UNIVERSITI PUTRA MALAYSIA

APPLICATION OF HUTVEC HYDROLOGICAL MODEL TO TWO MALAYSIAN WATERSHEDS

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APPLICATION OF HuTVeC HYDROLOGICAL MODEL TO TWO MALAYSIAN WATERSHEDS

By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia

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Dedicated to my parents, brother, sister and my wife, Suee In

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirements for the degree of Master of Science

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HuTVeC, an acronym for **Hu**mid **T**ropical **Ve**getation and **C**limate hydrological model was developed by Amjad Nabi in 1997. This model includes the plant leaf dependent parameters such as the leaf area index, light extinction coefficient, canopy storage coefficient, etc., which are controlled by the vegetation type. The output of this model are the daily evapotranspiration, canopy storage and streamflow.

The input data required for this model includes daily rainfall, minimum and maximum temperatures, minimum and maximum relative humidity and sunshine hours. Daily streamflow data is also required for model calibration and validation.

Application of HuTVeC model was carried out in a 66 square kilometre Trolak watershed using continuous five-year data from 1982 to 1986. For model application to a bigger watershed, Tanjung Malim watershed with watershed area of 186 square kilometres was selected using continuous five-year data from 1988 to 1992.

The results of the model application show that HuTVeC model underestimated the streamflow in both watersheds with up to 38.5 % underestimation for Trolak watershed and up to 50.8% underestimation for Tanjung Malim watershed. From the analyses, these underestimated streamflow were due to overstated canopy interception by up to 5% and overstated transpiration of up to 9%. Better results were obtained when the maximum rainfall was used in place of average rainfall in the watershed.

It is also found that if the ratio of modelled canopy interception to rainfall and the ratio of modelled transpiration to rainfall were maintained below 20% and 40% respectively, the modelled results were deemed acceptable.

The study also found that HuTVeC model is able to produce annual streamflow for planning purposes with more than 60% probability that the modelled annual flow and observed annual are having the same mean with good correlation between monthly modelled flow and observed flow.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan Ijazah Master Sains

**APLIKASI MODEL HIDROLOGI HuTVeC
PADA DUA KAWASAN TADAHAN
DI MALAYSIA**

Oleh

CHOONG WEE KANG

Februari 2000

Pengerusi : Professor Madya Ir. Dr. Mohd. Amin Mohd. Soom

Fakulti : Kejuruteraan

HuTVeC, singkatan untuk model hidrologi ***Hu**mid **T**ropical **Ve**getation and **C**limate* yang dibangunkan oleh Amjad Nabi in 1997. Model ini menggunakan parameter yang tertakluk kepada daun tumbuhan seperti indeks keluasan daun, angkali penghapusan cahaya, angkali simpanan kanopi yang kesemuanya dikawal oleh jenis tumbuhan. Output keluaran model ini termasuklah sejatpemeluhan harian, simpanan kanopi harian dan aliran sungai harian.

Input yang diperlukan dalam model ini termasuklah hujan harian, suhu minimum dan maksimum harian, kelembapan relatif minimum dan maksimum harian serta

jangkamasa pancaran matahari harian. Data aliran sungai harian juga diperlukan bagi tujuan pengujian dan kepastian model.

Aplikasi model HuTVeC dijalankan dalam dua kawasan tadahan iaitu kawasan tadahan Trolak dengan menggunakan data sebanyak lima tahun daripada 1982 ke 1986. Aplikasi model ini juga dijalankan dalam kawasan tadahan yang lebih besar saiznya, iaitu kawasan tadahan Tanjung Malim dengan menggunakan data 1988 ke 1992.

Keputusan aplikasi model menunjukkan anggaran model sentiasa lebih rendah daripada keadaan sebenar dalam kedua-dua kawasan takungan dengan kekurangan sebanyak 38.5% pada kawasan tadahan Trolak dan 50.8% pada kawasan tadahan Tanjung Malim. Keputusan model dianggap boleh diterima sekiranya nisbah pintasan kanopi kepada hujan dan nisbah transpirasi kepada hujan masing-masing dikekalkan di bawah 20% dan 40%.

Kajian ini juga mendapati bahawa model HuTVeC berupaya menjanakan kadar aliran sungai tahunan bagi kegunaan perancangan dengan kebarangkalian aliran tahunan janaan model dan aliran tahunan diperhatikan mempunyai purata yang sama melebihi 60% serta korelasi di antara aliran bulanan yang baik.

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%	percentage
γ	psychrometric constant
λ	latent heat of vaporisation
μ	populations mean
ρ	correlation coefficient
σ	population standard deviation
σ^2	population variance
$\bar{X}$	sample mean
S	sample standard deviation
S^2	sample variance
t	probability of Student t-test
U	Theil's coefficient
ET_a	actual evapotranspiration
ASCE	American Association of Civil Engineers
BASF	baseflow or groundwater flow
BFC	routing coefficient for groundwater reservoir
BLAI	base leaf area index
CCMX	maximum canopy conductance
CNMX	maximum canopy storage depth
CNSC	canopy storage depth
CSCF	rainfall interception storage coefficient
DAYL	day length
EVCN	evaporation from canopy
EXT	light extinction coefficient
GWS	groundwater storage
H	mean daily relative humidity
HuTVeC Model	Humid Tropical Vegetation and Climate Hydrological Model
INFL	infiltration
JPS	Department of Irrigation and Drainage (Jabatan Pengairan dan Saliran)
LAFC	leaf area adjusting factor
LAI	leaf area index
m	meter
mm	millimetre
Mo.	modelled results
MMS	Malaysian Meteorological Services
MSAE	Malaysian Society of Agricultural Engineers
NRAN	net rainfall

Ob.	observed streamflow
R	sunshine hour
r_a	aerodynamic resistance
RAN	rainfall
r_c	resistance to water vapours
REMX	maximum available soil moisture capacity of recharge zone
Sg.	Sungai / river
sq. km	square kilometres
SRO	surface runoff
SUBF	subsurface flow
T	mean daily temperature
TRANS	transpiration
UPM	Universiti Putra Malaysia

CHAPTER I

INTRODUCTION

Background

Malaysia is rapidly developing, converting from an agricultural based nation to an industrial nation. With the developments, water resources become an important raw material that every sector is competing for. However, being an agricultural based nation, the government has set a 65% self-sufficient rice production and hence the required water for paddy irrigation should be made available at all time.

The water resources engineers are placed in a tight situation to allocate water with correct quantity and quality at the right time to the right users. This results in a growing demand for information related to the availability and spatial distribution of water resources. Besides that, the ability to predict or generate artificial flow sequences are important for use in rationalising decisions regarding the irrigation requirements, effects of climate changes, effects of land use changes, water supplies, flood control measures and the effects of natural or induced watershed.

Hydrology

Hydrology is an earth science, which encompasses the occurrence, distribution, movement, and properties of water of the earth and their environmental relations. The hydrological cycle on the other hand is a continuous process by which water is transported from the ocean to the atmosphere then to the land and back to the sea with many sub-cycles namely, the evaporation of inland water, precipitation over land, plants transpiration, ground water flow, etc.

Hydrological Model

Hydrological models are the mathematical models that are designed and set up to simulate the hydrological processes in a watershed. Simulation is defined as the mathematical description of the response of a hydrological cycle to a series of events during a selected time period. For example, simulation can mean calculating daily, monthly, seasonal or annual streamflow based on rainfall; or computing the discharge hydrograph resulting from a known or hypothetical storm; or filling in the missing values in a streamflow record.

Hydrological model can be used as a planning tool in large-scale applications such as for metropolitan master plans. Models for such system must be as simple and as flexible as possible. Data processing for planning applications is often a much more

important practical consideration than the level of sophistication of hydrological process modelling.

Hydrological models can be classified as descriptive and conceptual models. The former have the greatest applications and are of particular interest to practising hydrologists because they are designed to account for observed phenomena through empiricism and the use of basic fundamentals such as continuity assumptions. Conceptual models, on the other hand, rely heavily on theory to interpret the phenomena rather than to represent the physical process. Examples of such model are those based on probability theory.

Descriptive models that use deterministic methods to model the hydrologic behaviour of a watershed have become popular. Deterministic simulation describes the behaviour of the hydrologic cycle in terms of mathematical relations outlining the interactions of various phases of the hydrologic cycle. Frequently, the models are structured to simulate streamflow from a given rainfall amounts within the watershed boundaries.

Hydrological models are calibrated by comparing results of the simulation with existing records. Once the model is adjusted to fit the known period of data, additional period of streamflow can be generated.

The hydrological models that ignore spatial variation in parameters throughout an entire system are classified as lumped parameter models whereas the distributed parameter models account for behaviour variations from point to point throughout the system.

HuTVeC Hydrological Model

The HuTVeC hydrological model is an acronym for **Hu**mid **T**ropical **Ve**getation and **C**limate hydrological model (Amjad Nabi, 1997). It is a deterministic, distributed and physically based hydrological model developed to check the climate change effects on streamflow for the humid tropical countries like Malaysia.

Taking into consideration the effects of land use and climate conditions to a watershed's hydrology, this model uses the rainfall abstraction concept and include three sub-models namely: i) the interception storage sub-model; ii) the evapotranspiration sub-model; and iii) streamflow sub-model.

Since HuTVeC model was designed to simulate the effects of climate changes on watershed streamflow, daily hydrological and meteorological data are among the input requirements of the model. Input data include: i) the daily rainfall data; ii) daily minimum and maximum temperature; iii) daily sunshine hours with empirical constants a and b that convert sunshine hours to short wave radiation; iv) daily