UNIVERSITI MALAYSIA SARAWAK
UNIMAS

Faculty of Engineering

Modelling of Road Subsurface as Component of On-Site Detention (OSD) Urban Drainage System

Nam Nguk Chiu

Master of Engineering (Civil)
2016

Modelling of Road Subsurface as Component of On-Site Detention (OSD) Urban Drainage System

Nam Nguk Chiu

A thesis submitted

in fulfillment of the requirements for the degree of Master of Engineering (Civil)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK

2016

UNIVERSITI MALAYSIA SARAWAK

Grade: WK01

Please tick (√)

Final Year Project Report	
Masters	√
PhD	

DECLARATION OF ORIGINAL WORK

This declaration is made on the ....16th...... day of ....May......... 2016.

Student's Declaration:

I NAM NGUK CHIU, 14020050, FACULTY OF ENGINEERING hereby declare that the work entitled MODELLING OF ROAD SUBSURFACE AS COMPONENT OF ON-SITE DETENTION (OSD) URBAN DRAINAGE SYSTEM is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

16th May 2016
Date submitted

Nam Nguk Chiu (14020050)

Supervisor's Declaration:

I DR DARRIEN MAH YAU SENG hereby certify that the work entitled MODELLING OF ROAD SUBSURFACE AS COMPONENT OF ON-SITE DETENTION (OSD) URBAN DRAINAGE SYSTEM was prepared by the above named student, and was submitted to the "FACULTY" as a partial fulfillment for the conferment of M.ENG. (CIVIL), and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: ____________ (Dr Darrien Mah Yau Seng)

Date: 16th May 2016

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirmed with free consent and willingness declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature ________________ (16th May 2016)

Supervisor signature: ________________ (16th May 2016)

Current Address:
NO. 40, JALAN PENDING HEIGHTS, FASA 1, 93450 KUCHING, SARAWAK.

Notes: * If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

To my beloved family and friends for their love, encouragement and support.

ACKNOWLEDGEMENT

The author would like to take this opportunity to thank her supervisor, Dr. Darrien Mah Yau Seng for his advice, support and guidance which helps the author to accomplish this thesis. Without the continuous supervision, this thesis would not have been completed successfully. Apart from this, the author would like to thank her supportive family for the spiritual support throughout the course of study.

ABSTRACT

On-site Detention (OSD) System is part of the proposed measures in *Manual Saliran Mesra Alam* (MSMA). It has been widely applied in Sydney since 1991; where developers provide detention storage for storm water on their project sites to limit rates of runoff. This research is to investigate the application of road subsurface as components of OSD Urban Drainage System by using XP Stormwater and Wastewater Management Model (XP-SWMM). The application of road subsurface as OSD system rather than open spaces is to overcome the problem of limitation of land. The water is infiltrated through permeable pavement and then flow into the detention storage under the road. Attempts are made to store storm water as a temporary storage in order to reduce the volume of surface runoff, and later slowly release with time in safe rate. This study examines the new subsurface storm water control system designed for detention purposes. From the modelling results, this system is able to decrease the surface runoff. The permeable pavement system is encouraged due to the several benefits such as reduction in surface runoff, soil improvement and water treatment through infiltration. Furthermore, using the road subsurface as urban drainage encourages more efficient land use where roads can be directed to be multi-purpose infrastructure.

ABSTRAK

Sistem Tahanan Tempatan adalah sebahagian daripada langkah-langkah yang dicadangkan dalam Manual Saliran Mesra Alam (MSMA). Ia telah digunakan secara meluas di Sydney sejak 1991; di mana pemaju menyediakan sistem tahanan air ribut di tapak projek mereka untuk menghadkan kadar air hujan di atas permukaan. Kajian ini adalah untuk mengkaji kesan penggunaan permukaan jalan sebagai komponen Sistem Tahanan Tempatan dengan menggunakan Storm Water Modeling Management (SWMM). Penggunaan permukaan jalan sebagai Sistem Tahanan Tempatan daripada penggunaan kawasan lapang adalah untuk mengatasi masalah tanah yang terhad. Air hujan akan menyusup melalui turapan telap dan kemudian mengalir ke dalam simpanan tahanan di bawah jalan. Usaha untuk menyimpan air hujan di tahanan sementara adalah untuk mengurangkan jumlah air hujan di atas permukaan, dan kemudian dilepaskan dalam kadar masa yang selamat. Kajian dijalankan untuk menguji tahap kompeten sistem kawalan air ribut ini yang direka untuk tujuan penahanan. Sistem turapan telap digalakkan kerana beberapa faedah seperti pengurangan air di permukaan, pembaikan tanah dan rawatan air melalui penyusupan. Tambahan pula, penggunaan permukaan jalan sebagai sistem saliran menggalakkan penggunaan tanah dengan lebih cekap di mana jalan boleh dijadikan sebagai infrastruktur pelbagai guna.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DID	-	Department of Irrigation and Drainage
MSMA	-	*Manual Saliran Mesra Alam*
WSUD	-	Water Sensitive Urban Design
OSD	-	On-site Detention
SWMM	-	Storm Water Management Modeling
EPA	-	Environmental Protection Agency
BMP	-	Best Management Practices
ASCE	-	American Society of Civil Engineers
JKR	-	*Jabatan Kerja Raya*
ARI	-	Average Recurrent Interval
USM	-	*Universiti Sains Malaysia*
REDAC	-	River Engineering and Urban Drainage Research Centre

CHAPTER 1

INTRODUCTION

1.1 Background

The removals of vegetations and construction of impervious surface from pervious area had resulted in changes of surface runoff pattern (Goonetilleke et al., 2005), increasing storm water surface runoff volumes and peak flows (Al-Hamati et al., 2010 and Barbosa et al., 2012). Hibbert (1967) mentioned that there is clearly an increase in water yield due to reduction of forest cover while Hollis (1975) concluded that small frequent floods have increased many times by urbanisation, while large rare floods are not significantly affected.

The large volumes of storm water runoff have been found to be one of the major causes of flash flood due to the decreasing in infiltration and ground water recharges, and increasing in precipitation (Liew et al., 2012). The existing drainage systems are insufficient to carry away the runoff volume during the precipitation periods. Conventional approach practiced in Malaysia is to allow developers to put in drains where appropriate and the drain size is determined by the engineers to comply with the drainage capacity and final discharge outlet requirement; to further maximize housing density, developers normally channel all drainage to concrete-lined and open channel type large trunk drains (Zakaria et al., 2004).

The conventional drainage system in Malaysia is based on the first urban drainage manual "Planning and Design Procedure No.1: Urban Drainage Design Standards and Procedure for Malaysia" which was published by Department of Irrigation and Drainage (DID) Malaysia in 1975. This manual unfortunately has led to the occurrence of flash floods at the downstream of catchments, and therefore conventional drainage is no longer an effective measure in solving flood problems (Zakaria et al., 2004).

In order to solve this problem, DID has introduced another urban drainage manual known as Urban Storm Water Management Manual for Malaysia (*Manual Saliran Mesra Alam* or MSMA). Water Sensitive Urban Design (WSUD) is implemented as the core concept of MSMA. It is meant to control the quantity and quality of runoff through detention/retention storages, infiltration facilities, and engineered water ways which are capable of retarding peak flows (Zakaria et al., 2004). The application of MSMA, in long term, helps to minimize the government allocation for flood mitigation programs. Among the many WSUD measures, On-site Detention (OSD) System is chosen as the focus of study in this research project.

1.2 On-site Detention System

Stormwater detention provides flood-control benefits, by capturing portions of urban runoff, thus reducing the runoff volume. OSD system have been widely applied in Sydney since 1991; where developers provide detention storages for storm water on their project sites to limit rates of runoff (O'Loughlin et al., 1995). Case studies of such system are highlighted in Chapter 2.

However, problem persists to adopt this practice when availability of land is difficult to obtain. Therefore, it is an experiment to use road subsurface in this project, rather than open spaces as in existing OSD. Attempts are made to store storm water under the road to achieve the function of an OSD.

1.3 Problem Statement

Availability of land is one of the limitations for overcome flash flood in urban areas as on-site stormwater detention system requires large empty area for storage usage. Thus, it is a new concept to introduce the application of road subsurface as the component of detention system. The design of the OSD system in this study is made up of constructed chamber as road subsurface layer. The chamber is called as modular unit and details are discussed in Chapter 3. The modular unit is act as a single detention storage.

In the context of hydrology, the extent of such design to intercept urban runoff and its effectiveness as OSD are crucial data to convincingly introduce this measure to the community. Thus, this study is to develop a computer model which would give a convenient outlook to better inform the performances of such design. The effectiveness of the system in term of reducing the surface runoff is the main concern of the detention purpose. Besides that, the provided storage is also another concern in order to determine the optimum sizing of the modular unit.

A storm water conveyance model will be developed for simulate the condition of application of the OSD system. Several scenarios are carried out in the modelling simulations in order to determine the effectiveness of the OSD system in term of reduction of the runoff under two conditions:

- Installation of OSD system for whole road section
- Installation of OSD system for partial of road section

1.4 Aim and Objectives

The aim of this study is to investigate the application of road subsurface as OSD by using XP Stormwater and Wastewater Management Modeling (XP-SWMM) 11.0. The objectives of the study are:

i. To develop a storm water conveyance model incorporating road subsurface OSD; and

ii. To investigate the effectiveness of road subsurface OSD by applying in several scenarios.

1.5 Scopes of Study

The scopes of study consist of:

i. Selected study area is a low-lying township Kota Samarahan which is located in the state of Sarawak;

ii. Develop a computer model for OSD;

iii. Simulation is analyzed using XP-SWMM software; and

iv. Design guidelines of stormwater system are referred to MSMA.

1.6 Organization of Thesis

The first chapter of this thesis is introduction for this study. It consists of general view of the topic, problem statement, aim and objectives, and the scopes of study.

The second chapter is literature review, in which important terms and necessary information are explained in details. The information are gathered from journals and case studies in similar field. This chapter consists of elaboration of WSUD, storm water management, OSD, and modeling of storm water system.

The third chapter is methodology which discusses the procedures in order to achieve the objectives of this study. This chapter explains the methods adopted for the research which included model building and assumptions made.

The forth chapter covers results obtained from the methods adopted in Chapter 3. The results are elaborated and evaluated in order to investigate the application of road subsurface as OSD. The last chapter concludes the project and recommendations are presented for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Natural Hydrologic Cycle

Hydrology is the study of water and its properties, distribution, and effects on earth as it cycles through earth's surface, subsurface, and atmosphere (McCuen, 2005). Physical hydrologic processes that control the distribution and movement of water in the area, over the surface of the Earth, and through the ground are best understood in terms of the hydrologic cycle.

The hydrologic cycle defines the naturally occurring processes that manage water. It shows that the processes are interdependent, with knowledge of each necessary to understand problems related to water quantity and quality as well as their solutions. The whole cycle is ultimately driven by solar radiation, which evaporates water from the ocean and lifts it up in the atmosphere.

Figure 2.1 shows the process of the hydrologic cycle system. The complete hydrologic cycle consists of atmospheric, surface, subsurface and interfacial processes. The atmospheric processes consist of cloud condensation and precipitation; while the surface processes consist of snow accumulation, overland flow, river flow and lake storage. Infiltration, soil-water storage and groundwater flow are classified as subsurface processes; while evaporation, transpiration, sediment-water exchange are interfacial processes. In short, the components of hydrologic cycle are surface runoff, evaporation, transpiration, infiltration, precipitation and groundwater storage.

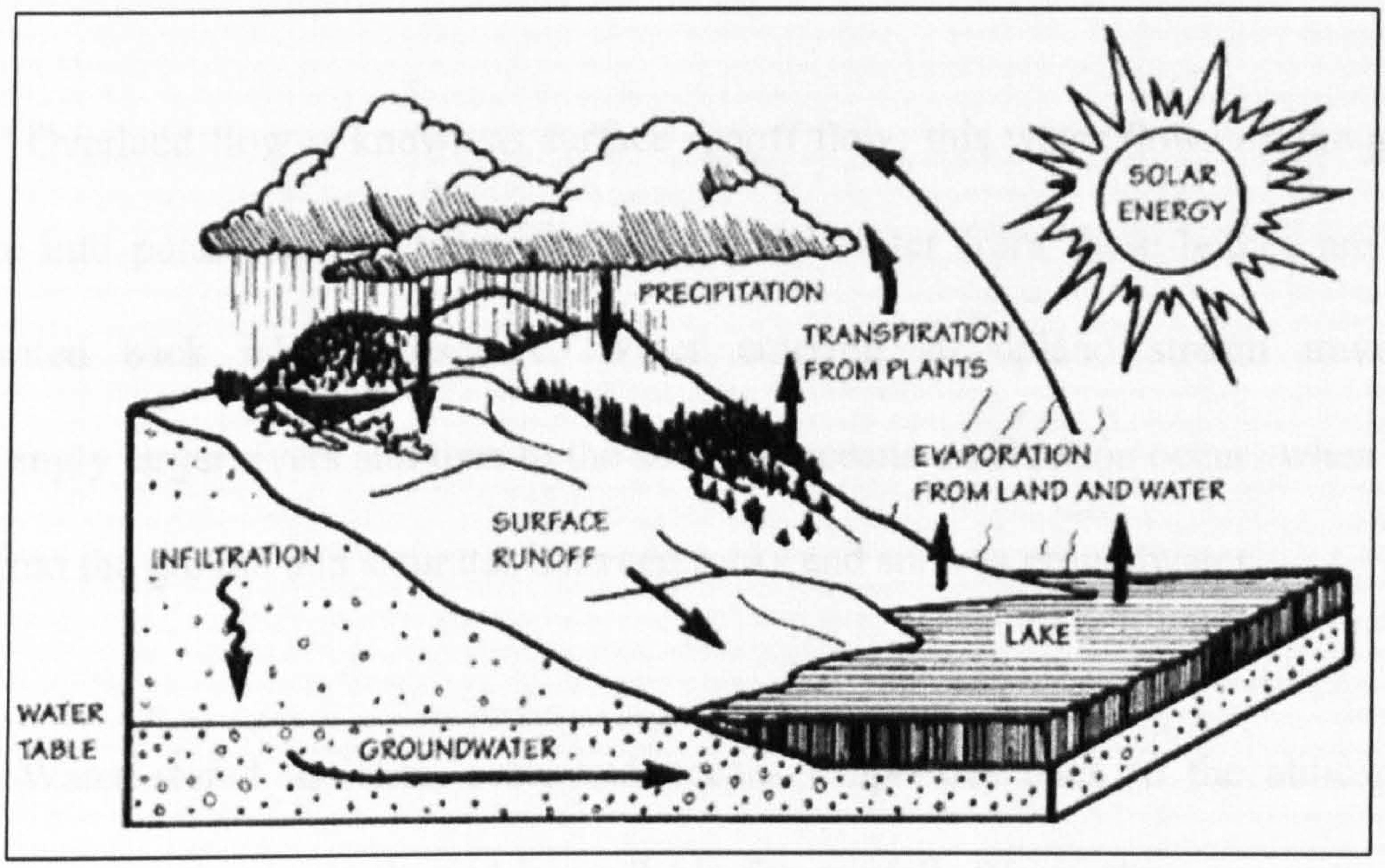

Figure 2.1: Hydrologic Cycle

(Adopted from *http://www.pikeconservation.org/Water_cycle.htm*)

Precipitation is the hydrologic cycle component that initiates runoff (Davis and Cornwell, 2008). As rainfall begins, it ultimately falls onto either a pervious or an impervious surface while certain amount of this water forms clouds by the process of condensation and precipitates to the ground surface again as rainfall. Rain falling on Earth enters a water body directly, flow over the land surface, or infiltrate into the ground. Some rain is intercepted by vegetation where the intercepted water is temporarily stored on the vegetation until it evaporates back to the atmosphere. Some rain is stored in surface depressions, with almost all of the depression storage infiltrating into the ground.

Water stored in depressions, water intercepted by vegetation, and water that infiltrates into the soil during the early part of a storm represent the initial losses where the water does not appear as runoff during or immediately following a rainfall event.

Overland flow is known as surface runoff flow; this water flows on the ground surface into ponds, lakes, streams or oceans and water from these bodies are again evaporated back into atmosphere. Water entering an upland stream travels to increasingly larger rivers and then to the seas and oceans. Infiltration occurs when water seeps into the ground and saturates between rocks and soils as groundwater.

Water stored in lakes, seas, and oceans evaporates back to the atmosphere, where it completes the cycle and is available for rainfall. Water also evaporates from soils devoid of vegetation. Rain that falls on vegetated surfaces is intercepted; however, after the storage that is available for interception is filled, the water immediately falls from the plant surfaces to the ground and infiltrates into the soil. Some of the water stored in the soil near plants is taken up by the roots of the vegetation, and subsequently passes back to the atmosphere from the leaves of the plants; this process is called transpiration.

2.2 Urban Hydrologic Cycle

Hydrologic cycle system is interrupted by the rapid development in urban areas. As the population of the world has increased, changes to the land have often been significant, with major changes to the runoff characteristics of a watershed as a result. The biggest problem associated with urbanisation is the increase of impervious surfaces.