UNIVERSITI SAINS MALAYSIA

PERFORMANCE OF URBAN STORMWATER DRAINAGE SYSTEM THROUGH DRY DETENTION POND (CASE STUDY: KOTA DAMANSARA, SELANGOR)

By

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Thesis submitted in fulfilment of the requirements for the degree of Master of Science

JULY 2009

ACKNOWLEDGEMENT

First and foremost, I would like to convey my deepest appreciation to my supervisor, Professor Dr. Aminuddin Ab. Ghani, Deputy Director of River Engineering and Urban Drainage Research Centre (REDAC) for his technical assistance, guidance with patience and encouragement throughout my research for 2 years. Apart from that, I would like to thank my co-supervisor, Professor Dr. Nor Azazi Zakaria who is also the Director of REDAC for his valuable comments.

Besides that, I would like to extent my gratitude to Ir. Hj. Ahmad Jamaluddin Shaaban, Director-General of National Hydraulic Research Institute of Malaysia (NAHRIM), Ir. Dr. Salmah Zakaria, the former Director-General of NAHRIM, Mrs. Hajah Zalilah Selamat, Senior Researcher from River Research Center, Dr. Mohamed Roseli Zainal Abidin and Mr. Tan Teow Soon, the former Head of Hydraulic Engineering Division as well as Tn. Hj. Abd. Jalil Hassan, the former Senior Researcher for their guidance throughout the project and my colleagues in River Research Centre, NAHRIM for their support and involvement in this study. Not to left out my sincere thanks to all the technical team in REDAC especially Mr Chang Chun Kiat for his assistance particularly in information searching.

Last but not least, special thanks are due to my beloved parent and my siblings for their warmest care, patience, understanding and support as well as words of encouragement which made this research possible and complete finally after 2 years.

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LIST OF ABBREVIATIONS

ALSM	Airborne Laser Swath Mapping
AMC	Antecedent Moisture Content
ARI	Annual Recurrence Internal
BMPs	Best Management Practices
CHI	Computational Hydraulics International
CN	Curve Number
DAP	Drainage Area Planning
DEM	Digital Elevation Model
DID	Department of Irrigation and Drainage, Malaysia
DMP	Drainage Master Plan
DOA	Department of Agriculture, Malaysia
DSS	Decision Support System
GIS	Geographical Information System
HSG	Hydrologic Soil Group
IDF	Intensity-Duration-Frequency
InfoWorks CS	InfoWorks Collection System
IUD	Integrated Urban Drainage
JUPEM	Department of Survey and Mapping Malaysia
LiDAR	Light Detection and Ranging
MOUSE	Modelling of Urban Sewers
MSL	Mean Sea Level
MSMA	Urban Stormwater Management Manual for Malaysia
NAHRIM	National Hydraulic Research Institute of Malaysia
PCSWMM	Personal Computer Stormwater Management Model
PKNS	Pembangunan Kemajuan Negeri Selangor
REDAC	River Engineering and Urban Drainage Research Centre
SCS	Soil Conservation Services
SMS	Short Messaging System
SRTM	Shuttle Radar Topography Mission

LIST OF ABBREVIATIONS

SSRM	Strategic Sewer River Model
SWMM	Stormwater Management Model
TRRL	Transport and Road Research Laboratory
USCS	United States Soil Conservation Services
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agencies
UK	United Kingdom
WaPUG	Wastewater Planning Users Group
WASSP	Wallingford Storm Sewer Package
XPSWMM	Stormwater and Wastewater Management Model

LIST OF SYMBOLS

Symbol	Definition
Δt	Routing interval (h)
A	Flow cross-sectional area (m^2)
A_i	Time-area histogram ordinates (ha)
$F(t)$	Cumulative infiltration (mm)
$f(t)$	Infiltration rate (cm/hr)
f_c	Minimum or Ultimate Value of f_p (m/s)
f_o	Maximum or Initial Value of f_p (m/s)
f_p	Infiltration capacity of soil (m/s)
g	Gravitational acceleration (m/s)
I	Inflow (m^3/s)
i	Number of isochrones area contributing to the outlet
i_1	Inflows at beginning of routing period (m^3/s)
i_2	Inflows at end of routing period (m^3/s)
I_a	Initial abstraction (mm)
I_i	Excess rainfall hyetograph ordinates (mm/hr)
k	Decay coefficient (s^{-1})
K	Storage coefficient/Hydraulic conductivity
k_1	Storage delay times at beginning of routing period (s)
k_2	Storage delay times at end of routing period (s)
n	Manning's roughness coefficient
P	The accumulated precipitation (mm)
P_e	The accumulated runoff (mm)
Q	Discharge through A (m^3/s)
q_1	Outflows from the storage at beginning of routing period (m^3/s)
q_2	Outflows from the storage at end of routing period (m^3/s)
q_i	The flow hydrograph ordinates (m^3/s)
R	Hydraulic Radius
r^2	Coefficient of Determination (R-squared)
S	Storage (m^3) / Bed Slope
S_1	Storages volume at beginning of routing period (m^3)

LIST OF SYMBOLS

S_2	Storages volume at end of routing period (m^3)
S_f	Friction Slope
S_o	Channel Slope
t	time (s)
x	Longitudinal direction measured horizontally (m)
Y	Depth of flow (m)
η	Porosity
τ	Dummy variable of time in the integration (s)
Θi	Initial moisture content
ψ	Wetting front soil suction head (cm)

KEBERKESANAN SISTEM SALIRAN BANDAR MELALUI KOLAM TAKUNGAN KERING

(KAJIAN KES: KOTA DAMANSARA, SELANGOR)

ABSTRAK

Lantaran daripada pembangunan yang pesat, banjir kian menjadi. Senario ini semakin meruncing akibat sistem saliran yang tidak sesuai di kawasan perumahan. Sekiranya keadaan ini dibiarkan berlanjutan, besar kemungkinan ia akan membawa risiko banjir yang lebih serius dan lebih kerosakan harta serta kehilangan nyawa.

Sejak pelaksanaan Manual Saliran Mesra Alam (MSMA) pada 2001 oleh Jabatan Pengairan dan Saliran, langkah-langkah pengurusan yang baik melalui pembinaan kolam takungan adalah digalakkan. Selepas 8 tahun pelaksanaannya, kajian untuk mempertimbangkan semula keperluan pembinaan kolam takungan dengan menilai keberkesanan kolam takungan dari segi kuantiti melalui kaedah numerikal adalah amat diperlukan.

Kajian ini bertumpu ke atas penilaian sistem saliran khususnya kolam takungan yang sediada serta menjangka keberkesanan kolam takungan kering tersebut akibat aktiviti-aktiviti pembangunan pada masa akan datang dengan menggunakan perisian InfoWorks CS melalui kaedah “Soil Conservation Service (SCS)”. Kes kajian yang dipilih ialah kolam takungan kering di Seksyen 6, Kota Damansara, Selangor yang dibina pada tahun 1996 dengan kawasan tadahan sebanyak 428 hektar. Guna tanah utama di kawasan tadahan tersebut ialah kawasan perumahan dan rumah kedai di mana ia menyumbang kepada lebih 50% kawasan tidak telap selain daripada kawasan hutan, sekolah, landskap dan kawasan lapang.

Daripada hasil kajian, ia menunjukkan kolam takungan kering sediada dapat berfungsi dengan baik untuk hujan kala 100 tahun tanpa banjir di Jalan Cecawi 6/19

berdekatan dengan kolam takungan. Kolam takungan tersebut juga berupaya mengurangkan kadaralir sebanyak 39.94 m^3/s serta melambatkan masa ke puncak sebanyak 40 minit untuk hujan kala 50 tahun. Bagi hujan kala 100 tahun, ia dapat mengurangkan kadaralir sebanyak 42.36 m^3/s serta melambatkan masa ke puncak sebanyak 45 minit.

Dengan pembangunan di kawasan hutan di sebelah hulu kawasan tadahan, hasil kajian juga menunjukkan ia masih dapat berfungsi dengan baik tanpa banjir untuk hujan kala 100 tahun di Jalan Cecawi 6/19 berdekatan dengan kolam takungan kering. Senario ini meningkatkan kadaralir dari 8.88% hingga 52.95% dan ketinggian air dari 8.09% hingga 28.79% bagi kadaralir pada hujan kala 2, 10, 50 dan 100 tahun. Namun, masa ke puncak adalah 5 minit lebih lambat berbanding dengan keadaan sediaada disebabkan aliran penuh di saliran yang melambatkan aliran air ke hilir. Melalui kes perbandingan keadaan penambahan saiz saliran selepas perubahan guna tanah dengan keadaan sediaada, ia menunjukkan penambahan kadaralir lebih kurang 30% untuk hujan kala 50 dan 100 tahun dan menpercepatkan masa ke puncak sebanyak 10 minit.

Pada keseluruhannya, kolam takungan kering sediaada dapat menampung hujan kala 100 tahun yang dicadangkan dalam MSMA. Pembinaan kolam takungan perlu digalakkan untuk pembangunan perumahan yang baru bagi mengawal kuantiti air kerana ia didapati berkesan. Sebarang pembangunan perlu mempertimbangkan faktor seperti perubahan guna tanah yang akan meningkatkan kadaralir dan kuantiti air dan permodelan numerikal patut digunakan untuk tujuan penyelesaian masalah dan membuat keputusan dengan pantas.

PERFORMANCE OF URBAN STORMWATER DRAINAGE SYSTEM THROUGH DRY DETENTION POND
(CASE STUDY: KOTA DAMANSARA, SELANGOR)

ABSTRACT

Due to the rapid development, flooding occurred progressively. This scenario is worsened if improper drainage systems were implemented. The inattentiveness to all the problems occurred will generate the possibility for more severe flooding risk and creates further damages of property and loss of lives.

Since the implementation of Urban Stormwater Management Manual of Malaysia (MSMA) in 2001 by Department of Irrigation and Drainage, Malaysia, the Best Management Practices (BMPs) through construction of detention ponds have been encouraged. After 8 years of implementation, there is a need to reconsider the recommendation of constructing detention pond for water quantity control by evaluating performance of the constructed dry detention ponds using computer modelling.

This research focused on the evaluation of the existing and future performance under the stress of development of the existing drainage system particularly the constructed dry detention pond by using InfoWorks CS through United States Soil Conservation Services Method (SCS).

The case study is dry detention pond at Section 6, Kota Damansara, Selangor built in 1996 with the total catchment area of approximately 428 hectares. The major landuses in Kota Damansara are housing areas and shops which contribute more than 50% of impervious areas apart from forest, schools, landscape and fields.

From the research, it is found that the existing pond is functioning well and could perform well up to the design rainfall of 100-year ARI without flood on

Cecawi 6/19 Road nearby**.** The dry detention pond could attenuate flow at the outlet of the dry detention pond at 39.94 m^3/s and slower by 40 minutes for 50-year ARI and 42.36 m^3/s and slower by 45 minutes for 100-year ARI events.

Under the landuse changed scenario, the existing dry detention pond could still cater the 100-year ARI design rainfall without flooding at surrounding area. The scenario show an increase in flow ranging from 8.88% to 52.95% and also increase in water depth ranging from 8.09% to 28.79% in all simulated cases for 2-, 10-, 50- and 100-year ARI. However, the time to peak after landuse changed condition is 5 minutes slower for existing scenario due to conduits full flow condition that slow down the flow to downstream.

The comparison between the existing drainage condition and drainage resized condition after landuse changed at the outlet culvert of detention pond show an increase runoff about 30% for both 50- and 100-year ARI and quicker time to peak at 10 minutes.

As overall, the dry detention pond is functioning to cater 50-year ARI recommended in MSMA. The construction of detention pond needs to be encouraged for any new housing development to control water quantity. Future development need to consider landuse changed factor which could induce in more flow generation and water volume from upper catchment area and it should be studied using the numerical approaches to solve the problem and ease the decision making processes.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia is geographically sheltered from the "Pacific Rim of Fire" and it is relatively considered as a safe haven (Wong, 2005). It is free from the ravages and destructive caused by volcanic eruptions, earthquakes and typhoons (Abdul Malek, 2005). Nevertheless, Malaysia experiencing a higher probability of seasonal flash flood, landslides and severe haze episodes. Since 20 to 30 years ago, Malaysia is developing rapidly. The growths of population and urbanisation have brought water quantity and water quality problems. Issues deal with water quantity are floods (Figure 1.1) and droughts, while water quality issues (Figure 1.2) may be due to erosion and sedimentation from uncontrolled development (Figure 1.3) which deteriorate the quality of water. In urban areas such as Kuala Lumpur and Penang, improper urban stormwater drainage system design has been one of the causes of flash flood following an intensive, localised and short-duration thunderstorms. It is worsened by rubbish dumped which clogged the drain and further blocked the runoff flow.

In many urban areas, drainage is a completely artificial system of sewers with pipes and structures to collect and dispose stormwater. There are two types of water which require drainage namely stormwater and wastewater (Butler and Davies, 2000).

Figure 1.1: Flooding Problems in Malaysia

Figure 1.2: Degradation of Water Quality

Figure 1.3: Erosion and Sedimentation Problem in Malaysia

Butler and Davies (2000) defines urban stormwater drainage as the facilities which help to drain rainwater or water resulting from any form of precipitation) that has fallen on a built up area. Basically, urban stormwater drainage acts as the carriage of surface water from one drain to another connecting drain or sump, then to lake, ponds or river system prior to the sea. Stormwater contains some pollutants resulting from the rain and air or the catchment surfaces. Therefore, if it is not properly drained, it will cause inconvenient, degradation of water quality, flooding, environmental problems and further threatening human health.

Urban wastewater drainage is the facilities provided to drain wastewater from domestic housing areas, industry and other means of water uses. Wastewater normally contains dissolved material, fine solids and larger solids. Thus, having a well planned urban wastewater drainage system could maintain a healthy standard of living at the same time it satisfies the needs of the industry.

Historically, drainage system was developed as soon as humans attempt to control their environment. Drainage engineer started to design drains for efficient removal of the excessive surface water from the ground to the rivers or seas. The first aim was to remove rainwater on the surfaces especially on the roads, and then disposed via the drain and to the nearest watercourse rapidly. These concepts may cause damage to the environment and increase the risk of flooding elsewhere. Nowadays as the environmental issues are getting more concern, the nature of progress in relation to urban drainage, its consequences, desirability and limits are being closely reassessed and examined. General attention is diverted to manage the stormwater in a more natural way.

In 2000, the Department of Irrigation and Drainage, Malaysia (DID) published the Urban Stormwater Management Manual for Malaysia or in Bahasa

Malaysia, *"Manual Saliran Mesra Alam Malaysia"* (MSMA) that aims to promote the Best Management Practices (BMPs) in stormwater management. In 1 January 2001, the Cabinet officially approved the MSMA to steer drainage development (Yong and Md Noh, 2005).

BMPs in stormwater management involved constructing detention and retention facilities, infiltration trench, groundwater recharge, porous pavements for infiltration and provision of rough surface such as swales to retard flow reaching the watercourse and to decrease the peak flow of runoff. After 8 years of the implementation, this study is needed to reconsider the recommendation of constructing detention pond for water quantity control by evaluating performance of the constructed dry detention ponds using computer modelling. InfoWorks Collection System or InfoWorks CS version 8.5 developed by Wallingford Software Ltd. is used for model development in the present research.

MSMA uses the concept of stormwater management at source which is within the catchment and essentially involves runoff quantity and quality management. As the advancement in computer hardware and software development, computer modelling of drainage system begins to gain the popularity. The use of models will encourage far and depth understanding on the operation of the system. The introduction of the drainage modelling has made huge savings in cost and time. Urban stormwater drainage modelling is encouraged to be utilized in drainage system study to research and analyse the high technologies problems occurred. Therefore, further suggestion on improvement of the drainage system design can be determined and implemented.

1.2 RESEARCH OBJECTIVES

This research will utilize hydraulic software by HR Wallingford which is well known as InfoWorks CS version 8.5 to model the drainage system in the study areas. The main objectives of the study are as follows:

i) To determine the hydrology and hydraulic parameters of the catchment,

ii) To analyse on the performance of the existing dry detention pond, and

iii) To predict the performance of the urban stormwater drainage system through existing dry detention pond in future development

1.3 RESEARCH SCOPES

The research site as shown in Figure 1.4 is located at Kota Damansara, Selangor which is about 10 kilometres from Sungai Buloh, North-South Highway tol. Sungai Tambul, tributary of Sungai Damansara is the main stream flowing in the pond. This study focuses on the dry detention pond with an area about 6.55 hectares as shown in Figure 1.5 situated in Section 6, Kota Damansara, Selangor built in 1996. The total catchment area contributing to the dry detention pond are comprises of areas in Section 5, 6, 7, 10 and 11, cover a total of approximately 428 hectares. The catchment area is further distributed into 177 sub-catchments to study the behaviours of rainfall-runoff relationship in the ponds. The topography of the project area is hilly to undulating. The project area rises from 21.72 to 202 metre above mean sea level (MSL). The nearest road as shown in Figure 1.5 is Jalan Cecawi 6/27 on the left bank of dry detention pond with ground level of 28 metres above MSL. For this research, it will only cover the performance of the dry detention pond on water quantity aspect. Figure 1.6 and Figure 1.7 show the condition of dry detention pond during dry season and after storm event while Figure 1.8 and Figure 1.9 show the pond outlet/culvert inlet during dry season and after storm event.

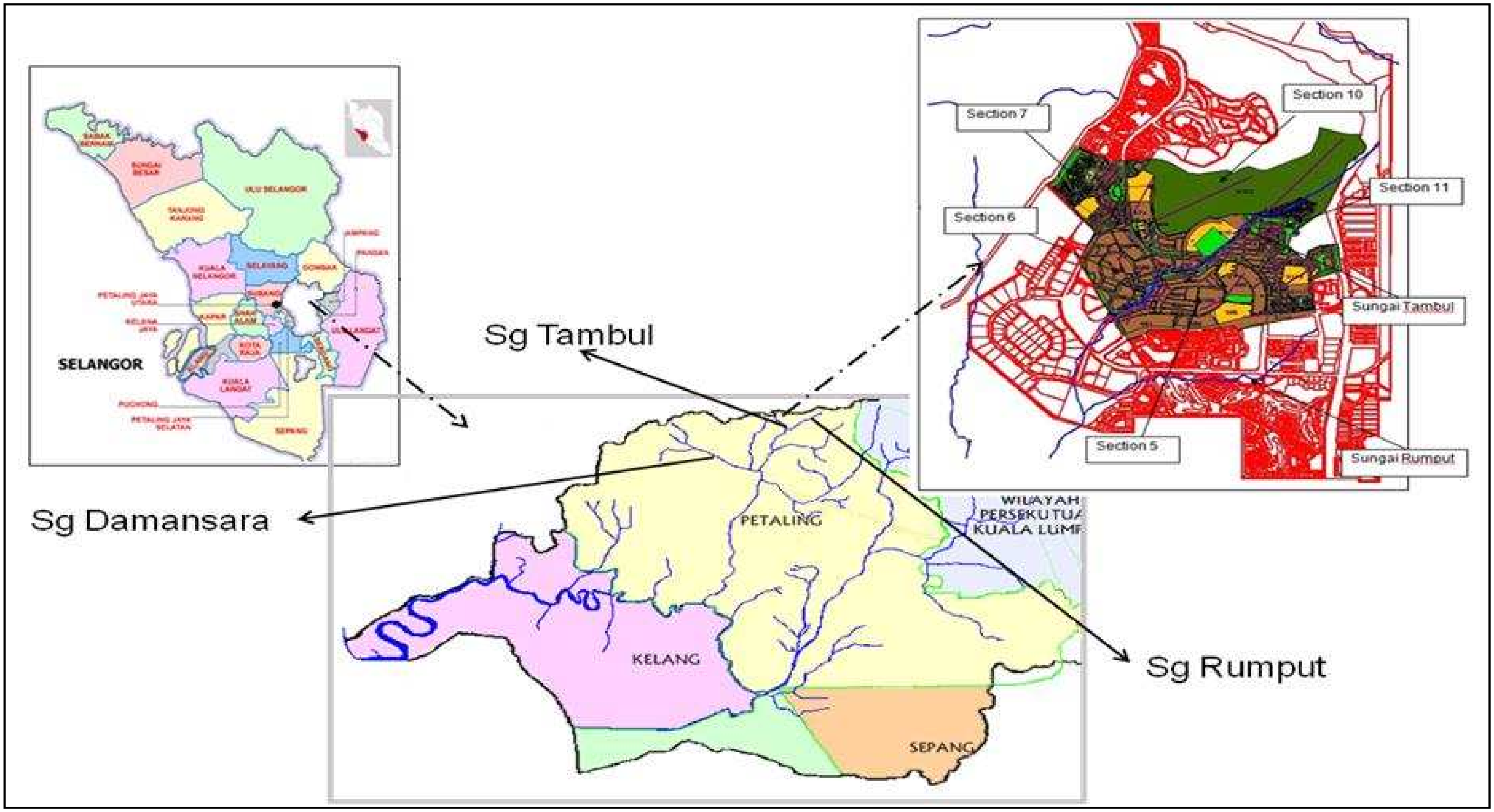

Figure 1.4: Location of Study Area

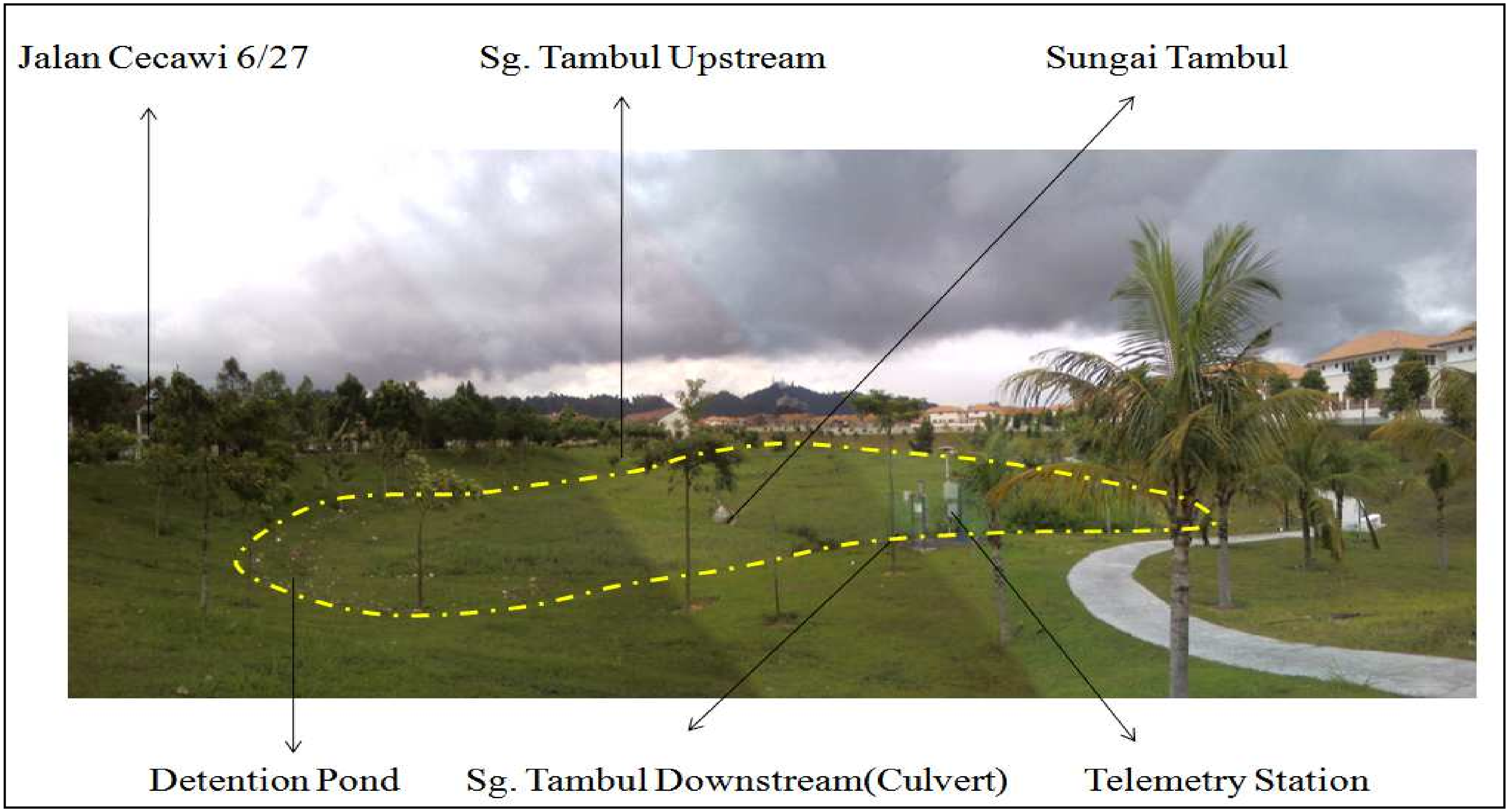

Figure 1.5: Location of Dry Detention Pond

Figure 1.6: Condition of Dry Detention Pond during Dry Season

Figure 1.7: Condition of Dry Detention Pond after Storm Event


Figure 1.8: Condition at Pond Outlet/Culvert Inlet during Dry Season


Figure 1.9: Condition at Pond Outlet/Culvert Inlet after Storm Event

1.4 RESEARCH NEEDS

As mentioned in the previous section, the initial aim in providing drainage system is to remove stormwater from the surfaces, especially roads, to the drain and the receiving watercourse or sea as quickly as possible. This theory of fast in-fast out is left with many environmental issues such as pollution, degradation of water quality, erosion and sedimentation as well as flooding risk.

Due to the rapid development, these issues occur progressively and create water quantity and quality problems. The reasons leading to the environmental issues are improper landuse planning and lack of laws, rules and regulations in controlling current housing development plan. The scenario is worsening if the development has improper drainage system design or poor maintenance. Moreover, the drainage systems in some housing areas are already in-placed since 10 to 20 year ago and no improvement or maintenance of drainage system has been done. The inattentiveness to all the issues will increase the possibility of more severe flooding risk and create more damages of properties and loss of lives.

Since the implementation of MSMA in 2001, BMPs through construction of detention ponds have been encouraged. However, could these detention ponds perform in controlling the water quantity from development areas? Further, are there any better drainage systems in urban areas to address the flooding problems? It is also difficult to justify spending huge sums of money on such facilities as detention basins, if the receiving waters are not endangered, or if experience suggests that those measures will be ineffective. It is difficult to analyse the complicated or series of connecting drains and sump by having the physical models. Thus, the utilizing of computer model is undeniably a safe of time and cost.

Moreover, after 8 years of MSMA implementation, there is a need to reconsider the construction of detention pond by evaluating the performance of the detention pond in controlling water quantity by utilizing computer advancement in modelling. Besides, the dry detention pond for the present study was built in 1996 before implementation of MSMA. Thus, it is needed to evaluate the performance of the pond under the MSMA requirement. The findings will show on the appropriateness to include the construction of retention and detention facilities for any new medium size housing scheme in the future as the study area is approximately 50% developed housing scheme. This is essential to achieve and help on recommending improvement of urban drainage for new housing scheme.

1.5 THESIS STRUCTURES

This thesis is organised into eight (8) chapters. Chapter 1 in brief introduces the problems, objectives and needs for the study. Chapter 2 describes literature review on Urban Drainage System, Best Management Practices particularly detention pond and experiences on urban drainage models in foreign countries. Chapter 3 details the research methodology and catchment hydrologic and hydraulic parameter while Chapter 4 focuses on model development and data input. Chapter 5 and Chapter 6 cover model calibration and verification respectively. In Chapter 7, model simulations will be discussed and the final Chapter 8 comprises recommendations and conclusion.

CHAPTER 2

URBAN DRAINAGE SYSTEM

2.1 BACKGROUND

As soon as humans attempted to control their environment, artificial stormwater drainage systems were developed (Butler and Davies, 2000). Archaeological evidence depicts that drainage was provided to the buildings of many ancient civilization such as the Mesopotamians, the Minoans (Crete) and the Greeks (Athens) (Butler and Davies, 2000). The ruins from Mesopotamian cities contain well-constructed storm drainage and sanitary sewer system (Burian and Edwards, 2003). The Mesopotamians viewed urban runoff as a nuisance flooding concern, waste conveyor and a vital natural resource. While, from the Middle Minoan Period about 1900 to 1700 B.C., the Minoans had constructed the well-built stone drains as shown in Figure 2.1 which carried sewerage, rainwater and general drainage (Gray, 1940). Ruins from the palace-city of Knossos on the island of Crete indicated that a two-conduit system was installed, where separate conduits were used in collecting sewage and rainwater (Burian and Edwards, 2003).

In 1800s, the Roman was the only civilization in all of western Asia and Europe to build a carefully planned road system with properly drained surfaces. In addition, rainwater collection system was incorporated into roadway design and construction. Rainfall from rooftops was collected into a cistern and massive underground structures as shown in Figure 2.2 built to store water draining from a large area (Burian and Edwards, 2003).

Figure 2.1: Minoan Stone Drain at Palace City of Knossos
(Daedalus Informatics Ltd, 2006)

Figure 2.2: The Roman Cistern in Fermo, Italy. (Burian and Edwards, 2003)

Apart from that, the Romans are well known for their impressive aqueducts bringing water into the city; and later to meet the urban drainage needs, the artificial drains were built, of which the best known is “Cloaca Maxima” (Butler and Davies, 2000). It is primarily conduits for the removal of surface drainage (rain water) and underground water (Gray, 1940). The outfall of the Cloaca Maxima as shown in Figure 2.3 and Figure 2.4 into the river Tiber is still visible today near the bridge Ponte Rotto, and near Ponte Palatino, Rome (Wikipedia, 2008).

Figure 2.3: Outfall of the Cloaca Maxima (Wikipedia, 2008)

Figure 2.4: View of the Interior of the Cloaca Maxima (Wikipedia, 2008)

Before the 19th century, the word 'sewer' referred to an artificial drainage channel such as a trench or an open ditch, which used to drain land (The Commission of Sewers, Isle of Wright, 2008). The English word sewer is derived from an Old Northern French word, se(u) wiere, which means “to drain off”, related to the Latin ex-(out) and aqua (water) (Butler and Davies, 2000). This modern meaning of an enclosed, constructed for the passage of human waste evolved much later, owing to the habit of using sewers or ditches for the disposal of human and household waste (The Commission of Sewers, Isle of Wright, 2008)

From Oxford English Dictionary, it gives the earliest meaning of sewer as “an artificial watercourse for draining marshy land and carrying off surface water into a river or the sea” (Butler and Davies, 2000).

According to Chocat (2000), the major objectives of urban drainage remain public hygiene, flood protection and pollution control. In developed countries, the first two objectives have been accomplished and emphasis mainly on pollution control. However, in developing countries like Malaysia, hygiene and flood protection are still major issues.

In many part of the world, we can imagine animals living wild in their natural habitat and humans living in small groups making a very little impact on their environment. Natural hydrological processes would have prevailed. In the past, there might experience major floods, but these would not have been made worse by human alteration of the surface of the natural ground. Even the waste would have been “treated” in natural processes. The effects of urbanisation to drainage will be discussed in the next section.

Before the 19th century, urban drainage was viewed as pertinent natural resources, an efficient waste transport medium, a flooding concern, a nuisance wastewater, or a transmitter of disease. During the 19th century, the perspective on urban drainage was significantly modified in Europe and United States. It was viewed as a highly important public works system worthy of massive expenditures to prevent disease transmission. At present, urban drainage is considered as a vital component of a sustainable urban system (Burian and Edwards, 2003).

2.2 EFFECTS OF URBANIZATION TO DRAINAGE

Water circulates in the hydrosphere through the maze of paths constituting the hydrologic cycle. The cycle has no beginning or end, and its many processes occur continuously (Chow et al., 1988). In nature, when rainwater falls on a natural surface, some water returns to the atmosphere through evaporation, or transpiration by plants, some infiltrates the surface as subsurface flow and further percolate deeper to becomes groundwater and some portion runs off the surface as surface runoff (Chow et al., 1988 and Butler and Davies, 2000). Figures 2.5 illustrate the hydrologic cycles.

Butler and Davies (2000) stated that the relative proportions depend on the nature of the surface and vary with time during the storm. For instance, the surface runoff tends to increase as the ground becomes saturated. Both groundwater and surface runoff are likely to find their way to a river, but surface runoff arrives much faster. The groundwater will eventually contribute to the river system as general base flow rather than being part of the increase in flow due to any precipitation.

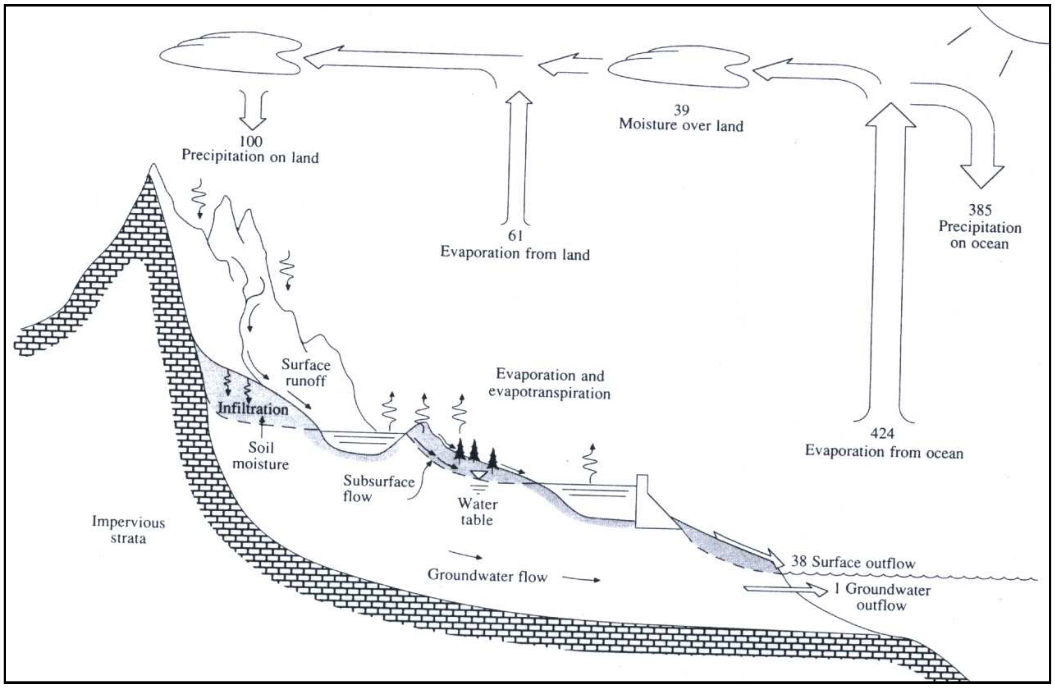

Figure 2.5: Hydrologic Cycle with Global Annual Average Water Balance Given in Units Relative to a Value of 100 for the Rate of Precipitation on Land
(Chow et al., 1988)

An undeveloped area or forest is great collectors and storerooms of water. Their root structure holds together the soil and their leaf litter gets broken down and combined with minerals to form the equivalent of gigantic sponges which slowly releasing water into surrounding areas at a dependable rate (World Wildlife Fund, 2009). The ability to grab soil will minimize the problem of erosion and sedimentation. The infiltrated water into the sub-surface of soil will act as the source of groundwater recharge. In this condition, even rains continuously from the forest area, the downstream water level rise can still be controlled. Definitely, flooding problems can be reduced drastically.

However, urbanization or replacing one part of the natural water cycle with any artificial system of urban drainage has changed the hydrologic cycles (Butler and Davies, 2000). Apart from that, numerous studies on the effects of landuse changes, especially those related to urbanization, show that urbanization can have profound impacts on the hydrologic cycles and its runoff characteristic (Mansell, 2003; Noorazuan et al., 2003 and Buytaert et al., 2006).

In many urban areas, urban drainage is developed to direct the flow of water generally originating from rainfall to the river system. The general effect of urbanization is to reduce the amount of infiltration (Buytaert et al., 2006). In a study done in Texas, it shows as much as 60% of infiltration is reduced due to urbanization (Vicars-Groening and Williams, 2006). In reducing infiltration, the speed of runoff will be increased as surface runoff travels quicker over hard surfaces and through sewers than it does over natural surfaces and along natural streams (Mansell, 2003). It has also impacted on daily base flow (Noorazuan et al., 2003) and thus poorer recharge of groundwater reserves (Butler and Davies, 2000 and Hantush and Kalin, 2006).

There are also numerous studies done in other part of the United States such as Colorado, Texas and Washington that indicate higher imperviousness in an area will result greater peak discharge (Leopold et al., 2005; Vicars-Groening and Williams, 2006 and Davis et al., 2006). According to the United States Forest Service (2003), peak discharges generated from urban areas can be more than six times greater than those in rural conditions. In a study done in Texas by Vicars-Groening and Williams (2006), the results suggest that urbanization profoundly impacts storm response more than doubling peak discharge and storm runoff volume. The lag time between the precipitation peak and discharge peak can be reduced by a factor of up to 8 in urban areas (Mansell, 2003). In other study in Texas, lag time can decrease to about 25% (Vicars-Groening and Williams, 2006). A conceptual change in hydrograph following urbanization is shown in Figure 2.6.

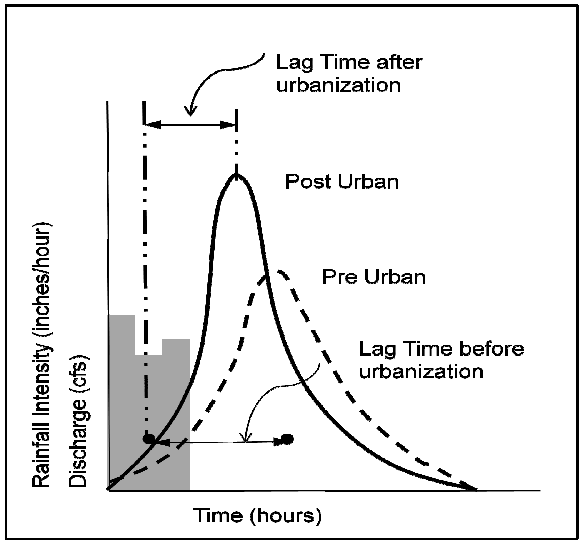

Figure 2.6: Conceptual Changes in Hydrograph Following Urbanization
(Vicars-Groening and Williams, 2006)

The effect of urbanization on the overall response of a catchment tends to be greater for small, frequent floods rather than more extreme events. In the latter case, the catchment is saturated and the extra runoff from the paved areas will be marginal (Mansell, 2003). From a study done in Langat River Basin, Malaysia by Noorazuan et al. (2003), effects of urbanization has increased more than 50% increase of surface runoff in 10 years time (1983-1994).

The other important effect of urbanization is that it increases the exposure to the flood hazard (Mansell, 2003 and Khalequzzaman, 2004). Rapid urbanization has aggravated the flooding problem in Bangladesh. In Dhaka, a city that is totally served by storm drains and 60 percent of the land surface is covered by roads and buildings, flooding frequency increases by a factor of six compared to pre-urbanisation period (Khalequzzaman, 2004). In a study at metropolitan city of Mashhad, Iran, the results indicate that the rapid growth of the city from 1966 to 2002 has excessive destructive effects on the catchments area, thus has caused the decrease of impervious surfaces and an increase peak discharge of the urban floods (Hosseinzadeh, 2005).

There is also some evidence that urban areas can actually increase the amount of precipitation. The increase in precipitation in urban areas can be up to 15% (Mansell, 2003). It is resulted from the higher temperatures in urban areas that will increase convection and the roughness of the surfaces which enhances the upward movement of air. However in studies done by Pitman (2004) in southwest Western Australia and Kaufmann et al. (2006) in Pearl River Delta, China show that urban precipitation deficit occurs in which urbanization reduces local precipitation. This reduction may be caused by changes in surface hydrology that extend beyond the urban heat island effect and energy-related aerosol emissions.

The change of drainage patterns from the provision of artificial stormwater drainage as well as water supply and foul drainage system has contributed an effect on the water balance (Mansell, 2003 and Buytaert et al., 2006). An extensive stormwater drainage system will direct water into channels and rivers rather than allowing it to infiltrate into the ground. The direct consumption of this water is generally less than 10% and most of the water will end up either being removed by the drainage system or recharging the groundwater through leaking pipes (Mansell, 2003).

Another effect of urbanization on drainage is the implication on water quality. The balance between the sediment transport capacity of a stream or channel and the amount of sediment delivered from its watershed is disrupted. Uncontrolled or unregulated development increases stormwater runoff that causes downstream flooding and accelerates channel erosion and sediment carried downstream (Rohrer, 2004). The rapid runoff of stormwater will also cause pollutants to be washed off the surface (Mansell, 2003). In an developed environment, there are likely to be more pollutants on the catchment surface and in the air than there will be in a natural environment. Also, drainage systems in which there is mixing of wastewater and stormwater may allow pollutants from the wastewater to enter the river (Mansell, 2003). In Malaysia, the problem of wastewater and stormwater mixing will not rather happen as separated drainage system is used.

In summary, the effects of urbanization on drainage which replaces natural drainage by urban drainage are to reduce infiltration and groundwater recharge, produce higher and more sudden peak discharge and flooding frequency. Urbanisations will disrupt the water balance cycle and hydrologic cycles. In other extent, it introduces pollutants and increase sediment transport thus degrades the water quality of the river. Table 2.1 depicts the general effects on environment due to urbanization compared to rural environment.

Table 2.1: Effects on Environment due to Urbanization
(United States Forest Service, 2003)

Element	Compared to Rural Environs	
Contaminants	Condensation nuclei (particles that serve to attract condensation)	10 times more
	Paticulates (e.g. soot)	50 times more
	Gaseous admixtures (mixtures of5–25 times more polluting gases)	5-25 times more
Radiation	Total on horizontal surface	0–20% less
	Ultraviolet, winter	30% less
	Ultraviolet, summer	5% less
Cloudiness	Clouds	5–10%
	Fog, winter	100% more
	Fog, summer	30% more
Precipitation	Amounts	5–15% more
	Days with less than 5 mm	10% more
	Snowfall, inner city	5-10% more
	Snowfall, lee of city	10% more
	Thunderstorms	10-15% more
Temperature	Annual mean	0.5–3.0°C more
	Winter minimums (average)	1–2°C more
	Summer maximums	1–3°C more
	Heating degree days	10% less
Relative Humidity	Annual mean	6% less
	Winter	2% less
	Summer	8% less
Wind speed	Annual mean	20-30% less
	Extreme gusts	10-20% less
	Calm	5-20% more

2.3 URBAN DRAINAGE SYSTEM IN MALAYSIA

In Malaysia, the drainage system is a separate system where different systems are used to handle stormwater and wastewater separately. This is partly due to easier system management and the design capacity for the respective system can be minimized. Apart from that, wastewater and stormwater carried in separate pipes could avoid pollution associated with them (Butler and Davies, 2000). Despite of the advantages of the separate system, this type of system can induced higher construction and material cost due to the usage of two type of piping system to be utilized for stormwater and wastewater respectively. Separate system requires more spaces to occupy as compared to combined drainage system. In early year, the provision of stormwater drainage works was performed by the Hydraulics Branch, Public Works Department until the formation of Department of Irrigation and Drainage (DID) in 1st January 1932 (Wikipedia, 2008). DID is under the Ministry of Natural Resources and Environment since 2004. The maintenance of the sanitary or wastewater drainage system lies under the Local Authorities, Ministry of Housing and Local Government.

Traditionally, stormwater management in Malaysia focused primarily on managing the impacts of flooding by adopting a conveyance-oriented approach (DID, 2000). The traditional drainage systems were designed to collect runoff and immediately dispose as quickly and efficiently as possible to downstream channel. This is in order to minimize damage and disruption within the collection area.

The first urban drainage manual, “Planning and Design Procedures No.1: Urban Drainage Design Standards and Procedures for Peninsular Malaysia” was published by DID, Malaysia in 1975 (DID, 2008). This manual was prepared as a guideline for engineers in drainage system design and had been referred by various agencies at federal and state level for the drainage requirements needed in new development of urban areas. The manual was in use as a guideline for more than twenty five years since its publication.

However, through the time, a potentially effective and preferable approach to stormwater management is the storage-oriented approach. A new Stormwater Management Manual in Malaysia (MSMA) has been introduced and published in 2000 by DID and officially approved by Cabinet in 1 January 2001 to promote this approaches and steer drainage development (Yong and Md Noh, 2005).

MSMA promotes new approaches to manage the urban drainage in the country and incorporate the environmental friendly concepts in designing the overall drainage system in the new develop areas. The control at source concepts has been strengthened in the manual. There is more emphasis on managing the stormwater in a more sustainable manner through Best Management Practices (BMPs). BMPs in stormwater management involves constructing detention and retention facilities such as dry and wet detention ponds, infiltration, groundwater recharge, porous pavements for infiltration, swales and provision of rough surface to retard flow reaching the watercourse and decrease the peak flow of runoff. There are several recent examples of the implementation of the concepts in new developments in the country. For instance, at the Federal Government Administrative Center in Putrajaya as shown in Figure 2.7, this new approach has been applied by incorporating the lake and wetland as storage and purifier of stormwater. There are new housing developments adopting the control at source concept as shown in Figure 2.8 such as Kota Warisan, Bandar Baru Salak Tinggi, Selangor, Sierramas in Kepong, Selangor, Diamond Creek in Tanjung Malim, Perak and Leisure Farm in Johore. Others implementations include the constructing of swales as shown in Figure 2.9 to replace the rigid concrete drains at Engineering Campus, Universiti Sains Malaysia, Penang and the provision of porous pavement for parking as shown in Figure 2.10 in Taman Botani, Putrajaya. In designing the BMPs for drainage system, a new approach is taken through the use of available computer models. At present, even though the numerical modelling of drainage system is still lacking in Malaysia, it is getting more popular in recent years due to the time and cost saving.

Figure 2.7: Wetland at Putrajaya

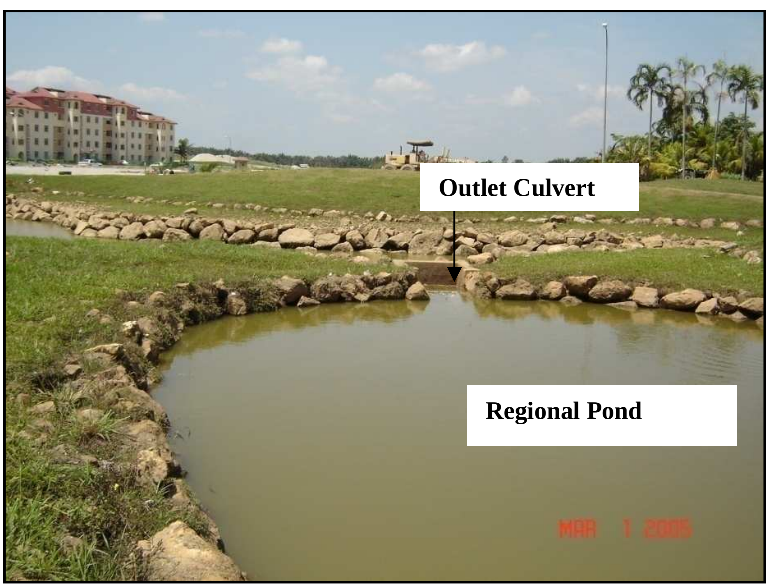

Figure 2.8: Regional Detention Pond in Kota Warisan, Bandar Baru Salak Tinggi, Selangor