DETERMINE OF SOIL PROPERTIES AND SOIL EROSION AT UNIVERSITI MALAYSIA PAHANG, PEKAN

MOHAMED FAIROS BIN BURKANUDEEN

AA 13044

A Final Year Project submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Civil Engineering (Hons)

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

JANUARY 2017

SUPERVISOR'S DECLARATION

"I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Civil Engineering (Hons)."

Signature : …………………………………………………………………...
Name of Supervisor : PN NADIATUL ADILAH BINTI AHMAD ABDUL GHANI
Position : LECTURER
Date : 10 JANUARY 2017

Signature : …………………………………………………………………...
Name of Co-Supervisor: DR YOUVENTHARAN A/L DURAISAMY
Position : SENIOR LECTURER
Date : 10 JANUARY 2017

STUDENT'S DECLARATION

I hereby declare that this Final Year Project entitled ***"Determine of Soil Properties and Soil Erosion at Universiti Malaysia Pahang, Pekan"*** is the result of my own research expect as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………………………
Name : MOHAMED FAIROS BIN BURKANUDEEN
ID Number : AA13044
Date : 10 JANUARY 2017

"Don't read success stories, you will get only message.

Read failure stories, you will get some ideas to get success."

-A.P.J. Abdul Kalam

Dedicated to my beloved parent and my siblings

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ABSTRACT

A study on soil properties and soil erosion was conducted at Universiti Malaysia Pahang, Pekan. In order to determine the rate of erosion on two type of land surface and their soil properties, several related were soil testing conducted in the Geotechnical Laboratory, UMP. Testing that involved are a particle size distribution, moisture content, specific gravity, falling head, and fine analysis that were carried out in classify properties of the soil sample. The empty surface area is poorly graded sand with Cu < 4 and for vegetation surface area is well graded sand with Cu > 4. The specific gravity test showed that the soil sample empty surface and vegetation surface are 2.63mg/m^3 and 2.58mg/m^3 respectively. The moisture content for empty surface 1 and surface 2 are 7.37 % and 9 % respectively. The moisture content for vegetation surface 1 and surface 2 are 4.56 % and 5.83 % respectively. Soil erosion is a process of a portion of the soil profile or soil surface detachment to the ambient environment. Four major factors that affect erosion potential are soil characteristics, vegetative cover, topography and climate. The Revised Universal Soil Loss Equation (RUSLE) to predict the average annual soil loss rate at Campus Pekan, Universiti Malaysia Pahang. The result indicates that the average annual soil loss (A) for empty surface 1 and empty surface 2 is 9551.93ton/ha/yr and 9071.33ton/ha/yr respectively. For vegetation surface 1 and vegetation surface 2 is 59.67ton/ha/yr and 73.44ton/ha/yr respectively.

ABSTRAK

Satu kajian mengenai sifat-sifat tanah dan hakisan tanah telah dijalankan di Universiti Malaysia Pahang, Pekan. Dalam usaha untuk menentukan kadar hakisan pada dua jenis permukaan tanah dan harta tanah mereka, beberapa berkaitan adalah ujian tanah dijalankan di Makmal Geoteknik, UMP. Ujian yang terlibat adalah taburan saiz zarah, kandungan kelembapan, graviti tentu, kepala jatuh, dan analisis halus yang telah dijalankan di hartanah Kelaskan sampel tanah. Luas permukaan kosong adalah kurang digred pasir dengan Cu <4 dan bagi kawasan permukaan tumbuhan dengan baik digred pasir dengan Cu> 4. Ujian graviti tentu menunjukkan bahawa sampel permukaan tanah kosong dan tumbuh-tumbuhan permukaan adalah 2.63mg / m3 dan 2.58mg / m3 masing-masing. Kandungan lembapan bagi permukaan kosong 1 dan permukaan 2 masing-masing adalah 7.37% dan 9%. Kandungan kelembapan untuk tumbuh-tumbuhan permukaan 1 dan permukaan 2 masing-masing adalah 4.56% dan 5.83%. Hakisan tanah adalah proses sebahagian daripada profil tanah atau permukaan tanah detasmen kepada suasana persekitaran. Empat faktor utama yang menjejaskan potensi hakisan adalah ciri-ciri tanah, perlindungan vegetatif, topografi dan iklim. Semakan Kehilangan Tanah Universal Persamaan (RUSLE) untuk meramalkan tahunan purata kadar kehilangan tanah di Kampus Pekan, Universiti Malaysia Pahang. Hasil kajian telah menunjukkan bahawa purata kehilangan tanah tahunan (A) untuk permukaan kosong 1 dan kosong permukaan 2 adalah 9551.93ton / ha / tahun dan 9071.33ton / ha / tahun masing-masing. Bagi tumbuhan permukaan 1 dan tumbuh-tumbuhan permukaan 2 adalah 59.67ton / ha / tahun dan 73.44ton / ha / tahun masing-masing

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Name : MOHAMED FAIROS BIN BURKANUDEEN

No. ID : AA 13044 No. Phone: - No. H/p: 016 2899786

Permanent Address : NO 239, JALAN DESARIA 25, TAMAN DESARIA, 71800 NILAI, NEGERI SEMBILAN.

Mail Address: five_ross91@yahoo.com

THESIS DETAILS :

PSM Project Title : DETERMINE OF SOIL PROPERTIES AND SOIL EROSION AT UNIVERSITI MALAYSIA PAHANG, PEKAN

Supervisor : PN NADIATUL ADILAH BINTI AHMAD ABDUL GHANI

Field of Project: ~~Structure & Material~~ / Hydraulics, Water Resources & Environment
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LIST OF ABBREVIATIONS

UMP	Universiti Malaysia Pahang
AASTHO	American Association of State Highway and Transportation Officials
USCS	Unified Soil Classification System
ASTM	American Society for Testing and Material
USLE	Universal Soil Loss Equation
RUSLE	Revised Universal Soil Loss Equation
JPS	Department of Irrigation and Drainage
US	United State
Cu	Uniformity Coefficient
Cc	Coefficient of Gradation

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Soil erosion is a naturally occurring process that affects all landforms. Erosion by human activity is agriculture, logging, burning and mining. Erosion will cause flooding, disruption of ecosystems, and water pollution. The erosion is an action by which the surface of the Earth into feeble. The erosion can be affected with water, ice, and wind are fluids because they will flow to one place to another place with to the force gravity. These are three elements is a main agent to happen of soil erosion in the earth's surface.

Water Erosion is rainfall and the surface runoff which may result from rainfall. The have four type of soil erosion from water is sheet erosion, gully erosion, splash erosion and rill erosion. Sheet erosion is the transport of loosened soil particles by overland flow. If runoff has adequate energy flow, it will carry sediment particles down slope. Second, gully erosion is happening when the runoff water accumulates, and fast flowing in narrow channels during or after heavy rainfall or melting snow, remove the soil to considerable depths. Third, splash erosion is the impact of raindrop that create a small crater in soil. The last, rill erosion is a series of small channels on a slope carved by running water (Mohamadi, 2015).

1.2 PROBLEM STATEMENT

Soil erosion can be effect for the land and its inhabitants in both off-site and on-site effects. Off-site effect, movement of sediments and agricultural pollutants into watercourses are the major problem, leading to sedimentation in rivers and disruption of ecosystems. While in, on-site effect is directly created through the loss of soil nutrients. This effect is particularly crucial on agricultural land because it involves the loss of soil stability, soil quality, and structure.

Nowadays, the rate of soil erosion increases the rate of soil formation over wide areas resulting in the depletion of soil. Rate of soil loss can have determined by measurement of annual precipitation, elevation, crop cover and practiced erosion control factors. Using RUSLE model, the rate of annual soil loss (A) can be predicted based on parameters such as; annual rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cropping factor (C), practice and erosion control (P) factors.

Most measurements and determination of parameters have used in USLE and RUSLE equation are taken from studies conducted outside Malaysia, in particular, Europe. Malaysia different greatly in terms of vegetation, due to the leaf size, tree diameter and soil formation, compared to the temperate countries. Erosion particularly in forested and cultivated areas needs the accurate measurement of rate of soil loss. By using the existing parameters in RUSLE, the soil loss rates may contain a certain amount of error either too high or too low for Malaysia (Liu & Evett, 2005).

1.3 OBJECTIVES

The objectives of this study are:

a) To determine soil properties at Universiti Malaysia Pahang, Pekan
b) To compare soil erosion between two type of land surface at Universiti Malaysia Pahang, Pekan.

1.4 SCOPE OF STUDY

This study will estimated the soil erosion rates on the disturbed soil surfaces;

a) Soil loss will be measured at two different type of land cover (empty surface and vegetation surface).
b) To compare the estimation soil loss by using Revised Universal Soil Loss Equation (RUSLE).

1.5 LOCATION OF STUDY

The location of this study is located in Campus Pekan, University Malaysia Pahang. This area has been proved from time to time to be highly affected during heavy monsoon rain due to the area incapability to flow and infiltrate the excessive water. Floods in Pekan are mainly due to overflowing from Sungai Pahang which coincides with high tide that cause an increase in water level at surrounding swamps (Morgon,1991). Flooding at Pekan has causes loss to soil properties and vegetation. The empty surface is located at 3°32'47.2"N 103°25'33.3"E and the vegetation surface is located at 3°33'00.4"N 103°25'46.9"E in Campus Pekan, University Malaysia Pahang. Figure 1.1 and Figure 1.2 shows the location of sample plot at Campus Pekan, Universiti Malaysia Pahang.

Figure 1.1: Sample plot for empty surface

Figure 1.2: Sample plot for vegetation surface

1.6 SIGNIFICANT OF STUDY

This study will give information on the properties of soil at UMP, Pekan especially the properties of soil parameter. This information is beneficial for further research about the properties of soil at UMP, Pekan. Soil erosion removes valuable topsoil, results in lower yields and higher costs of production. Hence, it is very important to study the loss of soil erosion. RUSLE was selected as a model to determine rate of soil loss in the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 SOIL EROSION

Soil erosion is three phase phenomena consisting of the detachments of individual soil particles from the soil mass and their transport by erosion agents, such as water, ice, and wind. When sufficient energy is no longer available with erosion agents to transport the particles then the third phase is called a “deposition” takes place. The potential for soil erosion varies from watershed to watershed depending on the configuration of the watershed (shape, topography), the soil characteristics, the local climatic conditions and the land use and management practices implemented on the watershed (Suresh R, 2000 and Arora K, 2003).

2.1.1 Splash Erosion

Splash erosion is a first stage on erosion process. It happens when raindrops hit the bare soil. The explosive impact breaks up soil aggregates so that individual soil particles are ‘splashed’ onto the soil surface. The splashed particles can rise as high 60cm above the ground and move up to 1.5 meters from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms the crust that reduces infiltration and increases runoff (Lal R, 1994).

2.1.2 Sheet Erosion

Sheet erosion is the removal of soil in slightly layers by raindrop impact and shallow surface flow. It results in loss of the finest soil particles that contain most of the available organic and nutrients matter in the soil. Soil loss is so gradual that the erosion usually goes unexpected, but the cumulative impact accounts for large soil losses. Soils most vulnerable to sheet erosion are overgrazed and cultivated soils where there is little vegetation to protect and hold the soil. Early signs of sheet erosion include the bare areas, exposed tree roots, exposed subsoil or stony soils, water puddling as soon as rain falls, and visible grass roots. Soil deposits on the high side of obstructions such as fences may indicate active sheet erosion (Lal R, 2009).

2.1.3 Rill Erosion

Rills are shallow drainage lines less than 30cm deep. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is common in bare agricultural land, particularly overgrazed land, and in freshly cultivated soil where the soil structure has been loosened. The rills can usually be removed with farm machinery. Rill erosion can be reduced by reducing the volume and speed of surface water with filter strips and grassed waterways, contour drains, and ripped mulch lines. Rill erosion is often the described as the intermediate stage between sheet erosion and gully erosion (Silleos G N, 1990).

2.1.4 Gully Erosion

Gullies are channels deeper than 30cm that cannot be removed by normal cultivation. They can be spectacular to look at but over time actually lose less soil than sheet and rill erosion. Gullies occur when smaller water flows concentrate and cut a channel through the soil. Most gullies extend upslope as a result of the head of the gully being continually undercut and collapsing. However, slumping and collapse of sidewalls usually contribute a greater proportion of soil loss (Silleos G N, 1990).

2.1.5 Stream and Channel Erosion

The removal of soil from the stream occurs due to either water flowing over the sides of the stream from overland runoff or the water flowing in the stream and scouring the channel. The stream erosion is a continuous process in perennial stream and is caused by the souring and undercutting of the soil below the water surface caused by wave action during normal stream flow events (Suresh R, 2000 and Arora K, 2003). Figure 2.1 shows the four type of soil erosion on exposed slope.

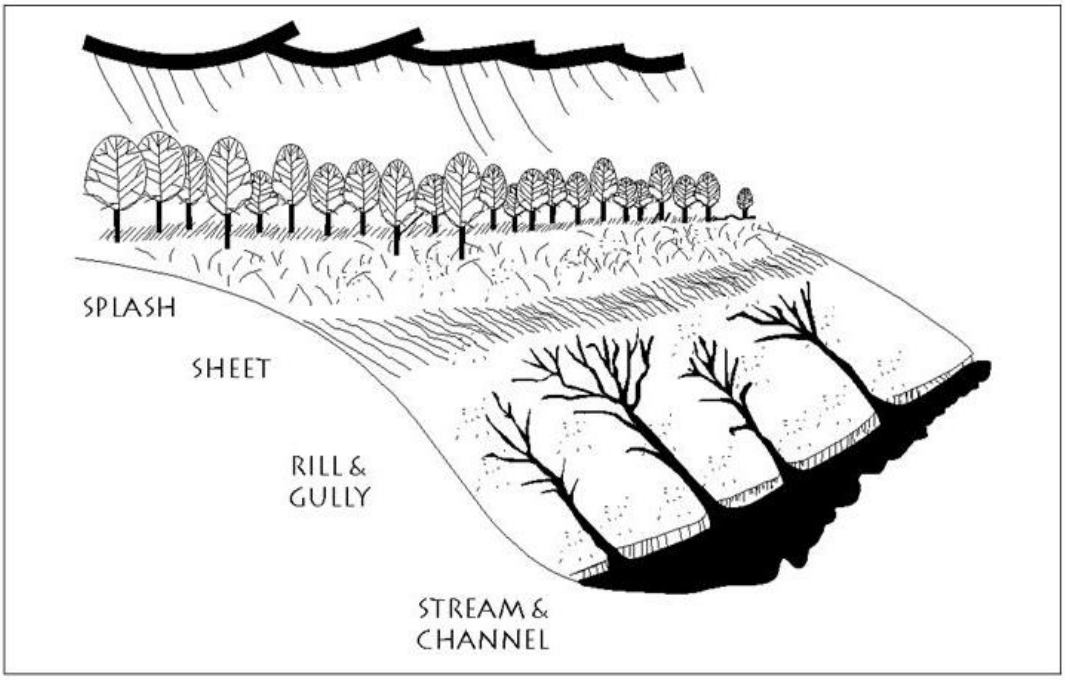


Figure 2.1: Fours type of soil erosion on an exposed slope

2.2 SOIL

Soil may also be separated into three (3) very broad categories which are cohesionless, cohesive and organic soil. Cohesionless soil are silt, sand, and gravel. This type of soil particles does not tend to stick together. Organic soil is described as soil containing a sufficient amount of organic matter to affect its engineering properties. While cohesive soils are soil that characterized by very small particle size where surface chemical predominate and in other words, the particles tend to stick to others (Liu & Evett, 2005). Basically, the most common type of cohesive soil is clay as the soil particles are closer together.

Most of areas in Malaysia have soft clay soil as the major soil distribution percentage. This is occurring from the fact that Malaysia has lot of parts of coastal areas and also have rivers that located in lot of state in Peninsular Malaysia. Fine grained saturated soils are believed to be located at lot of near coastal and river area (Schaefer, 1997). In Peninsular Malaysia, the areas that consist of soft clay area are shown in Figure 2.2. The location for the study is located in Pekan.

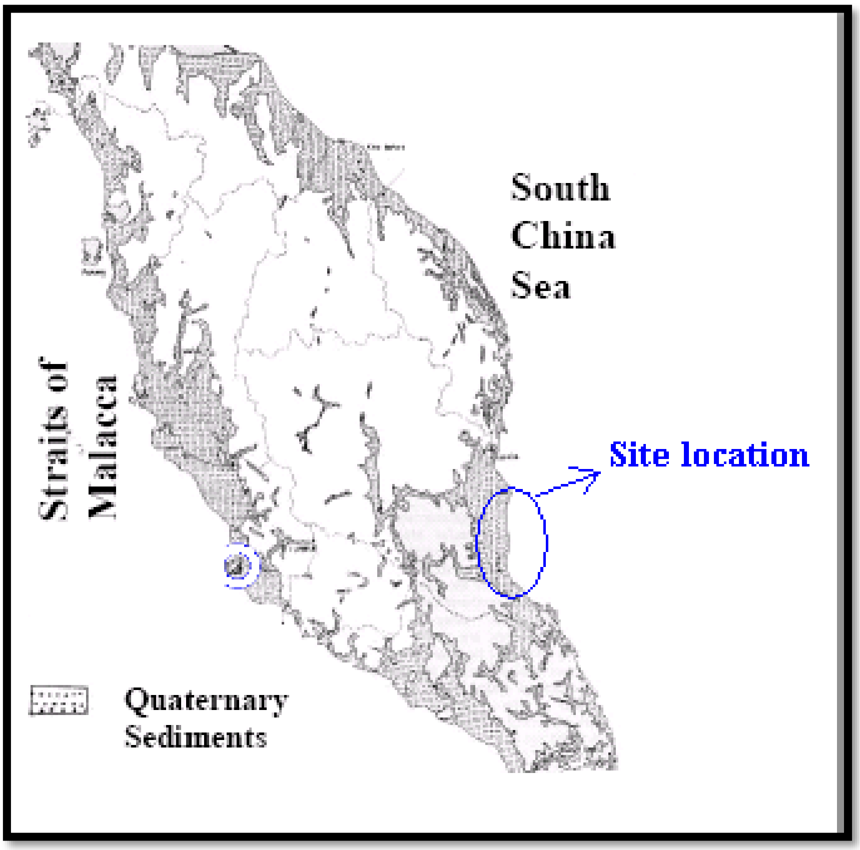
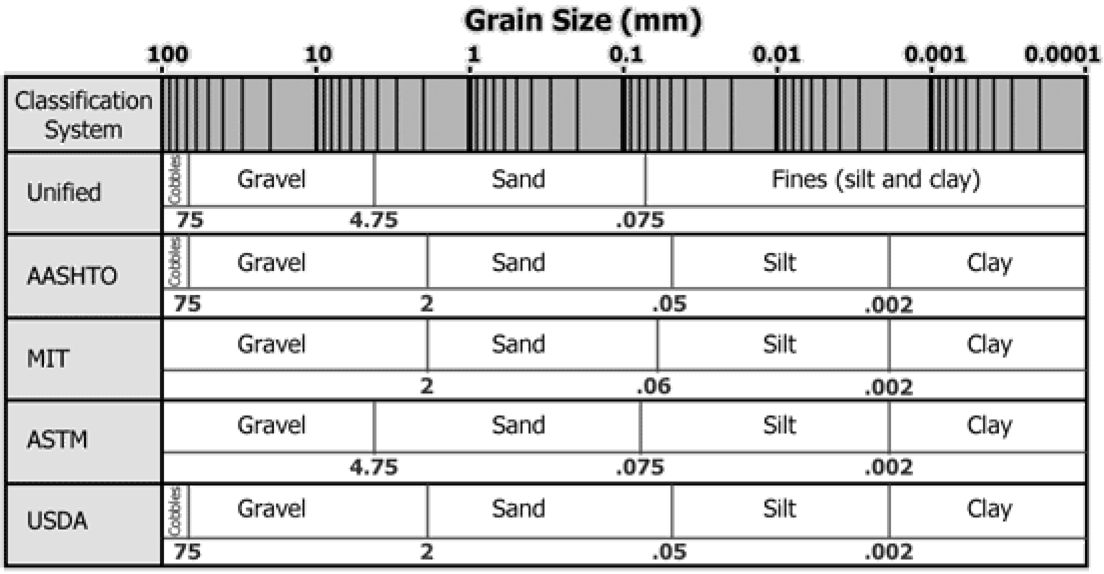


Figure 2.2: Soft clay area in peninsular Malaysia (Chin, 2005)

2.3 CLASSIFICATION OF SOIL

Soil which have lot of different properties but similar in some aspects may be classified into sub groups and groups according to their engineering behavior. Table 2.1 indicates of how the classification of soil being grouped using two major classification system in soil engineering based on grain size. American Association of State Highway and Transportation Officials (AASTHO) system defined that clay particles are less than 0.002mm size. However, Unified Soil Classification System (USCS) system stated that silt and clay are generally in the same grain sizes which are less than 0.075mm (Arora K, 2003). Classification systems of soil provide the explanations of the general characteristics of soils, which is generally based on soil parameters.

Table 2.1: Soil classification based on grain size (Arora K, 2003)



2.3.1 American Association of State Highway and Transportation Officials Classification System (AASTHO)

American Association of State Highway and Transportation Officials (AASTHO) system was developed in 1929 as Public Road Administration classification system. AASTHO system defined that clay particles are less than 0.002mm grain size. The system provides a classification of soil using seven major groups; A-1 until A-7. Soils which are classified under A-1, A-2 and A-3 are known as granular materials which 35% or less of the particles pass through the No.200 sieve. Particles in group A-3, A-4, A-5, A-6 and A-7 are mostly silt and clay-type materials as more than 35% pass through the No.200 sieve (Arora K, 2003). The classification is as shown in Table 2.2

Table 2.2: American Association of State Highway and Transportation Officials (AASTHO) classification criteria (Arora K, 2003)

Criteria	Description
Grain size	a) Gravel: Fraction passing the 75mm sieve and retained on the No.10 US sieve b) Sand: Fractions passing the No.10 US sieve and retained on the No.200 US sieve c) Clay and Silt: Fractions passing the No.200 US sieve

2.3.2 Unified Soil Classification System (USCS)

Unified Soil Classification System (USCS) system is more preferred to be used by geotechnical engineer as accordance in American Society for Testing and Material (ASTM) in D-2487 standard requirement. This system is recovered by Casagrande in 1942 during engineering work in World War. The system classified coarse-grained soils that are gravelly and sandy in nature with less than 50% passing through the No.200 sieve. The group symbols are GW, GP, GM, GC, SW, SP, SM and SC. The symbols that started with a prefix G stands for gravel or gravelly soil and symbol that started with S are sand or sandy soil (Liu & Evett, 2005). The other symbols used are W for well graded soil and P for poorly graded soil. However, fine-grained soils are 50% or more passing through the No.200 sieve with symbols of M, which represent inorganic silt, C for inorganic clay, or O for organic silts and clay. The symbol of Pt is for peat, muck and other highly organic soils (Arora K, 2003). Table 2.3 shows how soils are identified according to the letter of group symbol.

Table 2.3: First and second letters of group symbols (Arora K, 2003)

Soil Identification	First Letter of Group Symbol	Second Letter of Group Symbol
Coarse grained soil	G: gravel, S: sand	W: Well graded P: Poorly graded
Fine grained soil	M: silt, C: clay	L: Low plasticity (LL less than 50) H: High plasticity (LL more than 50)
Organic soil	O	L: Low plasticity (LL less than 50) H: High plasticity (LL more than 50)
Highly organic soils	Pt	No second letter

2.4 VEGETATION

Vegetation intercepts rain, can be reduce the energy and prevent splash erosion. It also moving slowly runoff, reducing sheet erosion, and strong and reinforces the soil with its root system. Figure 2.3 shows how erosion rate decreases as the soil is covered by vegetation. Flow water on Surface runoff from vegetated areas is much less than that from bare soil due to a combination of surface roughness, infiltration, and interception. Runoff normally does not exceed 10 to 20 percent of the rainfall received on small watersheds covered with grass or trees. Without vegetation, however, this could be as high as 60 to 70 percent. Water moving across a bare soil surface erodes soil and transports particles already detached. Vegetation limits selecting plants, the sodding, and a planting design appropriate for the slope area (Office, 1996).

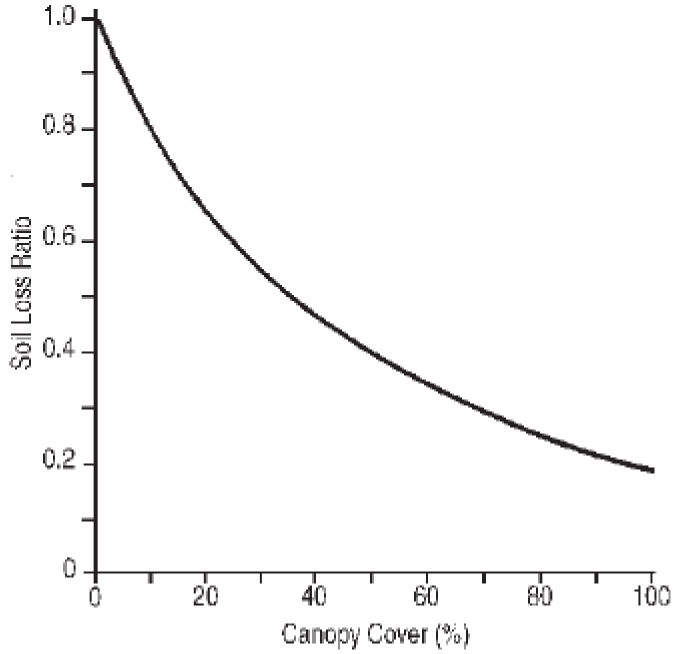


Figure 2.3: Change in erosion rate due to increasing vegetative cover. (Office, 1996)

2.4.1 Grass

Grass plants are useful for erosion control and have the added benefit of fitting readily into the landscape. They will easily transplant and take in conditions that mimic their natural habitat. Grasses also need low maintenance as they are adapted to the region in which they occur and receive most of their needs in the existing site. The right grasses for soil erosion depend upon your zone and region. Planting a garden of grass can help stabilize embankments by providing a root system to stabilize things. Varying heights of vegetation can stagger rainfall, lessening its impact on the ground (Wischmeier and D.Smith, 1965)

2.5 RAINFALL

Malaysia is warm and humid throughout the year, as characteristic by the equatorial climate. It has an average annual rainfall of more than 2500mm with monthly variation for selected cities and town. The West Coast of Peninsula is subject to localized and convective storms generate by the inter monsoon season or Sumatra wind system in the months of April until May and October until November. The highest monthly rainfall in Pahang are recorded in April and November. Storms mainly occur in late afternoon and evening. Intense short rainfall has frequently caused flash floods in many cities located in Temerloh and Kuantan (Jabatan Pengairan dan Saliran, 2014).

The South-West Monsoon (usually from May until September) produces less rain in the West Coast of the peninsula whilst the North-East Monsoon, from November to March, carries longer and heavier rains to East Coast of the Peninsula, North Sabah, and Sarawak. In peninsula the wettest area in Taiping, Perak whilst the driest in Kuala Pilah, Negeri Sembilan (Jabatan Pengairan dan Saliran, 2014). Figure 2.4 shows the data from Jabatan Pengairan dan Saliran Malaysia Meteorological Year 2008 until 2015.

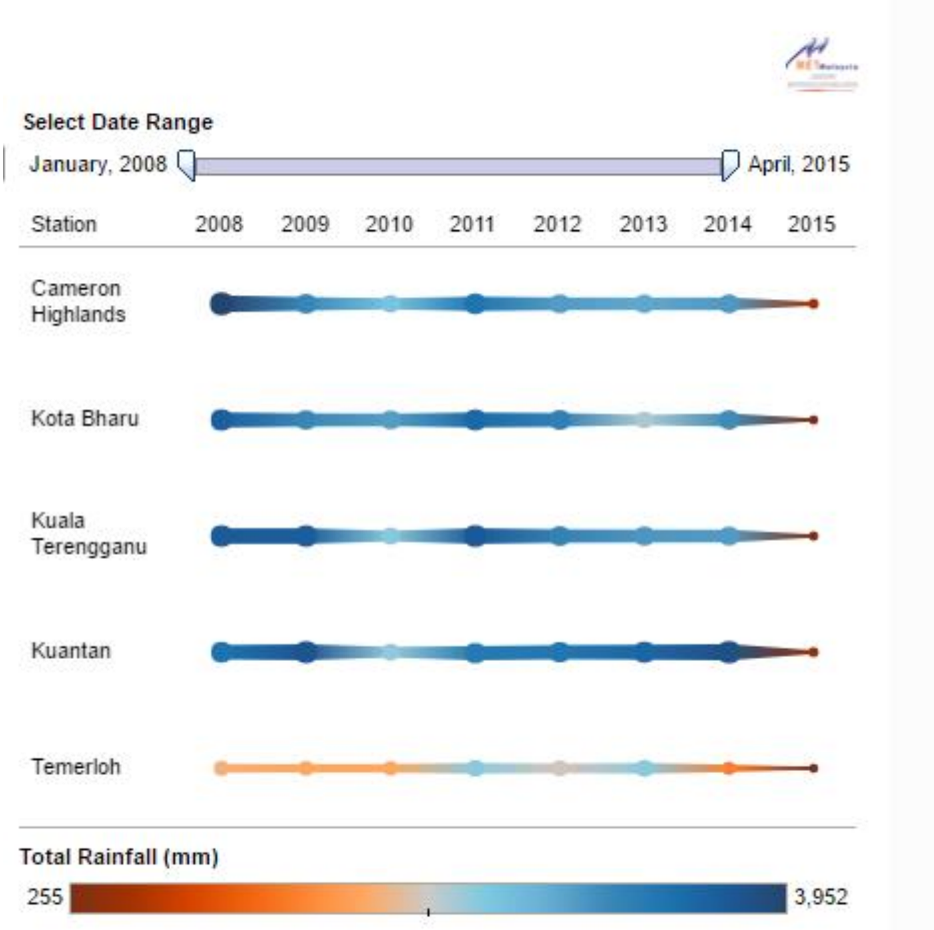


Figure 2.4: Data from Malaysia Meteorological Year 2008 until 2015

2.6 APPLICATION METHOD

Based on the data assembled at the Data Center and previous studies, (Wischmeier and D.Smith, 1965) developed the Universal Soil Loss Equation (USLE). An Agriculture Handbook describing USLE was published in 1965 and RUSLE in 1978. The development of Revised Universal Soil Loss Equation (RUSLE). RUSLE has the same formula as USLE, but has several improvements in determining factors.

2.6.1 Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning.

Five main factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages (Wischmeier and D.Smith, 1965).

The USLE for estimating average annual soil erosion is:

$$A = R*K*LS*C*P \qquad \text{Equation 2.1}$$

a) **A** = average annual soil loss
b) **R** = rainfall erosivity factor
c) **K** = soil erodibility factor
d) **LS** = slope length and steepness factor
e) **C** = cover management
f) **P** = practice factor

2.6.2 Revised Universal Soil Loss Equation (RUSLE)

Based on the data assembled at the Data Center and previous studies, Wischmeier, Smith, and others developed the Universal Soil Loss Equation (USLE). An Agriculture Handbook (No. 537) describing USLE was published in 1965 and revised in 1978. With a widespread acceptance, USLE has become the major conservation planning tool which is used in the United States and other countries in the world.

With additional research, experiments, data, and resources become available, research scientists continue to improve USLE, which led to the development of Revised Universal Soil Loss Equation (RUSLE). RUSLE has the same formula as USLE, but has several improvements in determining factors. These include some new and revised isoerodent maps; a time-varying approach for soil erodibility factor; a subfactor approach for evaluating the cover-management factor; a new equation to reflect slope length and steepness; and new conservation-practice values (Renard, et al., 1997). A new Agriculture Handbook (No. 703) which describes RUSLE in great detail was published in 1997 by the U.S. Department of Agriculture.

The RUSLE for estimating average annual soil erosion is:

$$A = R*K*LS*C*P \qquad \text{Equation 2.2}$$

a) **A** = average annual soil loss
b) **R** = rainfall erosivity factor
c) **K** = soil erodibility factor
d) **LS** = slope length and steepness factor
e) **C** = cover management
f) **P** = practice factor

Table 2.4: The summary of different between USLE and RUSLE.

Factor	USLE	RUSLE
R	Based on long term average rainfall conditions for specific geographic areas in the U.S.	Generally, the same as USLE in the Eastern U.S. The computes a correction to R to reflect the effect of raindrop impact for flat slopes striking water ponded on the surface.
K	Based on soil texture, organic matter content, permeability, and other factors inherent to soil type.	The adjusted to account for seasonal changes such as freezing and thawing, soil moisture, and soil consolidation.
LS	Based on length and steepness of slope, regardless of land use.	Refine USLE by assigning new equations based on the ratio of rill to inter rill erosion, and accommodates complex slopes.
C	Based on cropping sequence, surface residue, surface roughness, and canopy cover, with are weighted by the percentage of erosive rainfall during the six crop stages. Lumps these factors into a table and tillage scheme.	Recalculate a new soil loss ratio every time a tillage operation changes one of the sub factors. RUSLE provides improved estimates of soil loss changes as they occur throughout the year, especially relating to surface and near surface residue and the effect of climate on residue decomposition.
P	Based on installation of practices that slow runoff and thus reduce soil movement, P factor values changes according to slope ranges with some distinction for various ridge heights.	RUSLE computes the effect of strip cropping based on the transport capacity of flow in dense strips relative to the amount of sediment reaching the strip. The P factor for conservation planning considers the amount and location of deposition.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

Erosion pan design for laboratory studies and preparation of soil samples placed in the pans also can influence erosion results. Standardization of rainfall simulator design and test procedures will allow better comparison of erosion results to be made among researchers. In terms of collecting data of vegetation coverage, the have function of vegetation type, which affects change in land cover was analyzed. Soil erosion load estimation is one of the key issues in soil erosion research. This studies the method and technique of soil erosion load estimation with RUSLE before that need to analyzing for effects of empty surface and vegetation surface factors on soil erosion.

3.2 LABORATORY TESTING

The laboratory testing for soil properties are involved are mechanical sieve analysis, fine analysis, moisture content, falling head and specific gravity.

3.2.1 Soil Classification

First of all, as usually the soil sample is tested to determine the basic soil properties such as particle size distribution, and moisture content. The tests are useful to classify the soil. A classification of the soil is important because soil particle size is a strong determinant of soil behavior. Of particular importance is the transition from sand to silt and clay size. Table 3.1 shows the types of testing that was involved in this project and their testing method to achieve the objective.

Table 3.1: Laboratory testing and method (BS 1377:1990)

TESTING	METHOD
Particle size distribution	Mechanical sieve analysis and fine analysis
Moisture content	Oven drying
Specific gravity	Density bottle
Permeability	Falling head

3.2.2 Particle Size Distribution

A particle size distribution analysis is a necessary index test for soils, especially coarse soils, in that it presents the relative proportions of different sizes of particles. From this, it is possible to tell whether the soil consist of predominantly silt, sand, gravel or clays sizes, and to a limited extent which of these sizes ranges is likely to control the engineering properties. Particles size curves are of greater value if supplemented by descriptive detail such as colour and particle shape, together with grain packing and fabric when observed in the undisturbed state. But engineering behavior also depends on factor other than size of particles, such as mineral types, structures and geological history, which have significant effect on engineering properties and cannot be assessed form particle size alone.

3.2.3 Sieve Analysis Test

The separation of soils sample in their different size fractions is done using sieves with different mesh sizes down to the upper boundary for silt size, corresponding to the No. 200 sieves (63μm). Standard equipment for sieve analysis test that has been used is according to the BS 1377: Part 2:1990 Clause. Figure 3.1 shows the shaker sieve machine for using sieve analysis.

Figure 3.1: Shaker sieve machine for sieve analysis

3.2.4 Fine Analysis (Hydrometer)

Size analysis for coarse grained soil is used to determine the distribution of large grain sizes. The soil is passed through a series of sieve with the mesh size reducing progressively, and the proportions by weight of the soil retained on each sieve are measured. There are a range of sieve that can be used, and the finest is usually a 63µm sieve. Sieving can be performed either wet or dry. Because of the tendency for fine particles to clump together, wet sieving is often required with fine grained soils. Figure 3.2 shows the take reading for hydrometer testing.

Figure 3.2: Take reading for hydrometer test

3.2.5 Moisture Content

Moisture content testis to determine the water (moisture) content of soils. The water content is the ratio, expressed as percentage, of the mass of 'pore' or 'free' water in given mass of soil to the mass of the dry soil. Before done this test, the selection of particle size is crucial. Figure 3.3 shows the sample empty surface and vegetation surface after dry oven for moisture content.

For fine-grained soils (maximum particle size 2mm)

1. A thermostatically controlled oven preferably of the forced-draught type, capable of maintaining a temperature between 105℃ and 110℃.
2. A balance readable and accurate to 0.01 g.
3. Numbered aluminium weighing tins with close fitting numbered lids. A suitable size 75mm diameter and 25mm deep.
4. A desiccator containing anhydrous self-indicating silica gel. A suitable size is 250 mm diameter.

For medium-grained soils (maximum particle size 10mm)

1. A thermostatically controlled oven preferably of the forced-draught type, capable of maintaining a temperature between 105℃ and 110℃.
2. A balance readable and accurate to 0.2g.
3. Suitable airtight corrosion-resistant container of about 400g capacity.
4. A scoop

For coarse-grained soils (maximum particle size >10mm)

1. A thermostatically controlled oven preferably of the forced-draught type, capable of maintaining a temperature between 105℃ and 110℃.
2. A balance readable and accurate to 1g.
3. Suitable airtight corrosion-resistant container of about 3.5kg capacity.

4. A scoop

Figure 3.3: After dry soil sample for moisture content

3.2.6 Specific Gravity

Specific gravity is performed to determine the specific gravity of soil using density bottle. Specific gravity is ration of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at stated temperature. The ample was prepared according to the BS 1377: Part 2: 1990: Clause 8.3. Figure 3.4 shows the density bottle in vacuum desiccators for specific gravity.

Figure 3.4: Density bottle in vacuum desiccators

3.2.7 Falling Head Permeability

The falling head permeability test is used for measuring the permeability of soils of intermediate and low permeability (less than 0.0001m/s), i.e. silts clay, a relatively short sample is connected to a standpipe, which provides both the head of water and the means of measuring the quantity of water, flowing through the sample. Several standpipe of different diameter are normally available from which can be selected the diameter most suitable for the type of material being tested. Figure 3.5 shows the permeability for falling head test.

Figure 3.5: Permeability for falling head test

3.3 PREPARATION OF SOIL SAMPLE

Soil sampling is a particularly difficult task when attempting to get a representative sample. Normally a 3-kilogram sample is submitted to the laboratory for analysis. Factors that need to be considered when sampling soil include the depth and time of sampling. Proper sampling depth is affected by the crop being grown, past cropping, depth of plowing and also the nutrient of interest. Subsoil samples are important for most crops. Standard sampling times should be used due to the difficulty in comparing samples taken at different times. The fertility level of a field will vary over the course of the year and interpreting results for samples taken at different times of the year will be very difficult. Sampling between crops will give more consistent results. Figure 3.6 shows the collect undisturbed soil sample at Campus Pekan, Universiti Malaysia Pahang.

Figure 3.6: Collect undisturbed soil sample

3.4 RAINFALL DATA

The rainfall data in order to identify the different between rainfall data will collect by using rain gauge and weather station. The collected data also can be used for research and planning our daily activities. The location weather station and rain gauge existed in University Malaysia Pahang (UMP) Pekan. The data from Department of Irrigation and Drainage (JPS KUANTAN) also can used to know more accurate. The rainfall data collected from a weather station UMP, Pekan will to identify the trend of rainfall event at UMP, Pekan and make comparison with data rainfall and wind data collected using weather station. The relationship between relative humidity, temperature and wind speed towards the rainfall pattern was analyzed. Figure 3.7 shows the Rainfall erosivity map for Peninsular Malaysia.

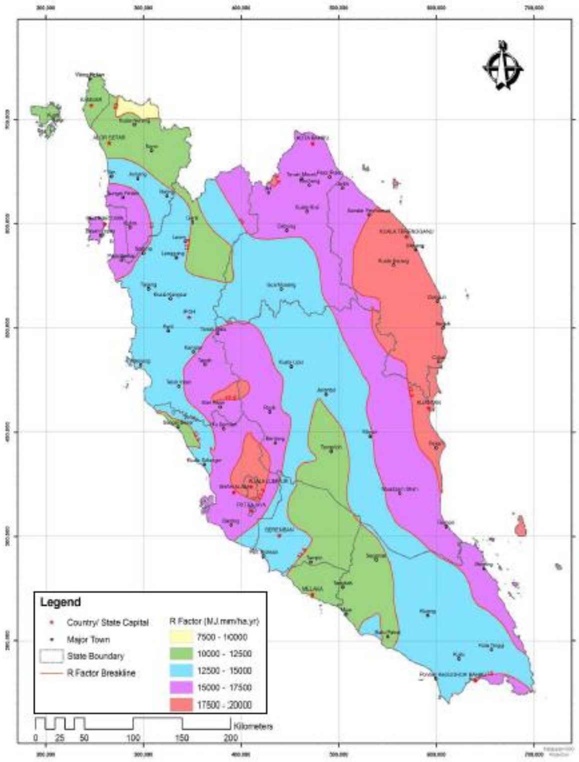


Figure 3.7: Rainfall erosivity map for Peninsular Malaysia

3.5 RUSLE METHOD

Rainfall erosivity factor (R), Soil erodibility factor (K), Slope Length and Steepness Factor (LS), Cover management (c) and Support practice (P) factor are the major parameters in application of RUSLE. Figure 3.8 shows the flow chart for calculate RUSLE.

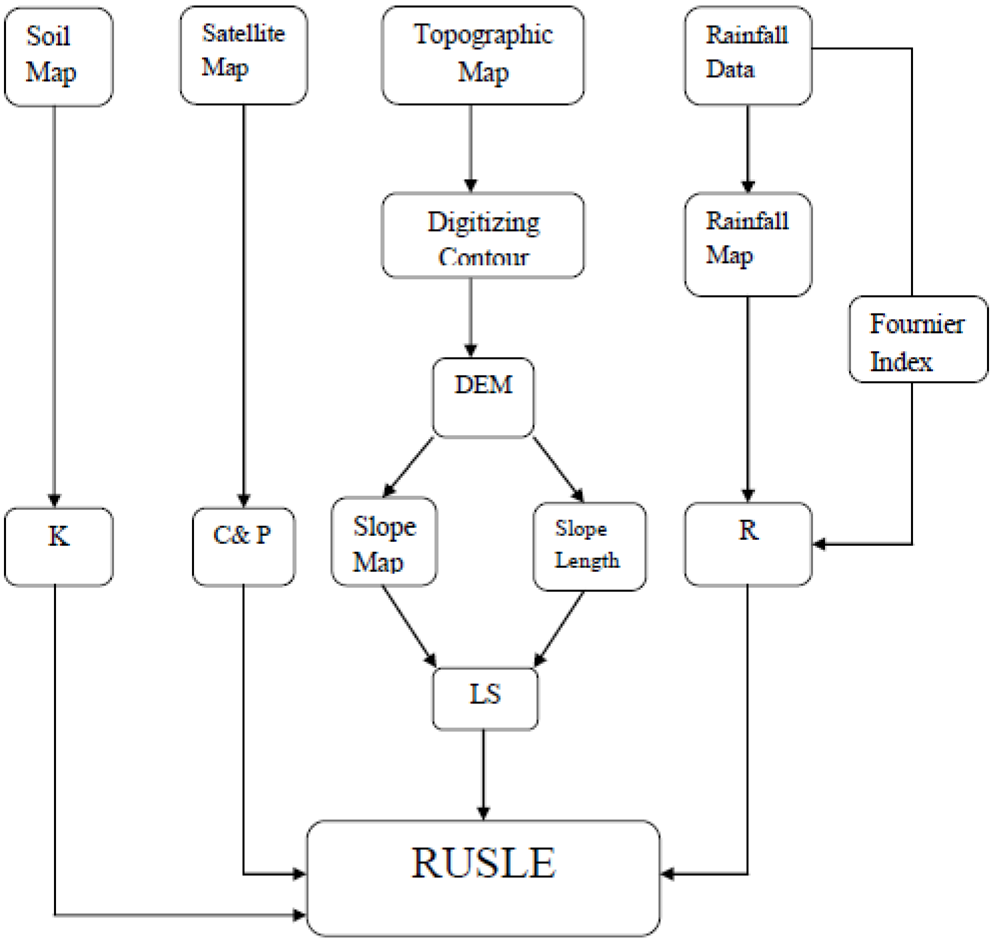


Figure 3.8: Flow chart for calculate RUSLE.

3.5.1 Rainfall Erosivity (R factor)

R is a measure of erosivity of rainfall which is the product of storm kinetic energy and maximum 30-minute intensity EI_{30}. When intensity (I_{30}) (Arnoldus, 1978).

Most of the time rainfall intensity and storm kinetic energy data are not available at national meteorological stations. By the absence rainfall intensity and storm kinetic energy data for this study area, mean annual and monthly rainfall data have been used to estimate the R factor (Arnoldus, 1978).

3.5.2 Soil Erodibility Index (K factor)

Soil erodibility factor represents both susceptibility of the soil to erosion and the rate of runoff, as measured under the standard unit plot condition. The value of this factor is affected by infiltration capacity and structural stability or the soil. So, the K values run from 1.0 to 0.01 with the highest values for soils with high content of silt or very fine sand. For example, soil high in clay have low K values, about 0.05 to 0.15, because they resistant to detachment. Coarse textured soils, such as sandy soils, have low K values, about 0.05 to 0.2, because of low runoff even though these soils are easily detached. Medium textured soils, such as the silt loam soils, have a moderate K values, about 0.25 to 0.04, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having high silt content are most erodible of all soils. They are easy detached; tend to crust and produce high rates of runoff. Values of K for these soils tend to be greater than 0.4 (Weesies A. 1978).

3.5.3 Slope and Slope Length (LS) Factors

L and S are factors representing the topography of the land and they define the effects of slope length slope angle on sheet and rill erosion. The slope length factor L is defined the distance from the source of runoff to the point where deposition begins, or runoff becomes focused into a defined channel. The length of slope and interaction of angle has an effect on the magnitude of erosion. For example, soil loss from plot on irregular slopes may be dependent on the slope immediately above the points of measurements. The result from interaction, the degree of slope and effect of slope must be considered together (Edwards, 1987).

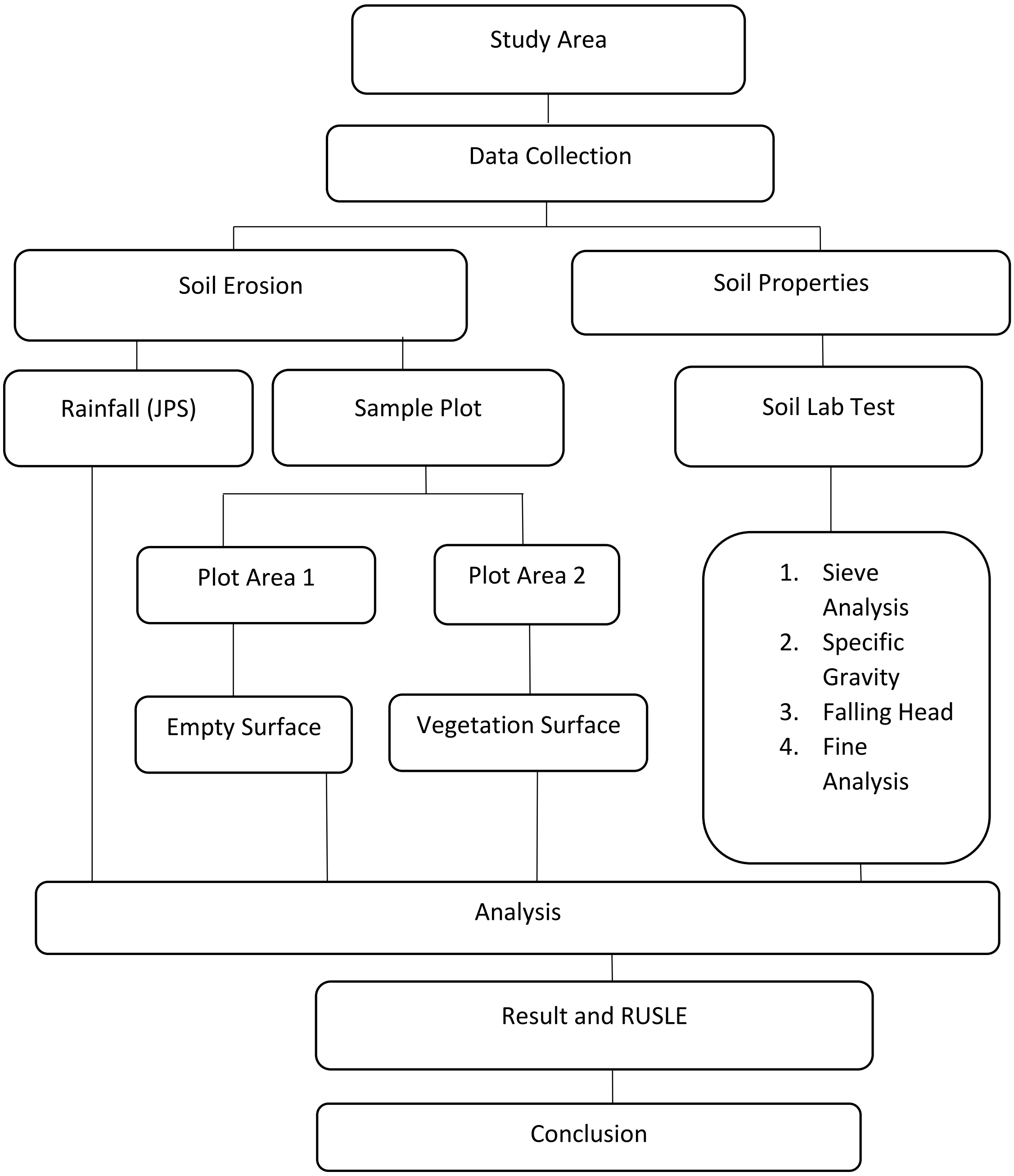
3.5.4 Cover management factor (C)

Cover management factor is a crop or land cover management factor and measure the combined effect of all interrelated vegetative cover and management variable. In other words, this factor measures the protection of the soil surface from raindrop impact by vegetative material at some height above the soil surface and the additional protection from raindrop impact and overland flow by cover in contact with the soil surface cover. It is defined the ratio of the soil loss from land maintained under specified conditions to the corresponding loss from continuous tilled bare fallow. Value can be varying from zero is very well protected soils to 1.5 for finely tilled, ridged surface that produces much runoff, leave it susceptible to rill erosion (Van der Knijff et al., 2000).

3.5.5 The Support Practice (P factor)

The support practice is support or land management practices factor. The RUSLE, support factor is normally applying to disturbed land and represent how surface and management practice such as terracing, strip cropping, and contouring is used to reduces soil erosion. For area where there is no support practice the P factor is set to 1.0 (Simms A.D 2003).

3.6 FLOW CHART METHODOLOGY



CHAPTER 4

RESULT AND ANALYSIS

4.1 INTRODUCTION

In order to determine the soil erosion rate on two type land at Universiti Malaysia, Pekan Campus obtained by the methods of Revised Universal Soil Loss Equation (RUSLE) and their soil properties, several related testing were conducted in the soil laboratory. Testing are involved for this study such a mechanical sieve analysis, fine analysis (hydrometer), moisture content, falling head, and specific gravity that were carried out in order to classify properties of the soil samples. To measure the amount of rain intensity that get exact amount rainfall intensity map for Peninsular Malaysia average heavy rainfall at Pekan area. After conducting soil laboratory testing, the data obtain from the test analyzed and presented in form of table and graphs for result.

4.2 SOIL PROPERTIES

The soil properties are involved are mechanical sieve analysis, fine analysis, moisture content, falling head and specific gravity.

4.2.1 Mechanical Sieve Analysis

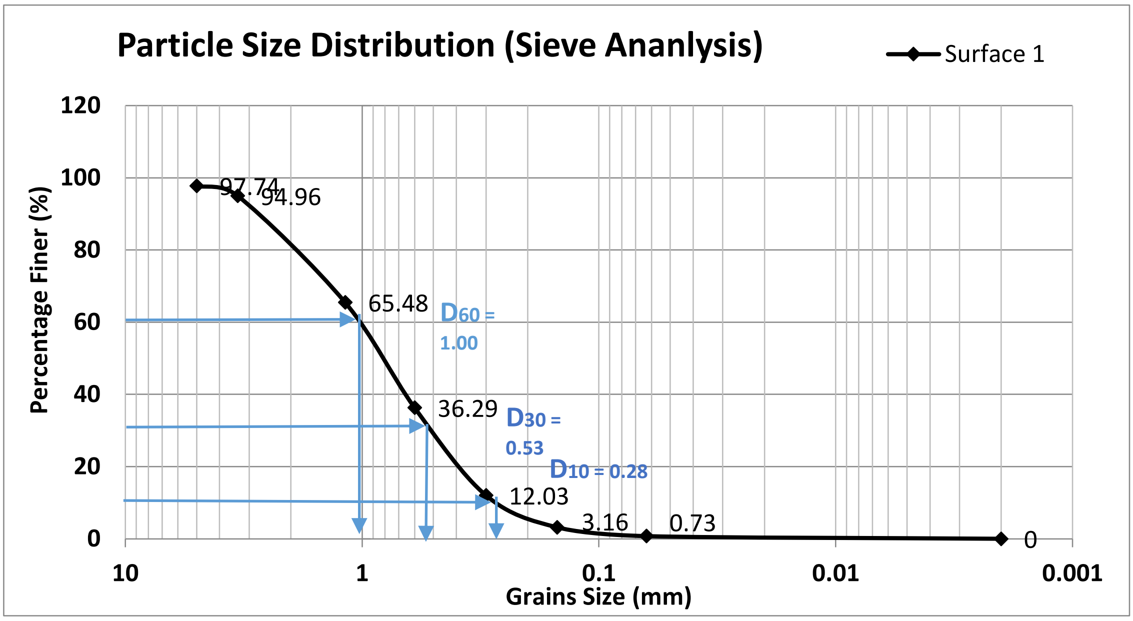


Figure 4.1: Particle size distribution curve for soil sample empty surface 1

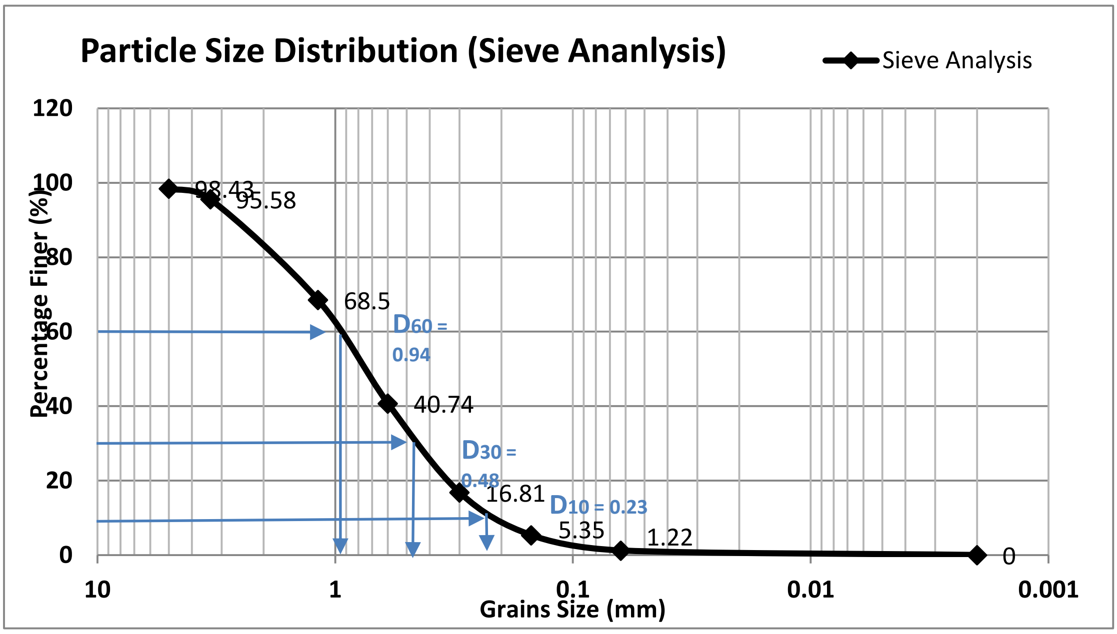


Figure 4.2: Particle size distribution curve for soil sample empty surface 2

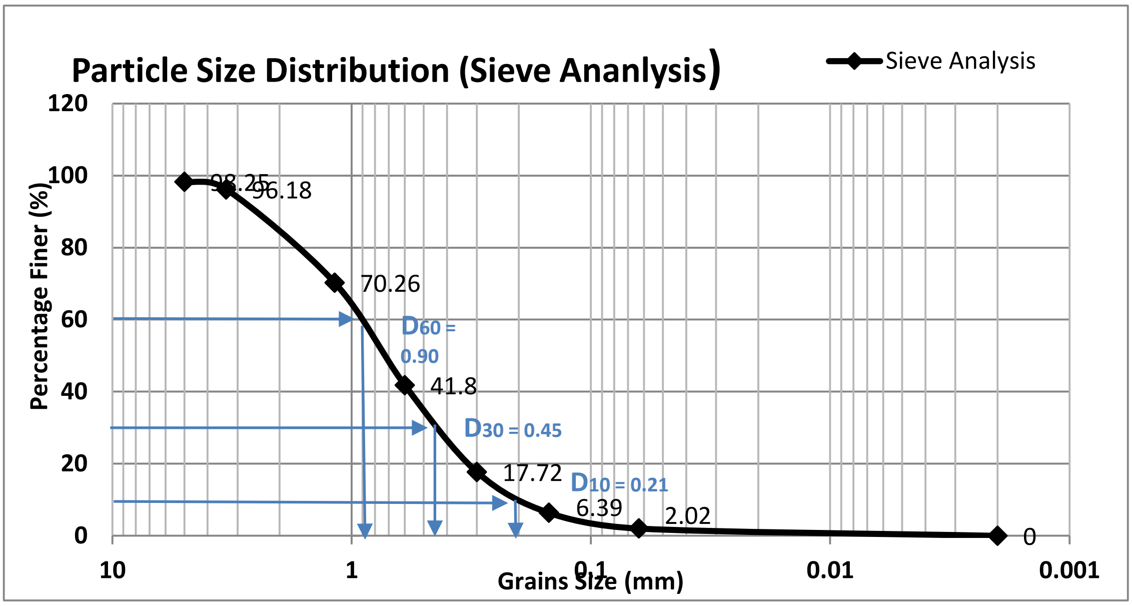


Figure 4.3: Particle size distribution curve for soil sample vegetation surface 1

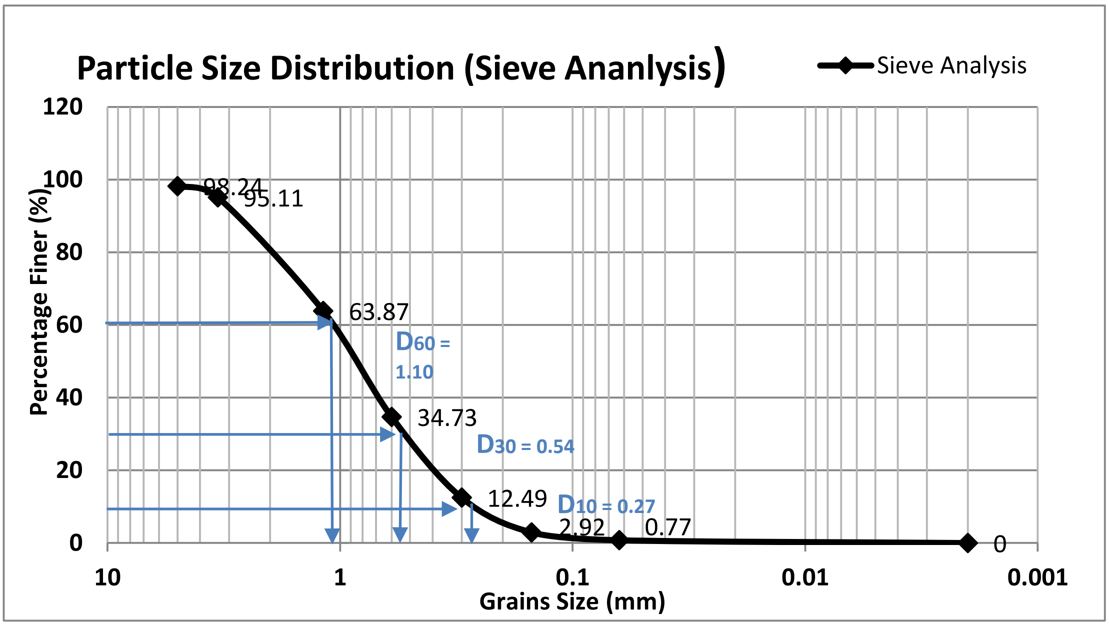


Figure 4.4: Particle size distribution curve for soil sample vegetation surface 2

Table 4.1: Result uniformity coefficient and coefficient of gradation

Location	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	Cu	Cc
Empty Surface 1	0.28	0.53	1.00	3.57	1.00
Empty Surface 2	0.22	0.48	0.93	3.92	1.12
Vegetation Surface 1	0.21	0.45	0.90	4.29	1.07
Vegetation Surface 2	0.27	0.52	1.10	4.07	1.03

Figure 4.1 and Figure 4.2 the particle size distribution curve indicates that percent passing No. 200 sieve is 2.26 % and 1.73 %. According to Unified Soil Classification System (USCS), it is soil sample empty surface 1 and empty surface 2 respectively. The percent retained on No.4 sieve is 0.73 % and 1.22 %. Hence, it is a sandy soil. Effective size (D_{10}) is the diameter in the particle size distribution curve corresponding to 12% finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil sample empty surface 1 and empty surface 2 respectively. From the graph and Table 4.1, the value of C_u is 3.57 and C_u is 3.92. C_c is 1.00 and C_c is 1.12. As the result these two soil sample surface can be categorized as poorly graded sand (Appendix A).

Figure 4.3 and Figure 4.4 the particle size distribution curve indicates that percent passing No. 200 sieve is 1.75 % and 1.76 %. According to Unified Soil Classification System (USCS), it is soil sample vegetation surface 1 and vegetation surface 2 respectively. The percent retained on No.4 sieve is 2.02 % and 0.77 %. Hence, it is a sandy soil. Effective size (D_{10}) is the diameter in the particle size distribution curve corresponding to 12% finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil sample vegetation surface 1 and vegetation surface 2 respectively. From the graph and Table 4.1, the value of C_u is 4.29 and C_u is 4.07. C_c is 1.07 and C_c is 1.03. As the result these two soil sample surface can be categorized as two soil sample vegetation is well-graded sand or fine to coarse sand (Appendix A).

4.2.2 Specific Gravity

To obtain the specific gravity of the soil, the test must be conducted by using a density bottle. Specific gravity is ratio of the mass of unit volume of soil at s stated temperature to the mass volume of gas free distilled water at a stated temperature. According to BS1377: Part 2: 1990: 8.3, specific gravity test is suitable for fine gained soil.

The specific gravity test result are shown in Table 4.2. All the result of specific gravity are tabulated and presented in Appendix B. According to the result that gained form test, the average specific gravity result of soil sample empty surface 1 and empty surface 2 is 2.63 mg/m^3. For average specific gravity result of soil sample vegetation surface 1 is 2.60 mg/m^3 and vegetation surface 2 is 2.58 mg/m^3

Table 4.2: Result specific gravity of soil

Type of soil	**Specific gravity**
Empty Surface 1	2.63 mg/m^3
Empty Surface 2	2.63 mg/m^3
Vegetation Surface 1	2.60 mg/m^3
Vegetation Surface 2	2.58 mg/m^3

4.2.3 Moisture Content

To obtain moisture content, the test must be conducted at the moment when the soil sample arrived at soil laboratory to avoid moisture content in sack to evaporate by high temperature if it kept too long.This soil sample collect at 0.69 m depth (2 feet) and average moisture content percentage (%) of the soil two type land at Universiti Malaysia Pahang, Pekan. The average moisture content result are shown in Table 4.3

Table 4.3: Average moisture content result

Type of soil	Moisture content (%)
Empty Surface 1	7.37
Empty Surface 2	9.00
Vegetation Surface 1	4.56
Vegetation Surface 2	5.83

4.2.4 Falling Head

The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test can be carried out in a Falling Head permeability cell or in an oedometer cell. The falling head test result are shown in Table 4.4. On the basis of the test results, the permeability of the sample can be calculated as tabulated and presented in Appendix C.

Table 4.4: Result permeability of soil

Type of soil	T1 (cm/s)	T2 (cm/s)	T3 (cm/s)
Empty Surface 1	3.1721×10^{-7}	4.0217×10^{-7}	6.7433×10^{-7}
Empty Surface 2	3.3575×10^{-6}	3.8845×10^{-6}	6.4327×10^{-6}
Vegetation Surface 1	2.8817×10^{-7}	4.0190×10^{-7}	8.0336×10^{-7}
Vegetation Surface 2	6.0334×10^{-7}	6.0039×10^{-7}	1.3214×10^{-7}

According to the result that gained form test, the falling head result of soil sample empty surface 1 and empty surface 2 typical permeability coefficient is silts. For falling head result of soil sample vegetation surface 1 and vegetation surface 2 typical permeability coefficient is silts.

4.2.5 Fine Analysis

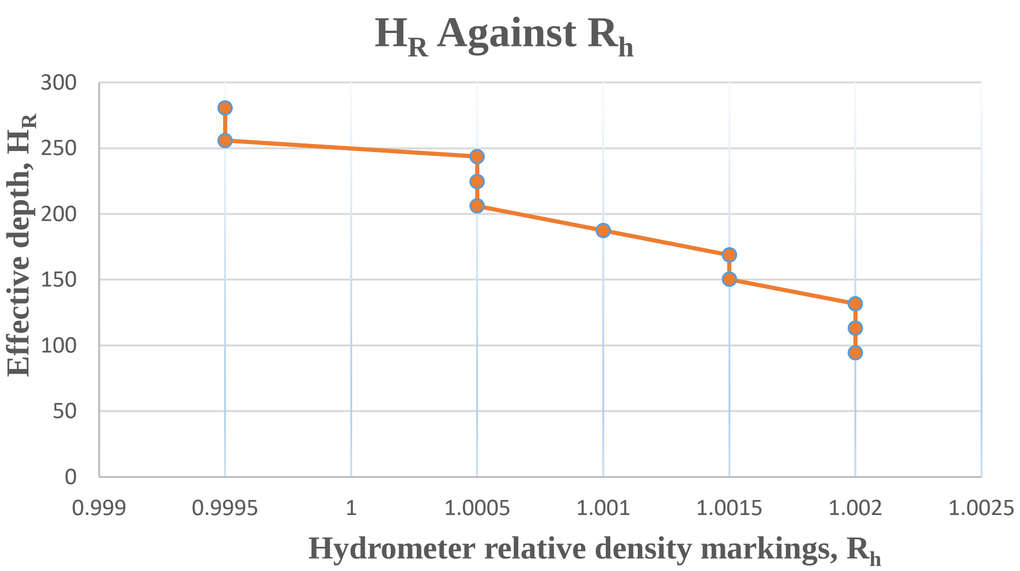


Figure 4.5: Equivalent HR against Rh for soil sample empty surface 1

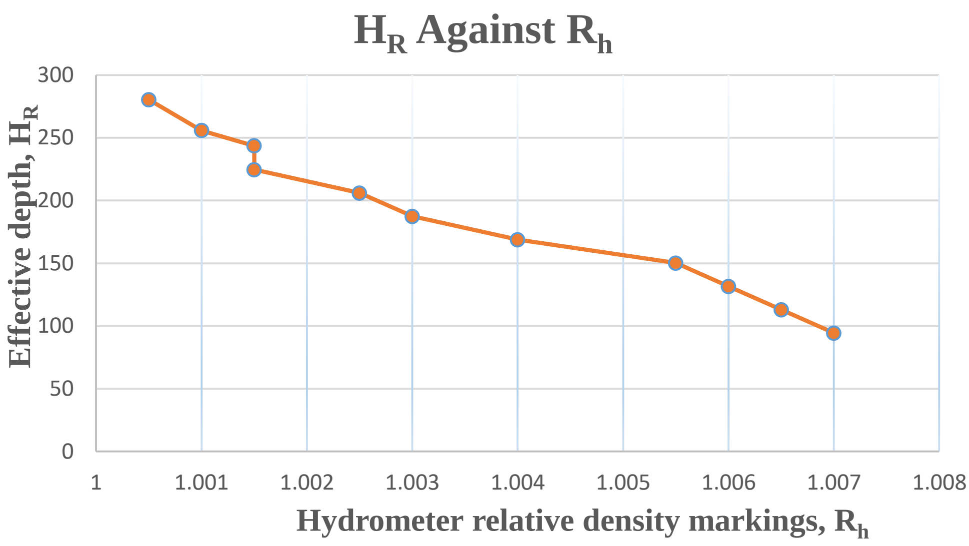


Figure 4.6: Equivalent HR against Rh for soil sample empty surface 2

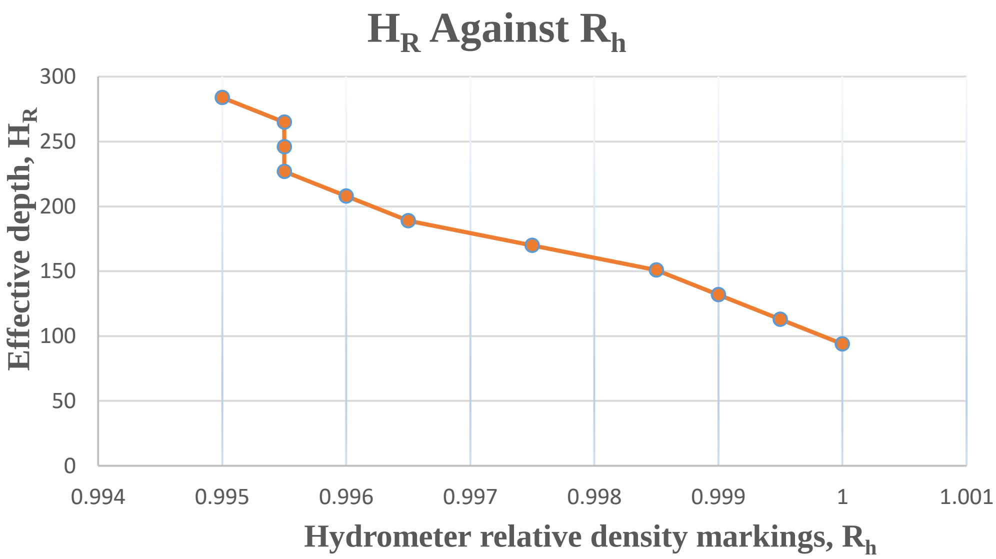


Figure 4.7: Equivalent HR against Rh for soil sample surface vegetation 1

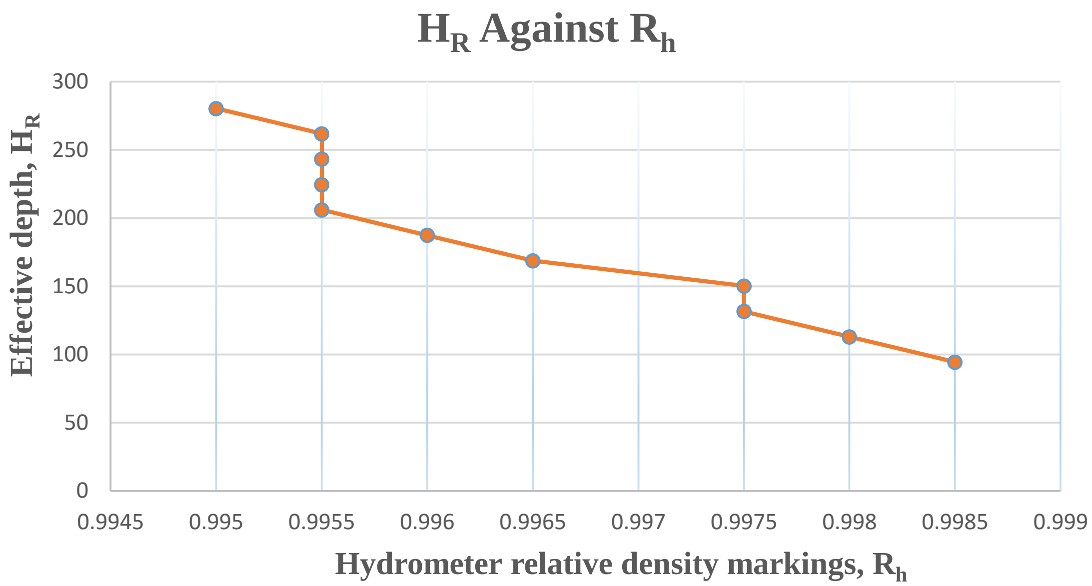


Figure 4.8: Equivalent HR against Rh for soil sample surface vegetation 2

The hydrometer test is conducted to find the particle-size distribution curve of soil solids smaller than 0.075mm. The test principle is based on sedimentation of soil solids in water. As soil particles will settle with different velocities in the water depending on sizes, weight and shapes of the soil solids and the viscosity of water.

From the Figure 4.5 and Figure 4.6, the data such as particle diameter (D) and % finer than D (K) is range from 0.48 to -0.030 and 1.93 to -0. 16 respectively. From all the data, provide a grading curve and at the same time we can find the effective depth for the experiment.

From figure 4.7 and 4.8, the data such as particle diameter (D) and % finer than D (K) is range from 0.84 to -0.81 and 0.34 to -0. 85 respectively. From all the data, provide a grading curve and at the same time we can find the effective depth for the experiment. The calculation are tabulated and presented in Appendix D

4.3 REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE)

The RUSLE that contain the information of five factors which are rainfall erosivity factor (R factor), soil erodibility factor (K factor), slope length factor (LS factor), cover management factor (C factor), and practice management factor (P factor).

4.3.1 Rainfall Erosivity (R factor)

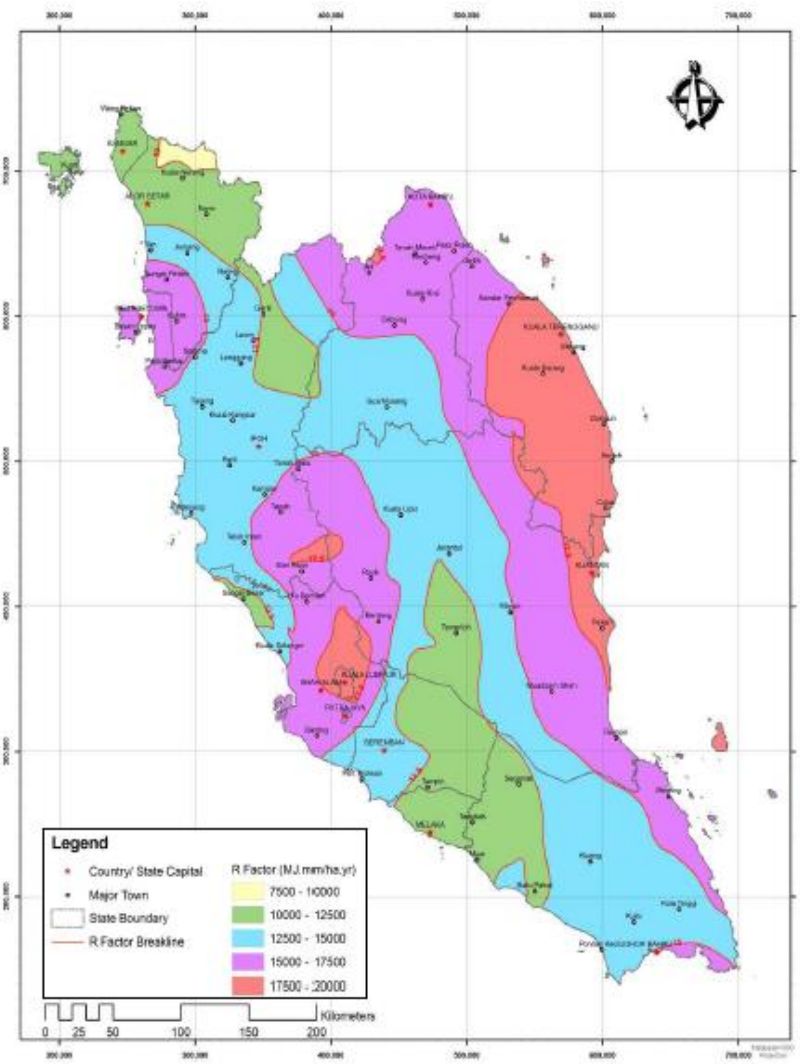


Figure 4.9: Rainfall erosivity map for Peninsular Malaysia

4.3.2 Soil Erodibility (K factor)

The soil erodibility parameter is based on the soil texture, structure, organic matter, and even permeability this all value and calculation are tabulated and presented in Appendix E. The percentage of soil particle class can be obtained through result soil laboratory analysis of soil sample. The K factor value for two surface and two vegetation soil sample are shown in Table 4.5.

Table 4.5: Result soil erodibility factor

Location	M (%)	Organic Matter (OM) (%)	Soil Structure (S)	Permeability (P)	Soil Erodibility (K)
Empty Surface 1	386.16	0.11	1	1	0.159
Empty Surface 2	648.00	0.11	1	1	0.151
Surface Vegetation 1	824.99	0.11	1	2	0.065
Surface Vegetation 2	365.17	0.11	1	2	0.080

4.3.3 Slope Length and Steepness (LS factor)

The Table 4.6 shows rate of soil erosion is very much affected by both slope length (L) and slope steepness (S) in term of gradient slope. The slope length (λ) for area soil sample plot surface is 3.75m and the slope steepness (S) is 34.37 %. The slope length (λ) for area soil sample plot vegetation is 5.88m and the slope steepness (S) is 28.85 %. The slope length factor (LS) for surface is 3. 204. For the slope length factor (LS) for vegetation is 3.060. The calculation is tabulated and presented from MSMA 2 in Appendix F.

Table 4.6: Result slope length factor

Location	Slope length (λ)	Slope steepness (S)	(LS factor)
Empty Surface 1	3.75m	34.37 %	3. 204
Empty Surface 2	3.75m	34.37 %	3. 204
Surface Vegetation 1	5.88m	28.85 %	3.060
Surface Vegetation 2	5.88m	28.85 %	3.060

4.3.4 Cover Management Factor (C factor)

The cover management factor that can be used to control soil loss at s specific site. The value C factor taken from best management practices at construction sites from MSMA 2 in Appendix F. Table 4.7 shows the result cover management based on erosion control treatment.

Table 4.7: Result cover management

Location	Erosion control treatment	C factor
Empty Surface 1	Bare soil	1.00
Empty Surface 2	Bare soil	1.00
Surface Vegetation 1	Grass seeding	0.02
Surface Vegetation 2	Grass seeding	0.02

4.3.5 Practice Management Factor (P factor)

The practice management factor is needed to stop silt and sediment in flowing water from running off the site. It is possible to minimize erosion at a construction site, the value P factor refer the best management practice at construction and development site and presented at MSMA 2 in Appendix F. Table 4.8 shows the result practice management based on support control practice.

Table 4.8: Result practice management

Location	Support control practice	P factor
Empty Surface 1	Bare soil	1.00
Empty Surface 2	Bare soil	1.00
Surface Vegetation 1	Grass	0.80
Surface Vegetation 2	Grass	0.80

4.4 AVERAGE ANNUAL SOIL LOSS (A)

The average annual soil loss is the rate soil loss in tonnes/hectare/year, R is the rainfall erosivity factor in MJ.mm/ha.yr, K is the soil erodibility factor in tonnes/ha/MJ/mm, L is the slope length factor, S is the slope steepness factor, C is cover management factor and P is the conservation support practice factor. The five factor was calculating to find the average annual soil loss using RUSLE equation.

Table 4.9: Result annual soil loss

Location	**Average Annual soil loss (A)**
Empty Surface 1	9551.93
Empty Surface 2	9071.33
Surface Vegetation 1	59.67
Surface Vegetation 2	73.44

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the study, the soil empty surface 1 and surface 2 are classified as poorly graded sand, according to USCS standard. The specific gravity test showed that the soil sample have specific weight of 2.63mg/m^3 which is grouped as sand and gravel. Besides, the falling head test, it shows that the permeability of the soil for empty surface 1 are 3.1721 x 10^{-7}cm/s, 4.0217 x 10^{-7}cm/s, and 6.7433 x 10^{-7}cm/s respectively for 3 different size of the tubes. From the results, conclude that the soil sample is silts. The moisture content for empty surface 1 and surface 2 are 7.37 % and 9 % respectively.

The soil vegetation surface 1 and surface 2 are classified as well-graded sand, according to USCS standard. The specific gravity test showed that the soil sample have specific weight of 2.58mg/m^3 which is grouped as sand and gravel. Besides, the falling head test, it shows that the permeability of the soil for vegetation surface 1 are 2.8817 x 10^{-7}cm/s, 4.0190 x 10^{-7}cm/s, and 8.0336 x 10^{-7}cm/s respectively for 3 different size of the tubes. From the results, conclude that the soil sample is silts. The moisture content for vegetation surface 1 and surface 2 are 4.56 % and 5.83 % respectively.

Using Revised Universal Soil Loss Equation (RUSLE), The average annual soil loss estimated were by empty surface 1 and empty surface 2 is 9551.93ton/ha/yr and 9071.33ton/ha/yr respectively. For vegetation surface 1 and vegetation 2 is 59.67ton/ha/yr and 73.44ton/ha/yr respectively.

5.2 Recommendation

As a final note, it is important to have some necessary suggestions in which this study could be brought to another level in the near future. The recommendations are listed here as followings:

It is recommended to study on runoff/rainfall regarding the slope soil erosion. Surface runoff can cause erosion of the Earth's surface, eroded material may be deposited a considerable distance away. There are four main types of soil erosion by water are splash erosion, sheet erosion, rill erosion and gully erosion.

The splash erosion is the result of mechanical collision of raindrops with the soil surface and soil particles which are dislodged by the impact then move with the surface runoff. Sheet erosion is the overland transport of sediment by runoff without a well-defined channel.

Soil surface roughness causes may cause runoff to become concentrated into narrower flow paths, the small but well-defined channels which are formed are known as rills. These channels can be as small as one-centimeter-wide or as large as several meters. If runoff continue to incise and enlarge rills, they may eventually grow to become gullies. Gully erosion can transport large amounts of eroded material in a small time period.

Additionally, analysis and comparison of soil loss can be done between another method available which is Modified Universal Soil Loss Equation (MUSLE).

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APPENDIX A

Mechanical Sieve Analysis

Dry mass: 1922 g **Sample soil: Empty Surface 1**

Sieve size (mm)	Mass of sieve (g)	Mass retained on sieve + sieve (g)	Mass retained on sieve (g)	Cumulative mass retained (g)	Percent retained (%)	Percent finer (%)
5.00	524.73	567.96	43.23	43.23	2.26	97.74
3.35	541.36	594.64	53.28	96.51	2.78	94.96
1.18	428.65	992.94	564.29	660.80	29.48	65.48
600μm	491.87	1050.64	558.77	1219.57	29.19	36.29
300 μm	433.04	897.57	464.53	1684.10	24.26	12.03
150 μm	421.94	591.74	169.80	1853.90	8.87	3.16
63 μm	257.91	304.41	46.50	1900.40	2.43	0.73
Pan	372.91	386.92	14.01	1914.41	0.73	0
Total			1914.41		100.0	

Uniformity coefficient, Cu $= \frac{D60}{D10} \quad = \frac{1.00}{0.28}$

$= 3.57$

Coefficient of gradation, Cc $= \frac{(D30)^2}{D10 \times D60} \quad = \frac{(0.53)^2}{0.28 \times 1.00}$

$= 1.00$

Percentages of gravel, sand, silt, and clay by using the Unified Soil Classification System:

Size		Percent	Finer	
76.2	100	100 – 97.74	= 2.26 %	**gravel**
4.75	96.58	97.74 - 0.73	= 97.01 %	**sand**
0.075	4.01	0.73- 0	= 0.73 %	**silt and clay**

Dry mass: 1880 g **Sample soil: Empty**
Surface 2

Sieve size (mm)	Mass of sieve (g)	Mass retained on sieve + sieve (g)	Mass retained on sieve (g)	Cumulative mass retained (g)	Percent retained (%)	Percent finer (%)
5.00	524.70	554.05	29.35	29.35	1.57	98.43
3.35	540.20	593.67	53.47	82.82	2.85	95.58
1.18	428.55	935.88	507.33	590.15	27.08	68.50
600µm	491.34	1011.37	520.03	1110.18	27.76	40.74
300 µm	432.79	881.12	448.33	1558.51	23.93	16.81
150 µm	421.90	636.48	214.58	1773.09	11.46	5.35
63 µm	258.97	336.14	77.17	1850.26	4.12	1.22
Pan	365.11	388.02	22.91	1873.17	1.22	0
Total			1873.17		100.0	

Uniformity coefficient, Cu $= \frac{D60}{D10} = \frac{0.94}{0.24}$

$= 3.92$

Coefficient of gradation, Cc $= \frac{(D30)^2}{D10 \text{ x } D60} = \frac{(0.48)^2}{0.22\text{x } 0.93}$

$= 1.12$

Percentages of gravel, sand, silt, and clay by using the Unified Soil Classification System:

Size		**Percent**	**Finer**	
76.2	100	100 – 98.43	= 1.57%	**gravel**
4.75	96.58	98.43 - 4.01	= 94.42%	**sand**
0.075	4.01	1.22- 0	= 1.22%	**silt and clay**

Dry mass: 1940 g **Sample soil: Vegetation surface 1**

Sieve size (mm)	Mass of sieve (g)	Mass retained on sieve + sieve (g)	Mass retained on sieve (g)	Cumulative mass retained (g)	Percent retained (%)	Percent finer (%)
5.00	524.75	558.48	33.73	33.73	1.75	98.25
3.35	540.83	580.77	39.94	73.67	2.07	96.18
1.18	428.03	928.58	500.55	574.22	25.92	70.26
600μm	491.58	1041.22	549.64	1123.86	28.46	41.80
300 μm	432.89	897.94	465.05	1588.91	24.08	17.72
150 μm	421.94	640.78	218.84	1807.75	11.33	6.39
63 μm	257.97	344.50	84.53	1892.28	4.38	2.02
Pan	365.07	404.13	39.06	1931.34	2.02	0
Total			1931.34		100.0	

Uniformity coefficient, Cu $= \frac{D60}{D10} = \frac{0.90}{0.21}$

$= 4.29$

Coefficient of gradation, Cc $= \frac{(D30)^2}{D10 \text{ x } D60} = \frac{(0.45)^2}{0.21 \text{ x } 0.90}$

$= 1.07$

Percentages of gravel, sand, silt, and clay by using the Unified Soil Classification System:

Size		Percent	Finer	
76.2	100	100 – 98.25	= 1.75 %	**gravel**
4.75	96.58	98.25 - 2.02	= 96.23 %	**sand**
0.075	4.01	2.02- 0	= 2.02 %	**silt and clay**

Dry mass: 1928 g **Sample soil: Vegetation surface 2**

Sieve size (mm)	Mass of sieve (g)	Mass retained on sieve + sieve (g)	Mass retained on sieve (g)	Cumulative mass retained (g)	Percent retained (%)	Percent finer (%)
5.00	524.74	558.64	33.90	33.90	1.76	98.24
3.35	541.69	601.96	60.27	94.17	3.13	95.11
1.18	428.22	1029.53	601.31	695.48	31.24	63.87
600µm	491.75	1052.67	560.92	1256.40	29.14	34.73
300 µm	432.96	861.05	428.09	1684.49	22.24	12.49
150 µm	422.01	606.22	184.21	1868.70	9.57	2.92
63 µm	257.69	298.83	41.14	1909.84	2.14	0.77
Pan	372.86	387.63	14.77	1924.61	0.77	0
Total			1924.61		100.0	

Uniformity coefficient, Cu $= \frac{D60}{D10} \quad = \frac{1.10}{0.27}$

$= 4.07$

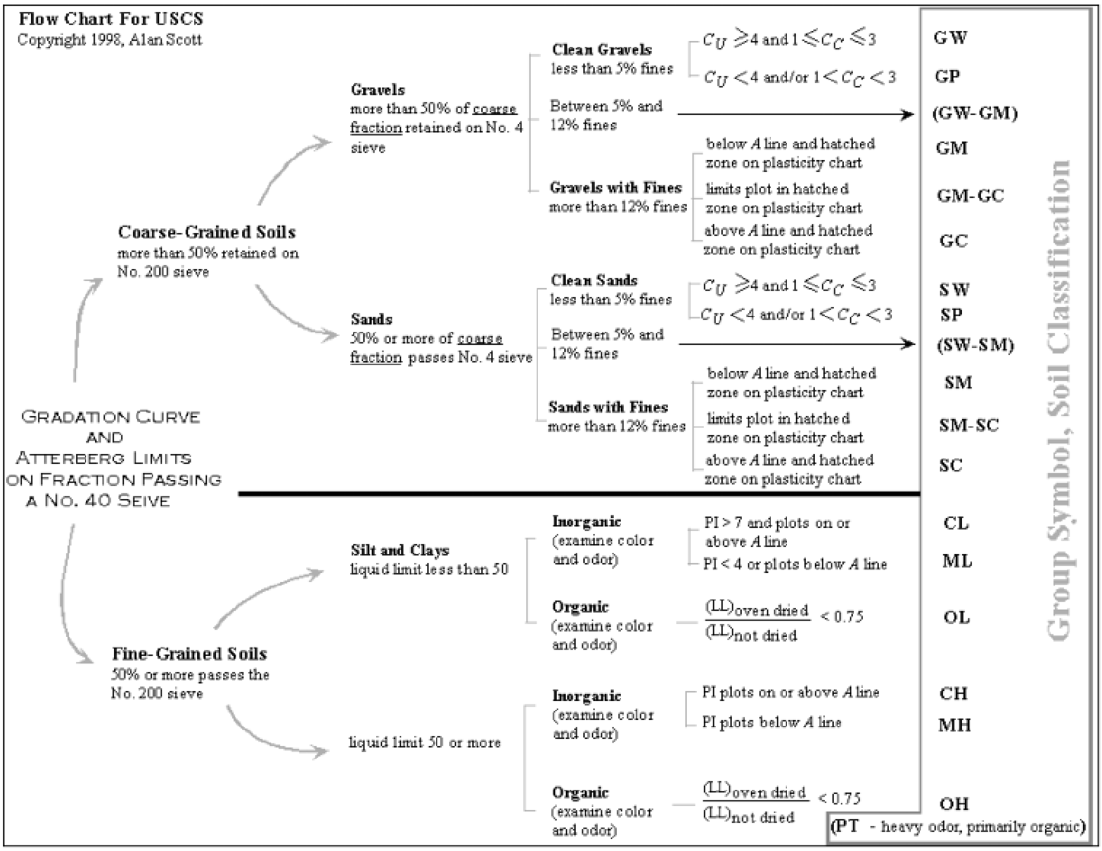
Coefficient of gradation, Cc $= \frac{(D30)^2}{D10 \times D60} = \frac{(0.54)^2}{0.27 \times 1.10}$

$= 1.03$

Percentages of gravel, sand, silt, and clay by using the Unified Soil Classification System:

Size		**Percent**	**Finer**	
76.2	100	100 – 98.24	= 1.76 %	**gravel**
4.75	96.58	98.24 - 0.77	= 97.47 %	**sand**
0.075	4.01	0.77- 0	= 0.77 %	**silt and clay**

Table: Unified Soil Classification System (USCS)



APPENDIX B

Specific Gravity Result

Sample soil: Empty surface 1

TEST NO.	units	1	2	3
Density bottle No.		C	1	3 (22)
Weight of density bottle	g	26.91	27.59	26.81
Weight of bottle + Stopper (W_1)	g	31.09	32.18	31.21
Weight of bottle + Stopper + Dry soil (W_2)	g	41.08	42.20	41.30
Weight of bottle + Stopper + Soil + Water (W_3)	g	137.80	138.57	137.88
Weight of bottle + Stopper + Water (W_4)	g	131.58	132.40	131.66
Weight of dry soil (W_2 - W_1)	g	9.99	10.02	10.09
Weight of water (W_4 - W_1)	g	100.49	100.22	100.45
Weight of soil + Water ($W_3 – W_2$)	g	96.72	96.37	96.58
Specific gravity	mg/m^3	2.65	2.60	2.63
Average specific gravity	2.63			

Sample soil: Empty surface 2

TEST NO.	units	1	2	3
Density bottle No.		4	B (11)	A
Weight of density bottle	g	32.98	30.32	31.35
Weight of bottle + Stopper (W_1)	g	37.49	34.76	35.80
Weight of bottle + Stopper + Dry soil (W_2)	g	47.56	44.80	45.82
Weight of bottle + Stopper + Soil + Water (W_3)	g	144.08	140.91	142.06
Weight of bottle + Stopper + Water (W_4)	g	137.70	134.71	135.98
Weight of dry soil (W_2 - W_1)	g	10.07	10.04	10.00
Weight of water (W_4 - W_1)	g	100.21	99.95	100.18
Weight of soil + Water (W_3 – W_2)	g	96.52	96.11	96.24
Specific gravity	mg/m^3	2.73	2.61	2.54
Average specific gravity	2.63			

Sample soil: Vegetation surface 1

TEST NO.	units	1	2	3
Density bottle No.		6	7	8
Weight of density bottle	g	31.72	32.61	31.38
Weight of bottle + Stopper (W_1)	g	35.83	36.78	35.66
Weight of bottle + Stopper + Dry soil (W_2)	g	45.85	46.86	45.72
Weight of bottle + Stopper + Soil + Water (W_3)	g	141.61	142.94	141.74
Weight of bottle + Stopper + Water (W_4)	g	135.82	136.71	135.25
Weight of dry soil (W_2 -W_1)	g	10.02	10.08	10.06
Weight of water (W_4 - W_1)	g	99.99	99.93	99.59
Weight of soil + Water ($W_3 – W_2$)	g	95.76	96.08	96.02
Specific gravity	mg/m^3	2.37	2.62	2.82
Average specific gravity	2.60			

Sample soil: Vegetation surface 2

TEST NO.	units	1	2	3
Density bottle No.		20 (3)	5	3A
Weight of density bottle	g	29.11	29.48	32.36
Weight of bottle + Stopper (W_1)	g	33.55	33.88	37.43
Weight of bottle + Stopper + Dry soil (W_2)	g	43.55	43.92	47.42
Weight of bottle + Stopper + Soil + Water (W_3)	g	140.24	140.36	142.70
Weight of bottle + Stopper + Water (W_4)	g	134.01	134.25	136.66
Weight of dry soil (W_2 - W_1)	g	10.00	10.04	9.99
Weight of water (W_4 - W_1)	g	100.46	100.57	99.23
Weight of soil + Water (W_3 – W_2)	g	96.69	96.44	95.28
Specific gravity	mg/m^3	2.65	2.55	2.53
Average specific gravity	2.58			

APPENDIX C

Falling Head Result

Empty Surface 1

Diameter, Φ	$99.50x10^{-3}$	m
Length, L	0.1290	m
Area, A	$7.7756x10^{-3}$	m^2

Manometer tube	Diameter	Start level h1 (m)	End level h2 (m)	Time, t (sec)
T1	0.0163	1	0.895	2.02
T2	0.0073	1	0.480	2.02
T3	0.0085	1	0.420	2.02

Manometer tube	H1/h2	Log h1/h2	Time, t	Radius, r	Area, A	A x t	Area of monometer, a
T1	1.1173	0.0482	2.02	$8.15x10^{-3}$	$7.7756x10^{-3}$	$15.7067x10^{-3}$	$2.0867x10^{-4}$
T2	2.0833	0.3188	2.02	$3.65x10^{-3}$	$7.7756x10^{-3}$	$15.7067x10^{-3}$	$4.x10^{-5}$
T3	2.3810	0.3768	2.02	$4.25x10^{-3}$	$7.7756x10^{-3}$	$15.7067x10^{-3}$	$5.6745x10^{-5}$

Permeability of the soil

T1	3.1721×10^{-9}	m/s
T2	4.0217×10^{-9}	m/s
T3	6.7433×10^{-9}	m/s

$$\mathbf{Kt} = \frac{\mathbf{3.84} \times \mathbf{a} \times \mathbf{L} \times \mathbf{log}\left(\frac{\mathbf{h1}}{\mathbf{h2}}\right) \times \mathbf{0.00001}}{\mathbf{A} \times \mathbf{t}}$$

$$\text{Kt1} = \frac{3.84 \times 2.0867\text{x}10^{-4} \times 0.1290 \times 0.0482 \times 0.00001}{15.7067\text{x}10^{-3}}$$

$$= 3.1721 \times 10^{-9} \text{ m/s}$$

Empty Surface 2

Diameter, Φ	$98.05\text{x}10^{-3}$	m
Length, L	0.1288	m
Area, A	$7.5507\text{x}10^{-3}$	m^2

Manometer tube	Diameter	Start level h1 (m)	End level h2 (m)	Time, t (sec)
T1	0.0163	1	0.890	2.06
T2	0.0073	1	0.495	2,06
T3	0.0085	1	0.440	2.06

Manometer tube	H1/h2	Log h1/h2	Time, t	Radius, r	Area, A	A x t	Area of monometer, a
T1	1.1236	0.0506	2.06	$8.15\text{x}10^{-3}$	$7.5507\text{x}10^{-3}$	$1.5554\text{x}10^{-3}$	$2.0867\text{x}10^{-4}$
T2	2.0202	0.3054	2.06	$3.65\text{x}10^{-3}$	$7.5507\text{x}10^{-3}$	$1.5554\text{x}10^{-3}$	$4.\text{x}10^{-5}$
T3	2.2727	0.3565	2.06	$4.25\text{x}10^{-3}$	$7.5507\text{x}10^{-3}$	$1.5554\text{x}10^{-3}$	$5.6745\text{x}10^{-5}$

Permeability of the soil

T1 3.3575×10^{-8} m/s
T2 3.8845×10^{-8} m/s
T3 6.4327×10^{-8} m/s

$$\mathbf{Kt} = \frac{\mathbf{3.84} \times \mathbf{a} \times \mathbf{L} \times \mathbf{log}\left(\frac{\mathbf{h1}}{\mathbf{h2}}\right) \times \mathbf{0.00001}}{\mathbf{A} \times \mathbf{t}}$$

$$\text{Kt1} = \frac{3.84 \times 2.0867\text{x}10^{-4} \times 0.1288 \times 0.0506 \times 0.00001}{1.5554\text{x}10^{-3}}$$

$= 3.3575 \times 10^{-8}$ m/s

Vegetation Surface 1

Diameter, Φ	$99.30\text{x}10^{-3}$	m
Length, L	0.1292	m
Area, A	$7.7444\text{x}10^{-3}$	m^2

Manometer tube	Diameter	Start level h1 (m)	End level h2 (m)	Time, t (sec)
T1	0.0163	1	0.900	2.12
T2	0.0073	1	0.465	2.12
T3	0.0085	1	0.340	2.12

Manometer tube	H1/h2	Log h1/h2	Time, t	Radius, r	Area, A	A x t	Area of monometer, a
T1	1.1111	0.0457	2.12	$8.15\text{x}10^{-3}$	$7.7444\text{x}10^{-3}$	$16.4181\text{x}10^{-3}$	$2.0867\text{x}10^{-4}$
T2	2.1505	0.3325	2.12	$3.65\text{x}10^{-3}$	$7.7444\text{x}10^{-3}$	$16.4181\text{x}10^{-3}$	$4.\text{x}10^{-5}$
T3	2.9412	0.4685	2.12	$4.25\text{x}10^{-3}$	$7.7444\text{x}10^{-3}$	$16.4181\text{x}10^{-3}$	$5.6745\text{x}10^{-5}$

Permeability of the soil

T1	2.8817×10^{-9}	m/s
T2	4.0190×10^{-9}	m/s
T3	8.0336×10^{-9}	m/s

$$\mathbf{Kt} = \frac{\mathbf{3.84} \times \mathbf{a} \times \mathbf{L} \times \mathbf{log}\left(\frac{\mathbf{h1}}{\mathbf{h2}}\right) \times \mathbf{0.00001}}{\mathbf{A} \times \mathbf{t}}$$

$$\text{Kt1} = \frac{3.84 \times 2.0867\text{x}10^{-4} \times 0.1292 \times 0.0457 \times 0.00001}{16.4181\text{x}10^{-3}}$$

$$= 2.8817 \times 10^{-9} \text{ m/s}$$

Vegetation Surface 2

Diameter, Φ	$99.55\text{x}10^{-3}$	m
Length, L	0.1295	m
Area, A	$7.7835\text{x}10^{-3}$	m^2

Manometer tube	Diameter	Start level h1 (m)	End level h2 (m)	Time, t (sec)
T1	0.0163	1	0.850	1.56
T2	0.0073	1	0.430	1.56
T3	0.0085	1	0.270	1.56

Manometer tube	H1/h2	Log h1/h2	Time, t	Radius, r	Area, A	A x t	Area of monometer, a
T1	1.1767	0.0706	1.56	$8.15\text{x}10^{-3}$	$7.7835\text{x}10^{-3}$	$12.1423\text{x}10^{-3}$	$2.0867\text{x}10^{-4}$
T2	2.3256	0.3665	1.56	$3.65\text{x}10^{-3}$	$7.7835\text{x}10^{-3}$	$12.1423\text{x}10^{-3}$	$4.\text{x}10^{-5}$
T3	3.7037	0.5686	1.56	$4.25\text{x}10^{-3}$	$7.7835\text{x}10^{-3}$	$12.1423\text{x}10^{-3}$	$5.6745\text{x}10^{-5}$

Permeability of the soil

T1 6.0334×10^{-9} m/s
T2 6.0039×10^{-9} m/s
T3 1.3214×10^{-8} m/s

$$\mathbf{Kt} = \frac{\mathbf{3.84 \times a \times L \times \log\left(\frac{h1}{h2}\right) \times 0.00001}}{\mathbf{A \times t}}$$

$$\text{Kt1} \quad = \frac{3.84 \times 2.0867\text{x}10^{-4} \times 0.1295 \times 0.0706 \times 0.00001}{12.1423\text{x}10^{-3}}$$

$$= 6.0334 \times 10^{-9} \text{ m/s}$$

APPENDIX D

Fine Analysis Result

Sample soil: Empty surface 1

Time	**Elapse time Elapse time (t min)**	**Temp (T°C)**	**Reading ($R_h{}'$)**	**($R_h{}'$)+Cm (R_h)**	**Effective depth ($H_R mm$)**	**Particle Diameter (D mm)**	**R_h' -$R_o{}'$ (R_d)**	**% $finer$ $than$ D ($K\%$)**
10:08	0.5	25.0	1.0015	1.0020	94.4265	0.0298	0.0015	0.48
10:09	1.0	25.0	1.0015	1.0020	113.0265	0.0275	0.0015	0.48
10:19	2.0	25.0	1.0015	1.0020	131.6265	0.0231	0.0015	0.48
10:23	4.0	25.0	1.0010	1.0015	150.2265	0.0186	0.0010	0.32
10:31	8.0	25.0	1.0010	1.0015	168.8265	0.0145	0.0010	0.32
10:47	16	25.1	1.0005	1.0010	187.4265	0.0112	0.0005	0.16
11:19	32	25.1	1.0000	1.0005	206.0265	0.0085	0.0000	0
12:19	60	25.1	1.0000	1.0005	224.6265	0.0066	0.0000	0
2:19	120	25.1	1.0000	1.0005	243.6265	0.0049	0.0000	0
6:19	240	25.1	0.9995	0.9995	255.8265	0.0037	-0.0010	-0.03
10:08	1440	25.1	0.9990	0.9995	280.4265	0.0016	-0.0010	-0.03

Equivalent particle diameter, D (mm):

$D = 0.005531\sqrt{\frac{\eta H}{(\rho_s - 1)t}}$ $\quad D = 0.005531\sqrt{\frac{(0.891)(26.57\ )}{(2.63-1)(0.5)}}$ $\quad D = 0.02$

Percentage by mass, K :

$K = [\frac{100\rho_s}{m(\rho_s - 1)}]R_d$ $\quad K = [\frac{100(2.63)}{50.23(2.63-1)}](0.0015)$ X 100% $\quad K = 0.48$

Sample soil: Empty surface 2

Time	**Elapse time** **Elapse time (t min)**	**Temp (T°C)**	**Reading ($R_h{}'$)**	**($R_h{}'$)+Cm (R_h)**	**Effective depth ($H_R mm$)**	**Particle Diameter (D mm)**	**R_h' - $R_o{}'$ (R_d)**	**% $finer$ $than$ D ($K\%$)**
9.25	0.5	26.0	1.0065	1.0070	93.8363	0.0292	0.0060	1.93
9:26	1.0	26.0	1.0060	1.0065	112.6363	0.0270	0.0055	1.77
9:28	2.0	26.0	1.0055	1.0060	131.4363	0.0227	0.0050	1.61
9:32	4.0	26.0	1.0050	1.0055	150.2363	0.0182	0.0045	1.45
9:40	8.0	26.0	1.0035	1.0040	169.0363	0.0143	0.0030	0.97
9:56	16	26.0	1.0025	1.0030	187.8363	0.0110	0.0020	0.64
10:31	32	26.0	1.0020	1.0025	206.6363	0.0084	0.0015	0.48
11:31	60	26.0	1.0010	1.0015	225.4363	0.0065	0.0005	0.48
1:31	120	26.1	1.0010	1.0015	244.2363	0.0049	0.0005	0.16
5:31	240	26.1	1.0005	1.0010	263.0363	0.0036	0.0000	0
9:25	1440	26.1	1.0000	1.0005	281.8363	0.0015	-0.0005	-0.16

Equivalent particle diameter, D (mm):

$D = 0.005531\sqrt{\frac{\eta H}{(\rho_s - 1)t}}$ $\quad$ $D = 0.005531\sqrt{\frac{(0.854)(26.60)}{(2.63-1)(0.5)}}$ $\quad$ D = 0.0292

Percentage by mass, K :

$K = [\frac{100\rho_s}{m(\rho_s - 1)}]R_d$ $\quad$ $K = [\frac{100(2.63)}{50.04(2.63-1)}](0.0060)$ X 100% $\quad$ K = 1.93

Sample soil: Vegetation surface 1

Time	Elapse time	Elapse time (t min)	Temp (T°C)	Reading (R_h')	(R_h')+Cm (R_h)	Effective depth ($H_R mm$)	Particle Diameter (D mm)	R_h' - R_o' (R_d)	% $finer$ $than\ D$ (K%)
10:38	0.5		26.0	1.0025	1.0000	93.91	0.0290	0.0025	0.84
10:39	1.0		26.0	1.0020	0.9995	112.91	0.0269	0.0020	0.65
10:41	2.0		26.0	1.0015	0.9990	131.91	0.0226	0.0015	0.48
10:45	4.0		26.0	1.0010	0.9985	150.91	0.0182	0.0010	0.32
10:53	8.0		26.0	1.0000	0.9975	169.91	0.0143	0.0000	0
11:09	16		26.0	0.9990	0.9965	188.91	0.0110	-0.0010	-0.32
11:41	32		26.0	0.9985	0.9960	207.91	0.0083	-0.0015	-0.48
12:41	60		26.0	0.9980	0.9955	226.91	0.0065	-0.0020	-0.65
2:41	120		26.0	0.9980	0.9955	245.91	0.0049	-0.0020	-0.65
6:41	240		26.0	0.9980	0.9955	264.91	0.0036	-0.0020	-0.65
10:40	1440		26.0	0.9975	0.9950	283.91	0.0015	-0.0025	-0.81

Equivalent particle diameter, D (mm):

D = $0.005531\sqrt{\frac{\eta H}{(\rho_s-1)t}}$ D= $0.005531\sqrt{\frac{(0.854)(26.6\ )}{(2.60-1)(0.5)}}$ D = 0.0290

Percentage by mass, K:

K = $[\frac{100\rho_s}{m(\rho_s-1)}]R_d$ K = $[\frac{100(2.60)}{49.76(2.60-1)}](0.0025)$ X 100% K = 0.81

Sample soil: Vegetation surface 1

Time	**Elapse time**	**Elapse time (t min)**	**Temp (T°C)**	**Reading ($R_h{}'$)**	**($R_h{}'$)+Cm (R_h)**	**Effective depth ($H_R mm$)**	**Particle Diameter (D mm)**	**R'_h -$R_o{}'$ (R_d)**	**% $finer$ $than\ D$ (K%)**
11:11		0.5	26.0	1.0010	0.9985	94.4265	0.0296	0.0010	0.34
11:12		1.0	26.0	1.0001	0.9980	113.0265	0.0273	0.0005	0.17
11:14		2.0	26.0	1.0000	0.9975	131.6265	0.0223	0.0000	0
11:18		4.0	26.0	1.0000	0.9975	150.2265	0.0185	0.0000	0
11:26		8.0	26.0	0.9990	0.9965	168.8265	0.0144	-0.0010	-0.34
11:42		16	26.0	0.9985	0.9960	187.4265	0.0111	-0.0015	-0.51
12:14		32	26.0	0.9980	0.9955	206.0265	0.0084	-0.0020	-0.68
1:14		60	26.0	0.9980	0.9955	224.6265	0.0066	-0.0020	-0.68
3:14		120	26.0	0.9980	0.9955	243.2265	0.0049	-0.0020	-0.68
7:14		240	26.0	0.9980	0.9955	261.8265	0.0037	-0.0020	-0.68
11:11		1440	26.0	0.9975	0.9950	280.4265	0.0016	-0.0025	-0.85

Equivalent particle diameter, D (mm):

D = $0.005531\sqrt{\frac{\eta H}{(\rho_s-1)t}}$ D= $0.005531\sqrt{\frac{(0.854)(26.57\ )}{(2.58-1)(0.5)}}$ D = 0.0296

Percentage by mass, K:

K = $[\frac{100\rho_s}{m(\rho_s-1)}]R_d$ K = $[\frac{100(2.58)}{47.78(2.58-1)}](0.0010)$ X 100% K = 0.34

APPENDIX E

Result Soil Erodibility Factor

K = $\frac{[\ 1 \times 10^{-4}\ (12-\text{OM})M^{1.14} + 4.5(\text{S}-3) + 8.0\ (\text{P}-2)]}{100}$

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

OM = % of organic matter;

S = soil structure code; and

P = permeability class.

Sample soil: Empty surface 1

Fine sand : 3.16 %

Silt and clay: 0.73 %

OM = 0.11%

S = 1

P = 1

K = $\frac{[\ 1 \times 10^{-4}\ (12-0.11)386.16^{1.14} + 4.5(1-3) + 8.0\ (1-2)]}{100}$

= 0.159

Sample soil: Empty surface 2

Fine sand : 5.34 %

Silt and clay: 1.22 %

OM = 0.11%

S = 1

P = 1

K = $\frac{[\ 1 \times 10^{-4}\ (12-0.11)648.0^{1.14} + 4.5(1-3) + 8.0\ (1-2)]}{100}$

= 0.151

Sample soil: Vegetation surface 1

Fine sand : 6.40 %

Silt and clay: 2.02 %

OM = 0.11%

S = 1

P = 2

$$K = \frac{[\ 1 \times 10^{-4}\ (12-0.11)824.99^{1.14} + 4.5(1-3) + 8.0\ (2-2)]}{100}$$

$= 0.065$

Sample soil: Vegetation surface 1

Fine sand : 2.91 %

Silt and clay: 0.77 %

OM = 0.11%

S = 1

P = 2

$$K = \frac{[\ 1 \times 10^{-4}\ (12-0.11)365.17^{1.14} + 4.5(1-3) + 8.0\ (2-2)]}{100}$$

$= 0.080$

Table: Soil Structure

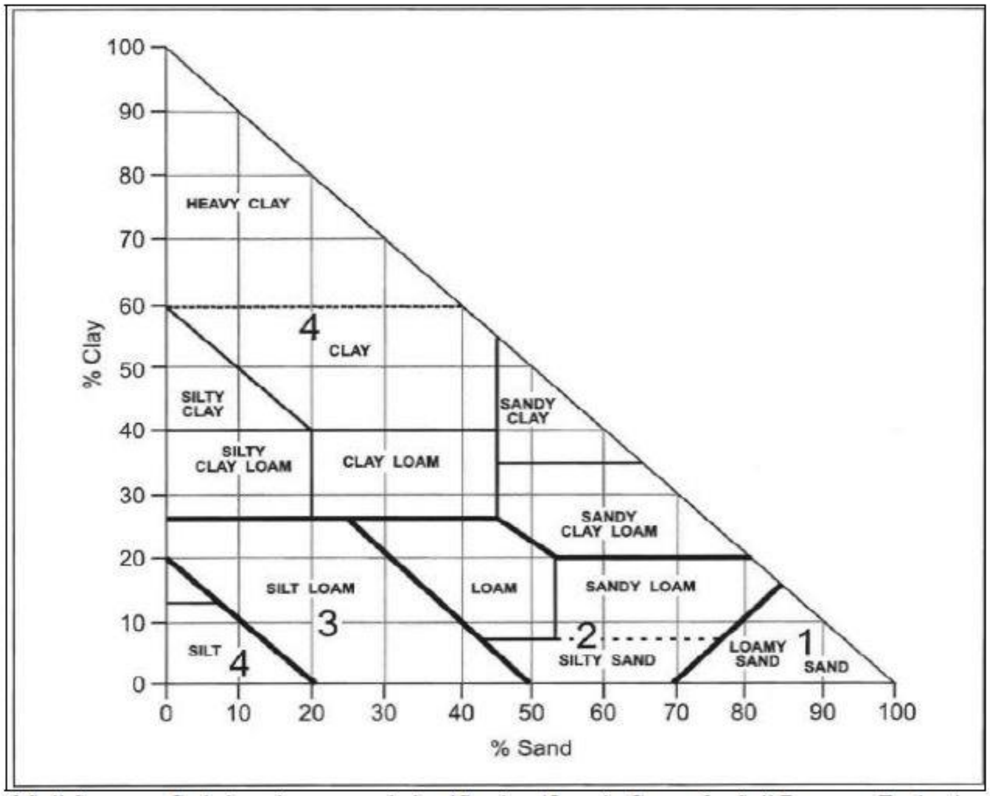


Table: Soil Permeability

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

APPENDIX F

Result Slope Length Factor

Result Cover Management Factor

Result Practice Management Factor

Table 12.3: *LS* Factor for Various Slopes and Slope Lengths

Slope Steepness, S (%)	Slope Length, λ (m)											
	2	5	10	15	25	50	75	100	150	200	250	300
0.1	0.043	0.052	0.059	0.064	0.071	0.082	0.089	0.094	0.102	0.108	0.113	0.117
0.5	0.055	0.067	0.076	0.083	0.092	0.106	0.114	0.121	0.131	0.139	0.146	0.151
1.0	0.057	0.075	0.093	0.105	0.122	0.150	0.170	0.185	0.209	0.228	0.243	0.257
2.0	0.089	0.117	0.144	0.163	0.190	0.234	0.264	0.288	0.325	0.354	0.379	0.400
3.0	0.100	0.144	0.190	0.224	0.275	0.362	0.426	0.478	0.563	0.631	0.690	0.742
4.0	0.135	0.195	0.257	0.302	0.371	0.489	0.575	0.646	0.759	0.852	0.932	1.002
5.0	0.138	0.218	0.308	0.377	0.487	0.688	0.843	0.973	1.192	1.376	1.539	1.686
6.0	0.173	0.273	0.387	0.474	0.612	0.865	1.059	1.223	1.498	1.730	1.934	2.119
8.0	0.255	0.404	0.571	0.699	0.903	1.277	1.564	1.806	2.212	2.554	2.855	3.128
10.0	0.353	0.559	0.790	0.968	1.250	1.767	2.165	2.499	3.061	3.535	3.952	4.329
15.0	0.525	0.909	1.378	1.757	2.388	3.619	4.616	5.486	6.997	8.315	9.506	10.605
20.0	0.848	1.470	2.228	2.841	3.860	5.851	7.463	8.869	11.311	13.442	15.368	17.145
25.0	1.249	2.164	3.279	4.183	5.683	8.613	10.986	13.055	16.651	19.788	22.623	25.239
30.0	1.726	2.991	4.533	5.782	7.855	11.906	15.185	18.046	23.017	27.353	31.272	34.887
40.0	2.911	5.045	7.646	9.752	13.250	20.083	25.614	30.440	38.824	46.139	52.749	58.846
50.0	4.404	7.631	11.567	14.753	20.044	30.382	38.749	46.050	58.733	69.798	79.798	89.023
60.0	6.204	10.751	16.296	20.784	28.239	42.802	54.590	64.875	82.744	98.333	112.420	125.416
70.0	8.312	14.404	21.833	27.846	37.833	57.344	73.138	86.917	110.856	131.741	150.615	168.026
80.0	10.728	18.590	28.177	35.938	48.827	74.008	94.391	112.174	143.070	170.025	194.383	216.854
90.0	13.451	23.309	35.329	45.060	61.221	92.793	118.350	140.648	179.386	213.182	243.723	271.898
100.0	16.482	28.560	43.289	55.212	75.014	113.700	145.016	172.337	219.803	261.214	298637	333.159

Table 12.4c: Cover Management, *C* Factor for BMPs at Construction Sites

Erosion Control Treatment	C Factor
Bare soil / Newly cleared land	1.00
Cut and fill at construction site	
Fill Packed, smooth	1.00
Freshly disked	0.95
Rough (offset disk)	0.85
Cut Below root zone	0.80
Mulch	
plant fibers, stockpiled native materials/chipped	
50% cover	0.25
75% cover	0.13
100% cover	0.02
Grass-seeding and sod	
40% cover	0.10
60% cover	0.05
≥90% cover	0.02
Turfing	
40% cover	0.10
60% cover	0.05
≥90% cover	0.02
Compacted gravel layer	0.05
Geo-cell	0.05
Rolled Erosion Control Product:	
Erosion control blankets / Turf reinforcement mats	0.02
Plastic sheeting	0.02
Turf reinforcement mats	0.02

Note: The values are compiled from Layfield (2009), Troeh et al. (1999), Mitchell and Bubenzer (1980), ECTC (2006), Israelsen et al (1980), Weischmeier and Smith (1978), and Kuenstler (2009).

Table 12.5: Support Practice, *P* Factor for BMPs at Construction and Development Sites

Support/ Sediment Control Practice		P Factor
Bare soil		1.00
Disked bare soil (rough or irregular surface)		0.90
Wired log / Sand bag barriers		0.85
Check Dam		0.80
Grass buffer strips (to filter sediment laden sheet flow)		
Basin slope (%)		
0 to 10		0.60
11 to 24		0.80
Contour furrowed surface (maximum length refers to downslope length)		
Slope (%)	Maximum Length (m)	
1 to 2	120	0.60
3 to 5	90	0.50
6 to 8	60	0.50
9 to 12	40	0.60
13 to 16	25	0.70
17 to 20	20	0.80
> 20	15	0.80
Silt fence		0.55
Sediment containment systems (Sediment basin/Trap)		0.50
Berm drain and Cascade		0.50
Terracing		
Slope (%)		
1 to 2		0.12
3 to 8		0.10
9 to 12		0.12
13 to 16		0.14
17 to 20		0.16
> 20		0.18

Note: The values are compiled from Layfield (2009), Troeh et al. (1999), Mitchell and Bubenzer (1980), ECTC (2006), Israelsen et al (1980), Weischmeier and Smith (1978) and Kuenstler (2009)