UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A DECISION SUPPORT SYSTEM TO PRESERVE* Neolissochilus hexagonolepis *(McClelland, 1839) IN PELUS RIVER, PERAK, MALAYSIA

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FPAS 2016 10

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By

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

December 2016

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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December 2016

Chairperson: Assoc. Prof. Latifah Abd Manaf, PhD
Faculty: Environmental Studies

Over the past decades, water management has become a global issue and the challenges that relate are increasing globally. Malaysia, which is located at the equatorial zone, has abundant of freshwater resources. Despite that, the country faces challenges of water shortage due to anthropogenic activities. In order to maintain river health, river flow is considered as one of the most important factors to be considered. Environmental Flow Assessment (EFA) specifically determines the quantity, quality, and timing flow of water required over time to sustain water body ecosystems and human livelihoods as well as wellbeing that depend on overall ecosystem. However, with the growing complexity and uncertainty of river flows, it is a challenge for stakeholders as they are required to understand its natural diversity in order to preserve and conserve both goods and services. Hence, in this study, a Decision Support System (DSS) by using IF-THEN rule concept is established to assist decision makers to decide the best possible action in order to maintain the optimum flows. The system is developed specifically based on case study area in Pelus River, Perak as it is classified as an altered river due to dam operation that can directly or indirectly affect the environment. The *Neolissochilus hexagonolepis* (McClelland, 1839) in Pelus River, Perak fulfils all the must-have criteria for a target fish species. The system has three different modules that cover analysis in the aspects of hydrology, hydraulic, and ecology. Module of river classification implements backward chaining process, which aims to identify the problem parameters in the analysis of river classification. The second module applies Multiple Linear Regression analysis to determine the relationship between hydraulic and ecology aspects in river flow analysis. For the third module, the prediction of minimum river flow based on Mean Annual Minimum analysis is conducted. The verification and validation process of the system is conducted in Pelus River, Perak. The system is also verified by the experts in the respective field which involves evaluation on system functioning and user friendliness aspects. In conclusion, this system is absolutely convenient, comprehensive, and could assist better decision making which then become useful tools in solving problems of river management, specifically in Pelus River in order to preserve the target species, *N. hexagonolepis.*

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

PEMBANGUNAN SISTEM SOKONGAN KEPUTUSAN BAGI MEMELIHARA *Neolissochilus hexagonolepis* (McClelland, 1839) DI SUNGAI PELUS, PERAK, MALAYSIA

Oleh

NUR SYAFIQAH BINTI CHE HUSSIN

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Pengerusi: Prof. Madya Latifah Abd Manaf, PhD
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Sejak beberapa dekad yang lalu, pengurusan air telah menjadi satu isu yang cabarannya semakin meningkat di peringkat global. Malaysia yang terletak di zon khatulistiwa yang mempunyai banyak sumber air tawar. Walaupun begitu, negara masih menghadapi cabaran kekurangan air akibat dari aktiviti antropogenik. Dalam usaha untuk mengekalkan kesihatan sungai, aliran sungai dianggap sebagai salah satu faktor yang paling penting dan perlu dipertimbangkan. Penilaian Aliran Alam Sekitar *(EFA)* khusus menentukan kuantiti, kualiti, dan aliran masa air yang diperlukan dari masa ke masa untuk mengekalkan ekosistem sungai dan kehidupan manusia serta kesejahteraan yang bergantung kepada ekosistem tersebut. Walau bagaimanapun, dengan kerumitan yang semakin meningkat dan ketidaktentuan aliran sungai, mewujudkan satu cabaran bagi mereka yang bertanggungjawab terhadap perkara ini kerana mereka perlu memahami kepelbagaian semula jadi bagi memelihara dan memulihara perkhidmatan tersebut. Oleh itu, dalam kajian ini, Sistem Sokongan Keputusan (SSK) dengan menggunakan konsep peraturan JIKA- KEMUDIAN diwujudkan bagi membantu pembuat keputusan untuk memutuskan tindakan yang terbaik dalam mengekalkan aliran optimum. Sistem ini dibangunkan khusus berdasarkan kawasan kajian iaitu di Sungai Pelus, Perak kerana sungai ini diklasifikasikan sebagai sungai yang diubah disebabkan operasi empangan yang sebenarnya telah memberi kesan kepada alam sekitar secara langsung atau tidak langsung. Spesis ikan yang dikenali sebagai *Neolissochilus hexagonolepis* (McClelland, 1839) terdapat di dalam Sungai Pelus dipilih sebagai ikan sasaran, berdasarkan kriteria yang telah digariskan. Sistem ini mempunyai tiga modul yang berbeza yang meliputi analisis dalam aspek hidrologi, hidraulik, dan ekologi. Modul klasifikasi sungai melaksanakan proses rantaian ke belakang, yang bertujuan untuk mengenal pasti parameter bermasalah dalam analisis pengkelasan sungai. Modul kedua mengaplikasikan *Multiple Linear Regression (MLR)* dalam menentukan hubungan antara aspek hidraulik dan ekologi bagi analisis aliran sungai. Bagi modul ketiga adalah berkaitan ramalan aliran sungai minimum berdasarkan analisis Purata Minimum Tahunan dijalankan. Pengesahan dan validasi proses untuk sistem ini dijalankan di Sungai Pelus, Perak. Selain itu, sistem ini juga disahkan oleh pakar-pakar yang terlibat dalam bidang ini yang

merangkumi kelancaran fungsi sistem dan aspek kemesraan pengguna. Kesimpulannya, sistem in sangat memudahkan pengguna, menyeluruh dan dapat membantu pengguna untuk membuat keputusan yang lebih baik dan seterunsya boleh menjadi alat yang sangat berguna dalam menyelesaikan masalah pengurusan sungai, khususnya di Sungai Pelus, Perak disamping memelihara spesis sasaran iaitu *N. hexagonolepis*

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful

All praise is due to ALLAH, the Lord of the worlds. I thank Him for the opportunities, trials, and strength that are showered over me during my study. His works are truly splendid and wholesome, and His knowledge is truly complete with due perfection.

I would like to express my greatest appreciation and heartfelt gratitude to my supervisor Assoc. Prof. Dr. Latifah Abd Manaf for her guidance, advice, support, patience, and willingness to spend time to guide me throughout my study. Also, my appreciation and sincere gratitude to my co-supervisor, Dr. Rohaizah Jamil for the motivation, kind-cooperation, and thoughtful suggestions to improve my study. My sincere appreciation also goes to the lecturers of Faculty of Environmental Studies and Faculty of Science of Universiti Putra Malaysia, staff of the Department of Irrigation and Drainage, National Hydraulic Research Institute of Malaysia, Department of Environment, and National Water Service Commission who directly and indirectly contribute to this study.

I also wish to extend my sincerest appreciation and gratitude to my beloved parents Che Hussin bin Che Noh and Che Salmah binti Ismail, who have always been my source of inspiration and motivation. Without their invaluable sacrifice, I would not be able to achieve what I have today. Also, my appreciation to my other family members, Muhammad Noh Hilmi, Muhammad Noh Hamzi, Muhammad Noh Haqim, Suwaibatul Asslamiah, and my dearest nephew, Umar Azziyad and Amna Syuhada for their continuous moral support and love, which give me immeasurable strength throughout my study.

Last but not least, this appreciation also goes to my helpful and supportive friends, Fadilah, Fatma, YingChiee, KarMun, Nurjaliah, Farhana, Zarith, Syakirin, and Hazman, for their wise guardian and support throughout my study. To those who directly and indirectly contributed to this study, your kindness means so much to me. Thank you.

I certify that a Thesis Examination Committee has met to conduct the final examination of Nur Syafiqah binti Che Hussin on her thesis entitled Development of Decision Support System to Preserve *Neolissochilus hexagonolepis* (McClelland, 1839) in Pelus River, Perak in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Degree of Master Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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I hereby confirm that:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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Signature: ______________________
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Signature: ______________________
Name of Member of
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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AN	Ammoniacal Nitrogen
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DBMS	Database Management System
DEIA	Detailed Environmental Impact Assessment
DID	Department of Irrigation and Drainage
DO	Dissolved Oxygen
DOE	Department of Environment
DPSIR	driving force-pressure-state-impact-state-response
DSS	Decision support system
EFA	Environmental Flow Assessment
GDSS	Group Decision Support System
GIS	Geographic Information System
GUI	Graphical User Interface
HTML	HyperText Markup Language
IDE	Integrated Development Environment
INWQS	Interim National Water Quality Standards
IRBM	Integrated River Basin Management
JPS	Jabatan Pengairan dan Saliran
JRI	JPS River Index
MAM	Mean Annual Minimum

MAR	Minimum Annual Rainfall
MIT	Massachusetts Institute of Technology
MLR	Multiple Linear Regression
MOA	Ministry of Agriculture and Agro-based Industry
NAHRIM	National Hydraulic Research Institute of Malaysia
NGO	Non-Government Organizations
NRE	Ministry of National Resources and Environment
NWRP	National Water Resource Policy
PCs	Personal Communications System
PHP	Personal Home Page
NWSC	National Water Service Commission
SF	Specific Flow
SI_{AN}	Sub-Index for Ammoniacal Nitrogen
SI_{BO}	Sub-Index for Biochemical Oxygen Demand
SI_{COD}	Sub-Index for Chemical Oxygen Demand
SI_{DO}	Sub-Index for Dissolved Oxygen
SI_{pH}	Sub-Index for pH
SI_{SF}	Sub-index for specific flow
SI_{TDS}	Sub-index for TDS
SI_{TSS}	Sub-index for Total Suspended Solid
SI_{Turb}	Sub-index for Turbidity
SS	Suspended Solids
SQL	Structured Query Language
TDS	Total Dissolved Solid

TSS	Total Suspended Solid
Turb	Turbidity
UM	University of Malaya
UPM	Universiti Putra Malaysia
Web	World Wide Web
WFD	Water Framework Directive
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Over the past decades, water management has become a global issue and its challenges are increasing globally. Water is the most delicate part of the environment, which is essential for human and industrial development**.** Water resources development is a catalyst for socioeconomic development in a country. Increasing population leads to an increase in the demand of safe water supply. This valuable resource needs to be managed in a sustainable manner in order to ascertain a sustainable development of human population in an environment with finite amount of resources. In most parts of the world, the water situation has changed from one relative abundance to one of scarcity (Abidin, 2004; Clark et al., 2007; Afroz et al., 2014).

The main crisis of water issue is not about having too little water to satisfy public needs but it is a crisis of managing water that involves billions of people and the whole environment suffers from it (Abidin, 2004). The consequences from human activities such as degrading water storage, decline in water quality, and decreasing conveyance capacity affect the river corridors and consequently, fluctuates the quantity and quality of the habitat. Besides that, any forecasted changes to flow regimes also contribute to the increasing pressure of freshwater biodiversity. In order to maintain the river health, the river flow must be considered as an important factor, as the river flow has to be in balance with the dependent ecological services such as fish abundance (Clark et al., 2007; Summers et al., 2015).

The term 'environmental flow' is usually used to emphasize the flow (high, medium, and low flow) needed to be maintained, which highlights the freshwater allocation in rivers to bear with the necessary human well-being, ecological, and geomorphological conditions. Specifically, the process to identify this flow is known as 'environmental flow assessment (Davis & Hijri, 2003; Dunbar et al., 2004; Martin et al., 2014). In Malaysia, environmental flow is not prescribed in the national legislation but under general term, only as framework laws. It is considered as minimum in-stream flow required by the water diversion for downstream. Eventually, all developers have to present this approach as a part of the Detailed Environmental Impact Assessment (DEIA) for their Water Protection Plans. Legislation developments in Malaysia tend to consider environmental flows in the perspective of environmental sustainability. In the context of sustainable development, it is considered as one of the basic principles in the search for ways to multiple and challenging the uses of water with environmental protection (Toriman, 2010).

1.2 Problem Statement

In Malaysia, river health is one of the most common highlighted issues. Today, supplying freshwater to consumers is considered a challenge with the increasing demand of 4 percent annually and it is expected to reach about 20 billion m^3 by 2020. Studies indicated that in future, extensive freshwater treatment is needed and the cost will be absorbed to the public since 97 percent of freshwater that we depend on are from rivers (Afroz et al., 2014). This fact alone is enough to make the government, stakeholders, and the public conscious about the future conditions of rivers (Ujang et al., 2008).

Although Malaysia is known for its abundance of freshwater sources, however, this availability is not guaranteed to be adequate for all users (Afroz et al., 2014). Human impoundments such as dams, diversion, weirs and extraction for urban and agriculture supply, and natural disturbance modify the river flows. This condition impairs the distribution and abundance of aquatic life forms, ecological integrity of the river ecosystem, and water quality of receiving waters. As a result, this situation increases the vulnerability especially to the poor who depend such services for their livelihoods (Davis & Hijri, 2003; Martin et al., 2014). The uncertainties in the river flows variability turns out to be more serious with additional pressure from external climate change drivers and the availability of non-consumptive uses such as environmental conservation and recreation (Arthington et al., 2006; Martin et al., 2014).

Environmental flow assessment (EFA) is a method to assist in and maintaining the river health. The assessment determines the amount of river flow needed for sustainable uses. Normally, EFA is implemented for rivers where there are development plans, or for a river that requires health improvement. EFA is important in maintaining river health as it specifically determines the quantity, quality, and timing of the river flows required over time to sustain water body ecosystems and human livelihoods that depend on this ecosystem. However, in order to achieve optimum level of environmental flow, the water managers require time to analyze all the causative factors. These challenges are added with the other difficulties of EFA that lies in the lack of understanding in the relationship between river flow and multiple components of river ecology and scarcity of data (Mazvimavi et al., 2007).

The stakeholders have become more interested in knowledge model generation to integrate in the decision making process, which could address wider aspects of environmental management (Jackson et al., 2015). Advanced technology tools facilitate systematic river management in order to ensure the sustainability of Malaysian water resources. The tools must have criteria that can improve consistency, transparency, and process clarity in the water management. With that, the validity of this technology could be depended on and accepted with identification of the limitations of tools involved (Andreu et al., 1996).

1.3 Decision Support System as a Solution

Decision support system (DSS) is defined as a computer information system that typically focuses on how information technology supports users to make decision effectively from a provided application domain through analytical decision process with the access to the databases for complex and ill-structured tasks (Labadie, 2006). The emergence of DSS marks the initiation of information system, specifically on the decision support purpose of top management (Tian et al., 2007).

There are two different areas of DSS before it evolved significantly since their development in the 1970s. The first one is at the Carnegie Institute of Technology in the late 1950s and early 1960s, where the organizational decision making focused on theoretical studies. The second is during 1960s at Massachusetts Institute of Technology (MIT), which focused on technical work (Shim et al., 2002). On the other hand, the components of classic DSS tool designs are (i) the capabilities of sophisticated database management with access on both internal and external data, knowledge, and information, (ii) model management system access by powerful modelling functions, and (iii) interactive queries, reporting, and graphing functions that enable simpler yet powerful user interface designs. In each of this domain, much research and practical design effort are to be conducted (Shim et al., 2002).

Additionally, there are broad range capabilities presented by the modern DSS to their users. Decision tasks facilitate from wide variety of current DSS, which include sensitivity analysis, collaboration, information gathering and analysis, alternative evaluation, model building, and decision implementation (Bhargava et al., 2007). The World Wide Web (Web) provides opportunities for DSS particularly on information dissemination to decision-makers. This process enables DSS to be more efficient and widely used (Shim et al., 2002).

Generally, in the scope of river basin management, DSS acts as a tool to aid the stakeholders in gaining better understanding in the corresponding complex river basin systems, which involve multiple jurisdictional entities. All criteria that have impacts to the river health need to be considered in system assessment. The evaluation of environmental, ecology, economic, and institution/legal impacts, which are related to river management and development scenarios, are needed (Acreman & Dunbar, 2004; Labadie, 2006).

In fact, DSS for environmental flow assessment has the potential to be modified in the most interactive way to become a useful software, which targets most water resource managers and researchers particularly in this country. In the aspect of economic contributions, this project is cost-efficient in terms of revenue from consultancies and sales of manufactures products, as well as time-efficient.

1.4 Objectives of Study

The general objective of this study is to develop a prototype of Decision Support System (DSS) for environmental flow assessment. The specific objectives of this study are as follows:

i. To structure the knowledge based for the domain of environmental flow assessment
ii. To evaluate the effectiveness of prototype DSS by conducting a case study

1.5 Scope of Study

The study specifically focuses on developing a prototype in order to facilitate the river management based on environmental flow assessment particularly in Malaysia. This approach is actually well known in other countries, but for Malaysia, it is only recently introduced. Thus, this study becomes an important benchmark for Malaysia in the advancement of river management system. Further studies for enhancing the prototype should be conducted for more complex management of river, considering multiple aspects of management. In the future, this system will become one of important approaches for the stakeholders to manage river systems.

Generally, this study considers three different components in the environmental flow assessment, which are hydrology, hydraulic, and ecology aspects of the river system. Each modular in the system implements IF-THEN rule because this rule is easier for users to understand. Besides that, backward-chaining concept is also considered in this study, which is emphasized in the first modular of the system. The application of programming language such as HTML, PHP, and MySQL ensures the system to be developed in the systematic manner, and enables the users to simply access the system through the internet. The system has three different modules, where users are presented with suggestions and recommendations as guideline in handling the related river flow issues at the final stage of system analysis. Last but not least, the system is verified and validated through the selected case study area in Malaysia.

1.6 Thesis Organization

This study aims to develop a prototype of decision support system for environmental flow assessment for river management in Malaysia. The thesis consists of five chapters, which are organised as follows:

Chapter 2 further explains on the background of study, specifically the scope that must be considered for environmental flow assessment and decision support system. The discussion also involves the river management in Malaysia with the present river conditions. Besides that, discussion on integration of DSS with the river management system is also highlighted in this chapter.

Chapter 3 further explains about methodology involved in this study. The discussion focuses on the development of prototype by the application of IF-THEN rule with the analysis of EFA. The discussion also involves the knowledge acquisition process as well as the selection of DSS prototype tools.

Chapter 4 generally discusses about the results of system presented in this study. This chapter specifically describes the architecture of prototype with the developed modules. Detailed discussion on the validation and verification process to the targeted users in the selected study area, Pelus River, Perak is presented. The overall effectiveness of the system is highlighted in this chapter.

Chapter 5 presents the conclusion of this study. In this chapter, recommendations to enhance the effectiveness of the system for more complex river management system of Malaysia are presented.

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