solved in an approximate manner via finite difference or finite element spatio-temporal discretisation methods . The main problems with such models, which they share to some degree with the larger conceptual models, are two-fold: first, the inability to measure soil physical properties at the scale of the discretisation unit, particularly in relation to sub-surface processes; and second, their complexity and consequent high dimensional parameterisation. This latter problem makes objective optimisation and calibration virtually impossible, since the model is normally so over-parameterised that the parameter values cannot be uniquely identified and estimated against the available data. Moreover, the physically based models are based on our understanding of the physics of the hydrological processes, which control the catchment response, and use physically based equations to describe these processes. A discretization of spatial and temporal coordinates is made and the solution is obtain hydrological applications has broadened dramatically over the past four decades. Although the problems of flood protection and water resources management continue to be of importance and relevance for the security of communities and for human, social and economic development, many applied problems relating to the wider role of hydrology have come into focus.

2.3.2 Conceptually Based Model

Conceptually based model is vary considerably in complexity but are normally based on the representation of internal storages, as in the original Stanford Watershed Model of the nineteen sixties (Crawford and Linsley, 1966), although the hypothesis of catchment-scale response is sometimes included, as in TOPMODEL (Beven and Kirkby, 1979). The essential feature of all these models, however, is that the model structure is specified a priori, based on the hydrologist/modeller's perception of the relative importance of the component processes at work in the catchment; and then an attempt is made to optimise the model parameters in some manner by calibration against the available rainfall and flow data.

Conceptual rainfall–runoff models have been currently used for catchment water balance studies across the world. The observed runoff used to calibrate and validate these models was recorded at the catchment outlet and as such is an aggregated response of spatially variable rainfall across the catchment. There are uncertainties associated with the rainfall data, and the measured point rainfall data are usually available only at limited locations within a catchment or close to the catchment. This has been recognized in hydrologic literature as it poses a major problem for calibrating hydrological models (Vaze et al., 2011). Estimating the catchment streamflow is of a great importance because the deficiency in streamflow can lead to financial losses and its excess, in the form of flood, can cause financial as well as life losses. The necessity to appropriately predict the river flows in engineering constructions, river management, the surface water reservoir management and flood warning systems is tangibly felt. Also, the simulation of the river flows for the purpose of getting aware of the prospective river flow rates are among the significant and applied issues in water resources management

2.3.3 Metric Based Model

Metric based Model are based primarily on observational data and seek to characterise the flow response largely on the basis of these data, using some form of statistical estimation or optimisation (e.g. Young, 1986). These include purely black-box, time-series models, such as the discrete-time transfer function or the neural network representations. Often, such models derive from, or can be related to, the earlier unit hydrograph theory but this is not always recognised overtly.

2.3.4 Hybrid Metric Conceptual

Hybrid Metric conceptual (HMC) Models, in which (normally quite simple) conceptual models are identified and estimated against the available data to test hypotheses about the structure of catchment scale hydrological storages and processes. In a very real sense, these models are an attempt to combine the ability of Metric Models to efficiently characterise the observational data in a statistical terms (the principle of parsimony: Box and Jenkins, 1970), with the advantages of Conceptual Models that have a prescribed physical interpretation within the current scientific paradigm.

2.4 Identification of unit Hydrograph and Component Flows from Rainfall, Evaporation and Streamflow (IHACRES)

IHACRES model is conducted using conceptual based model. The simplicity of the metric model is used to reduce the parameter uncertainty inherent in hydrological model. It often requires six (6) parameters to be calibrated and performed well on variety catchment sizes and area. The main objectives of IHACRES is to characterize catchment scale hydrological behaviour (Abushandi & Merkel, 2013). In hydrological modelling, conceptual-lumped rainfall runoff models usually require less input data than distributed models. However, a distributed rainfall runoff model may offer a better approach for flood hydrograph simulation in catchments characterized by the heterogeneity of rainfall distribution (Yu and Jeng 1997). Consequently, a spatial rainfall dataset is required for successful distributed rainfall runoff model analysis (Abushandi & Merkel, 2013).

The IHACRES model is a continuous simulation model that represents rainfall-river flow transformation processes using two components, a nonlinear production module, and a linear routing module. The nonlinear production module calculates the proportion of effective rainfall that feeds river flow over time and is not lost to storage recharge and evapotranspiration. The linear routing module determines the timing of river flows from the effective rainfall. This module provides for a flexible configuration of conceptual routing stores, but for most catchments two stores in parallel is the best option (Jakeman and Hornberger, 1993). With this configuration, quickflow (stormflow) and slow flow (baseflow) components combine to yield the total river flow (Hope, Decker, & Jankowski, 2008). Table 2.1 shows the comparison between the IHACRES model and other rainfall runoff model.

Table 2.1 Literature Review of the Study

Author	Comparisons
(Abushandi and Merkel, 2013)	IHACRES is preferred because it has simple structure and parsimonious parameterization compared with HEC-HMS model, though it has more good performance in simulating stream flow event.
Neil McIntyre et al 2009	KIneros2 and IHACRES was applied in arid oman.Kineros2 performed more poorly overall than IHACRES especially for flow peaks.kineros2 is a complex model both conceptually and numerically. The simple semi distributed version of IHACRES

	was preferred over the other approaches for predicting flow peaks and volumes.
Hassan et al.,2015	The ANN and IHACRES model were able to capture the observed runoff. However, compared to the IHACRES model the ANN model was unable to provide an identical trend for daily and annual runoff series.

2.5 Data requirements IHACRES rainfall model

The IHACRES model minimum data required is daily bases rainfall, temperature and stream discharge. According to Wheater et al, rainfall-runoff models fall into several categories: metric, conceptual and physics-based models. To characterize the response of a catchment, Metric models using observed data (rainfall and stream flow) and are typically the simplest ones. Depending on the structure of the model, Conceptual models impose a more complex representation of the internal processes involved in determining catchment response, and can have a range of complexity. Physics-based models involve numerical solution of the relevant equations of motion.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The main aim of this study is to generate the future streamflow at Yap. River To obtain the streamflow equation, the best of six important parameters have been selected by using IHACRES model. **Figure 3.1** below shows the methodology of the study.

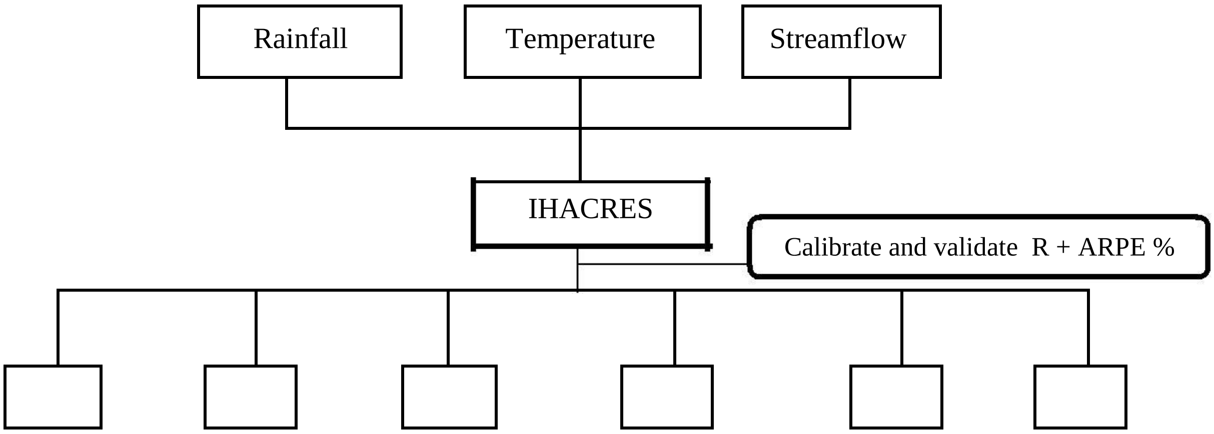


Figure 3.1: Flow Chart of Research Methodology

3.2 IHACRES model

The IHACRES model was developed by collaboration between the UK Institute of Hydrology and the Centre for Resource and Environmental Studies at the Australian National University (Boughton and Droop, 2001). It is easy to use and its input data requirement is simple, and the processes represented in this model are easily understandable. The IHACRES model (Jakeman et al., 1990) is a lumped parameter, hybrid conceptual– metric model containing a non-linear loss module which converts observed rainfall to effective rainfall (loss module); and a linear module that transforms effective rainfall to streamflow discharge (unit hydrograph module) (Croke and Jakeman, 2008). A comprehensive description of the IHACRES model structure is proposed by Croke et al. (2004). However, the significant part of the model is the flow routing components, quick flow and slow flow, which can be connected in series or parallel.

The IHACRES is a lumped conceptual model, which simulates rainfall-runoff response of catchments to total stream flow, with calibrated parameters prior to simulation by comparison with observed stream flow data (Alredaisy, 2011). The advantages using the spatially lumped approach is that it requires only a few (six) parameters, three in the non-linear module from model rainfall to rainfall excess and three in a linear module from rainfall excess to stream flow. The IHACRES model is widely used in various catchments in different sizes under different climate conditions. It is also used to study the impact of the streamflow when the land use changes (Kim, 2015). IHACRES allows the simulation of streamflow either continuously or for individual events using discrete time interval data.

IHACRES can identify unit hydrographs (UH) for total streamflow, rather than for just a direct runoff component of streamflow. The UH for total flow can often be resolved into quick and slow UHs, corresponding to flow components which act in parallel. These quick and slow UHs allow the modelled hydrograph to be separated into its dominant quick and slow flow components, a feature of IHACRES that has potential application across a wide range of water quantity and quality investigations. When the hydrograph can be separated in this way, a Slow Flow Index (SFI) is a by-product of the analysis. Data time intervals can range from less than hourly, for modelling small catchments with flashy responses, to daily or even monthly, for larger catchments with more subdued responses.

Selection of models depends on the availability of data and issue to be addressed. IHACRES model which is the hybrid of conceptual- metric model reduce the parameter uncertainty in hydrological models due to it is metric model, at the same time internal process is detail represented as since it is conceptual model.

Figure 3.2 Shows the IHACRES methodology in effort to develop the streamflow equation. It is comprises two modules in series. The first module operates nonlinearly to calculate effective rainfall from rainfall and temperature data. The second module (the UH part) operates linearly to convert the effective rainfall to streamflow. With three parameters in the first module, and typically three in the second, the IHACRES model is parametrically parsimonious. When good model-fits are obtained, the parameters characterize the hydrological response of the catchment.

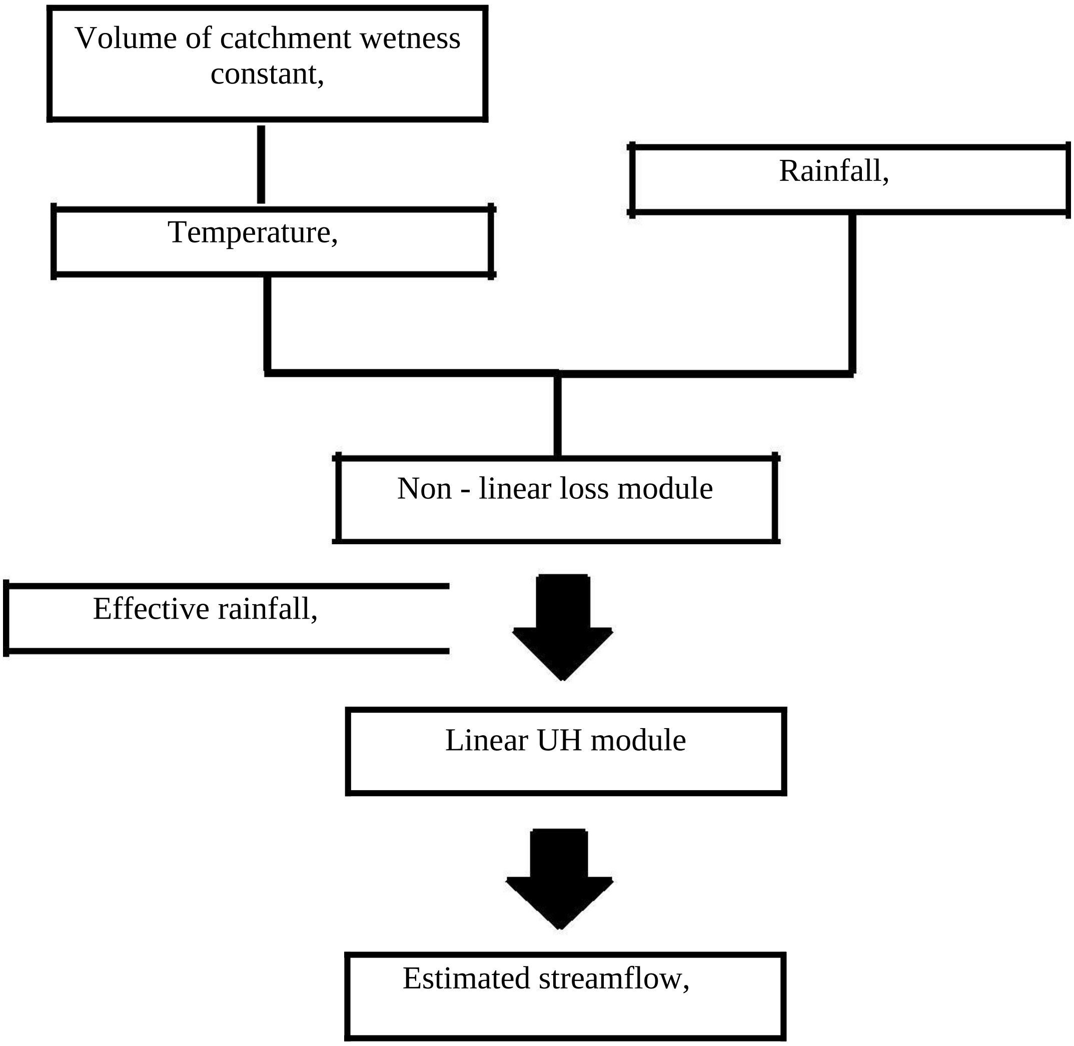


Figure 3.2: The schematic diagram of IHACRES

3.3 Calibration and Validation of IHACRES

IHACRES model is an assessment for quality and accuracy of predictive. The model require adjustment of the model parameters to calibrate match model output with the measured data for the selected period and scenarios. The model will be test at the validation period to test model simulation capability, which is not use during calibration. If during validation process the model not performed, calibration will be repeating again with the different period until the model performance in calibration and validation. In this study, calibration and validation for 19 years (1984 -2003) are used. In order to evaluate the performance of rainfall runoff models the choice of appropriate parameters on calibration data set is essential since it affects the output dramatically. Among objective functions that are added in the IHACRES the Nash- Sutcliffe efficiency indicator is used to assess the model performance This period choose because available data and higher quality of observed rainfall, temperature and streamflow. The best calibration is based on the higher value of (R^2) value of determination and lower percentage of average relative parameter Error (ARPE %) using following equations :

$$= - \quad \frac{\sum (\qquad - \qquad)}{\sum (\qquad - \qquad)} \qquad (1)$$

$$\% = \quad \_ \times \sum_{=} \quad \frac{(\ \_ \qquad)}{\qquad\qquad} \times \qquad (2)$$

Where refers to the observed streamflow, is the mean of observed streamflow, and is total number of streamflow. A high D and low ARPE % indicated that the model had been well calibrated and validated.

3.4 Development of Streamflow Equation

The conceptual model used here, IHACRES (Jakeman et al., 1990; Jakeman and Hornberger, 1993), extends unit hydrograph theory by assuming a linear relationship not only between effective rainfall and quick flow, but between effective rainfall and other identifiable hydrograph response components.

The model consists of a nonlinear rainfall loss module, which converts observed rainfall, at time step k, into effective or excess rainfall, , and a linear module which converts the excess rainfall into observed stream- flow, . Usually the two modules use, in total, seven or eight parameters, also called dynamic response characteristics (Jakeman and Hornberger, 1993), to describe the way in which observed rainfall becomes observed streamflow. The nonlinear rainfall loss module used here transforms the measured precipitation, , into effective rainfall,

Where is a catchment wetness index, a function of , the evaporation at time k, and three dynamic response characteristics , a time constant for the decline in the catchment wetness index, f, which regulates the degree of evaporation dependence of the loss time constant, and c, which is selected to conserve the mass-balance of the catchment. The exponential loss parameter p, and a nonzero threshold value for rain to give streamflow, l, may sometimes be required to account for extra loss of rainfall in the catchment (Ye et al., 1996).

The linear module uses a transfer function to allow the effective rainfall to pass through any combination of stores, in parallel and series, to become streamflow. The most common configuration uses two stores in parallel, one attributed to quick flow $1^{()}$, and one to slow flow $1^{()}$ These combine to yield the stream- flow, 1

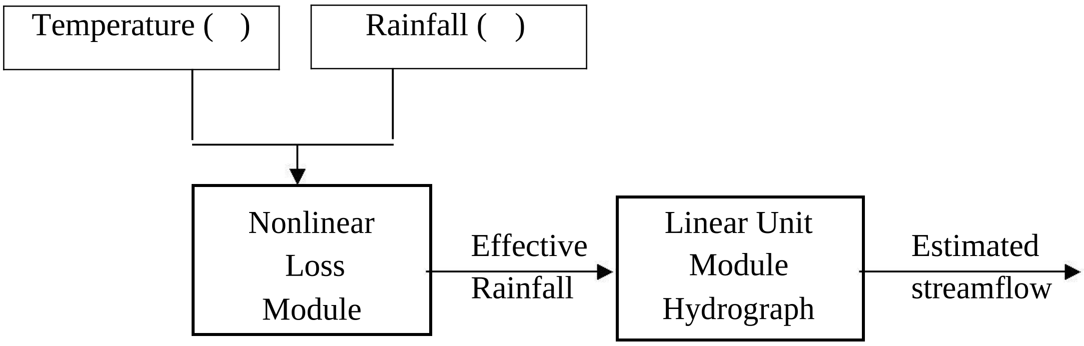


Figure 3.3: Basic Concept of Runoff Model By IHACRES
(Source : Croke *et al.*, 2005)

The streamflow (   ) the volume estimates in units cumecs from the following equations:

$$=_{(\ -1)} + \qquad (1)$$

$$= \qquad (2)$$

$$= \quad +1- \quad \frac{1}{(\quad) \ (-1)} \qquad (3)$$

$$(\ ) = \quad 0.062\,(\ - \ ) \qquad (4)$$

Where refers to the observed rainfall (mm), a and b are the parameters of unit effective rainfall in a linear unit hydrograph module with b > 0 and -1< a < 0

$$_0 \quad = {}_0 \quad ^{(\,)} + {}_0 \quad (\,) \qquad (5)$$

$$_1 \quad = {}_0 \quad ^{(\,)} \ {}_1(\,) + {}_0 \quad ^{(\,)} \ {}_1(\,) \qquad (6)$$

$$1 \quad = {}_1 \quad (\,) + {}_1(\,) \qquad (7)$$

$$_2 \quad = {}_1 \quad (\,) + {}_1(\,) \qquad (8)$$

3.5 Description of Study Area

Pahang River Basin receives high total rainfall during northeast monsoon period with almost 40 percent of total rainfall annually (MMD, 2010). An extreme rainfall which triggered by northeast monsoon is the main factor that resulted to higher river flow and water level and finally contributed to serious flood events at Pahang River Basin (DID, 2009). The increased of river flow that is resulted by the large total rainfall is responsible for the change of size of river channel which involved changes in width and depth. On the other hand, due to its dynamic system, the river would involve in the process of evolution (Camporeale et al., 2007; Robert, 2003). However, climatic condition, especially rainfall as well as human activities in the form of exploitation of natural resources and developments are always the external factors which affect and increase the river dynamic process. In addition, these changes may continue to river degradation

(Jackson et al., 1995). The objective of this study is to determine the changes of river hydrology due to rainfall factor and compares the relationships between long-term hydrological factors and rainfall, which treated as the main climatic factor and have given impact to the river.

Pahang has 11 districts. There are Temerloh, Bera, Rompin, Pekan, Raub, Maran, Kuantan, Lipis, Jerantut, Bentong and Cameron Highland. The area fraction for each district in Pahang state is: Temerloh (2,250 km^2), Bera (2,228 km^2), Rompin (5,296 km^2), Pekan (3,805 km^2), Raub (2,269 km^2), Maran (1,995 km^2), Kuantan (2,960 km^2), Lipis (5,198 km^2), Jerantut (7,561 km^2), Bentong (1,831 km^2) and Cameron Highland (721 km^2).

The topographic and condition for each district in Pahang state is Temerloh district is the second largest town in Pahang. It is located at the intersection of Sungai Pahang and Sungai Semantan. Temerloh experience a temperature range between 23 ° C and 34 ° C each year and the average rain down about 390 mm/monthly. Bera is especially important in the agricultural sector. The Bera Lake is a freshwater lake and surrounding wetlands. Bera experience a temperature range between 24 ° C and 33 ° C each year and the average rain down about 425 mm/monthly.

Kuantan is near the mouth of Sungai Kuantan and facing the South China Sea. The distance measure is along the East coast of Peninsular Malaysia. Kuantan experience a temperature range between 23 ° C and 33 ° C each year and the average rain down about 780 mm/monthly. Lipis is a district located in the North-West of Pahang state. This district is bordered by Cameron Highlands. Lipis experience a temperature range between 23 ° C and 34 ° C each year and the average rain down about 412 mm/monthly.

The selected study area, the Pahang Basin is located between longitude of 101° 30' E - 103° 30' E latitude 3° 00' N - 4° 45' N, is the largest river basin in Peninsular Malaysia. The climate of Pahang Basin generally is hot and wet, with an average annual rainfall between of 2,000 - 3,000 mm. Central Mountain Range bounds Pahang Basin along its western side while East Coast Range in the North-East. The main river in Pahang Basin is Pahang River, which flows for a length of 440 km and is the longest river in

Peninsular Malaysia. Pahang's climate is classify as tropical. The rainfall in Pahang is significant with precipitation even during the driest month. The average annual temperature in Pahang is 26.8 °C. The average annual rainfall is 2039mm/year. Pahang River is the main channel to drain off water from the inundated area of Pahang Basin to the South China Sea during wet season, which is caused by the northeast monsoon. Most of the inundations of lower areas of Pahang River Basin were caused by overflowing of the Pahang River. The statistics of rainfall and hydrological factors were calculated in terms of their means for the period from 1980 to 2009. The highest water level recorded at Sg. Yap was 45.36m and the lowest was 43.49m. The highest monthly total rainfall at Sg. Yap was 254.01mm and the lowest was 106.67mm. The mean discharge of Sg Yap (1980-2009) was 845.78m³/s. The water levels, which beyond the danger level in recent three decades, had also been identified.

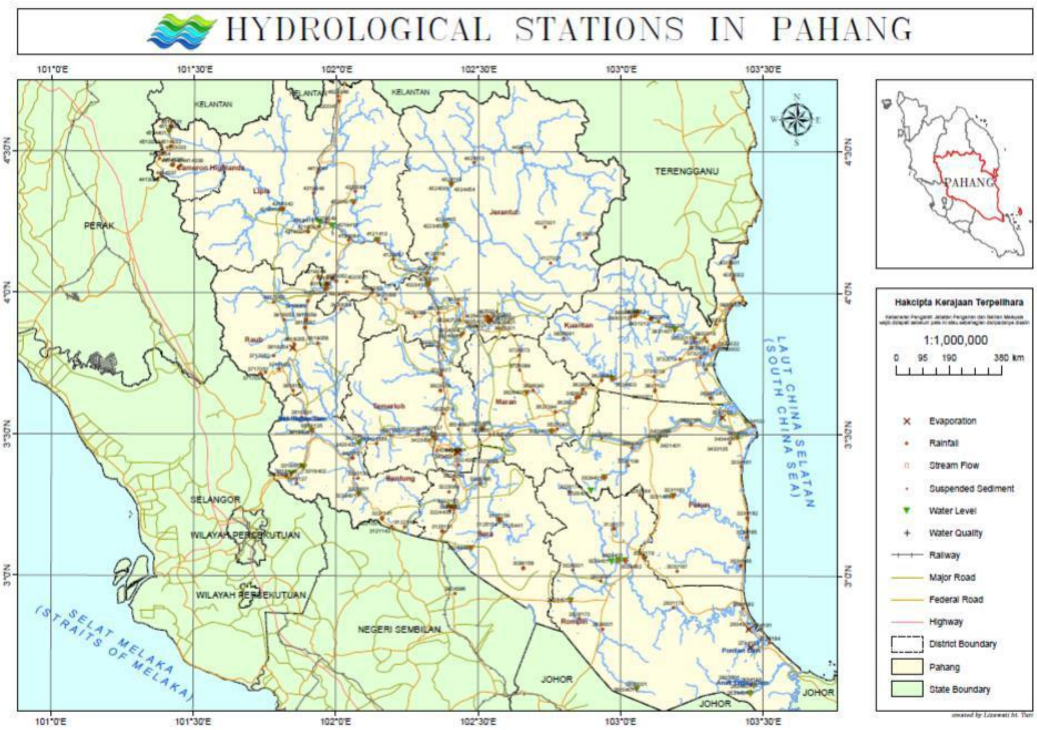


Figure 3.5: The map of Pahang River

(Source : Jabatan Pengairan Dan Saliran Pahang)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The result of the study are presented and discussed in three main parts there are:

I. The result of calibration and validation of the IHACRES model

II. Statistical analysis result from the calibration and validation of IHACRES model

III. The developing of the equation to predict the long-term pattern of the streamflow from the result of calibration and validation of IHACRES model.

In this study, the historical years from temperature (1984-2013) and rainfall (1973-2013) have been used to develop the water stream flow in year 1972-2016 based on the rainfall-runoff relationship. The IHACRES model has been chosen in this analysis because it takes into the account about the effect of rainfall and temperature at the study area. IHACRES model is the metric based model, which needs minimum input to operate, which set of time series data of observed rainfall, temperature and observed streamflow.in addition, the catchment area is required.

4.2 Calibration Model Parameters Result of IHACRES model

After running the IHACRES model, an efficiency indicator (R^2) which was represented in the model as square root (R^2_sqrt), logarithm (R^2_log) and inverse (R^2_inv) of the flow objective functions. The values R^2 = 0.114, R2_sqrt = -1.644103, R2_log = -1.6009763 and R2_inv = -5.4024321 for calibrated years and for the rest of data R2 = 0.115, R2_sqrt = -2.275, R2_log -2.033 and R2_inv = -3.774

Table 4.1 shows the parameter values that has been used in this study. The parameter was selected by trial and error using IHACRES model. Based on the result it has good agreement because it has higher correlation coefficient (r) with lower average relative parameter error (% ARPE).

Table 4.1: Calibrated Model Parameters Value for IHACRES Model

Parameter	**Value**
Mass Balance (c)	**0.2474**
Drying Rate At Reference Temperature ($_w$)	**20.0**
Temperature Dependence Of Drying Rate (f)	**0.5**
Reference Temperature (t_{ref})	**20.0**
Moisture Threshold For Producing Flow (l)	**0.00**
Power On Soil Moisture ( )	**1.0**
Correlation Coefficient (r)	**0.114**
Average Relative Parameter Error (%ARPE)	**0.30**

4.3 Calibration and Validation Result In IHACRES Model

IHACRES model is an assessment for quality and accuracy of predictive. In the calibration stage, the model requires adjustment of the model parameters to match output with measured data for selected period and situation entered to the model. After getting the result for IHACRES parameters, the model will be tested at the validation period to the model simulation capability, which using independent data and period of time, which are not used in calibration. If during validation the model not performed, calibrating is repeating again with different period until the models performs in both of calibration (Jan 2000- Jan 2004) and validation (April 2001 – Dec 2001). The period selection based on the availability data and high quality of historical rainfall, temperature and streamflow. The IHACRES model has high capability to automated calibration in order minimum error in volume. The best calibration is depending in the value of R-squared and lower relative bias in the analysis. The stimulated and historical values for low and high ranges have been presented in **Figure 4.1 and Table 4.2**.

Table 4.2 shows the result of calibrated and validated of IHACRES model. The value of correlation coefficient (r) recorded has lower value that is -0.053 and -1.301 respectively. The percentages of error is also has poor result that is between 0.303% to 0.141%.It is show that the result not in well predicted.

Table 4.2 : Result Of calibrated and validated process using IHACRES

Result	Parameters	
	R	Error
Calibrate	0.114	0.303
Validate	0.115	0.141

Figure 4.1 show the performance of calibrated and validated result. It is based on the r (coefficient coefficient) with (Percentage Average Relative Parameter Error) ARPE% of value. In this calibration and validation, the highest value for the historical streamflow is on February 2001 and the lowest value of the historical streamflow recorded is on august 2001. For the highest value of the stimulated streamflow is recorded on November 2001 and the lowest value of the stimulated streamflow is on august 2001. In addition, the largest biases (Average annual error) that is 23103.5 mm/year and the percentages of bias is 30% for the calibration.

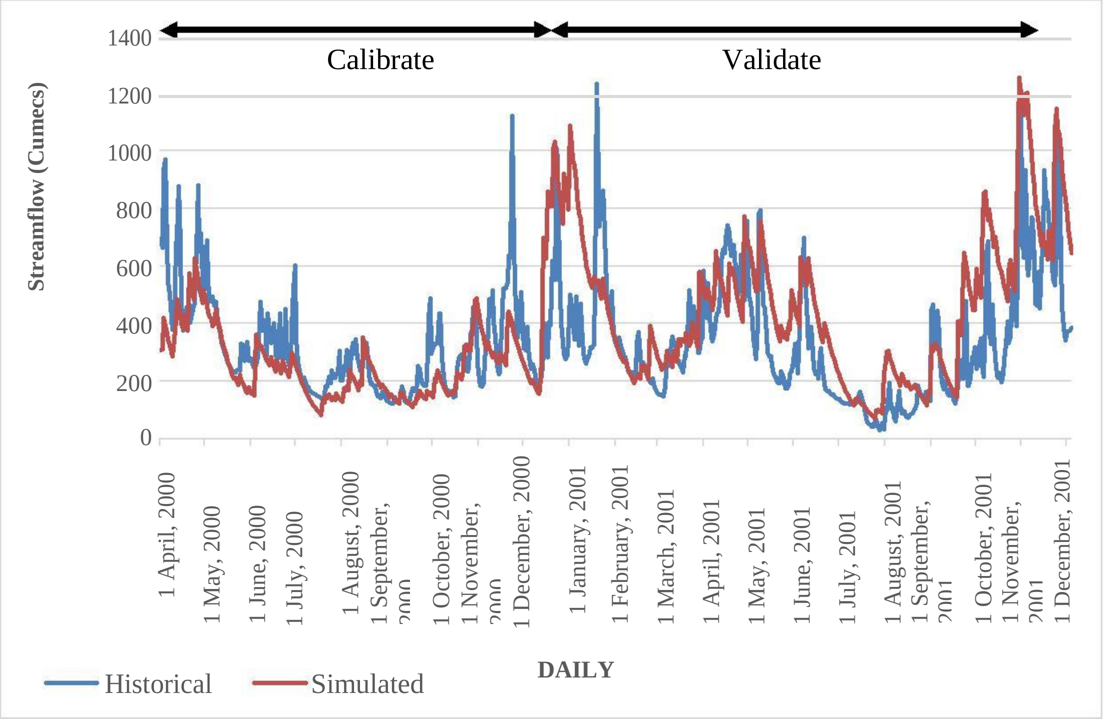


Figure 4.1: Calibrated (Jan 2000- Jan 2004) and validated (April 2001 – Dec 2001) results of IHACRES model

4.4 Performances of IHACRES model based on Statistical Analysis

The original structure of the IHACRES model uses exponential soil moisture drying rate index. Several versions of the model recently been developed to achieve a better simulation of streams. IHACRES model is divided into two modules that is non-linear and linear. In this calibration and validation processes of the Sungai Yap streamflow, about four statistical analyses have been used to control the accuracy and reliability of the results there are Correlation Coefficient (R) ,the Average Relative Parameter (ARPE%) , Standard Deviation and the Percent Of Error between simulated and historical data.

Table 4.3 shows the statistical analysis to measures the performances of the historical value to compare to stimulated value. In this statistical analysis for the correlation coefficient (r) the average value is 0.921. For the average relative parameter error (ARPE %) the average is -0.102 and the average of standard deviation 126.223. For the absolute error, the average is 38.44 %.

Table 4.3: The statistical analyses of IHACRES model

Month	Correlation Coefficient (R)	Average Relative Parameter Error (ARPE %)	Standard Deviation (SD)	Absolute Error (E)
Apr 2000	0.934	-0.832	156.271	31.236
May 2000	0.972	-0.535	118.383	17.385
Jun 2000	0.933	-0.899	84.361	28.595
July 2000	0.932	-0.844	50.790	25.314
Aug 2000	0.995	-0.235	60.000	26.345
Sep 2000	0.944	-0.768	64.613	28.262
Oct 2000	0.989	-0.337	97.286	25.432

Nov 2000	0.942	-0.785	156.265	38.419
Dec 2000	0.777	1.493	287.045	65.372
Jan 2001	0.967	0.896	222.605	59.346
Feb 2001	0.990	0.077	53.651	20.196
Mar 2001	0.990	0.451	92.636	28.438
Apr 2001	0.976	-0.710	122.341	23.931
May 2001	0.994	-0.350	137.795	17.627
Jun 2001	0.994	-0.343	110.221	34.775
Jul 2001	0.822	1.861	48.184	70.027
Aug 2001	0.517	2.686	65.787	81.402
Sept 2001	0.890	-1.487	96.487	44.620
Oct 2001	0.921	-1.234	187.572	38.614
Nov 2001	0.928	0.876	219.225	41.537
Dec 2001	0.935	-1.120	219.225	60.375
Average	**0.921**	**-0.102**	**126.223**	**38.440**

In **Figure 4.2**, the highest percentages of error of the streamflow is on December 2000 65.372% and the lowest percentages error of the streamflow is on May 2001 that is 17.627 %. The performance of the IHACRES in every month is not same trend due to the very few data and due to the missing data, which is temperature, streamflow and rainfall.

In **Figure** 4.3, the highest correlation value is 0.994 on June 2001 and the lowest correlation value is 0.777 on August 2001.The average value for the correlation value is 0.921.The historical data of the statistical analysis is in range of the good Correlation value R that is 0.9 to 0.99 compared to the stimulated value This is because of few data streamflow, rainfall and temperature and also the missing data.

In **Figure 4.4**, shows that the average relative parameters(ARPE%).In this figure, the highest ARPE% is on august 2001 that is 2.686 % and the lowest ARPE is on September 2001 that is -1.487% .

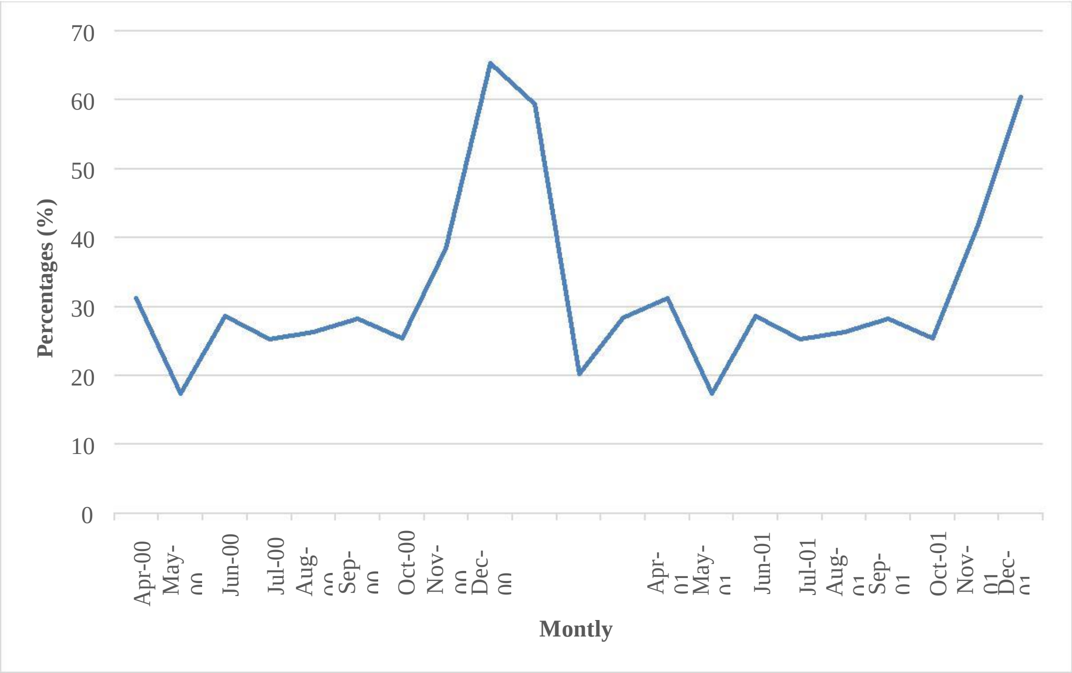


Figure 4.2: The Percentages Error of the Streamflow

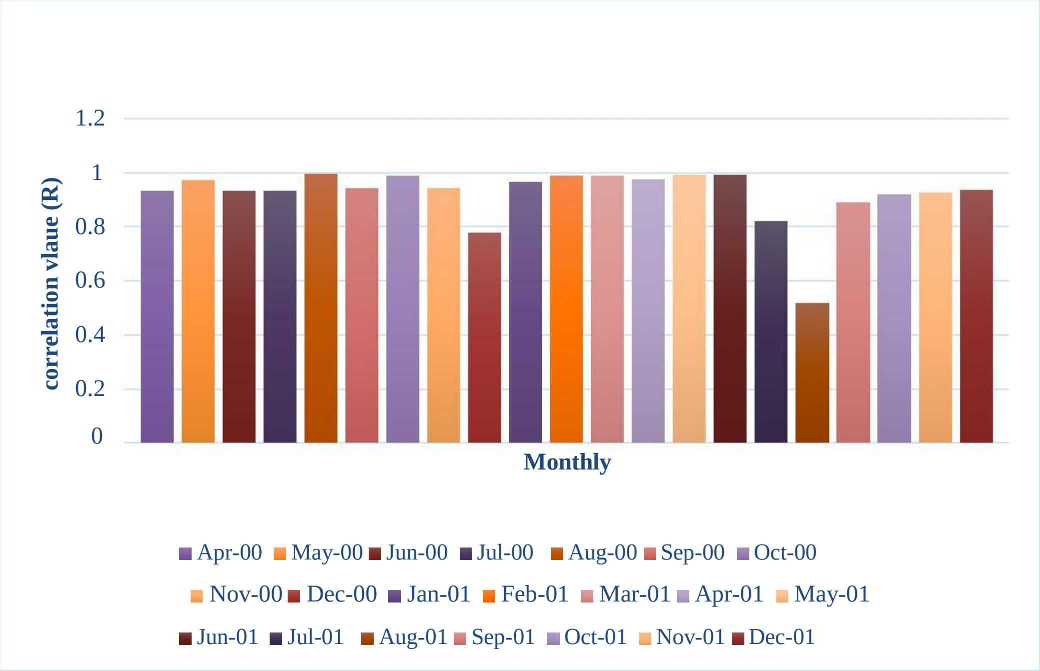


Figure 4.3: The correlation value (R) of the streamflow

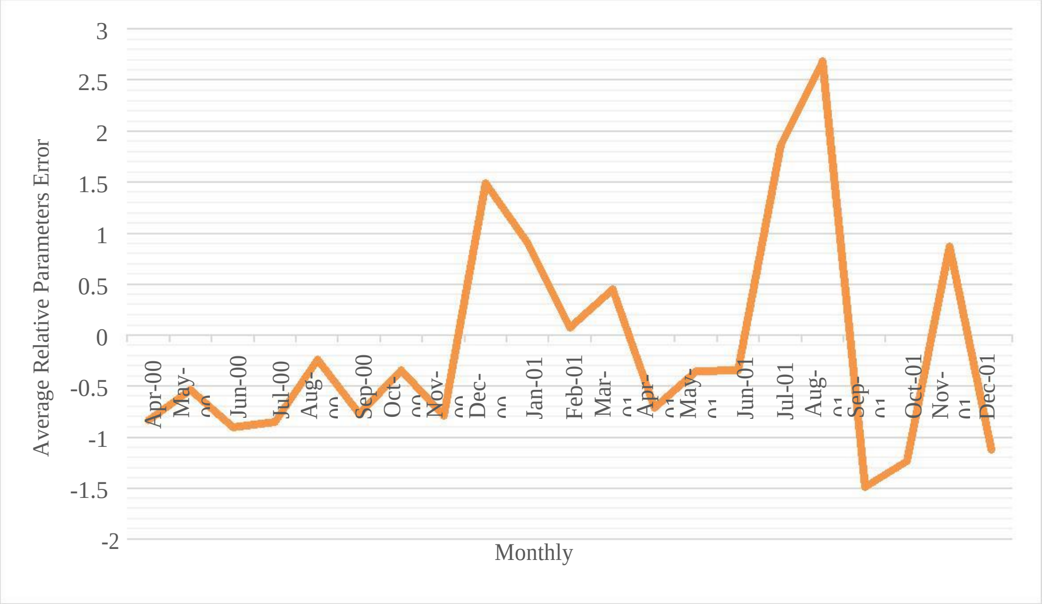


Figure 4.4: The Average relative parameters of the streamflow (ARPE %)

4.5 Development of long term Streamflow Equation

The long-term equation based on the six best parameters that have been calibrate and validate from the IHACRES model. Summarizes the six parameters describing the IHACRES model. We selected values for the catchment drying time constant ( ) and the temperature modulation factor ( ) in the non-linear module. The program calculated the parameters in the linear module and the parameter 1/c (the volume-forcing constant) in the non-linear module automatically. The coefficient of determination (R^2) and a percentage 'average relative parameter error' for the parameters in the linear module (%ARPE) are program outputs. We used the criteria that a good model is one that has a high value for correlation coefficient (R) and a low value for % ARPE. In addition, these six parameters may referred to as together they can be used to predict the daily hydrologic response of a catchment. They are defined as follows :

1) (Days) is the time constant governing the rate of water loss from the catchment at 20℃.
2) varies is the time constant water loss due to a unit change in temperature, producing the variable ( )
3) (mm) is defined such that the total volume of modelled effective rainfall is equal to the total volume of observed streamflow.it may be regarded as the maximum volume of the non-linear store, since when the volume of the non-linear store equal to ( ),all of the observed rainfall becomes runoff
4) (Days) is the time constant governing the rate of slow flow recession of the streamflow from the catchment.
5) is the proportion of slow flow to total flow, thus
6) ( ) is the peak of the unit hydrograph resulting from a unit input of effective rainfall

Table 4.4 and 4.5 provides the model parameters obtained from calibration of the model on each catchment, which were then used to validate the model and perform the long-term simulation.

Table 4.4: Parameters values for Streamflow equation

Parameter	Value
Mass Balance (c)	**0.2474**
Drying Rate At Reference Temperature ($_w$)	**20.0**
Temperature Dependence Of Drying Rate (f)	**0.5**
Reference Temperature (t_{ref})	**20.0**
Moisture Threshold For Producing Flow (l)	**0.00**
Power On Soil Moisture ( )	**1.0**

Table 4.5: Additional parameters in streamflow equation development

Parameter	Value
Recession rate 1	-0.938
Peak response 1	0.062
Time constant 1	15.600
Volume proportion	1.000

From the equations above the long-term equation where added based on the best simulation from the best parameters from the IHACRES model.

Soil moisture index,

$$= .+ - \qquad \frac{\qquad\qquad}{} \tag{1}$$

Long-term streamflow,

$$= .\times (-) + . \tag{2}$$

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This study contributes the long-term streamflow equation with concerning the climate parameters in the streamflow generation. As the result of this study the average value of R and %ARPE are 0.921 and -0.102 Respectively. This is sufficient for the study with limited length data records. From the calibration and validation of IHACRES model, the result of the stimulated data produce the best six parameters that is c = 0.2474, $_w$ =20.0 , f = 0.5 , t_{ref} =20.0 , l = 0 and = 1.0 From the best parameters that have been calibrated and validated, several equations has been develop as a guidance to create long-term streamflow equations. It is can be as guideline for the stakeholder in predicting the streamflow generation in the future year.

In addition, IHACRES is likely to generate useful flow predictions for smaller catchment with spatially represented rainfall measurements. The performance of the model IHACRES is tested first and the results suggests that the IHACRES model could simulate the flows reasonably well. The peak flows could not be simulated properly as the results of the study to some extent may be influenced by the quality of data as these have been used as such. In the discharge hydrographs of the catchments considered for this study, the base flow part is quite appreciable and is prominent. An important feature of IHACRES is that it captures this base flow separately (as slow flow component). This feature of IHACRES by itself can be used to study base flows from different catchments

This chapter presents the main conclusions from the discussion in preceding chapters. The study has drawn several specific conclusion as listed in following section

5.1.1 To determine the reliability of the IHACRES model to generate the streamflow upstream Pahang River

a) The flow generated by IHACRES model is found to be reliable and the model successfully simulated likely similar pattern to the historical value during calibration and validation process.

b) The highest ARPE% is on august 2001 that is 2.686 % and the lowest ARPE is on September 2001 that is -1.487%.

c) In statistical analysis for the correlation coefficient (r), the average value is 0.921. For the average relative parameter error (ARPE %) the average is -0.102 and the average of standard deviation 126.223. For the absolute error, the average is 38.44 %.

d) The highest percentages of error of the streamflow is on December 2000 65.372% and the lowest percentages error of the streamflow is on May 2001 that is 17.627 %. The performance of the IHACRES in every month is not same trend due to the very few data and due to the missing data, which is temperature, streamflow and rainfall.

e) The value of correlation coefficient (R) recorded has lower value that is -0.053 and -1.301 respectively. The percentages of error is also has poor result that is between 0.303% to 0.141%.It is show that the result not in well predicted.

f) The highest percentages of error of the streamflow is on December 2000 65.372% and the lowest percentages error of the streamflow is on May 2001 that is 17.627 %. The performance of the IHACRES in every month is not same trend due to the very few data and due to the missing data, which is temperature, streamflow and rainfall.

5.1.2 To determine the best six parameters values for the long-term streamflow estimation at Yap river .

a) After running the IHACRES model, efficiency indicator (R2) which are represented in the model as square root (R2_sqrt), logarithm (R2_log) and inverse (R2_inv) of the flow objective functions. The values R2 = 0.114, R2_sqrt = -1.644103, R2_log = -1.6009763 and R2_inv = -5.4024321 for calibrated years and for the rest of data R2= -0.115, R2_sqrt = -2.275 , R2_log -2.033 and R2_inv = -3.774.

b)

Parameter	Value
Mass Balance (c)	**0.2474**
Drying Rate At Reference Temperature ($_w$)	**20.0**
Temperature Dependence Of Drying Rate (f)	**0.5**
Reference Temperature (t_{ref})	**20.0**
Moisture Threshold For Producing Flow (l)	**0.00**
Power On Soil Moisture ( )	**1.0**

5.1.3 To develop a long term streamflow equations based on the six selected parameters.

a) Soil moisture index,

$$= 0.2474 + 1 - \frac{1}{20 \quad {}^{0.62-0.013}} \qquad (1)$$

b) Long-term streamflow,

$$= 0.938 \times (- 1) + 0.062 \qquad (2)$$

5.2 Recommendation In Future

Several recommendation are provided in enhancing the performances and application of IHACRES model:

a) Applying the unit hydrograph and component flow from rainfall, evaporation and streamflow data IHACRES is recommended to project runoff or discharge and to predict the streamflow pattern of the water streamflow

b) It is important that to have large enough data set to use IHACRES model to predict stream flow for better performance.

c) Generally, conceptual models like IHACRES are essential in water resource management of areas where limitation in availability data is observed since the model is perform enough to produce vital source of information.

d) It is important that the number of stations for measured data should be increased in as much as possible in the rangeland since the area is larger and for further study to provide information and knowledge in hydrology.

e) The IHACRES model results presented and discussed here, should be regarded as a bench mark for modelling exercises and therefore future work with spatially distributed models (using long warm-up periods) may provide insights to help model the catchments by the IHACRES approach.

REFERENCES

1. Abushandi, E., & Merkel, B. (2013). Modelling Rainfall Runoff Relations Using HEC-HMS and IHACRES for a Single Rain Event in an Arid Region of Jordan. *Water Resources Management, 27*(7), 2391-2409. doi:10.1007/s11269-013-0293-4

2. Aliagha, U. G., Jin, T. E., Choong, W. W., Jaafar, M. N., & Ali, H. M. (2014). Factors affecting flood insurance purchase in residential properties in Johor, Malaysia. *Natural Hazards and Earth System Sciences, 14*(12), 3297-3310. doi:10.5194/nhess-14-3297-2014

3. Alredaisy, S. M. A. (2011). Recommending the IHACRES model for water resources assessment and resolving water conflicts in Africa. *Journal of Arid Land, 3*(1), 40-48. doi:10.3724/Sp.J.1227.2011.00040

4. Asmara, T. A. T., & Ludin, A. N. M. (2014). Mapping Perception of Community Preparedness towards Flood in Muar River, Johor Malaysia. *8th International Symposium of the Digital Earth (Isde8), 18*. doi:Artn 01212610.1088/1755-1315/18/1/012126

5. Bourdin, D. R., Fleming, S. W., & Stull, R. B. (2012). Streamflow Modelling: A Primer on Applications, Approaches and Challenges. *Atmosphere-Ocean, 50*(4), 507-536. doi:10.1080/07055900.2012.734276

6. Chitanda. G. Alfred (2004), Comparison of System, Conceptual and Physically Based Models for Application in Simiyu Catchment, Msc. Thesis University of Dar es salaam

7. Croke, B.F.W., Norton, J.P (2004), “Regionalisation of Rainfall-runoff Model”, In Pahl, C., Schmidt, S., Rizzoli, A.E. and Jakeman, A.J. (Eds), Complexity and Integrated Resources Management, Transactions of the 2nd Biennial Meeting of the International Environmental Modeling and Software Society, Vol.3,pp.12011207.iEMSs,June 2004

8. Evans, J. P., Jakeman, A. J (1998), “Development of a Simple, Catchment-scale, Rainfall–Evapotranspiration–runoff Model”. Environmental Modelling and Software

13, 385–393 Fleming, G (1975), “Computer Simulation Techniques in Hydrology”. Environmental Sciences Series, Elsevier, New York

9. Jakeman, A.J., I.G. Littlewood and Whitehead, P.G (1990), “Computation of the Instantaneous Unit Hydrograph and Identifiable Component Flows with Application to two Small Upland Catchments”. Journal of Hydrology, 117, 275300

10. Halwatura, D., & Najim, M. M. M. (2013). Application of the HEC-HMS model for runoff simulation in a tropical catchment. *Environmental Modelling & Software, 46*, 155-162. doi:10.1016/j.envsoft.2013.03.006

11. Harding, R. J., Weedon, G. P., van Lanen, H. A. J., & Clark, D. B. (2014). The future for global water assessment. *Journal of Hydrology, 518*, 186-193. doi:10.1016/j.jhydrol.2014.05.014

12. Hope, A., Decker, J., & Jankowski, P. (2008). Utility of gridded rainfall for IHACRES daily river flow predictions in southern California watersheds. *Journal of the American Water Resources Association, 44*(2), 428-435. doi:10.1111/j.1752-1688.2008.00172.x

13. Joo, J., Kjeldsen, T., Kim, H. J., & Lee, H. (2014). A comparison of two event-based flood models (ReFH-rainfall runoff model and HEC-HMS) at two Korean catchments, Bukil and Jeungpyeong. *Ksce Journal of Civil Engineering, 18*(1), 330-343. doi:10.1007/s12205-013-0348-3

14. Khailani, D. K., & Perera, R. (2013). Mainstreaming disaster resilience attributes in local development plans for the adaptation to climate change induced flooding: A study based on the local plan of Shah Alam City, Malaysia. *Land Use Policy, 30*(1), 615-627. doi:10.1016/j.landusepol.2012.05.003

15. Kim, H. S. (2015). Application of a baseflow filter for evaluating model structure suitability of the IHACRES CMD. *Journal of Hydrology, 521*, 543-555. doi:10.1016/j.jhydrol.2014.12.030

16. Lehbab-Boukezzi, Z., Boukezzi, L., & Errih, M. (2016). Uncertainty analysis of HEC-HMS model using the GLUE method for flash flood forecasting of Mekerra watershed,

Algeria. *Arabian Journal of Geosciences, 9*(20). doi:ARTN 75110.1007/s12517-016-2771-5

17. Lima, A. R., Cannon, A. J., & Hsieh, W. W. (2016). Forecasting daily streamflow using online sequential extreme learning machines. *Journal of Hydrology, 537*, 431-443. doi:10.1016/j.jhydrol.2016.03.017

18. Maheswaran, R., & Khosa, R. (2012). Comparative study of different wavelets for hydrologic forecasting. *Computers & Geosciences, 46*, 284-295. doi:10.1016/j.cageo.2011.12.015

19. Mousavi, S. J., Abbaspour, K. C., Kamali, B., Amini, M., & Yang, H. (2012). Uncertainty-based automatic calibration of HEC-HMS model using sequential uncertainty fitting approach. *Journal of Hydroinformatics*, *14*(2), 286-309. doi:10.2166/hydro.2011.071

20. Noor, M. S. F. M., Sidek, L. M., Basri, H., Husni, M. M. M., Jaafar, A. S., Kamaluddin, M. H., . . . Osman, S. (2016). Development of Flood Forecasting Using Statistical Method in Four River Basins in Terengganu, Malaysia. *International Conference on Advances in Renewable Energy and Technologies (Icaret 2016), 32*. doi:Artn 01202310.1088/1755-1315/32/1/012023

21. Santos, C. A. G., & da Silva, G. B. L. (2014). Daily streamflow forecasting using a wavelet transform and artificial neural network hybrid models. *Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, 59*(2), 312-324. doi:10.1080/02626667.2013.800944

22. Vaze, J., Post, D. A., Chiew, F. H. S., Perraud, J. M., Teng, J., & Viney, N. R. (2011). Conceptual Rainfall–Runoff Model Performance with Different Spatial Rainfall Inputs. *Journal of Hydrometeorology, 12*(5), 1100-1112. doi:10.1175/2011jhm1340.1

23. Yaseen, Z. M., Jaafar, O., Deo, R. C., Kisi, O., Adamowski, J., Quilty, J., & El-Shafie, A. (2016). Stream-flow forecasting using extreme learning machines: A case study in a

semi-arid region in Iraq. *Journal of Hydrology*, *542*, 603-614. doi:10.1016/j.jhydrol.2016.09.035