FLOW CHARACTERISTIC OF WETPOND

By

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ABSTRAK

Air merupakan sumber yang terpenting dalam kehidupan kita. Ianya menjadi nadi kepada kewujutan segala benda hidup dimuka bumi ini termasuklah mewakili dua pertiga isipadu keseluruhan bumi. Kewujudan sistem bagi mengawal sumber-sumber air ini daripada tercemar atau membawa kemusnahan kepada manusia amatlah diperlukan. Ini penting bagi memastikan kestabilan yang wujud dapat dikekalkan. Maka atas inisiatif ini kajian terhadap kaedah pengawalan air di bahagian punca dijalankan sehingga terhasilnya sistem BIOECODS dimana kolam basah merupakan salah satu komponen utama didalamnya. Dalam kajian ini, data kadar alir di bahagian pintu masuk dan keluar kolam basah dikumpul dan dianalisis bagi mengatahui sejauh mana kemampuan kolam basah ini dapat berfungsi dalam memastikan pengecilan kadar alir dapat berlaku. Analisis yang dilakukan adalah amat penting bagi menghasilkan arahan rujukan bagi pembinaan sistem ini pada pembinaan yang akan datang. Keputusan yang diperolehi mengesahkan keupayaan kolam basah untuk mengecilkan hidrograf. Bagi kejadian hujan kurang daripada 3 bulan ARI, luahan bagi aliran keluar adalah hampir kosong .

ABSTRACT

Water is the most vital source in our life. It has become the nerve of the existence of all living things on earth and it encompasses two – thirds of the earth surface. A system to control these water sources from being polluted or causing annihilation for mankind is much needed. It is important to ensure the stability to be maintained. Hence, on this initiative, a research has been carried out on the methods of controlling water at the source and the result is the Bio-Ecological Drainage System (BIOECODS) system where wetpond is one of the main components in it. In this study, the data on the flow rate at the inlet and outlet of wetpond are accumulated and analyzed to know the capabilities of the pond to function in ensuring that reduction of water flow rate can happen. Data and analysis conducted are very important to produce reference order for the construction of the system at future projects. The results confirm the attenuation effect of the wetpond. For rainfall event less than 3-month ARI, the outflow discharge is almost zero.

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I wish to express my special thanks to Assoc. Prof. Dr. Aminuddin Abdul Ghani for his constant support and supervision throughout this project. I would also like to express my gratitude to Miss Khairul Rahmah Ayub for her help and guidance to completion of this project. Not forgetting to thank to the research officers of REDAC for their comment and suggestion. Last but not least, I would like to express my appreciation to all the technicians of REDAC's Laboratory of USM Engineering Campus, friends and family members for their help and inspiration throughout this project and make it a success.

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CHAPTER 1

INTRODUCTION

1.1 General

Water is one of the main basic components in our life, without water any creature in the world cannot survive. River also is a basic place to all early civilization to grow up like Egypt, India and others.

In the new era, even we do not stay and build our civilization near to the river but water become more important until we create system how to recycle the water from waste water to reuse it as drinking water as in Singapore which is called "New Water". Nowadays flash flood are the main problem that happen in the big city and town like Kuala Lumpur, Penang and others. Government increases the budget in every year to make sure the flooding is solved.

The main reason why flood happens in the city and town is because all the natural catchments are already gone. The entire grown surface in the city and town are replaced by pavement. Because of that water from rain cannot seep trough the soil and becomes surface run off. The catchments that we design to convey the flow from conventional drainage system cannot carry all the surface run off at the same time. As a result flash flood occurs and our government loses one about RM 100 millions a year to flooding (Abdullah, 1999).

Earlier engineers thought that the problem could be solve by widening drains and river, but the problem are that the area is limited. In every new development we need to increase the drain size to make sure its can carry the surface run off..

As a result, we need to think new ways to solve flush floods problem and to make sure that the next generation can live comfortable and safe.

1.2 Bio-Ecological Drainage System (BIOECODS)

Bio-Ecological Drainage System or BIOECODS is a new concept to unsure flush floods will be solved.

This system is constructed and being use in USM engineering campus. USM campus is located in Mukim 9 of Seberang Perai Selatan District, Penang. It lies between latitudes 100^0 29.5' South and 100^0 30.3 North between longitudes 5^0 9.4' East and 5^0 8.5' West. The place is known as Sri Ampangan, Nibong Tebal, Pulau Pinang. It is implemented by Pusat Penyelidikan Kejuruteraan Sungai dan Saliran Bandar (REDAC) in cooperation with Jabatan Pengairan dan Saliran Malaysia (JPS). It covered 320 acres of area to the whole completed USM engineering campus.

The main reasons of developing BIOECODS are to induce flow attenuation and water quality treatment. The main components of this system are swales, dry pond, detention pond, wet pond and wetland. All the component work as one system to make sure the objective of developing this system can be done.

The difference between BIOECODS and conventional system (concrete drainage system) are flow attenuation and the treatment of storm occur water trough out this system. BIOECODS are do not bring all the garbage and pollutant from developing area like conventional system and as added advantage, BIOECODS filter the storm water. As a result we can get high quality of storm water from BIOECODS.

One of the most important features of this system is, that it maintains the quality of area to look natural and at the same time the ground water table is maintained as at predevelopment stage. As a result these systems are more sustainable than conventional drainage method because it:

- Manages runoff flow rates, reducing the impact o urbanization on flooding.
- Protects or enhance water quality.
- Provides amenities such as recreational pond and wading river.
- Provides a habitat for wildlife in urban watercourses.
- Encourages natural groundwater recharge (where appropriate).

1.3 Objective.

The main objectives of this study are as follow:

a) To investigate the effectiveness of the wet pond in flow attenuation.

b) To study the engineered waterway flow capability.

The inflow and outflow discharge will be measured for several rainfall events. Comparisons of the discharge will be made to quantify the ability of wetpond to attenuate flow.

1.4 Project Background

Wet pond is one of the alternatives to attenuate peak flow as mentioned in the Manual Saliran Mesra Alam. A wet pond was build as a compount of BIOECODS. It caters run off from the school part of the engineering campus. Wetpond is used to attenuate peak flow and its will help the system (BIOECODS) to reduce the velocity of water at the downstream.

1.5 Project Overview

The study is very important because all the data be produce are suit to Malaysian conditions. The technology is also very potential to be applied to other countries especially in ASEAN and country having same climate like Malaysia.

This study is a supportive mechanism to validate the current MSMA. The results from the study and the knowledge for the land use/development effect on environment and urban water resources are useful for water related agencies to apply to the urban runoff management.

CHAPTER 2

DESIGN CRITERIA

2.1 Introduction

Now days, flash flood was become one of the most hot topics that everybody talk about. In the news paper the reporter always wrote about this topic especially when it happens to main towns like Kuala Lumpur, Pulau Pinang and Johor Baharu. The point now is how to manage water system due to storm water especially in urban area. This is become one of the big problems to us and the big problem to our country. Flash flood event are increase year by year because of the increase in urban areas (Abdullah 2000). Our government plan to spend around RM 10billion to make sure Malaysia is safe from flood during 2010 and it is a big budget just only to settle the problem that make by our self. This is because we did not plan our development area with a good drainage system.

Malaysia uses conventional drainage system since 1975 and until now we still use it. The conventional drainage systems are based on the first urban drainage manual "planning and Design Procedure No.1: Urban Drainage Design Standard and Procedure for Malaysia". In this conventional drainage system, all the design for drainage system should make sure all the storm water runoff leaves the development area as fast as possible without delay.

For example, 40% of urbanizations will increase the quantity of storm water runoff until 190% and the velocity of runoff increase 2 time higher (Embi, *1999*). This is because in urban area concrete pavements are using to cover the surface and its will decrease the surface for water to infiltrate. As a result the surface run off will be channeled through the rapid disposal drainage system and in the short time receiving area can get flooding.

The conventional drainage system also has become one of the medium for bring all the pollution from the urban area to receiving water area. This is the most difficult problem to control. Water will carry out everything (garbage, grist oil, sand and soil from erosion) while it flow. No mater how much it is, its will flow together trough the channel and finally the river ststem.

As a progressive way how to handle this problem especially in Malaysia, University Sains Malaysia (USM Engineering campus) has taken this problem as a new challenge and the successful of this challenge will profit all the people around Malaysia. For the engineer this is a part of new era and they need to change their mind and look up for design the new system especially to control the magnitude of discharge generated from an urbanized catchments. From that part USM engineering campus cooperates with Jabatan Pengairan dan Saliran Malaysia to build a new system that are called Bio-Ecological Drainage System (BIOECODS) to control and manage the drainage system in the new campus of USM as a core pilot to the new system. This BIOECODS are based on the new manual. *Manual Saliran Mesra Alam (MSMA).*

One of the most important components in Bio-Ecological Drainage System (BIOECODS) is a wet pond needed to investigate and the wet pond capability in flow attenuation. As a result this study will provide data to help engineers design the wet pond.

2.2 Wetpond

A wet pond is an open pond with the outlet set higher than the bottom of the facility. This usually results in a permanent pool of water that serves as "dead storage" and is very effective at removing pollutants. This is one of the important components that are needed while using Best Management Practices (BMP). This also the concept that is applied in new campus of Universiti Sains Malaysia Engineering campus to make sure mission to be an Universiti Dalam Taman can be realize.

Bio-Ecological Drainage System or BIOECODS is the system that is applied in Universiti Sains Malaysia Engineering campus as a drainage system. Bio-Ecological Drainage System (BIOECODS) integrating the Ecological Ponds (ECOPOND) for storm water treatment before leaving the campus. In this system, wet pond becomes one of the main components that are needed to make sure this Bio-Ecological Drainage System (BIOECOD) can be operational. Wet pond is also called storm water ponds, retention ponds or wet extended detention ponds, these facilities are basins that have a permanent pool of water throughout the year. The wet pond is constructed to store runoff during and after storms. Wet ponds treat and filter storm water runoff through settling and through nutrient uptake by plants and other aquatic organisms.

In BIOECODS, all the storm water come from whole area of Universiti Sains Malaysia Engineering campus will infiltrate to the bio-retention swale system, dry pond and ecological swale plus subsurface detention before going trough wet pond. From the wet pond the water flows step by step until last destination which is river Kerian. Part from that, wet pond is important to make sure the time flow rate of storm water runoff from all over the area of Universiti Sains Malaysia Engineering campus can be delayed, store and treatment before go trough river Kerian as a receiving water area. (figure 2.1)

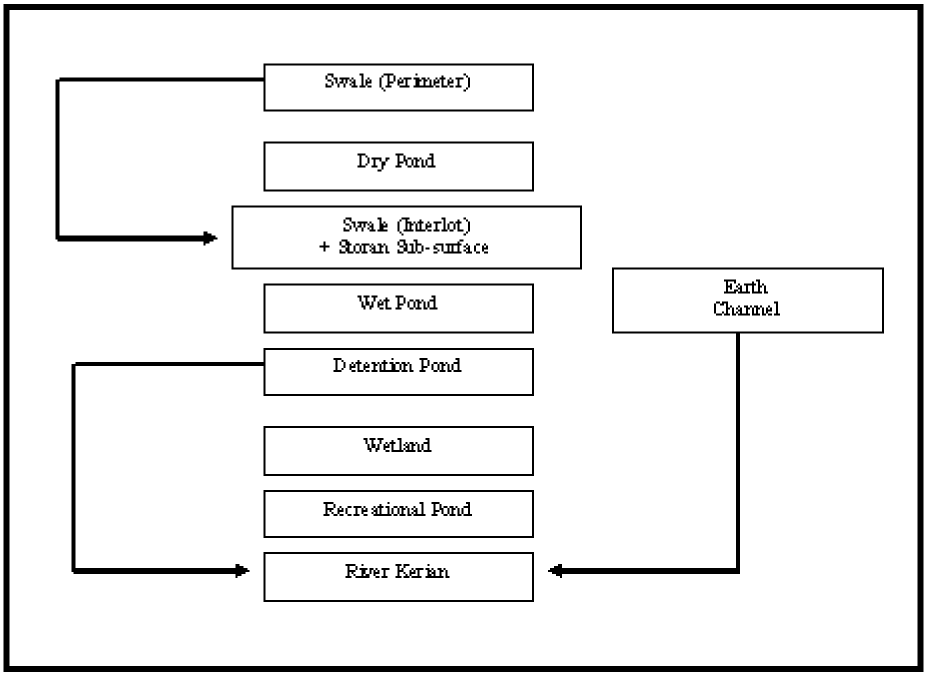

Figure 2.1: Flow chart for storm water runoff for BIOECODS

As the result, this permanent pool enhances particulate settling by increasing residence time, and also provides conditions for growth of aquatic vegetation, thereby enhancing filtration, and metals and nutrient uptake (transpiration). The permanent pool volume is often defined as the volume equivalent to three times the water quality volume or 12.7 mm (0.5 in) of runoff from the contributing drainage area (Yu and Kaighn, 1992). Pollutant removal efficiency is a function of pond depth, residence time, drainage area-to-pool volume ratio, and existence of aquatic vegetation. The post development increases in total storm water runoff volume may not be significantly changed by retention ponds.

A summary of criteria to be considered in designing a wetpond is given herein.

2.2.1 Flood Control

One objective of storm water treatment practices is to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Wet ponds can easily be designed for flood control, by providing flood storage above the level of the permanent pool.

2.2.2 Channel Protection

One result of urbanization is channel erosion caused by increased stormwater runoff. Traditionally wet ponds have been designed to provide control of the two-year storm . It appears that this design storm has not been effective in preventing channel erosion, and recent research suggests that control of a smaller storm may be more appropriate (MacRae, 1996). Choosing a smaller design storm (one-year) and providing longer detention time (12 to 24 hours) is now thought to be the best method to reduce channel erosion.

2.2.3 Pollutant Removal

Wet ponds are among the most effective storm water treatment practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wet ponds. Table 2 provides pollutant removal estimates derived from CWP's National Pollutant Removal Performance Database for Stormwater Treatment Practices:

Table 2.1. Pollutant Removal Efficiency of Stomwater Wet Ponds (Winer, 2000)

Pollutant	Removal Efficiency (%)
TSS	80±27[1]
TP	51±21
TN	33±20
NOx	43±38
Metals	29-73
Bacteria	70±32
1: ± values represent one standard deviation	

2.2.4 Design criteria of a wet pond

To maintain the permanent pool, at least 25 acres of area for drainage system are needed, this is need to supply water trough the pool and all the ecosystem of the pool can survive. It is also needed to make sure have some minimum water can flow trough the inlet and outlet of the wet pond where all the data can be collected.

Wet ponds can be used on sites with an upstream slope up to about 15%. The local slope within the pond should be relatively shallow, however. While there is no minimum slope requirement, there must be enough elevation drops from the pond inlet to the pond outlet to ensure that water can flow through the system by gravity.

As usual, wet ponds can be used in almost all soils and geology, with minor design adjustments for regions of karst topography all type of soil can be use. For design wet pond in Karst TopographyIn or karst (i.e., limestone) topography, wet ponds should be designed with an impermeable liner to prevent groundwater contamination or sinkhole formation, and to help maintain the permanent pool.

One maintenance concern in wet ponds is potential clogging of the pond outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no low flow orifice should be less than 3" in diameter (smaller orifices are more susceptible to clogging).

Direct access is needed to allow maintenance of both the forebay and the main pool of ponds. In addition, ponds should generally have a drain to draw down the pond or forebay to enable periodic sediment clean outs.In addition to incorporating features into the pond design to minimize maintenance, some regular maintenance and inspection practices are needed. The table below outlines these practices.(WMO,1997)

Table 2.2. Typical Maintenance activities for wet ponds (WMO 1997)

Activity	Schedule
• Inspect for damage. • Note signs of hydrocarbon build-up, and deal with appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and	Annual Inspection

operational	
• Repair undercut or eroded areas.	As Needed Maintenance
• Clean and remove debris form inlet and outlet structures. • Mow side slopes.	Monthly Maintenance
• Removal of sediment form the forebay	5 to 7 year Maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	20 to 50 year Maintenance

2.2.5 Design Considerations

There are some design features that should be incorporated into all wet pond designs .These design features can be divided into five basic categories: pretreatment, treatment, conveyance, maintenance reduction, and landscaping.

2.2.6 Pretreatment

Pretreatment features are designed to settle out coarse sediment particles before they reach the main pool. By trapping these sediments in the forebay, it is possible to greatly reduce the maintenance burden of the pond. A sediment forebay is a small pool (typically about 10% of the volume of the permanent pool) located near the pond inlet. Coarse sediments are trapped in the forebay, and these sediments are removed from the smaller pool on a five to seven year cycle.

2.2.7 Treatment

Treatment design features help enhance the ability of a stormwater treatment practice to remove pollutants. Several features can enhance the ability of wet ponds to remove pollutants from stormwater runoff. The purpose of most of these features is to increase the amount of time that stormwater remains in the pond.

One technique to increase pond pollutant removal is to increase the volume of the permanent pool. Typically, ponds are sized to be equal to the water quality volume (i.e., the volume of water treated for pollutant removal). Designers may consider using a larger volume to meet specific watershed objectives, such as phosphorous removal. Regardless of the pool size, designers need to conduct a water balance analysis to ensure that sufficient inflow is available to sustain a permanent pool.

Other design features can increase the amount of time stormwater remains in the pond, and help to eliminate short circuiting. Wet ponds should always be designed with a length to width ratio of at least 1.5:1. In addition, the design should incorporate features to lengthen the flow path through the pond, such as underwater berms designed to create a longer flow path through the pond. Combining these two measures helps ensure that the entire pond volume is used to treat stormwater. Another feature that can improve treatment is to use multiple ponds in series as part of a "treatment train" approach to pollutant removal. This redundant treatment can also help slow the rate of flow through the system.

2.2.8 Conveyance

Storm water should be conveyed to and from all wet ponds safely and to minimize downstream erosion potential. The outfall of pond systems should always be stabilized to prevent scour. In addition, an emergency spillway should be provided to safely convey large flood events. In order to prevent warming at the outlet channel, designers should provide shade around the channel at the pond outlet.

2.2.9 Maintenance Reduction

Several design features can be incorporated to ease the maintenance burden of wet ponds. Maintenance reduction features include techniques to reduce the amount of maintenance needed, as well as techniques to make regular maintenance activities easier.

One maintenance concern in wet ponds is potential clogging of the pond outlet. Ponds should be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris. Another general rule is that no low flow orifice should be less than 3" in diameter (smaller orifices are more susceptible to clogging).

Direct access is needed to allow maintenance of both the forebay and the main pool of ponds. In addition, ponds should generally have a drain to draw down the pond or forebay to enable periodic sediment clean outs.

2.2.10 Landscaping

Landscaping of wet ponds can make them an asset to a community, and can also enhance the pollutant removal. A vegetated buffer should be created around the pond to protect the banks from erosion, and provide some pollutant removal before runoff enters the pond by overland flow. In addition, ponds should incorporate an *aquatic bench* (a shallow shelf with wetland plants) around the edge of the pond. This feature provides some pollutant uptake, and also helps to stabilize the soil at the edge of the pond and enhance habitat and aesthetic value.

2.11 Schematics of Wetpond

Several examples of the layout of a wetpond is given in Figure 2.2

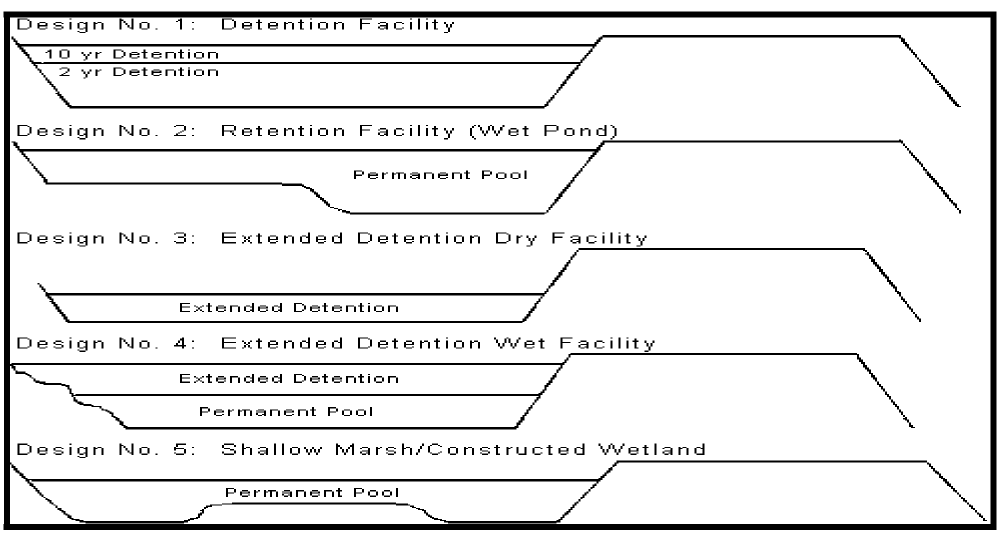

Figure 2.2. Design Variations of wetpond.

An example of a wetponds cross section is given in Figure 2.3

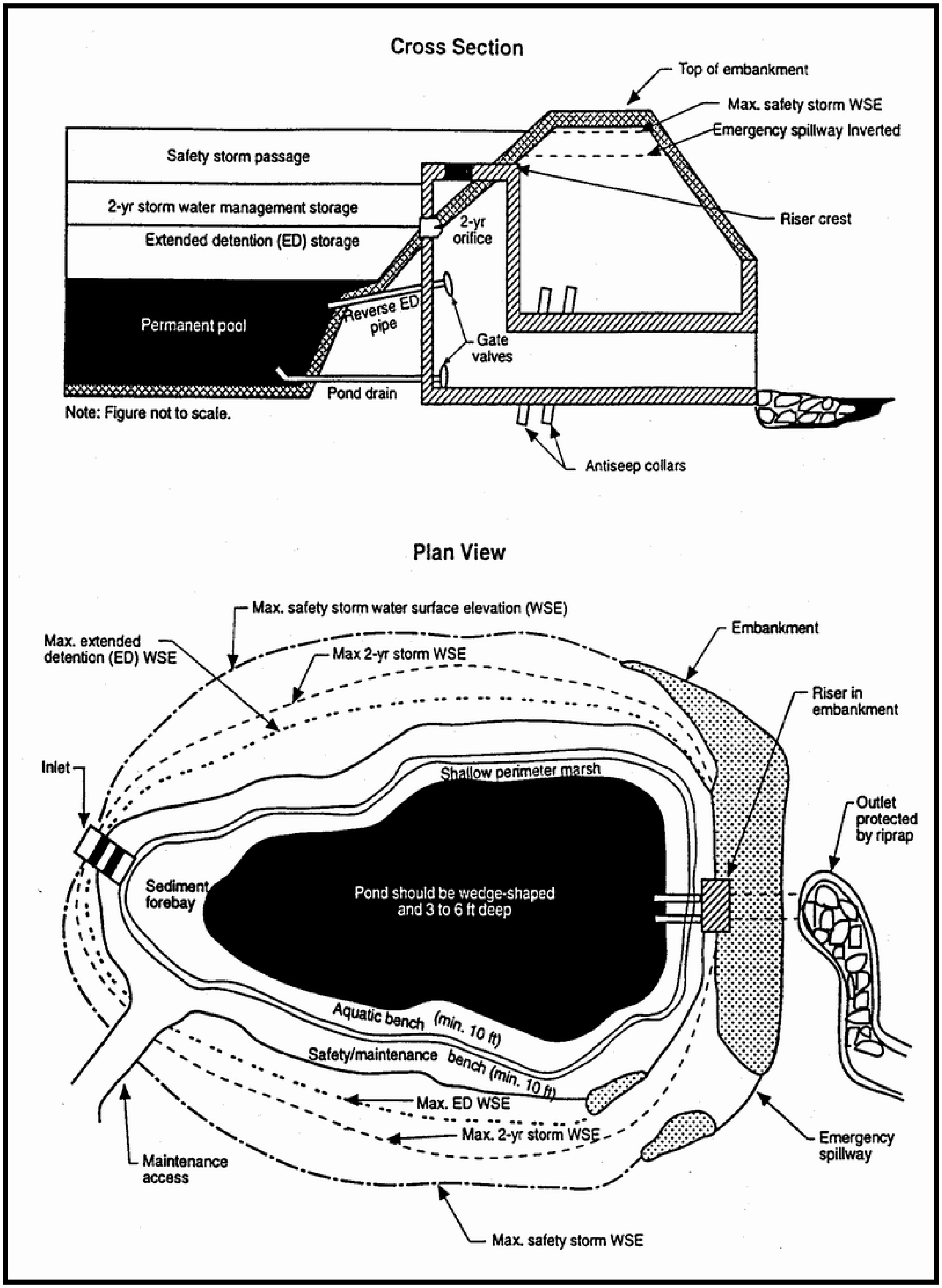

Figure 2.3: Plan view and cross section of wetpond

2.3 Case Study:

This study site was conducted by two group of students from California State University, Sacramento and one group of professional engineer from RBF Consulting Irvine, California in 2002. This study is made for California Department of Transportation (Department) and the project sites are near the San Francisco-Oakland Bay Bridge.

These projects are called the SR-73 project. Water quantity and quality data from flow-composite samples of storm water runoff will be collected over a three-year period. Other factors such as maintenance thresholds, the ability to produce vectors, and cost to construct and maintain these wetland-type BMPs are also will be investigated.

Other than that the main point of this project is to investigate the potential of ecological pond on physical, biological, and chemical processes to remove pollutants from storm water runoff. Sedimentation processes remove particulates, organic matter, and metals and make sure downstream water quality and erosion control is improved. The lasting reason for this project is to investigate the design criteria of the ecological pond. All the result are useful to produce a guide line for the next constructions of ecological pond in California. Table 2.3 to table 2.6 provides the details of the design criteria adopted.

Table 2.3. Results of Reconnaissance Study

Rank	Site Location	Project
1	Eastbound I-80 I-80 / I-580 / I-880 Interchange	San Francisco-Oakland Bay Bridge BMP for Replacement of Eastern Span
2	Southbound SR-73 El Toro Road Off-ramp (Basin 765L)	CSF BMP Replacement Project
3	Northbound SR-73 Bonita Canyon Drive On-ramp (Basin 1080R)	CSF BMP Replacement Project

Table 2.4. Hydrologic Summary

Parameter	Wet Pond	Constructed Wetland
WQV	3814 m^3	347cm
Drainage Area	25 Ha	2.3 ha

Table 2.5. Summary of Permanent Pool Sizing Criteria

BMP	Cited Criteria	Permanent Pool Volume to Water Quality Volume Ratio
Constructed Wetland	CASQA, 2003	2:1
	Denver Urban Drainage Flood Control (Urbonas, et al. 1992)	0.75:1
	Selected for SR73 Wetlands Project	0.75:1
Wetbasin/Wetpond	King County, 1996	3:1
	Schueler, 1987 (Young et al., 1996)	1 to 4:1 (approx.)
	CASQA, 2003	2:1
	Denver Urban Drainage Flood Control (Urbonas, et al. 1992)	1 to 1.5 : 1
	Selected for SR73 Wet Detention Pond Project	1:1

Table 2.6. Selected Design Features

Design Criteria	Selected Design for the Constructed Wetlands	Selected Design for the Wet Pond
Pretreatment	· A sediment forebay/small pool (typically about 10 percent of the volume of the permanent pool) will be incorporated to allow for pretreatment · Design features will be incorporated to ease maintenance of both the forebay and the main pool of ponds. Maintenance access will be provided.	· A sediment forebay/small pool (typically about 10 percent of the volume of the permanent pool) will be incorporated to allow for pretreatment · Design features will be incorporated to ease maintenance of both the forebay and the main pool of ponds. Maintenance access will be provided.
Treatment	· 0.75:1 (permanent pool to volume treated) ratio · Basin is designed with a length-to-width ratio of at least 1.5:1. In addition, the design will incorporate features to lengthen the flow path through the pond, such	· 1:1 (permanent pool to volume treated) ratio · Basin is designed with a length-to-width ratio of at least 1.5:1.

Design Criteria	Selected Design for the Constructed Wetlands	Selected Design for the Wet Pond
	as underwater berms/baffles designed to create a longer route through the pond.	
Vegetation	· Vegetation coverage is at least 50 percent.	· Vegetation coverage is at least 25 percent.
Permanent Pool Depth	· 0.5 to 1.2 meters	· 1.2 to 2.4 meters
Pond Side Slopes	· Basin side slopes will vary between 1:2 and 1:4 (H: V) to meet safety and maintenance requirements. · A vegetated buffer will be provided around the pond to protect the banks from erosion and provide some pollutant removal before runoff enters the pond by overland flow. · Ponds will incorporate an aquatic bench (i.e., a shallow shelf with wetland	· Maximum pond side slopes 1:2 (H:V) · Pond design will incorporate an aquatic bench (i.e., a shallow shelf with wetland plants) about 2 m wide within the pond.

Design Criteria	Selected Design for the Constructed Wetlands	Selected Design for the Wet Pond
	plants) around the edge of the pond.	

CHAPTER 3

METHODOLOGY

3.1 Introduction

Bio Ecological Drainage system is one of the new concept for drainage system in Malaysia and it was apply totally as drainage system in USM engineering campus. The completion of the construction at the end of December 2002 continues with 10-years of data collection (2003-2010) covering quantity and quality aspects of the drainage system. This study is only a small part of the data collection that can be used as a guideline to design Bio Ecological Drainage system in the future.

The summary methodology of all for this project is given in Figure 3.1

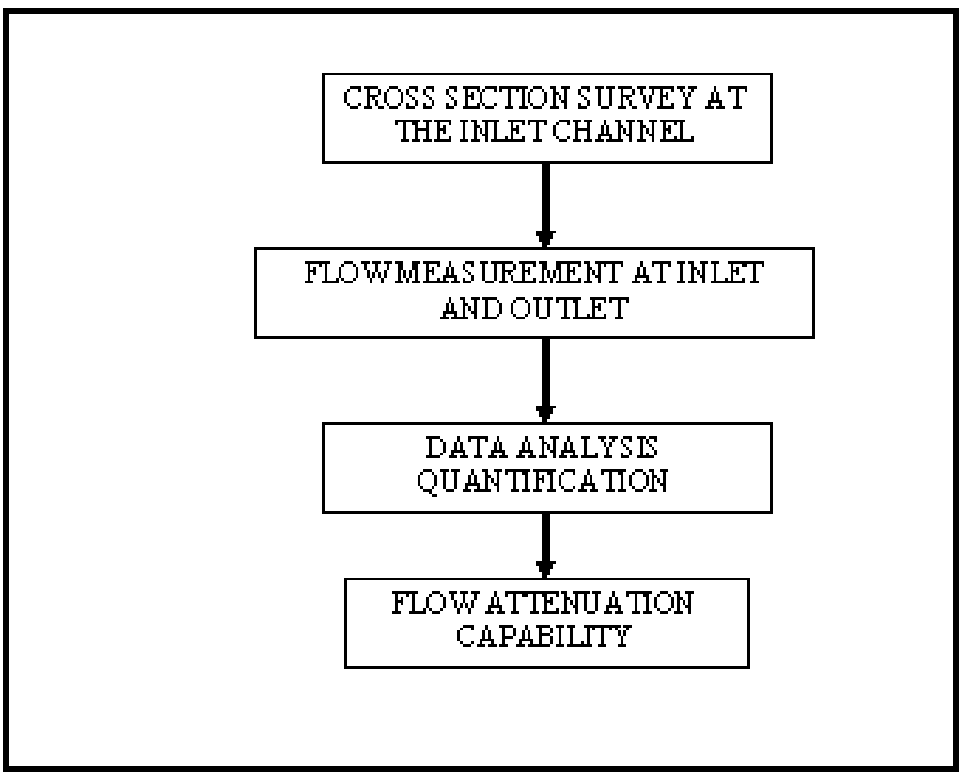

Figure 3.1: Methodology

3.2 Study site.

The wetpond is located along Permatang Pelajar. An engineering waterway connects the ecological swale type with the wetpond in Figure 3.2.

Table 3.1: Description of inlet and outlet locations

Location	Description
1	Inlet at Wetpond
2	Outlet at Wetpond

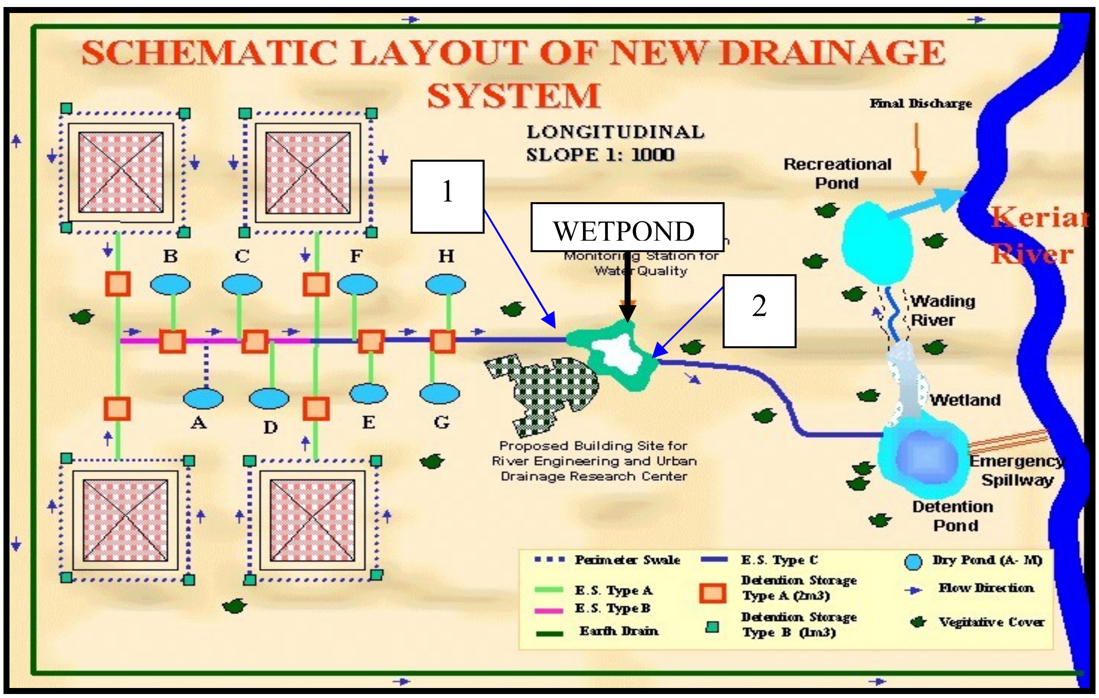

Figure 3.2: Schematic Layout of BIOECODS