The Study of Pollutants Removal Efficiency in a Vegetated Swale System

By

Siti Ameera Shahary
6270

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

July 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

The Study of Pollutants Removal Efficiency in a Vegetated Swale System

by

Siti Ameera Shahary
6270

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

____

(Mr Muhamed Mubarak bin Abdul Wahab)

Universiti Teknologi PETRONAS
Tronoh, Perak
July 2008

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge and thank everyone that has given me all the supports and guidance throughout the whole period of completing the final year project. Firstly, many thanks to Universiti Teknologi PETRONAS (UTP) and the Final Year Project coordinators that have coordinated well and made the necessary arrangements, especially in terms of the logistics, for this study.

I must also acknowledge the endless help and support received from my supervisor, Mr Muhamed Mubarak bin Abdul Wahab throughout the whole period of completing the final year project. His guidance and advices are very much appreciated.

I would also like to thank the lab technicians in UTP for their endless support in terms of the preparation of logistics during the lab experiments for this study. Their continuous support and help throughout the whole period of experiments are very much appreciated.

Finally, I express many thanks to my fellow colleagues for their help and ideas throughout the completion of this study. Thanks to all for the support in the completion of this research for final year project.

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The 21st century has seen the arousal of awareness for the environment whereby people around the world are starting to pay attention to pollution, the dwindling of natural resources and climate change. Cited from a 'Green Technology website, green technology means the management of continuously evolving group of methods from techniques for generating energy to non-toxic cleaning products. The aims of green technology are to produce sustainable design, to produce 'cradle to cradle' design (products that can be reuse), reducing waste and pollution by changing patterns of production and consumption, develop alternatives to current technology that cause pollutions, create products or technologies that are environmental friendly and etc (California Department of Green Technology).

This green technology is applied in all fields, including infrastructure. Infrastructure is basically the structural elements that provide the framework supporting and entire structure like roads, bridges, drainages, etc. Green technology design concept for infrastructures simply means creating or designing a sustainable infrastructure system. The author's research is based mostly on the articles and journals found from the internet. In Malaysia, the practice of green technology is still very new therefore data obtained about green technologies are mostly from the overseas countries. Infrastructure in Malaysia is developing and the author takes this chance to incorporate the idea of green technology into its design of civil infrastructure.

Highways and roadways impact the society in both beneficial and non-beneficial ways. The idea of a vegetative swale came in when the author found out that run off from roadways or pavements bring a lot of contaminants into the drains and hence are introduced into the water body as well. A few transportation studies have found high concentrations of petroleum, hydrocarbons, solids, metals, and nutrients in the soils, water and air near roadways. Highway runoff can have adverse effects if no measures are taken to remove the contaminants before it reaches the receiving water body and receiving water body is very easily affected by the contaminants because it is exposed directly to the contaminants released in air and also the discharge from non-point and point sources

The basic mechanisms for constituent removal are gravity settling, infiltration of soluble nutrients through soil or filter, or biological or chemical processes. These contaminants can be reduced by practicing the best management practices (BMPs) which can be further classified into structural BMPs or non-structural BMPs. BMPs help to reduce, control and minimize the contaminants' movement into surface and underground water body. The selection of BMPs will take into consideration the expected amount of runoff, type and amount of contaminants, availability of land and the physical characteristic of site. Structural BMPs are incorporating the infiltration, filtration, retention, filtering systems and porous pavements technologies. For this purpose, the author has chosen to study on the usage of vegetated swale to control contaminants from roadways runoff before entering the water body. Vegetated swales and filter strips are very much recommended for sites with limited space. These technologies are designed to catch and filter highways and roadways runoff and to enhance the biological uptake of its constituent. Vegetated swales incur moderate capital cost compared to the others and their effective life span is 5 – 20 years (U.S Department of Transportation, 1999).

Picture below is showing a vegetated swale:

Figure 1: A vegetated swale

1.2 Problem Statement

The development in our country has taken over the natural permeable ground surfaces and replaces them with constructed impermeable surfaces like roads, parking lots, walkways, etc. This causes a rise in the non point source pollution when rainwater travels over the impermeable surfaces and collect pollutants as they move and finally is disposed to lakes, rivers, water treatment plants, etc. These pollutants include oil, grease, toxic chemicals, sediments, bacteria and nutrients (phosphorus, nitrates). The natural infiltration rates of water into ground are also not balance and thus the hydrologic cycle is disturbed. This also becomes one of the causes of water quality problems and can affect our drinking water supply, recreation, fisheries and wildlife. A vegetated swale can help solve this problem. Vegetated swales are open, shallow channels with thick covered vegetation covering the side slopes and bottom that are able to collect and convey slowly the runoff and promotes infiltration cum pollutants removal.

Rain in Malaysia is throughout the year, so a proper design of sustainable vegetated swales would be put to use throughout the year. Malaysia is a developing country so the amounts of pollutants produced are a lot and is increasing as well. The author has chosen to use this engineered design vegetated swale to control some of the pollutants and to infiltrates water naturally back into the ground as was done previously before the development has taken over.

1.3 Objective

The objectives of this project are:

- To search for the suitable type of grass to be planted in the swale.
- To study the effect of slope on swale filtration and infiltration.
- To study the swale removal efficiency on pollutants.

1.4 Scope of Study

During the initial stage, a lot of research has been done to narrow down the scope of this project. Current issues and problems that are related to the infrastructure in Malaysia are being looked into and decided on the best applied solution that is closely related to green technology. This is also to promote green technology construction design concept in the country.

Throughout the project, study focused on:

- Grass type suitable for vegetative swale
- Slope value that will promote better filtration and infiltration.
- Design of vegetative swale itself.

As mentioned before, the usage of vegetated swale in Malaysia is still very new and data obtained are mostly from overseas countries. The author will have to do a study and research on the plant type in Malaysia that is suitable to be planted in the vegetated swale. The most desired types of plants are those of the native type whereby they can be obtained locally to save energy and cost. Slope affects the filtration and infiltration capacity as well whereby if the slope is at a higher value, the velocity will also increase and this will decrease the filtration and infiltration capacity of swale.

Malaysia is receiving rain throughout the year, especially during the end of year so the study also focuses on the design of this earthen drainage that is suitable to be implemented in accordance with our environment. However, the design of this vegetated swale project is a scale-down model for running the experiment.

Initially, the author has found a vegetated swale located in UTP and this swale is supposed to be used to test water samples taken from a few locations around UTP but method is then changed to modeling the swale system with a scaled-down model. Samples obtained were from the monsoon drain in UTP. Vegetative swale is not widely practiced in Malaysia and green technology itself is very new to us so the author will start this vegetative swale project from the fundamentals and proceed steadily depending on the data, resource, material and most importantly the time frame available at a later time.

CHAPTER 2

LITERATURE REVIEW & THEORY

2.1 Data & Information Gathering

Surveys and findings are done to gather available data related to the study. Unfortunately most data obtained are used in overseas country so interaction and site visit are done within campus location. Existing design of earthen drains are being studied to find the flaws and improvements to be made later on.

2.1.1 Removal Efficiencies

All the vegetative or grassed swale projects around the world have shown quite fulfilling results in view of the pollutants removal. Patrick M. Walsh et al. (1997) had conducted an experiment on swale removal efficiencies. They constructed a swale model and the parameters being checked on are Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Nitrate (NO_3^-), Total Phosphorus (PO_4^{3-}), Total Kjedahl Nitrogen (TKN), and metals (Zinc and Iron). TSS and Metals were reported to have high removal efficiencies, followed by the group of TKN, Phosphorus, COD and lastly Nitrate which in some cases produces negative removals. Removal efficiencies of swale experiment conducted by Patrick are shown in the next page.

Table 1 : Removal efficiencies result from swale experiment by Patric M. Walsh

Constituent	Distance Along Swale, m			
	10	20	30	40
TSS	35-59	54-77	50-76	51-75
COD	13-61	26-70	26-61	25-79
Nitrate	(-5)-7	(-5)-17	(-28)-(-10)	(-26)-(-4)
TKN	4-30	20-21	(-14)-42	23-41
Total Phosphorus	25-59	33-46	24-67	34-45
Zinc	41-55	59-77	22-76	66-86
Iron	46-49	54-64	72	76

Other studies regarding swale removal efficiencies were also being conducted by Claytor and Schueler (1996). Alongside with this, the Federal Highway Administration of U.S Department of Transportation's website also shown the removal efficiency of swale, which is presented in the table shown below:

Table 2 : Pollutant removal effectiveness for swale prepared by FHWA

Study	TSS	TP	TN	NO_3	Metals	Comments
Claytor and Schueler (1996)	80-90 %	65 %	50 %	-	80-90 %	-
City of Austin (1995)[1]	68	43	23	-2	-	Grassed channel
Yu et al. (1993)[2]	21-95	32-85	-	-	-	Vegetated swale
Yu et al. (1994)[2]	49	33	-	-	13	Length of swale evaluated reduced to 100 ft.
Yu and Kaighn	30	Negligib le	-	-	11	Grassed swale
Yousef et al. (1985)[1]	-	(-48)-48	(-14)- 25-	-	(-25)-92	Grassed swale
Kahn et al. (1992)[2]	83	29	-	-	30-72	200 foot swale

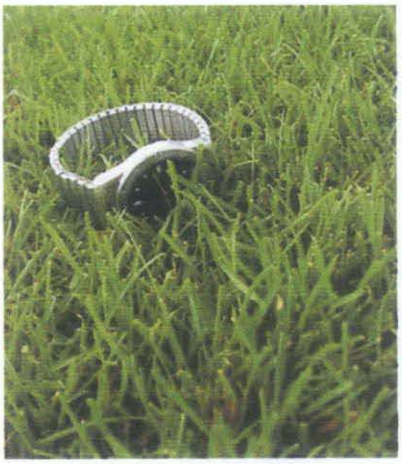
[1]Removal based on concentration

[2] Removal efficiencies base on mass loading

The purpose of vegetated swale is to infiltrate storm water, while limiting groundwater contamination by providing filtering of pollutants. It can also help to attenuate the peak flows through the reduction of runoff velocities and volumes. Vegetated infiltration swales are best suited for low to medium residential land uses and non residential areas where infiltration of runoff is allowable under Chapter NR 151. Swales are intended to treat relatively flat and small drainage areas and large areas require multiple vegetated swales to treat its water. Swales are also not suitable to be built in a steep topography area or in an area whereby the soil can be eroded easily (California Stormwater Quality Association, 2004).

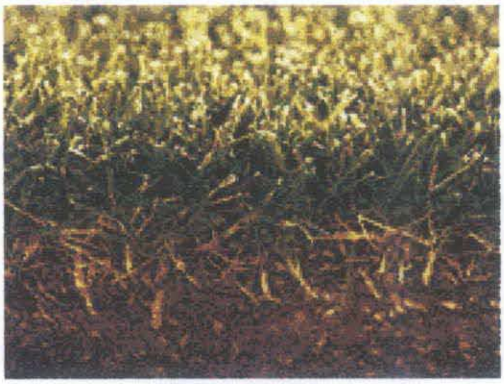
2.1.2 Swale Vegetation

Vegetated swales are shallow, typically flat bottom channel that are planted with either grass or other low vegetation with the purpose to convey stormwater. Stormwater flows along the vegetated swale, increasing the quality of water as the grass blades filter pollutants and soil promotes infiltration. Patrick M. Walsh et al. had opted for the Buffalo Grass (Buchloe dactyloides) natively found in Austin, Texas that is weather tolerance. In another study conducted by Jason T. Kirby (2005) et al., they had used Bluegrass, Centipede and Zoysia grass species which is commonly cultivated to study the effect they have on small flow (lower flow depth) conveyance.



Bluegrass species

Centipede species



Zoysia species

Figure 2 : Photos of Bluegrass, Zoysia and Centipede species used for low flow vegetative swale

Photos courtesy of Seedland.com

2.2 Design

Generally there are two types of grassed swale; dry swale and wet swale. The purpose of dry swale is to provide water quality benefits by introducing infiltration and the wet swale is to use its residence time and natural growth to treat stormwater (Claytor & Schueler, 1996). Figure below shows the channels and swale design illustration according to Claytor and Schueler (1996).

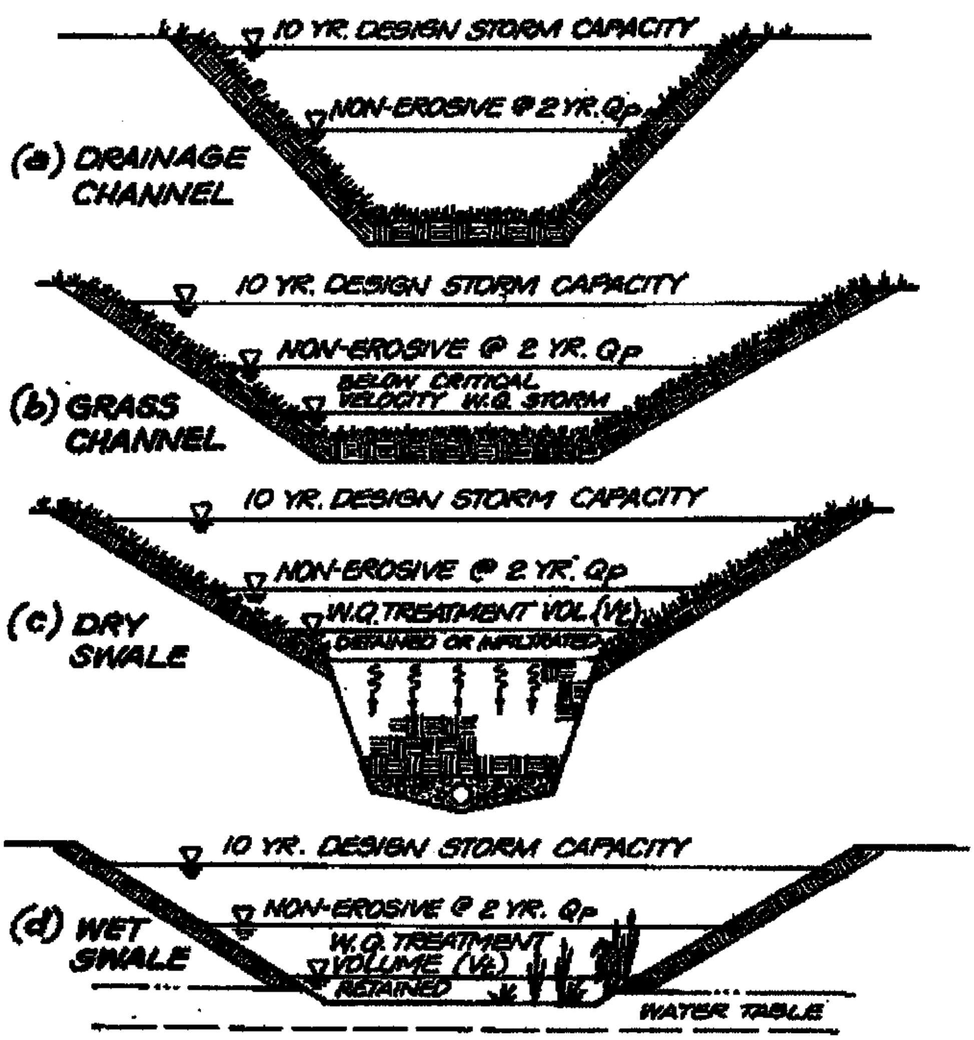


Figure 3: Vegetated swale illustration of Claytor and Schueler (1996)

Dry swales are distinguished from the others by addition of careful selection of highly permeable soil, check dams and an underdrain system. Check dams are to ensure sufficient retention time is available for treating stormwater. On the other hand, wet swales are maintained in a saturated condition in soil at the bottom of swale. The idea of a wet swale is to depict an elongated wetland treatment system (Claytor & Schueler, 1996).

Patrick M. Walsh et al. (1997) states that reduction of most pollutants occurred during the first 20 m of swale and hence design length more than 20 m is not cost effective anymore. It also reported that the removal efficiency for constituent of particulate nature decreased with increased water depth. In the Urban, Hydrology, Hydraulics and Stormwater Quality textbook, the side slope of swale should be 3 horizontal:1 vertical or flatter for maximum efficiency and check dams can be installed to increase retention time that result in higher infiltration capacity. Longitudinal slopes for swale should be between 2 % - 4% (J. Brett Jokela et al.,1994). Vegetative swale however is not capable of removing soluble pollutants (A. Osman Akan & R.J Houghtalen, 2003).

Swale vegetation should be of the type of native vegetation to save energy and cost or seeded with turf grass. The vegetation type chosen should also withstand road salt and wetness besides a suitable planting medium which can support the vegetation. Vegetation is maintained by designing the swale not to have standing water for 24 hours after rainfall or runoff event. Sod is not to be used because it does not establish roots as well as seed and often has muck soil which is not conducive for the infiltration of water. The location of swales must also be considered whereby it must be located in a public right-of-way, not hydraulically connected to foundations or give negative impacts to structures and should not be in a location whereby its overflows can cause flooding to existing or proposed buildings (Wisconsin Department of Natural Resources, 2007).

2.3 Modelling/ Scaled-Down Swale Construction

Grass swales look like stormwater channels but are purposely wider to accommodate a design flow below the height of the vegetation. After all parameters have been calculated, the modeling or prototype construction is performed to test the performance and effectiveness of the proposed design. Patrick M. Walsh et al (1997) constructed a grassed line channel in the laboratory at University of Texas to study the influence of parameters (swale length, water depth and season) on swale's removing efficiency. The soil and grass were installed in a steel flume and 11 experiments were performed.

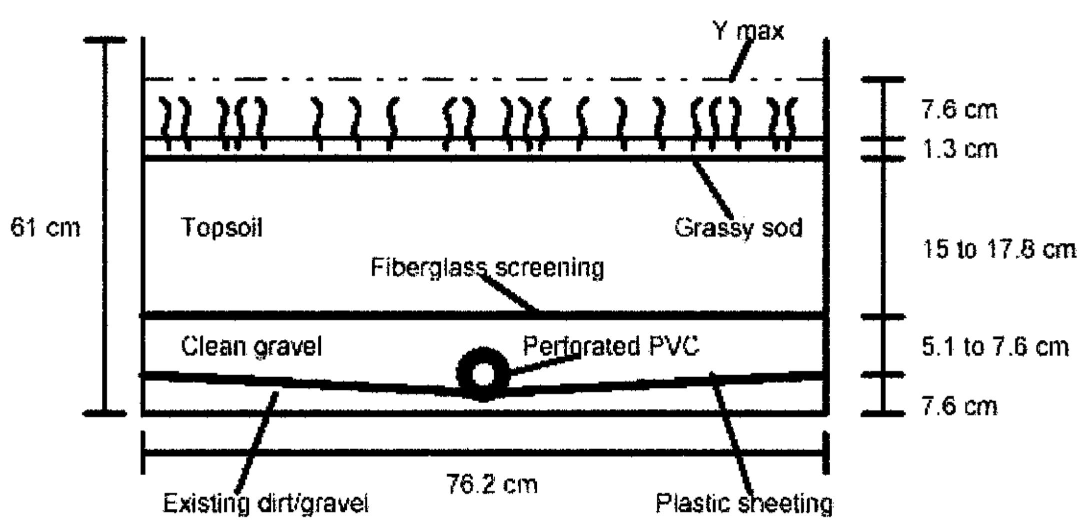


Figure 4 : Side view of constructed vegetative swale in a flume (Patrick M. Walsh et al.)

Besides laboratory model construction, an on field construction is sometimes performed. For the on field modeling, the infiltration area has to be calculated beforehand to check on the availability or requirement of the site. The effective infiltration area is defined in NR 151 as the area of the infiltration system that is used to infiltrate runoff not including the area used for site access, berms or pretreatment (U.S Department of Transportation). There are three (3) vegetative swale shapes under the Wisconsin Department of Natural Resources' Interim Technical Standard and the area of infiltration is basically calculated based on the wetted parameter. The effective infiltration area is calculated with the formula below:

Effective Infiltration Area (ft^2) = ½ * Wetted Perimeter (ft) * Length of Vegetated Infiltration Swale (ft)

The three (3) vegetative swales in used for the standard are having trapezoidal, triangular and parabolic cross section. Refer for the wetted perimeter calculation for each shape.

CHAPTER 3

METHODOLOGY

There are methods and procedures planned and developed to perform on this project. This methodology would be the guidelines to ensure the project is in the correct path and is carried out within the scope and time frame. The Vegetated Swale project concentrates on the modeling of a scaled-down swale. Experiment on the filtration and infiltration of water sample is performed for the water samples obtained from a monsoon drain in UTP. The varying parameter here would be the type of vegetation and the slope.

3.1 Health, Safety and Environment (HSE)

HSE awareness is an issue that is being given attention nowadays. The purpose of HSE is to prevent accidents from happening, keep students and public in a safe state, maintain university's image and upgrade its performance, prevent properties from damage and also to increase productivity. So the precaution steps when executing the tasks are also included in this report.

Hazard is defined by the Federal Aviation Army (FAA) Order 8040.4 as a 'condition, event of circumstances that could lead to or contribute to an unplanned or undesirable event'. Identifying workplace hazard is one of the earliest tasks to do before starting with any laboratories work. Developing hazard checklists, analyzing work processes and observation of the surrounding lab area helps a lot to create a safe working environment. An observation on the labels and safety precaution of materials to be used is also needed. Hazard faced is divided into 3 categories; chemical, physical and biological hazard and different precaution steps are taken for each category. By performing hazard analysis, the unacceptable risks are identified and the means of controlling or eliminating them is selected.

3.1.1 Collecting Samples Outdoor/ Field Experiments

Collecting samples outdoor and doing field experiments can cause hazards that one cannot predict sometimes. Hazards that might be faced are like slip/ fall, in contact with pathogen or other dangerous materials, etc. The author's outdoor activities are sampling of water, in search for swale vegetation and also the vegetation collection for swale prototype. The precaution steps considered while working outdoor are:

- Wearing shoes – prevent stepping on sharp n dangerous materials, lessen the impact of animal bite
- Put on gloves – prevent in contact with harmful pathogens
- Appropriate outfit – allow a more comfortable and suitable working attire so as not to pose a possible threat.
- Proper container for keeping samples – avoid sample from leaking elsewhere

3.1.2 Laboratory Experiments

Laboratory can be a dangerous environment to work in with all the chemicals and other physical hazards. Firstly the rules and regulations of laboratory are to be read, comprehended and followed. Always be alert in the laboratory and precaution steps taken when working in the lab are:

- Put on gloves – prevent in contact with dangerous chemicals and pathogens.
- Wearing shoes – prevent dangerous chemicals to spill on body parts expose to it.
- Appropriate outfit – to allow more comfortable working attire and also to prevent chemicals to easily come in contact or attack body parts that are exposed or thinly protected by attire.
- Contact lenses not allowed – working with high heat temperature in the lab would most likely to cause harm to the contact lenses that are made of plastic in the eyes.

3.2 Sampling

Water sample from the monsoon drain in UTP will be collected and tested for their chemical properties in lab. Water samples collected are then compared with the standards available in Malaysia. Batches of samples are collected from a few sites to get the average parameters value. The amount of sample taken is such that it is sufficient to run at least 2-3 tests for each water sample. Containers to collect and store water samples must be free from contaminant. Apart from water sample, vegetation samples are collected too for early observation of the plant criteria.

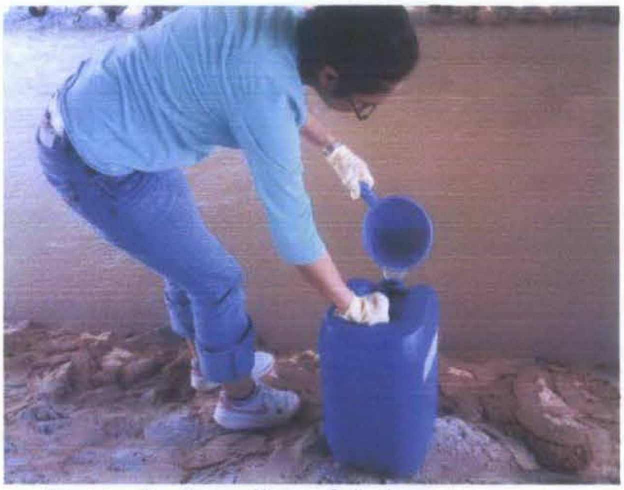


Figure 5 : Sampling of drain water

Figure 6 : Sampling of vegetation

3.3 Swale Design and Model

A swale prototype is being constructed with steel. Dimension of swale model is shown below:

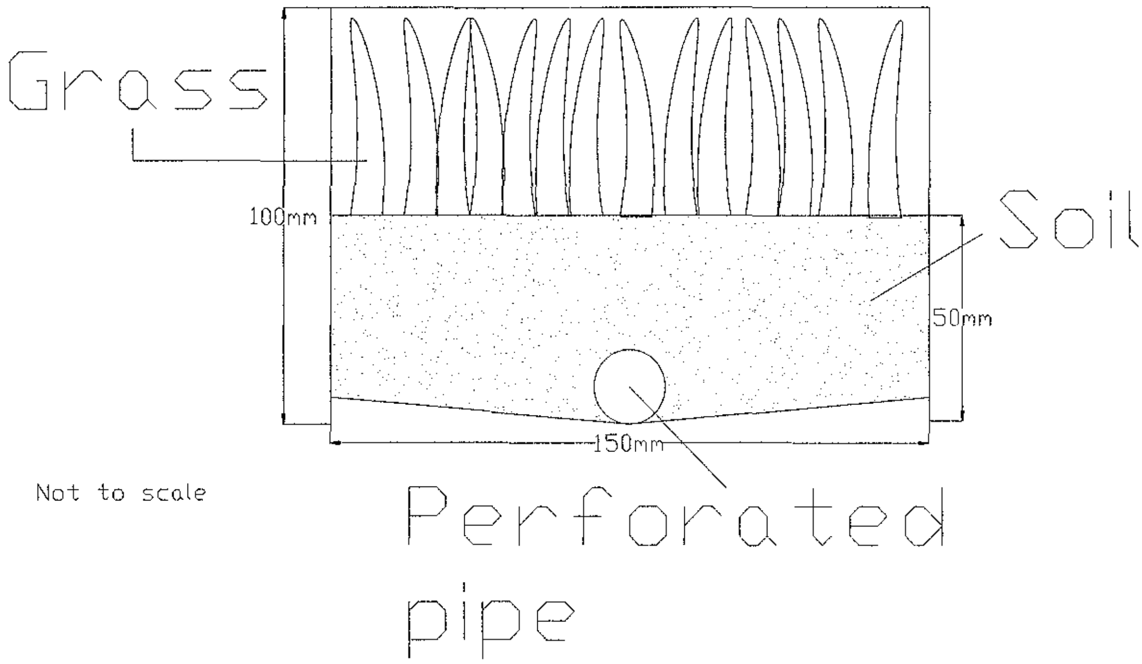


Figure 7 : Front view of swale prototype

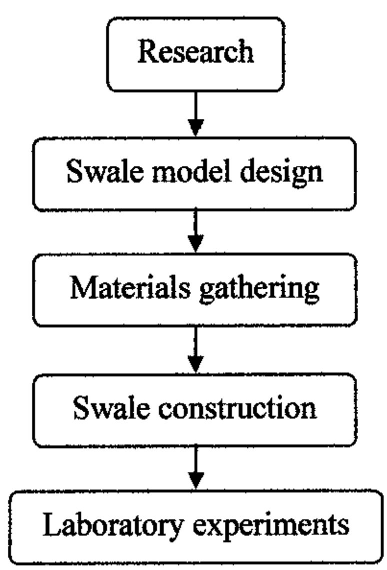
Prototype swale is having a width of 150 mm, depth of 100 mm whereby 50 mm is placed with soil grown with vegetation and a total length of 4000 mm. Perforated tube or pipe is placed at the center of bottom soil along the swale for collecting the samples of infiltrated water. Filtration water sampling on the other hand is done by placing a horizontal tube or pipe at the mid width and mid depth and let flow into a sampling container.

In this experiment, besides the varying vegetation type, water removal efficiency is also being tested on different longitudinal slopes. Two (2) slopes value within the range of 0.5 % - 4 % are to incorporated in this project and for each slope, the removal efficiency is to be tested for two (2) types of vegetation, which their scientific names are yet to be founded. Water depth in this experiment is not varied because of the time consuming factor. Swale prototype is placed in an area whereby the vegetation is exposed to the sunlight to exhibit closely the field swale environment.

3.4 Scaled-down Model Construction

3.4.1 Project Work Sequence

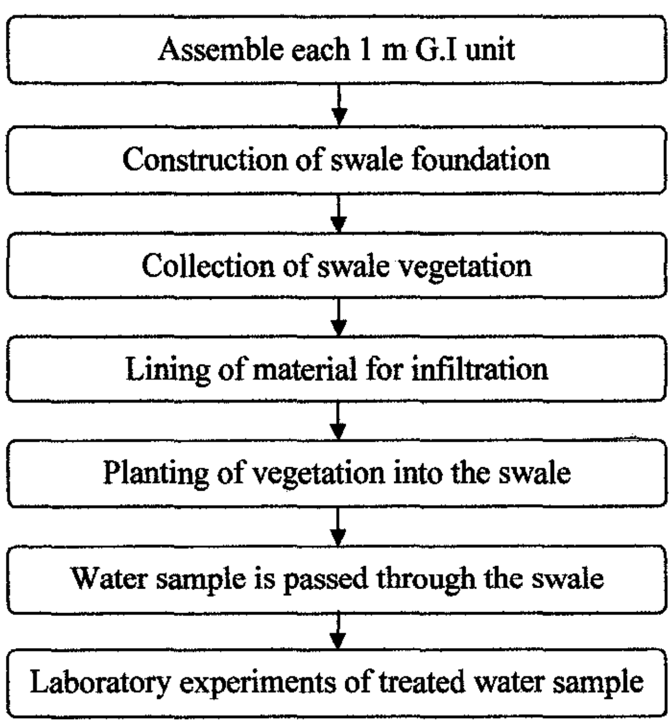
Swale project is started with a detail research on available swale projects all around the world. The next step is to design the author's own swale prototype. During the design stage, the author also started to look for materials for the swale construction and also the types of vegetation to be planted in the swale. Then after all materials have been gathered, the construction phase began. After it is completed, water samples are flowed through the swale model and lastly laboratory experiments are conducted on treated water samples. The flow of project work is shown below:



Flowchart 1: Project flow process

3.4.2 Construction of Scaled-down Swale Model

The construction of swale prototype itself took a few days. The swale profile is made of galvanized iron (G.I) unit. G.I unit is of length 1 m and is pre-fabricated at a hardware store. Each 1 m G.I unit is connected to form a total length of 4 m swale prototype. The work is continued with the building of swale's base. This is to provide a sufficient foundation when swale is filled with 6 cm soil. This also raised the level of swale to make space for container for infiltration sampling. Swale is lined with material to facilitate the infiltration process. Then when swale is ready, vegetations are collected from specific location and planted into the swale. Then water sample is flowed through and then laboratory testing of the treated water sample is performed. Shown below is the flow chart for those activities:



Flowchart 2: Construction of swale prototype process

3.5 Vegetation

After the construction of a scaled-down swale model, vegetation is planted. There are two types of grass being used which are the *'Rumput Sambau'* family grass and the *'Cowgrass'*. *'Rumput Sambau'* family grass is obtained from a nearby lake area which is situated opposite UTP while the *'Cowgrass'* is abundant inside of UTP itself. The reasons the author has chosen *'Rumput Sambau'* family grass and *'Cowgrass'* are because the availability and the easy access to this grasses, therefore cheaper cost consumption. The author has also done a brief study on the physical characteristic of *'Cowgrass'* and *'Rumput Sambau'* family grass.

Figure 8: *Rumput Sambau* family grass

Figure 9: *Cowgrass*

A brief characteristic comparison between *'Rumput Sambau'* family grass and *'Cowgrass'* are shown below:

Table 3: Comparison between *'Rumput Sambau'* family grass and *'Cowgrass'*

Characteristic	*'Rumput Sambau'* family grass	*'Cowgrass'*
Grass width	Less than 10 mm	2.5 – 15 mm
Habitat	Needs sun and a high moisture content soil	Needs sun but tolerate shade and less moisture content than *'rumput sambau'* family grass
Soil	Very moist ground, slightly humid climate, less compact soil than *cowgrass'* soil	Rich soils, moist ground, a slightly humid climate, compact soil
Roots	A little bit reddish in color	Yellowish white color

3.6 Laboratory Experiments

The types of tests performed on samples are chosen by referring to the available vegetative swale projects. Some journals tested on a number of parameters and a few were tested only on certain parameters so the author has summarized the tests to be performed on water samples as follows:

1. Total Suspended Solid (TSS)
2. Turbidity
3. pH
4. Chemical Oxygen Demand (COD)
5. Biological Oxygen Demand (BOD)
6. Nitrate (NO_3)
7. Phosphate $\left(PO_4^{3-}\right)$
8. Metals : Zink (Zn), Pb (Lead), Iron (Fe)

3.6.1 Total Suspended Solid (TSS)

Total suspended solid is the dry weight of particles trapped by a filter with specified pore size that remains on it. TSS test is performed by placing a 47 mm filter disc in the filter holder with the wrinkled surface upward. Then a 100 ml of well mixed representative water sample is filtered by applying vacuum to the flask and followed with three separate 10 ml washings of deionized water. Next, the vacuum is slowly released from the filtering system and the filter disc is removed gently from the holder. The disc is placed on the watch glass. Filtrate is inspected to ensure proper trapping of solids is accomplished on the disc. Watch glass and filter is placed in the drying oven at 103^{0}C for 1 hour and is removed and placed carefully in a desiccator cabinet to cool to room temperature. Lastly disc is carefully removed from the desiccator cabinet and is weighed to the nearest 0.1 mg with an analytical balance.

The calculation of TSS value is done with the formula below (Environmental lab manual).

$$TSS = \frac{(weight of' pan + filter paper' before filtering) - (weight of' pan + filter paper' after filtering)}{sample size(L)}$$

3.6.2 Turbidity

Turbidity is the measure of the light-transmitting properties of water. Turbidity test is conducted by firstly collecting a representative sample in a clean container. The sample water then is filled into a sample cell up to the line (15 ml). Sample cell is wiped clean and lastly placed in the turbidity meter to take the reading. The turbidity unit measured depends on such variables as size, shape and refractive index of the particles. Unit of turbidity measured will be in Nephelometric Turbidity Units (**NTU**).

3.6.3 pH Measurement

pH is to measure how alkaline or acid a water sample is. Water sample is poured into a beaker and the pH is checked by using the pH meter. 2 – 3 samples are taken to get the average value.

3.6.4 Chemical Oxygen Demand (COD)

The COD measurement is a test to determine the amount of chemical oxygen demand in the input and output sample. The test was conducted by adding 2 ml of water sample into a vial. 3 vials had been prepared for each sample. The samples were heated at 150°C for 2 hours in the heater. The blank sample was prepared by pipetting the distilled water into the vial and heats it for 2 hours at 150°C. After the sample finished heated, wait for the samples to cool down after being heated, and the COD reading was taken using the spectrophotometer (Environmental lab manual).

3.6.5 Biochemical Oxygen Demand (BOD)

The BOD measurement is a test to determine the amount of oxygen demand in the input and output sample. The test was conducted by preparing the sample and poured into the BOD bottle according to the volume needed. Blank samples were also prepared. After sample was prepared, the initial DO for sample was measured by the DO probe that was equipped with stirring mechanism. The BOD bottle were then placed in the refrigerator at 20 ^{0}C temperature and left for 5 days. After 5 days incubation, the final DO is measured by using the Do probe. So the total oxygen consumed is calculated with the following formula:

$$BOD, mg/L = \frac{Initial\ dissolved\ O_2\ of\ sample - Final\ dissolved\ O_2\ of\ sample}{Fraction\ of\ wastewater\ volume\ to\ total\ combined\ volume}$$

3.6.6 Nitrate $\left(NO_3^-\right)$

The nitrate measurement is conducted by filling up a square sample cell with 10 mL of wastewater sample. One packet of NitraVer 5 Nitrate Reagent Powder Pillow is poured into the sample cell and is stopper. The sample cell is shaken for 1 minute and left it for 5 minutes for reaction to occur. Finally, the wastewater sample cell is wiped and inserted into the cell holder. Once the read button is pressed, the result in mg/L will be displayed (Environmental lab manual).

3.6.7 Phosphate (PO_4^{3-})

The phosphorus measurement is conducted by turning on and preheat DRB200 reactor to 150^{0}C. A pipet is used to add 5.0 mL of sample to a Total and Acid Hydrolyzable Test Vial and a funnel is used to add the contents of one Potassium Persulfafte Powder Pillow for Phosphonate to the vial. Vial is then capped tightly and is shaken to allow powder to dissolve. Next the vial is inserted into the DRB200 and the protective cover of reactor is closed. Reactor is started and a 30 minute heating period begins. When timer expires, the hot vial is carefully removed from the reactor and is inserted in a test tube rack and let cool to room temperature. 2 mL of 1.54 N Sodium Hydroxide Standard Solution is pipette into the vial that is then capped and mixed. It is then inserted into the 16 mm cell holder to get the 'zero' reading. A funnel is used to add the contents of one Phosver 3 Powder Pillow to the vial and immediately capped and shaken to mix for 20 - 30 seconds. Sample reading is taken after 2-8 minutes of reaction period. The prepared sample vial is inserted into the 16 mm cell holder and results are taken (Environmental lab manual).

3.6.8 Metals (zinc, lead, iron)

10 ml of sample is pipette into a vial and is tested using the Atomic absorption Spectrophotometry (AAS) machine. 2 samples are prepared for each test to take the average value.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

January 2008 has seen water samples collected from two (2) sources; from the drain that directs water out of UTP and from a lake that also happens to drain its water out of UTP. Similar tests were performed on both water sample and it took place in the environmental laboratory. In July 2008, another water sample is taken, that is from the monsoon drain inside UTP. Tests performed are the Total Suspended Solid (TSS), Turbidity, pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Nitrate (NO_3^-), Phosphate (PO_4^{3-}) and Metals measurement.

There are three locations whereby water samples were collected from and the author had decided on the monsoon drain water sample to be used in this project for certain reasons. There are two vegetation types on which water samples will travel, namely the *'rumput sambau'* family grass and '*axonopus compressus*' (*Cowgrass*). After the scaled-down swale model is constructed, water sample taken from the monsoon drain is passed through the swale. As there are two types of vegetation being used, water sample from monsoon drain is also taken twice for each vegetation experiment denoted by I (*rumput sambau family grass*) and II (*Cowgrass*). The results of pollutants removal are as follows:

4.2 Total Suspended Solids (TSS)

Total suspended solid is defined as the dry weight of suspended solid in sample that is trapped by a filter with specified pore size. Result obtained is shown below:

Table 4 : Result of total suspended solid test

Location		**Weight of 'pan + filter paper' before filtering (g)**	**Weight of 'pan + filter paper' after filtering (g)**	**TSS (mg/L)**	
Drain		1.3402	1.3369	33	
Lake		1.4236	1.4218	18	
Monsoon drain	**I**	1.2732	1.2675	57	35.67
		1.3260	1.3238	22	
		1.2774	1.2746	28	
	II	1.2812	1.3070	130	

Of all the three water samples, monsoon drain has the highest total suspended solid content. When comparing with the Interim National Water Quality Standard for Malaysia, all water samples are in class I.

Table 5: Treated TSS concentration and removal efficiency

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
		***'Rumput Sambau'* family**		
TSS (mg/L)	35.67	17.5	8.5	9
Removal efficiency (%)	-	50.9	76.2	74.8
		***'Axonopus Compressus'* (cowgrass)**		
TSS (mg/L)	130	50	38.2	40
Removal efficiency (%)	-	61.5	70.6	69.2

Table above shows the result of treated TSS concentration. The percentage reduction of TSS for infiltration is higher than filtration. Infiltration 1 and infiltration 2 are located at a distance of 200 cm and 350 cm each from the entry point of water sample. Percentage reduction for infiltration 1 is higher than infiltration 2. A percentage reduction graph is shown below with blue bar representing the *'Rumput Sambau'* family grass and purple bar representing the '*Cowgrass*'.

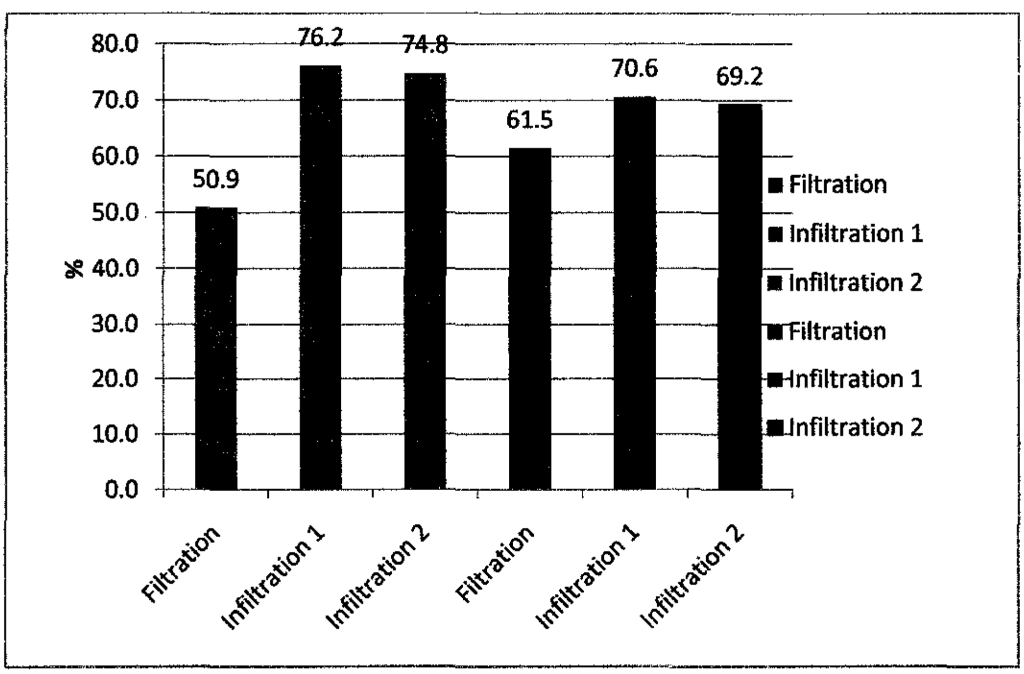


Figure 10: TSS removal efficiency

4.3 Turbidity

Turbidity is a measure of how murky a water body is. This test is performed with the turbidity meter whereby it uses the scattering and absorbing property of light which passes through the particulate matter present and give a reading.

Table 6 : Turbidity measured for water sample

Location		Turbidity (NTU)
Drain		7.58
Lake		26.2
Monsoon drain	**I**	99.4
	II	140

Of all three water samples, monsoon drain is showing the highest turbidity measurement. This means that monsoon drain water sample is the murkiest among all. Referring to the Interim National Water Quality Standard for Malaysia, drain and lake water samples fall in class I whereas monsoon drain water sample is above class IIB. More lights are being scattered and absorbed by the particulate present in monsoon drains and that explains the high reading given by a turbidity meter. How much light reflects for a given amount of particulates is dependent upon properties of the particles like their shape, color, and reflectivity. For this reason (and the reason that heavier particles settle quickly and do not contribute to a turbidity reading), a correlation between turbidity and total suspended solids (TSS) is somewhat unique for each location or situations.

Table 7: Treated turbidity concentration and removal efficiency

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
***'Rumput Sambau'* family**				
Turbidity, mg/L	99.4	42.6	30	40.2
Removal efficiency (%)	-	57.1	69.8	59.6
***'Axonopus Compressus'* (cowgrass)**				
Turbidity, mg/L	140	50.8	35	41
Removal efficiency (%)	-	63.7	75	70.7

As shown in the table, removal efficiency for turbidity is well above 50%. Infiltration promotes higher removal efficiency than filtration. The removal efficiency for infiltration 2 is lower than infiltration 1. A percentage reduction graph is shown below with blue bar representing the *'Rumput Sambau'* family grass and purple bar representing the '*Cowgrass*'.

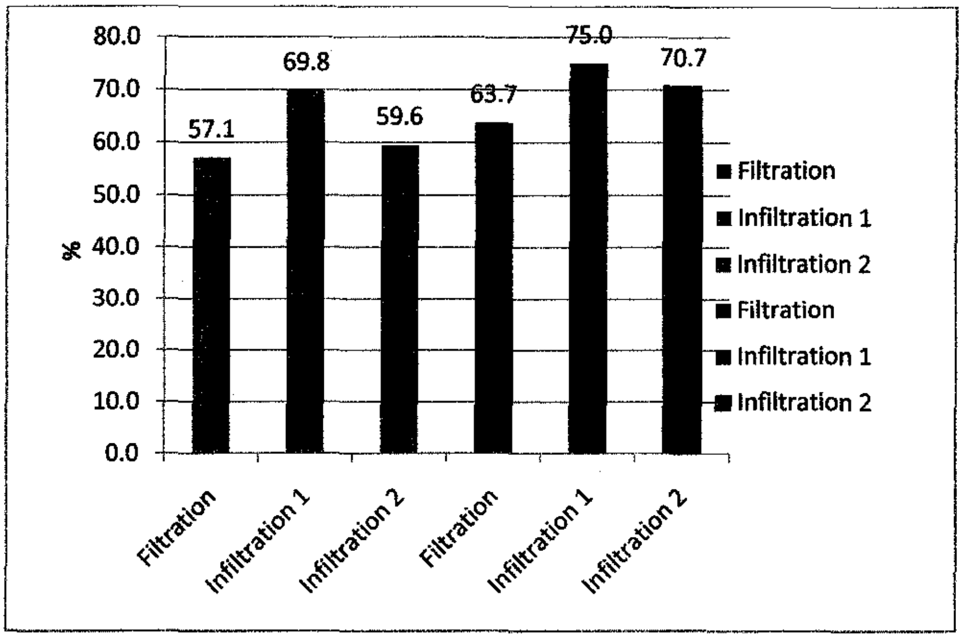


Figure 11: Turbidity removal efficiency

4.4 pH

The Interim National Water Quality Standard for Malaysia has set the pH of water body to be in the range of 6.5 – 8.5 to be classified in class I.

Table 8 : pH value measured for water sample

Location		pH
Drain		7.17
Lake		7.18
Monsoon drain	**I**	6.24
	II	6.55

Results above show that drain and lake water sample are within the range of class I while monsoon drain water sample falls in class II for the first water intake and the second water intake falls in category I. Their pH does not differ much from each other. Water sample from monsoon drain is slightly acidic and the other two are very close to neutral. Below shows the table for treated water sample.

Table 9: Treated pH concentration

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
***'Rumput Sambau'* family**				
pH	6.24	6.54	6.75	6.20
pH Control efficiency (%)	-	4.8	8.2	-0.6
***'Axonopus Compressus'* (cowgrass)**				
pH	6.55	7.35	6.50	7.87
pH Control efficiency (%)	-	12.2	-0.8	20

Acidity of monsoon drain water sample is generally being reduced closer to neutral. It also shows that water sample has successfully been shifted from class II to class I except for water sample infiltrated at location 2 by *'Rumput Sambau'* family grass. The addition of acidity is very small, that is less than 1 percent and can be seen here too the reduction of water sample's acidity is higher for *'Cowgrass'* comparing to the *'Rumput Sambau'* family grass. A pH control efficiency bar graph is shown below with blue bar representing *'Rumput Sambau'* family grass and purple bar representing *'Cowgrass'*.

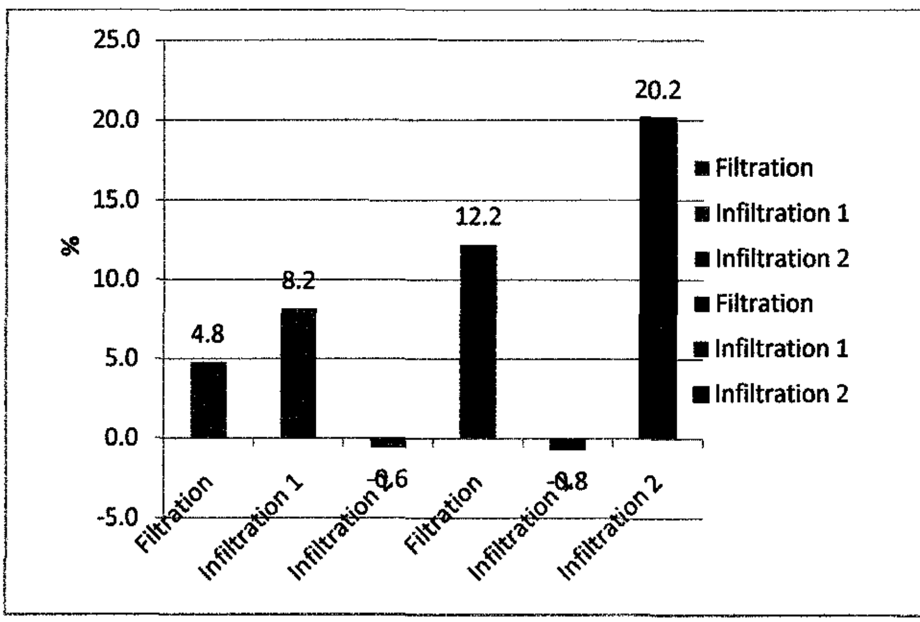


Figure 12: pH control efficiency

4.5 Chemical Oxygen Demand (COD)

Measuring chemical oxygen demand will give the result of the organic strength of water sample. It is the amount of oxygen required to oxidize an organic compound including biodegradable and non-biodegradable to Carbon Dioxide (CO_2) and water (H_2O) under the influent of strong oxidant in an acid environment.

Table 10 : COD result for water sample

Location		Chemical Oxygen Demand (COD), mg/L
Drain		44
Lake		22
Monsoon Drain	**I**	30
	II	11.5

Result in the table above shows that the oxygen demand to oxidize both biodegradable and non-biodegradable organic compound for drain water sample is the highest. Can be justified here, drain water sample is somewhat more 'polluted' than the lake water and monsoon drain water. Comparing with the Interim National Water Quality Standard for Malaysia, drain and the first intake of monsoon drain water sample is above class II Lake and the second intake of monsoon drain water sample is in class I. Monsoon drain water sample which has been chosen as the water sample to be flowed through the vegetated swale is having a COD concentration of 30 mg/L and 11 mg/L each for intake I and II. Below shows the treated COD concentration:

Table 11: Treated COD concentration and removal efficiency

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
'Rumput Sambau' family				
COD, mg/L	30	41	39	61
Removal efficiency (%)	-	-36.67	-30.00	-103.33
***'Axonopus Compressus'* (cowgrass)**				
COD, mg/L	11.5	51.5	23	40.35
Removal efficiency (%)	-	-347.8	-100	-250.9

After water has passed through the swale, no significant removal is seen for both grass type. In fact the COD concentration has increased. This might be due to the biodegradable and non-biodegradable compound found in the soil that adds up to the water sample. *'Cowgrass'* increases the COD concentration more than *'Rumput Sambau'* family grass. Even then, treated water sample of both types of grasses is still within class III. A percentage reduction graph is shown below with blue bar representing the *'Rumput Sambau'* family grass and purple bar representing the *'Cowgrass'*.

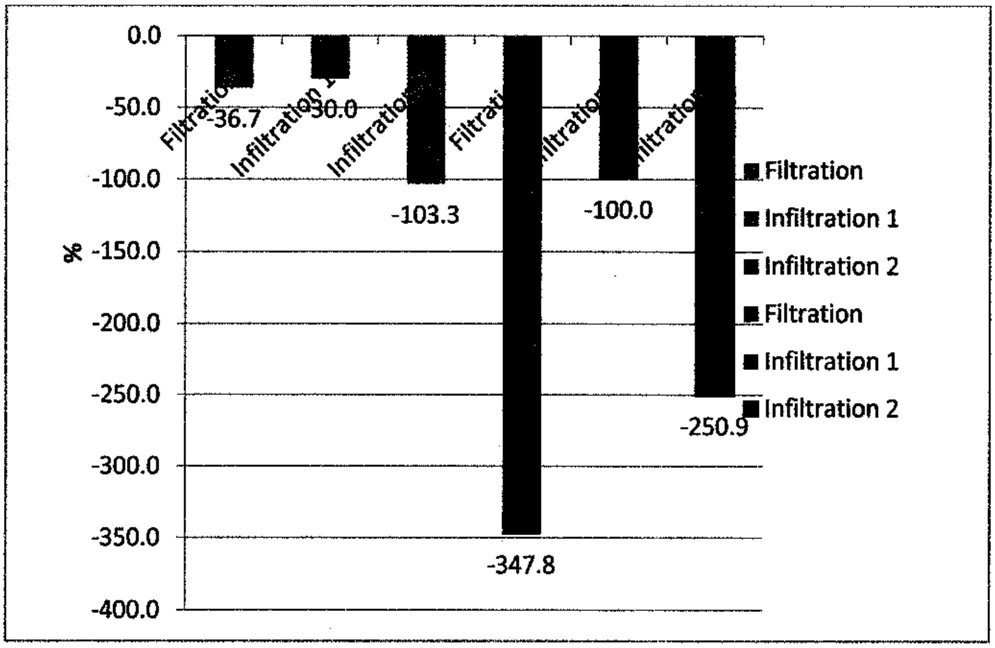


Figure 13: COD removal efficiency

4.6 Biological Oxygen Demand (BOD)

Biological oxygen demand measures the amount of dissolved oxygen used up by microorganism to do the biodegradation process. Higher BOD value implies that high content of nutrient (contamination) is present and biodegradation process is actively engaged by microorganism.

Table 12 : BOD result for water sample

Location	**Drain (mg/L)**			**Lake (mg/L)**		
Intial DO*	9.00	8.99	9.07	9.07	9.09	9.03
Final DO	8.19	8.06	8.46	7.93	7.79	7.86
BOD value	8.10	9.30	6.10	11.4	13.0	11.7
Average	**7.83**			**12.03**		

** DO-Dissolved Oxygen*

Result in the above table shows that BOD value in lake is higher than in the drain. Comparing to the Interim National Water Quality Standard, the standard for lake has reached class V and for the drain it is nearing to class IV. Initially, BOD test is to be performed on water sample but this test has been omitted as it consumes time.

4.7 Nitrate (NO_3).

Nitrate content can also show how bad the pollution of a water body is. It can speed up the blooming of algae in a water body. All three water samples are showing a very low nitrate concentration.

Table 13 : Nitrate content measured for water sample

Location		**Nitrate (NO_3), mg/L**
Drain		0.2
Lake		0.4
Monsoon drain	**I**	0
	II	0.5

Referring to the National Interim Water Quality Standard for Malaysia, drain falls in category I class while lake and monsoon drain are considered in the class II category.

For the first intake of monsoon drain water sample, nitrate concentration can either be nil or the concentration is too small to be detected by the spectrophotometer.

Table 14: Treated Nitrate concentration and removal efficiency

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
		'Rumput Paya'		
Nitrate, mg/L	0	0.2	0.55	0.45
		***'Axonopus Compressus'* (cowgrass)**		
Nitrate, mg/L	0.5	0	0.3	0
Removal efficiency (%)	-	100	40	100

Table above shows that *'Rumput Sambau'* family grass is not able to remove the nitrate concentration while the *'cowgrass'* can reduce the nitrate concentration to 0 except for the infiltration 1 location. The increment of nitrate concentration might be from the soil itself. Removal done by *'Rumput Sambau'* family grass is all negative while *'Cowgrass'* shows positive removal efficiency. A percentage reduction graph is shown below with blue bar representing the *'Rumput Sambau'* family grass and purple bar representing the *'Cowgrass'*.

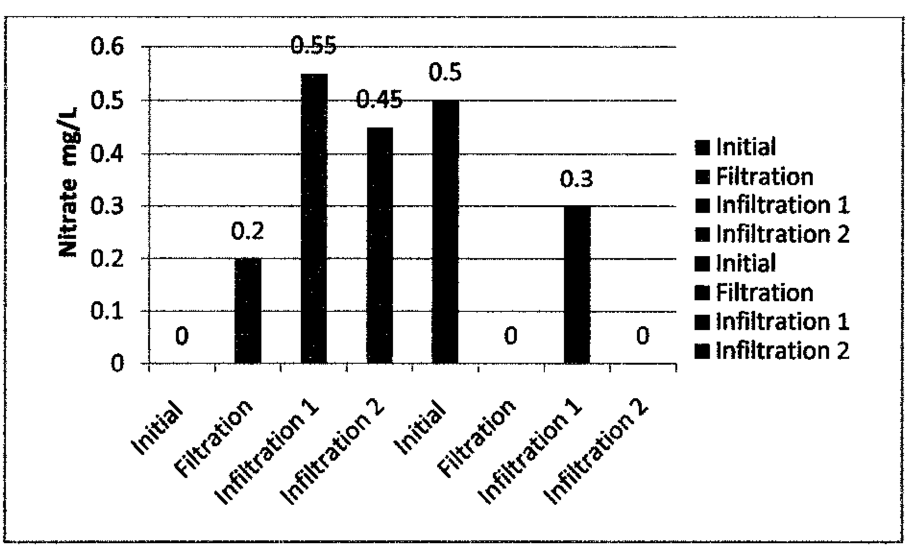


Figure 14: Nitrate removal

4.8 Phosphate $\left(PO_4^{3-}\right)$

Phosphate concentration in a water body also indicates how bad the water is polluted. Phosphorus is considered as one of the nutrients that promote the growth of algae which will cause the depletion of oxygen content in a water body. Below shows the initial testing of phosphate concentration for water samples obtained at three different locations:

Table 15 : Phosphate concentration measured for water sample

Location	Phosphate $\left(PO_4^{3-}\right)$, mg/L		
Drain	0.69	0.51	0.58
		0.59	
Lake	0.56	0.76	0.6
		0.64	
Monsoon Drain	0.98	0.88	0.91
		0.92	
	1.76	1.94	1.88
		1.86	

From the table above, water samples collected from the monsoon drain is showing the highest phosphate concentration. Intake 1 has a phosphate concentration of 0.92 mg/L and intake 2 water sample shows a concentration of 1.86 mg/L.

Table below shows the result of treated Phosphate concentration:

Table 16: Treated Phosphate concentration and removal efficiency

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
***'Rumput Sambau'* family**				
Phosphate, mg/L	0.92	0.71	0.60	0.91
Removal efficiency (%)	-	22.8	34.8	1.1
***'Axonopus Compressus'* (cowgrass)**				
Phosphate, mg/L	1.86	1.64	1.65	1.94
Removal efficiency (%)	-	11.8	11.3	-4.3

Phosphate also shows a positive reduction in its concentration except for the location at infiltration 2. In this experiment, *'Rumput Sambau'* family grass is able to reduce more of phosphate concentration comparing to the '*Cowgrass*'. There is no certain pattern to the removal of phosphate. A percentage reduction graph is shown below with blue bar representing the *'Rumput Sambau'* family grass and purple bar representing the '*Cowgrass*'.

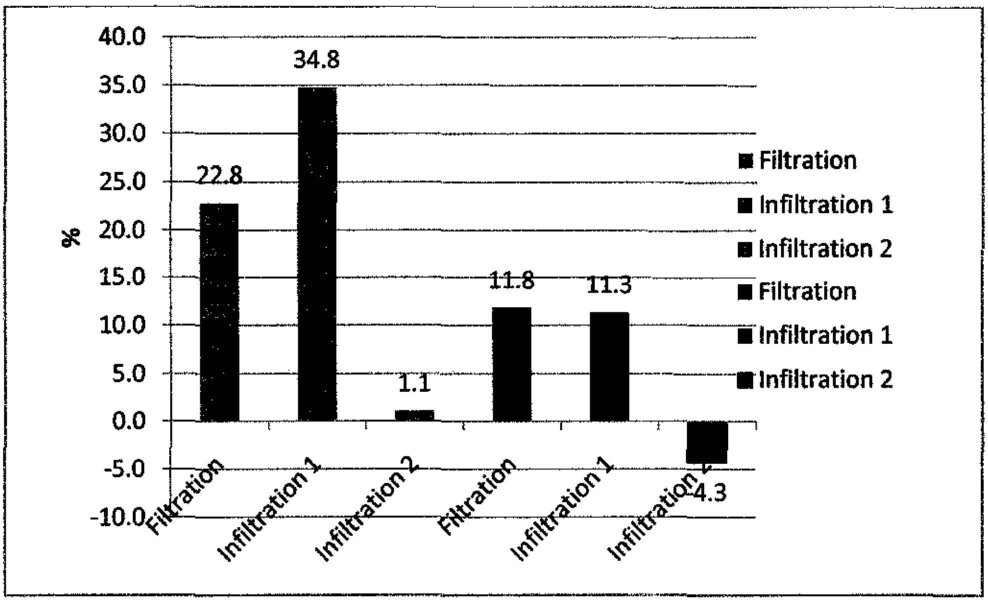


Figure 15: Phosphate removal efficiency

4.9 Metals

Metal contamination is very serious and therefore has to be checked also apart from all the other parameters above. Presence of metals was tested using the Atomic Absorption Spectrophotometer (AAS) with the help of technician and test results are shown below:

Table 17 : Metal experiment result using AAS

<table>
<tr><th colspan="2">Location</th><th>Lead</th><th>Zinc</th><th>Iron</th></tr>
<tr><td colspan="2">Drain (mg/L)</td><td>0.0974</td><td>-0.8478 (0)</td><td>0.3486</td></tr>
<tr><td colspan="2">Lake (mg/L)</td><td>0.0974</td><td>-1.0781 (0)</td><td>0.4182</td></tr>
<tr><td rowspan="2">Monsoon Drain (mg/L)</td><td>I</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>II</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Experiment shows that zinc content in both drain and lake is not detectable as a result of too low a concentration or not present at all. Iron content is higher in the lake compared to drain and lead content is the same for both areas. Comparing with the Interim National Water Quality Standard, iron and zinc are within the limits value but not lead. For monsoon drain water sample, 0 content of lead, zinc and iron are found in both intakes 1 and intake 2 of the water sample and therefore metal testing is also not performed on the treated water sample.

4.10 Result summary

From all the experiments that have been conducted, the results are summarized in table below:

Table 18 : Comparison between water sample parameters and Interim National Water Quality Standard for Malaysia (Grass type: ***Rumput Sambau family grass***)

Parameters	Interim National Water Quality Standard for Malaysia						Initial			Treated Monsoon Drain Water Sample		
	I	**II A**	**II B**	**III**	**IV**	**V**	**Drain**	**Lake**	**Monsoon drain**	**Filtration**	**Infiltration 1**	**Infiltration 2**
TSS, mg/L	25	50	50	150	300	300	**33**	**18**	**35.67**	17.5	8.5	9
Turbidity, NTU	5	50	50	*N/A*	*N/A*	*N/A*	**7.58**	**26.2**	**99.4**	42.6	30.0	40.2
pH	6.5-8.5	6-9	6-9	5-9	5-9	*N/A*	**7.17**	**7.18**	**6.24**	6.54	6.75	6.20
COD, mg/L	10	25	25	50	100	>100	**44**	**22**	**30**	41	39	61
Nitrate, mg/L	Natural levels	7		*N/A*	5	*Levels above IV*	**0.2**	**0.4**	**0**	0.2	0.55	0.45
Phosphate, mg/L	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	**0.59**	**0.64**	**0.92**	0.71	0.60	0.91

The results for metals and BOD experiments are omitted because nil metal concentration is found in monsoon drain water sample and BOD experiments is dropped out as it consumes time.

Table 19: Comparison between water sample parameters and Interim National Water Quality Standard for Malaysia (Grass type: ***Cowgrass***)

Parameters	**Interim National Water Quality Standard for Malaysia**						**Initial**			**Treated Monsoon Drain Water Sample**		
	I	**II A**	**II B**	**III**	**IV**	**V**	**Drain**	**Lake**	**Monsoon drain**	**Filtration**	**Infiltration 1**	**Infiltration 2**
TSS, mg/L	25	50	50	150	300	300	**33**	**18**	**130**	50	38.2	40
Turbidity, NTU	5	50	50	*N/A*	*N/A*	*N/A*	**7.58**	**26.2**	**140**	50.8	35	41
pH	6.5-8.5	6-9	6-9	5-9	5-9	*N/A*	**7.17**	**7.18**	**6.55**	7.35	6.50	7.87
COD, mg/L	10	25	25	50	100	>100	**44**	**22**	**11.5**	51.5	23	40.35
Nitrate, mg/L	Natural levels	7		*N/A*	5	*Levels above IV*	**0.2**	**0.4**	**0.5**	0	0.3	0
Phosphate, mg/L	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	**0.59**	**0.64**	**1.86**	1.64	1.65	1.94

The results for metals and BOD experiments are omitted because nil metal concentration is found in monsoon drain water sample and BOD experiments is dropped out as it consumes time.

All 3 water samples have been successfully tested for TSS, turbidity, pH, COD, Nitrate and Phosphate. The author has decided on the monsoon drain water sample to be passed through the scaled-down vegetated swale system. The reason is after comparing tested parameters against all three water samples, monsoon drain water sample appear to be the most polluted. Furthermore, its location is situated inside UTP and the amount of water that can be obtained from the monsoon drain is more than the other two locations.

Both grass types are able to remove more than 50% of the total suspended solids (TSS) found in the water sample. Comparing these two grasses, the average removal percentage is about the same. Turbidity removal is also well above 50% by both grasses. By averaging the turbidity removal efficiency, *'Cowgrass'* species slightly surpasses the *'Rumput Sambau'* family grass species.

The best pH that can be attained by drain water is pH 7. This is because it will reduce energy consumption in treating drain water or if it enters another water body, it will act as a buffer. So pH control efficiency for this thesis is based on how close the pH is able to be shifted to neutral. Those two grasses are able to reduce the monsoon drain water sample's acidity with *'Rumput Sambau'* family grass shifting the acidity to less than neutral and *'Cowgrass'* shifting the acidity to a little bit over the neutral region. Both grasses are able to shift monsoon drain's water sample nearer to neutral.

Both grasses are not able to remove the organic compound found in water sample. Instead they increase the chemical oxygen demand of monsoon drain's water sample. The organic compound found in *'Cowgrass'* system is more than in the *'Rumput Sambau'* family grass system. *'Rumput Sambau'* family grass contributes to less organic pollutant so it is better than the *'Cowgrass'*.

Due to the '0' initial nitrate concentration for the first batch of water sample, the author has decided to present removal efficiency of nitrate in the form of the concentration in water sample after it has flowed through the swale system. *'Rumput Sambau'* family grass has not been able to reduce nitrate concentration. Instead it contributes to the nitrate content in water sample. On the other hand, *'Cowgrass'* shows a positive reduction in nitrate concentration so *'Cowgrass'* performs better than *'Rumput Sambau'* family grass in this case.

Both grass types show a positive and a negative reduction in phosphate concentration with *'Rumput Sambau'* family grass performs slightly better than the *'Cowgrass'*.

CHAPTER 5

CONCLUSION

From the study done, it is shown in table below the grass type preferable to treat each parameter (shown in shaded box):

Table 20: Comparison between *Rumput Sambau* family and *Cowgrass*

Parameters	***'Rumput Sambau'* family**	***Cowgrass***
TSS		
Turbidity		
pH		
COD		
Nitrate		
Phosphate		

Can be deduced from the table above, both grass types are showing equal capability of reducing pollutants. *'Rumput Sambau'* family grass is obtained near a lake area whereby the soil moisture content should always be high to enable it to perform in best condition. *'Cowgrass'* on the other hand is obtained easily inside UTP area. Quoted from OxyWave website "*The major species of grass in Malaysia for ground cover are Cow grass (Axonopus compressus), Bermuda grass (Cynodon dactylon), Zoysia grass (Zoysia matrella), Bahia grass (Paspalum notatum), and the very commun weed, Lalland (Imperata cylindrica)*" (Omar b. Che May et al). This means that 'Cowgrass' can be obtained easily in any area within Malaysia and is grown in abundant. With this, the author has decided on the *'Cowgrass'* as the grass species to be planted on a vegetated swale.

The author has successfully undergone the study on grass type suitable for the vegetated swale system and decided on the usage of *'Cowgrass'*. Apart from that, the author has also succeeded in studying the pollutants removal efficiency by those grasses which is very satisfying as more than 50% of turbidity and TSS reduction happens. Unfortunately the study on vegetated swale slope cannot be continued due to time constraint.

CHAPTER 6

RECOMMENDATION

1. Sodded grass is used in this experiment. It is better to use a seeded grass in the swale system whereby grass seed is planted inside swale. This way, the removal efficiency can be increased because grass blades are denser and less erosion occurs as grass roots are held steadily by the soil.

2. The velocity of water in this experiment is controlled by ensuring that the water level in basin before entering the swale is at a specified level. It is easier and more accurate if velocity is controlled by a water pump.

3. To search on the scientific name of the *'Rumput Sambau'* family's grass scientific name. This can be done by sending in samples of the grass to Federal Research of Institute Malaysia (FRIM). Characteristics of grass will be studied and grouped accordingly by their scientist.

4. To continue on the author's work of studying the effect of slope has on the pollutants removal efficiency and also to work on few other types of grasses as well to be planted in the vegetated swale system.

CHAPTER 7

REFERENCES

A. Osman Akan & Robert J. Houghtalen (2003). "Urban Hydrology, Hydraulics and Stormwater Quality." John Wiley & Sons, Inc, New Jersey, USA.

California Department of Green Technology - Green Technology Magazine. "What is Green Technology?," [Cited March 2008]. <http://www.green-technology.org/what.htm>

California Stormwater Quality Association (2004). California Stormwater Best Management Practice Handbook. "New Development and Redevelopment".

Claytor, R.A, & Schueler, T.R (1996). "Design of Stormwater Filtering System" Available from the Center for Watershed Protection. U.S EPA.

Jason T. Kirby et al. (2005), "Hydraulic Resistance in Grass Swale Designed for Small Flow Conveyance". Journal of Hydraulic Engineering, Vol 131, No. 1.

J. Brett Jokela et al. (1994), "Guidance for Design of Biofiltration Facilities for Stream Water Quality Control". Montgomery Watson, Alaska.

M. Walsh, Patrick et al. (1997). "Use of Vegetative Controls for Treatment of Highway Runoff". Journal of Environmental Engineering, Vol. 124, No. 11.

Omar B. Che May et al. (2001), OPEN ALL – OxyWave Products, Selma Research Center, [Cited October 2008].
<http://www.openallsoil.com/selma_test.html>

Universiti Teknologi PETRONAS (2004). Wastewater Engineering Lab Manual. Civil Engineering Department.

U.S Department of Transportation– Turner-Fairbank Highway Research Center. FHWA Environmental Technology Brief (September 20th, 1999). "Is Highway Runoff a Serious Problem?," [Cited March 2008].
<http://www.tfhrc.gov/hnr20/runoff/runoff.htm>

Wisconsin Department of Natural Resources Conservation Practice Standard (May 2007). Interim Technical Standard (1005). [Cited April 2008]. <httpwww.dnr.state.wi.usrunoffpdfstormwatertechstdspostInterim_Infiltration_Swale_1005.pdf>

APPENDICES

Appendix A : Calculation

Appendix A-1 : Total Suspended Solid

Appendix A-2 : Biological Oxygen Demand

Appendix A-3 : Removal efficiency

Appendix A-4 : Calculation for Channel Cross Section

Appendix A-1 : Total Suspended Solid (TSS)

	Weight of 'pan + filter paper' before filtering (g)	Weight of 'pan + filter paper' after filtering (g)	TSS (mg/L)
Drain	1.3402	1.3369	33
Lake	1.4236	1.4218	18

$$TSS\ Drain = \frac{1340.2\,mg - 1336.9\,mg}{0.1\,L} = 33\,mg\,/\,L$$

$$TSS\ Lake = \frac{1423.6\,mg - 1421.8\,mg}{0.1\,L} = 18\,mg\,/\,L$$

Appendix A-2 : Biological Oxygen Demand (BOD)

	Drain (mg/L)			Lake (mg/L)		
Intial DO*	9.00	8.99	9.07	9.07	9.09	9.03
Final DO	8.19	8.06	8.46	7.93	7.79	7.86
BOD value	8.10	9.30	6.10	11.4	13.0	11.7
Average	**7.83**			**12.03**		

*DO – Dissolved Oxygen

The biological oxygen demand is calculated based on the formula below:

$$BOD = \frac{DO_i - DO_f}{P} = mg/L$$

Whereby,

DO_i – Initial Dissolved Oxygen

DO_f – Final Dissolved Oxygen

P – Fraction of wastewater sample volume to total combined volume

Example calculation taken from the first data for drain

$$BOD = \frac{9 - 8.19}{\frac{30}{100}} = 8.10\,mg/L$$

Appendix A-3 : Removal efficiency

e.g Removal efficiency for phosphate

Parameter	Initial	Filtration	Infiltration 1	Infiltration 2
Phosphate, mg/L	0.92	0.71	0.60	0.91
Removal efficiency (%)	-	22.83	34.78	1.09

$$\text{Removal efficiency} = \frac{\text{Initial concentration} - \text{Final concentration}}{\text{Initial concentration}} \times 100$$

Filtration

$$\text{Filtration efficiency} = \frac{0.92 - 0.71}{0.92} \times 100 = 22.83\%$$

Infiltration 1

$$\text{Infiltration 1 efficiency} = \frac{0.92 - 0.60}{0.92} \times 100 = 34.78\%$$

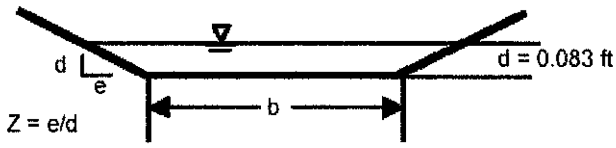
Infiltration 2

$$\text{Infiltration 2 efficiency} = \frac{0.92 - 0.91}{0.92} \times 100 = 1.09\%$$

Appendix A-4 : Calculation for Channel Cross Section

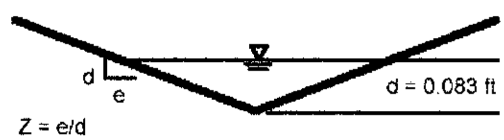
Trapezoidal Channel Cross section:

Wetted Perimeter, p
$p = b + 2d (Z^2 + 1)^{1/2}$



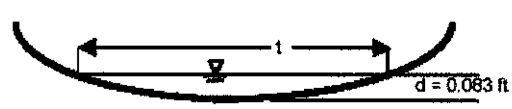
Triangular Channel Cross section:

Wetted Perimeter, p
$p = 2d (Z^2 + 1)^{1/2}$



Parabolic Channel Cross section

Wetted Perimeter, p	Top Width of flow, t	Cross-sectional Area of flow, a
$p = t + (8 d^2) / (3 t)$	$t = a / (0.67 d)$	$a = 2/3 (t d)$



[1] Words in the standard that are shown in italics are described in IX. Definitions. The words are italicized the first time they are used in the text.

Appendix B : Tables

Appendix B-1 : Class Parameter for Interim National Water Quality Standard

Appendix B-2 : Interim National Water Quality Standard

Appendix B-1 : Class Parameter for Interim National Water Quality Standard

Class Parameter	Remarks on Water Quality
Class I	Conservation of natural environment, Water Supply I – practically no treatment necessary, Fishery I – very sensitive aquatic species.
Class IIA	Water supply II – conventional treatment required, Fishery II – sensitive aquatic species.
Class IIB	Recreational use with body contact
Class III	Water supply III – extensive treatment required, Fishery III – common, of economic value, and tolerant species Livestock drinking
Class IV	Irrigation
Class V	None of the above

Appendix B-2 : Interim National Water Quality Standard

INTERIM NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA TABLE2.3

INTERIM NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

		CLASSES				
PARAMETERS	UNIT	I	IIA	IIB	III	IV
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7
BOD	mg/l	1	3	3	6	12
COD	mg/l	10	25	25	50	10(
DO	mg/l	7	5 - 7	5 - 7	3 - 5	<3
pH		6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 -
Colour	TCU	15	150	150	-	-
Elec. Conductivity *	umhos/cm	1000	1000	-	-	60(
Floatables		N	N	N	-	-
Odour		N	N	N	-	-
Salinity (%)	%	0.5	1	-	-	2
Taste		N	N	N	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	40(
Total Suspended Solid	mg/l	25	50	50	150	30(
Temperature (C)	^oC	-	Normal $+2^oC$		Normal $+2^oC$	-
Turbidity (NTU)	NTU	5	50	50	-	-
Faecal Coliform **	counts/100mL	10	100	400	5000 $(20000)^a$	50((2C a
Total Coliform	counts/100mL	100	5000	5000	50000	50(

Notes

N : No visible floatable materials or debris or No objectionable objectionable taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : maximum not to be exceeded

Class		Uses
CLASS I	:	Conservation of natural environment water supply 1 - practicall necessary.
		Fishery 1 - very sensitive aquatic species
CLASS IIA	:	Water Supply II - conventional treatment required
		Fishery II - sensitive aquatic species
CLASS IIB	:	Recreational use with body contact
CLASS III	:	Water Supply III - extensive treatment required
		Fishery III - common, of economic value, and tolerant species lives
CLASS IV	:	Irrigation

Last Updated (Wednesday, 21 September 2005)

Appendix C : Pictures

Appendix C-1 : Collection of project samples

Appendix C-2 : Swale prototype construction process

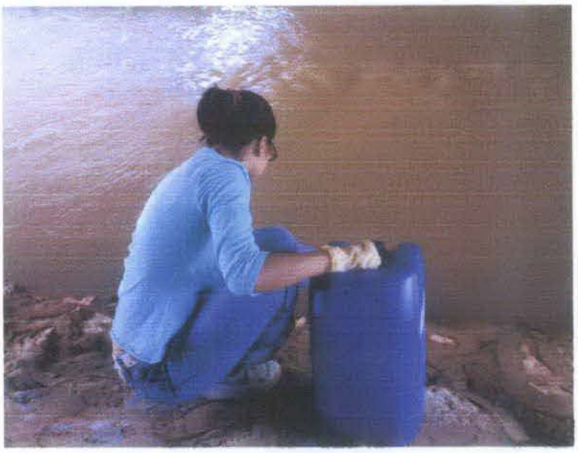
Appendix C-3 : Laboratory experiment

Appendix C-1 : Collection of project samples

Collection of water sample from lake

Collection of water sample from drain leading out from UTP

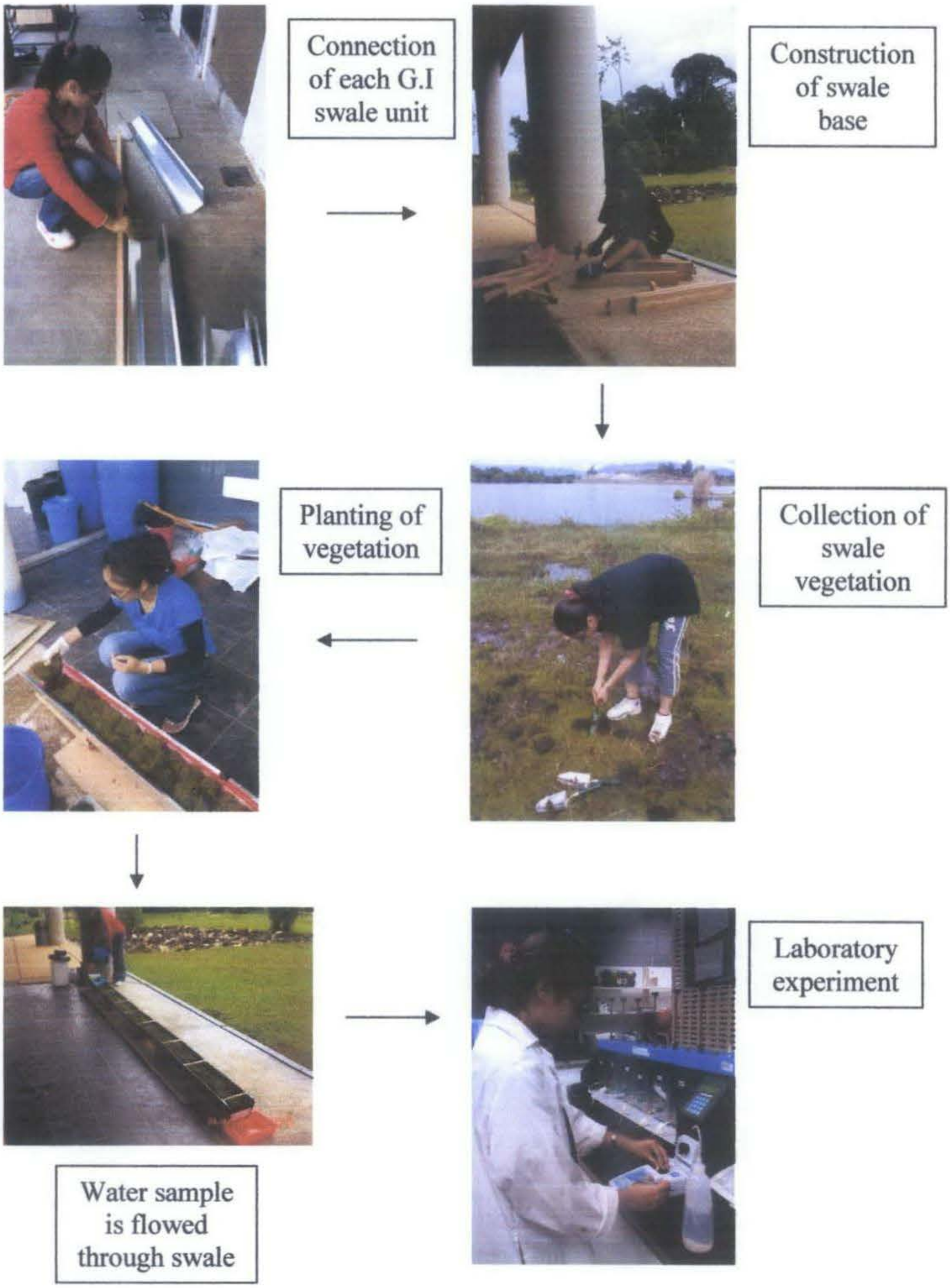
Appendix C-1 : Con't



Collection of water sample from monsoon drain

Collection of swale vegetation

Appendix C-2 : Swale prototype construction process



Appendix C-3 : Laboratory experiment



Process involved in Total Suspended Solid experiment


Process involved in Turbidity experiment

Process involved in pH measurement

Appendix C-3 : Con't

Process involved in Chemical Oxygen Demand experiment

Process involved in Phosphate and Nitrate experiment

Process involved in AAS metal experiment

Appendix D : Gantt Chart

PHASE	MONTH											
	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dis
Research and Background Studies	■	■	■	■	■	■	■					
Searching for Existing Swale Location				■								
Collection and Testing of Water Sample					■							
Report Preparation						■						
Design of Swale Prototype							■	■				
Gathering of Materials & Preparation									■			
Construction of Swale Prototype									■			
Swale Prototype Experiment									■	■	■	
Final Report Preparation											■	■

Appendix E: Sketch of the scaled-down vegetated swale model