EFFECTIVENESS OF WATER SENSITIVE URBAN DESIGN IN STORM WATER MANAGEMENT: CASE STUDY OF SARAWAK URBAN CATCHMENT, BAU CATCHMENT AREA

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Master of Engineering
(Civil Engineering)
2014
UNIVERSITI MALAYSIA SARAWAK

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Final Year Project Report
Masters
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CASE STUDY OF SARAWAK URBAN CATCHMENT, BAU CATCHMENT AREA

ADNAN B BAUSAH

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Engineering (Civil)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2014
ACKNOWLEDGEMENT

"Dengan Nama Allah Yang Maha Pemurah Lagi Maha Penyayang"

First of all, I would like to express my deepest gratitude to the Faculty of Engineering for giving me this opportunity to complete this thesis. Special thanks and appreciations given to my supervisor, Prof. Dr. F. J. Putuhena for his guidance, wisdom, encouragement, help and support throughout the whole process and journey of this thesis project.

I would like to express my heartfelt thanks to my wife, Ross Azura Zahit, my children Qayyum, Qeesha and Qaireen as well as my family members who have been very supportive and understanding and always behind in me every step of the way in making this thesis a reality. Last but not least, I would like to thank UNIMAS staff and everyone who has been giving contribution directly or indirectly. Without them, this research would not have been possible.

Finally, I hope that this study will give inputs for future study and contribute in the development of the nation, especially in the field of storm water management.
Abstract

Water Sensitive Urban Design (WSUD) has been introduced as Best Management Practices in managing the urban runoff problems, in term of quantity and quality cause by the changing of ground surface conditions due to development activities. In term of runoff quantity, the aim of WSUD is to make sure that the peak discharge from post-development area is same or less compared to the pre-development. Objectives of this thesis are to analyse the performances of WSUD elements compared to the conventional methods in the development area. The study area is located inside the catchment area of Bau, Sarawak. A proposed low-cost residential area is set up following the Development Control Standard Manual guidelines. Type and size of drainage for the residential area are determined according to the Manual Saliran Mesra Alam (MSMA). Comparisons of drainage performance between conventional methods and the application of WSUD elements are conducted using the SWMM 5.0 software. The results of conventional drainage in rectangular concrete drain and composite drain have shown that the peak discharge is higher than that of pre-development. The applications of WSUD elements (swale, rainwater harvesting, porous pavement and dry-detention pond) have shown reduction up to 80 per cent in peak flow compared to conventional methods. However, without the use of dry detention pond, the reduction is not achieving the desired level as of pre-development. So, in this particular study, it is concluded that the WSUD is only effective through combination of WSUD elements rather than a single measure. The findings of this thesis hopefully can be made as references to implement the MSMA in Sarawak.
Abstrak

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<td>ARI</td>
<td>Average Recurrence Interval</td>
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<td>BMP</td>
<td>Best Management Practices</td>
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<td>DCSM</td>
<td>Development Control Standard Manual</td>
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<td>DGPPP</td>
<td>Draf Garis Panduan Pembangunan Perumahan</td>
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<td>Department of Irrigation and Drainage</td>
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<td>DOE</td>
<td>Department of Environment</td>
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<td>Geographic Information System</td>
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<td>IDF</td>
<td>Intensity Duration Frequency</td>
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### Notations

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CHAPTER 1

INTRODUCTION

1.0 Overview

During the launch of Sixth Malaysia Plan in 1991, the government introduced the Vision 2020. The vision called for the Malaysian to achieve a self-sufficient industrialized nation by the year 2020. There are a few criteria to achieve this vision; one of them is the physical development in terms of amount of widespread infrastructures and general standards of living. Malaysia must be in average positive economic growth to make sure the vision become reality.

The physical development, however, certainly changes the natural environment conditions. Most problem arise in development areas (during and after) had effected to the river conditions (physical, chemical and biological). Due to poor
management and control during the development proses, the silt debris from
construction site is channelled to water stream paths and to the surrounding areas.
This is causing the stream bed to become shallow which leads to flood events.

At the post-development stage, due to application of conventional system,
flood happens since the volumes of water in the river drastically increase. Besides
that, pollution of rubbish in the river becomes a major problem in urban areas
compared to rivers in rural areas. Both of these problems are costly to overcome and
it happens more frequently if there is no best application introduced to the related
system.

According ‘Updating Flood Condition’, (2012) the loss due to flood is RM
915 million per year meanwhile in Mingguan Malaysia news, edition February 4,
2007, reported that the cost for cleaning polluted river in the country is up to RM
400 million.

1.2 Definition of Terms

In this sub chapter, the terms of the title are elaborated. The title of this study
is “Effectiveness of Water Sensitive Urban Design in Storm Water Management:
Case Study of Sarawak Urban Catchment”.

According to Oxford Fajar Dictionary (2000), effective is having an effect or
producing the intended result. Then the effectiveness is the capability of producing a
desired result. When something is deemed effective, it means it has an intended or
expected outcome, or produces a deep, vivid impression.
According to Wong and Ashley (2006), as cited in Wong (2007), the water sensitive urban design comprises two parts, namely “water sensitive” and “urban design”. “Urban design” is a well-recognised field associated with the planning and architectural design of urban environments. It is covering issues that have traditionally appeared outside of the water field but nevertheless interact or have implications to environmental effects on water. Water sensitive urban design brings sensitivity to water to urban design to ensure that water is given due prominence within the urban design processes.

The word “water sensitive” defines a new paradigm in integrated urban water cycle management that integrates the various disciplines of engineering and environmental sciences associated with the provision of water services including the protection of aquatic environments in urban area.

According to MSMA (2011) the Stormwater management is defined as the mechanism for controlling stormwater runoff for the purposes of minimizing the catchment flow rates, runoff volumes, frequency of flooding and degradation of surface water quality through implementation of construction erosion and sediment control, quantity control and treatment best management practices (BMPs) to diminish the effect of land use changes.

According to Walesh (1989), stormwater management, simply stated is everything done with in a catchment to remedy existing stormwater problems and to prevent the occurrence of new problems. Meanwhile in the Stormwater Management Handbook produced by Pocono Northeast (n.d), storm water management is the activities which is involve the control of surface runoff where the volume and rate are substantially increased as land surfaces are developed.
With that, the "Effectiveness of Water Sensitive Urban Design in Storm Water Management: Case Study of Sarawak Urban Catchment" can be understood as how the water conditions in terms of quality and quantity are affected if in the case study area, so that water is given due prominence.

1.3 Case Study Area

In this study, the area is located at the upstream of Bau Bridge station. The station is located at Sarawak Kanan River Catchment Area in Bau district. The selection is made by considering the Sarawak Integrated Water River Management Master Plan, (SIWRMMP) data, that by year 2020, the population is estimated at 60000 and the land use demand is increased up to 871 hectare, meanwhile the portable water demand is projected up to 20.3 MLD. With this data, it is shown that the urbanisation is expected to expand in Bau district. The detail explanation on the selection of case study area is discussed in chapter 3.

1.4 The Significant of Area to the Study

Since storm water management is defined as managing the quality and quantity of storm water, then the consideration to choose the case study area must be significantly in term of quality and quantity.
In term of water quality, Povlsen, (2001) reported the Sarawak Kanan River is under the class IIA/IIB. Study by Long, (2003) reported that the river quality is categorised as class IIA/IIB and III, in which the study also explained that the water quality in the river varied with location. The upstream area was of good quality compared to downstream. These two findings are consistent to the report of Department of Environment (2008), which put Sarawak Kanan River to class IIA/IIB. Besides that, the area is considered significant with the presences of Bau water treatment plant within the case study area and Seniawan water treatment plant located at downstream of discharge station.

In term of water quantity the area is considered significant since Bau is located at upstream of Kuching city, any increment of water volume will affect city. According to Mah et al (2007) the town of Bau and surrounding areas are well-known as flood prone area. During the major flood of February 2003 and January 2004 in Bau, much of Kuching city areas were affected also.

1.5 Objectives of Study

The first objective of this study is to study the concept of water sensitive urban design and how its components such as; rainwater harvesting, detention pond and swale work in managing urban storm water. The second objective is to analyse the storm water quantity at discharge point if the catchment area is developed using computer simulation packages.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Urbanisation is a continuous process. Every nation has their own planning on how to build their country for being better than previous time by exploring new technology or adopt conventional method with some innovation. The major topic nowadays that has been highlighted around the world is how to harmonise (complement) development processes to the environment, which is also known as sustainable development.

Water Sensitive Urban Design (WSUD) is one of the current technology that has been introduced in managing stormwater. This term is initially used in Australia; however different term is used in other regions, for instance Low Impact Design (LID) in the United State (U.S.) and Sustainable Urban Drainage System (SUDS) in the United Kingdom (U.K.). Nevertheless, the concept of WSUD in Malaysia, which
is patronised under the Department of Irrigation and Drainage, is known as Manual Saliran Mesra Alam (MSMA).

Wong, Peter and Lloyd (2000), pointed out that the changing of land surface conditions due to urban development can lead to significant changes in catchment hydrology, with the most obvious effect - the increment of stormwater flow events in volume in the urban creeks; and the consequential impact on flooding and public safety. The conventional approach of engineering field in design, construction and managing the stormwater is focused on the issue of drainage, specifically in working on how the water from sources point can convey to the water path; safely and economically.

The quantity and rate of stormwater runoff generated from impervious surfaces usually lead to extensive channel erosion and an increased frequency of flooding. The conventional approach to resolve these problems is to increase the hydraulic capacity of waterways by using a combination of channelization and partial, or complete, concrete lining. Stormwater management in urban catchments now places more emphasis on meeting multiple objectives, including drainage, flood protection, ecosystem protection and the optimisation of recreational and landscape opportunities.

2.2 Surface Runoff in Development Area

Davenport (2002) indicated that 'the paths taken by water determine many of the characteristic of landscape, the generation of storm runoff, the uses to which it may put, and the strategies required for wise land management', which explained
the pathway precipitation takes after it falls to earth would affect many aspects of stream flow including quantity, quality, and timing. Precipitation can flow from three possible paths from the time it hits the ground until its ultimate discharge to the surface water. The three possible paths are:

a. Water may flow over the land surface without infiltration;
b. Water may infiltrate to the ground water, then flow towards and eventually discharges into surface water; and
c. Water may infiltrate and moves as interflow.

As summarised by Heathcote (2009), the natural precipitation processes are:

1. Rain falls continuously over the watershed - input of precipitation is constant over the land surface;
2. Initial flows are intercepted by trees and other plants, on leaves and bark and on rough surfaces. The rain water begins to flow toward the land surface;
3. Rainfall infiltrates into soils as ground water and capacity of soils to absorb is dependent to the soil moisture content;
4. Once soils are saturated, small surface depression begins to fill, puddles begin to form on the land surfaces;
5. When the surface storage is full then the remaining precipitation begins to flow overland through the gulling and sheet flow; and
6. When the capacities of sheet flow are reached and the precipitation still continue then the flood is produced.
In urbanized areas, soil surfaces change from pervious to impervious surface, resulting in quicker processes which has been aforementioned by Heathcote (2009) and subsequently, eliminate the processes of no. 2, 3 and 4.

According to Whitney (2007), runoff from developed area, construction sites, rooftop, road and highways is categorised as urban stormwater runoff. As an area becomes more densely developed, a large percentage of land is covered by hardened surfaces, making the rainfall that would have been absorbed by plants or filtered into groundwater aquifers instead flows into the local water path and storm drain. During dry period, stream base flow is substantially reduced because none of the past rains are able to saturate the ground, as shallow groundwater storage is diminished. As a result, less water is available to gradually, because there is no opportunity for plants to absorb the moisture that falls on pavement. A much larger volume of stormwater drains into stream that flows from urban area. This large quantity of water reaches streams too quickly, flowing across the water channel such as drain or pipe. Drastic fluctuations in stream river flow level increase the potential for destructive flooding.

Figure 2.1: Runoff on two different surface conditions. Courtesy by www.mdcoastalbays.org
According to DID Malaysia (2000), study in Subang Jaya, Selangor, revealed that for 40 per cent of impervious surface, it is lead to reduce the time concentration, $T_c$ of surface runoff to 50 per cent and increase the discharge volume, $Q$ may up to 90 per cent. This finding is supported by Roesner et al. (2001), as cited in Aminuddin Abd Ghani (2004); which they highlighted the increase in quantity of surface runoff as compared to previous day, as well as the increment of peak flow by twice to ten times.

Figure 2.2: Illustrated the percentage of surface runoff with the changing of land surface. *Courtesy by www.fairfaxcounty.gov*
2.3 Water Sensitive Urban Design (WSUD)

As mentioned earlier, the term of WSUD was originally coined in Western Australia to describe a new Australian approach to urban planning and design. According to Wong (2007), the original conceptualisation of WSUD (in Perth, Western Australia) was as an alternative planning and design framework for urban development that attempts to break the dependency of urban environments on large water services infrastructure that is not integrated in a manner that manages all water streams resources, promotes recycling, mitigates the impact of urban stormwater on the urban water environment through the promotion of at source detention and retention of stormwater using landscape features.

Wong (2007) also explained WSUD is centred on integration at a number of levels:

i. Integrated management of the three urban water streams of potable water, wastewater and storm water;

ii. Integration of the scale of urban water management from individual allotments and buildings, to precincts and regions;

iii. Integration of sustainable urban water management into the built form, incorporating building, landscape and public art; and

iv. Integration of structural and non-structural sustainable urban water management initiatives.

In Wollongong Development Control Plan (2009) part E, WSUD is defined as a holistic approach in urban development project cycle, from initial to completion
stages, to minimise negative impacts on the natural water cycle and at the same time, protect the health of aquatic ecosystems. Besides that, it also promotes the integration of stormwater, water supply and wastewater management at the development stage. WSUD requires the consideration of urban water cycle at the early planning stage to ensure all possible opportunities for application of best practice in water cycle management solutions can be realised.

2.3.1 Water Sensitive Urban Design Objectives

The Wollongong Development Control Plan (2009) part E also, listed the WSUD main objectives related to water quantity such as:

i. To sustainably the environmental condition with urbanisation;
ii. To integrate the management of stormwater into landscape design;
iii. To ensure that WSUD is taken into consideration in any development;
iv. To maximise the urban runoff reuse;
v. To minimise the quantity of stormwater as possible back to the normal condition; and
vi. To reduce the peak flows from urban with the appropriate elements of WSUD.

Achieving these objectives directly saves the budget related authority and also provides the conditions to the society. To achieve the objectives, they introduce the key principles as guidance. They are: