A Study on the Water Turbidity from Soil Erosion due to Rainfall under Different Percentage of Grass Cover.

by

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(12522)

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

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CERTIFICATION OF APPROVAL

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Approved by,

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Dr. Hj. Khamaruzaman Wan Yusof

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

CERTIFICATION OF ORIGINALITY

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

AMIR EHSAN BIN MOHAMAD

ABSTRACT

Soil erosion due to runoff and rainfall has been quite common in slope areas where vegetation cover is limited. Over the past years there has been quite number of cases of soil erosion on the hill areas due to the unprotected cover. Eroded soil under the influence of runoff and rainfall has given its effect towards the water quality in terms of suspended solids and turbidity and towards the environment in the long run. This paper will focus on the study on the simulation of effects of the water quality due to the runoff and rainfall with the effects on the different percentage cover. This study will also discuss the results and the best practice to improve the water quality by vegetation covers. A full scale experimental works has been done by using the rainfall simulators to obtain the water sample. Each of the sample is been sent to the lab for analysis obtaining results. The studies shows that the grass cover plays an important role in reducing the water turbidity and different percentage of grass cover will significantly change the turbidity results. At the end of the studies, it has been suggested at what percentage of grass cover will be feasible to improve the water quality as well as considering the economic factor.

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CHAPTER 1

INTRODUCTION

Project Background

Rainfall is an uncommon condition in a country where it has a tropic climate and a very high humidity. Rainfall brings a lot of benefits to the ecosystem including providing a fresh water source for drinking, provides minerals towards the plants, and cools the surrounding temperature and many more. But on the backside of the benefits is that rainfall also contributes towards some unwanted problems such as floods and for this case, soil erosion.

Soil erosion occurs when there is a heavy or light rainfall come into contact with the soil and with the sufficient forces applied by the water droplets or runoff, the soil will be able to degrade and causes soil erosion. This usually happens at the hill side whether it is natural occurring or man-made. The effect of the soil erosion in this scope of study is to identify the presence of the suspended soil particles within the catchment water area.

Suspended solids in the water system is said to be the main cause of the water turbidity and causes a lot of implications towards the environment. This includes disturbing the water supply, poses harm towards the aquatic life and of course giving an unpleasant image of the river, ponds and lakes. This project also will take into consideration of the effects of the grass (vegetation) cover towards the soil erosion and directly the effects towards the suspended solids in the water and also its turbidity.

Problem Statement

Development of structures such as highways has always required the dredging of the hills and development of embankments. This poses potential threats towards the water irrigation systems as unprotected sloping with exposed soil will tend to reduce the water quality due to suspended solids from the soil erosions runoff. A good, efficient and cost effective method is needed to protect and minimize the soil from eroded. The method of planting vegetation will be discussed in this study on how its effectiveness towards the soil erosion and also how does the different percentage of vegetation cover effects the results.

Figure 1: The effects of soil erosion towards the turbidity of water

Figure 2: Eroded soil from the slope contaminate the water

Figure 3: The embankment cover along the highway

Study Objectives and Scope

The objective of the study is to:

- Identify the turbidity of the runoff water generated by the eroded soils from the rainfall.
- Proposed an efficient percentage of grass cover to sufficiently reduce the water turbidity as well consider the economic values of highway embankments.

The study will also take into account the different rainfall intensities and percentage of grass cover into the results.

The scope of the study also limited towards the direct rainfall contact and its surface runoff will be collected for test with infiltrated water will not taken into calculations. But the study will include the minimizing of infiltration water as much as possible.

Also, the scope of the study will also limited to the state of Perak, in which effects on the grass type and also rainfall intensities.

CHAPTER 2

LITERATURE REVIEW

Literature Review

Water turbidity has been extensively used for suspended particles monitoring by computation of optical properties of the water (H. Sun et al. 2001). The rapid cause of the natural processes of soil erosion and sediment removal has been directly pointed out towards the human activity and has been growing concern globally (Andreas Gericke, Markus Venohr 2012). About 75 billion metric tons of soil are removed every year from agricultural land by water and wind erosion (R.K. Malik et al. 2000). Understanding this erosion and suspended solids transport processes is vital in developing better water protection and pollutant control strategies, as prescribed by e.g. the EU Water Framework Directive (WFD). The rate of erosion in a catchment depends on land use, climate and a number of landscape characteristics such as slope, topography, soil type, vegetation and drainage condition (Hannu Marttila, Bjørn Kløve 2010). Land use and surface cover are the major factor of erosion rates (Ruiz-Colmenero et al. 2013).

Increasingly, it is identified that landslides are a key influence on the sediment delivery in upland river catchments, controlling both the release of sediment and its mechanical characteristics. Landslides are also increasingly considered a main factor dominating the turbidity of rivers and reservoirs hence, they may act as a major control on the occurrence of hyperpycnal flow in rivers. Indeed, several studies indicate that much of the sediment produced in upper basins often does not immediately drift downstream but is instead deposited in the riverbed, resulting in channel aggradations (Guan-Wei Lin et al. 2010). It is essential to know the values of turbidity in the river downstream in natural condition, in the absence of dams or river training works (De Vicenzo et al. 2011).

Soil erosion can occur in areas when the soil is erodible, the terrain is sloped and high-intensity rainfall coincides with limited vegetation cover (Wei Ouyang et al. 2010). It is suggested that use of cover crops and vegetations has the potential of decreasing erosion during the critical early years after establishment. (R.K. Malik et al. 2000)**.** Soil erosion is a cumulative process, and the time to trigger significant erosion depends on factors such as crop management, vegetation cover, climate, and topography, and on soil physical properties such as texture, organic matter, structure and porosity (Ruiz-Colmenero et al. 2013).

It is shown that a grass covered surface significantly reduced runoff and soil loss as compared to a bare soil during the final stages of simulated rainfall events. However, differences in vegetation, soil properties, and surface conditions complicated the interpretation of the experimental results (Xiao Peiqing et al. 2011). Long term turbidity in water leads to many problems including difficulties in water purification (e.g. reduction in filter run time or increased use of coagulant chemicals), particle adhesion to agricultural products during application, damage to marine life (fish are unable to find prey or prey become impacted), low recreational value of watershed areas, and impacts on the ecosystem via potential changes in light penetration and primary production (Iwata et al. 2011).

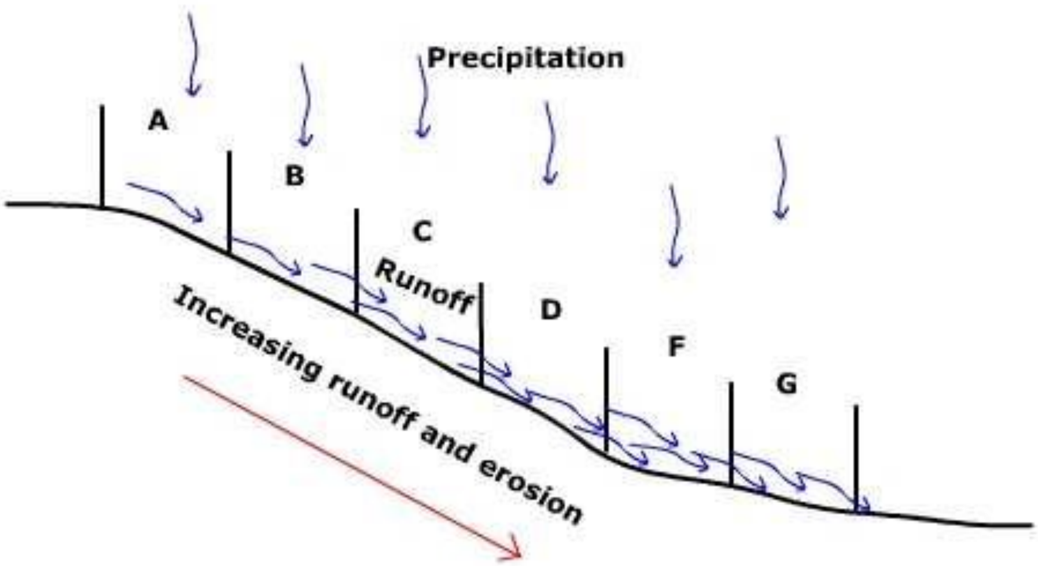

Figure 4: Hill slope position, runoff & erosion (Ritter, Michael E. 2012)

Earlier studies have shown that delivery ratios of landslides differ from 20% to 70% when wide-scale slope failure occurs in mountainous environments. The relationship between landsliding and total sediment discharge reveals that high landslide ratios do not correspond to high sediment discharge because sediment discharge is still dominated by water discharge and landslide debris possibly still stay on slopes. (Guan-Wei Lin et al. 2010). The main causes of soil erosion are inappropriate agricultural practices, deforestation, overgrazing, land abandonment, forest fires and construction activities (Adélia N. Nunes et al. 2011). Road cuttings may also lead to sites of major erosion and land slippage (Murakami T. et al. 2013).

CHAPTER 3

METHODOLOGY

Methodology

The study will be conducted in Universiti Teknologi PETRONAS, Perak, Malaysia. The study will be made by experimental works on a full scale test where a real rainfall simulation will be made. A rainfall simulator will be made on top of a 30° sloped soil with a water container is placed at the bottom of the slope in order to collect the runoff together with the suspended solids.

In order to minimize the amount of water loss during the simulation runs, couple of mitigation has been designed to overcome this problem. At the top of the simulator, a cement floor is been placed in order to avoid any water seeping into the ground and into the plot during any rainy occasion. Geotextile sheets are also placed under the soil to ensure less water seepage through the soil during the experiment runs.

Figure 5: The Rainfall Simulator Site

The soil plot chosen for the run will be divided into 4, which are bare plot, 30% covered grass plot, 50% covered grass plot and fully covered grass. The dimensions of each plot will be 2x6m ($12m^2$). The plot size is sufficient enough to conduct the study as the used small plots of $7m^2$ in size proved to be appropriate for comparing soil erosion in different vegetation covers as been said by (Kateb H.E. et al. 2013). The grass that has been chosen to be used in this experiment is the cow grass which is a very common type of grass used in Malaysia. The grass is also known to germinate quickly within the period of 3 months.

Figure 6: The Bare Soil Plot

Figure 7: The Fully Grass Cover Plot

The rainfall will be simulated by using a heavy spray sprinklers placed on top of each plot. The intensities used for the simulation is selected by analyzing the average maximum rainfall intensities for the state of Perak. By using the rainfall data obtained from the Department of Meteorology Malaysia, the rainfall intensity to be used are 40mm/hr and 52mm/hr.

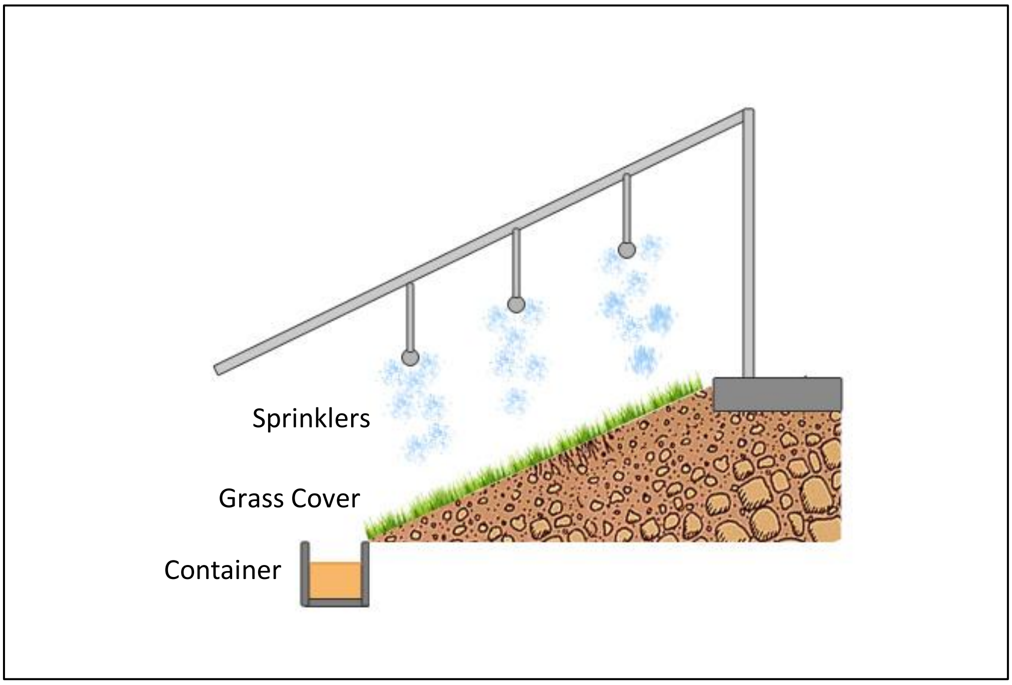

Figure 8a: The illustration of fully covered grass plot simulator

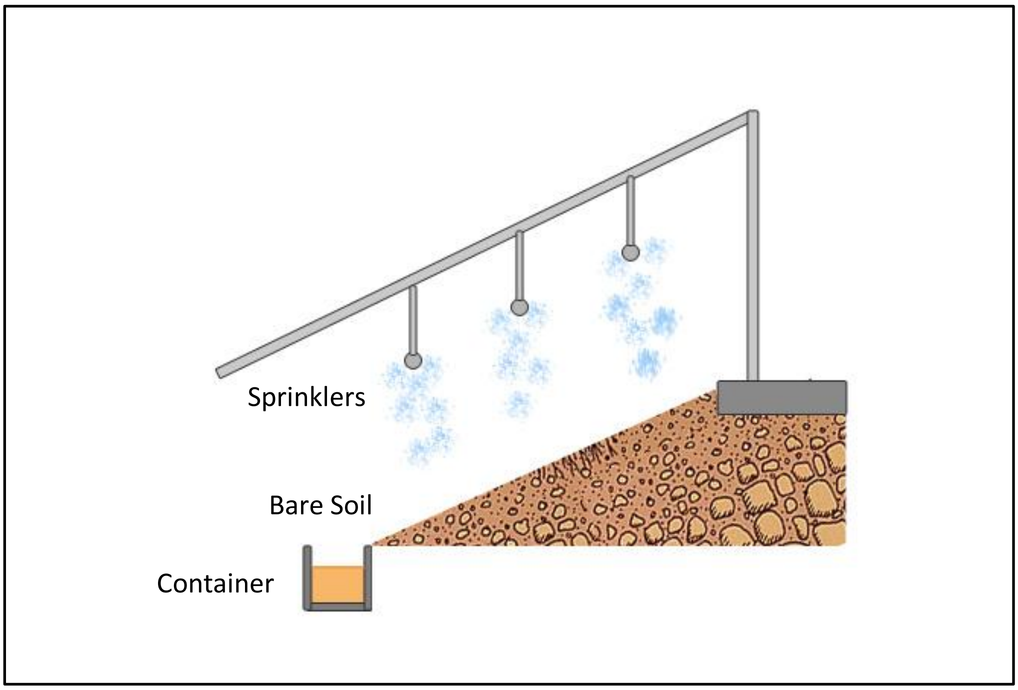

Figure 8b: The illustration of bare soil plot simulator

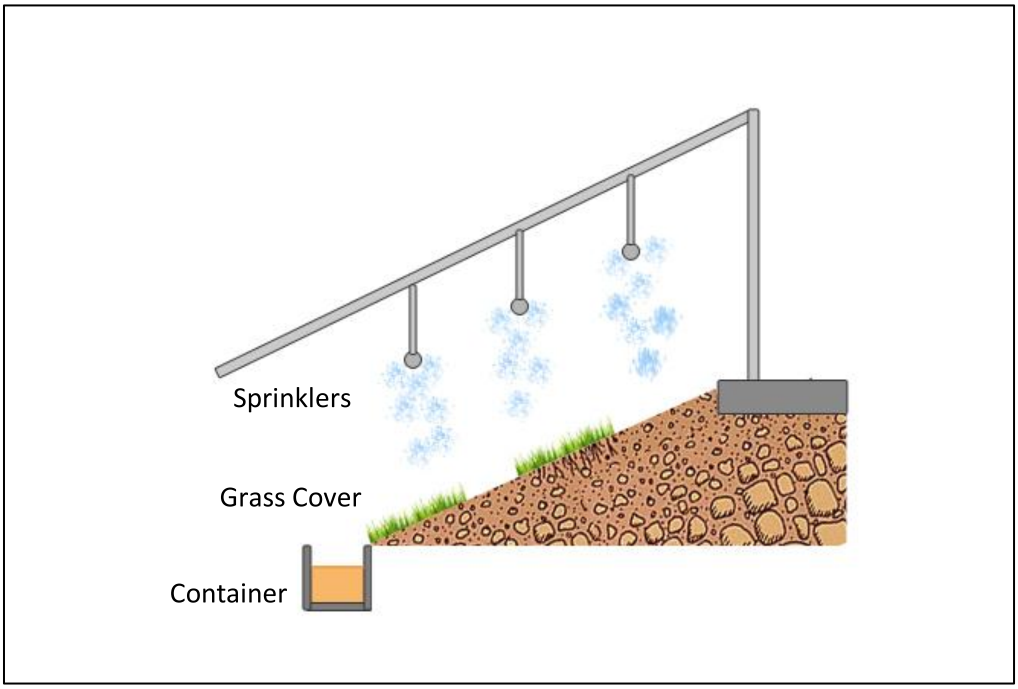

Figure 8c: The illustration of 50% grass cover plot simulator

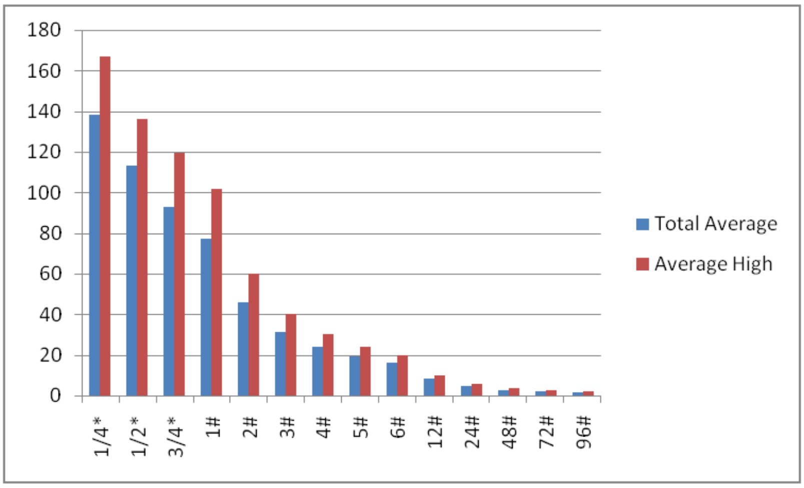

Figure 9a: The total and High average rainfall intensity at different intervals of time, Ipoh Station

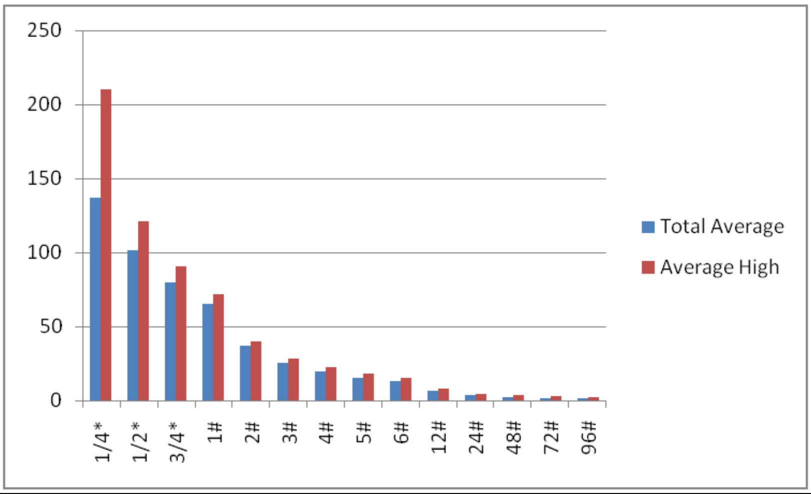

Figure 9b: The total and high average rainfall intensity at different intervals of time, Lubok Merbau Station

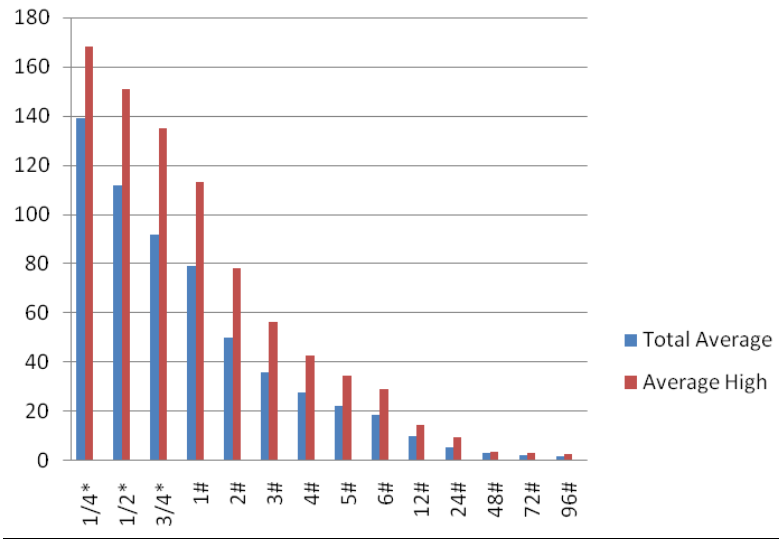

Figure 9c: The total and high average rainfall intensity at different intervals of time, Setiawan Station

The simulation will be run at for 2 hours and for every 15 minutes interval (15, 30, 45, 60, 75, 90, 105, 120 minutes), a water sample will collected from the container with a bottle for the lab test to measure the suspended solids and turbidity

Figure 10: The Water Container where sample is taken

The lab test for turbidity will require 1mL of sample for each interval. The 1mL of the sample will be titrated with distilled water to 1:50 because the turbidimeter unable to detect a turbidity higher than 99 NTU. Diluting the sample will make sure the sample is readable by the device. From the titrated sample, 10mL will be taken to be tested for the turbidity reading. For each sample will be done 3 times in order we can get an average value.

All of the results from all the plots under the different rainfall intensities will be collected by the end of the experiment and will analyse for its reliability.

Gantt Chart and Key Milestone

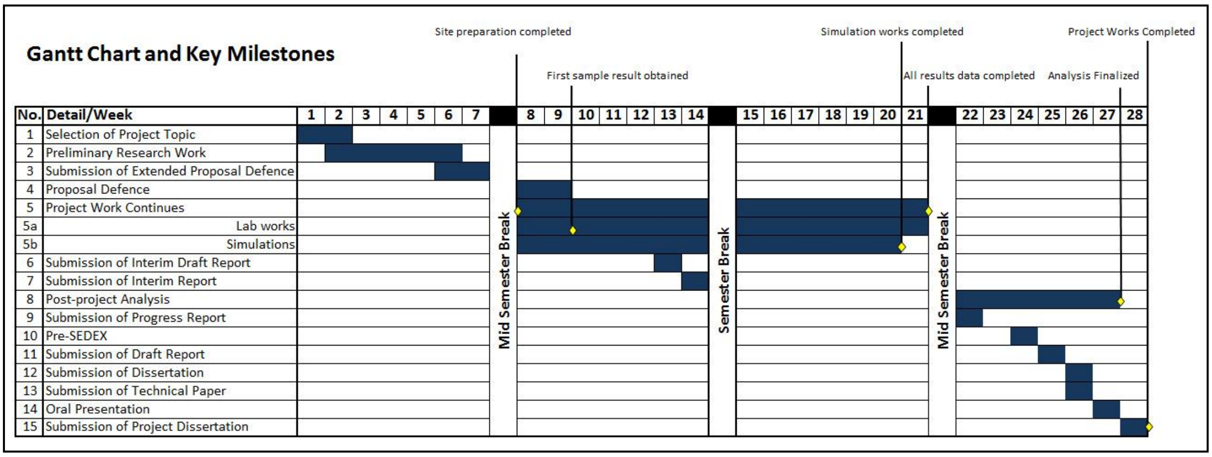

Figure 11: Projected Gantt Chart and Key Milestone for the study

CHAPTER 4

RESUTS AND DISCUSSION

Data and Result Gathering

The simulation for the bare soil plot, 30% covered grass plot, 50% covered grass plot and fully covered grass plot has been completed for both the intensity of 40mm/hr and 52mm/hr. The water sample from the simulations has been collected and has been analysed in the lab. The results of the analysis are shown below.

BARE PLOT SOIL

Water Turbidity for **Bare Soil Plot** under 52mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	1310	1255	1240	1268.3
30	1125	1195	1055	1125.0
45	1020	1020	815	951.7
60	925	1065	955	981.7
75	1625	1355	1310	1430.0
90	1400	1280	1380	1353.3
105	1955	2010	1935	1966.7
120	2615	2645	2495	2585.0

Table 1: Water Turbidity for Bare Soil Plot under 52mm/hr rainfall simulation

Water Turbidity for **Bare Soil Plot** under 40mm/hr rainfall simulation

Time (minute)	Turbidity (NTU)			Average Turbidity
	Test Number			(NTU)
	1	2	3	
15	990	1025	990	1001.7
30	1270	1200	1185	1218.3
45	1410	1405	1565	1460.0
60	1225	1205	1235	1221.7
75	1685	1590	1620	1631.7
90	1200	1315	1410	1308.3
105	1290	1365	1305	1320.0
120	1385	1465	1515	1455.0

Table 2: Water Turbidity for Bare Soil Plot under 40mm/hr rainfall simulation

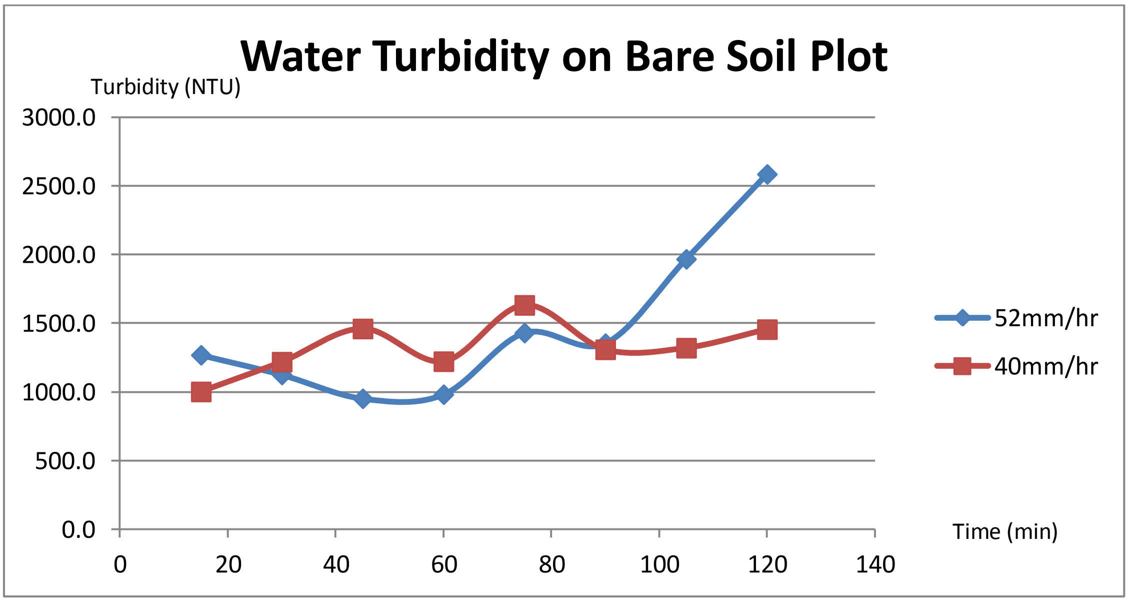

Figure 12: Water Turbidity for Bare Soil Plot under 40mm/hr rainfall simulation graph

FULLY COVERED GRASS PLOT

Water Turbidity for **Fully Covered Grass Plot** under 52mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	125	75	80	93.3
30	95	95	120	103.3
45	135	90	95	106.7
60	115	110	90	105.0
75	185	110	110	135.0
90	150	95	125	123.3
105	150	85	85	106.7
120	115	95	75	95.0

Table 3: Water Turbidity for Fully Covered Grass Plot under 52mm/hr rainfall simulation

Water Turbidity for **Fully Covered Grass Plot** under 40mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	105	60	60	75.0
30	20	15	60	31.7
45	95	65	40	66.7
60	30	45	100	58.3
75	45	35	40	40.0
90	50	40	75	55.0
105	55	55	50	53.3
120	55	85	70	70.0

Table 4: Water Turbidity for Fully Covered Grass Plot under 40mm/hr rainfall simulation

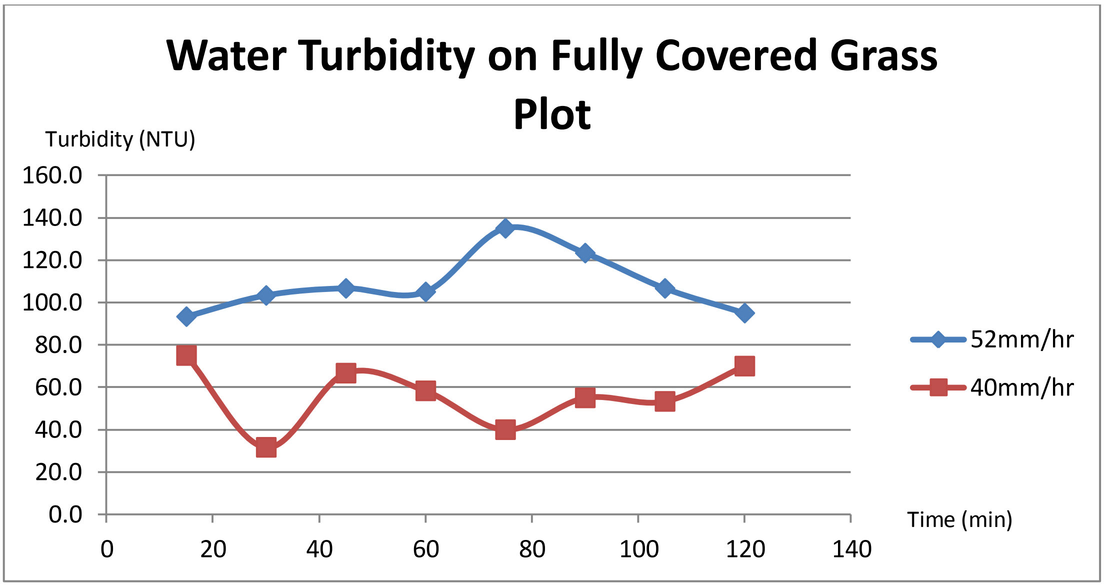

Figure 13: Water Turbidity for Fully Covered Grass Plot under 40mm/hr rainfall simulation graph

50% COVERED GRASS PLOT

Water Turbidity for **50% Covered Grass Plot** under 52mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	655	590	625	623.3
30	645	650	740	678.3
45	415	415	410	413.3
60	425	435	420	426.7
75	380	405	435	406.7
90	365	320	300	328.3
105	545	745	535	608.3
120	370	375	425	390.0

Table 5: Water Turbidity for 50% Covered Grass Plot under 52mm/hr rainfall simulation

Water Turbidity for **50% Covered Grass Plot** under 40mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	340	185	175	233.3
30	665	335	395	465.0
45	370	585	370	441.7
60	440	440	440	440.0
75	415	405	395	405.0
90	545	375	365	428.3
105	465	550	455	490.0
120	455	380	300	378.3

Table 6: Water Turbidity for 50% Covered Grass Plot under 40mm/hr rainfall simulation

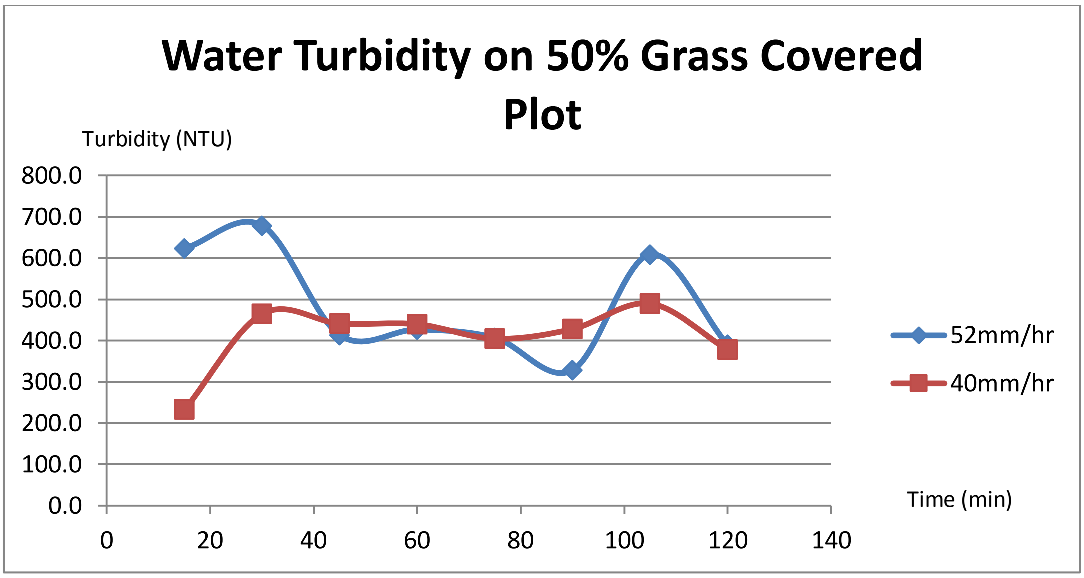

Figure 14: Water Turbidity for 50% Covered Grass Plot under 52mm/hr rainfall simulation

30% COVERED GRASS PLOT

Water Turbidity for **30% Covered Grass Plot** under 52mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	1400	1130	1505	1345.0
30	1415	1380	1250	1348.3
45	1000	1300	1060	1120.0
60	1130	1525	1600	1418.3
75	1650	1305	1210	1388.3
90	1455		1490	1472.5
105	1745	1170	1475	1463.3
120		1460		1460.0

Table 7: Water Turbidity for 50% Covered Grass Plot under 52mm/hr rainfall simulation

Water Turbidity for **30% Covered Grass Plot** under 52mm/hr rainfall simulation

Time (minute)	Turbidity (NTU) Test Number			Average Turbidity (NTU)
	1	2	3	
15	1135	715	875	908.3
30	1090	1010	1630	1243.3
45	1740	1635	1560	1645.0
60	1275		1210	1242.5
75	1665	1615	1435	1571.7
90	1800	1475	1520	1598.3
105	1785	1645	1730	1720.0
120	1375	1555	1245	1391.7

Table 8: Water Turbidity for 50% Covered Grass Plot under 52mm/hr rainfall simulation

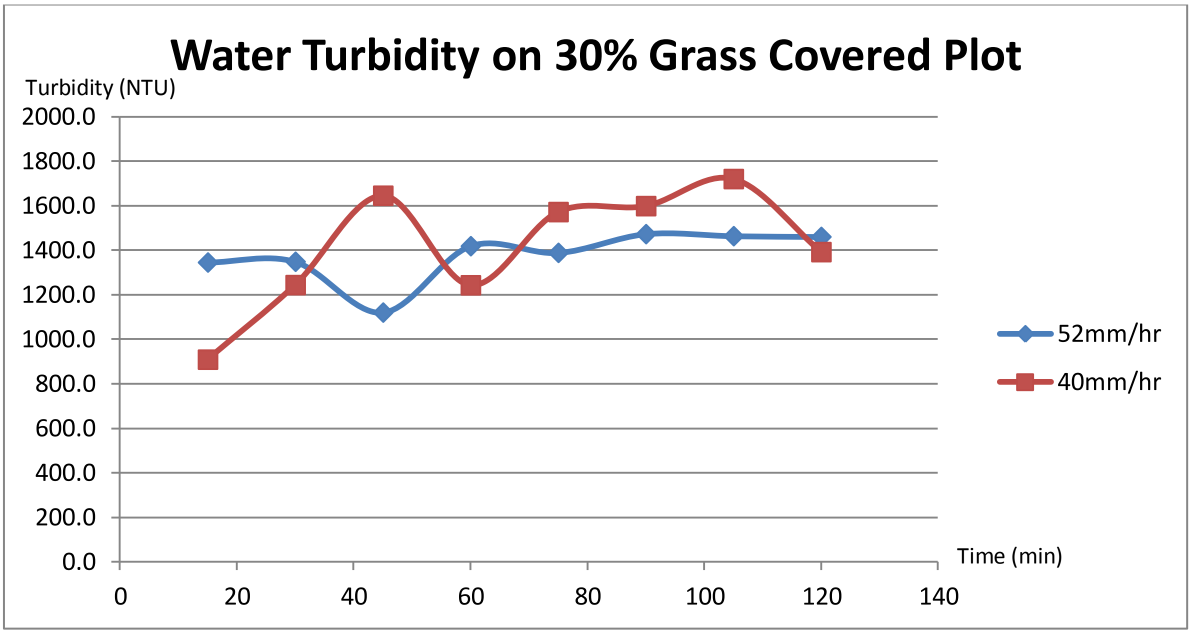

Figure 15: Water Turbidity for 50% Covered Grass Plot under 52mm/hr rainfall simulation

COMPILED DATA

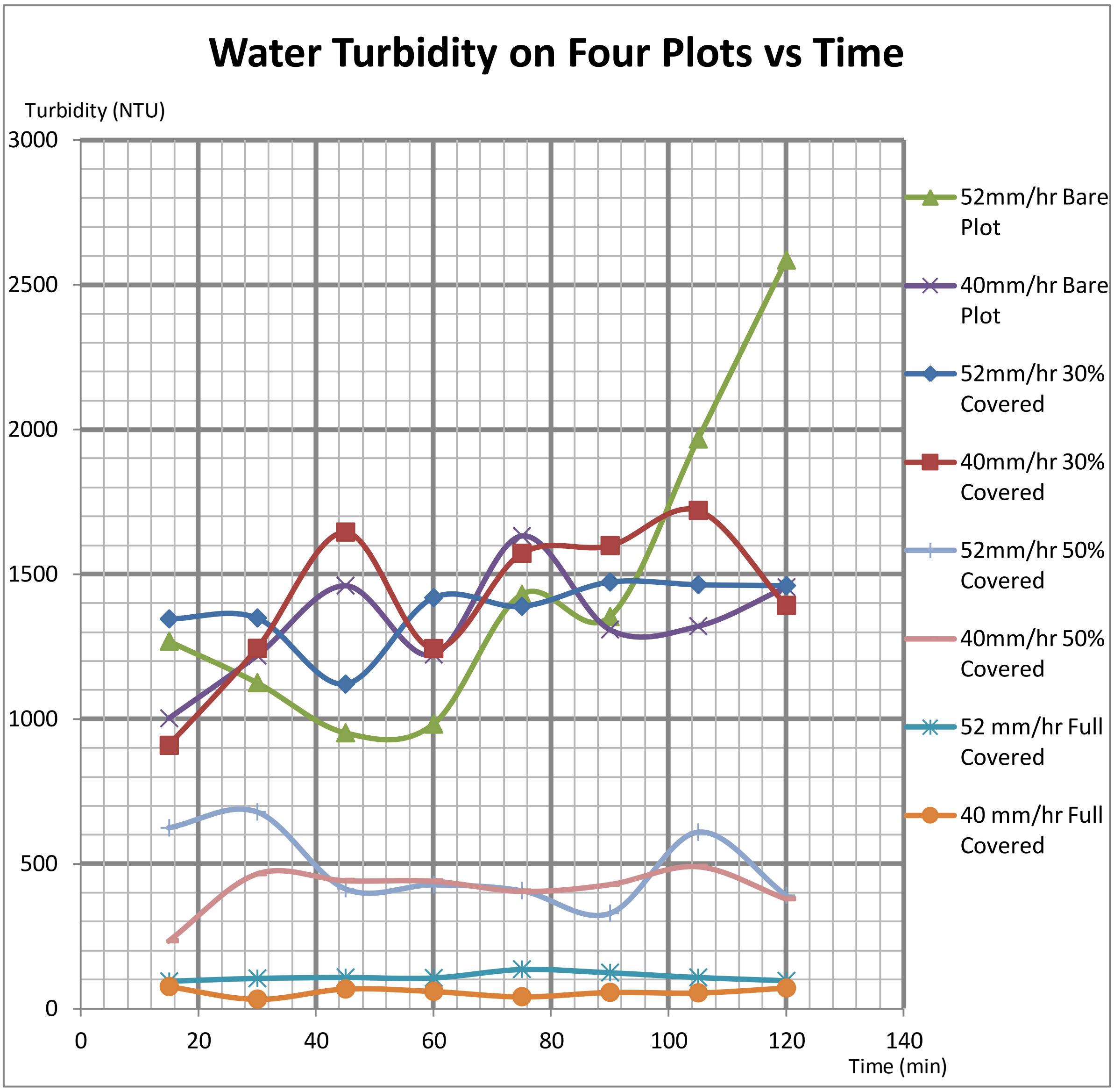

Figure 16: Water Turbidity for 4 plots under both rainfall intensities graph

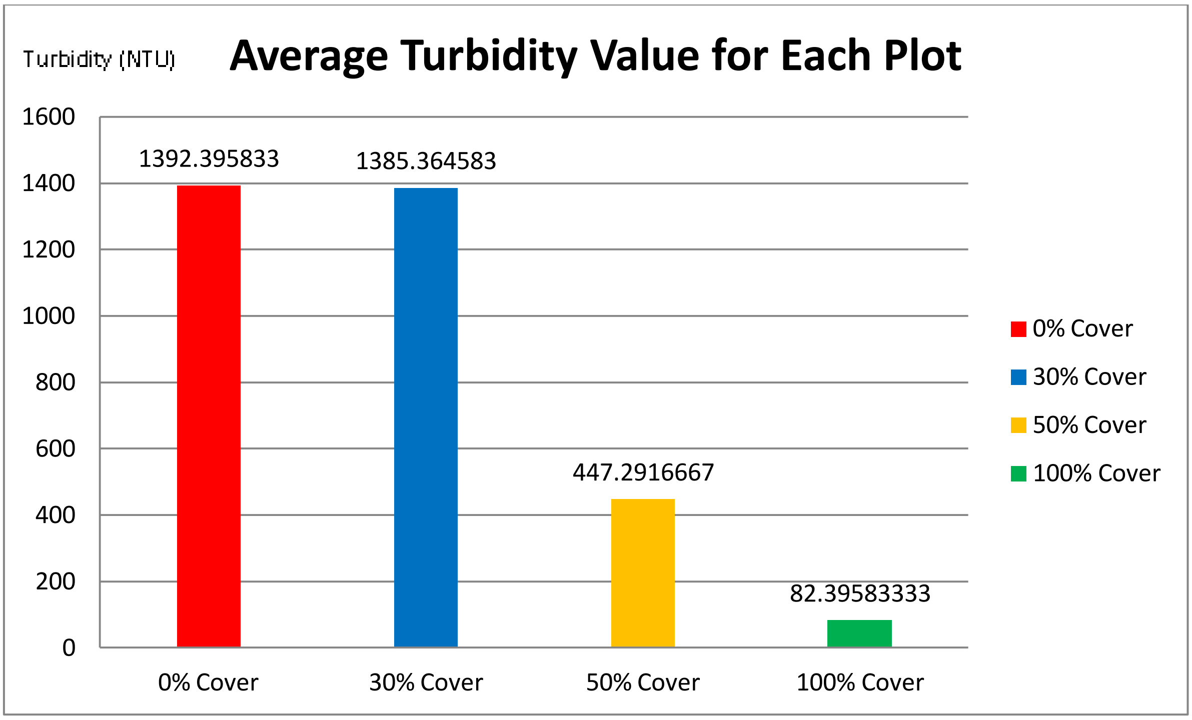

Figure 17: Average water turbidity value for 4 plots under both rainfall intensities chart

Discussion

From the result obtained, we can see that the in whole that the turbidity for the simulation run of bare soil and 30% covered plot have a higher value compared to the fully covered grass and 50% covered. Plots that have a lot of soil exposed to the environment are prone to the full penetration of the rainfall precipitation. The bare plot gives no protection whatsoever towards the rainfall and runoff and the water wears off the soil on the plot which led to higher erosion while 30% covered plot emulate almost the same result towards the bare soil as 30% exposure is considered as high exposure percentage. The soil erosion occurred lead to a higher turbidity value due to the high amount of eroded soil in the water.

The fully covered grass plot offers a very little amount of water turbidity after the rainfall simulation was made. This is due to the very small or negligible amount of soil exposed towards the environment. The soil is being covered by the grass, thus provide a very small amount of soil to be eroded from the plot. The observed runoff from the rainfall was also small. This may due to the grass act as a damper for the runoff water from flowing down the slope. As water flow slows down, it tends to increase the chances for it to infiltrated into the soil, hence reduce the runoff even more which eventually lead to less water turbidity due to the lower amount of soil eroded due to the runoff.

The 50% covered grass proved to be critical in significantly reducing the runoff. From the experiment that has been run, the turbidity values for the 50% covered plot achieve a significantly lower turbidity rate compared to the bare plot and the 30% covered plot. Even more interesting is that the values for 50% covered plot are even closer towards the bare soil than towards the 30% covered. This can be explain in the term of the exposed soil area of the 50% covered is less than the bare soil, reducing the soil erosion, hence the lower turbidity values. The grass covers for the 50% also act as a 'filter' for the soil erosion. Some of the soil in this plot did get eroded but did not managed to go through the plot and into water the container due to the grass cover blocks the soil from further going down. It is observable at the back of the grass after the experiment run. This natural filter able to reduce the water turbidity as less soils are able to erode towards the bottom of the container where the water sample has been taken.

In comparing the rainfall intensities towards the water turbidity, it can be shown that the high water intensity produced a higher amount of erosion for all of the plots. The reason suggested is that the higher rainfall intensity will generate more water, hence more surface runoff. Higher runoff will give a higher erosion rate as more water will tend to erode the soil and the eroded soil will combine with the water and produce higher water turbidity. Also, higher rainfall intensities are subjected to higher rainfall velocity. The high velocity will made the soil easier to degrade as it will penetrate into the soil top layer much easier as the rainfall droplets will have a higher force.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Conclusion

It is hypothesized that the grass cover will be an important factor in improving the water quality in slopes by effectively reducing the exposed soil area which is penetrable by the rainfall and runoff and reducing the runoff flow. The planting of vegetation cover which includes grass will be effective in highway slope protection in reducing the water turbidity and its effects towards the environment. 100% fully covered grass is currently in this study has proven its benefits, and the 50% cover grass seem to be sufficient to reduce the water turbidity.

Based from the studies made, the 100% grass cover is the best solution in reducing the turbidity of the water from the hill slope area specifically highway embankments. But a more economical way to overcome the problem is by planting the embankments with grass with the amount of 50%. The turbidity of the runoff water from the 50% grass cover from this experiment has shown a significantly low level of turbidity compared to the 30% cover and bare soil.

By planting the embankments with 50% of grass cover, it will reduce the cost of grass planting by 50%. Although it will increase the turbidity values by 5-fold compared to the fully covered grass, but the value will drastically reduced because the grass will grow at a very fast pace and by 3 months, it is expected the embankments will be fully covered with grass hence will obtained the results for the 100% grass cover.

Recommendations

Further improvements can be made in this study. One of it is the selecting the best grass pattern to be planted to achieve to lowest amount of turbidity. The design grass pattern chosen in this project is evenly spread throughout the plot. Different pattern design may results in different outcome. This can be recommended for futher enhancements for the studies.

Different type of grass may also be one of the contributing factors in reducing or increasing the turbidity of water. This study focussed on the use of cow grass, which is a normal, home grown and widely abundant type of grass in Malaysia. Different type of vegetation cover such as pearl grass, Bermudan grass, vetiver grass, shrubs or even wood strands may also provide different outcome in this studies.

Another major variable that can be considered for the further research of this study is the rainfall intensity factor. For this study the rainfall intensity taken was the annual maximum rainfall intensity and the annual average rainfall intensity which are 52mm/hr and 40mm/hr respectively. Bear in mind that these rainfall intensities are averaged out throughout the year and there are some storm events that records up to 60-80mm/hr of rainfall intensity but in a short period of time. During these storm events, the erosion rates and its effects towards the turbidity may be different under different percentage of grass cover and further studies are needed to verify its effectiveness.

The structure of the site simulators that has been used is made from steel for the column, transparent Perspex sheets for the roof and plastic sheets for the wall to cover the plot. There are some difficulties on having plastic sheets for the plot wall as it tends to ripped apart easily in the event of heavy winds. The plastic sheets have ripped off numerous times and has to be replaced quite often which contributed to delays up to weeks just to complete the run on a single plot. For further studies of this experiment, a different material such as Perspex or high quality plastic sheets should be used to cover the plots as the wall so that time delays can be avoided.

Figure 18: The top part has been ripped off due to heavy storm

Figure 19: The bottom part has been ripped off due to strong winds

Figure 20: Examples of Perspex sheets that can be used to replace the plastic sheets for the plot wall. [Retrieved from: www.ecplaza.net]

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APPENDICES

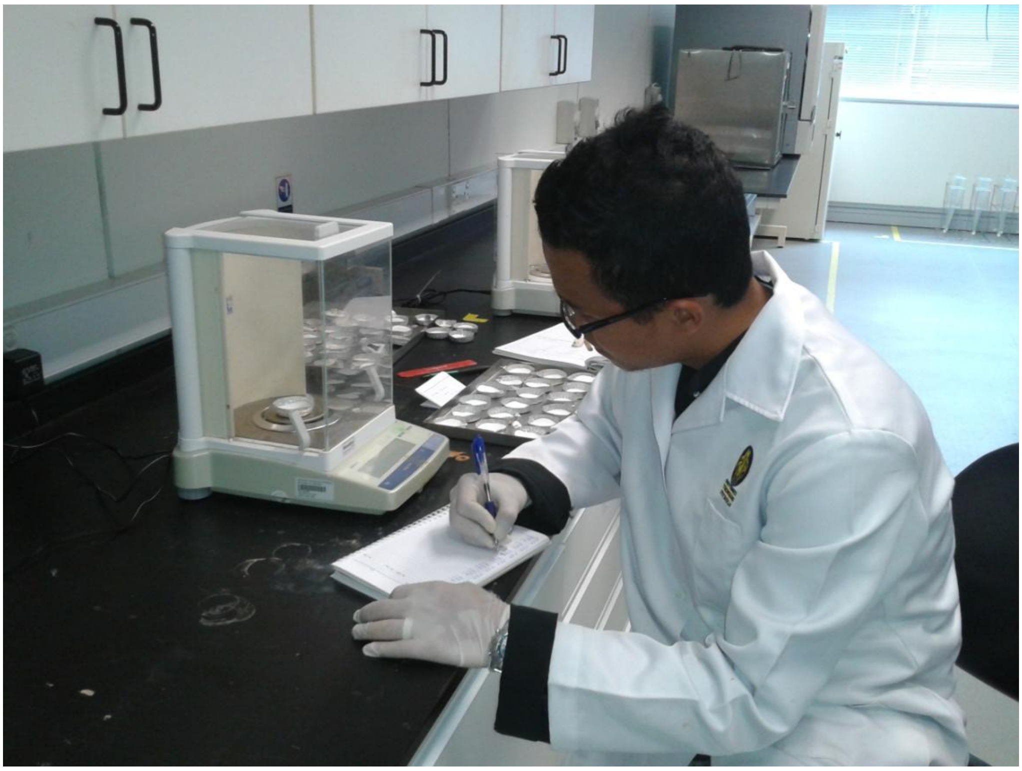
The difference in water turbidity for fully covered grass (left) and bare soil (right)

The 50% covered grass plot after 3 months from planting

The 50% covered grass plot before the run is made

During the experiment run

The apparatus used during the simulation run. (From right) Stopwatch; sample bottle; sample plastic



During the result gathering in the lab