EROSION AND SEDIMENT YIELD EVALUATION IN REGARDS OF EROSION SEDIMENT CONTROL PRACTICES (ESCP)

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"IN THE NAME OF GOD, THE MOST GRACIOUS, THE MOST COMPASSIONATE"

Alhamdulillah, I thought the time to write this section would never arrive, and often I even wondered why I'd ever decided to start on my Masters. Now I've reached the end and it is time to express my gratitude to all the people who have encouraged me to finish this work. For sure, the fulfillment of this research is due to the cooperation of many people. Therefore I can only hope that I mention you all and those who I forget at this moment please forgive me and think that despite this lapse I really do appreciate you all

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LIST OF ABBREVIATIONS

AGNPS	Agricultural Non-Point Source Pollution Model
ANSWERS	Areal Nonpoint Source Watershed Environment Response Simulation
ARI	Average Recurrence Intervals
ASML	Above Sea Mean Level
BLIA	Bayan Lepas International Airport
BMP	Best Management Practices
CREAMS	The Chemical Runoff and Erosion from Agricultural Management Systems model
DID	Department of Irrigation and Drainage
DOA	Department of Agricultural Malaysia
DOE	Department of Environmental
ECP	Erosion Control Plan
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan (EMP)
EPA	Environmental Protection Agency
ESCP	Erosion Sediments Control Practices
EWRC	Environment Waikato Regional Council
F.R.	Forest Reserves
FAO	Food and Agriculture Organization of the United Nation
FRIM	Forest Research Institute Malaysia
GIS	Geographic Information Systems
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
LESTARI	The Institute for Environment and Development
MDRN	Missouri Department of Natural Resources

MMS	Malaysia Meteorological Services Department
MPPP	Majlis Perbandaran Pulau Pinang
MSC	Multimedia Super Corridor
MSLE	Modified Soil Loss Equation
MSMA	Manual Saliran Mesra Alam
MUSLE	Modified Universal Soil Loss Equation
NC DEHNR	North Carolina Department of Environment, Health and Natural Resource
NSW	New South Wales
NWQSM	National Water Quality Standard of Malaysia
PERFECT	The Productivity, Erosion and Runoff, Functions to Evaluate Conservation Techniques
RMSE	Root Mean Square Error
RUSLE	Revised Universal Soil Loss Equation
SIR	Storie Index Rating
SWAT	Soil and Water Assessment Tools
TIA	Traffic Impact Assessment
TSS	Total Suspended Solids
UNEP/GPA	United Nations Environment Programme/Global Programme of Action
USDA	United States Department of Agriculture
USEPA	United State Environment Protection Agency
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project
WQI	Water Quality Index

LIST OF SYMBOLS

SYMBOLS	DESCRIPTIONS
Hx	Measured height
A	Erosion rate for RUSLE
B	Weir base width
C_{SCW}	Constant for Rectangular Sharp Crested Weir
E	Rate of erosion for MUSLE
EI	Rainfall Erosivity index
H	Head above weir crest excluding velocity head
Hc	Height of the weir until the bottom of the opening
I_{30}	Rainfall intensity for 30 minutes
IA	Fraction of impervious area
K	Soil Erodibility Factor
LS	Slope Length Factor
m	Exponent
n	Number of end contractions for weir
OM	Organic Matter
P	Annual rainfall
Q	Weir discharge
qc	Erosion Rate for MSLE
Q_{P}	Peak runoff rate per event
q_P	Peak flow rate
R	Rainfall Erosivity
RO	Total runoff rate per event for MUSLE
S	Soil structure code
T	Sediment yield per storm event
TSS	Total Suspended Solid
V	Volume of runoff
VM	Vegetation management factor
α	Constant for MUSLE
Ψ_2	Constant for MUSLE

PENILAIAN HAKISAN DAN HASILAN ENDAPAN BERKAITAN DENGAN AMALAN KAWALAN HAKISAN ENDAPAN

ABSTRAK

Tapak projek pembinaan adalah terdedah kepada risiko hakisan air disebabkan oleh aktiviti kerja tanah yang giat dijalankan. Bagi tapak pembinaan ini, didapati cerun bukit terdedah begitu sahaja tanpa sebarang tanaman dan sistem pemparitan yang sedia ada pula dipenuhi dengan hasilan endapan. Hasilan endapan ini akan menyebabkan peningkatan ketara bagi beban endapan ke kawasan tadahan sungai manakala teknik pembinaan yang digunakan turut menyumbang kepada pencemaran di kawasan sekeliling tapak pembagunan ini. Hakisan yang berlaku di tapak kajian adalah disebabkan oleh aktiviti penebangan pokok, keamatan lebat hujan yang tinggi dan juga kegagalan kolam endapan untuk berfungsi dengan berkesan.Kajian ini dijalankan untuk menilai hakisan dan hasilan endapan yang disebabkan oleh hujan lebat dan air larian di tapak kajian yang terletak di Sungai Ara, Pulau Pinang, Malaysia. Jumlah kehilangan tanah ditentukan dengan menggunakan kaedah permodelan empiric bagi hakisan iaitu Revised Universal Soil Loss Equation (RUSLE), Modified Soil Loss Equation (MSLE) dan Modified Universal Soil Loss Equation (MUSLE) dan juga berdasarkan kepada sampel yang telah diambil di kawasan kajian. Keputusan kajian menunjukkan kadar hakisan dan enapan adalah tinggi bagi kawasan kajian ini. Kadar hakisan tahunan tertinggi adalah direkodkan di Lubang Jara 19 melalui persamaan RUSLE iaitu sebanyak 7,772 ton/hektar/setahun. Dengan menganalisa sampel yang diambil di Kolam Endapan B, keputusan beban enapan terampai (TSS) yang diperolehi melalui aliran masuk ke kolam enapan adalah diantara 352 mg/l sehingga 5031 mg/l manakala di aliran keluar pula mencatatkan nilai diantara 309 mg/l ke 5375 di mana kesemua nilai ini diklasifikasikan sebagai Kelas V bagi Jabatan Alam Sekitar Malaysia. Walaubagaimanapun, berdasarkan sampel yang telah diambil, didapati kadar kehilangan tanah adalah jauh berkurangan jika dibandingkan dengan kaedah pengiraan kehilangan tanah.

EROSION AND SEDIMENT YIELD EVALUATION IN REGARDS OF EROSION SEDIMENT CONTROL PRACTICES (ESCP)

ABSTRACT

During construction, large areas of soil are exposed to the risk of water erosion due to earthworks activities. Bare slopes and drains choked with sediment can often be observed on construction sites. This erosion may result in a significant increase in sediment loads to receiving waters and the construction techniques used on site can cause offsite contamination. Erosion from the study area occurred due to the removal of the vegetation cover, high rainfall intensity and the failure of the sediment basins to function effectively. The present study aims to evaluate the erosion and sediment yield due to storm rainfall and runoff on a construction site located at Sungai Ara, Penang state of Malaysia. The soil loss was evaluated by using empirical erosion modelling namely the Revised Universal Soil Loss Equation (RUSLE), Modified Soil Loss Equation (MSLE) and Modified Universal Soil Loss Equation (MUSLE) and from the water samples taken at the study area. Results showed that large amount of sediment has being eroded from the study area. The highest annual erosion rates estimated is by using the RUSLE equation is recorded at Borehole 19 with soil loss of 7,772 tons/ha/y. By analyzing the samples collected at the Pond B, the TSS value is noted from 352 mg/l to 5031 mg/l at Inflow and 309 mg/l to 5375 mg/l at Outflow which fall under the Class V according to the classification by Department Of Environment in Malaysia. However, the results shows that the measured soil loss was very much smaller compared to the calculated soil loss.

CHAPTER 1

INTRODUCTION

1.0 General

In Malaysia, township and urban areas were rapidly developed. By the 1970s, urbanization and industrialization touched most of the country. As a result, land became an increasingly scarce resource in many of the developed areas such as Kuala Lumpur, Petaling Jaya, Penang and Johor Bahru. In the last ten years, intensification of industrialization, housing and construction, the development of tourism and agriculture, and greater urbanization have led to greater pressure on land. Even land reclamation (in some coastal areas) has not eased the pressures as demand for land remains high. As such, developers have turned to developing hill land (Ibrahim et al., 2002).

Hill land, which is located on the upstream of drainage basins, is extremely sensitive to human induced environmental changes (Ibrahim et al., 2002). Even small changes caused by forest clearance could lead to severe damage on natural systems such as flora, fauna, climate, hydrology and soils (Ibrahim et al., 2002). Rapid development of the foothills, slopes and hill tops since the 1970s, have resulted in depletion of forest, destruction and deterioration of water catchments, changes in micro climatic elements, endangering of wild life, high rates of soil erosion, increased incidence of landslide and rock-falls, high rates of sedimentation leading to rapid siltation and reduce capacities of rivers leading to an increased frequencies and magnitudes of downstream flooding (Chan, 1998), besides the pollution of the river water (Ibrahim et.al. 2002).

In line with vision 2020, Malaysia has undergone tremendous land development, especially in the development of infrastructures. Although these activities form an integral part of the socio economic advancement in this country, their success is indeed limited, if insufficient attention is paid to the adverse effects of land development particularly on soil erosion issues (Faisal and Tew, 2006).

As all of us are aware, degradation of the non-renewable soil resource by accelerated (human sinduced) erosion is a serious environmental problem (Sutherland, 1989). Accelerated erosion results from agriculture, mining and any activities related to urbanization, such as building construction, utility development and road building (Wolman and Schick, 1967; Anderson and McCall, 1968; Guy and Jones, 1972; Reed, 1980). Goldman et al. (1986) stated that when land is disturbed for construction, road building, mining, logging, landscaping or other activities, the soil erosion rate increases from two to forty thousand times. Construction areas are of particular concern because they are considered to be one of the most severe modifications of the human landscape (Meyer, et al., 1971). It was reported by Fifield (2008) and North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR) (1993) that erosion rates at construction sites may be ten to twenty times greater than for undisturbed lands. Over a short period of time, construction sites can contribute more sediment to receiving streams than was previously deposited over several decades (NC DEHNR, 1993).

On the other hand, studies in the Auckland region shows that construction sites yield ten to hundred times more sediment than untouched land (Associated Rockery Contractors (ARC) 1992; The Auckland Regional Authority (ARA) and Auckland Regional Water Board (ARWB), 1983; Swales 1989).

In engineering perspective, soil erosion is defined as a general destruction of soil structure by the action of water and wind (Beasley, 1972). It is essentially the smoothing process with soil particles being carried away, rolled and washed down by the force of gravity (Morgan, 1993). Rainfall is the prime agent of soil erosion, whereby the rain's runoff will scour away, loosen and break soil particles and then carry them away, thus leaving behind an altered bare earth surface (Wischmeier et al., 1978). In the case of a slope, an altered bare surface of the slope with the formation of sheet, rill and gully erosion features will cause instability of the slope. This situation will gradually cause slope failure or landslide as commonly known. The soil erosion phenomenon is basically the function of the erosivity of the rainfall and the erodibility of the soil (Roslan, 1992). In other words, when the rainfall acts upon the earth surface, the amount of the soil erosion loss will basically depend upon the combination of the strength and the magnitude of the rainfall to cause the erosion process and the ability of the soil to withstand the rain itself (Hudson, 1979).

1.1 Background

The Penang state of Malaysia has made remarkable progress in its economic development over the past few decades. The diversification of the economy from agricultural sector into manufacturing sector has meant rapid urbanization and industrialization. Bayan Baru and Bayan Lepas Industrial Estates were established since 1969 (Penang Development News, 2003) to boost the economic growth in the island. George Town has been extended and became a regional hub for Northern Region of Malaysia. Following the impetus for economic expansion, comes the related demand for manpower especially in the fields of manufacturing and commercial businesses. Since then, the influx of population from other states to Penang has contributed to the greater growth of its population.

Increasingly, land is a scarce resource which is much sought after in Penang Island, Malaysia. This is because Penang is largely made up of steep topography and much of the lowland areas are already been developed as shown in Figure 1.1 and Figure 1.2.

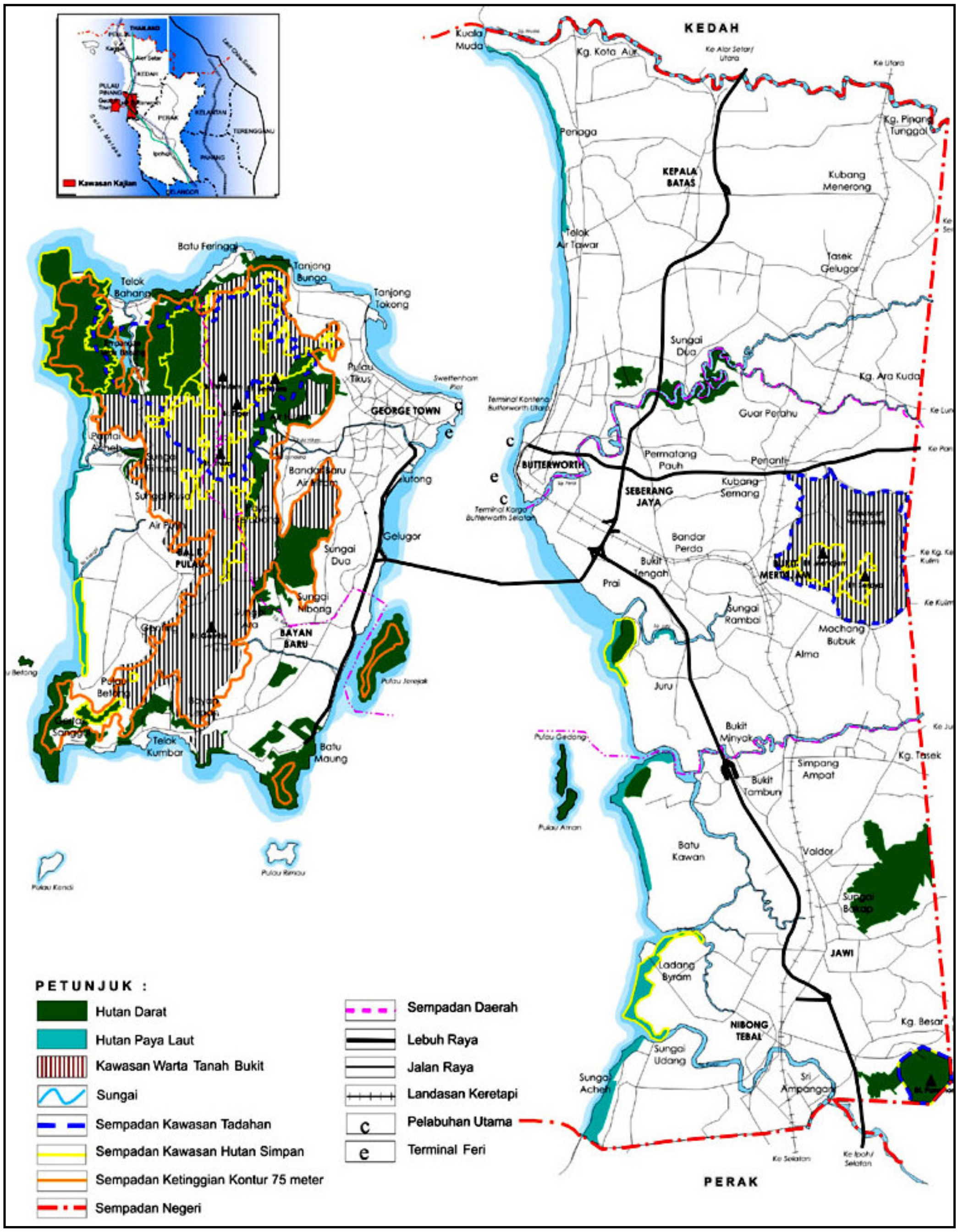

Figure 1.1: Physical Topographical of Penang (Penang Structure Plan 2005 – 2020)

Source: Penang Structural Plan, 2005 – 2020

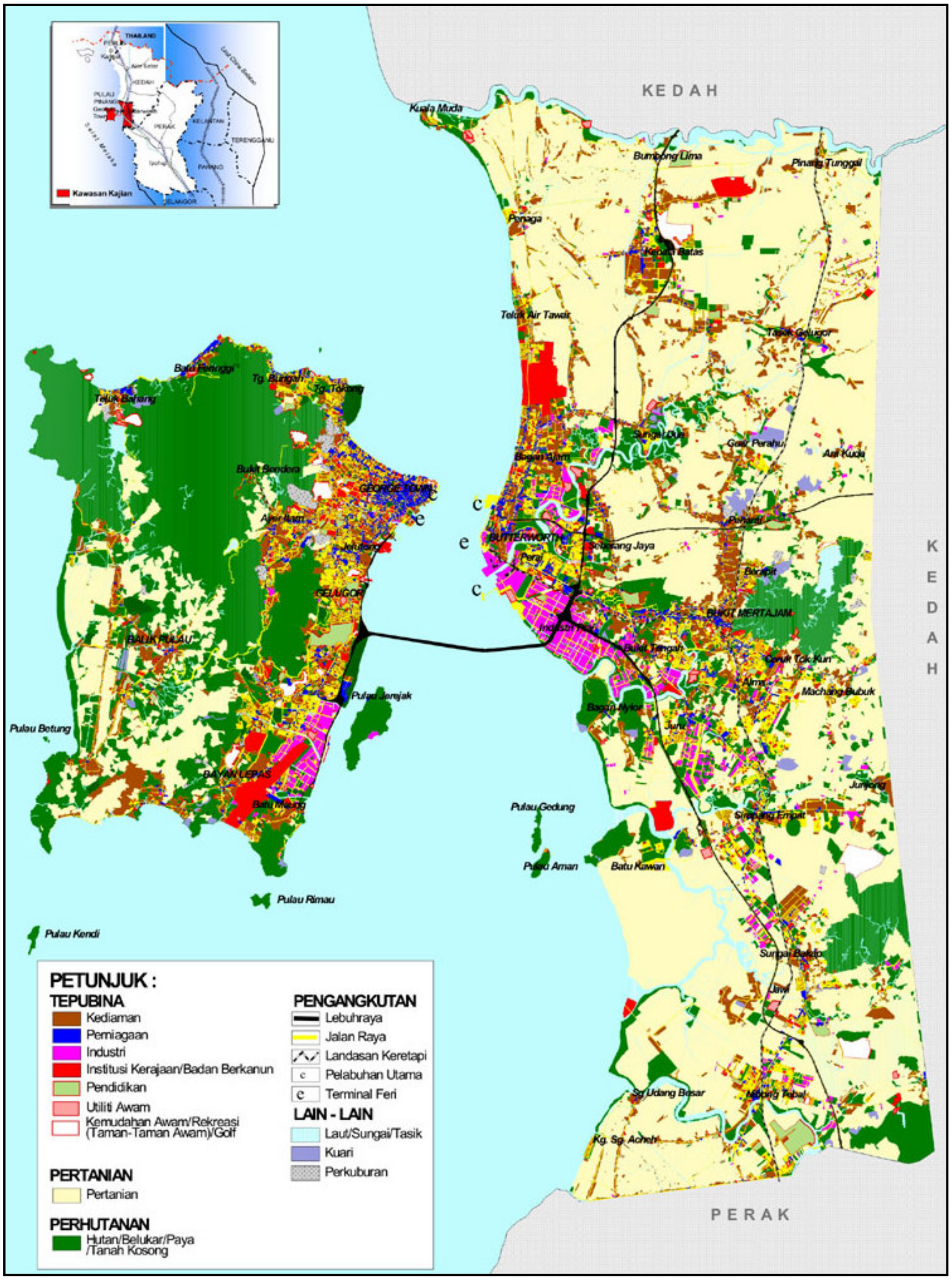

Figure 1.2: Landuse in Penang Year 2004 (Penang Structure Plan 2005 – 2020)

Source: Penang Structural Plan, 2005 – 2020

Penang is one of the many rapidly industrializing states in Malaysia with a largely urban populace. In recent decades, efforts at industrialization and the development of other economic sectors have been intensified, leading to greater urbanization and greater pressures on land (Chan, 1998). The rapid urbanization and industrialization has also accelerated its impact on the hydrology and geomorphology of the island. The tremendous increase in the population of the island due to internal migration and influx of people from other countries such as Indonesian and Bangladeshi, seeking jobs in the island's industries, have caused and increased demand for more land for development of housing estates as shown in Table 1.1, Figure 1.3 & Table 1.2. The intention of the State Government to make Penang the leading industrial state in Malaysia has also caused more flatlands to be developed for industrial use (Ismail, 1997).

Table 1.1: Population Distribution and Yearly Average Growth Rate Percentages for Penang According to District from 1980 to 2000
(Interim Reports on Penang State Structure Plan (2005-2020))

District	**1980**		**1991**		**2000**		**Yearly Average Growth Rate (%)**		
	Population	**%**	**Population**	**%**	**Population**	**%**	**1980 - 1991**	**1991 - 2000**	**1980 - 2000**
North East	391,400	43.5	395,714	37.2	444,923	33.9	0.1	1.31	0.6
South West	76,390	8.5	122,764	11.5	169,442	12.9	4.4	3.7	4.1
Northern Main Land	199,449	22.1	224,647	21.1	259,823	19.8	1.1	1.6	1.3
Central Main Land	161,975	18.0	236,270	22.2	313,607	23.9	3.5	3.2	3.4
Southern Main Land	71,558	7.9	84,771	8.0	125,654	9.6	1.6	4.5	4.5
Penang	**900,772**	**100**	**1,064,166**	**100**	**1,313,449**	**100**	**1.5**	**2.4**	**1.9**

Source: Department of Statistic Malaysia, 2002

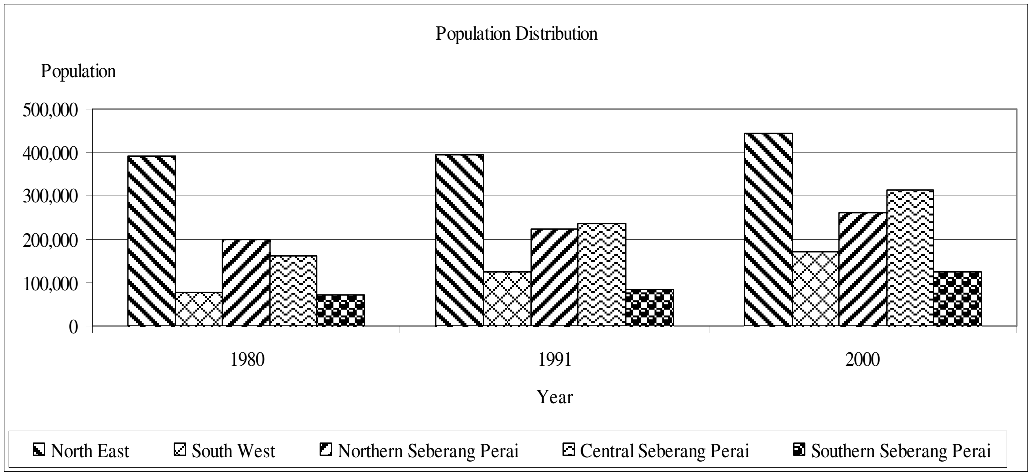

Figure 1.3: Population distribution for Penang according to district, 1980 to 2000
(Interim Reports on Penang State Structure Plan (2005-2020)
Source: Department of Statistic Malaysia, 2002

Table 1.2: Migration distribution according to States, 1995 to 2000
(Interim Reports on Penang State Structure Plan (2005-2020))

State	1995			2000		
	Migrate In	Migrate out	Net Migration	Migrate In	Migrate out	Net Migration
Selangor	78,005	40,370	37,635	60,941	36,637	24,304
Penang	**24,436**	**11,925**	**12,511**	**29,735**	**15,077**	**14,658**
Johor	22,387	24,471	(2,084)	31,522	18,146	13,376
Terengganu	11,689	15,913	(4,224)	19,953	11,519	8,434
Melaka	13,224	10,961	2,263	9,688	9,507	181
Kedah	18,798	17,943	855	22,530	23,143	(613)
Negeri Sembilan	23,535	15,438	8,097	16,293	17,100	(807)
Perlis	2,897	2,484	413	1,832	3,567	(1,735)
Pahang	17,218	25,488	(8,270)	17,908	19,720	(1,812)
Sarawak	8,133	9,709	(1,576)	9,284	12,066	(2,782)
Perak	15,975	36,346	(20,371)	20,711	27,656	(6,945)
Sabah	12,685	11,615	1,070	13,147	21,079	(7,932)
Kelantan	22,406	17,679	4,727	12,846	21,422	(8,576)
Kuala Lumpur	14,137	45,183	(31,046)	4,459	34,200	(29,741)

Source: Migration Investigation Report, 1995 – 2000, Department of Statistic
Note: ( ) Means a negative value

Although land reclamation has eased the pressures somewhat, it is not enough to satisfy the high demand for land on the island. Due to its small size of 285 km^2 in area and lack of flat land, developers have turned to the remaining hill land on the island. Many hills and their environs are already being developed and many hill projects are in the pipe line (Ismail, 1997), which is very common in Penang Island nowadays. As all of us are aware, construction industries are the backbone of any land development and it growths rapidly as well. The immediate response that will come across our mind of any construction development is the negative impacts to the adjacent areas or downstream such as deforestation, decimation of water catchments, destruction of endangered fauna and flora, soil erosion, landslides, water pollution, sedimentation and downstream flooding. Some of these problems have been exacerbated and turned into disasters due to the extremely fragile and sensitive nature of hill ecosystems. Despite such problems, the State Government has decided to lift the freeze on development of hill land since January 1998 and this has effectively opened up all hill land for development on the island (Chan, 1998).

As a result of growing population comes a corresponding need for adequate housing. It is projected that between the year 1996 to 2010, an average of 3,800 housing units are required annually in the island (Majlis Perbandaran Pulau Pinang (MPPP), 2007). Table 1.3 and Table 1.4 shows the Housing Development and Land demand in Penang. However, the figure is expected to increase by taking into account those immigrants from other States. As to hasten development and accelerate the pace towards Vision 2020, the housing woes must first be solved. To deal with the issue, there must be concerted efforts by the private and public sector to reduce the present housing shortage and to satisfy future housing needs. The objective of housing development as outlined in the Penang Island Structure Plan (1989) is to ensure an adequate housing provision at an appropriate location accompany with range of utilities, social amenities and recreational facilities as tabulated in Table 1.5.

Table 1.3: Housing Development in Penang, 1991 to 2000
(Interim Reports on Penang State Structure Plan (2005 to 2020))

District		Residential Unit			Unit Increments		Percentage of increments (%)	
		1991	1995	2000	1991 - 1995	1995 - 2000	1991 - 1995	1995 - 2000
Island	Northeast	79,631	99,530	130,612	19,899	31,082	25.0	31.2
	Southwest	26,562	32,927	44,847	6,365	11,920	24.0	36.2
	Total	**106,193**	**132,457**	**175,459**	**26,264**	**43,002**	**24.7**	**32.5**
Main Land	Northern	48,112	52,300	58,779	4,188	6,479	8.7	12.4
	Central	55,618	66,565	83,940	10,947	17,375	19.7	26.1
	Southern	19,550	23,307	34,648	3,757	11,341	19.2	49.7
	Total	**123,280**	**142,172**	**177,367**	**18,892**	**35,195**	**15.3**	**24.8**
Total for Penang		**229,473**	**274,629**	**352,826**	**45,156**	**78,197**	**19.7**	**28.5**

Source: Department of Statistic Malaysia Special Request, 2000 & Penang Structural Plan, 2005 - 2020

Table 1.4: Estimated Demand for Residential Land 2000 - 2020.

District		%	2000 – 2005		2006 - 2010		2011 - 2015		2016 - 2020		Total	
			Amount	Land Area (Ha)	Amount	Land Area (Ha)	Amount	Land Area (Ha)	Amount	Land Area (Ha)	Amount	Land Area (Ha)
Island	Northeast	10										
		40										
		50										
		Total										
	Southwest	10			78	5.2	234	15.6	286	19.1	598	39.9
		40			312	4.2	935	12.6	1,145	15.5	2,392	32.3
		50			391	2.6	1,168	7.8	1,432	9.5	2,991	19.9
		Total			**781**	**12.0**	**2,337**	**36.0**	**2,863**	**44.1**	**5,981**	**92.1**
Main Land	Northern	10			26	1.7	146	9.7	178	11.9	350	23.3
		40			104	5.0	584	27.8	711	33.9	1,399	66.7
		50			130	1.1	731	5.8	888	7.1	1,749	14.0
		Total			**260**	**7.8**	**1,461**	**43.3**	**1,777**	**52.9**	**3,498**	**104.0**
	Central	10					120	8.0	336	22.4	456	30.4
		40					480	22.9	1,346	64.1	1,826	87.0
		50					601	4.9	1,682	13.5	2,283	18.4
		Total					**1,201**	**35.8**	**3,364**	**100.0**	**4,565**	**135.8**
	Southern	10					29	1.9	236	15.7	265	17.6
		40					114	5.4	946	45.0	1,060	50.4
		50					142	1.1	1,183	9.5	1,325	10.6
		Total					**285**	**8.4**	**2,365**	**70.2**	**2,650**	**78.6**
Total					**1,041**	**19.8**	**5,284**	**123.5**	**10,369**	**267.2**	**16,694**	**410.5**

Source: Penang Structural Plan, 2005 - 2020

Table 1.5: Projection of the Development Land needed for Residential by Sector for every 5 Year in Penang (Hectare)

Land Usage	2000 – 2005	2006 - 2010	2011 - 2015	2016 - 2020	Total
Residential	0	20	124	267	**411**
Business	211	254	316	444	**1,225**
Industrial	302	565	565	570	**2,002**
Community Facilities & Recreations	691	198	311	269	**1,469**
Total	**1,204**	**1,037**	**1,316**	**1,550**	**5,107**

Source: Penang Structural Plan, 2005 - 2020

As all of us are aware, the construction activities usually cannot be done without disturbing the existing plants, trees, soil and rocks under the ground. Problems often occur when soil is put aside for a short time, used to fill holes or low areas, or removed from the area. Other problems might occur from careless handling of construction materials or fuels on-site. Nutrients, trace metals and hydrocarbons seep into the ground from leaking containers or spills. During storm events, these contaminated soils may be carried away from the construction site. When these soil particles settle out, they become a source of pollution to the downstream water bodies (Fifield, 2008). Some of the adverse effects of soil erosion are as shown in Table 1.6.

Table 1.6: Major impact of soil erosion failures for on-site and off-site scenarios (Goh and Tew, 2006)

Locations	Effects of soil erosion failures
On-site	• Loss of value, productivity and services from affected land • Undermining of roads and utilities • Sediment and mud on roads with associated traffic problems and road safety issues • Clogged drains and increased nuisance flooding • Sedimentation and bank damage on construction sites • Increased down time on construction and building sites after storm events • Unsightly appearance of construction works • Accelerated sedimentation and excessive soil loss • High cost of reconstruction and maintenance

Off-site	• Sedimentation in nearby reservoirs and other storage structure, with resulting loss of water storage capacity • Instability of stream channels nearby caused by increased runoff and sediment loads • Reduction in channel capacity leading to greater frequency of floods caused by siltation and sedimentation of rivers • Proliferation of exotic weeds within watercourse due to high nutrients content of silt and sediment • Smothering of aquatic and marine flora and fauna: high turbidity in rivers excluding light penetration affects fish life. • Land degradation caused by gully erosion/sediment deposition • Increased pollution of river and streams • Loss of navigable reaches of a river or watercourse • Adverse ecology effects on high sediment loads, deposition and dredging and de-silting of waterways • Decline or total loss of fishing industry, particularly as a results of increased turbidity due to sediment load

The total amount of sediment in the water is called total suspended solids (TSS). When TSS in water occurs in large quantities, degraded water quality can be harmful to animals and plants (Fifield, 2008).

1.2 Study area

This study site comprises of 3 lots (Lot 11897, 11898 and 12025, Mk.12. DBD) of land at Sungai Ara in Penang state, Malaysia, with a total area of 103.572 acres. The project site is located in the southern end of South-West District on Penang Island and is situated adjacent to Bayan Lepas Town as shown in Figure 1.4. The site is about 2 km away from Bayan Lepas Town, 3.5 km from Sungai Ara and approximately 5 km from Bayan Baru's town hub. As the project site was previously a golf course, large portions of the site is covered with secondary vegetation such as trees, shrubs and golf's course grasses. Rocks and boulders could be found in few locations in the project area. Areas toward the north and west of the site consist of several hills namely Bukit Gambir and Bukit Papan which form the main catchments for Sungai Air Terjun and Sungai Bayan Lepas.

In view of the pressing need on housing, this project proponent has taken some necessary steps to alleviate the problem by developing a large scale housing scheme in Sungai Ara which is close to Bayan Lepas Industrial Estate and Bayan Baru Town.

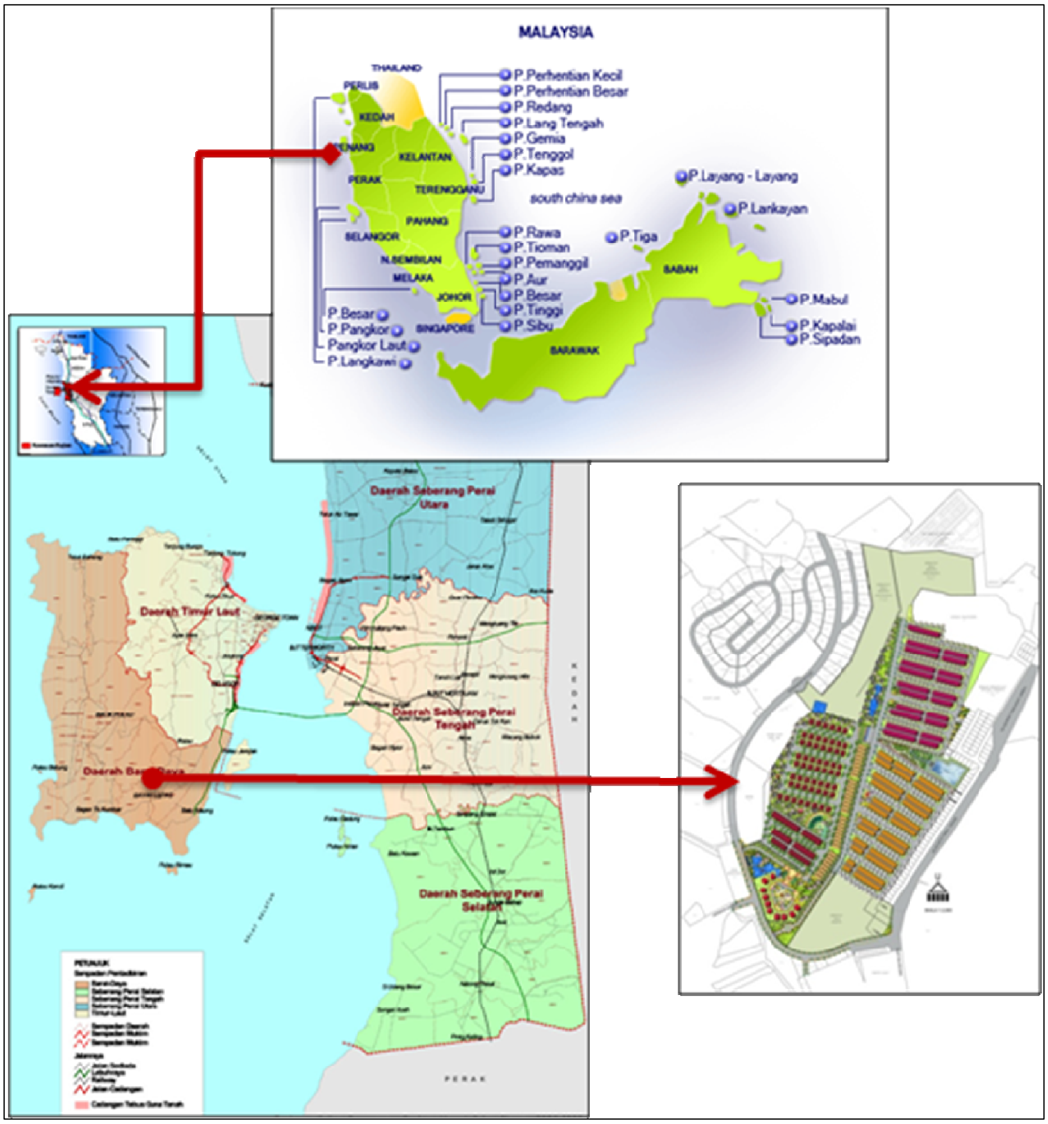

Figure 1.4: Location map of the study area

1.2.1 Rational for Selection of Study Area

This study area is located at hilly land categorized as hill land development in Penang. As reported in the Geotechnical Report (2006), the suitability of the Land with respect to the proposed development area taking into account the site geology, terrain condition and the terrain component was assessed as shown in the table 1.7.

Table 1.7: Landuse Suitability at the study area (Geotechnical Report, 2006)

Land use Suitability	Area (m^2)	Percent (%)
Class I (0 – 15°)	301,703.5	74.56
Class II (16° - 25°)	54,932.9	13.57
Class III (26° - 35°)	31,584.9	7.81
Class IV (> 36 °)	16,448.7	4.06

As this is a big scale of hillslope development, (i.e. sensitive area to erosion and sedimentation) which is under rapid construction activities, this area was selected for this researched. During heavy rainfall, high velocity of surface runoff will caused more erosion activities especially on the slope surface. Running water removes soil and organic matter from gentle sloping land and steeper sites by a variety of processes which often starts off as splash erosion, leading to sheet erosion and as the conditions change this will lead to rill erosion and subsequently develop gullies. The eroded particles will be transported and settled at downstream which will lead to siltation and sedimentation. Thus, the depth of the river and drainage system will be shallower which subsequently reduces the capacity of the system and caused flooding. Besides, the eroded particle will also pollute the water quality of the river. On the other hand, the uncontrolled removal of vegetations at the study area has lead to reduction of the infiltration capacity since the surface runoff is force to flow downstream due to the bare surface.

1.3 Problem statement

Sungai Ara has been selected as the research area for its rapid development for the past 10 years. As a result of massive urbanization, erosion problems can be accelerated by a variety of human activities, including unrestricted development, removal of surface cover and increased imperviousness that increases runoff. Every phase of a construction project has the potential of contributing significant quantities of sediment runoff.

With its rapid urbanization, the incremental of public awareness for land development in Penang is undeniable. People have deep feelings about a place or strongly connect with a community when they are in contact with the environment and with other people. In parallel with the developments related to the quality concept in all sectors, various approaches on various scales can be seen for a solution to quality problems in the urban environment. The public are well educate and demanding on the quality of the environment for better living and lifestyle. They are more concern on the safety measures implemented in all the land development in order to avoid any hazardous event. Besides, the State Government has fear on the safety of this development by trying to enforce more guidelines and implementing additional engineering studies especially for hill slope projects such as Geotechnical Report for Hill Land Committee approval, Environmental Impact Assessment (EIA) Report, Environmental Management Plan (EMP), Erosion Sediments Control Practices (ESCP) report, Traffic Impact Assessment (TIA) report, and others.

For this study area, land development which involves massive construction activities and shaping of this land will definitely alter the land cover and the soil in many ways. These alterations often detrimentally affect on site stormwater patterns and eventually off-site stream and streamflow characteristics. Protective vegetation is reduced and removed during the earthworks activities, excavations are made, topography is altered, the removed soil material is stockpiled and often without protective cover and the physical properties of the soil itself are changed. While rainfall patterns may or may not have been affected by human activities, it is clear that runoff has changed significantly with human development shown in Figure 1.5.

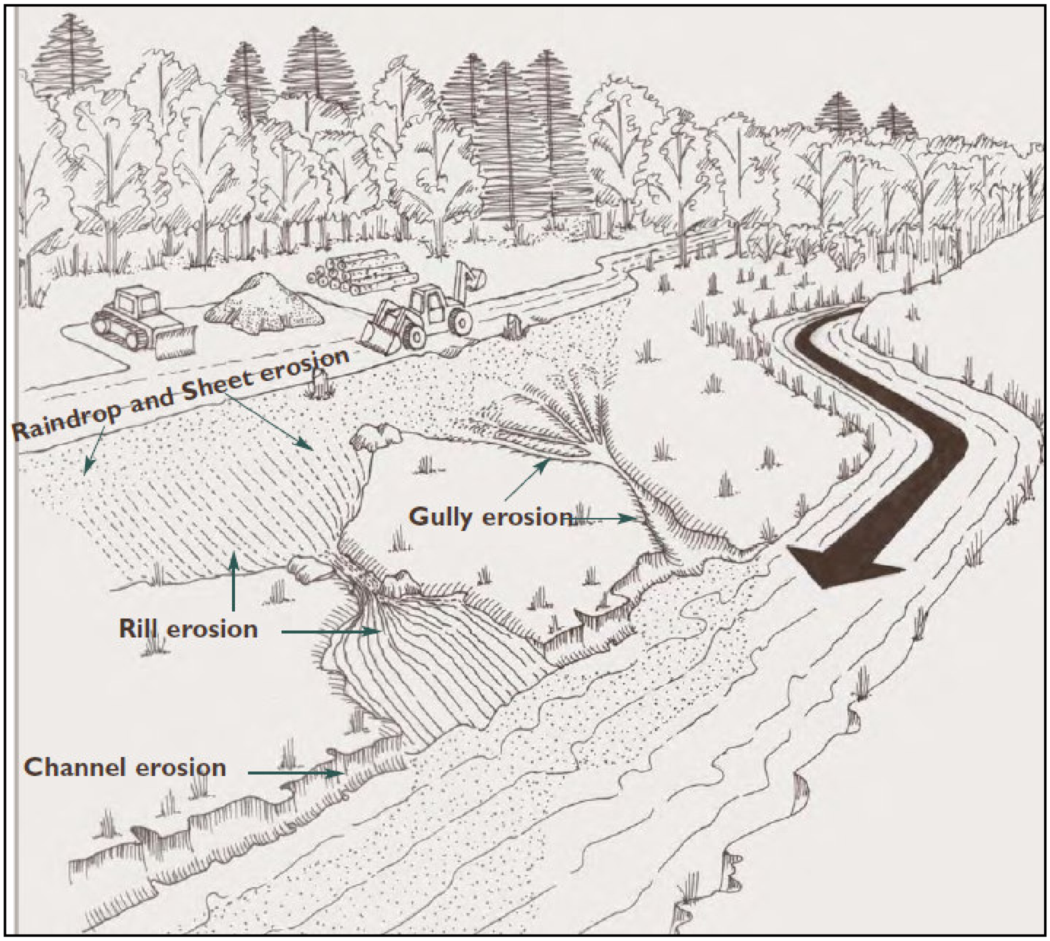

Figure 1.5: Artist illustrations on land development impact on soil erosion
Source: Connecticut Guidelines for Soil Erosion and Sediment Control, 2002

While all lands erode, not all land can be the source of sediments pollution. There has always been naturally occurring erosion. However, major problems can occur when large amounts of sediment enter our wetlands, watercourses and drain systems. On developing land, erosion frequently is in the form of gully erosion on land disturbed for a year or less. Both conditions result in lower quality of soil and water resources. However, gully erosion which is the result of concentrated flows of surface runoff generates high sediment volumes requiring costly clean-up and continual need for site stabilization during development. A construction is typically erodes at a rate of 50 tons/acre/year. This erosion rate is five times greater than cropland erosion and 250 times greater than woodland erosion (Connecticut Guidelines for Soil Erosion and Sediment Control, 2002).

Plate 1.1: Typical example of Soil Erosion features on construction site

Uncontrolled erosion and sediment from urban development often cause considerable economic damage to individuals and to surrounding society in general. Improperly planned and maintained land management of the construction site causes continual erosion and sedimentation problem, both during and after construction. The excess runoff from this construction site can cause erosion to the adjacent areas.

On the other hand, the main on-site impact is the reduction in soil quality which results from the loss of the nutrient rich upper layers of the soil and the reduced water holding capacity of many eroded soils. In addition to its on site effects, the soil that is detached by accelerated water erosion may be transported at a considerable distances. Hence, increased downstream flooding and local damage to property may also occur due to the reduced capacity of eroded soil to absorb water.

While we strive to improve the quality of our lives, the fact that much of human activities results in damage to the environment comes as no surprise to many of us living in or near to the City. We take on the responsibility of attempting to control and reduce the amount of damage as a society inflict on our water, air, and land. The activity at hand is construction and the damage to focus on in our discussion is the pollution construction contributes to stormwater.

The knowledge of the potential erosion problems on a construction site will enable the site planner to better manage site development and erosion controls in order to minimize soil loss off the property. Prevention is much more effective than trying to improve water quality of the runoff. Therefore, this research is a necessity in order to carry out a study on the efficiencies of the site temporary works and Best Management Practices (BMPs) that has been implemented in order to control the negative impact cause from the study area.

1.4 Objectives

The primary objectives of the study are as follow:

1. To evaluate the soil erosion occurring at the study area during the pre-construction activities by using the empirical modeling.

2. To compare various equations used by researchers for estimating soil erosion (e.g. Modified Soil Loss Equation (MSLE), Revised Universal Soil Loss Equation (RUSLE) and Modified Universal Soil Loss Equations (MUSLE)).

3. To determine the efficiencies of the silt/sedimentation pond as the Erosion and Sediment Control Practices (ESCP) implemented for this Project.

1.5 Research Significance

This work will help in the analysis and assessment of the environmental quality of natural resources and can assist as a future guideline for land use planning in the study area. The result of spatial change detection results and other related findings in this work will helped to identify the main soil erosion process that takes place in the study area.

The various hypothesis considered are as follows;

i. The degree of deterioration of the environment quality is not uniform throughout the study area.
ii. The natural influences are determining factors for the soil erosion process in the study area.
iii. Revised Universal Soil Loss Equation (RUSLE), MUSLE and MSLE equations may be helpful in evaluating the soil loss.
iv. The Soil investigation reports may be helpful in the estimating the K factor (soil erodibility factor).
v. The Geotechnical and Environmental Impact Assessment (EIA) reports may be useful for the determination of slope length and gradient and also the land cover factor.

1.6 Research Report Outline

This research report is organized in six (6) chapters followed by sections and subsection as follows:

i. Chapter One briefly introduces the research, a short description of the study area with respect to its location including objectives and scope of works of the study.
ii. Chapter Two contains literature review of relevant studies regarding to data collection, soil erosion, modeling and etc.
iii. In Chapter Three, Materials, Research Methods and Techniques are discussed together with site description including its location, climate, hydrology and geology.

iv. Chapter Four contains the overall result for data analysis and its discussion includes the general description of soil erosion models using MSLE, RUSLE and MUSLE equations.

v. Chapter Five is the further discussion on the results obtained from data analysis; and

vi. Chapter Six is the conclusion and recommendations for this research.

The summary showing the research work flow is illustrated in Figure 1.6.

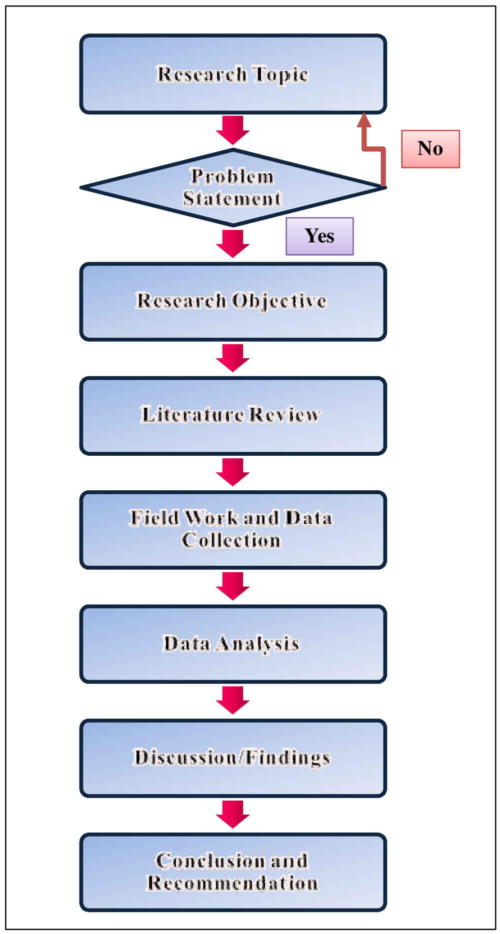

Figure 1.6: The research work flow

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Erosion can be a major environmental problem worldwide as shown in Plate 2.1. It can affect the land and its inhabitants either in direct or indirect ways. Soil erosion is an issue where the adage "think globally, act locally," is clearly apropos. Think globally as soil erosion is a common problem that will always continue to impact the global community. Act locally since effective erosion control requires action at the hill slope, field, stream channel and upland watershed scales (Toy et. al., 2001).

Plate 2.1: Soil erosion phenomena on bare slope

2.1 Definition of Soil Erosion

The word "erosion" is derived from the Latin "erosio", meaning "to gnaw away". In general terms soil erosion implies the physical removal of topsoil by various agents, including rain, water flowing over and through the soil profile, wind, ice or gravitational pull (University of Hong Kong, 2000).

Erosion is the process of carrying away or displacement of sediment by the action of wind, water, gravity, or ice (Smith and Smith, 1998). The process of deposition of sediment from a state of suspension or solution in a fluid is called sedimentation. Natural sources of sediments transported to the sea include erosion of bedrock, soil and decomposition of plants and animals (United Nation Environment Programme and Gems Water Programme [UNEP/GPA], 2006). However, anthropogenic activities or those which are carried out by man often change the processes of erosion and sedimentation as well as modifying the flow of rivers and the amount of sediments it can carry. Most land based activities that occur in sectors such as agriculture, forestry, urbanization and mining contribute to these changes. Another significant cause of changes in sedimentation and erosion patterns is through hydrological modifications that may occur from construction of reservoirs, dams and causeways, dredging of water bodies and development of large scale irrigation schemes (UNEP/GPA, 2006a).

Al-Kaisi (2002) stressed that soil erosion is a gradual process that occurs when the impact of water or wind detaches and removes soil particles causing the soil to deteriorate. According to Al-Kaisi, soil deterioration and low water quality due to erosion and surface runoff have become severe problems worldwide.

Soil erosion events are quick processes (Blaikie and Brookfield, 1987; Lal, 1990; and Eaton 1996) and can be defined as a physical process. It refers to the wearing away of land surface by water or wind as well as to the reduction in soil productivity due to physical loss of topsoil, reduction in rooting depth, removal of plant nutrients and loss of water.

It is particularly problematic in tropical countries because of high rainfall intensities and generally less fertile soil. It is also a threat to those developing countries when agriculture production is crucial to development and the majority of the rural population base livelihood strategies on the primary sector. Unfortunately, many of such rural residents have been pushed to the margins of agricultural production, i.e. shallower and poorer soils, and the sloping land and forest frontiers of the uplands. In this situation, agriculture can be the main cause of soil erosion and watershed deterioration, though the impacts of other activities such as road construction or logging operation should not be downplayed. Cultivating upland soils often lead to a reduction in natural soil fertility and crop productivity thus undermining future income generation (Alfsen et al., 1996) and economic growth (Alfsen et al., 1997). Soil erosion and the depletion of soil resources have an important economic implications for countries whose economic depend heavily on the agricultural sector (Barbier and Bishope, 1995).

Adapted from Maine Department of Transportation (MaineDOT) BMPs for Erosion Sediment Control (ESCP) Manual (2008), erosion is the detachment and movement of soil particles by the action of water, ice, gravity, or wind. Natural erosion always occurs but the rate is slow enough that the environment can adjust. When humans began to manipulate the landscape, it will accelerate the process by exposing soil to the forces of water and wind. On the other hand, sedimentation is the deposition of soil particles that were detached and transported by the erosion process. Sedimentation occurs when the velocity of the wind or water becomes insufficient to keep the soil particles in suspension. Particles can be transported at great distances and deposited in environmentally sensitive areas such as rivers, lakes and wetlands. It is sedimentation that can severely alter water quality, damage an aquatic ecosystem and destroy a wetland.

According to Mortlock (2007) soil is naturally removed by the action of water or wind. Soil erosion has been occurring for some 450 million years ago since the first land plants formed the first soil. In general, erosion removes soil at roughly the same rate as soil is formed. But 'accelerated' soil erosion (loss of soil at a much faster rate than it is formed), is a far more recent problem. It is always a result of mankind's unwise actions that leave the land unprotected and vulnerable during times of erosive rainfall or windstorms where soils may be detached, transported, and deposited.

The Global Assessment of Human Induced Soil Degradation (GLASOD) (1987-1990) study as shown in Figure 2.1 estimated that around 15% of the Earth's ice free land surface is afflicted by all forms of land degradation. From this, accelerated soil erosion by water is responsible for about 56% and wind erosion for about 28%. This means that the area affected by water erosion is roughly around 11 million square km and the area affected by wind erosion is about 5.5 million square km (Mortlock, 2007).

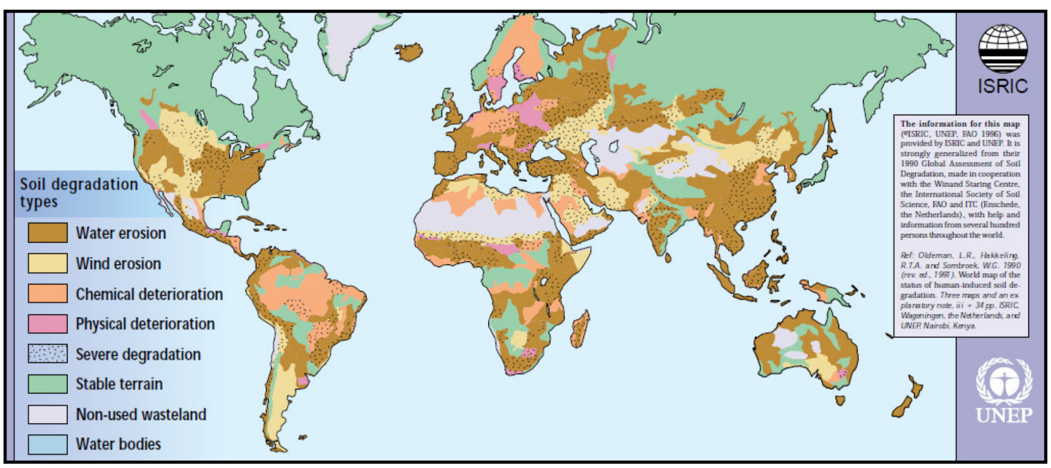

Figure 2.1: The GLASOD estimate of global land degradation
(Note that this includes all forms of soil degradation, not just erosion)
Source: UNEP (World Atlas of Desertification) GRID (Mortlock, 2007)

The consequences of soil erosion can be seen both on site and off site. On site effects are the loss of soil, the breakdown of the soil structure and a decline in organic matter. Erosion also reduces available soil moisture, resulting in more draught-prone conditions. Off site problems result from sedimentation downstream or downwind which reduces the capacity of rivers and drainage ditches, increases the risk of flooding, blocks irrigation canals and shortens the design life of reservoirs. Eroded sediment is also a pollutant which the chemicals absorbed by it can increase the levels of nitrogen and phosphorus in water bodies and result in eutrophication (University of Hong Kong, 2000).

2.1.1 Why does erosion occur?

Erosion is very much depends on the power balance between the rainfall and the soil. Rain and its runoff provide the force to drive water erosion. If the force applied to the soil is greater than the resistance of the soil, then particles will detach and move away in either splash or in surface flows. As the force increases so does the rate of detachment. This gives the first clue to keeping erosion down to acceptable limits. We can do very little about reducing the force applied by the rain but we can work at dissipating its energy before it reaches the soil surface (Cummings, 1998).

2.1.2 How does erosion occurs

Detachment, transport and deposition are basic processes that occur on upland areas (Foster, 1982). Detachment occurs when the erosive forces of rainfall drop impact or when flowing water exceeds the soil's resistance to erosion. Detached particles are transported by the splash and flow of raindrop. Deposition occurs when the sediment load of eroded particles exceeds its corresponding transport capacity and generally will be transported down slope flowing into rills and gullies as shown in Figure 2.2. Understanding the soil erosion mechanism is very important to design the soil erosion measurement system and develop the soil erosion control techniques (Choi et al., 2005).