ESTIMATION OF SOIL ERODIBILITY FACTOR (K) FOR SOIL SERIES IN KUANTAN RIVER BASIN

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ABSTRAK

Faktor hakisan tanah adalah penunjuk kerentanan tanah terhadap kesan hujan, larian dan proses hakisan lain. Ia adalah salah satu komponen Universal Soil Loss Equation (USLE) dan boleh dipengaruhi oleh banyak faktor seperti jenis tanah, kadar penyusupan, kadar kebolehtelapan dan kandungan bahan organik. Dalam kajian ini, sebanyak tiga belas siri tanah Kuantan iaitu Durian-Munchong-Bungor , Malacca-Tavy-Gajah Mati, Holyrood-Lunas, Kuala Brang-Kedah-Serdang, Kranji, Kuantan, Mined Land, Peat, Rudua, Rengam-Bukit Temiang, Rengam-Jerangau, Steepland, Telemong-Akob-Local Alluvium and Urban Land dikaji mengenai komposisi tanah seperti peratusan bahan organik, pasir halus serta graviti spesifiknya. Dengan hasilnya, faktor hakisan tanah dapat dikira menggunakan persamaan erodibility tanah Wischmeier dan persamaan erodibility tanah yang diubahsuai Tew. Pengiraan menunjukkan bahawa faktor K yang dihitung oleh Wischmeier lebih kecil daripada Tew dan siri tanah Rudua kurang terhakis. Rudua mempunyai peratusan tertinggi bahan organik dengan 10.98% dan peratusan lumpur terendah sebanyak 0.04% yang menjadikannya kurang terhakis. Sebaliknya, Peat lebih terhakis berbanding dengan siri-siri tanah yang lain kerana ia mempunyai peratusan tertinggi dengan lumpur dengan 16.38% dan dengan jumlah organik yang kecil sebanyak 5.48%.

ABSTRACT

Soil erodibility factor is the indicator of the susceptibility of a soil to raindrop impact, runoff and other erosion processes. It is one of the components of the Universal Soil Loss Equation (USLE) and can be affected by many factors such as soil type, infiltration rate, permeability rate and organic matter content and. In this study, a total of fourteen soil series found in Kuantan River Basin namely Durian-Munchong-Bungor, Malacca-Tavy-Gajah Mati, Holyrood-Lunas, Kuala Brang-Kedah-Serdang, Kranji, Kuantan, Mined Land, Peat, Rudua, Rengam-Bukit Temiang, Rengam-Jerangau, Steepland, Telemong-Akob-Local Alluvium and Urban Land was studied with regards to the composition of soil such as percentage of organic matter, silt, clay and fine sand as well as its specific gravity. With the results, the soil erodibility factor can be computed using the Wischmeier soil erodibility equation and Tew modified soil erodibility equation. The computation shows that K factor computed by Wischmeier was smaller than Tew and Rudua soil series was less erodible. Rudua soil series has the highest percentage of organic matter at 10.98% and the lowest percentage of silt at 0.04% which made it less erodible. In contrast, Peat was more erodible compared to other soil series as it had the highest percentage of silt at 16.38% and with a relatively small amount of organic matter around 5.48%.

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LIST OF SYMBOLS

˚C	Degree Celsius
µm	Micrometre
%	Percentage
km	Kilometre
km^2	Square Kilometre
m^3/s	Cubic metre per second
m	Metre
C_c	Coefficient of Gradation
C_u	Coefficient of Uniformity
K	Soil Erodibility Factor
Mm	Millimetre
Sg	Sungai

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BMP	Best Management Practice
BS	British Standard
DID	Department of Irrigation and Drainage
ESCP	Erosion and Sediment Control Plans
GIS	Geographical Information System
KRB	Kuantan River Basin
MASMA	Urban Stormwater Management Manual for Malaysia
MUSLE	Modified Universal Soil Loss Equation
RUSLE	Revised Universal Soil Loss Equation
USLE	Universal Soil Loss Equation
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Background

Soil erosion is one of the processes whereby the upper layer of soil is displaced or detached to the ambient environment. It can be categorized as one form of soil degradation. It normally occurs physically through natural environmental agents such as wind and water as well as through rapid human activities on undisturbed land which will likely cause huge disturbances to the land. In addition, with human population growing, there is a boom in industrial production to satisfy human needs, development of housing for living purposes and cultivation of food production for human consumption which subsequently leads to voracious acquisition of land area for such purposes, especially forest area. This phenomenon has caused massive land clearing or better known as deforestation that largely causes soil erosion.

The soil erodibility factor (K factor) of the USLE equation represents an indicator of the susceptibility of a soil to raindrop impact, runoff and other erosion processes. Splash erosion and surface runoff are usually the contributors to the erosion. In short, the K factor represents how easily the soil will be susceptible to detachment and transport processes. It can be affected by many factors such as soil type, infiltration rate, permeability rate, organic matter content and so on. In the water erosion, raindrops that fall on bare soil directly destroy the original soil structure, making the soil particles detach away. If on sloping land, water in the form of runoff will move down the slope carrying the detached particles. Therefore, it is very important to protect the surface of the soil from erosion.

In order to control soil erosion, the factors that contribute to soil erosion must first be defined. Then with the known factors, appropriate methods can be proposed to counter this problem such as control plans and the Best Management Practices (BMP) to mitigate soil erosion and sedimentation problems which is happening especially at construction site. In Malaysia, the Department of Irrigation and Drainage Malaysia (DID) had come up with a design procedure guideline manual handbook named Urban Stormwater Management Manual for Malaysia (MASMA) in year 2001 which serves as a guide to all the engineers, town planners and designers that are involved in stormwater management implementation. With this manual, it will help to ease the process of designing, planning and maintenance of the stormwater management as well as suggest the suitable BMP that need to be adopted for a particular construction site. In 2011, DID has further introduced a document entitled, "Guideline for Erosion and Sediment Control in Malaysia". This manual emphasizes that any stormwater infrastructure design or urban development planning has to consider the design for erosion and sediment control. In addition, all the projects that involve soil disturbing activities and site preparation need to prepare ESCP (Erosion and Sediment Control Plans) due to the requirement of Department of Environment (DOE), Malaysia in 2011 as part of the environmental assessment approval under the Environmental Impact Assessment (EIA) Order, 1987.

The development of mathematical models such as Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE) serves as a vital tool in helping to assess the risk of site erosion, preparation of sediment control plans and the planning to conserve the soil. At the moment, USLE is the most frequently used mathematical model in helping to predict the possibility of soil erosion threat as a result of human activities such as industrial or rural and urban developments.

1.2 Problem Statement

Soil erosion is a serious problem that is currently affecting all the countries in the world. Malaysia, a Southeast Asian country, is not spared from the problem too. As a country influenced by the tropical climate, Malaysia frequently receives high rainfall intensity particularly during the monsoon season which normally happens from November to March and coincidently this affect the research area which is Kuantan, Pahang. As Kuantan is located at the east coast region of Malaysia, the effect of monsoon season clearly signify potential soil erosion problems. In this context, water is the main agent of soil erosion and the removal of vegetative cover such as trees during deforestation also contribute to soil erosion as the runoff increases while infiltration of water into the soil reduces. All this is happening partly due to the rapid increase in human activities near the waterways. As is known, waterways comprise of drainage basin or watershed. This is the area of land where the precipitation of rain that falls will drain through the drainage basin before it escape into rivers, lakes, oceans and seas. When heavy rain occurs, the rain will wash away the topsoil and bring along the detached soil to the river basin as a result of land exposure due to human activities near the river basin such as overcropping, overgrazing and deforestation. Therefore, there is a need to study the soil erodibility factor for soil series found in the Kuantan river basin to determine areas which have high soil erodibility that will undoubtedly cause flooding as the sediments that deposits on the river bed will reduce the cross sectional area of the river, causing it unable to cope with large volumes of runoff during heavy rain.

1.3 Objectives of Study

The aim of this study is to estimate and compute the soil erodibility factor, K for soil series found in Kuantan river basin. To achieve this, the main specific objectives are outlined below:

a) To compute the soil erodibility factor for soil series found in Kuantan river basin using Tew (2011) modified soil erodibility equation and using Wischmeier (1978) soil erodibility equation.

b) To compare between the soil erodibility factor computed using modified soil erodibility equation by Tew (2011) and using soil erodibility equation by Wischmeier (1978) for each soil series found in Kuantan river basin.

1.4 Scope of Study

This study estimates the soil erodibility factor (K) of USLE for soil series found in Kuantan river basin. A series of data regarding soil characteristics such as organic matter, sand, silt and clay content was collected for each soil series. Then, with all the relevant data, the soil erodibility for the soil series can be computed using Wischmeier (1978) and modified Tew (2011) erodibility equation. The scope of study also include field works for soil sample collection and experimental works to obtain the soil properties. The study also utilizes GIS software to identify the location for the soil sample collection.

1.4.1 Study Area

The study area is Kuantan river basin. It is located at the north east of Pahang state in Peninsular Malaysia. In this basin, the total area for the basin is 1638 km^2 while the stream length is 86 km. The river begins from Gunung Tapis at the western border and it flows through Sungai Lembing and Kuantan town before discharging into the South China Sea. Kuantan river basin is largely rural. Natural forests dominate the upper catchments while the middle and lower catchments are largely dominated by oil palms and small amount of rubber plantations. An average annual rainfall of 2470 mm and mean annual discharge at Bukit Kenau (582 km^2) is 37.7 m^3/s recorded for this basin. Sg. Chereh, Sg. Kenau, Sg. Belat, Sg. Reman and Sg. Riau are the main tributaries of Sg Kuantan. Chereh Dam is the main reservoir for the basin. It is located at Sg. Chereh which works as a water storage tank and prevent flooding (Ghani, Othman, & Baharudin, 2013) Figure 1.1 show the area of the study.

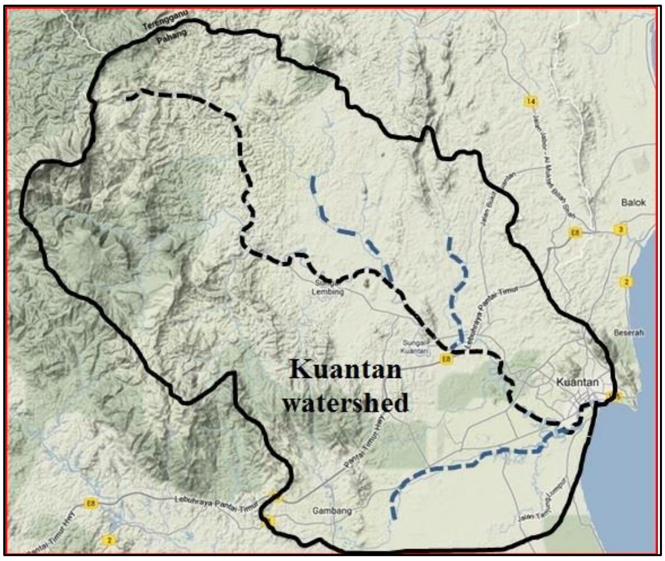

Figure 1.1: Kuantan Rver Basin

Source: Zaidi (2014)

1.4.2 Field Works

The field works in this study consists of soil sample collection from the Kuantan area. There are fourteen different types of soil series for the Kuantan area. The soil series are namely Durian-Munchong-Bungar (DRN-MUN-BGR), Malacca-Tavy-Gajah Mati (MCA-TVY-GMI), Holyrood-Lunas (HYD-LUS), Kuala Berang-Kedah-Serdang (KBG-

KDH-SDG), Kuantan (KUA), Kranji (KNJ), Mined Land (MLD), Rengam-Bukit Temiang (RGM-BTG), Peat (PET), Rudua-Rusila (RDU-RUS), Rengam-Jerangau (RGM-JRA), Steepland (STP), Telemong-Akob-Local Alluvium (TMG-AKB-LAA) and Urban Land (ULD). The apparatus that was used for soil sample collection is hand auger. The depth of the sample collection is 0.5 m below the ground level and the sample should be undisturbed soil sample. All the samples were stored in resealable plastic bags to avoid contamination to the soil samples.

1.4.3 Experimental Works

The experimental works include computer and lab works. The computer works involve the use of GIS software while the experiment works is to determine the soil series properties. GIS software was used to identify the location for soil sample collection. For the experiment works, the organic matter content and the percentage of very fine sand, silt and clay as well as the soil texture of each of the soil series need to be determined. The experiments that were conducted were the sieve analysis, hydrometer analysis, particle density and loss on ignition according to the ASTM and BS standards.

1.5 Significance of Study

This study is very significant to Kuantan area as it is well known that Kuantan is located at the east coast region which experiences monsoon season starting from November to March. During the monsoon, heavy rain is expected and therefore the KRB should be expected to hold a large volume of runoff from the rain. But at the end of 2013, a catastrophic flooding happened as majority of the Kuantan area was inundated by water and completely paralyzed. The daily maximum rainfall recorded by Kuantan rainfall station was of 175 mm/day before the catastrophic flood in 2013 but during the catastrophic flood, the average amount of rainfall exceeded 800 mm during December 2013 to January 2014 (Wahid, Nasir, Hassan, Abu Bakar, & Tahir, 2015). Hence, it is very important to investigate the soil erodibility factor, K for soil series found in KRB so that this knowledge can enable related parties to select the suitable BMP to be applied to mitigate the soil erosion problems as well as curb the flooding woes. It is very vital to analyze the K factor in the Kuantan area since the physical conditions such as the topography, weather, vegetation and soil types vary between each state.

CHAPTER 2

LITERATURE REVIEW

2.1 Soil Erosion

Soil erosion is a natural occurring process throughout all the land in the world. It can be classified as one form of soil degradation along with other types of soil degradation such as soil compaction, low organic matter, soil acidity problems, poor internal drainage, and loss of soil structure (Wall, Baldwin, & Shelton, 2007). Normally, these other types of soil degradation, if considered significant, it will usually accelerate the soil erosion process. Even though the soil erosion may be a slow process that go unnoticed sometimes, it can happen at a frighten pace which in turn causes massive loss topsoil. In majority of the farmland, this phenomenon has potentially reduce the crop production, affect the surface water quality and damaged drainage networks. This loss of topsoil problem at farmland is discussed as the on-site effects from soil erosion. (Morgan, 2005) mentioned that the on-site effects serve a vital role in agricultural land. The soil fertility and cultivable soil depth are largely depend on the soil structure content, soil own organic matter and nutrient content, amount of soil loss from field, and soil distribution within a field. The erosion that happened lead to decrease in availability of soil moisture, resulting an arid conditions. As a result, soil fertility that lost through erosion ultimately leads to lands being deserted and there will be major concerns about the food production later on.

The human activities such as deforestation, overgrazing and overexploitation of the vegetative cover for domestic use are typically the major contributors of the soil degradation. According to (Gabriels & Cornelis, 2009), the removal of natural vegetative on a particular land for the purposes for fuel wood, agriculture and industry is considered as deforestation. It is increasing at an alarming rate and causing 579 million ha of soil degradation in which 50% is located in Asia. This is follow by South America with 17%.

(Gabriels & Cornelis, 2009) also highlights about the livestock which concentrated around watering points is overgrazing the vegetation and destroying the land around wells and villages. This activities accounts for 679 million ha of soil degradation and Africa alone causes 243 million ha of it in comparison of Asia that only constituted of 197 million ha.

Soil degradation caused by erosion is a significant threat and will continue affect all the county in the world (Lal, 2016). Almost 10 million ha of agriculture land is gone in each year due to the effect of soil erosion, thus it greatly affect the food production for the world. Not only that, the rate of soil formation is much slower compare to the soil loss from land areas which approximately much faster (Pimentel, 2006). In China alone soil erosion is the worst among the world. Particularly when there are around 1.6 billion tons of sediments are deposited in the Yellow River which causes the rise of the riverbed level (Bin, 2009).

2.1.1 Factors Affecting Erosion

The main factors affecting the soil erosion can be divided into four categories which is the climate, vegetative cover, topography and lastly the structure and composition of the soil itself. Climate is a force to be reckon when soil erosion happened. With high amount and intensity of precipitation, the runoff and splash of rain will also quickly erode the soil's surface. This relationship is further intensified when the soil's surface is bare and not protected well with vegetative cover. In addition, the velocity and size of rain drop also hugely influence the soil erosion as greater velocity and size will generate greater kinetic force that displace the soil particles at a much faster rate in a larger distance compare to small size and velocity of rain drop (Blanco & Lal, 2010). For vegetative cover, it acts as a medium between the soil and the atmosphere. The vegetative cover shelter the soil's surface from wind and rain by binding the soil together thus forming a mass of solid that is not susceptible to wind and rain soil erosion agents. In the meantime, a steep slope of topography will accelerate the soil erosion by means of increasing the velocity of the runoff along the slope. Soil structure and its composition also play a part in preventing soil erosion. In this context, the texture, organic matter content, macroporosity, and water infiltration capacity of the soil structure will mostly influence the soil erosion rate (Blanco & Lal, 2010). The texture of a soil represents the sizes and proportions of the particles of the soil. Normally, soil can be divided into three categories which is sand, silt, and clay. Soil which has high proportions of sand will be considered coarse-textured and high infiltration rate. Therefore, the potential of soil erosion on sandy soils is relatively low. In comparison, soils with a large amount of clays and slits are consider fine-textured. Clay has a capability to bind the soil particles together and reduce soil erosion. However, when fine particles encounter rapid flowing water, the fine particles will erode quickly before settling. In terms of organic matter content, the organic matter in a soil will help to build a more rigid soil structure by binding together soil colloids (Blanco & Lal, 2010). Thus, it made the soil more resistance to erosion. On the other hand, the soil macropores is different in for every soil categories. Silty and clayey soils usually have smaller pores in comparison to sandy soils (Gardner, 1979). But the pores is generally larger to sandy soil. This is the reason why silty and clayey soils are able to store as much water compare to sandy soils due to the present of larger and smaller macropores. Lastly, the water infiltration capacity refers to the capability of the soil structure to allow water movement into the soil. It is also known as soil permeability. The soil texture and organic matter content are directly influencing the soil permeability. A gravel and sand mixtures of soil that are affected by minor erosion from rainfall and shallow surface runoff will be off high permeability.

2.1.2 Soil Erosion Agents

The main erosion agents that are significant at this moment is wind and water. This agents will determine the erosion type. In erosion affected by water agent, it can be further divided into splash, sheet, rill, channel and gully erosion. In erosion affected by wind agent, it can divided into suspension, saltation and surface creep. Soil erodes by water normally is the most dominant compare to wind as shown in Figure 2.1.

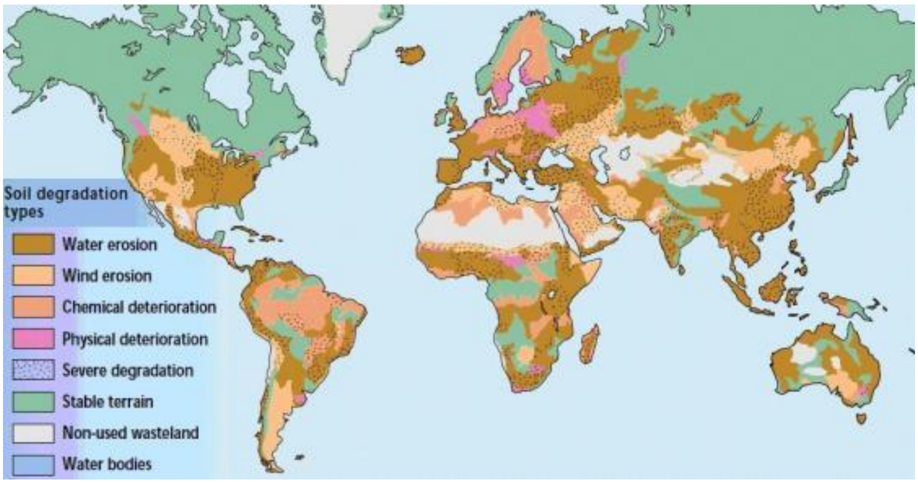

Figure 2.1: Map of Global Status of Human Induced Soil Degradation
Source: ISRIC, UNEP, & FAO (1996)

The water runoff from storm will accumulate downstream and causes a high velocity flow which in turn erode the soil surface. On the other hand, wind erosion will largely help in removal of soil by bringing it from one place and deposit it at another place. It normally occur in flat and bare land areas. The figure below shows how the movement of soil particles by wind erosion.

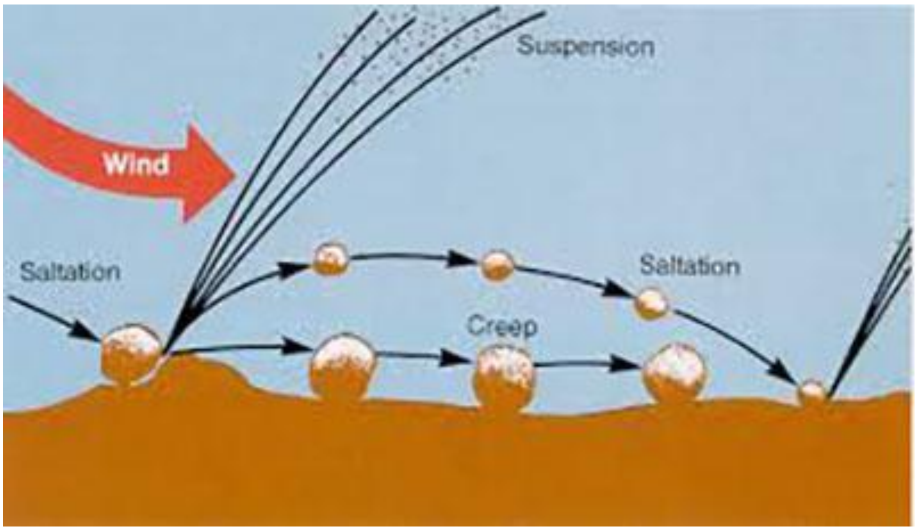

Figure 2.2: Movement of Soil Particles by Wind Erosion
Source: Kaisi (2015)

In Malaysia, the most of the erosion happen is due to water compare to wind. As Malaysia is a tropical countries, it normally receives heavy rain annually. With this condition, soil erosion will mostly happen particularly at deforested and overgrazing areas.

2.2 Soil Erosion Modelling

By using different soil erosion modelling, there will be plenty of ways to be predict soil erosion under different condition. Some of the models are more towards statistical and some are more physical. In short, the different soil modelling can be divided into physical, analogue and digital model in Table 2.1.

Table 2.1: Physical, Analogue and Digital Soil Erosion Modelling

Type	Description
Physical	This is the hardware model built in laboratory that is scaled-down and assumption of dynamic similitude between model and real world is needed.
Analogue	This type required the usage of mechanical or electrical analogue to system under investigation.
Digital	This type uses digital computers in order to process plenty of data.

Source: Gregory & Wailing (1973)

Based on this three model, the digital model is the most popular compare to the physical and analogue models to be used for soil erosion modelling. This is because it is based on most important factors, observation data, measurements, experiments and statistical techniques (Morgan, R.P.C, 1995). In the digital model, it can be further divided into three which is the physical-based, stochastic and empirical (Table 2.2). The empirical models are mostly dependent on observations and the results are usually statistical. It is very easy to use as an estimation of average soil erosion and in addition, some are even deploy to predict sediments. In the meantime, conceptual models is mostly utilize the continuing equation of water and sediment. It acts as a medium between empirical and physical models. Lastly, physical models usually make use of the physical equations. This is in order to study the ways runoff and sediment are locally distributed during rainfall. This models has the capability to estimate the whole runoff and loss of soil (Eslamian, 2014). Table 2.3 shows the differences of soil erosion modelling equation by water.

Table 2.2: Digital Soil Erosion Models

Water Erosion	**Water Erosion (Runoff only)**	**Wind Erosion**	**Tillage Erosion**
• ANSWERS(Areal Nonpoint Source Watershed Environment Response Simulation) • PESERA(Pan-European Soil Erosion Risk Assessment Model) • CREAMS(Chemical, Runoff and Erosion from Agriculture Managements Systems) • RUSLE(Revised Universal Soil Loss Equation) • EGEM(Ephemeral Gully Erosion Model) • WEPP(Water Erosion Prediction Project) • EPIC(Erosion-Productivity Impact Calculator) • GeoWEPP(Geo-spatial interface for WEPP) • MUSLE(Modification Universal Soil Loss Equation) • MWISED(Modelling Within-Storm Sediment Dynamics)project • EUROSEM(European Soil Erosion Model) • PESERA(Pan-European Soil Erosion Risk Assessment Model) • GLEAMS(Groundwater Loading Effects of Agriculture Management Systems) • USLE(Universal Soil Loss Equation) • WATEM(Water and Tillage Erosion Model) • MOSES(Modular Soil Erosion System) • LISEM(Limburg Soil Erosion Model) • MWISED(Modelling Within-Storm Sediment Dynamics) • AGNPSA(Agricultural Non-point Source pollution model)	• TCRP (Tillage-Controlled Runoff Pattern Model) • TOPMODEL	• WERU (Wind Erosion Simulation Models)	• WATEM (Water and Tillage Erosion Model)

Table 2.3: Differences in Soil Erosion Modelling by Water

Equation	Characteristics	USLE	MUSLE	RUSLE	WEPP
i) Empirical	Temporality	Static (Simulation of erosion on average annual basis)	Static (Simulation of erosion on average annual basis)	Semi Static (Simulation of erosion by period)	Static (Simulation of erosion on average annual basis)
	Process	Implicit	Implicit	Implicit	Implicit
	Complexity	Simple	Simple	Simple	Complex
	Requirements	Few input parameters	Few input parameters	Few input parameters	Few input parameters
	Scale	Plot size	Plot size	Plot size	Plot size
	Application	Croplands, forests	Croplands, forests	Use for non-agriculture or non-forested areas	Croplands, forests
	Other limitations	Sediment position unknown, ephemeral gullies not taken into account, plenty land use on slope problems		Sediment position unknown, areas without field calibration will be inaccurate	Need complicated monographs for prediction
	Other advantages	Simple, easy to use	Simple, erosivity accounted during runoff	Simple, an upgrade of USLE	Interaction between factors allowed
	Output	The average of soil loss per unit area of long time	The average of soil loss per unit area of long time	Rill/Interrill erosion	Mean annual wind erosion
Equation	**Characteristics**	**CREAMS**	**WEPP**	**GUEST**	**EUROSEM**
ii) Physical-based	Temporality	Dynamic	Dynamic	Semi static	Semi static
	Process	Explicit	Explicit	Explicit	Explicit
	Complexity	Very complex	Very complex	Complex	Complex
	Requirements	Many input parameter	Many input parameter	Not so many parameter	Not so many parameter
	Scale	Plots, catchments	Plots, catchments	Plots and small catchments	Plots and small catchments
	Application	Croplands, rangelands	Croplands, rangelands	Croplands, rangelands	Croplands, rangelands

	Other limitations	Chemical movement do not considered, only considered single crop	Permanent channels and streams erosion not able to be predicted	Need to include empirically relationships to simplify equation	Eroded sediment not taken into account
	Other advantages	Able to estimate long term erosion rates	Parameters need calibration	Erosion calculated using erosion	The values of soil and plant cover parameters need choose properly
	Output	Non-point source pollution considered	Sediment yield	Sediment concentration (Event based)	Rill, interrill erosion
Stochastic: 1) The statistical characteristic of existing sample data is based on the synthetic sequence of data 2) When data that is available for short period of observation, it useful to generate input sequences to physical based and empirical model					

Source: Gregory & Wailing (1973)

2.2.1 Universal Soil Loss Equation (USLE)

One of the most important event that happen during the 20th century in the soil and water conservation field was the establishment of the Universal Soil Loss Equation (USLE). Most of the soil erosion that happen through surface runoff and raindrop impact is investigated by this empirical formula. The success of this development is due to the sheer hard work from all the college and scientists from United States that continue to experiment the soil erosion phenomenon. Then, in 1965, the empirical formula was first issued in USDA Agriculture Handbook 282 and in 1978, it was further revised in Agriculture Handbook 537.

Universal Soil Loss Equation (USLE) is an empirical formula that is based on basic runoff of 10,000 plot-years and soil-loss data at 49 locations across the United States (Wischmeier & Smith, 1978). It is used to predict the soil erosion rate of sheet and rill erosion. This erosion model is able to use for agriculture and non-agriculture purposes. For agriculture, it targeted specific crop and management systems. For non-agriculture, it can be apply to construction sites.

The Universal Soil Loss Equation (USLE) is as shown in Equation 2.1:

$$A = R \times K \times L \times S \times C \times P \qquad 2.1$$

where;

A = Annual soil loss per unit area (tonnes/ha/year)

R = Rainfall and runoff factor, (Usually, $R = \sum_{i=1}^{n} EI_{30}$, where EI_{30} is the kinetic energy of a particular storm times a maximum 30 minute intensity)

K = Soil erodibility factor, (Soil loss from a plot of land of specific soil measured at 72.6 feet length, 9% slope continuously in clean-tilled fallow)

L = Slope-length factor, (The ratio of a field slope length to that from a 72.6-ft length under same conditions)

S = Slope-steepness factor, (The ratio of soil loss from field slope gradient to that of a 9% slope under same conditions)

C = Cover and management factor, (The ratio of soil loss from an area with specific cover and management to that from an identical area in tilled continuous fallow)

P = Support practice factor, (The ratio of soil loss with support practice such as contouring, terracing and strip-cropping to that with straight-row farming up and down the slope).

After the Agriculture Handbook No 537 issued, many research had been done to further improve the empirical formula of the USLE. Some of the included the revaluation of isoerodent maps; to display freeze-thaw conditions and consolidation caused by removal of moisture by a growing crop using time-varying approach for erodibility factor (K); establish a sub-factor to assess the cropland, rangeland and disturbed areas for the cover-management factor (C); a new formula to describe slope length and steepness (LS) that describe also ratio of rill to interrill erosion; and new cover and management factor values (P) for both cropland and rangeland practices (Renard, Meyer, & Foster, 1991). On the following sections, there will be detailed explanation of the USLE factors as well as reviews of works or case study regarding the USLE factors.

Since the improvement of USLE, the changes in the improvement of USLE are now translated in the Modified Soil Loss Equation (MUSLE) and Revised Universal Soil Loss Equation (RUSLE). (Williams, 1975) had come up with the Modified Soil Loss equation in 1975 . The modified soil loss equation focus on finding the sediment yield from a single storm event. Single storm is the rainfall event of 0.25 cm of precipitation and separated by previous storm of 72 hours of dry weather. Williams substituted the R factor with a runoff factor with the assumptions that sediment yield from runoff is greater than rainfall. Williams showed that modified R factor of runoff volume and peak discharge of the single storm event is more accurate in predicting the sediment yield than the R factor of the USLE.

(Renard et al., 1991) proposed the RUSLE in 1991. It is an update of the USLE empirical formula. RUSLE contained a computer program to ease the calculation processes and new data had been introduced to calculate the terms for specific conditions. However, the original USLE equation is still use in RUSLE with several modifications to the ways to calculate the factors (Renard et al., 1991). For the R factor, the databases had been cover up to the western United States as well as establishments of the correlation of the rainfall on ponded water. The K factor has been made time varying and there are some changes of the soil profile for rock fragments. The C factor is now amount to prior land use, surface cover, surface canopy, surface roughness, and soil moisture instead of seasonal soil-loss ratio. The LS factor have been use to relate rill and interrill erosion.

The P factor is including the conditions for rangelands, contouring, stripcropping, and terracing (Renard et al., 1991). However, RUSLE is not suitable to be applied to areas with obvious overland flow where the soil loss cannot be calculated (Collins et al., 1996).

In the following descriptions, there will be some literature review based on soil erosion studies in Kuantan and other area using the USLE empirical model.

(Mir, Gasim, Rahim, & Toriman, 2010) study the soil loss in the Tasik Chini catchment at Pahang, Malaysia. In this study, USLE model as well as GIS is used to predict the soil erosion risk at Tasik Chini so that the suitable measures can be done to tackle the problems that arise. The R factor, LS factor and C factor values for the USLE model were calculated from the rainfall data, topographic map and land use map. The K factor was determined from the analysis of the soil samples such as the particle size distribution, organic matter content, texture and hydraulic conductivity. A total of 55 samples from eleven different soil series namely Tebok, Lating, Serdang, Kuala Brang, Kedah, Bungor, Kekura, Malacca, Rasau, Prang and Gong Chenak were analysed. In the rainfall erosivity factor (R), the rainfall erosivity index was calculated from the Morgan and Roose calculation (Morgan, 2005). The P value of 2544.5 mm that use in both of the calculation is the annual rainfall mean for the study area which is taken from 2006 rainfall data of the Felda Chini Dua Climatology Station, Chini. The average R factor calculation from the both method is 1654.5 Mj mm/ha h yr. For the soil erodibility factor (K), it was determined from the formulas and their ranks. The formula is shown as Equation 2.2.

$$K = [2.1x\ 10^{-4}\ (12 - OM\%)(N1XN2)^{1.14} + 3.25(S-2) + (P-3)]/100 \qquad 2.2$$

The OM is the organic matter content; N1 is the % of silt + very fine sand; N2 is % of silt + very fine sand + sand (0.125 -2 mm); S is the soil structure code and the soil permeability class represents P. The particle size distribution was determined using the pipette method together with dry sieving while the triangle of texture used to determine the texture of soils. The organic matter content was determined using the loss on ignition method. The hydraulic conductivity was determined using Table 2.4.

Table 2.4: Hydraulic conductivity for K value

Hydraulic Conductivity (cm/hr)	Class	Rank
<0.125	Very slow	7
0.125-0.5	Slow	6
0.5-2.00	Moderately slow	5
2.00-6.25	Moderate	4
6.25-12.50	Moderately rapid	3
12.50-25	Rapid	2
>25	Very rapid	1

For the topographical factor (LS) and vegetative cover factor (C), the topographical map and land use map that was digitalized from IIWIS 3.3 and ArcView GIS 3.3 software was chosen to analyse both factor. In the meantime, the conservation factor (P) for this study on both rubber and oil palm plantation was assumed to be contour terracing practice on slopes. The P value was allocated by overlaying the slope map and land use map together. When all the factors was determined, the soil erosion rate was calculated based on the USLE model. It showed that Tebok, Lating, Burgor, Kekura and Gong Chenak soil series had the lowest rates of soil loss while the Serdang and Prang series had the moderate rates of soil loss. For the moderate high soil loss, Kuala Brang and Rasau soil series averaged 57.16 and 57.93 ton/ha/yr respectively. On the other hands, the Malacca series had the high rate of soil loss but not as high as the Kedah soil series which averaged 180.49 ton/ha/yr. With a high erosion rate, there will be a high generation of sedimentation rate into the Tasik Chini water body that increases the lake level.

(Taha & Kaniraj, 2010) had carry out the study of soil erosion at a site near the Chemical Engineering Laboratory in UNIMAS. This study used the field survey to investigate the topographical features of a site prone to erosion within University Malaysia Sarawak while the laboratory test was carried out on the soil samples collected from the site. The site recorded a total of 52.85 t ha-1 amount of soil loss and the soil erosion risk was moderately high. The study also outlined 9 steps for Erosion and Sediment Control Practice (ESCP) and 5 steps for Best Management Practice (BMP). The nine steps were identification of issues and concerns, development of goals and objectives, collection and analysis of data, development of BMP selection criteria, nomination of candidate BMP, screening and selection of BMP, development of ESCP, operation, monitoring, and maintaining the system and updating the plan. The five steps for the best management practice (BMP) were temporary vs permanent BMP, availability, feasibility, suitability for the site and cost effectiveness.

2.2.1.1 Soil Erodibility Factor

The term of soil erodibility is totally different from the term of soil erosion. Soil erosion rate in the soil loss equation is affected by land slope, the characteristics of rainstorm, cover and management rather than the soil properties itself. Compare to the soil erodibility, it takes into account of the soil properties for the soil that erode easily when the factors affected the soil erosion rate is similar (Wischmeier & Smith, 1978). The soil erodibility factor sum up the effect of the properties and profile characteristics of the soil itself (Römkens et al., 1991). There are also some interrelationship between soil erodibility factor with other RUSLE factors. For example, the slope length and steepness factors (Wischmeier & Smith, 1978). They were derived from the measurements of soil-loss on medium-textured, poorly aggregated surface soils. The errors and drawback in the topographic effects will carry out into K values if the relationships are used to determine K values.

(Zhang, Li, Peng, & Yu, 2004) had conduct a study in the Loess Plateau of China regarding the erodibility of agriculture soils. The study found out that the K factor in the USLE is more suitable for this region. It is because it completely neglect the properties of soil on soil erosion as well as completely independent of the topographical factor such as slope steepness. In this study, the K values are derive from nomograph and the experimental works of the field measurements. As a result, the K factor values that this study got is heavily related to the contents of clay of the loessial soils. In short, USLE is able provide a strong guidance to assess the soil erodibility and its correlation with properties of soil. However, if the nomograph method is used to estimate the soil erodibility directly then it will over-estimate the soil erosion rates for these sites.

(Yusof, Abdullah, Azamathulla, Zakaria, & Ghani, 2011) had conduct a study on the modified soil erodibility, K factor for Peninsular Malaysia soil series. The purpose of the study is to investigate the 76 soil series soil erodibility factor, K of Peninsular Malaysia using the Tew erodibility equation with some modification on the way to determine the soil structure and soil permeability code. In this study, the soil erodibility factors is determined at different depth which is at surface soil (0m-0.5m deep), subsoil (0.51m-1.00m deep) and substratum (1.00m – 1.50m deep). Then, the M values that represent the percentage of silt, clay and very fine sand is determined using particle size distribution of the soil using wet or dry sieve analysis but in this case it was extracted from available soil survey report which also yields the organic matter content. With the M values, the soil structure code and soil permeability code was determined. From the study, the range of erodibility factor for silt loam to clay soil of 76 soil series in Peninsular Malaysia was determined using Tew equation but with modification on the way to determine the soil structure and permeability code. The soil structure code was determined using Soil Textural Pyramid by USGS while Tew just use physical observation to classify the soil. The soil permeability code was determined using USDA National Soil Handbook, 1983 while Tew used the permeability test results of 26 soil series. This outcome from study gives engineers a better understanding of information in determining soil loss and sediment yield for a particular development area and further enhance the Tew equation (1999) compare to Wischmeier equation (1978) in using USLE for Malaysian soil series condition.

(Addis & Klik, 2015) had conduct a study to estimate the soil erodibility factor (K-factor) using Universal Soil Loss Equation nomograph. The study also focus on the spatial distribution of the predicted K-factor in a mountainous agricultural watershed. The study had successfully applied the USLE nomograph to the prediction of the K-factor to the watershed. The study area was northwestern Amhara region, Ethiopia of 54 km^2 which was divided into 500 m by 500 m square grid to investigate the K-factor. Then, about 234 topsoil samples were collected at approximately centre of each grid with 10 to 20 cm depth roughly. The organic matter content, sand, silt and clay were analysed while United States Department of Agricultural (USDA) document was used to obtain the soil permeability and structure class codes. The estimated soil erodibility factor values were highest at the outlet and central part of the watershed. In the meantime, the lowest ones was observed in the north and, rarely, in the other parts of the watershed.

(Ezeabasili, Okoro, & Emengini, 2014) had conduct the study on the relative erodibilities of some soils from Anambra basin. The soil erodibilities was studied in twelve locations where severe guily erosion were observed. The study found out that the soils of Anambra basin was mostly sandy with low silt, low clay, low organic matter and very high permeability. The soil erodibility factor estimated values using the Wischmeier were general low but the potential soil, product of erosivity and erodibility is high. The annual seasonal rainfall also increased to 200 mm in most parts and with very high intensities. Therefore, erosivity was more likely to contribute to the erosion in the area rather than erodibility.

(Haron, Ariffin, & Yusoff, 2014) had carried out the study of nomograph of different soil matrix with respect to erodibility and erosivity coefficients. The purpose of this study was to estimate soil erodibility and rainfall erosivity coefficients as well as to find out the soil loss on bare plot with different soil matrix. The objective also was to establish a nomograph of soil erodibility and rainfall erosivity with different soil matrix. The study conclude that as the percentage of finer soil increased in the mix the soil erodibility coefficients increased. The rainfall energy that hit on bare soil was able to move the soil particles in a short distance. The nomograph for the rainfall intensity was I_{30} = 0.0018 inch / hr and the value of soil erodibility can be read directly from the nomograph.

(Belasri, Lakhouili, & Iben Halima, 2017) had carried out the soil erodibility mapping and its correlation with soil properties of Oued El Makhazine watershed, Morocco. Geographical Information System (GIS) tools were used to map the soil erodibility in the study area. The soil samples were taken from the watershed and analysed in the laboratory for organic matter content and soil texture. The USLE nomograph was used to generate the soil erodibility map or the watershed and it found out that the soil erodibility or this watershed range from moderate up to severe level.

(Imani, Ghasemieh, & Mirzavand, 2014) was able to carried out the mapping and determining the soil erodibility factor for the Yamchi watershed in Northwest of Iran. For this study, a total of 38 samples of surface soil of 0 to 15 cm depth were collected from the watershed and the percentage of silt, clay, sand, and organic matter content were determined in soil laboratory. The texture of the soil samples were later used to determine the soil permeability and structure class by referring to the United States Department of Agriculture (USDA) published information. The K factor was obtained using the USLE nomograph equation and the average soil erodibility factor and average standard error from the interpolated map was 0.442 and 0.0076 $t \cdot ha \cdot h \cdot ha^{-1} \cdot Mj^{-1} \cdot mm^{-1}$. The soil erodibility map or the entire study area was constructed from the kringing interpolation method.

2.3 GIS Application in Soil Loss and Erosion Study

GIS or better known as Geographical Information System is basically a computer system which is designed to help to store, capture, manipulate, analyse and display the spatial or geographical data. According to (KJ, 1979), GIS is a unique information systems where the database contain of observations on spatial distributed features, activities or events. All this observations are actually definable in space as points, lines or areas. This software has the capability to alter the data which is define in space as points, lines or areas so that the ad hoc quarries and analyses of data is known. In the meantime, (Environmental Systems Research Institure, 2006) stated that, GIS is like computer-based tool used for mapping and analysing things around the Earth. It able to provide a unique visual and geographic analysis together with common database operations. In short, GIS is like an image that is based on the earth and has x and y coordinate. All this image contains characteristics that is stored in the form of table. Those who use GIS software are able to get important values such as the area of forest on a land use map through the query builder tool. Besides that, the combination of different layers of map also can be done through GIS. This combination has the capability to provide new information.

Soil erosion studies in Malaysia is not a new thing, A lot of researches had been done previously such as (Mir et al., 2010). All this studies used field measurement and computerize ways such as GIS to compute the soil erosion in selected study areas. There are also several studies that utilize GIS as well as remote sensing to compute the soil erosion risk.

For example, Kamaruzaman and Serwan (1999) develop a soil erosion risk map or Langkawi Island by using the USLE empirical model equation, remote sensing and GIS. This study provide a useful platform for planners that are going to develop the island as they able to know how well the soil erosion problems in the island and incorporate the measures to counter it before acquire the land for developments. The results show that remote sensing and GIS is very helpful in producing soil erosion information that is in quantitative form. The study found out that the island highland areas are more prone to soil erosion as the factors of slope length and steepness (LS) factor of USLE empirical formula indicated so.

(Rendana, Abdul Rahim, Idris, Lihan, & Ali Rahman, 2017) also used remote sensing and GIS technique in assessing the soil erosion in Tasik Chini catchment. RUSLE equation model and remotely sensed geospatial data was integrated in this study. With the soil erosion data which is estimated using remote sensed data then more pragmatic developments can be done at Tasik Chini catchment area. The results from this study shown that northwest and southeast region of Tasik Chini is more prone to soil erosion due to the land use of agricultural, mining activities and new settlements. In general, the rainfall, the slope and land use with open canopies have a direct relationship with the increment of soil erosion.

(Pradhan, Chaudhari, Adinarayana, & Buchroithner, 2012) used GIS to integrate with the USLE soil erodibility equation to model the soil erosion quantitatively as well as to forecast the potential of erosion hazard over a large area for Penang Island. The results shown that the relationship between soil erosion intensity map and landslide events data was quite satisfactory. The soil erosion map was correlate with the landslide map or the locations. The correlation was later verified by frequency ratio analysis using the location of landslides.

2.4 Summary

In summary, this chapter clearly signify the usage of GIS in the estimation of soil erodibility. In addition, the USLE equation was the most used equation in most of the soil erosion studies.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses on how the methods and data were obtained in order to achieve the objectives of this study. In this study, the quantitative way of experimental approach methodology was utilized. This involved testing analysis and programming analysis and the analytical data will be in empirical results.

For this study, testing analysis was more on laboratory works to obtain the percentage of organic matter, silt, clay and fine sand as well as specific gravity for the soil series. The programming analysis utilized the GIS software to identify the location for soil sampling. This is very important in order to compute the soil erodibility factor, K of the Universal Soil Loss Equation (USLE) using modified Tew and Wischmeier erodibility equation. Figure 3.1 shows the flowchart of the research methodology process.

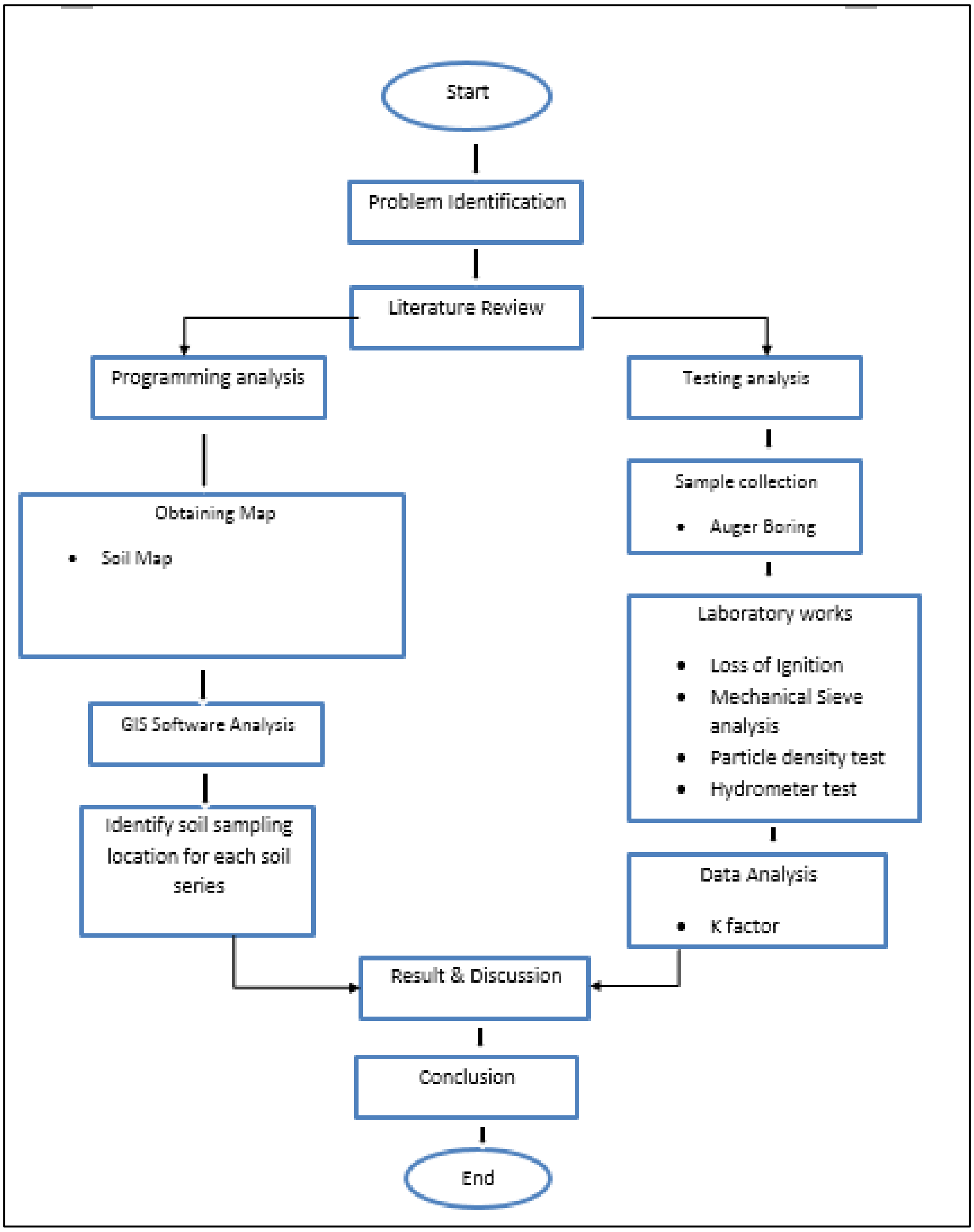

Figure 3.1: Flowchart of Research Methodology Process

3.2 Testing analysis

Testing analysis was divided into sample collection and laboratory works. The sample collection was done using auger boring method. The laboratory works was mainly used to determine the percentage of organic matter, percentage of silt, percentage of very fine sand and percentage of clay.

3.2.1 Sample Collection

In sample collection, the reference standard that used is American Society for Testing and Materials, ASTM D1425, Standard Practice for Soil Exploration and Sampling by Auger Borings. The type of hand-operated that used is Post-Hole Auger of Iwan Type as shown in Figure 3.2. Iwan type of hand auger consists of two tubular steel segments. This segments is connected to the top of a handle or extension to form a nearly complete tube but with opposite openings. At the end, it has two radial blades pitched. This radial blades function as cutters as well as blocking the contained soil from escaping. Auger boring was very easy compare to wash boring, percussion or rotary drilling as it is fast and economical due to the equipment used which is light and inexpensive. This boring is so suitable for soft to stiff cohesive soils but not suitable for saturated cohesionless soil. The procedure is very simple according to (Astm, 2009). The auger is bored by rotating and advanced to the desired distance. In my study the depth of the sampling was fixed at 0.5 meters from the ground. The auger was then withdraw from the hole and the soil was removed. The empty auger was returned to the hole and the procedure was repeated until the required depth is fixed. The samples collected at 0.5 meters depth was then seal in resealable plastic. A total of 3 soil samples for one particular soil series was collected. The soil samples that collected were named after the initial name of each of the fourteen soil series for Kuantan area which were Durian (DRN), Gajah Mati (GMI), Holyrood (HYD), Kuala Brang (KBG), Kranji (KNJ), Kuantan (KUN), Mined Land (MLD), Peat (PET), Rudua (RDU), Rengam (RGM), Steepland (STP), Telemong (TMG) and Urban Land (ULD). The Rengam-Bukit Temiang (RGM-BTG) and Rangam-Jerangau (RGM-JRA) soil series was group together as one under Rengam (RGM). Hence, a total of thirteen soil samples were collected. Figure 3.3 shows the soil collection location determined from the soil map provided by Department of Irrigation and Drainage.

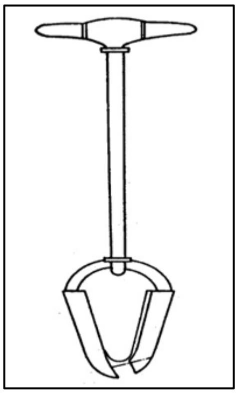

Figure 3.2: Post-Hole Auger of Iwan Type

Source: http://www.abuildersengineer.com/2012/10/boring-methods-site-exploration.html

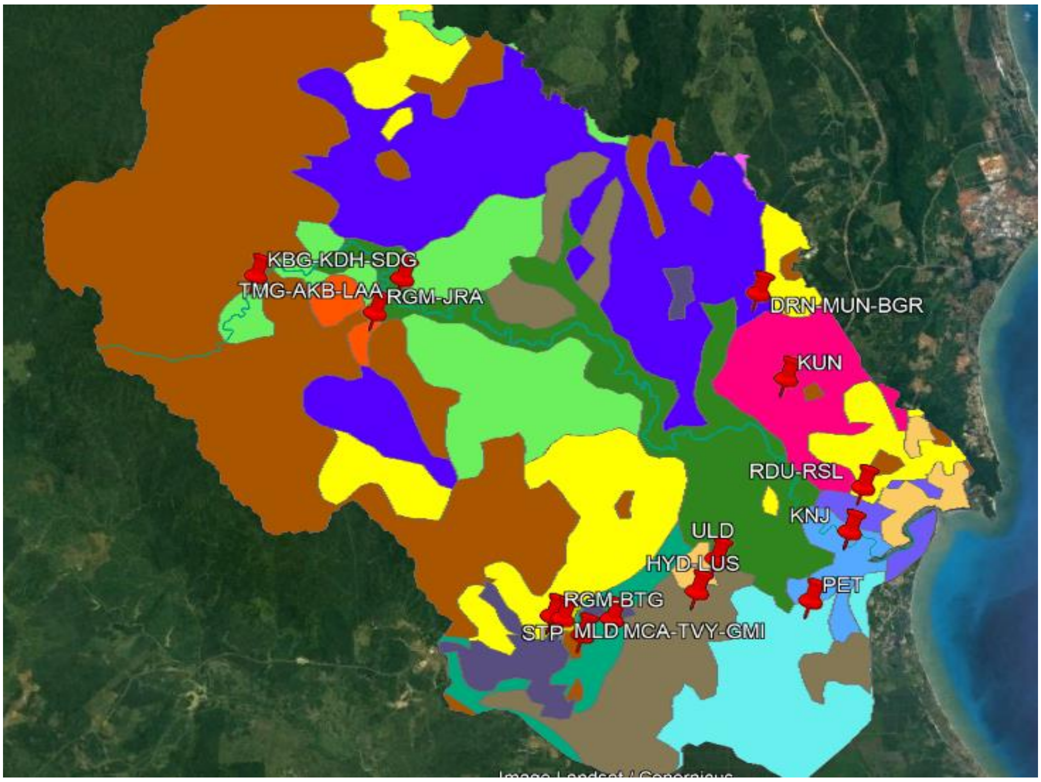

Figure 3.3: Soil Sampling Location

3.2.2 Laboratory Works

In the laboratory works, several tests was carried out as shown in Table 3.1 that according to British Standard (BS) and American Society for Testing and Materials Standard (ASTM) to determine the percentage of organic matter, percentage of silt, percentage of very fine sand and percentage of clay. The percentage of silt, percentage of clay and percentage of very fine sand were determined from Mechanical Sieve Analysis Test Result that was based on the size limits for soil separates of USDA Textural

Classification System as shown in Figure 3.4. Then with the known percentage of silt, clay and sand, the soil texture can be determined from USDA textural classification chart as shown in Figure 3.5. The soil texture was very important in determining the soil structure and permeability code as shown in Figure 3.6. The soil structure code, permeability code, % of organic matter, % of silt and % of very fine sand were very important to calculate the K factor of the Universal Soil Loss Equation (USLE) using the modified Tew soil erodibility equation and Wischmeier soil erodibility equation. Both equation to determine the K factor are shown in Equation 3.1 and Equation 3.2.

Modified Tew modified soil erodibility equation;

$$K = [\ 1.0 \times 10^{-4}(12 - OM)M^{1.14}\ + 4.5(S - 3) + 8.0(P - 2)]/100 \qquad 3.1$$

Where,

M = (% silt + % very fine sand) × (100 - % clay);

OM = % of Organic matter;

S = Soil Structure code; and

P = Permeability class

Wischmeier soil erodibility equation;

$$K = [\ 2.1 \times 10^{-4}(12 - OM)M^{1.14}\ + 3.25(S - 3) + 2.5(P - 2)]/100 \qquad 3.2$$

Where,

M = (100 - %clay) x (%modified silt or the 0.002-0.1 mm size fraction);

OM = % of Organic matter;

S = Soil Structurer code; and

P = Permeability class

Size Limits of USDA Soil Separates

Name of separate	Diameter range (millimeters)
Sand	2.0-0.05
Silt	0.05-0.002
Clay	less than 0.002

The sand separate is subdivided into very coarse sand, coarse sand, medium sand, fine sand, and very fine sand. The size ranges for these subdivisions are given below:

Subdivisions	Diameter range (millimeters)
Very coarse sand	2.0-1.0
Coarse sand	1.0-0.5
Medium sand	0.5-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05

Figure 3.4: Size Limits of USDA Soil Separates

Source: United States Department of Agriculture (1987)

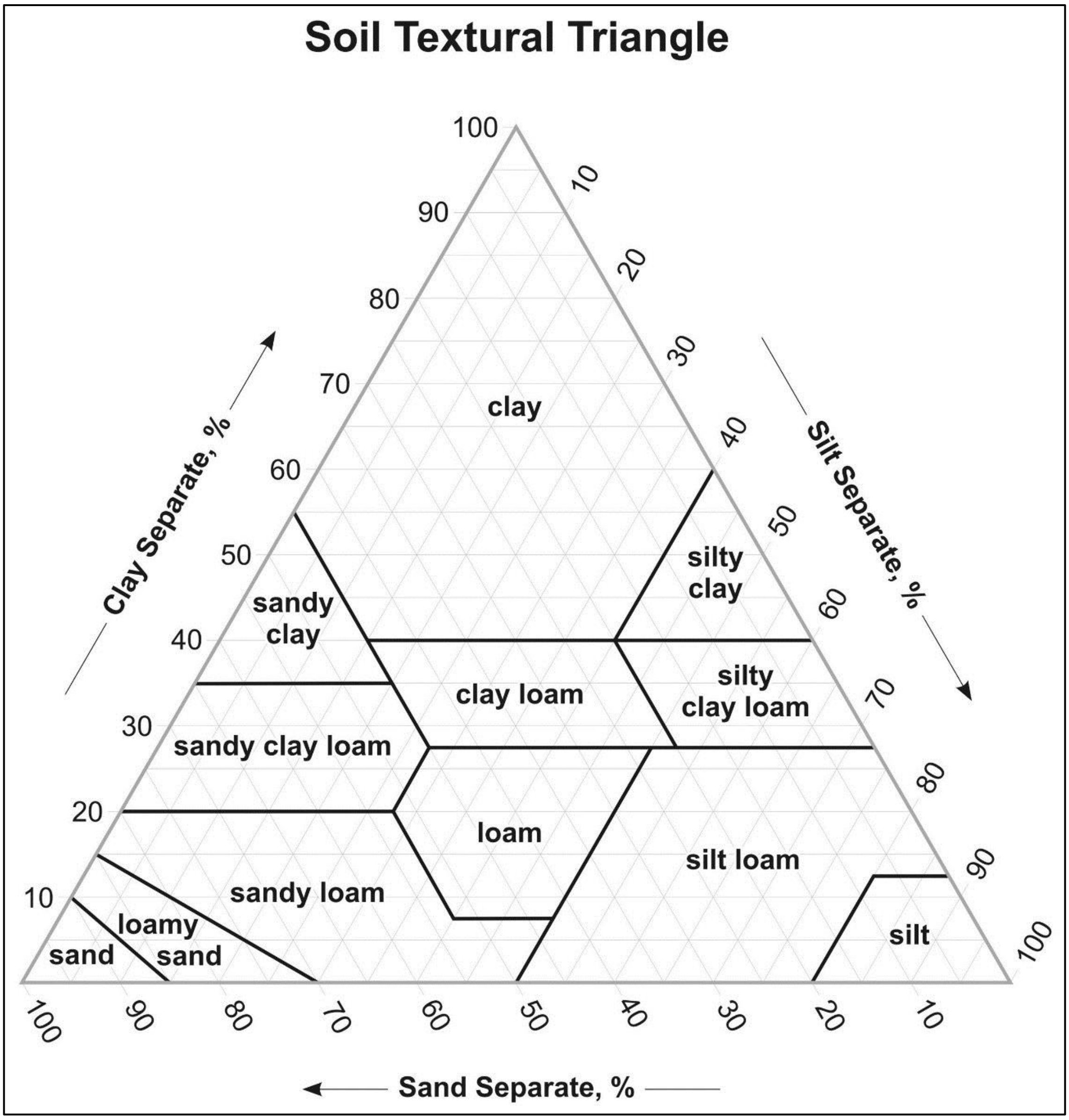

Figure 3.5: USDA Textural Triangle

Source: United States Department of Agriculture (1987)

Soil Texture	Permeability Code[1]	Hydrologic Soil Group[2]	Soil Structure Code[3]
Heavy Clay	6	D	4
Clay	6	D	4
Silty Clay Loam	5	C	4
Sandy Clay	5	C	4
Sandy Clay Loam	4	C	4
Clay Loam	4	C	4
Loam	3	B	2
Silty Loam	3	B	3
Loamy Sand	2	A	1
Sandy Loam	2	A	2
Sand	1	A	1

Note: 1 – National Soil Survey Handbook (NRCS, 2005)
2 – National Engineering Handbook (NRCS, 2007)
3 – Field Manual for Describing Soils in Ontario (Ontario Centre for Soil Resource Evaluation, 1993)

Figure 3.6: Soil Structure Code and Permeability Code for Various Soil Structure

Source: (MSMA 2nd Edition, 2012)

Table 3.1: Laboratory Test Standard

	Test Name	**Standard**
Determination of K factor laboratory test	Loss onIgnition	ASTM D2974
	Mechanical Sieve test	BS 1377: Part 2 1990: 9.6
	Specific Gravity test	BS 1377: Part 2 1990: 8.2
	Hydrometer test	BS 1377: Part 2 1990: 9.6

3.2.2.1 Mechanical Sieve Test

The mechanical sieve analysis was usually for coarse grained soil as it helps to determine the distribution of the larger grain sizes. There are plenty of sieve sizes that available and usually the finest one is a 63µm sieve. All the sieve sizes according to British Standard are shown in Figure 3.7. In mechanical sieve test, the soil was passed through a series of sieves. However, the sieves were arranged with the mesh size reducing progressively. Then, the proportions by weight of soil that was retained on each sieve are measured. In this test, the test sieves of sizes 6.30 mm, 5.00 mm, 3.35 mm, 1.18 mm, 600 µm, 300 µm, 150 µm and 63 µm as well as pan was used. The sieving can be done either in dry or wet condition but due to the tendency of the fine particles clump together, wet sieving is usually required for fine-grained soil. In the sieve analysis that was done, 500 gram of oven-dried soil sample was sieve through the sieve sizes of 6.3mm, 5.00mm, 3.35 mm, 1.18 mm, 600 µm, 300 µm, 150 µm and 63 µm as well as pan according to the British Standard, BS 1377: Part 2 1990: 9.6. Before the soil sample was sieved, the large soil particles which is not gravel that present in the soil sample was crumple to the appropriate sizes that is smaller to the sieve sizes. The duration of the sieve test was about 10 minutes.

Aperture size	*A. Full Set (19)*	*B. Standard Set (13)*	*C. Short Set (7)*	Suitable sieve diameters 450 mm	300 mm	200 mm
75 mm	+	+		+		
63 mm	+	+	+	+		
50 mm	+			+		
37.5 mm	+	+		+	+	
28 mm	+			+	+	
20 mm	+	+	+	+	+	
14 mm	+				+	
10 mm	+	+			+	
6.3 mm	+	+	+		+	
5 mm	+				+	
3.35 mm	+	+			+	+
2 mm	+	+	+	(+)	+	+
1.18 mm	+	+				+
600 μm	+	+	+	(+)	+	+
425 μm	+					+
300 μm	+	+				+
212 μm	+		+			+
150 μm	+	+				+
63 μm	+	+	+	(+)	+	+

Note: Many other test sieves, up to 125 mm and down to 38 μm aperture size, are available. They are manufactured to BS 410: 2000. (+) indicates sieves useful for wet sieving of large samples.

Figure 3.7: All Sieve Sizes according to British Standard

Source: Head (2006)

3.2.2.2 Hydrometer Test

For fine grained soil, hydrometer test was usually used to determine the grain size distribution of the material passing the 63 µm. The test will not be carry out if less than 10% of the material passes the 63 µm. In hydrometer test, the soil is mixed with water and a dispersing agent. The dispersing agent used in this test was sodium hexametaphosphate solution. The mixture was then stirred vigorously and allowed to settle to the bottom of a measuring cylinder. The specific gravity of the mixture reduces as the soil particles settle out of the suspension. The variation of specific gravity with time was recorded using a hydrometer as shown in Figure 3.8. By making use of Stoke's Law that relates the velocity of a free falling sphere to its diameter, this test provide the particle diameters and the % by weight of the sample finer than a particular particle size. The diameter of soil grain can be calculated using Equation 3.3.

$$v = \frac{G_S - G_W}{18\eta} (D)^2 \qquad 3.3$$

Where,

v = Settling velocity of the fluid, water plus dispersing agent

G_s = Specific velocity of the soil solids

G_w = Specific gravity of the water and dispersing agent solution

η = Absolute viscosity of the suspending fluid which depends on the temperature

D = Particle diameter

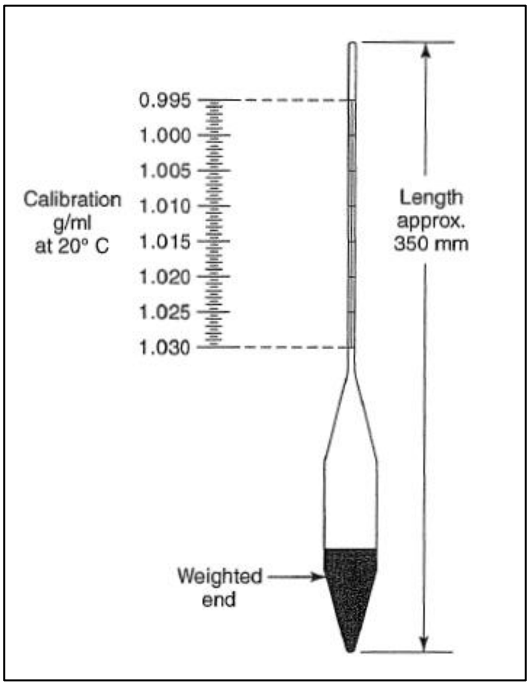

Figure 3.8: Soil Hydrometer

Source: Head (2006)

3.2.2.3 Specific Gravity Test

Specific gravity is the ratio of the mass unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. For a given volume of the soil, the specific gravity of a soil is used in the phase relationship of air, water and solids. The determination of specific gravity in this test is by using the

Small Pyknometer Method which is able to determine the specific gravity of soils consisting clay, silt and sand-sized particles. Small Pyknometer is a traditional way in measuring the density of particles that is heavier than water or density of liquids and is only suitable or soils that is finer than 2 mm. The most commonly used in this method is distilled water but other liquid such as kerosene can replaced the distilled water if the soil contains some soluble salts. If the distilled water is replaced by other liquid then the density of the other liquid need to be recalculated even though the test procedure is similar. To calculate the specific gravity, four different mass need to be recorded before the specific gravity can be calculated using Equation 3.4.

$$G_s = \frac{m_2 - m_1}{(m_4 - m_1)(m_3 - m_2)} \quad 3.4$$

Where;

m_1: Mass of density bottle + stopper (g)

m_2: Mass of bottle + dry soil + stopper (g)

m_3: Mass of bottle + soil + water + stopper (g)

m_4: Mass of bottle + water + stopper (g)

3.2.2.4 Loss on Ignition

For measuring the organic matter content in a soils the loss of ignition method is one of the most common method used compare to others. There are plenty of factors that will influence its accuracy during the measurement such as the furnace type, sample mass, duration and temperature of ignition and clay content of samples. In our study, the loss on ignition test on samples only involve the use of muffle furnace and does not involve the use of any chemicals. In this test using ASTM D 2974, the testing method will be according to the test methods C and D. The ash content of an organic soil sample was determined by igniting the oven-dried sample which is from the moisture content determination in a muffle furnace at 440˚C for test method C or 750˚C for test method D. After the ignition the sample remaining will be ash. The content of the ash was expressed as a percentage of the mass of the oven-dried sample and to find the organic matter, the percentage of ash content was subtracted from one hundred.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter focus on the continuity of the previous chapter which is the results and analysis that obtained from the testing and programming analysis.

4.2 Sieve Analysis Test Result

In the sieve analysis results, the uniformity coefficient was determine which was Coefficient of Uniformity, C_u and Coefficient of Gradation, C_c from the particle size distribution of each soil samples. Therefore, the typical value used in determining the uniformity coefficient were D_{10}, D_{30} and D_{60}. The D_{10}, D_{30} and D_{60} can be recognized as the average particle size. D_{10} was the effective particle size. It represent the 10 percent of the particles which are finer and 90 percent of the particles are coarser. D_{60} was the soil particles diameter for which the 60 percent of the soil particles are finer and the remaining 40 percent are coarser than D_{60}. The coefficient of Uniformity, C_u was the ratio of D_{60} by D_{10} while the Coefficient of Gradation, C_u was equivalent to the ratio of D_{30} square by D_{60} multiply D_{10}. The equation for C_u and C_c were shown in Equation 4.1 and Equation 4.2. The purposes of the C_u and C_c serve as a measure of the gradation as well as classification of the soil.

$$C_U = \frac{D_{60}}{D_{10}} \qquad 4.1$$

$$C_C = \frac{{D_{30}}^2}{(D_{60} \times D_{10})} \qquad 4.2$$

According to (M. Das & Sobhan, 2014), there are three type of Grading curves which is well graded curve, uniformly graded curve and poorly graded curve as shown in Figure 4.1. The curve I is a poorly graded soils which the grains of the soils are mostly same size. Coefficient of Uniformity, C_u for poorly graded soils less than four. The curve II represents a well graded soil. A well graded soils is where the soil particle sizes are distributed over a wide range. In the meantime, the curve III shows us the gap graded soil. A gap graded soil will sometimes show the combination of two or more uniformly graded fractions. For the well graded soils, the Coefficient of Uniformity, C_u must greater than four for gravels and six for sand. The Coefficient of Gradation, C_c for sands and gravels are around one to three.

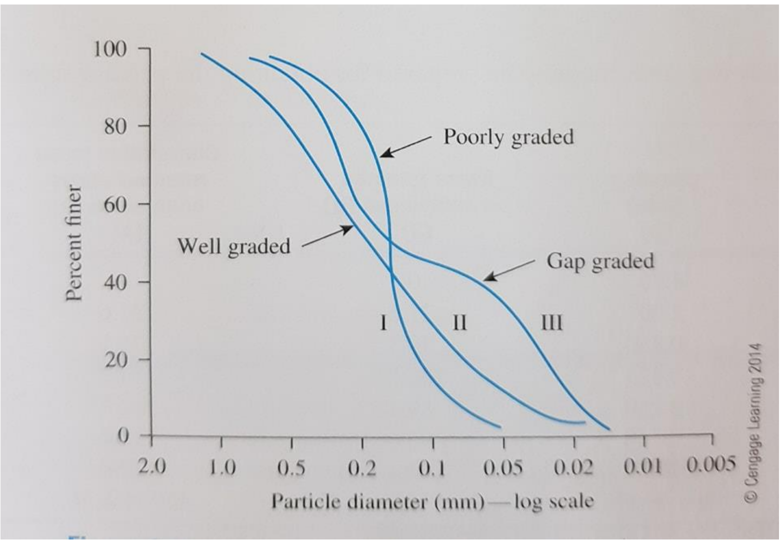

Figure 4.1: Different Particle-Size Distribution Curve

Source: M. Das & Sobhan (2014)

From the thirteen soil samples, the computation of Coefficient of Uniformity, C_u and Coefficient of Gradation, C_c were shown in Table 4.1 and 4.2. The computation of C_u and C_c were taken from the average of the three samples for each soil series. Based on the results, the Coefficient of Uniformity, C_u for the soil samples were mostly less than six except Durian (DRN), Peat (PET) and Urban Land (ULD). This is because the particle size distribution graph for Durian (DRN) and Peat (PET) shown in Appendix A clearly represent a well graded curve but contrasting to the Urban Land (ULD) that shown a poorly graded curve. The soil samples that Coefficient of Uniformity, C_u less than four were classify as poorly graded curve except Holyrood (HYD), Kuantan (KUN), Mined Land (MLD) and Rengam (RGM) which was between four to six which classify as well graded soil (Melorose, Perroy, & Careas, 2015). The range of the Coefficient of Uniformity, C_u values were from three to eleven. The lowest value of Coefficient of Uniformity, C_u was Telemong (TMG) with 3.2. The highest value of Coefficient of Uniformity, C_u was Urban Land (ULD) with 11.1. In the meantime, Coefficient of Gradation, C_c values for the thirteen soil samples range from zero to three. This range of values clearly match the values indicated by (M. Das & Sobhan, 2014) which stated that the range of Coefficient of Gradation, C_c values were around one to three for either sand or gravel. The graph of particle size distribution for the three sample for each series of soils samples were shown in Appendix A.

Table 4.1: Coefficient of Uniformity, C_u and Coefficient of Gradation, C_c for Kuantan Soil Samples

Soil samples name	**Coefficient of Uniformity, C_u**	**Coefficient of Gradation, C_c**
Telemong, (TMG)	3.2	1.3
Kranji, (KNJ)	3.4	1.3
Kuala Brang, (KBG)	3.8	0.9
Gajah Mati, (GMI)	4.2	2.1
Steepland, (STP)	4.7	1.3
Rudua, (RDU)	4.9	0.8
Holyrood, (HYD)	5.0	1.1
Mined Land, (MLD)	5.1	1.1
Rengam, (RGM)	5.2	1.8
Kuantan, (KUN)	5.6	1.2
Durian, (DRN)	7.8	0.9
Peat, (PET)	9.4	0.9
Urban Land, (ULD)	11.1	3.1

4.3 Particle Density Test Result

Table 4.2: Specific Gravity for Kuantan Soil Samples

Soil samples name	Specific gravity (Mg/m^3)
Steepland, (STP)	2.25
Rengam, (RGM)	2.33
Mined Land, (MLD)	2.44
Gajah Mati, (GMI)	2.49
Peat, (PET)	2.51
Kranji, (KNJ)	2.58
Kuantan, (KUN)	2.58
Telemong, (TMG)	2.60
Urban Land, (ULD)	2.65
Holyrood, (HYD)	2.65
Kuala Brang, (KBG)	2.69
Durian, (DRN)	2.91
Rudua, (RDU)	2.93

The specific gravity for the thirteen soil samples was shown in Table 4.3. The specific gravity range from two to three. Steepland (STP) soil sample had the lowest specific gravity with value 2.25 while Rudua (RDU) soil sample had the highest specific gravity with value 2.93. The range of specific gravity for solid substance of most inorganic soils given by (Department of the Army Washington, 1999) varies between 2.60 to 2.80 while the inorganic clay specific gravity range from 2.70 to 2.80. The range given by (Department of the Army Washington, 1999) shown that the Telemong (TMG), Urban Land (ULD), Holyrood (HYD) and Kuala Brang (KBG) soil samples were mostly inorganic soils while Durian (DRN) and Rudua (RDU) were mostly inorganic clay. In addition, the specific gravity of soil samples that less than 2.60 such as Steepland (STP), Rengam (RGM), Mined Land (MLD), Gajah Mati (GMI), Peat (PET), Kranji (KNJ) and Kuantan (KUN) were indicated as soils with a large amount of organic matter (Department of the Army Washington, 1999)

4.4 Hydrometer Test Result

Hydrometer test is normally carried out for fine grained soil as the sieve analysis does not provide a test result that is reliable. The fine grained soil range from 0.075 mm to 0.002 mm and this range of sizes are not suitable for sieve analysis as there are no sieve with smaller screen size. There also a possibility of sample lost during sieving. Therefore, the grain size analysis of fine grained soils is usually done with hydrometer analysis. In the hydrometer testing, the testing was done with three samples of each soil series. In such a way, the comparison and averaging the fine analysis results between the three samples of each soil series were done. The percent finer of silt particle of which sizes range from 0.05mm – 0.002mm and percent finer of clay particles which means particles smaller than 0.002mm were obtained. From the graph of fine analysis shown in Appendix B, the graph of soil samples of Durian (DRN), Gajah Mati (GMI), Kranji (KNJ), Mined Land (MLD), Peat (PET), Kuala Brang (KBG), Holyrood (HYD), Telemong (TMG), Steepland (STP) and Rudua (RDU) yield the same pattern but with different values for the percent finer for silt and clay. For Rengam (RGM) and Urban Land (ULD) soil samples, their graph of fine analysis had an overlap between two samples while Kuantan (KUN) soil sample graph of fine analysis had an abnormal pattern for a soil sample compare to the other two samples. The percentage finer of silt and clay are shown in Table 4.3. The silt percentage is higher for Peat (PET) soil sample with 0.46% while the clay percentage was higher in Holyrood (HYD) with 0.64%. According to (Wischmeier & Smith, 1978), a lower percentage of silt will made the soil less erodible even with the corresponding increase in the sand fraction or the clay fraction. This clearly indicated that the Gajah Mati (GMI), Rudua (RDU) and Kranji (KNJ) soil samples were less erodible compare to other samples as their percentage of silt was quite small with 0.03%, 0.04% and 0.07% respectively.

Table 4.3: Silt and Clay Percentage for Kuantan Soil Samples

Soil samples name	**Silt, %**	**Clay, %**
Gajah Mati, (GMI)	0.03	0.21
Rudua, (RDU)	0.04	0.08
Kranji, (KNJ)	0.07	0.17
Telemong, (TMG)	0.13	0.12
Mined Land, (MLD)	0.13	0.31
Steepland, (STP)	0.14	0.18
Holyrood, (HYD)	0.14	0.64
Durian, (DRN)	0.15	0.39
Rengam, (RGM)	0.18	0.22
Kuantan, (KUN)	0.22	0.20
Kuala Brang, (KBG)	0.25	0.31
Urban Land, (ULD)	0.29	0.19
Peat, (PET)	0.46	0.32

4.5 Organic Matter Test Result

Soil organic matter is a part of soil that consists of plant or animal tissue that undergoes several stages of decomposition. According to (Greenland, 1980), the organic matter comprised of humus, detritus and plant residues and living microbial biomass. The humus is also known as stable soil organic matter and detritus is the active soil organic matter. The percentage of organic matter of the thirteen soil samples was shown in Table 4.4. The range of organic matter was from one percent to ten percent. Rudua (RDU) soil sample had the highest percentage of organic matter with 10.98%. A high percentage of organic matter made the soil highly resistant to the soil erosion as organic matter helps to bind the individual soil particles together to form large stable aggregates. This large stable aggregates has the capability to resist erosion as well as withstand the forces of raindrop impact (Bot & Benites, 2005).

Table 4.4: Organic matter percentage for Kuantan Soil Samples

Soil samples name	Organic Matter, %
Urban Land, (ULD)	1.49
Telemong, (TMG)	1.86
Holyrood, (HYD)	1.91
Kuantan, (KUN)	2.23
KranjI, (KNJ)	2.83
Gajah Mati, (GMI)	3.87
Durian, (DRN)	4.12
Peat, (PET)	5.48
Mined Land, (MLD)	5.52
Rengam, (RGM)	6.11
Steepland, (STP)	6.17
Kuala Brang, (KBG)	7.40
Rudua, (RDU)	10.98

4.6 Calculation of Soil Erodibility Factor (K) using modified Tew and Wischmeier Soil Erodibility Equation

Modified Tew soil erodibility equation;

$$K = [\,1.0 \times 10^{-4}(12 - OM)M^{1.14} + 4.5(S - 3) + 8.0(P - 2)]/100 \qquad 4.2$$

Where,

M = (% silt + % very fine sand) × (100 - % clay);

OM = % of Organic matter;

S = Soil Structure code; and

P = Permeability class

Wischmeier soil erodibility equation;

$$K = [\,2.1 \times 10^{-4}(12 - OM)M^{1.14} + 3.25(S - 3) + 2.5(P - 2)]/100 \qquad 4.2$$

Where,

M = (100 - %clay) x (%modified silt or the 0.002-0.1 mm size fraction);

OM = % of Organic matter;

S = Soil Structurer code; and

P = Permeability class

The Permeability Code was extracted from National Soil Survey Handbook, (NRCS, 2005) and Soil Structure Code values was extracted from the Field Manual for Describing Soils in Ontario, (Denholm, Schut, & Irvine, 1993). The Permeability Code and Soil Structure Code was shown in Table 4.5. The overall percentage of sand, very fine sand, silt and clay for thirteen series of soil samples were shown in Table 4.6. The percentage of fine sand was obtained from the graph of sieve and fine analysis as the particle range from 0.10 mm – 0.05 mm according to size limits of USDA Soil Separates.

Table 4.5: Permeability Code and Soil Structure Code

Soil Texture	Permeability code[1]	Soil Structure code[2]
Heavy Clay	6	4
Clay	6	4
Silty Clay Loam	5	4
Sandy Clay	5	4
Sandy Clay Loam	4	4
Clay Loam	4	4
Loam	3	2
Silty Loam	3	3
Loamy Sand	2	1
Sandy Loam	2	2
Sand	1	1

Source: 1 – NRCS (2005)
2 – Denholm, Schut, & Irvine (1993)

Table 4.6: Overall Percentage of Sand, Very Fine Sand, Silt, Clay and Organic Matter for Kuantan Soil Series.

Soil samples series name	Sand, %	Very Fine Sand, %	Silt, %	Clay, %	Organic matter, %
Durian-Munchong-Bungor	99.46	11.99	0.15	0.39	4.12
Malacca-Tavy-Gajah Mati	99.76	2.46	0.03	0.21	3.87
Holyrood-Lunas	99.22	8.32	0.14	0.64	1.91
Kuala Brang-Kedah-Serdang	99.59	4.81	0.25	0.31	7.40
Kranji	99.78	2.06	0.07	0.17	2.83
Kuantan	99.58	3.34	0.22	0.20	2.23
Mined Land	99.55	2.15	0.13	0.31	5.52
Peat	99.22	16.38	0.46	0.32	5.48
Rudua-Rusila	99.86	1.06	0.04	0.08	10.98
Rengam-Bukit Temiang	99.61	3.43	0.18	0.22	6.11
Steepland	99.66	3.87	0.14	0.18	6.17
Telemong-Akob-LocalAlluvium	99.69	10.19	0.13	0.12	1.86
Urban Land	99.52	9.36	0.29	0.19	1.49

Based on the USDA Textural Triangle in USDA Textural Classification System (United States Department of Agriculture, 1987), the soil samples were classified as shown in Table 4.7 . The Permeability Code and Soil Structure Code were also shown in Table 4.7.

Table 4.7: Soil Classification, Permeability Code and Soil Structure Code for Kuantan Soil Series.

Soil samples series name	USDA Soil Classification	Permeability Code	Soil Structure Code
Durian-Munchong-Bungor	Sand	1	1
Malacca-Tavy-Gajah Mati	Sand	1	1
Holyrood-Lunas	Sand	1	1
Kuala Brang-Kedah-Serdang	Sand	1	1
Kranji	Sand	1	1
Kuantan	Sand	1	1
Mined Land	Sand	1	1
Peat	Sand	1	1
Rudua-Rusila	Sand	1	1
Rengam-Bukit Temiang	Sand	1	1
Steepland	Sand	1	1
Telemong-Akob-Local Alluvium	Sand	1	1
Urban Land	Sand	1	1

From the thirteen soil series for Kuantan area, all the soil samples were classified as Sand using the USDA Textural Soil Classification. This is due to a high percentage of sand with almost 100% for all the soil series that resulted the similar soil classification. Next, the M values exponent to 1.14 was calculated. This calculation was similar for both of the soil erodibility equation and was shown in Table 4.8. From the M values result for the thirteen soil series, there was some correlation between the M values with the percentage of fine sand. It was observed that if the percentage of fine sand in a soil sample for the soil series increased, a greater M value was obtained respectively. The Peat (PET) which had 16.38% of fine sand yield 4748.78 for the M value.

Table 4.8: M Value for Kuantan Soil Series.

Soil samples series name	M value
Rudua-Rusila	212.69
Kranji	450.32
Mined Land	487.64
Malacca-Tavy-Gajah Mati	538.23
Kuantan	810.36
Rengam-Bukit Temiang	822.12
Steepland	928.35
Kuala Brang-Kedah-Serdang	1204.67
Holyrood-Lunas	2156.32
Urban Land	2518.13
Telemong-Akob-Local Alluvium	2724.6
Durian-Munchong-Bungor	3268.95
Peat	4748.78

The final computation for the soil erodibility factor, K for the thirteen soil series according to modified Tew (Equation 4.1) and Wischmeier (Equation 4.2) soil erodibility equation for Kuantan Soil Series was shown in Table 4.9.

Table 4.9: Soil Erodibility Factor (K) for Kuantan Soil Series

Soil samples series name	Tew	Wischmeier
Peat	-0.1390	-0.0174
Telemong-Akob-Local Alluvium	-0.1424	-0.0245
Urban Land	-0.1435	-0.0269
Durian-Munchong-Bungor	-0.1442	-0.0284
Holyrood-Lunas	-0.1482	-0.0368
Kuantan	-0.1621	-0.0659
Kuala Brang-Kedah-Serdang	-0.1645	-0.0709
Steepland	-0.1646	-0.0711
Rengam-Bukit Temiang	-0.1652	-0.0723
Malacca-Tavy-Gajah Mati	-0.1656	-0.0733
Kranji	-0.1659	-0.0738
Mined Land	-0.1668	-0.0759
Rudua-Rusila	-0.1698	-0.0820

This final results that obtained for the soil erodibility factor, K using the modified Tew and Wischmeier soil erodibility equation was not the desired results that was expected as it yield negative value for all the thirteen soil series for Kuantan river basin. The soil erodibility factor, K factor should not be a negative value as many previous research proven that the K factor was positive. For example, the soil loss assessment by

(Mir et al., 2010) in the Tasik Chini catchment, Pahang, Malaysia provides a positive value for the K factor in the computation of the rate of soil loss.

The soil erodibility factor, K calculated from the Wischmeier soil erodibility equation was smaller than the soil erodibility factor, K calculated from the modified Tew soil erodibility equation. The percentage different between the K factor of modified Tew soil erodibility equation and K factor of Wischmeier soil erodibility equation was shown in Table 4.10.

Table 4.10: Percentage Different between the K Factor of Modified Tew Soil Erodibility Equation and K Factor of Wischmeier Soil Erodibility Equation

Soil samples series name	**Percentage different, %**
Peat	155.3923
Telemong-Akob-Local Alluvium	141.2784
Urban Land	136.7867
Durian-Munchong-Bungor	134.1569
Holyrood-Lunas	120.4659
Kuantan	84.4109
Kuala Brang-Kedah-Serdang	79.5538
Steepland	79.2855
Rengam-Bukit Temiang	78.1675
Malacca-Tavy-Gajah Mati	77.2719
Kranji	76.7969
Mined Land	74.9645
Rudua-Rusila	69.6805

The percentage different of K factor between modified Tew soil erodibility equation and Wischmeier soil erodibility equation range from 60% to 200%. From the table 4.10, the result clearly indicated that the Rudua (RDU) soil series was less erodible compare to others. Rudua-Rusila soil series had the highest percentage of organic matter and lowest percentage of silt content which made it less erodible. In contrast, Peat was more erodible compare to others soil series as it had the highest percentage of silt with 16.38 % and with a considerable small amount of organic matter of 5.48 %. This deduction was made by neglecting the fact the K value was supposedly a positive value.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the two specific objectives set earlier had been achieved through the study. The importance of soil erodibility factor, K in the USLE model was discovered through the study and how this factor will affect the computation of soil erosion rates using the USLE model. Basically, the soil erodibility factor taken into the consideration of organic matter, sand, fine sand, silt and clay percentage into its calculation. Each of this percentage will greatly affect the outcome of the value of the soil erodibility. Thus, the increase in one of the percentage will directly affect the value of the soil erodibility.

Therefore, this study is carried out to determine how each of this percentage will affect the soil erodibility factor on Kuantan soil series which differs from other states in Malaysia and finally determine the soil erodibility factor for the thirteen soil series in Kuantan area. The soil type will be a prime factor to determine how vulnerable a soil to erosion. A soil has many aspects to be taken into account such as permeability, soil texture, soil structure and soil organic matter. All this aspects will contribute significantly to the soil erodibility rate. Hence, with the known value of the soil erodibility on the thirteen type of the soil series in Kuantan area, it will indicate how easily the soil will erode. With that information, certain parties can use this information by applying the Best Management Practice (BMP) to curb the soil erosion problems. With regards to the four objectives of the study, there are several points that can be conclude or this study;

a) The Coefficient of Uniformity, C_u values for the thirteen soil series for Kuantan, Pahang were less than six except Durian-Munchong- Bungor, Peat and Urban Land soil series. This does not match the suggested value for sand which is six as all the thirteen soil series were classified as sand by USDA.

b) The sieve analysis experiment clearly produce the particle size distribution curve that match the Coefficient of Uniformity, C_u values for the thirteen soil series except for Urban Land that shows a poorly graded curve with C_u value more than four.
c) Specific gravity test according BS 1377: Part 2 1990: 8.2 gives reliable result as the specific gravity of soil series that less than 2.60 such as Steepland, Rengam, Mined Land, Malacca-Tavy-Gajah Mati, Peat, Kranji and Kuantan as noted by (Department of the Army Washington, 1999) mostly have considerable large amount of organic matter ranging from two to six percent.
d) Rudua soil series was less erodible compare to other soil series for Kuantan soil series as it has the highest percentage of organic matter as well as low percentage of silt. This is proven by the organic matter test, ASTM D2974 and hydrometer test, BS1377: Part2 1990: 9.

All the conclusion made above was by neglecting the fact that the negative value of K factor that calculated from this study was supposedly a positive value. However, even by using the calculated negative value of K factor, we discovered that the soil series that was less erodible which is Rudua had the supporting facts from the experiment that proved it less erodible even though it shown a negative value of K factor. It also shown that the smaller the negative value of K factor, the less erodible the soil series as it will have the less percentage of silt which made it less erodible.

5.2 Recommendation

This study findings suggest that there should be a few recommendation for improvements to be carried out so that the future studies on the estimation of the soil erodibility factor, K can be improved as follow:

a) The location of soil collection sample should be taken two or three places instead of one collection place according to the soil map to compare the soil composition results.
b) There should be a continuous studies on the soil erodibility factor, K factor on Kuantan soil series as there are none previous study before.
c) To ensure that the samples are not fill soil or others, the samples must be taken from the original soil at the area.

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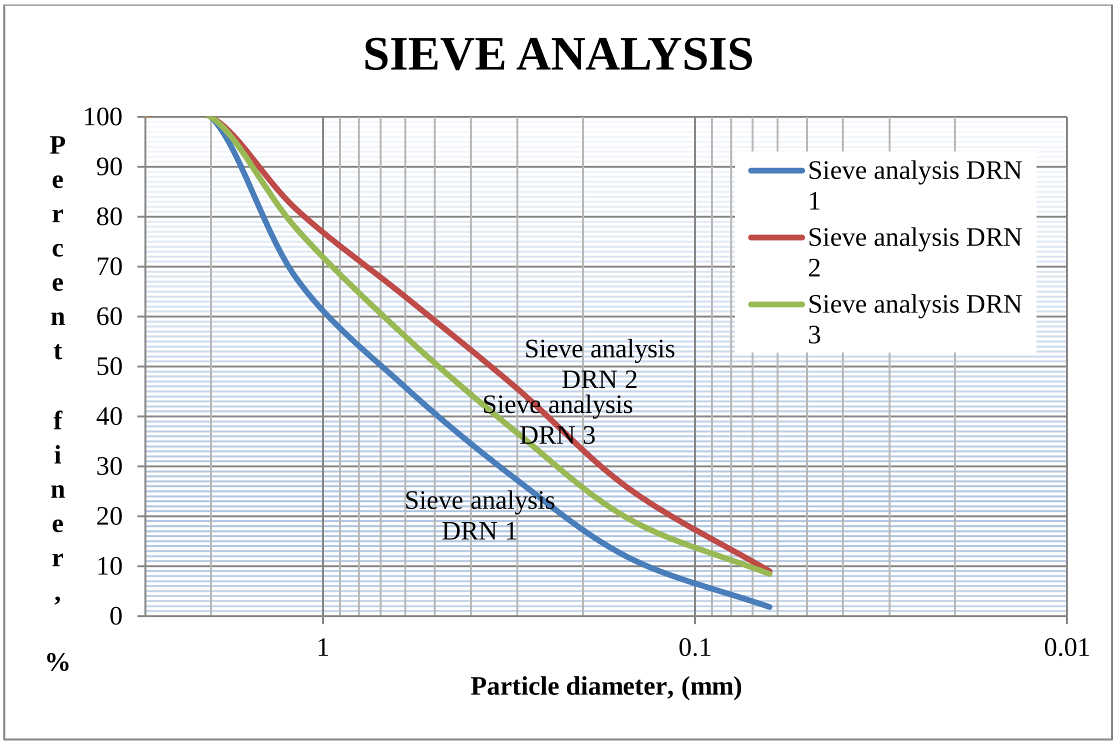
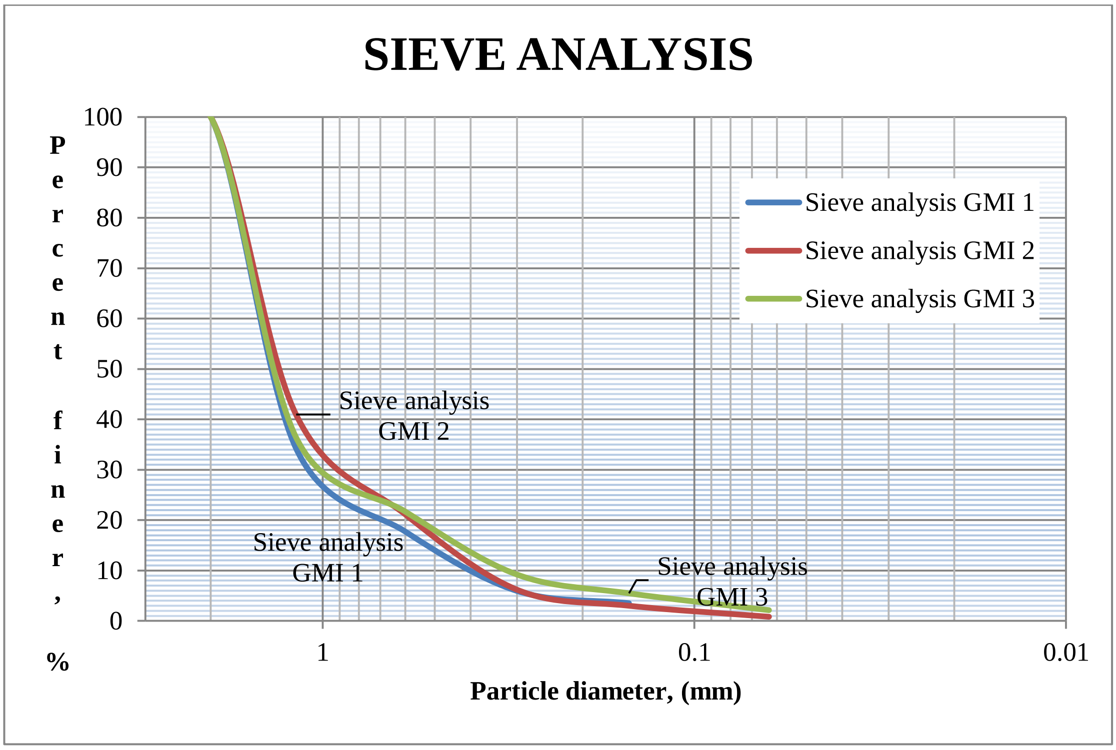
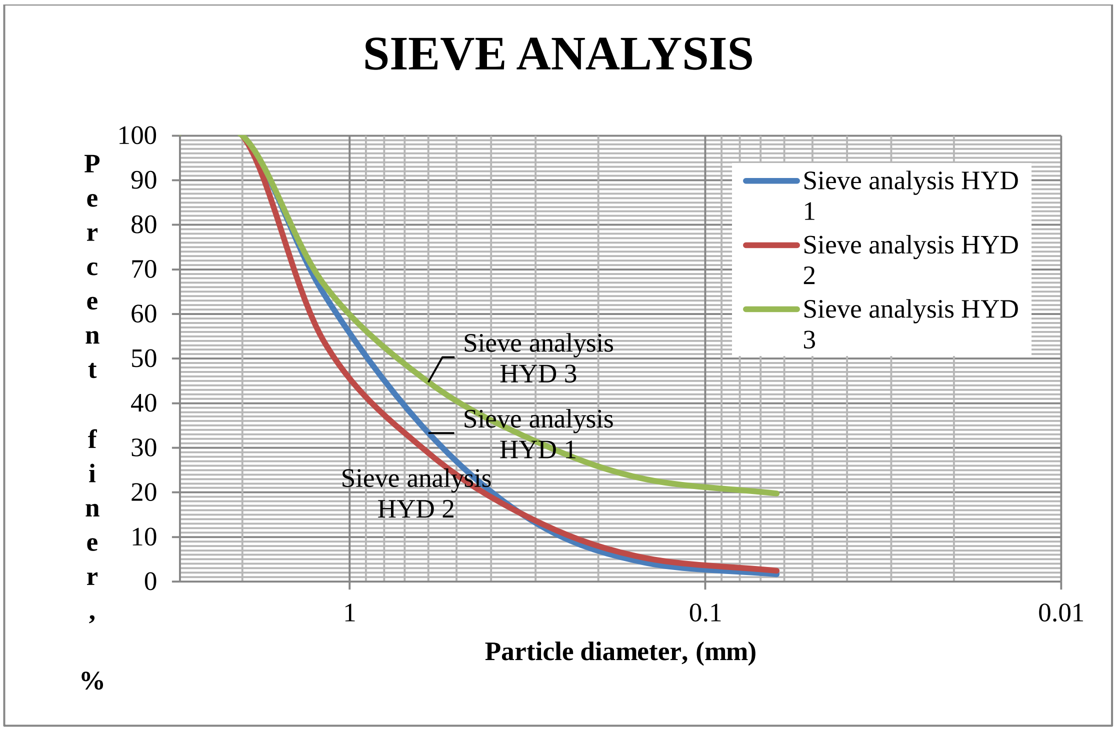
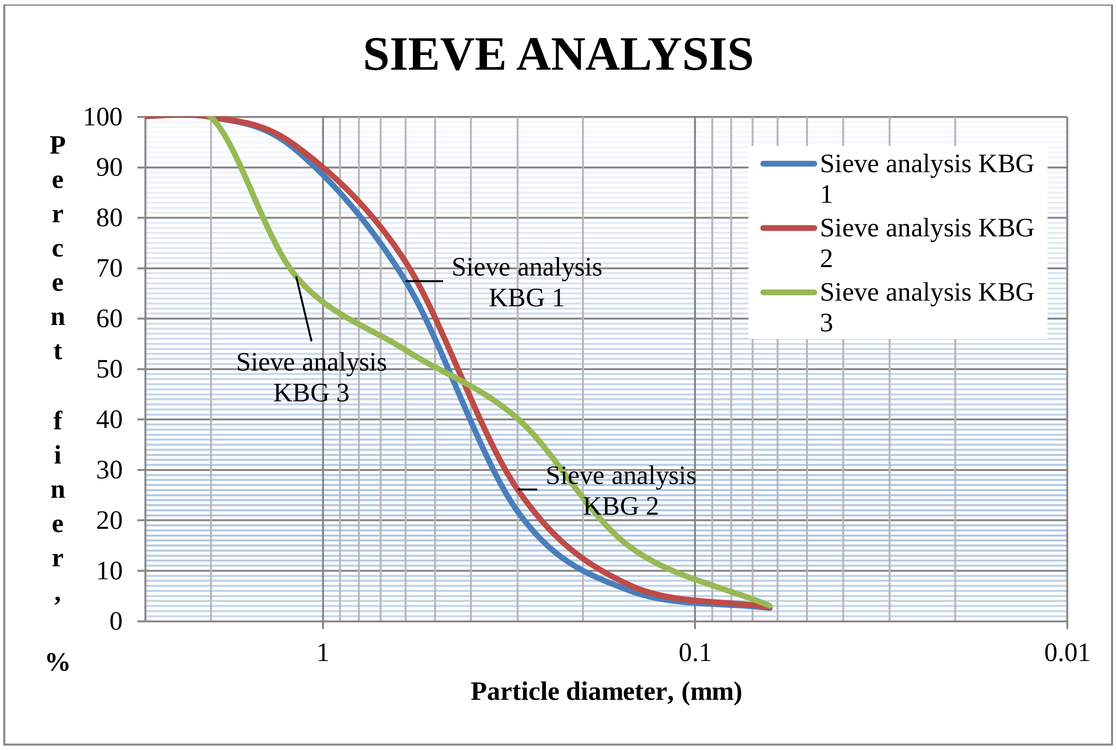
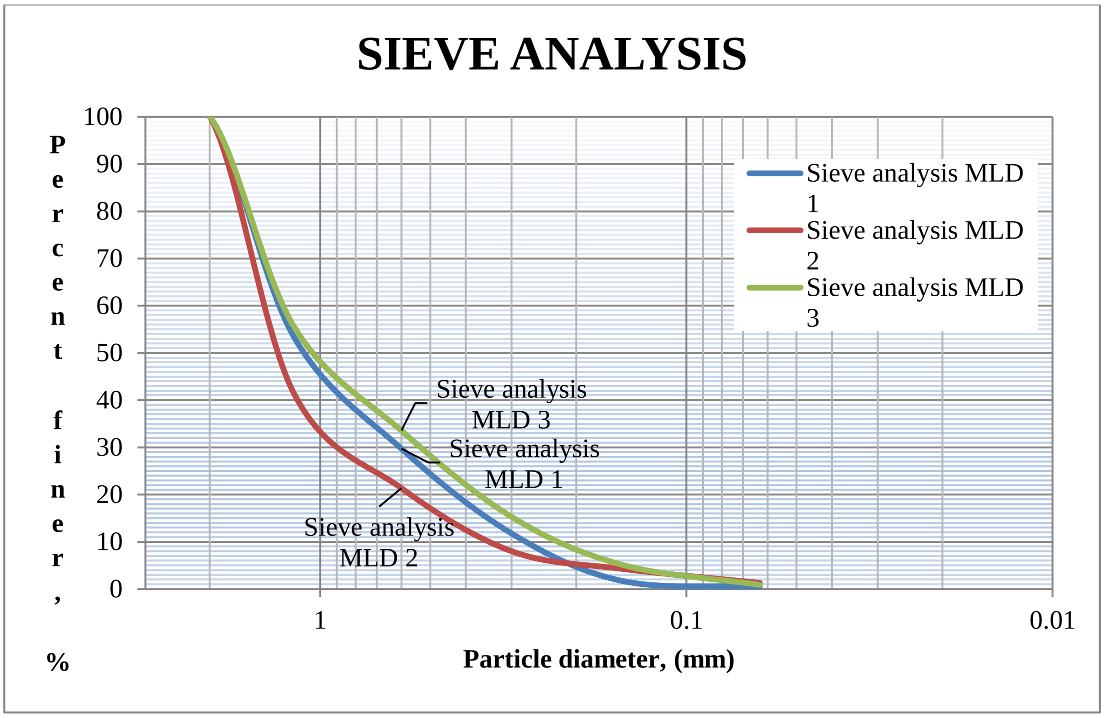
APPENDIX A
SIEVE ANALYSIS GRAPH FOR THIRTEEN SOIL SERIES

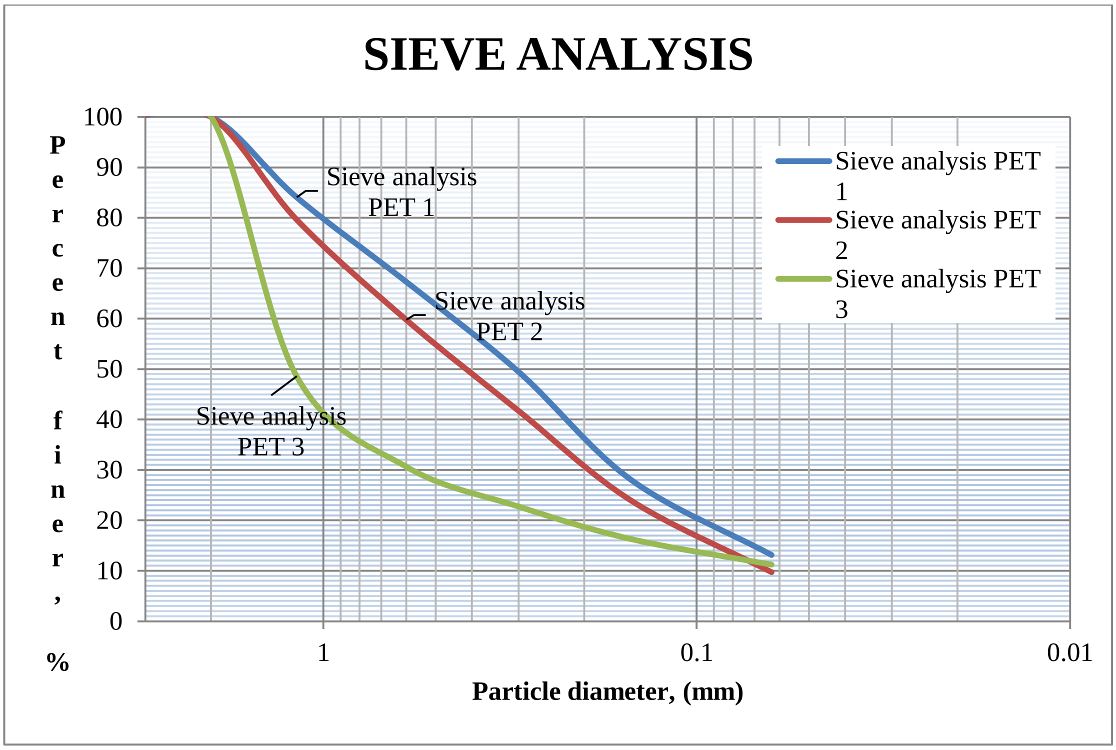


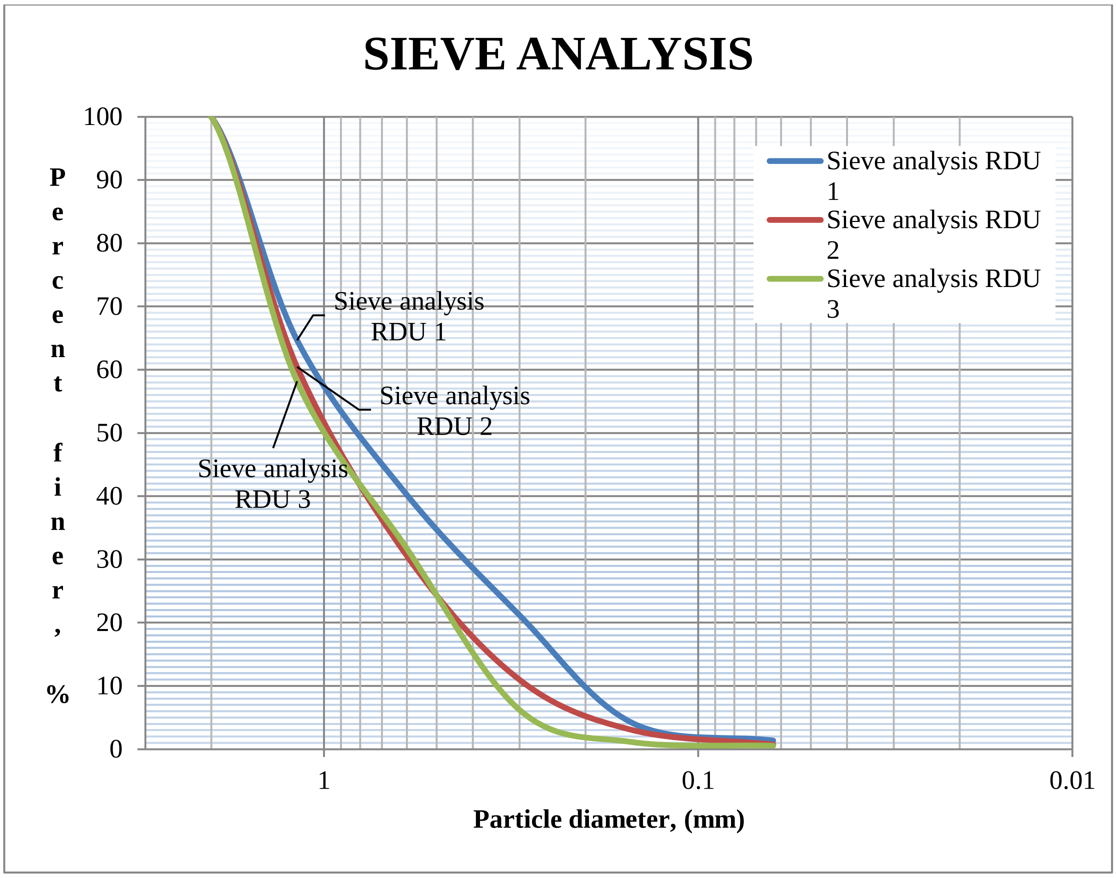


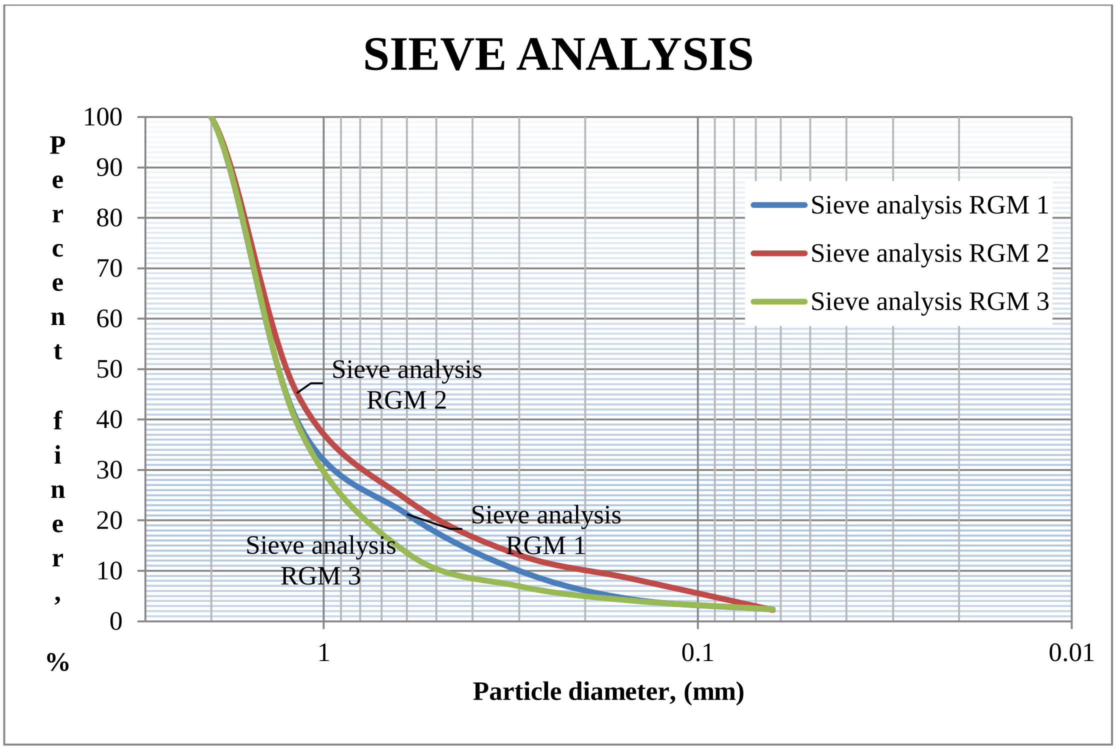

SIEVE ANALYSIS
Percent finer, %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis HYD 1
Sieve analysis HYD 2
Sieve analysis HYD 3

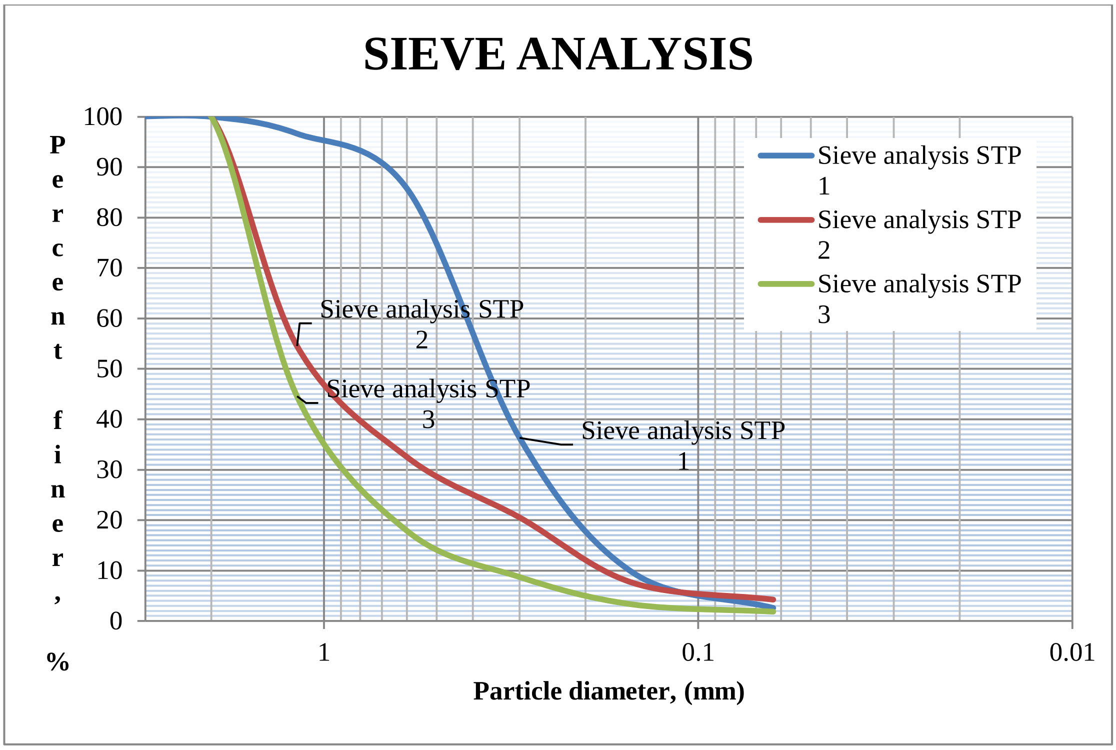

SIEVE ANALYSIS
Percent finer, %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis KBG 1
Sieve analysis KBG 2
Sieve analysis KBG 3

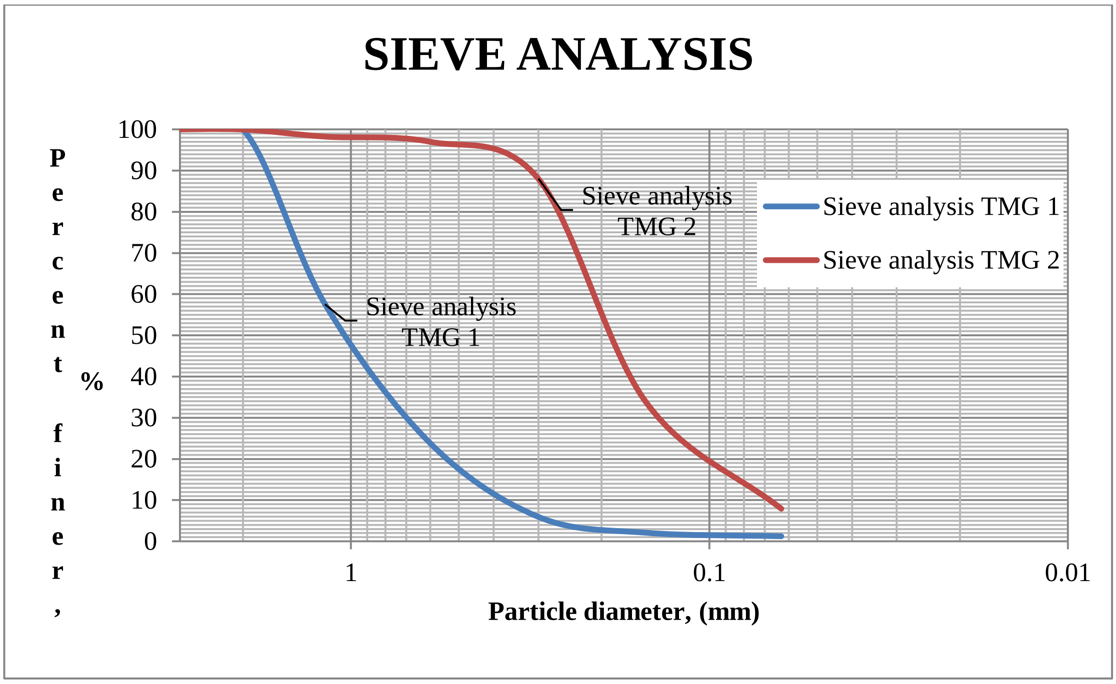

SIEVE ANALYSIS
Percent finer, %
Particle diameter, (mm)
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Sieve analysis MLD 1
Sieve analysis MLD 2
Sieve analysis MLD 3

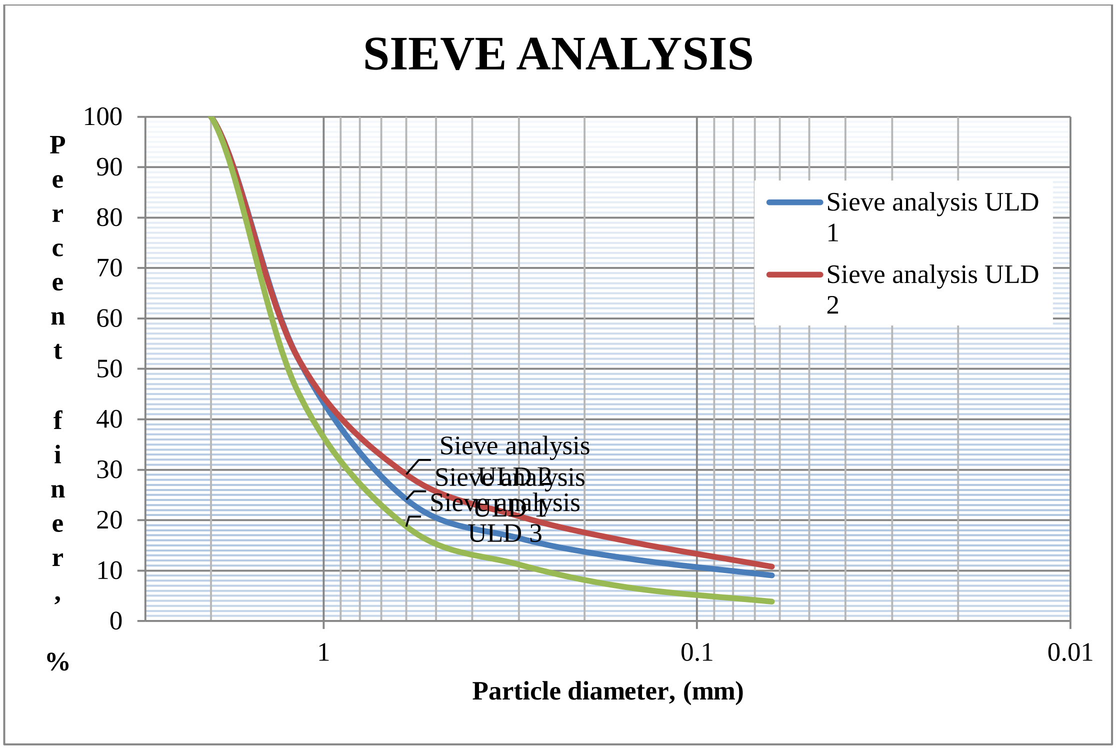

SIEVE ANALYSIS
Percent finer, %
Particle diameter, (mm)
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Sieve analysis PET 1
Sieve analysis PET 2
Sieve analysis PET 3


SIEVE ANALYSIS
P e r c e n t f i n e r , %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis RDU 1
Sieve analysis RDU 2
Sieve analysis RDU 3
Sieve analysis RDU 1
Sieve analysis RDU 2
Sieve analysis RDU 3

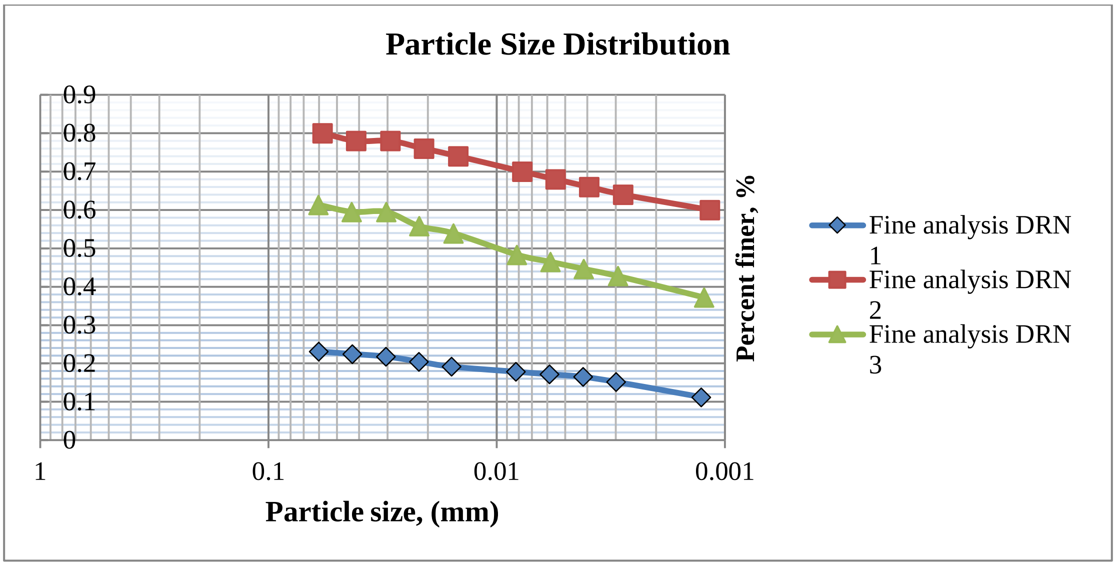

SIEVE ANALYSIS
P e r c e n t f i n e r , %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis RGM 1
Sieve analysis RGM 2
Sieve analysis RGM 3
Sieve analysis RGM 2
Sieve analysis RGM 1
Sieve analysis RGM 3

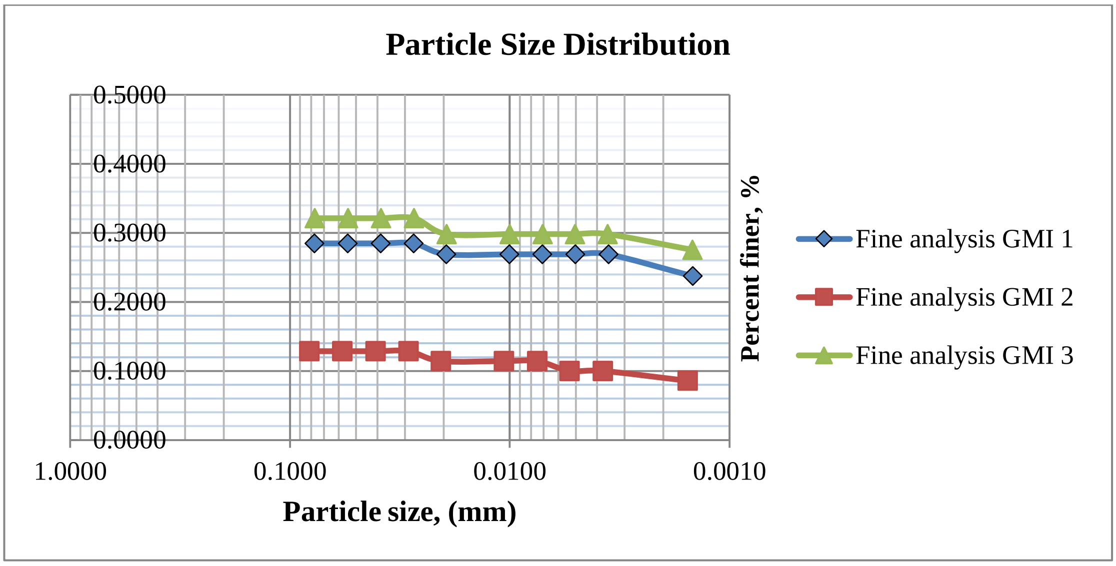

SIEVE ANALYSIS
Percent finer, %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis STP 1
Sieve analysis STP 2
Sieve analysis STP 3
Sieve analysis STP 2
Sieve analysis STP 3
Sieve analysis STP 1

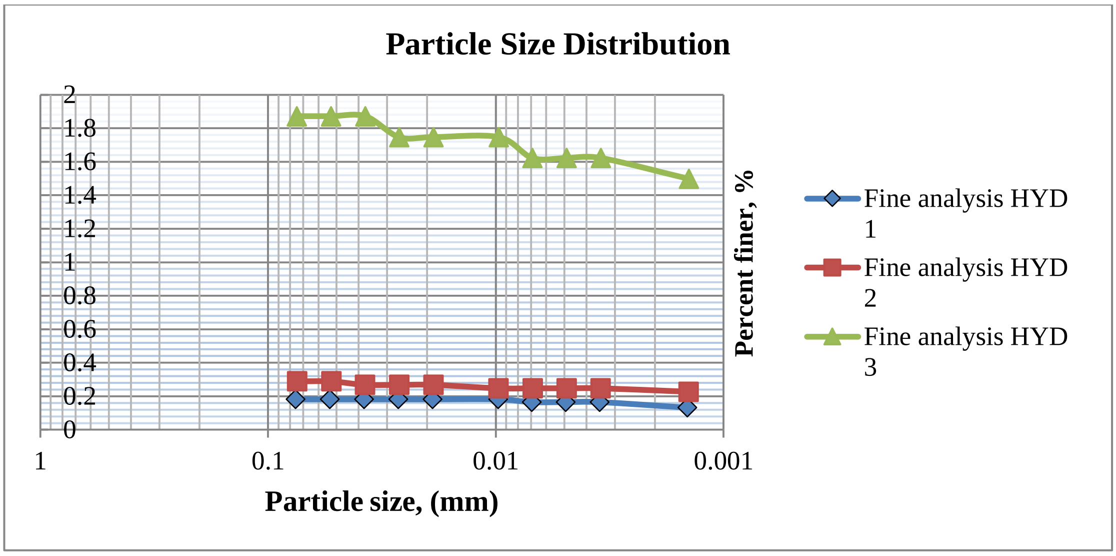

SIEVE ANALYSIS
Percent finer, %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis TMG 1
Sieve analysis TMG 2
Sieve analysis TMG 2
Sieve analysis TMG 1


SIEVE ANALYSIS
Percent finer, %
100
90
80
70
60
50
40
30
20
10
0
1
0.1
0.01
Particle diameter, (mm)
Sieve analysis ULD 1
Sieve analysis ULD 2
Sieve analysis ULD 2
Sieve analysis ULD 1
Sieve analysis ULD 3

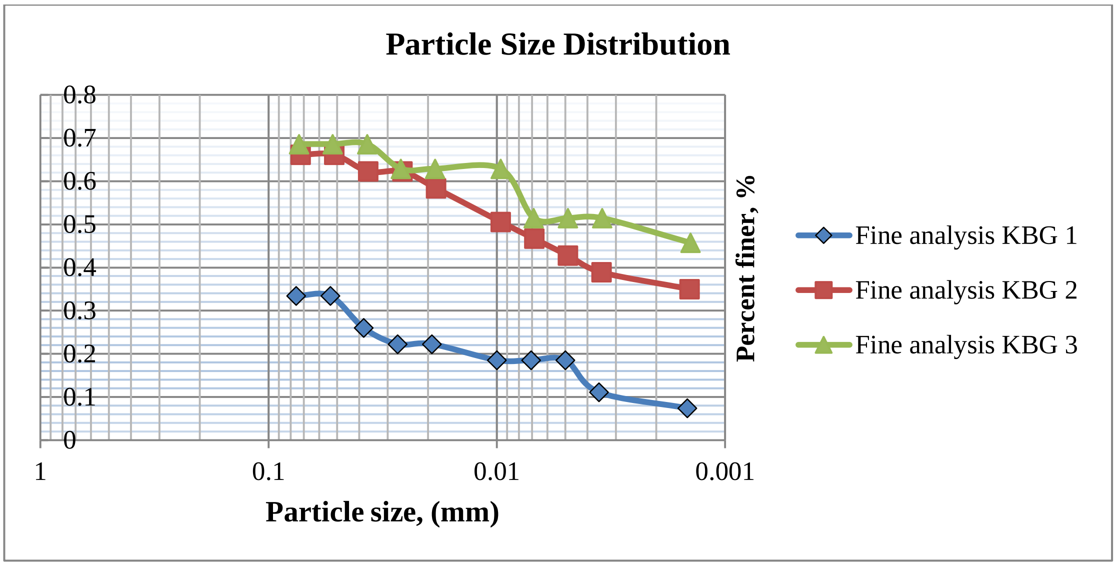
APPENDIX B
FINE ANALSIS GRAPH FOR THIRTEEN SOIL SERIES



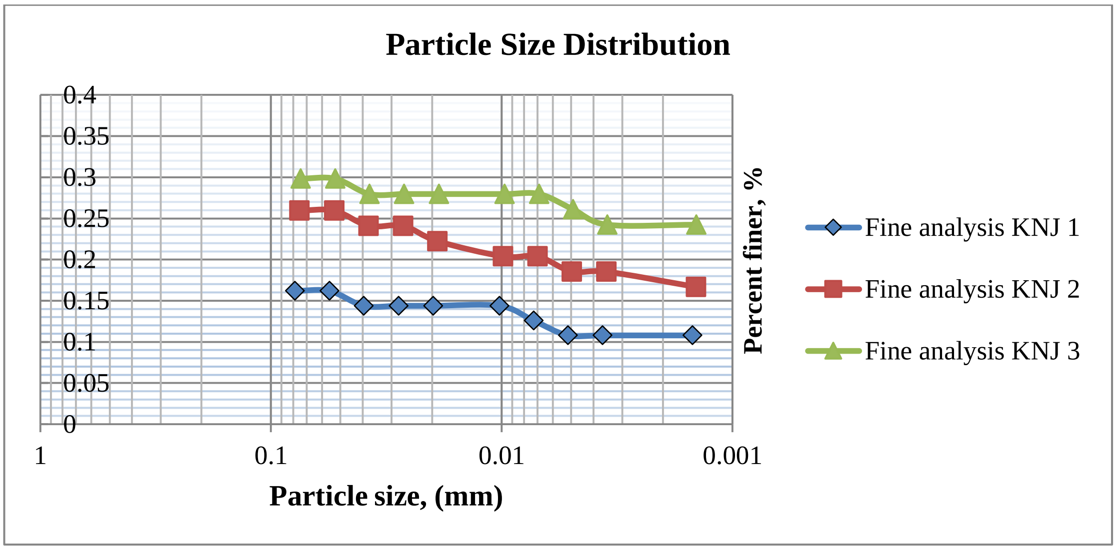




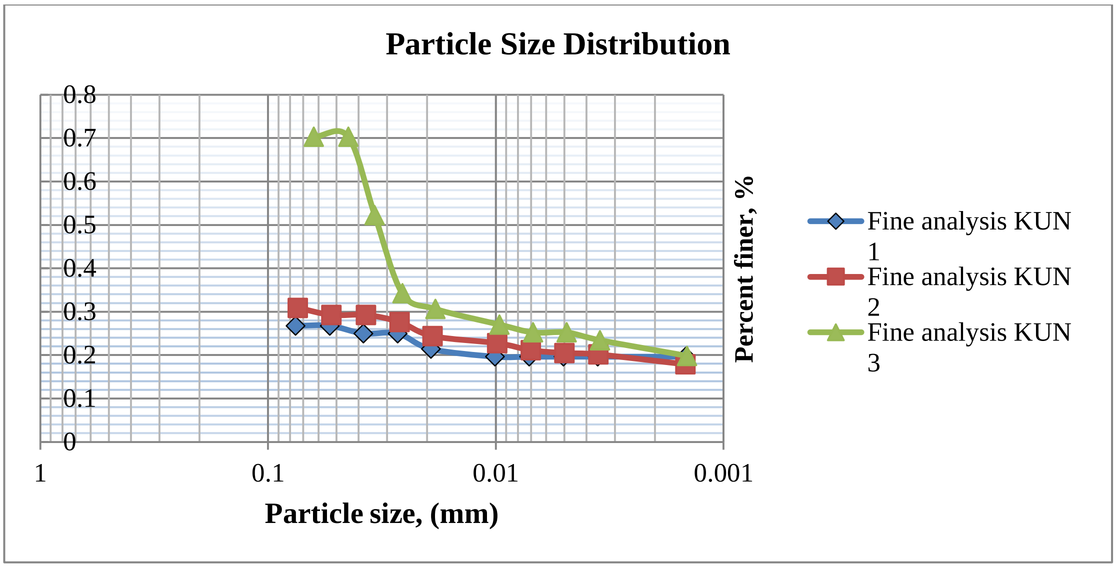
Particle Size Distribution
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine analysis HYD 1
Fine analysis HYD 2
Fine analysis HYD 3

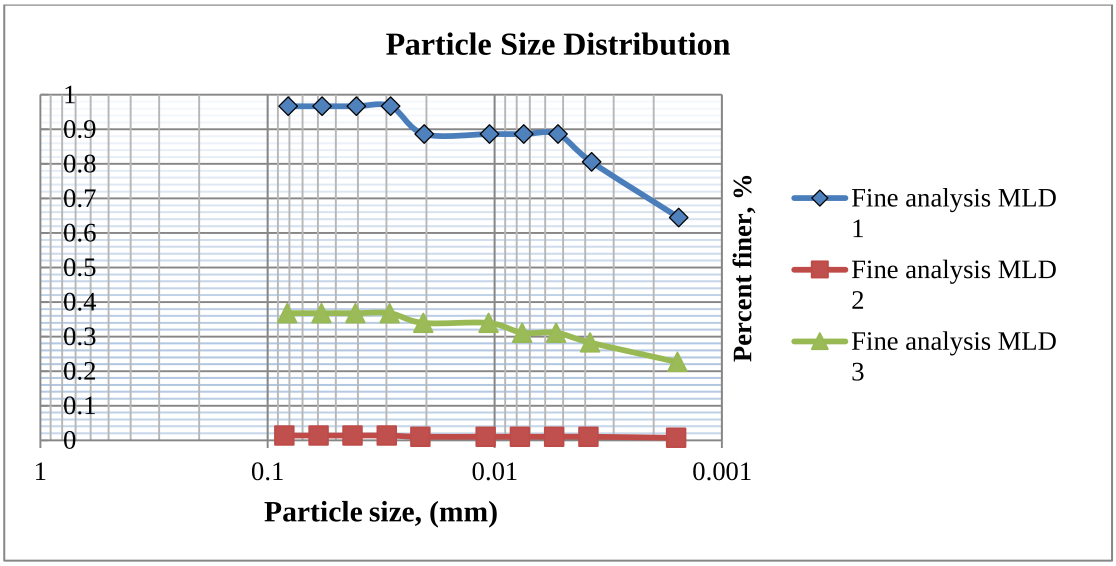


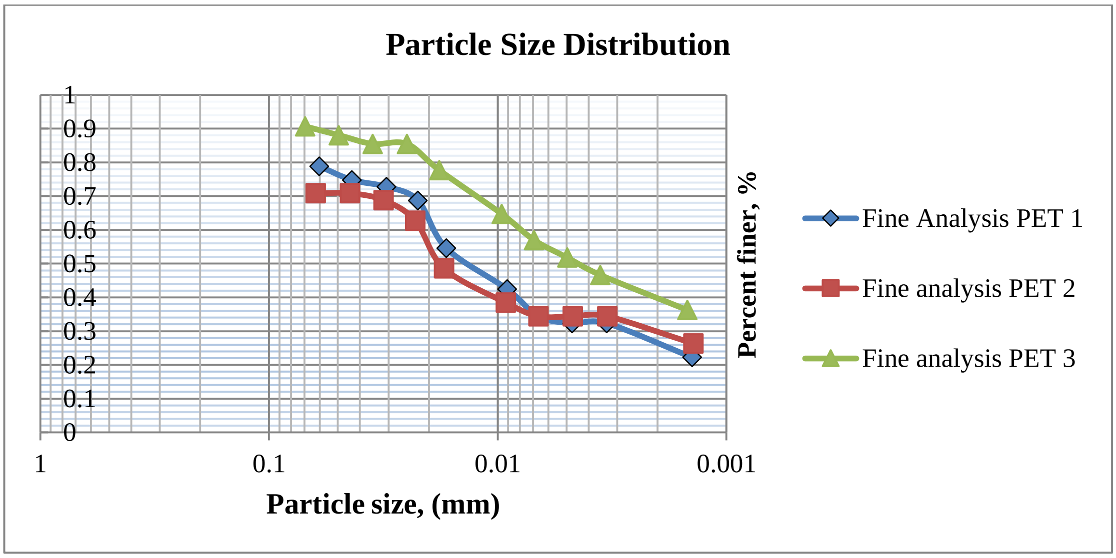
Particle Size Distribution
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine analysis KBG 1
Fine analysis KBG 2
Fine analysis KBG 3

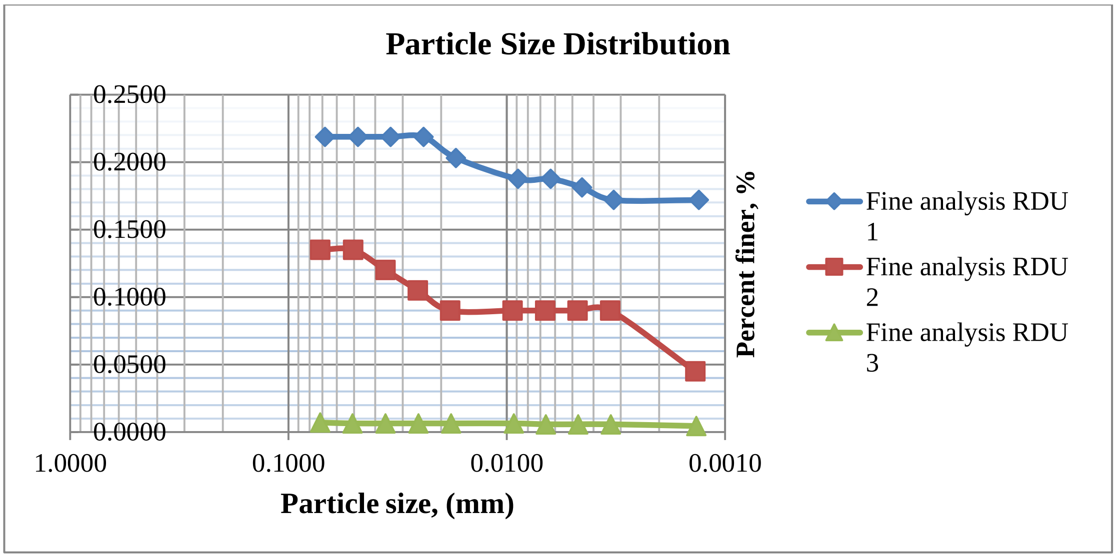


Particle Size Distribution
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine analysis KNJ 1
Fine analysis KNJ 2
Fine analysis KNJ 3

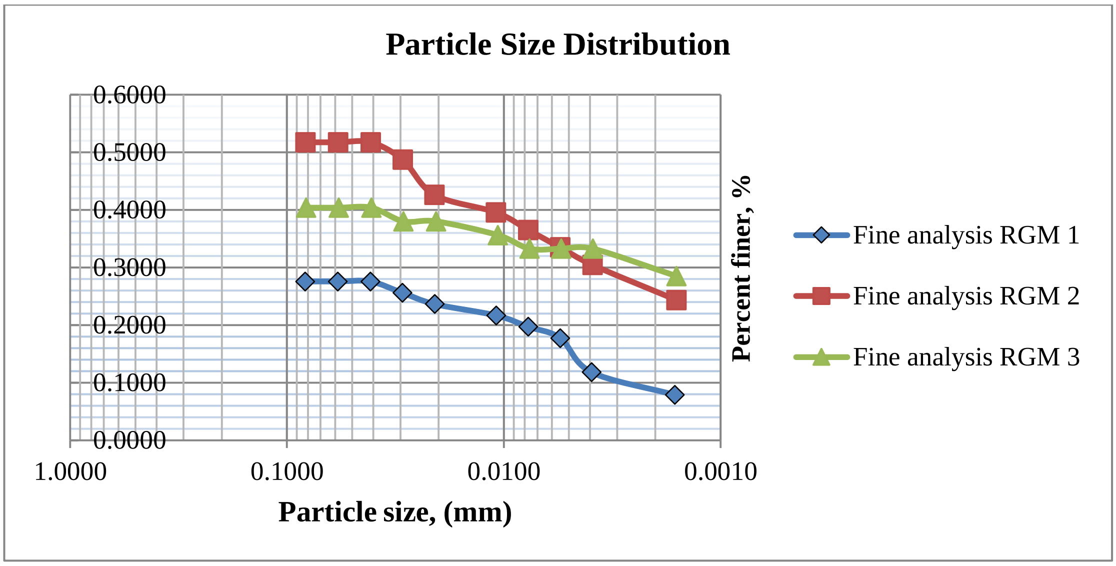

Particle Size Distribution
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine analysis KUN 1
Fine analysis KUN 2
Fine analysis KUN 3


Particle Size Distribution
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine analysis MLD 1
Fine analysis MLD 2
Fine analysis MLD 3

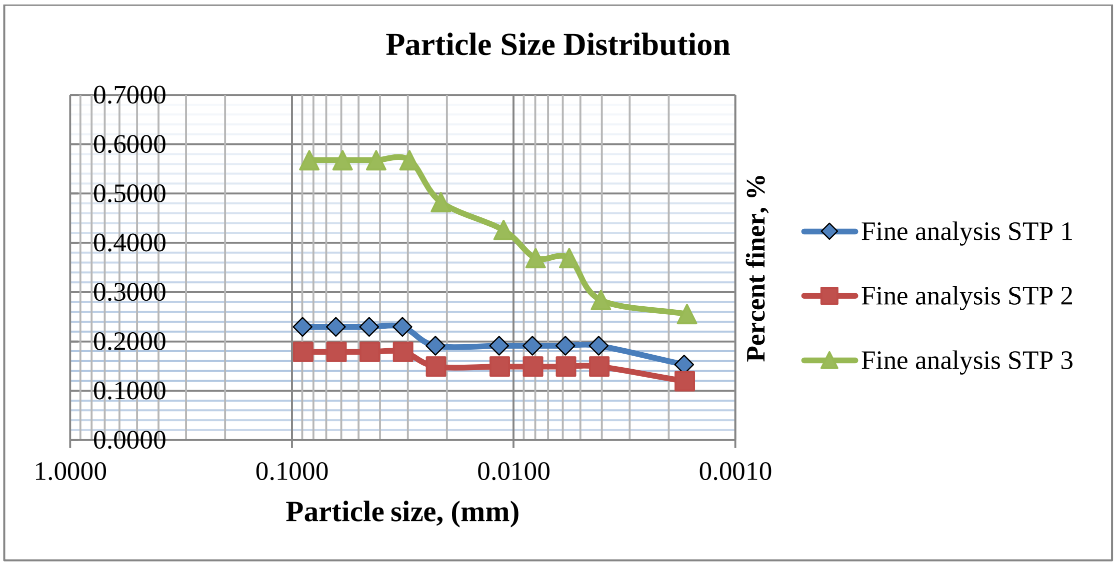

Particle Size Distribution
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
0.1
0.01
0.001
Particle size, (mm)
Percent finer, %
Fine Analysis PET 1
Fine analysis PET 2
Fine analysis PET 3



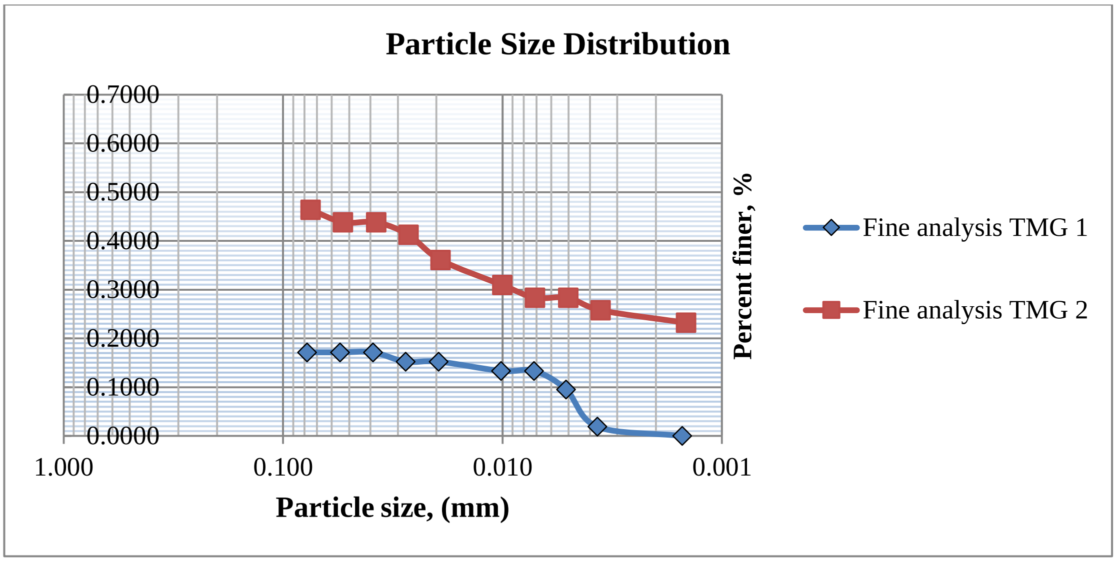
Particle Size Distribution
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
1.0000
0.1000
0.0100
0.0010
Particle size, (mm)
Percent finer, %
Fine analysis RDU 1
Fine analysis RDU 2
Fine analysis RDU 3

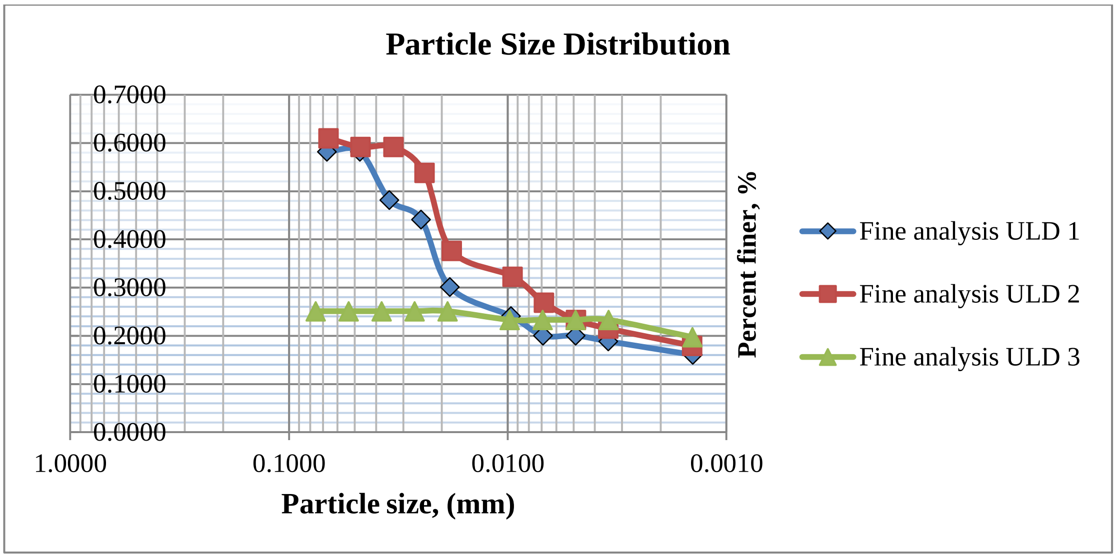


Particle Size Distribution
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1.0000
0.1000
0.0100
0.0010
Particle size, (mm)
Percent finer, %
Fine analysis RGM 1
Fine analysis RGM 2
Fine analysis RGM 3



Particle Size Distribution
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1.0000
0.1000
0.0100
0.0010
Particle size, (mm)
Percent finer, %
Fine analysis STP 1
Fine analysis STP 2
Fine analysis STP 3


Particle Size Distribution
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1.000
0.100
0.010
0.001
Particle size, (mm)
Percent finer, %
Fine analysis TMG 1
Fine analysis TMG 2


Particle Size Distribution
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1.0000
0.1000
0.0100
0.0010
Particle size, (mm)
Percent finer, %
Fine analysis ULD 1
Fine analysis ULD 2
Fine analysis ULD 3