Application of Infiltration Trench as a Community Retention Facility in Seri Iskandar

by

Mohd Farid Bin Rahmat Sam

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

JANUARY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(Assoc. Prof. Dr. Nasiman Sapari)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD FARID BIN RAHMAT SAM

ABSTRACT

This project examines the application of infiltration trench as an extension and improvements from the Urban Stormwater Management Manual for Malaysia (MASMA) published by the Department of Irrigation and Drainage Malaysia. The infiltration trench is a structure which collects stormwater runoff and allows it to infiltrate into the soil strata. The trench provides temporary underground storage in the form of a storage chamber filled with an open-graded coarse stone aggregate. The Seri Iskandar soil which contains 78.28% sand, 2.48% silt and 1.06% clay was examined to see its suitability for the infiltration trench. The infiltration rate through the soil is 40.0 mm/hr which is higher than the requirement by MASMA of 13 mm/hr. The cation exchange capacity is equivalent to 1.63 meq of cations that can be absorbed by 100g of dry soils of Seri Iskandar A model of infiltration trench conducted in laboratory using the Seri Iskandar soil was found to be able to remove 50% of COD, 72% of TSS, 31% of TP, 40% of ammonia-N and 70% of zinc. Addition of lime to the soil improves the effectiveness of the soil in removing those pollutants and the addition of lime promoted Seri Iskandar soil to become porous, increases the soil pH and soil moisture.

ACKNOWLEDGEMENT

First of all I would like express my thankfulness to Allah the Almighty who gave me the strengths to face challenges in completing this dissertation to fulfill the Final Year Project.

As a student, it would have been a daunting task to accomplish the objectives of Final Year Project. It is the support and patience of the following individuals that my Final Year Project is successful.

My foremost gratitude goes to Associate Professor Dr. Nasiman Sapari, beloved supervisor and lecturers from Civil Engineering Department of Universiti Teknologi PETRONAS. Being under their supervisions has being an irreplaceable experience. Their approaches towards my Final Year Project encompasses a variety elements, including skills and project based assignments, all of which are vital elements of research project.

I also extend my appreciation to the technician and lab assistants on their guidance and assist over my general progress during 28 weeks in contributing immensely towards my successful Final Year Project.

Many thanks to UTP Information Recourse Centre for their cooperation in allowing student to carry out literature review. Beneficial references were crucial in ensuring excel of student in Final Year Project.

Last but not least, a lot of thank you to all whether directly or indirectly help me upon completing my Final Year Project. All the support and guidance is really appreciated. Thank you.

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ABBREVIATIONS

AAS	Atomic adsorption spectrometry
BMPs	Best management practices
BS	British Standard
CEC	Cation exchange capacity
CMP	Corrugated metal pipe
COD	Chemical oxygen demand
DID	Department of Irrigation and Drainage, Malaysia
INWQS	Malaysian Interim Water Quality Standard
MASMA	Manual Saliran Mesra Alam, Malaysia
MPN	Most probable number
NTU	Nephelometric turbidity unit
NWQS	National Water Quality Standard, Malaysia
OM	Organic matter
PSD	Particle size distribution
SI	Seri Iskandar
SOP	Standard operating procedure
TSS	Total suspended solids
USDA	U.S department of agriculture

CHAPTER 1
INTRODUCTION

1. INTRODUCTION

Infiltration trench could be introduced in selected area of Seri Iskandar to increase the efficiency of runoff treatment. The project examines the use of infiltration trench as an integral truant of the inlet into possible engineered wetlands in the area. The infiltration trench can be viewed as pollutants control because this system can remove both suspended solids and dissolved pollutants. These include phosphorus and nitrogen, certain heavy metals and some exchangeable irons.

1.1 Background of Study

Seri Iskandar (SI) is a new township with a large area of wetlands originating from the natural swamps and mining lakes. It covers 5000 acres of land including commercial, residential, industrial and recreational facilities. The rapid growth of the area resulted in changes of surface characteristics and increases in runoff and soil erosions. Consequently environment impact such as siltation of rivers and flooding in the downstream area may occur. The existing wetlands situated in the middle of the town area has 124 ha size of catchments but the permanent water covers an area about 9 ha out of the total wetland area of 16 ha.

In order to control the possible flood, engineered wetlands might be proposed at selected locations. Engineered wetlands have been proposed for the control of urban runoff and recreational purposes. To improve the quality of runoff into the wetland, infiltration trench can help to reduce stormwater pollutants and more importantly, help to reduce stormwater volume. The function of infiltration trench is similar to rapid infiltration systems that are commonly used in wastewater treatment system. The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes: total suspended solids (TSS) 75-90%; total phosphorus (TP) 60-70%; total nitrogen 45-60%; and heavy metals 70-80% (Schueler, T.R. 1987)

1.2 Problem Statement

Runoff commonly has high sediments concentration and turbidity. Direct discharge of runoff into river or wetland may cause siltation problems. Without appropriate treatment, this water will caused the aesthetic value of recreational wetlands deteriorate overtime and look unattractive for recreational activities. High deposition of total suspended solids will take place in the wetland. It also can produce higher turbidity water in the wetlands.

Sedimentation in the wetland and infiltration trench may have serious impact. Wetlands and infiltration trench would not be an effective system that might control flood and runoff due to lack of appropriate of design parameters and best management practices (BMPs). Thus the possibility of failure always occurs.

For infiltration trench, the great concern is the potential for failure due to clogging by sediment in infiltration trench is of great concern. It may reduce the effectiveness and efficiency of the system. Therefore infiltration trench needs proper design and frequent inspection during initial stage of infiltration trench construction periods.

1.3 Objectives

The main objective is to introduce a new system of community retention facility for runoff control by reducing peak flow and to improve water quality according to the guidelines in Manual Saliran Mesra Alam (MASMA). In order to achieve the above objective, the following specific objectives were developed:

1. To examine the site conditions of Seri Iskandar
2. To analyze soil characteristics and water quality which meet the criteria for Class llB of the National Water Quality Standards
3. To analyze the effectiveness of soil modification by addition of calcium oxide.
4. To improve existing design of infiltration trench based on Manual Saliran Mesra Alam (MASMA).

1.4 Scope of Study

The scope of this study would be on the soils condition at the site. This includes data on soil permeability, soil textural and classification. The soil studies continue with analyzing the effectiveness of calcium oxide in improving the soil permeability. Another scope of study is to determine the efficiency of the trench as a pollutant control facility. The infiltration trench is expected to remove fine sediment and pollutants such as nutrients and metals in the runoff. Generally, some soluble pollutants can be effectively removed according to the degree of the holding time, the degree of bacterial activity and chemical bonding with the soil.

The quality of treated runoff and the efficiency of the system with and without addition of calcium oxide to the soil of the infiltration trench are major focus in this research. Some of the results are expected to be used as benchmark for MASMA implementation in Bandar Seri Iskandar.

CHAPTER 2
LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Soil Sampling

According to Richmond (1999), the Standard Operating Procedure (SOP) is applicable to the collection of representative soil samples. Analysis of soil may determine whether concentrations of specific contaminants exceed the established threshold levels, or if the concentrations present a risk to public health, welfare, or the environment. Soil samples may be obtained using various methods and equipment, depending on the soil profile required and the type of sample required (disturbed or undisturbed). Particle size and organic content are directly related to water velocity and flow characteristics of a body of water. Contaminants are more likely to be concentrated in soils typified by fine particle size and a high organic content. The selection of a sampling location has great influence on the analytical results.

Wayne (2006) mentioned that poor sampling gives misleading test results. Soil testing can be divided into three major steps: (1) collecting the sample, (2) analyzing the sample, and (3) interpreting the results. Collecting the sample is probably the most inaccurate of these three steps. Test results to represent an area can be no more accurate than the sample collected. Poor sampling techniques lead to inaccurate recommendations.

2.2 Urban Runoff Water Quality

According to Vassilios and Rizwan (1997), the urban runoff pollutant can be described into 4 major concerns. (1) Factors affecting urban pollution; urban runoff quantity and quality depend on several factors which determine flow rate magnitude and time distribution, as well as pollutant concentrations. These include rainfall patterns, volume, intensity, and antecedent number of dry days; traffic volume; land use; geographic and geologic characteristics of the region; maintenance practices; and drainage system configuration. (2) Pollutant affecting processes; the types of pollutants, wash off mechanisms, type of receiving water, and the extent of water quality degradation caused by the pollutants. Another factors affecting are atmospheric scrubbing, scour and erosion, surface wash off, deposition, and transport and transformation. (3) Types and sources of pollutants; suspended solids, heavy metals, chloride, and others constituencies such as oil, grease and other related hydrocarbons. And (4) Impacts of the receiving waters; the impact of urban runoff pollutants on water quality of a certain water body may vary significantly depending upon its existing water quality and the rates at which these pollutants are introduced into the system. Shock-loadings or immediate loadings in a short period of time usually bring dramatic changes in water quality. Various chemicals have different types of impacts on the water quality. For example, lead bio-accumulates on the bottom sediments, and may retard fish growth and reduce photosynthesis.

2.3 Infiltration Trench and Wetlands

Osman (2002) defined the infiltration trench as infiltration structure constructed to temporarily store stormwater and let it percolate into the underlying soil. These structures are used for small drainage areas. They are feasible only where the soil has adequate permeability and the maximum water table elevation is sufficiently low. They can be used to control the quantity as well as quality of stormwater runoff. Unlike detention basin, there is no existing widely accepted design standards and procedures for infiltration practices. Generally, an infiltration structure is designed to store a ''capture volume'' of runoff for a specified period of ''storage time.'' The definition of capture volume differs depending on the purpose of the infiltration structure and the stormwater management program being used.

Bastian et al. (1989) defined constructed wetlands as a designed and man-made complex of saturated substrates, emergent and submergent vegetation, animal life, and water that simulate natural wetlands for human use and benefits. Synonymous terms are man-made, engineered, or artificial wetlands. Most constructed wetlands used in wastewater treatment emulate marshes. Constructed wetland systems (1) are relatively inexpensive to construct and operate; (2) are easy to maintain; (3) provide effective and reliable wastewater treatment; (4) are relatively tolerant of fluctuating hydrologic and contaminant loading rates; and (5) may provide indirect benefit such as green space, wildlife habitats, and recreational areas. Disadvantages of constructed wetlands for wastewater treatment relative to conventional systems include: (1) relatively large land area requirements for advanced treatment; (2) currently imprecise design and operating criteria; (3) biological and hydrological complexity and a lack of understanding of important process dynamics; and (4) possible problems with pests.

2.4 Advantages and Disadvantages of Infiltration Trench

United States Environmental Protection Agency (USEPA, 1999) mentioned that infiltration trenches provide efficient removal of suspended solids, particulate pollutants, coliform bacteria, organics and some soluble forms of metals and nutrients from storm water runoff. The captured runoff infiltrates through the soils and increases groundwater recharge and baseflow in nearby streams. It may also being impacts which include the potential for groundwater contamination and a high likelihood of early failure if not properly maintained. The use of infiltration trenches may be limited by a number of factors, including type of native soils, climate, and location of groundwater tables. Site characteristics, such as excessive slope of the drainage area, fine-particle soil types, and proximate location of the water table and bedrock, may preclude the use of infiltration trenches. The slope of the surrounding area should be such that the runoff is evenly distributed in sheet flow as it enters the trench unless specifically designed for concentrated input. Generally, infiltration trenches are not suitable for areas with relatively impermeable soils containing clay and silt or in areas with fill. The trench should be located well above the water table so that the runoff can be filtered through the trench and into the surrounding soils and eventually into the groundwater.

Infiltration trenches function similarly to rapid infiltration systems that are used in wastewater treatment. Estimated pollutant removal efficiencies from wastewater treatment performance and modeling studies are shown in below.

Table 1: Typical pollutant removal efficiency

Parameter	Typical Percent Removal Rates
Sediment / Total Suspended Solid	75-90%
Total Phosphorus	60-70%
Total Nitrogen	45-60%
Biochemical Oxygen Demand	70-90%
Chemical Oxygen Demand	65%
Lead	70-80%
Zinc	70-80%

Source: Schueler, 1987

2.5 Nitrogen and Phosphorus in Sediment

It has been known that secondary eutrophication is caused by the release of primary compounds of nitrogen and phosphorus from the sediments to the water column when certain trophic level is reached. The amount of phosphorus in the soils mentioned by

Zulay et al. (2000) depends on the topography, the vegetative cover, degree of pollution and exchange of phosphorus between sediment and water. This in turn depends upon the capacity of the sediments to retain phosphorus and the fauna which alters the exchange equilibrium, releasing it.

The amount of nitrogen which arrives to the body of water from the atmosphere is not as important as compared with the load from the earth. However, the load of atmospheric nitrogen due to pollution is considerable for the nitrogen cycle and primary productivity Esteves (1988). It has been reported by Correll (1992) that ammonia and nitrate concentrations can partially control the fixation index on nitrogen since they stop the nitrogenase synthesis. Therefore, when waters in close contact with sediments have low concentrations of ammonia there is a tendency, through biochemical and physicochemical activities, to release nitrogen as ammonia, which passes by diffusion to the upper water. However, in the reverse situation, when the concentration of ammonia in waters is higher it is trapped by the sediments. Mostly nitrogen released by sediments comes from nitrification and denitrification processes and ammonification reactions in the water-sediment interface.

CHAPTER 3
METHODOLOGY

3. METHODOLOGY

Works plans for this study were developed in order to ensure that the project flow is smooth and accomplish in the given period.

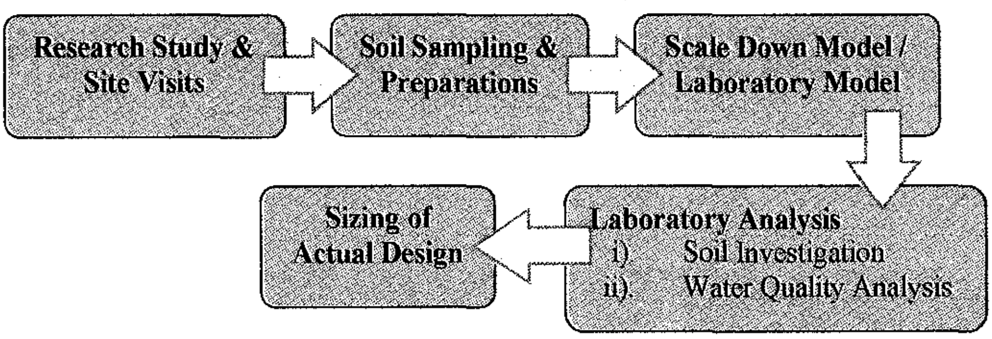

Figure 1 : Methodology involved

3.1 Research Study and Site Visits

The research started with an assessment of the technology based on published materials by previous researchers, MASMA, and National Water Quality Standards. Discussions and guides from the supervisor help a lot in the progress of the entire project. The research continued with site visits on the selected area in Seri Iskandar. All data were collected including the details of the topography in Seri Iskandar, size of the catchments area and the development of propose wetland area. Some of the information was retrieved from the related party and other sources.

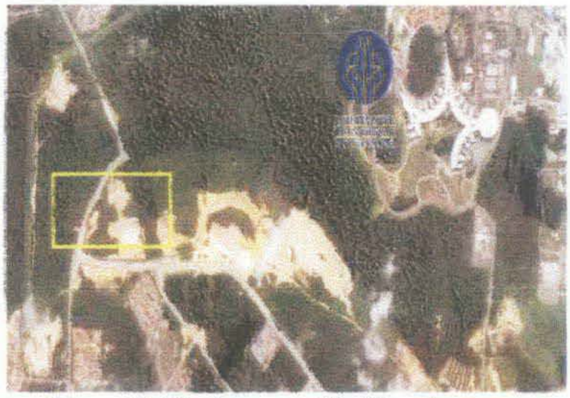

Figure 2: Study area of infiltration trench

Figure 3: Location of soil and water samples collected

3.2 Soil Sampling and Preparations

Soil sampling was carried for the residual soil and tested in lab. By using a precleaned stainless steel scoop, any vegetation (i.e. grass and plant) and top layer of soil was removed and then the desired volume of soil from the sampling area was collected. Over size materials (i.e. pebbles, rock) were removed from the soils. For the undisturbed soil sampling, the samples were taken with a small coring apparatus fitted with thin-walled stainless steel sample tubes. The sampling tubes were pushed into the soil; using a steel hammer with nylon heads. Undisturbed soils was packed and transported to the laboratory immediately to ensure the quality of sample was similar to the soil in the field.

Figure 4: Seri Iskandar soil sample

3.3 Scale Down Model

A scale down model was constructed to represent the infiltration trench in the field situation. This model was used as a guide to predict the performance of the infiltration trench in full size. All functions shall be maintained to ensure the model is alike the infiltration trench that will be installed on the selected area. The likely performance of a particular design at an early stage of development can be tested without incurring the full expense of a full-sized prototype. A scale down model was constructed with a ratio of 1:2.5 of actual size for each media layer.

Figure 5: Scale down model

3.3.1 Operation of the Infiltration Trench Model

The model was constructed with multi-layer of aggregates and two effluent paths acting as the outlets of the infiltration trench. Soil and water sampling were collected at the nearest location of existed wetland for twice a month just within 2 months. All samples were sealed and labeled properly and placed in the laboratory fridge and incubator. During construction of the trench model, all aggregates were washed rapidly to ensure the dirt and unnecessary matters did not accumulate and trap the aggregates. The Seri Iskandar soil was placed as the top layer in the infiltration trench. Filter cloth were placed on every layer to minimize the sediments accumulated in the samples collected. Grasses from Seri Iskandar were re-planted on the soil and the plantation period was extended for 1 week to encourage the grass to grow well and covered the soil surface. For the addition of calcium oxide, the soil was left for three days after the calcium oxide was added to the soil. Water sample was flow into the infiltration trench with the flow rate of approximately 66.7 mL/s and the effluent rate was measured for both outlets. For the water quality analysis, the sample was directly tested in the laboratory after water sample was collected in order to avoid exposure to surrounding and maintain the quality of the samples.

3.4 Laboratory Analysis

Consist of 2 sections which were soil analysis and water quality analysis. The soil samples collected from the field were analyzed for their particle size distribution, soil pH, infiltration rate and cation exchange capacity (CEC). Soil analysis experiments were conducted based on BS 1337: Part 2: 1990. The water samples collected from the scale down model were analyzed for their nutrients removal, total suspended solids (TSS), chemical oxygen demand (COD), turbidity, and heavy metals. Water quality experiments were conducted based on Standard Method, 2005: 21st Edition. Methodologies for soil and water quality analysis were as follows:

Soil Analysis	Method
Particle Size Distributions (PSD)	Dry Sieving
Infiltration Rate	Falling Head Permeameter Test
Cation Exchange Capacity (CEC)	Gillman and Sumpter Method, 1986
Soil pH	Electrometric Method
Water Quality Analysis	**Method**
Chemical Oxygen Demand (COD)	Reactor Digestion Method
Total Phosphorus	Acid Hydrolyzable
Zinc	Zincon Method
Ammonia Nitrogen	Nessler Method
Lead	Atomic Adsorption Spectrometry (AAS)
Turbidity	Nephelometric Method
E. coli and Fecal Coliform	Fecal Coliform Direct Test
Total Suspended Solids (TSS)	Gravimetric

3.5 Sizing of Actual Design

The design procedures were based on the water quality from the area that contribute to runoff and from expected runoff volume. The design equations may be defined for either case of stormwater quality or quantity control because the volume of water, V_w stored in the individual infiltration practice may be determined from the methods described in MASMA (Volume 4, Chapter 13).

CHAPTER 4
RESULTS AND DISCUSSION

4. ANALYSIS

In this section, all results of soil testing and water quality experiments are presented. The results are as follows:

4.1 Soil Analysis

4.1.1 Particle Size Distribution

Particle size distribution of soil in Seri Iskandar area is presented in Appendix A-1. Figure 7 shows the percentage of gravel, sand, silt and clay based on semi-log graph of particle size distribution as shown in Figure 6.

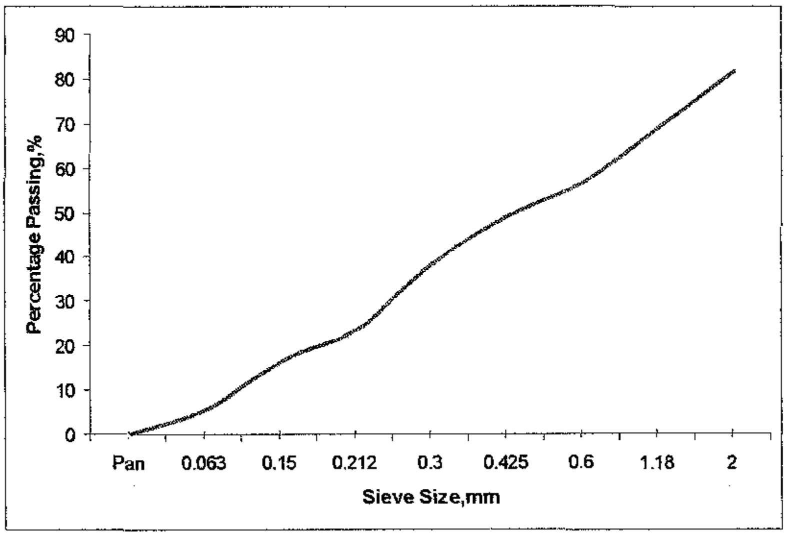

Figure 6: Semi-log graph of particle size distribution

Size (mm)	% finer	
>2	81.82	81.82-81.82 = **0% gravel**
2	81.82	81.82-3.54 = **78.28% sand**
0.05	3.54	3.54-1.06 = **2.48% silt**
0.002	1.06	1.06-0 = **1.06% clay**
0 (Pan)	0	

Figure 7: Percentage of gravel, sand, silt and clay particles

4.1.2 Soil Texture

Percentage of gravel, sand, silt and clay particles:

0% gravel	**78.28% sand**	**2.48% silt**	**1.06% clay**

Soil texture and classification was based on soil textural triangle (Appendix 1-2) recommended by U.S Department of Agriculture and the type of soil is loamy sand. The loamy sands are slightly cohesive when moist, and fragile casts can more readily be formed with them than with sands.

4.1.3 Infiltration Rate, f_c

Infiltration rate of Seri Iskandar soil was determined from falling head permeameter test conducted in the laboratory. The soil sample was kept in vertical cylinder of 78.54 cm^2 cross-sectional area. The test cylinder was kept in a container filled with water. Before the commencement of the test the soil sample was saturated by allowing the water to flow continuously through the sample from the stand pipe (fully saturated condition).

Table 2: Falling head test data

Initial head of water (mm)	600		
Final head of water (mm)	100		
Sample length (mm)	130		
Sample diameter (mm)	100		
Stand-pipe diameter (mm)	7.06		
No. of test	**1**	**2**	**3**
Measured height (mm)	500	.500	500
Time (s)	206	212	208
Average time taken	209s = 0.05806hr		

Table 3: Calculation of infiltration rate

Area of stand-pipe	$39.15mm^2$
Area of sample	$7853.98mm^2$
Coefficient of permeability, k or Design infiltration rate, f_d	20.0mm/hr
Minimum f_c or k	13mm/hr
f_d	$0.5f_c$
Infiltration Rate,f_c	**40.0mm/hr**

4.1.4 CEC Determination by the $BaCl_2$ Compulsive Exchange Method

Determining CEC by compulsive exchange is the method recommended by the Soil Science Society of America because it is a highly repeatable, precise, direct measure of a soil's CEC. CEC was conducted in laboratory with 3 samples from different places in Seri Iskandar. Table 5 below shows the weight difference for every sample after CEC experiments conducted. The calculation on determining the CEC of Seri Iskandar soil was done as shown in Appendix 1-3. The CEC value of the soil was found to be 1.63 meq/100 g soils and classified as a low rate as compared to the standard value of 5 meq/100g for good agriculture soil.

Table 4: Weight of 50ml centrifuge tubes

Centrifuge Tube	Initial Tube Weight (g)	Final Tube Weight (g)	Weight Difference (g)
1	14.6615	37.6360	22.9745
2	14.6900	40.6773	25.9873
3	14.4914	38.9450	24.4536
		Average weight	**24.4718**

4.2 Water Quality Analysis without Addition of Calcium Oxide in Soil

4.2.1 Flow Rate

The mean of flow rate is 0.1466 mL/s was obtained from 1 L influent and 907 mL total sample collected on both effluents (Table 5).

Table 5: Flow rate details

Parameter	Effluent 1*	Effluent 2*
Overall time taken (s)	2630	3487
Time taken for water to start flow out (s)	940	1250
Sample collected (mL)	354	553
Flow rate (mL/s)	**0.1346**	**0.1586**

* Effluent 1 & 2 is indicated on Figure 9

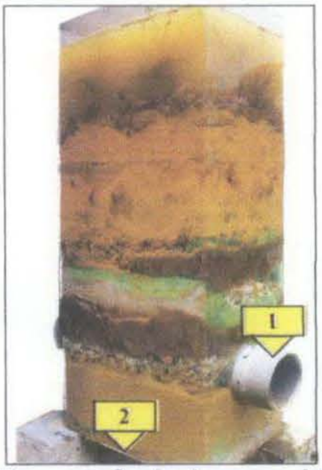

Figure 8: Scale down model

4.2.2 Soil pH

A saturated paste of SI soil sample is mixed with distilled water by having mix portion of one volume of soil to two volumes of distilled water (1:2) (Hershey, 1992). Details of soil pH are shown in Table 6.

Table 6: Soil pH of SI soil sample

Mix portion volume [soil sample (g) : distilled water (mL)]	pH
10:20	5.152
20:40	5.134
30:60	5.115
Average soil pH	**5.134**

4.2.3 Influent and Effluent

4.2.3.1 pH

The mean pH value of influent water sample was between pH 6.610 to 7.945 as shown in Table 7. The readings were consistent over the period of sampling weeks.

Table 7: pH of SI sample

Influent (pH)	6.610
Effluent (pH)	7.517

4.2.3.2 Turbidity

Turbidity in SI swamp has a mean value of 81.7 NTU (Nephelometric Turbidity Unit), which ranges from 81.4 to 81.9 NTU (Table 8). During early stages of the experiment in February, the mean turbidity exceeded 80.0 NTU in February due to rainy period.

Table 8: Turbidity of influent and effluent

Parameter	Exp. 1	Exp. 2	Exp. 3	Average (NTU)
Influent	81.9	81.4	81.9	**81.7**
Effluent	68.0	69.0	68.0	**68.3**

4.2.3.3 Total Suspended Solids (TSS)

The mean TSS in SI swamp for influent is 76.7 mg/L (Table 9). It was high value especially during heavy rained period. The abundant vegetations at the swamp-borders are played an important role of filtering the soil particulates from entering the swamp.

Table 9: Total suspended solids before and after infiltration

Parameter	No. of test	1	2	3	Average (mg/L)
Influent	Weight of pan + filter paper (g)	1.3346	1.3186	1.3389	**76.7**
	Weight of dried pan + filter paper (g)	1.3424	1.3263	1.3464	
	TSS (mg/L)	78.0	77.0	75.0	
Effluent	Weight of pan + filter paper (g)	1.2767	1.3483	1.3277	**19.3**
	Weight of dried pan + filter paper (g)	1.2783	1.3501	1.3301	
	TSS (mg/L)	16.0	18.0	24.0	

4.2.3.4 Chemical Oxygen Demand (COD)

The mean chemical oxygen demand (COD) in SI swamp is 43.0 mg/L, which ranges from 35.0 to 52.0 mg/L (Table 10). In February 2008, a high value of COD was observed in the swamp. This is probably due to the heavy rains which bringing more organics into the swamp.

Table 10: COD value of SI sample

Parameter	Exp. 1	Exp. 2	Exp. 3	Average (mg/L COD)
Influent	52.0	35.0	42.0	**43.0**
Effluent	20.0	23.0	19.0	**20.7**

4.2.3.5 Ammonia Nitrogen

The mean ammonia nitrogen content in SI swamp is 0.2 mg/L, which ranges from 0.18 to 0.22 m/L (Table 11). High concentration of ammonia in January and February 2008 coincided with high TSS contents when the area was having heavy rain. Runoff water which flow into the swamp might be enriched with ammonia-N and this generates the changes in swamp.

Table 11: Ammonia nitrogen of SI sample

Parameter	Exp. 1	Exp. 2	Exp. 3	Average (mg/L NH_3^- N)
Influent	0.22	0.18	0.20	**0.20**
Effluent	0.12	0.11	0.13	**0.12**

4.2.3.6 Total Phosphorus (Acid Persulfate digestion method)

The mean content of phosphate in SI swamp is 0.54 mg/L, which ranges from 0.51 to 0.59 mg/L are shown in Table 12.

Table 12: Total phosphorus in SI sample

Parameter	Exp. 1	Exp. 2	Exp. 3	Average (mg/L PO_4^{3-})
Influent	0.59	0.52	0.51	**0.54**
Effluent	0.39	0.34	0.39	**0.37**

4.2.3.7 *Zinc*

The mean value of zinc content in SI swamp is 0.07 mg/L, which ranges from 0.07 to 0.08 mg/L are shown in Table 13.

Table 13: Zinc content in SI sample

Parameter	Exp. 1	Exp. 2	Exp. 3	Average (mg/L Zn)
Influent	0.07	0.08	0.07	**0.07**
Effluent	0.01	0.03	0.03	**0.02**

4.2.3.8 *Lead*

Repetition on this experiment showed the lead content in SI sample is below detection limit which may vaied from the range of -0.3151 to - 0.1515 ppm for influent and -0.5381 to -0.5084 ppm for effluent. It is classified as "below detection limit".

4.2.3.9 *Total Coliform Bacteria and Fecal Coliform (E. Coli)*

These samples, as well as the other types parameter tested below, are collected from both effluents in 100 mL volumes. The total count is classified in MPN (most probable number) for every 100 mL as shown in Table 14.

Table 14: Total coliform and e-coli of SI sample

Details	Parameter	Large well units	Small well units	MPN
Influent	Total Coliform Bacteria	48	47	**960.6**
	E. Coli	16	4	**23.8**
Effluent	Total Coliform Bacteria	48	24	**328.2**
	E. Coli	1	-	**1**

4.3 Water Quality Analysis with Addition of Calcium Oxide in Soil

4.3.1 Flow Rate

The mean of total flow rate is 0.2711 mL/s, analyzed with 2 L of sample as influent but only 1757 mL total sample collected on both effluents as shown in Table 15.

Table 15: Flow rate details

Parameter	Effluent 1	Effluent 2
Overall time taken (s)	2703	3782
Time taken for water to start flow out (s)	392	613
Sample collected (mL)	735	1022
Flow rate (mL/s)	**0.2719**	**0.2702**

4.3.2 Soil pH

A saturated paste of SI soil sample is mixed with distilled water by having mix portion of one volume of soil to two volumes of distilled water (1:2) (Hershey, D.R. 1992) in order to measure soil pH as shown in Table 16.

Table 16: Soil pH of SI soil sample

Mix portion volume [soil sample (g) : distilled water (mL)]	pH
50:100	7.451
100:200	7.583
150:300	7.462
Average soil pH	**7.499**

4.3.3 Influent

Details of influent analysis are the same as mentioned above (clause 4.2.3)

4.3.4 Effluent

4.3.4.1 pH

The mean pH value in SI sample is 7.945 pH.

4.3.4.2 Turbidity

Turbidity in SI swamp has a mean value of 54.9 NTU (Nephelometric Turbidity Unit), which ranges from 54.7 to 55.1 NTU. During this stage of experiment, the mean turbidity was getting lesser compared to sample without CaO.

Table 17: Turbidity of SI sample

Day 3	Day 5	Day 7	Average (NTU)
55.1	54.7	54.9	**54.9**

Figure 9: Turbidity comparison of sample (left: influent; right: effluent)

4.3.4.3 Total Suspended Solids (TSS)

The mean TSS of effluent is 21.0 mg/L, with values ranging from 20.0 to 23.0 mg/L (Table 18). It was high value especially during heavy rain period.

Table 18: Total suspended solids of SI sample

No. of test	Day 3	Day 5	Day 7
TSS (mg/L)	21.0	20.0	23.0
Average (mg/L)		**21.0**	

4.3.4.4 Chemical Oxygen Demand (COD)

The mean chemical oxygen demand (COD) of the effluent is 21.3 mg/L, which ranges from 19.0 to 23.0 mg/L are shown in Table 19. In Figure 10 is shown the relationship between COD, TSS and turbidity.

Table 19: COD value of SI sample

Day 3	Day 5	Day 7	Average (mg/L COD)
23.0	22.0	19.0	**21.3**

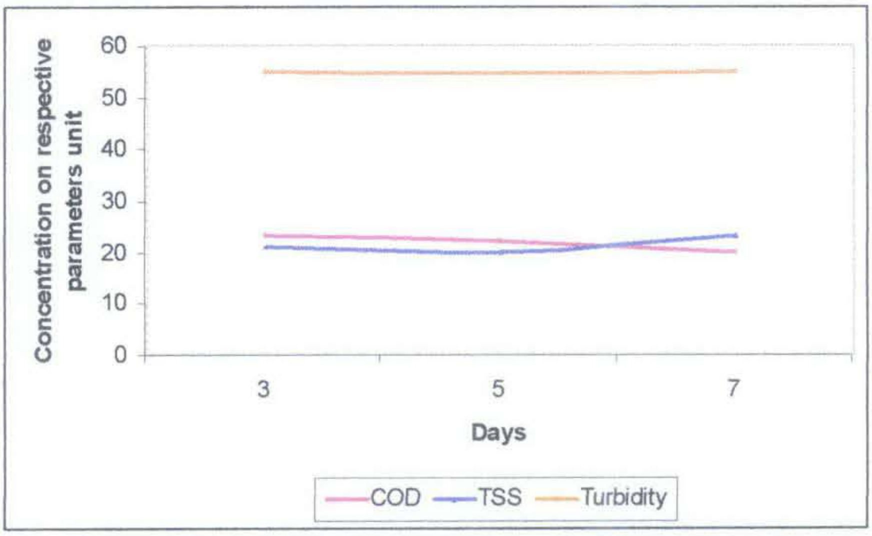

Figure 10: Relationships between COD, TSS and turbidity

4.3.4.5 Ammonia Nitrogen

The mean ammonia nitrogen content in the effluent is 1.05 mg/L. High concentration of ammonia in the sample is due to nutrient content in the soil.

Table 20: Ammonia nitrogen of SI sample

Day 3	Day 5	Day 7	Average (mg/L NH_3^- N)
1.01	1.07	1.06	**1.05**

4.3.4.6 Total Phosphorus

The mean content of phosphate in the sample is 0.60 mg/L, which ranges from 0.58 to 0.63 mg/L which is shown in Table 21.

Table 21: Total phosphorus in SI sample

Day 3	Day 5	Day 7	Average (mg/L PO_4^{3-})
0.58	0.63	0.61	**0.60**

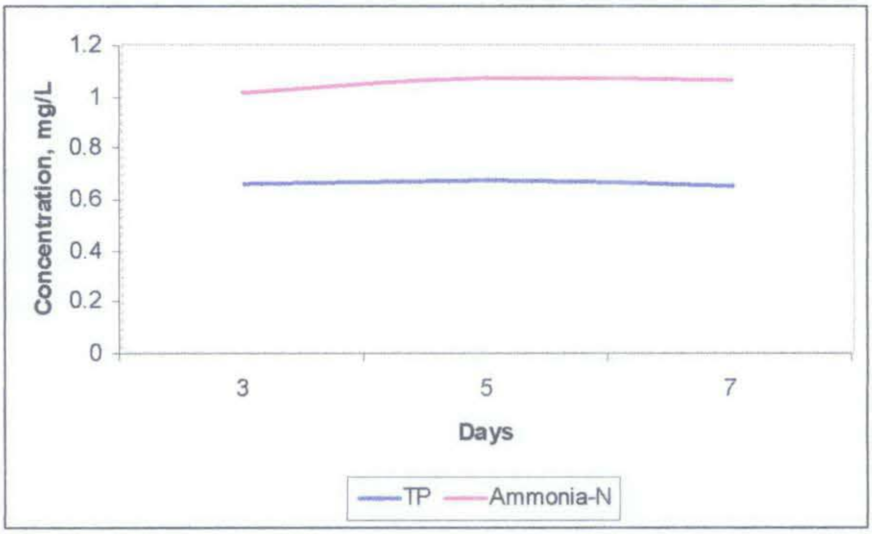

Figure 11: Relationship between total phosphorus and ammonia nitrogen

4.3.4.7 Zinc

The mean value of zinc content in SI swamp is 0.07 mg/L, which range from 0.05 to 0.09 mg/L. In Figure 12 shows the color is similar to the standard indication color of low concentration of zinc.

Table 22: Zinc content in SI sample

Day 3	Day 5	Day 7	Average (mg/L Zn)
0.07	0.05	0.09	**0.07**

Figure 12: Orange color shows the standard color for low concentration of zinc

4.3.4.8 Total Coliform Bacteria and Fecal Coliform (E. coli)

These samples, as well as the other types parameter tested noted below, are collected from both effluents in 100 mL volumes. The total count is classified in MPN (most probable number) for every 100 mL is shown in Table 23.

Table 23: Total coliform and e-coli of SI sample

Parameter	Large well units	Small well units	MPN
Total Coliform Bacteria	48	6	**153.9**
E. coli	1	1	**2**

The results are comparable with the expected percentage removal as shown in Table 24 and 25.

Table 24: Summary on SI influent and effluent (without CaO_3 in soil)

No	Parameter	Influent	Effluent	Standard Class IIB*	Percentage Removal (%)	Expected Percentage Removal (%)
1	pH	6.610	7.517	6-9	-	-
2	Turbidity (NTU)	81.7	68.3	50 NTU	16.40	-
3	TSS (mg/L)	76.7	19.3	50 mg/L	74.84	75 - 90
4	COD (mg/L COD)	43.0	20.7	25 mg/L COD	51.86	65
5	Ammonia Nitrogen (mg/L NH_3-N)	0.20	0.12	0.3 mg/L NH_3-N	40.00	45 – 60
6	Total Phosphorus (mg/L PO_4^{3-})	0.54	0.37	-	31.48	60 – 70
7	Zinc (mg/L Zn)	0.07	0.02	-	71.43	70 - 80
8	Lead (ppm)	**Below detection limit**		-	-	70 - 80
9	Total Coliform (MPN)	960.6	328.2	5000 (counts/100mL)	65.83	90
10	*E. coli* (MPN)	23.8	1	400 (counts/100mL)	95.80	90

Source of expected percentage removal: Schueler, 1987; Yu, 1993; City of Portland, 1995

* Class IIB is for recreational use with body contact
Source: Interim National Water Quality Standards for Malaysia

Table 25: Summary on SI influent and effluent (with CaO in soil)

No	Parameter	Influent	Effluent	Standard Class IIB*	Percentage Removal (%)	Expected Percentage Removal (%)
1	pH	6.610	7.945	6-9	-	-
2	Turbidity (NTU)	81.7	54.9	50 NTU	32.80	-
3	TSS (mg/L)	76.7	21.0	50 mg/L	72.62	75 - 90
4	COD (mg/L COD)	43.0	21.3	25 mg/L COD	50.47	65
5	Ammonia Nitrogen (mg/L NH_3-N)	0.20	1.05	0.3 mg/L NH_3-N	-425 [a]	45 – 60
6	Total Phosphorus (mg/L PO_4^{3-})	0.54	0.60	-	-11.11 [b]	60 – 70
7	Zinc (mg/L Zn)	0.07	0.07	-	0	70 - 80
8	Total Coliform (MPN)	960.6	153.9	5000 (counts/100mL)	83.98	90
9	*E. coli* (MPN)	23.8	2	400 (counts/100mL)	91.60	90

Source of expected percentage removal: Schueler, 1987; Yu, 1993; City of Portland, 1995

* Class IIB is for recreational use with body contact
Source: Interim National Water Quality Standards for Malaysia
[a] Increasing in ammonia nitrogen after addition of CaO
[b] Increasing in total phosphorus after addition of CaO

The removal of TSS and *E. coli* achieved the expected percentage removals which are 72.62% and 91.60%. The increase of ammonia-N and phosphorus may be due to cation exchange between nitrogen and phosphorus in the soil with Ca^{2+} from lime

4.4 Pearson Correlation Coefficient (r) of Various Water Quality Parameters

A positive value for the correlation implies a positive association for instance large value of X tends to be associated with large value of Y and so forth. A negative value for the correlation implies an inverse association for instance large value of X tends to be associated with small value of Y and vice versa. The interpretation of small, medium and large correlation coefficient is shown in Appendix 3-1, Table 31.

4.4.1 Without Addition of CaO in Soil

Table 26: Pearson correlation, r of various parameter of SI sample

	Turbidity	TSS	COD	Ammonia-N	TP	Zinc	pH	Lead
Temp.	0.76	0.98	0.23	0.33	-0.30	-0.76	-0.98	-0.61
Turbidity		0.87	0.81	0.87	0.40	-1.00	-0.87	0.05
TSS			0.41	0.50	-0.11	-0.87	-1.00	-0.45
COD				0.99	0.86	-0.81	-0.41	0.63
Ammonia-N					0.80	-0.87	-0.50	0.54
TP						-0.40	0.11	0.94
Zinc							0.87	-0.05
pH								0.45

Table 27: Pearson correlation, r of various parameter of effluent sample without CaO

	Turbidity	TSS	COD	Ammonia-N	TP	Zinc	pH	Lead
Temp.	-0.50	-0.94	-0.28	0.00	0.50	-1.00	-0.11	0.28
Turbidity		0.19	0.97	-0.87	-1.00	0.50	0.92	0.69
TSS			-0.05	0.33	-0.19	0.94	-0.22	-0.58
COD				-0.96	-0.97	0.28	0.99	0.85
Ammonia-N					0.87	0.00	-0.99	-0.96
TP						-0.50	-0.92	-0.69
Zinc							0.11	-0.28
pH								0.92

4.4.2 With Addition of CaO in Soil

Table 28: Pearson correlation, r of various parameter of effluent sample with CaO

	Turbidity	TSS	COD	Ammonia-N	TP	Zinc	pH	Lead
Temp.	0.87	-0.19	0.69	-0.99	0.00	0.00	-0.65	0.97
Turbidity		0.33	0.96	-0.93	-0.50	0.50	-0.94	0.72
TSS			0.58	0.03	-0.98	0.98	-0.62	-0.42
COD				-0.80	-0.72	0.72	-1.00	0.50
Ammonia-N					0.16	-0.16	0.76	-0.92
TP						-1.00	0.76	0.24
Zinc							-0.76	-0.24
pH								-0.45

4.5 Sizing of Infiltration Trench

4.5.1 Actual Size of Infiltration Trench

1 unit of infiltration trench for every 30,000 m^2 in Seri Iskandar (SI) is **88 m x 10 m and 1.4 m deep**. Calculation on actual sizing details are shown in Appendix 2-1. Below are the details of actual size proposed for SI site.

Parameter	Details
Permanent water covered area (m^2)	90,000
Proposed unit	3
Rainfall intensity; • 5-year ARI & t = 30, $^5I_{30}$ (mm/hr) • 5-year ARI & t = 30, $^5I_{15}$ (mm/hr)	 123 173
Runoff coefficient; • Pre-developed, C_{cs} • Post-developed, C_s	 0.374 0.594
Peak flow; • Pre-developed, $Q_{s\text{-}pre}$ (m^3/s) • Post-developed, $Q_{s\text{-}post}$ (m^3/s)	 0.3834 0.8564
Area of infiltration sump (m^2)	874.34

4.5.2 Scale Down Model of Infiltration Trench

A scale down model was constructed to represent the actual field conditions which included effluent pipe connected to wetland and effluent to groundwater, multi-layer of soil and aggregates. The detail of scale down model is 0.3 m x 0.2 m and 0.6 m deep which consist of 0.15 m deep of Seri Iskandar (SI) soil, 0.30 m deep of clean stone and 0.10 m deep of sand. The scale model is constructed with a ratio 1:2.5 (deep ratio) of actual size for each layer media.

4.6 Discussion

4.6.1 Particle Size Distribution

The sieve analysis was carried out by sieving a known dry mass of sample through the sieves placed one below the other so that the openings decrease in size from the top sieve downwards, with a pan at the bottom of the stack. Table 29 shows the particle-size classification based on USDA.

Table 29: Particle-size classification

	Grain size (mm)			
Name of organization	**Gravel**	**Sand**	**Silt**	**Clay**
U.S Department of Agriculture (USDA)	>2	2 to 0.05	0.05 to 0.002	<0.002

Based on the design criteria for soil suitability (MASMA, Volume 8, Chapter 21) the suitability of soil for infiltration trench, soil with 30% or greater clay content or 40% greater silt/clay content shall not be used. The results above show soil of Seri Iskandar is suitable for the infiltration trench.

4.6.2 Soil Texture and Classification

Soil texture is a term commonly used to designate the proportionate distribution of the different sizes of particles in a soil. It does not include any organic matter. These particles vary in size from those easily seen with the unaided eye to those below the range of a high-powered microscope. According to their size, these particles are grouped separately. The soil textures classification is presented as recommended by the U.S. Department of Agriculture (USDA) which is shown in Appendix 1-2.

4.6.3 Falling Head Permeameter

Based on the design criteria for infiltration rate, f_c MASMA, Volume 8, Chapter 21, the design infiltration rate, f_d is equal to one-half (factor of safety) the infiltration rate, f_c found from the experiment with minimum f_c of 13mm/hr. ($f_d = 0.5f_c$). The general expression for k or fc is:

$$\text{k or } f_c = 2.303 \frac{aL}{At} \log_{10} \frac{h1}{h2}$$

a	=	cross-sectional area of standpipe
A	=	cross-sectional area of soil specimen
t	=	time taken for total head to reduce from h1 to h2
h_1	=	initial height of water
h_2	=	final height of water

The experimental data indicates that the value of f_c of Seri Iskandar soil is 40.0 mm/hr which is higher than the minimum f_c required. Therefore the soil is suitable for infiltration trench.

4.6.4 Cation Exchange Capacity (CEC)

CEC of a soil is simply a measure of the quantity of sites on soil surfaces that can retain positively charged ions (cations) by electrostatic forces. CEC is commonly use in agriculture for maintaining adequate quantities of plant available calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+) in soils. The primary factor determining CEC is the clay and organic matter content of the soil. Higher quantities of clay and organic matter beget higher CEC. Soil CEC can also be use to indicate the capacity of soil for pollutants removal. The larger the CEC, the more cations of the soil can hold. Increasing the organic matter content of any soil will help to increase the CEC since it also holds cations like the clays. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination.

The CEC measured is 1.63 meq/100 g soils indicated the lower rate for loamy sand which the standard value is 5 meq/100g soils. It shows 1.63 meq of metal (cation) can be absorbed equivalently by the dry soils. The low value on CEC soil of Seri Iskandar due to less amount of clay that could retain cation in soil and perhaps the amount of organic matter in the soil is also lesser.

4.6.5 Turbidity, Total Suspended Solids and COD

In general, the water quality in Seri Iskandar (SI) swamp varies with season (dry, normal or wet season) and the location of the sampling. During wet season or heavy rained, discharge of main drain and other waste can contribute to high suspended solid (TSS and turbidity) and ammonia-N to the SI swamp and the effect to the sampling will depend on the level of the flood in the swamp. According to Malaysian Interim Water Quality Standard (INWQS) for Class IIB, standard value of turbidity and TSS is 50 NTU and 50 mg/L but sample collected shows both parameters exceeded the standard values. This finding supported with the clay, silt particles from soil erosion and pieces of decaying vegetation were observed in the water most likely become the main contributing factors to the high suspended solids in the water. However the effectiveness of multi-layer of soils reduced the TSS though with high removal range which is almost 75%. Compared to the soil with addition of CaO, the turbidity and TSS are lesser due to encourage solids binding and flocculation of particles filtered by the soil. Correlation analysis showed that turbidity has a large positive relationship with TSS ($r = 0.87$) of SI sample (Table 26).

Correlation as shown in Table 27 and 28 between TSS and turbidity showed small positive relationship of effluent from soil without CaO ($r = 0.19$) and medium positive relationship of effluent with CaO (r = 0.33). Both positive correlations implied more TSS and turbidity were removed in the infiltration trench. Large positive correlation could be interpreted for both results by required longer period of observation and more amount as influent with high concentration.

The COD results are mainly above the limit. The presence of decaying weeds and submerged vegetation in the water could be the reason for the COD value and this finding bring varies relationship values (r = 0.41, -0.05 and 0.58) between COD and TSS for SI sample and effluent.

Figure 13: High clay and silt particles observed at SI site

4.6.6 Total Phosphorus and Ammonia Nitrogen

Phosphorus and nitrogen are the nutrients that are the limiting factors in aquatic plant growth. Eutrophication might happen in SI swamp but is likely to be very slow because nutrient levels are very low in the influent and effluent water (without CaO). Effluent from soil (with CaO) shows higher level by nutrients. Total nitrogen in Seri Iskandar (SI) sample could be considered low according to Malaysia Interim Water Quality Standard (INWQS) which the standard value is 0.3 mg/L. The percentage ammonia-N removed during the experiment was 40%. Hydraulic retention time (in soil) is one of the most important factors in pollutant removal and it is considered that sufficient retention time can facilitate the purification mechanisms, namely, nitrification–denitrification for nitrogen.

According to INWQS, no standard for total phosphorus is provided. The results indicate that the percentage removal of ammonia-N and total phosphorus decreased with addition of CaO in soil which is -425% and -11.11% and can be relates due to ionic bonding between Ca^{2+} (cation) with PO_4^{3-} and NH^{3-} as anion. Strong ionic bonding between Ca^{2+} and PO_4^{3-} might help retained more anion carried in the sample and restore inside the infiltration trench. But according to Clifford W. (1984), to obtain maximum efficiency action of calcium oxide in soil, longer period is needed in order for the lime to move slowly through the soil. The correlation analysis between COD and nutrients (ammonia-N and phosphorus) indicated large negative relationship (r = -0.96, -0.97 without CaO and -0.80, -0.72 with CaO).

4.6.7 Metals

Zinc and lead are the metal examined in this study. Zinc is classified as nontoxic metal. According to Malaysia Interim Water Quality Standard (INWQS), no standard is provided for Class IIB and it is difficult to classify the zinc concentration. The results in influent and effluent are 0.07 mg/L and 0.02 mg/L respectively. This is equivalent to 71.43% of zinc removal by infiltration. Referring to Table 27 and 28, correlation analysis showed that zinc has a positive relationship with TSS. This means the zinc increased parallel with the TSS. The correlation analysis between zinc and TSS for both effluent samples showed the large positive relationship (r = 0.94 and 0.98).

Lead is classified as toxic metal harmful to humans and other organisms in small quantities. According to INWQS, no standard is provided and the results are below detection limit. There is a very small quantity of lead in SI sample but difficult to detect.

Table 26, 27 and 28 indicate the correlation coefficient between zinc and lead is negative relationship (r = -0.05, -0.28, -0.24).

4.6.8 Soil pH

Soil pH affects the solubility of minerals or nutrients essential for plant growth. Many plants (grass and lawn) could tolerate pH ranges between 5.2 and 7.8 and most turf grasses will not grow well in highly acid soils. Hence, soil pH control is important for the grass to grow well in order to control runoff, reduce turbidity and TSS. The abundant vegetations at the swamp–land borders are believed to play an important role of filtering the soil particulates from entering the swamp. pH recorded on this experiment is between 1 and 2 weeks to ensure and allow the lime to move deeper through the soil. Suitability of the CaO application depends on three main factors; neutralizing value, fineness of the lime and soil texture. The soil pH of SI is 5.134 and can be classified as strongly acid which range between 5.1 – 5.5 (Department of Primary Industries and Water, US, 2008). By introducing lime in SI soil sample, the pH increased up to 7.499 and thus can be classified as slightly alkaline which is suitable for the grass.

4.6.9 Functions of CaO (lime)

Lime is primarily a soil amendment or conditioner and not a fertilizer. Lime performs several important functions for instance it corrects soil acidity and pH; furnishes important plant nutrients; calcium and magnesium; promotes availability of major plant nutrients. Calcium acts as a regulator and bringing about desirable range of many plant nutrients and some of them is phosphorus and zinc. The most important functions are it makes the soil becomes more porous, increases air circulation and enable the soil to absorb and hold moisture (Clifford, 1984). Best practices on lime application on the soil at least 2.5 t/ha to get good response and the upper limit for one application is 7.5 t/ha.

But in this laboratory studies, amount of lime applied was between 15 g and 45 g for soil area in the model of 0.06 m^2.

4.6.10 Recommendation on Infiltration Trench Design

The potential for failure of infiltration practices due to clogging by sediments is of great concern. A temporary stormwater bypass should be constructed prior to construction of the infiltration trench. The geotextile filter cloth is to be used as lining on sides of infiltration trench. The soil of Seri Iskandar is to be used as upper layer for the growth of grass and one layer below occupied with small size gravels should be replaced annually or more frequently with introduction of replaceable sediment barrier in between of soil and small gravel layers. A few of corrugated metal pipe (CMP) may be used as horizontal drainage at the deeper clean stone layer (Fairfax County Soils Office, 1991). Holes in the CMP will allow input water to be distributed along the length of the trench. The CMP also provides storage and also traps the sediments through the pipes.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Results from the studies showed that Seri Iskandar has the potential to developed engineered wetlands connected to 3 units of infiltration trenches. 1 unit of infiltration trench will be covered up to 30,000 m^2 of water area in the specified locations. The size of the proposed infiltration trench is 88 m x 10 m and 1.4 m deep.

These results of the soil analysis indicated the soil in Seri Iskandar is suitable for the infiltration trench. The soil contains 0% gravel, 78.28% sand, 2.48% silt and 1.06% clay. The experimental data show the infiltration rate as 40.0 mm/hr which higher than minimum requirement by MASMA of 13.0 mm/hr. The primary factor determining CEC is the clay and organic matter content of the soil. In this case, the CEC value is equivalent to 1.63 meq of cations that can be absorbed by 100g of dry soils of Seri Iskandar. This value is relatively low due to low clay content of the soil.

From the summary on influent and effluent of the model, the percentage removal for the parameter tested can be concluded the percentage removal efficiency varies in descending order from >70% TSS, >50% COD, >15% turbidity and >30% nutrients. The maximum efficiency with calcium oxide addition would need more time in order for the lime moves slowly through the soil. Addition of CaO promoted soil to become porous increase the soil pH and soil moisture.

Further studies are required to monitoring the trench performance on site. The trench performances in the long run particularly the clogging effects need long term study.

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APPENDICES

APPENDIX 1-1

Particle size distribution data of Seri Iskandar

Table 30: Seri Iskandar particle size distribution data

Sieve Size (mm)	Weight Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
2	100	18.18	18.18	81.82
1.18	70	12.73	30.91	69.09
0.6	70	12.73	43.64	56.36
0.425	40	7.27	50.91	49.09
0.3	60	10.91	61.82	38.18
0.212	80	14.55	76.36	23.64
0.15	40	7.27	83.64	16.36
0.063	60	10.91	94.55	5.45
Pan	30	5.45	100.00	0.00
Total	550.00			

APPENDIX 1-2

Soil textural triangle

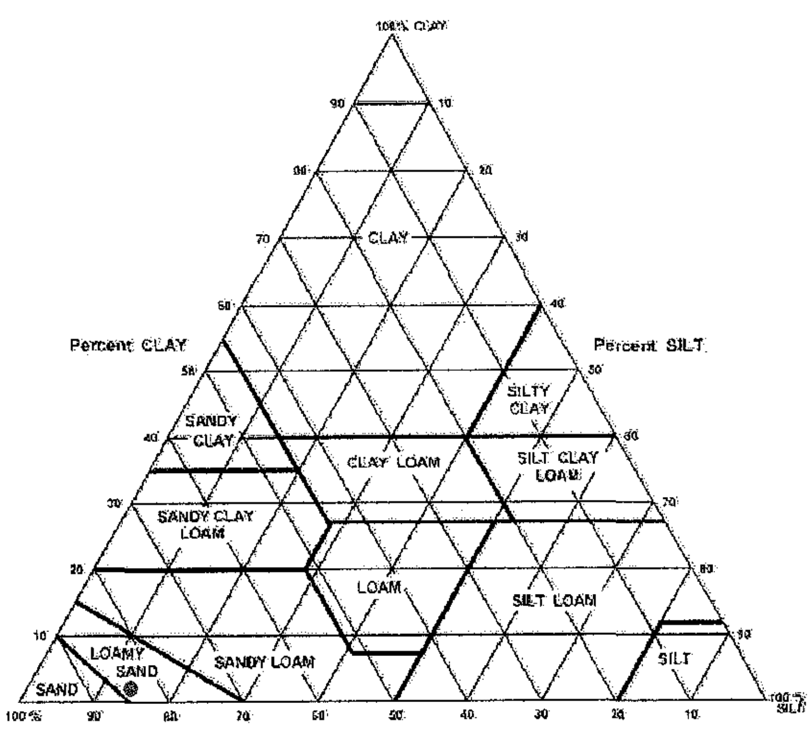


Figure 14: Soil textural triangle

APPENDIX 1-3

Cation Exchange Capacity (CEC)

Solutions control:

1. Slurry pH = 8.16
2. Conductivity of 1.5mM $MgSO_4$ solution = 95.4 x 10^{-6} Siemens cm^{-1}
3. Temperature of 1.5mM $MgSO_4$ solution = 23.4°C

Calculations of CEC:

1. **Total solution (ml) [assume 1ml weighs 1g];**

   = tube weight difference – 2g [weight of soil used]

   » 24.4718 – 2 = 22.4718 ml

2. **Magnesium in solution, not on CEC (meq);**

   = total solution (ml) x 0.003 (meq/ml) [1.5mM $MgSO_4$ has 0.003 meq/ml]

   » 22.4718 ml x 0.003 meq/ml = 0.0674 meq

3. **Total magnesium added (meq);**

   = 0.1 meq [meq in 10ml of 5mM $MgSO_4$] + meq added in 0.1M $MgSO_4$ [ml of 0.1M $MgSO_4$ x 0.2 meq/ml (0.1M $MgSO_4$ has 0.2 meq/ml)]

   » 0.1 meq + (0 ml x 0.2 meq/ml) = 0.1 meq

4. **CEC (meq/100g);**

   = (3 – 2) x 50 [total Mg added – Mg in final solution; 50 is convert from 2g of soil to 100g]

   » (0.1 – 0.0674) x 50 = 1.63 meq/100g soil

APPENDIX 2-1

Sizing of actual infiltration trench

- Permanent water covers an area about 90,000 m^2 out of the total wetlands area of 160,000 m^2

- Propose 3 units of infiltration trenches near to the proposed engineered wetland. Calculation on 1 unit of infiltration trench is covered up to 30,000 m^2 of water cover area. (Based on MASMA, Volume 8, Chapter 21, maximum area cover is 4 hectares)

Catchments area	=	30,000 m^2 = 3 ha
Soil type	=	Loamy sand
Infiltration capacity, (f_c)	=	0.04 m/hr

Following assumptions are made:

1. Time of concentration pre-development, t_{cs} = 30 minutes
2. Time of concentration post-development, t_c = 15 minutes
3. Porosity of fill materials, n = 0.35
4. Maximum storage time, t_s = 24 hours
5. Effective filling time, t_F = 2 hours

<u>Step 1</u>

Determine the initial characteristics infiltration sump

i). From equation 21.1 (MASMA, Volume 8, Chapter 21)

$$\text{Maximum allowable depth, } (d_{max}) = \frac{f_c T_s}{T_s} = \frac{(0.021)(24)}{0.35} = \mathbf{1.44\ m}$$

ii). Proposed depth, (d_t) = **1.4 m**

iii). Design infiltration rate, $(f_d) = 0.5f_c = (0.5)(0.04) =$ **0.02 mm/hr**

<u>Step 2</u>

Determine Q5-year for the pre-developed and post-developed conditions.

i). Rainfall intensity (refer MASMA, Volume 4, Chapter 13, Table 13.A1):

$$\ln(I) = a + b[\ln(t)] + c[\ln(t)]^2 + d[\ln(t)]^3$$

- For Ipoh, 5 year ARI and t = 30 minutes

a = 5.0007	b = 0.6149	c = -0.2406	d = 0.0127
a = 5.007	b[ln(t)] = 2.0914	c[ln(t)]^2 = -2.7833	d[ln(t)]^3 = 0.4997

ln I = 4.8085 $\therefore {}^5I_{30}$ = **123 mm/hr**

- For Ipoh, 5 year ARI and t = 15 minutes

a = 5.0007	b = 0.6149	c = -0.2406	d = 0.0127
a = 5.007	b[ln(t)] = 1.6652	c[ln(t)]^2 = -1.7644	d[ln(t)]^3 = 0.2522

ln I = 5.1537 $\therefore {}^5I_{15}$ = **173 mm/hr**

ii). From design chart 14.3 (MASMA, Volume 5, Chapter 14)

Runoff coefficient:

- Pre-developed, C_{cs} = **0.374** (category 8; cultivated fields with good growth sand strata)
- Post-developed, C_c = **0.594** (category 7; park lawns and meadows)

Step 3

Determine design volume enters the trench (V_w) that requires reducing in peak flow to pre-developed conditions

i). Peak flow,

$$Q_s = \frac{C.{}^5I_D.A}{360}$$

- Pre-developed, $Q_{s\text{-pre}} = \frac{(0.374)(123)(3)}{360} = \mathbf{0.3834\ m^3/s}$
- Post-developed, $Q_{s\text{-post}} = \frac{(0.374)(173)(3)}{360} = \mathbf{0.8564\ m^3/s}$

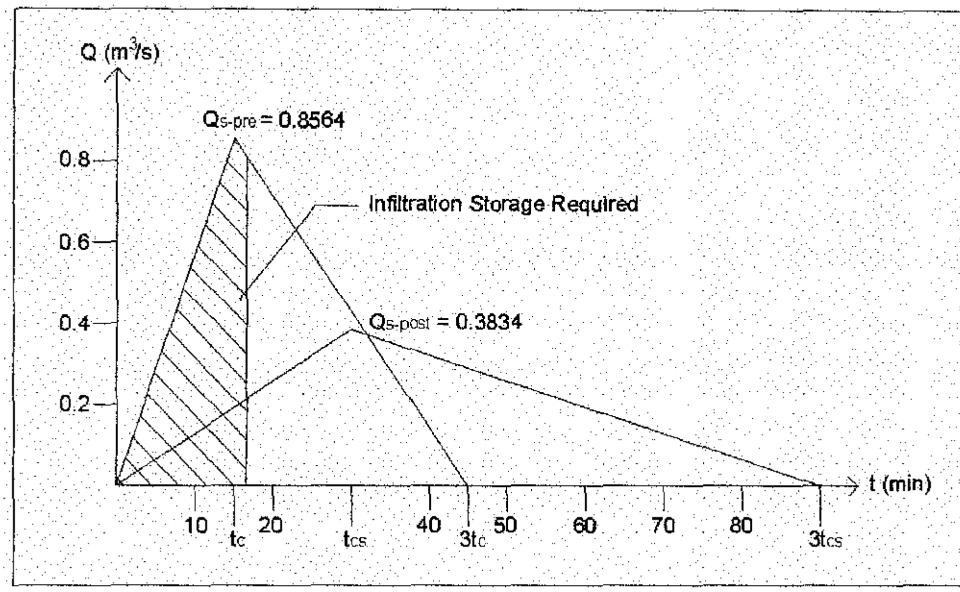


Figure 15: Determination of design volume V_w for the trench

$$V_w = [0.5(15x60)x0.8564] + [0.5x(1.57x60)x(0.8564 + 0.8)]$$

$$= \mathbf{463.4\ m^3}$$

Step 4

Estimate the dimension of the proposed trench using Equation 21.4 (MASMA, Volume 8, Chapter 21), the area of the infiltration sump can be estimated

$$A_t = \frac{V_w}{nd_t + f_d T_f}$$

$$= \frac{463.4}{(0.35x1.4) + (0.02x2)}$$

$$= 874.34\ m^2$$

$\therefore$Thus, the proposed of 1 unit infiltration trench for every 30,000 m^2 is **88 m x 10 m and 1.4 m deep**.

APPENDIX 3-1

Calculation of Pearson correlation coefficient (r) of various water quality parameters

Pearson correlation coefficient, r

$$\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

Where;

x, y = variables

$\bar{x}, \bar{y}$ = average value

Example:

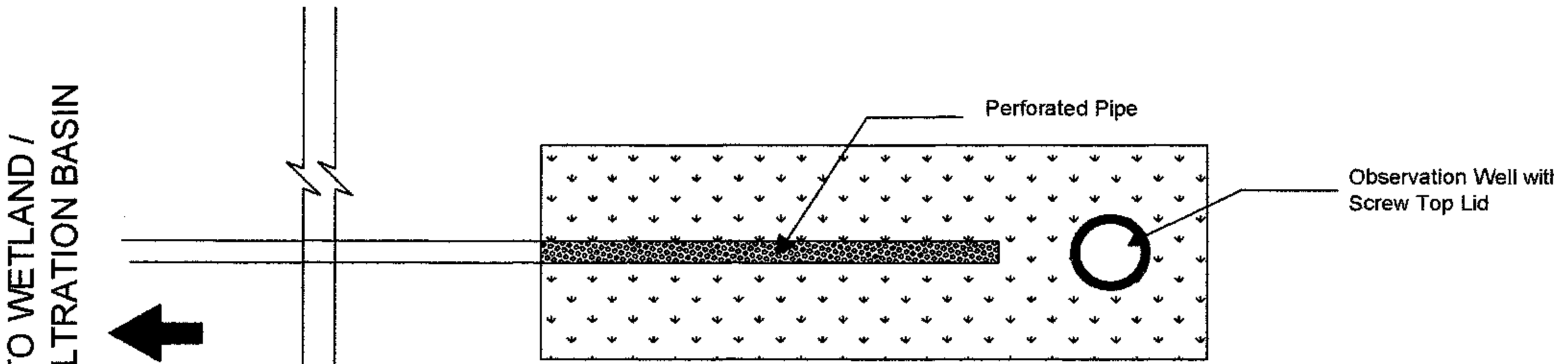
Temperature (x variable)	Turbidity (y variable)
23.5	55.1
23.2	54.7
23.2	54.9
$\bar{x} = 23.3$	$\bar{y} = 54.9$
$x - \bar{x}$	**$y - \bar{y}$**
0.2	0.2
-0.1	-0.2
-0.1	0

$$= \frac{(0.2)(0.2)+(-0.1)(-0.2)+(-0.1)(0)}{\sqrt{\left[(0.2)^2+(-0.1)^2+(-0.1)^2\right]\left[(0.2)^2+(-0.2)^2\right]}}$$

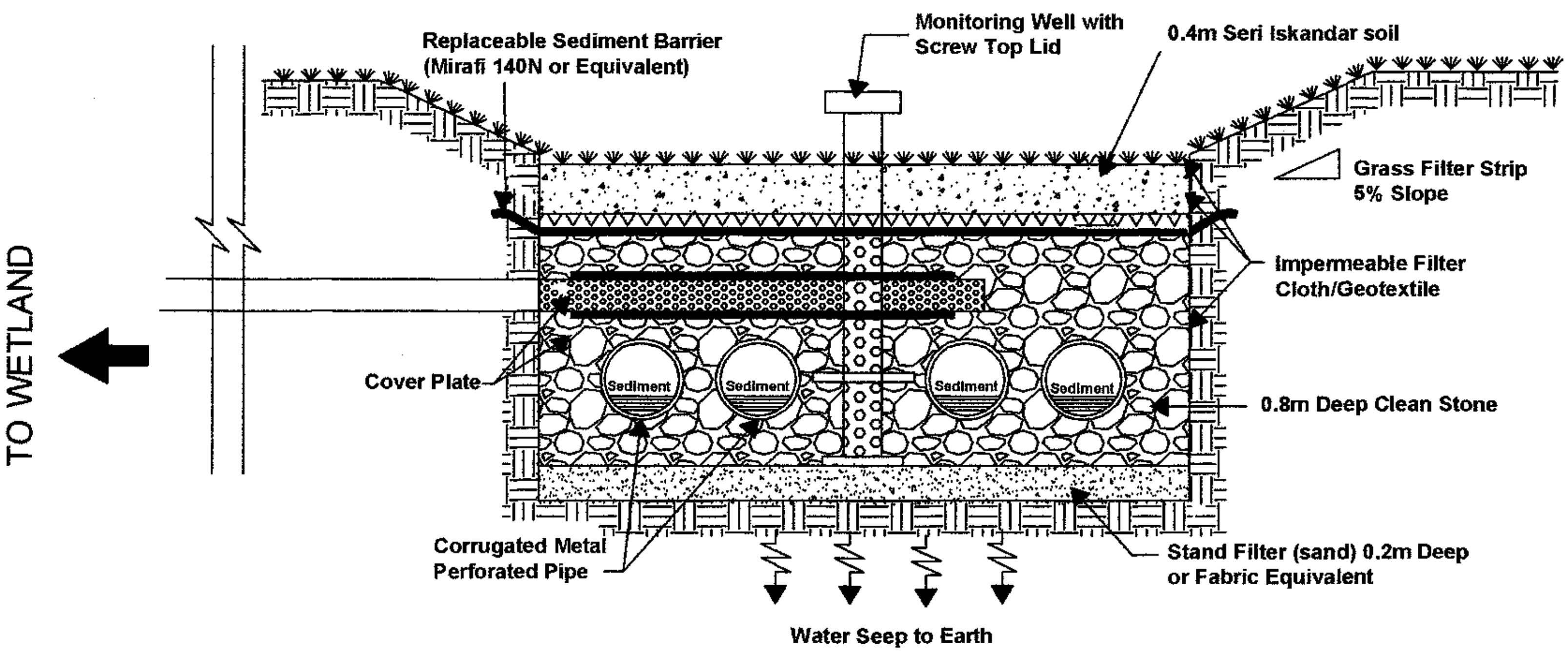
r = 0.866

Table 31: Interpretation of correlation coefficient

Correlation	Negative	Positive
Small	-0.3 to -0.1	0.1 to 0.3
Medium	-0.5 to -0.3	0.3 to 0.5
Large	-1.0 to -0.5	0.5 to 1.0



TOP VIEW



SIDE VIEW

NOTE:

1. ALL DIMENSIONS AND DEPTH SHALL BE ALLOCATED LATER

UNIVERSITI TEKNOLOGI PETRONAS

FINAL YEAR PROJECT 2 (FYP 2)

NO.	DATE	DETAILS

PROJECT:

USE OF INFILTRATION TRENCH AS A COMMUNITY RETENTION FACILITY IN BANDAR SERI ISKANDAR

DRAWING TITLE:

TYPICAL SECTION OF INFILTRATION TRENCH WITH CONCENTRATED OUTPUT AND SEDIMENT CONTROL

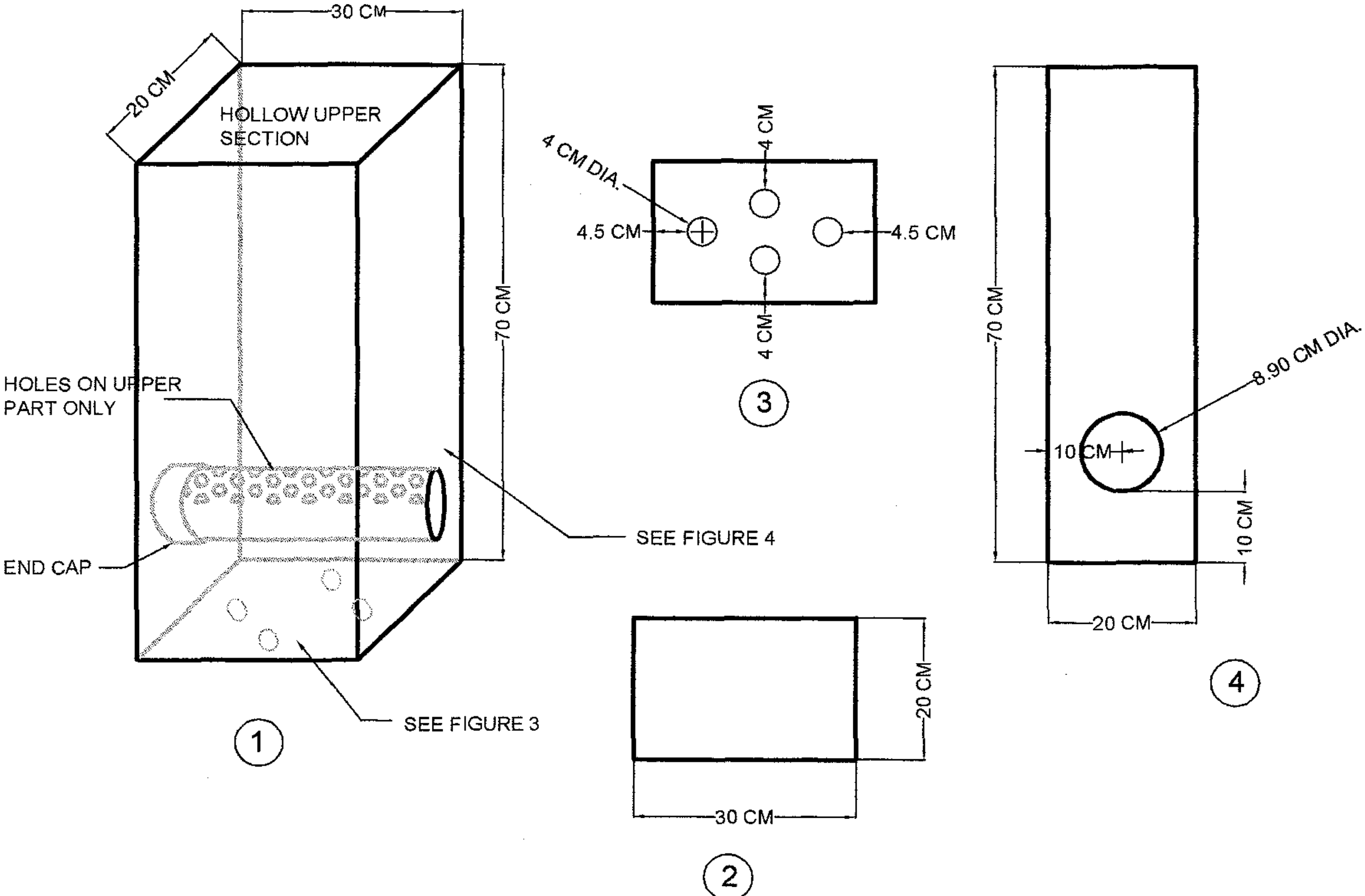
SCALE: NOT TO SCALE

DESIGNED BY: FARID

CHECKED BY: DR. NASIMAN

DATE: OCT. 2007

REFERENCE: B



NOTE

1. MODEL IN FIGURE 1
2. 1 UNIT BASE IN FIGURE 2 WITHOUT HOLES

UNIVERSITI TEKNOLOGI PETRONAS

FINAL YEAR PROJECT 2
(FYP 2)

NO.	DATE	DETAILS

PROJECT:

USE OF INFILTRATION TRENCH AS A COMMUNITY RETENTION FACILITY BANDAR SERI ISKANDAR

DRAWING TITLE:

SCALE DOWN MODEL OF INFILTRATION TRENCH

SCALE: NOT TO SCALE

DESIGNED BY: FARID

CHECKED BY: DR. NASIMAN

DATE: FEB 2008

REFERENCE: A