Faculty of Engineering

# 3D MODELLING USING SOLIDWORKS: WALL-MOUNTED RAINWATER TANK FOR STORMWATER DETENTION IN COMMERCIAL AREAS

**FOO SWEE WEN**

**Bachelor of Engineering with Honours**

**(Civil Engineering)**

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# 3D MODELLING USING SOLIDWORKS: WALL-MOUNTED RAINWATER TANK FOR STORMWATER DETENTION IN COMMERCIAL AREAS

FOO SWEE WEN

This project is submitted in partial fulfilment

of the requirement for the degree of

Bachelor of Engineering with Honours

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Dedicated To My Beloved Family and Friends.

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# ABSTRACT

Rapid urban growth with increment of paved areas has resulted in increased stormwater runoff within built environments which could lead to flood events. Therefore, rainwater harvesting is one of the common approaches to store the stormwater temporarily to reduce the volume of runoff in dense urban areas. Normally, conventional rainwater harvesting tank has big capacity and it occupies large land spaces. In this project, a wall-mounted rainwater harvesting system is introduced for commercial buildings with limited empty spaces. Due to the large roof catchment area, three storage tanks are proposed to be installed on the building wall to achieve the desired storage capacity. With the aid of Solidworks Flow Simulation, the effectiveness of the wall-mounted rainwater harvesting system is investigated under various inlet designs (T-Inlet, L-Inlet, and Inclined-Inlet) subjected to three pipe sizes (60mm, 90mm and 120mm). It is found that Inclined-Inlet with 120mm pipe is the ideal design for such a system. It has the most balanced characteristics of smooth water flowing, and associated pressures for closed system. Velocities at tank outlets are with the least differences with 0.116m/s in Tank 1, 0.181m/s in Tank 2 and 0.308m/s in Tank 3. Meanwhile, the pressure within the three tanks also gives a close value about 102 kPa. Hence, a wall-mounted rainwater harvesting system is proven of its appropriate fluid dynamics and pressures to be integrated into commercial buildings for urban stormwater management.

# ABSTRAK

*Pertumbuhan bandar yang pesat dengan pertambahan kawasan berturap telah menyebabkan peningkatan air larian yang boleh membawa kepada kejadian banjir. Oleh itu, penuaian air hujan adalah salah satu pendekatan biasa untuk menyimpan air ribut sementara untuk mengurangkan jumlah air larian di kawasan bandar yang padat. Biasanya, tangki penuaian air hujan konvensional mempunyai kapasiti yang besar dan ia menduduki ruang tanah yang besar. Dalam projek ini, sistem penuaian air hujan yang dipasang di dinding diperkenalkan untuk bangunan komersial dengan ruang kosong yang terhad. Disebabkan oleh kawasan tadahan bumbung besar, tiga tangki simpanan dicadangkan untuk dipasang pada dinding bangunan untuk mencapai kapasiti simpanan yang dikehendaki. Dengan bantuan Solidworks Flow Simulation, keberkesanan sistem penuaian air hujan yang dipasang di dinding disiasat mengikut pelbagai reka bentuk salur masuk (T-Inlet, L-Inlet, dan cenderung-Inlet) tertakluk kepada tiga saiz paip (60mm, 90mm dan 120mm). Didapati bahawa cenderung-Inlet dengan 120mm paip adalah reka bentuk yang sesuai untuk sistem tersebut. Ia mempunyai ciri-ciri yang paling seimbang air lancar mengalir, dan tekanan yang sesuai untuk sistem tertutup. Halaju di outlet tangki memberikan nilai berhampiran iaitu 0.116 m/s dalam Tangki 1, 0.181 m/s dalam Tangki 2 dan 0.308 m/s dalam Tangki 3. Sementara itu, tekanan di dalam tiga tangki juga memberikan nilai berhampiran kira-kira 102 kPa. Oleh itu, sistem penuaian air hujan yang dipasang di dinding terbukti dinamik bendalir yang sesuai dan tekanan untuk diintegrasikan ke dalam bangunan komersial untuk pengurusan air ribut bandar.*

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| | | |
|---|---|---|
| ARI | - | Average Recurrence Interval |
| CAD | - | Computer Aided Design |
| CFD | - | Computational Fluid Dynamics |
| DID | - | Department of Irrigation and Drainage |
| MSMA | - | Manual Saluran Mesra Alam |
| SUDS | - | Sustainable Urban Drainage System |
| SWMM | - | Stormwater Management Model |
| WSUD | - | Water Sensitive Urban Design |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Rainwater harvesting is an economic approach of Water Sensitive Urban Design (WSUD) which contains a few simple components to control the stormwater runoff. Basically, the type and size of the rainwater tank are the main considerations of the rainwater harvesting system. Conventional rainwater tank has big capacity which is placed above-ground or underground; but it is space consuming. A wall-mounted tank is introduced here as it could be fitted into urban built environment more adeptly than the conventional rainwater tank. It is installed to the wall of the buildings and it can save the space for other uses.

## 1.2 Problem Statement

Referring to Figure 1.1, Central City, Kota Samarahan is a modern township that has high density built-up units. Residential and commercial lots alike are designed with limited empty spaces. Therefore, wall-mounted rainwater harvesting tank is an alternative choice for the township. However, this project focuses on commercial lots as the spaces nearby the lot are used for parking lots (Wong, 2015). Normally, wall-mounted rainwater harvesting tank has a smaller capacity if compared to the other conventional storage tanks available in market. Then, multiple tanks can be connected to each others with interconnecting arrangement in order to achieve the desired storage capacity (Tang & Mah, 2015).

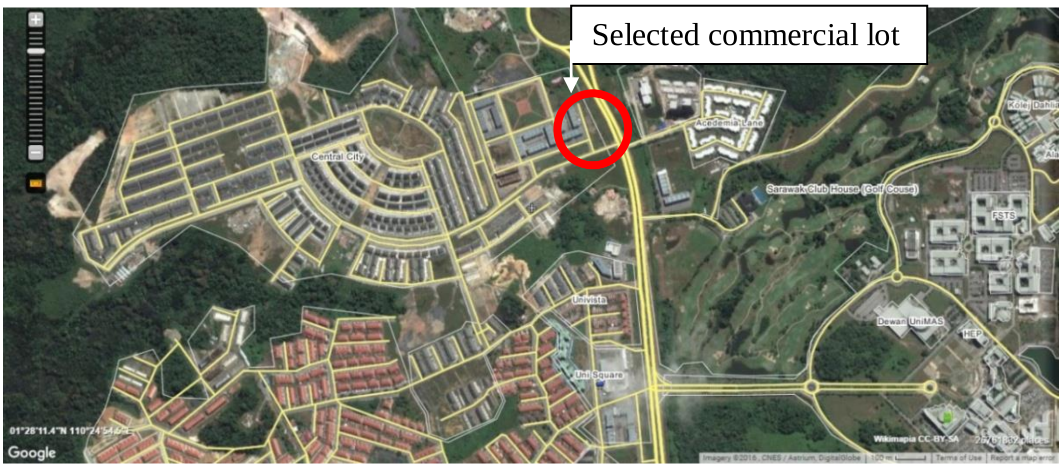


Figure 1.1: Selected Commercial Lot is Located at Central City, Kota Samarahan (http://wikimapia.org)

This project is an extension of Wong (2015) which the commercial lot of Central City was taken as the subject of case study. He suggested a series of three tanks would be the most economy against 15 minutes 10-year ARI design storm and the wall-mounted rainwater harvesting tank design is as showed in Figure 1.2 below. The design would be able to reduce the design storm volume by half, meaning half captured and the remaining released for environment flow. The investigation was carried out using the EPA SWMM 5.0 Software (US Environmental Protection Agency-Stormwater Management Model).

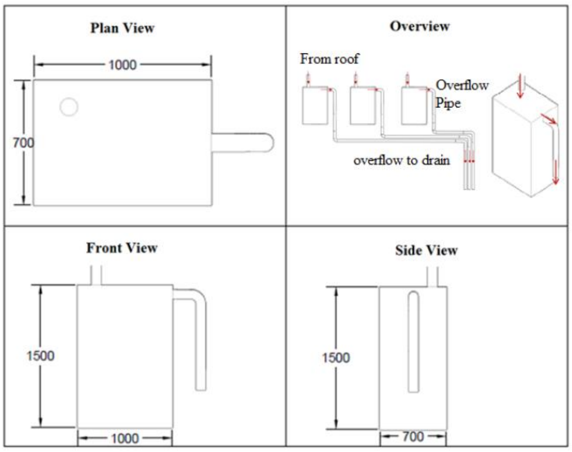


Figure 1.2: Design Layout of the Wall-Mounted Rainwater Harvesting Tank for Commercial Lot (Wong, 2015)

The concepts of SWMM are based on rainfall-runoff modelling; in which runoff is generated by rainfall over a catchment, then the runoff is routed through nodes and links until the running water reaching an outlet. In another word, the model is stimulating the volume of water over time over space generally.

However, SWMM lacks the details of the hydraulics. For example, it could not provide whether congestion of flow occurred at the length between the roof and inlet to tank. Besides, overflow pipe that is showed in Figure 1.2 could not be tested for its ease of flow to the stormwater drain. The two design issues highlighted here require detailed modelling. Therefore, this project is intended to go 3D modelling of Wong (2015)'s design to scrutinize the wall-mounted rainwater harvesting system further. A Computational Fluid Dynamics (CFD) modelling using SolidWorks Software is attempted here.

## 1.3 Objectives

i. To develop prototypes of wall-mounted rainwater harvesting system by using SolidWorks; and
ii. To investigate the detailed flow within the wall-mounted rainwater harvesting system by using SolidWorks Flow Simulation.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Urban Stormwater Management

Nowadays, continuous growth of population, expansion in urbanization, industrialization and irrigated agriculture are the common issues faced by most of the developing countries including Malaysia. There is no denying that urbanization changes the initial hydrology and hydraulic characteristics of catchment with the increment of paved areas (Zakaria, Ab. Ghani, & Chang, 2004). In forested areas, most of the rainfall infiltrates into the soil or trapped by the plants. The topsoil acts as natural temporary water retention media, thus the flooding is less likely to take place in those areas (Yong & Md Nasir, 2004).

In Malaysia, the average yearly rainfall is recorded to be around 3000mm with the average rainfall of 3830mm in Sarawak, 2630mm in Sabah, followed by 2420mm in Peninsular Malaysia (Alnaimi, Murugasen, & Al-Qrimli, 2015). Therefore, the degree of excess runoff generated from developed areas is tremendous as less rainwater infiltrates into the soil. In the past 30 years, rapid urban growth in Malaysia has resulted in increased stormwater flow into receiving waters, thus increasing the flood peaks, and also degrading the water quality (Zakaria et al., 2014). One of the example is the flood occurred at Kuala Lumpur and other states in January 1971 which had caused the loss of properties about RM 200 million and with 61 fatal cases recorded (Takaijudin et al., 2010).

In year 1975, "Planning and Design Procedure No.1: Urban Drainage Design Standard and Procedures" was first established and utilized by the Department of Irrigation and Drainage (DID) (Zakaria et al., 2004). It was a simple standard document with 10 chapters and had been used as a guideline to design conventional drainage system for more than 25 years since its publication. For this standard, the stromwater management had been practiced where all the surface runoff must be discharged directly to the nearest river or stream in shortest time (Mohd. Sidek et al., 2004). Unfortunately, this practice of rapid disposal and conveyance-oriented approach had caused the occurrence of flash flood and river pollution as well (Zakaria et al., 2004).

In year 2001, a manual which named as Urban Stromwater Management Manual for Malaysia, MSMA had been introduced by DID and widely adopted as a guideline for the development in stormwater management. It consisted of 48 chapters and mainly divided into nine parts such as background information on environmental process and stormwater management, administration aspects and planning processes, detailed information on hydrology and hydraulic, runoff quantity control and conveyance, source and treatment runoff quality controls, runoff quality controls during construction and special stormwater applications as well (DID, 2001). This MSMA manual promoted a more environmentally approach which was known as "control-at-source" approach to minimize the impact of development on stormwater quantity and also water quality control through best management practices (BMPs). Detention or retention facilities were promoted to control the peak and volume of runoff from a given catchment and to reduce the frequency of downstream flooding (refer Figure 2.1).

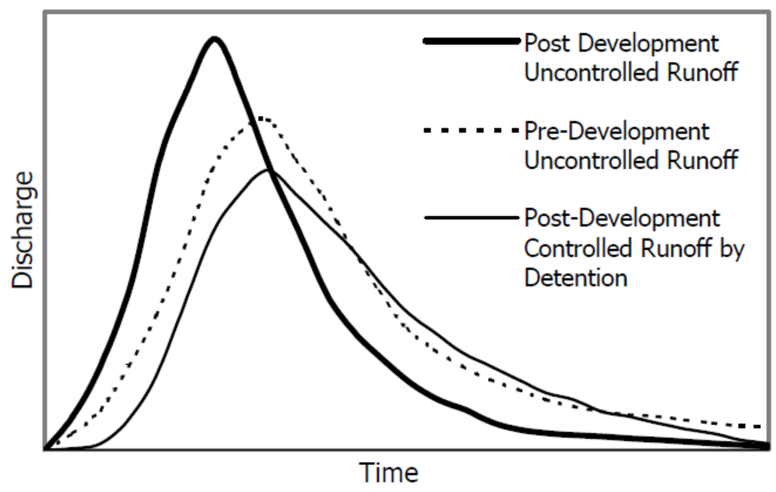


Figure 2.1: Zero Uncontaminated Discharge Principle (DID, 2001)

By referring to Figure 2.1, the post-development peak flow of runoff must be equal to or less than the pre-development peak flow of runoff as idealized in “zero peak flow contribution” (Zakaria et al., 2004). Besides, the volume of the post-development runoff hydrograph was also required to be reduced to the same volume as the pre-development runoff hydrograph as well. The latter required the retention facilities to retain the different in volume between the post and pre-development hydrograph. In addition, Figure 2.2 shows the suggested measures to achieve the aim of uncontaminated zero peak discharge contribution.

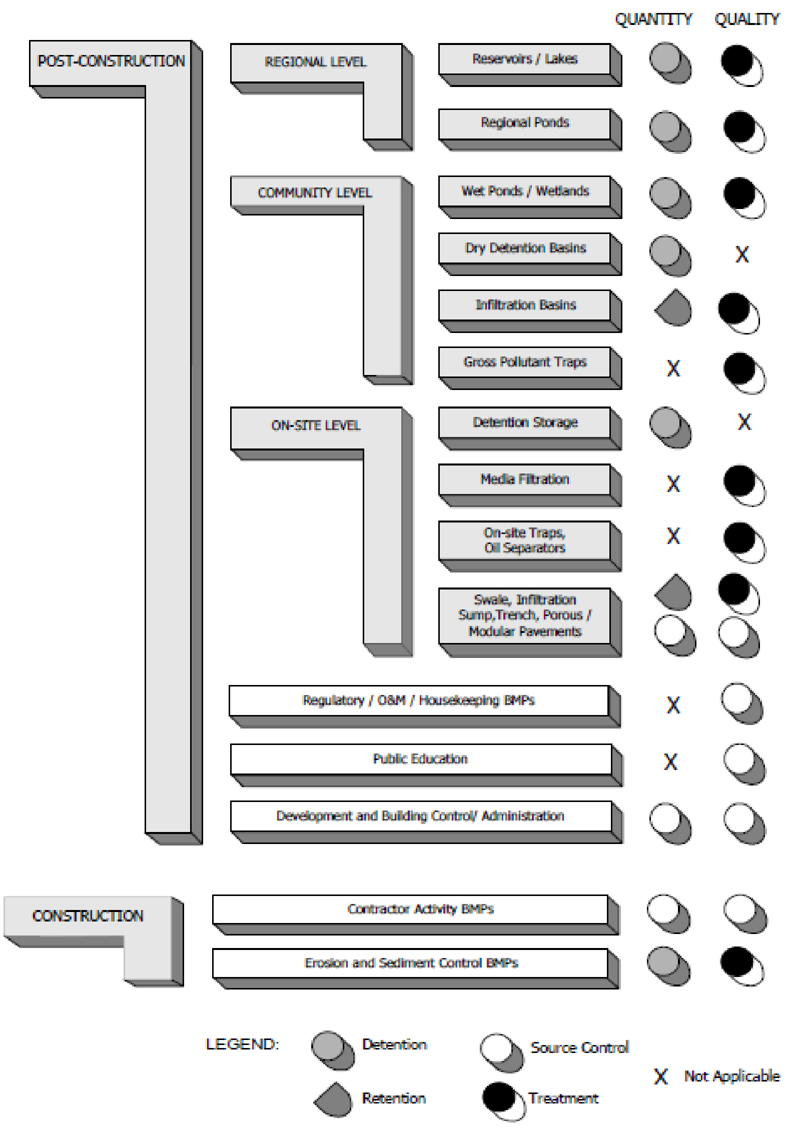


Figure 2.2: Typical Stormwater Management Measures

After ten years, the 2nd Edition of Urban Stormwater Management Manual for Malaysia (MSMA 2nd Edition) had been released in year 2011. It is an improved version of the MSMA 1st Edition to serve as an important guideline to the latest stormwater BMPs (DID, 2011). For MSMA 2nd Edition, there are 20 chapters which cover mainly administration, quantity control design, quality control design, conveyance design, annexure on planting and maintenance (DID, 2011a). In this edition, quality control facilities or BMPs shall be planned and designed to achieve good water quality standards released from completed development project. Besides, stormwater conveyance system shall also be planned and designed based on design storm average recurrence interval (ARIs) to ensure the safety of the public and protection for private and public properties.

## 2.2 Water Sensitive Urban Design (WSUD)

Urban and industrial developments dramatically alter landscapes from permeable vegetated surfaces to impervious surfaces. The increases in impervious surfaces then increase the rate and volume of stormwater runoff. Therefore, “environmental friendly” approaches should be applied to limit the runoff characteristics after development. This is the new direction for stormwater management system towards sustainable development.

In Malaysia, Urban Stormwater Management Manual for Malaysia (MSMA) has been introduced which associated to the stormwater management system. In other countries, their concept is more or less the same but with different names. For example, United States with Low Impact Development (LID), United Kingdom with Sustainable Urban Drainage System (SUDs), New Zealand with Low Impact Urban Design and Development (LIUDD) and Water Sensitive Urban Design (WSUD) in Australia (Takaijudin et al., 2010).

The term Water Sensitive Urban Design (WSUD) was probably first used in Australia in year 1994 when Whelans presented design guidelines for residential planning and design which are sensitive to the maintenance of the aquatic environment (Wong & Eadie, 2000). In Australia, the philosophy and guiding principles of WSUD were first published in the Water Sensitive Urban Design Guidelines (WSUDG) which