UNIVERSITI PUTRA MALAYSIA

APPLICATION OF REMOTE SENSING AND HYDROLOGICAL MODEL FOR RUNOFF ESTIMATION AND PREDICTION AT UPPER LANGAT WATERSHED

WONG TAI HONG

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By

WONG TAI HONG

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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SPECIAL DEDICATION

All praise and glory are expressed to almighty Lord for His blessings and strengthen me to complete this thesis

Utmost gratitude to my parents, Wong King Seng and Lau Kiin Hung for their patience, faithfully and undying love for my success.

Beloved brothers, Tai Chiew, Tai Yong, and Tai Fung for inspiring in me all the time

and

Finally, to my dearest wife "Lissa" (Chen Chai Khoon) who is always on my side, never ending support, patience and encouragement.

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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March 2004

Chairman : Associate Professor Shattri Mansor, Ph.D.

Faculty : Engineering

Rapid land development in recent years have degraded the environment and created a need for watershed modeling to quantify the impacts. During land development activities, natural flow paths in the watershed is normally being replaced or supplemented by paved gutters, storm sewers, or other form of artificial drainage. During rainfall, water remains above the land surface generating large amount of runoff within a short time.

This study was carried out to evaluate the effectiveness of using HEC-HMS hydrologic model, developed in the United States for predicting surface runoff from tropical watershed. The current and future impacts of land development on runoff rate were studied. The Upper Langat River Basin with a total area of 385km^2 was chosen for this study. The watershed is located in Selangor.

For this study, various datasets including topographical, hydrometeorological, river cross-section and land use data were used. The land use map was derived from

Landsat TM images. In order to extract land use information from remotely sensed data, two classification techniques were examined, namely pixel-based and object oriented classification. The result shows that the object oriented classification provides better accuracy (91.429%) as compared to pixel-based classification which has an overall accuracy of 81.667%.

The results from model application and statistical analysis show that HEC-HMS estimated an average gap of 27% at moderate flow. During heavy rainfall, the designed model seriously overestimated the runoff with an average gap of 70%. As a conclusion, the HEC-HMS provides a conservative estimate of runoff output.

It was also observed that the impact of land development on peak flow is directly proportional. Land development of 24.40km^2 in year 1994 caused a peak flow of 74.62m^3/s while in 1999, 50.23km^2 of land development caused the peak flow of 84.04m^3/s. In the proposed MSC land use plan for the year 2020, total area of 148.14km^2 will be developed. This development is predicted to cause 128.15m^3/s of peak flow. Therefore, it is important for urban planner to take into consideration the effect of the urbanization on the rate of runoff before developing a desired area. A well designed drainage system must be put in place during land development in order to prevent the flooding.

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

APPLIKASI PENDERIAAN JAUH DAN MODEL HIDROLOGI UNTUK PENAKSIRAN DAN RAMALAN ALIRAN LALUAN DI HULU LEMBAH LANGAT

Oleh

WONG TAI HONG

March 2004

Pengerusi : Profesor Madya Shattri Mansor, Ph.D.

Fakulti : Kejuruteraan

Ancaman pembangunan tanah yang pesat terhadap alam sekitar di Malaysia dalam beberapa tahun ini mencetuskan keperluan pemodelan lembangan sungai demi mengetahui kesannya. Semasa aktiviti pembandaran, aliran laluan semulajadi dalam sesuatu tadahan airbiasanya akan berubah atau bertukar kepada parit berturap, pembetung ribut, atau pembuatan sistem saliran daripada unsur-unsur lain. Semasa hujan, air itu akan terkumpul di atas permukaan bumi dan mengalir dengan jumlah besar dalam masa yang singkat.

Kajian ini telah dijalankan untuk menguji keberkesanan perisian HEC-HMS model hidrologi yang dihasilkan oleh Negara Amerika untuk menganggar aliran permukaan dari sebuah tadahan air yang berskala lembangan. Kesan semasa and masa depan guna tanah terhadap aliran permukaan juga telah dikaji. Hulu Lembah Sungai Langat dengan jumlah keluasan 380 km^2 telah dipilih untuk kajian ini. Kawasan tadahan air ini terletak di Negeri Selangor.

Untuk kajian ini, pelbagai jenis data telah digunakan termasuk topografi, hidrocuaca, keratan rentas sungai, dan data guna tanah. Peta guna tanah diperolehi daripada imej Landsat TM. Untuk memperolehi informasi guna tanah daripada data penderiaan jauh, dua teknik pengelasan telah diujikajikan, iaitu pengelasan berasaskan piksel dan pengelasan berasaskan objek. Keputusan pengelasan menunjukan bahawa pengelasan berasaskan objek memberi ketepatan yang lebih baik (91.429%) berbanding dengan pengelasan berasaskan piksel yang cuma mencatat 81.667% ketepatan keseluruhannya.

Keputusan daripada pengunaan model dan analisis statistik menunjukkan bahawa HEC-HMS mencatat perbezaan purata sebanyak 27% pada aliran laluan serdehana. Semasa hujan lebat, ia telah terlebih anggar aliran permukaan dengan serius, mencatatkan perbezaan purata sebanyak 70%.

Tambahan pula, adalah ditemui bahawa perhubungan di antara pembangunan dan pengaliran puncak bertambah berkadar terus. 24.40km^2 keluasan pembangunan pada tahun 1994 mengakibatkan 74.62m^3/s. Pada tahun 1999 pula, 50.23km^2 keluasan pembangunan telah mencatatkan pengaliran puncak sebanyak 84.04m^3/s. Cadangan pelan guna tanah MSC untuk tahun 2020, jumlah kawasan sebanyak 148.14km^2 akan dibangunkan. Pembangunan ini ia diramalkan mencatat aliran kemuncak sebanyak 128.15m^3/s. Ini adalah penting kepada perancang bandar untuk mengambil kira kesan pembangunan terhadap kadar pengaliran permukaan sebelum membangunkan sesuatu kawasan yang diingini. Satu sistem saliran yang baik perlu diambil kira semasa pembangunan demi mencegah banjir.

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Lastly, the author would like to express his sincere appreciation to his family especially to his lovely wife for their undying love, patience, encouragement and continues supports during the course of study.

I certify that an Examination Committee met on 2nd March 2004 to conduct the final examination of Wong Tai Hong on his Master of Science thesis entitled "Application of Remote Sensing and Hydrological Model for Runoff Estimation and Prediction at Upper Langat Watershed" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Putra Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committees are as follows:

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DECLARATION

I hereby declare that the 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 UPM or other institutions.

WONG TAI HONG

Date:

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LIST OF ABBREVIATIONS

3D	3 Dimensional
ASCE	American Society of Civil Engineers
CN	Curve Number
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage
DN	Digital Number
DOA	Department of Agriculture, Malaysia
DLG	Digital Line Graph
DTM	Digital Terrain Model
FEMA	Federal Emergency Management Agency
GCP	Ground Control Points
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
PDP	Planning and Design Procedure
JPBD	Town and Country Planning Department
JUPEM	Survey and Mapping Department of Malaysia
MACRES	Malaysian Centre of Remote Sensing
MSMAM	Urban Stormwater Management Manual for Malaysia
NDVI	Normalization Differential Vegetation Index
NN	Nearest Neighbor
PCA	Principal Component Analysis
PUAS	Perbadanan Urus Air Selangor Berhad
RMS	Root Mean Square
RSO	Rectified Skew Orthomophic Projection
SCS	Soil Conservation Service
SMA	Soil Moisture Accounting
VIR	Visible infrared
VIS	Visible
VDEMINT	Grid DEM from vector layer

CHAPTER 1

INTRODUCTION

1.1 General

When development replaces natural landscapes with impervious surfaces, the amount of rainfall that runs over the surface of the land greatly increases. A serious problem that relates to runoff is flooding. Flood severity is caused by increased rainfall intensity, duration, reduced infiltration capacity and in addition such factors like forest clearance, the blatant burning of forest and urbanization. More over, floods can cause death and at the same time bring damage to houses, buildings, plantation, livestock, etc.

Landuse will alter a watershed's response to precipitation. The most common effect is the reduction of infiltration especially on impervious surfaces, which significantly increase erosion, discharge and volume of storm runoff in a watershed. Then again, land development changes the pattern and distribution of runoff where natural flow paths in the watershed will be replaced or supplemented by paved gutters, storm sewers, or other elements of artificial drainage. The porous and varied terrain of natural landscapes like forests, grasslands, vegetation and wetlands can trap rainwater and allow it to slowly flow into the ground. Nevertheless, runoff will not slowly percolate into the ground in nonporous urban landscapes such as include roads, sidewalks, parking lots and buildings. The water will in this case remains above the surface and form massive runoff.

The need for improved methods for resource management and environmental assessment especially in Malaysia is vital. Remote sensing data can provide the reliable and timely information over a huge area. It is a fast and efficient system of data collection, processing, storage, retrieval and updating the land cover information. This study evaluates the feasibility of applying a remote sensing technique to obtain the land use information and its' changes, hence apply as parameter input and factor to the public domain software, Hydrologic Engineering Center – Hydrologic Modeling System, (HEC-HMS) in order to simulate the rainfall-runoff during the selected simulation period and analyze the impacts of urbanization to the rate of runoff.

1.2 Statement of Problem

On site data acquisition for watershed and land use studies is labour intensive, time consuming and expensive especially when the watershed is large and located in an inaccessible area. The application of remote sensing for data collection makes the coverage of extensive basins possible. Remote sensing may be the only way to obtain input data for remote and inaccessible areas, and a large number of basins in a particular region. In addition also, remote sensing provides fast, up to date, high accuracy and even cost effective data for watershed study.

The conventional method of extracting information from remote sensing data is in pixel basic. This conventional classification approaches to image analysis produces a characteristic, inconsistent salt-and-pepper classification, this method is however far from being capable of extracting objects of interest. It is able to carry out the classification parameter based on the spectral properties of each band that is available in the image only. Difficulties increased when dealing with temporal data where the spectral information represent the cloud cover and shadow occurred in optical remote sensing data always mix up with urbanization area, water body and vegetation classes. The object-oriented approach brings the supervised classification process into polygon base. It makes the remote sensing data contents manageable by performing the segmentation process. Beyond that, additional information such as criteria, textual or contextual information of the segments can be described in an appropriate way to derive improved classification results.

Malaysia has experienced the effects of erosion and flash flood. These phenomena have partly been attributed to the degradation of natural environmental and water yield, possibly caused by forest and plantation clearance for greatly urbanization development. These activities and their rate of persistent are apparently unchecked in recent year. The land use information that extracted from temporal remote sensed data can shows the trends of land development through out the years. This information can be used as a parameter input to a hydrological modeling to check on the impacts of current development and future development to the rate of runoff. It is important for urban planner to take into consideration effects of the urbanization on the rate of runoff before developing a desire area. A well drainage landscape must be taken into consideration during land development in order to prevent runoff and flash flood phenomena.

1.3 Objective

The overall aim of this research is to examine the trend of urbanization as a contributing factor to the surface runoff. In order to fulfill this aim, this study attempts to meet the following specific objectives:

1. To detect the change of land development based on remotely sensed data and compare the object oriented and pixel based classification techniques.
2. To access the effectiveness of remote sensed data in hydrological model for surface runoff estimation and prediction.