TWO-DIMENSIONAL SIMULATION OF UPPER SUNGAI LANGAT USING HEC-HMS, HEC-RAS AND RRI MODEL

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by

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LIST OF SYMBOLS

Q	Flow discharge
U	Cross-sectional averaged velocity
A	Cross-section surface area
g	Acceleration of gravity
h	Cross-sectional averaged water depth
S_0	Bed slope in the longitudinal direction
S_f	Friction slope (the slope of the energy line).
f	Darcy-Weisbach friction factor
C	Chézy coefficient
n	Manning-Gauckler or Manning’s coefficient
R	hydraulic radius (R=A/P, where P is the wetted perimeter
R^2	Correlation Coefficient

LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-HMS	Hydrologic Engineering Center Hydrologic Modelling System
RRI	Rainfall-Runoff Inundation
ArcGIS	Geographic Information System
2-D	Two-Dimensional
1-D	One-Dimensional
DID	Department of Irrigation and Drainage

SIMULASI DUA DIMENSI BAHAGIAN ATAS SUNGAI LANGAT MENGGUNAKAN MODEL HEC-HMS, HEC-RAS DAN RRI

ABSTRAK

Banjir merupakan salah satu bencana alam yang berlaku di Malaysia. Banjir biasanya berlaku disebabkan oleh limpahan air dari tebing sungai yang membanjiri kawasan sekitarnya. Daerah Hulu Langat yang terletak di Selangor sering terjejas disebabkan banjir. Sungai Langat merupakan sungai utama yang mengalir dari Banjaran Titiwangsa ke Selat Melaka dengan panjang kira-kira 141 km. Kawasan kajian adalah bertumpu di kawasan lembangan atas Sungai Langat di mana terletaknya bandar-bandar utama seperti Kajang, Bangi, Seri Kembangan dan Dengkil. Bandar-bandar ini yang terletak di hilir kawasan atas Sungai Langat kerap dilanda banjir semasa musim hujan lebat. Senario ini telah menyebabkan gangguan kepada penduduk sekitar kawasan banjir. Oleh itu, model HEC-HMS, HEC-RAS dan RRI digunakan dalam simulasi hujan-aliran air yang berlaku di bahagian atas Sungai Langat. Objektif- objektif kajian ini adalah untuk (a) mensimulasi banjir hujan di kawasan atas Sungai Langat menggunakan model HEC-HMS dan RRI; (b) membandingkan hasil daripada model HEC-HMS dan RRI berdasarkan nilai pelepasan dan; (c) menghasilkan peta banjir menggunakan model HEC-RAS dan RRI. Data hujan dan pelepasan yang digunakan sebagai data input untuk model HEC-HMS dan RRI telah dibekalkan oleh JPS. Data DEM dengan resolusi 1 arka-saat dan 30 arka-saat masing-masing telah digunakan dalam model HEC-RAS dan RRI. Simulasi lima kejadian hujan menggunakan model HEC-HMS dan model RRI telah dilakukan bagi menentukur parameter-parameter tertentu. Parameter-parameter yang telah ditentukur digunakan bagi mengesahkan tiga kejadian hujan bagi model

HEC-HMS dan RRI. Graf pelepasan tercerap melawan pelepasan simulasi telah dilakar bagi mencari korelasi antara kedua-dua data menggunakan koefisien korelasi, R^2. Semua graf menunjukkan julat nilai R^2 antara 0.5 - 1.0. (0.3 - 0.7 = sederhana; 0.7 - 1.0 = kuat). Secara keseluruhannya, data-data itu berkorelasi antara satu sama lain. Peta banjir telah dihasilkan menggunakan model HEC-RAS dan RRI berdasarkan data pelepasan simulasi. Berdasarkan peta yang dihasilkan daripada model HEC-RAS, hujan dan pelepasan tertinggi sebanyak 11.5 mm dan 132 m^3 / s telah membanjiri beberapa kawasan di Kajang. Peta banjir yang dihasilkan oleh model HEC-RAS adalah lebih jelas dan mudah difahami berbanding peta daripada model RRI disebabkan resolusi DEM yang rendah. Oleh itu, simulasi hujan-aliran menggunakan model HEC-HMS dan HEC-RAS adalah lebih praktikal.

TWO-DIMENSIONAL SIMULATION OF UPPER SUNGAI LANGAT USING HEC-HMS, HEC-RAS AND RRI MODEL

ABSTRACT

Flood is one of the natural disasters occurring in Malaysia. Floods usually occur due to the overflow of water from the riverbanks which inundates the surrounding area. Hulu Langat district, located in Selangor was severely affected by floods. Sungai Langat is the main river flowing from Banjaran Titiwangsa into the Strait of Malacca with a length of approximately 141 km. The study area is focused on the upper Sungai Langat basin area where main cities such as Kajang, Bangi, Seri Kembangan and Dengkil are situated. These cities which are located at the downstream area of upper Sungai Langat were frequently inundated during heavy rainfall events. This scenario had caused a nuisance to the surrounding people of the inundated areas. Thus, HEC-HMS, HEC-RAS and RRI models were used to simulate the rainfall-runoff occurrences in the upper Sungai Langat basin. The objectives of this study are to (a) simulate the flood inundation in upper Sungai Langat using HEC-HMS and RRI models; (b) compare the results of HEC-HMS and RRI models based on discharge values and; (c) produce flood maps using HEC-RAS and RRI models. The rainfall and discharge data which were used as the input data for HEC-HMS and RRI models were provided by the DID. DEM data of 1 arc-second and 30 arc-second resolutions were used in the HEC-RAS and RRI models respectively. Simulation of five rainfall events using HEC-HMS and RRI model were conducted to calibrate particular parameters. The calibrated parameters were used to validate three rainfall events using HEC-HMS and RRI models. The graphs of observed versus simulated discharges were plotted to find the correlations between both data using the

correlation coefficient, R^2. All plotted graphs showed that the range of R^2 values was between 0.5 - 1.0. (0.3 - 0.7 = moderate; 0.7 - 1.0 = strong). Overall, the data were found correlated to each other. Flood maps were generated using the HEC-RAS and RRI models based on the simulated discharge data. Based on the maps produced by the HEC-RAS model, highest precipitation and discharge of 11.5 mm and 132 m^3/s respectively had inundated some areas in Kajang. Inundation maps produced by the HEC-RAS model were clearer and easy to understand compared to the maps from RRI model due to low resolution of the DEM. Thus, the simulation of rainfall-runoff using HEC-HMS and HEC-RAS models is found more practical.

CHAPTER ONE

INTRODUCTION

1.1 Background

Malaysia is located in Northern Hemisphere, the northern part of the Equator Line which experiencing humid and cold throughout the year. A research was conducted showing that Malaysia received 907 million m^3 of rainfall in year 2016 (Sobiari, 2018) and its average annual rainfall in Malaysia range from 2000 mm to 4000 mm. This is one of the reasons why flood often occur in this country. Along with climate change, rapid urbanization associates with human activities which cause land use change had given impact in hydrological processes and flood risk (Zhang, 2008). According to Konrad (2016), removing plants and soil, change the original state of the land surface, and constructing drainage networks causing higher volume of runoff to streams. This scenario had result in increasing of peak discharge, volume, and frequency of floods in nearby streams.

Flood started from river which is the lowest land area in a catchment. As stated by Yoon et al. (2015) water flowing from upstream will fill up the river down to downstream area. Downstream area is prone to flood when heavy rain events occur as it needs to regulate large flows from the upstream part and amount of rainfalls in the same event. Study by Papathanasiou et al. (2013) shows that downstream area often faced inadequate response time and relevant means. When the streams no longer can flow to a lower area as the water in the river and land are at the same level, it will eventually overflow from the riverbank (Palmer and Allan, 2006). It will continue flowing towards the floodplain areas which are relatively flat lands adjacent to a river and end up inundates nearby area (Meitzen, 2018). Figure 1.1 shows residents moved their belongings to relief centers after their house were flooded after a heavy downpour.

Figure 1.1 Housing area in Kajang were inundated with water overflow from Sungai Langat
(Source: The Sun Daily, 2017)

1.2 Problem Statement

One of characteristics of watershed is it collect precipitation that falls on the ground surface and will eventually drained into the river. Leow et al. (2008) mentioned that the collected water in the river will drains out to an outlet such as reservoir and stream channel. A recent study by Shaari (2016) stated that natural disaster like flooding occured due to high amounts of water flowing in streams. Flood caused nuisance to affected victims and money losses for flood-relief works in the affected area. Study by Marx et al. (2012) shows that floods are responsible for socioeconomic and environmental impact which causes loss of human life and victim's belongings were destroyed during flood events.

Government had to spend a huge amount of money for flood-relief works every year due to flood such as RM121 million in 2015 in Selangor (Amran, 2017). Understanding the flood events resulted from heavy downpour and causing an area inundated will help in taking measures to mitigate potential impact of flooding thus reducing maintenance cost and save lives in the future. This can be possible when researchers conducting a study on flood and come out with few solutions to prevent this disaster in the future such as flood hazard map.

In order to study flood, researchers must collect some data such as previous flood event and characteristics of the study area (Musyoki et al. 2016). The recorded data usually be done manually or automatically using equipment. Department of Drainage and Irrigation (DID) is one of government bodies that is responsible in collecting data and giving information regarding flood management in Malaysia. Data can be collected from each rainfall and streamflow station. However, not all data are available because the river gauging stations may not function well due to disaster or less maintenance.

Software available such as HEC-RAS, RRI, MIKE, CFD, ArcGIS are suitable to use for flood forecasting and modeling. These software help in simulating the flood event and producing result in either one, two or three dimensional (Shokory et al, 2016). According to Aksoy et al. (2016), less time is required and more accurate result can be produced with the help of recent technology. However, software which needs a little input data and user-friendly are most likely to be chosen as it is easier for researchers to learn and understand the concept. Thus, a study on two dimensional simulation was done to simulate the flood inundation area using HEC-RAS (Hydrologic Engineering Center River Analysis System) and RRI (Rainfall-Runoff-Inundation) model.

1.3 Objectives

The main objectives in this study are:

a. To simulate the flood inundation of upper Sungai Langat using HEC-HMS and RRI model.
b. To compare the result of HEC-HMS and RRI model based on discharge values.
c. To produce flood map for upper Sungai Langat by using HEC-RAS and RRI model.

1.4 Scope of Study

The main focus in this study is to produce a flood map in upper Sungai Langat by simulation. Selected softwares and some necessary data are used in order to simulate the flood event. Softwares used in this study are as stated below:

a. ArcGIS (Geographic Information System)
b. HEC-HMS (Hydrologic Modeling System)
c. HEC-RAS (Hydrologic Engineering Center River Analysis System)
d. RRI (Rainfall-Runoff-Inundation)

Data used in this research are as stated below:

a. DEM (source : USGS HydroSHEDS)
b. Rainfall and discharge (DID Malaysia)
c. River cross-section

A resolution of 1 arc-second Digital Elevation Model (DEM) is downloaded from USGS HydroSHED website. ArcGIS software will use the DEM as data and produce a new watershed of upper Sungai Langat in terms of shapefile. Rainfall data collected from river gauging stations are available in terms of year, month, day, hour and minutes. These data will be an input in HEC-HMS software. The output of this model will be an input for HEC-RAS software in terms of discharge value. Cross-section and water discharge will be added in RRI model as an input to simulate the flood event. Result from both HEC-RAS and RRI model will be compared and validated with data of streamflow and water elevation which are collected from DID Malaysia. At the end of this study, data gathered and softwares used will helps in producing a flood hazard map in upper Sungai Langat.

1.5 Study Area

Hulu Langat is one of district in Selangor with an area of 840 km^2 and is located in the southeastern corner as shown in Figure 1.2. Among others eight districts, Hulu Langat is the fifth largest with a population approximately 1,067,744 in 2010. Back then, the population was only 864,451 in 2000 (Population and Housing Census Malaysia 2000). There are 7 mukim's that divides Hulu Langat district which are Hulu Langat, Ampang, Cheras, Hulu Semenyih, Kajang, Semenyih and Beranang.

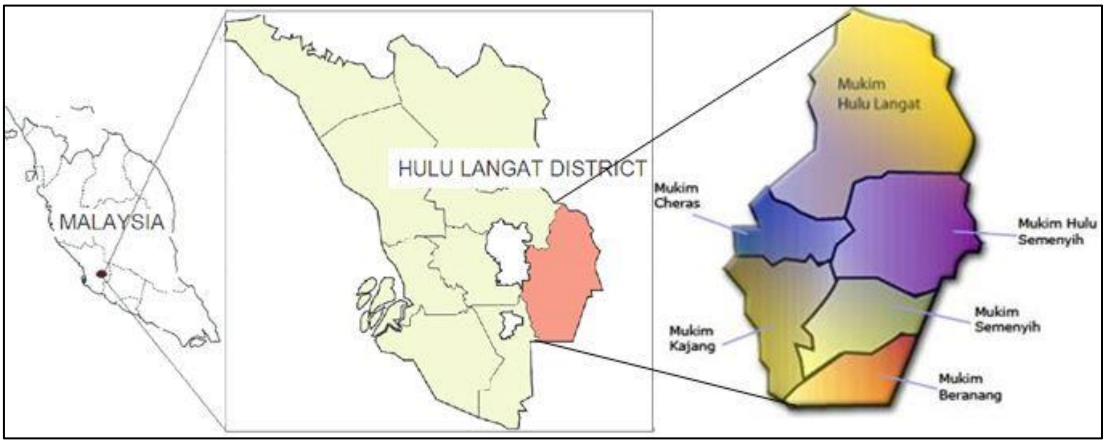

Figure 1.2 Location of Hulu Langat district

The main river in Hulu Langat is Sungai Langat with a distance of 180 km. The upstream of this river originates from Titiwangsa Range at Gunung Nuang and drains out to the Straits of Malacca located at westward. Sungai Langat has its major tributaries which are Sungai Semenyih and Sungai Labu. Sungai Semenyih main reach start from the Semenyih Dam flowing south-southwest direction through the town of Semenyih, Bangi Lama and finally merges with Sungai Langat. Meanwhile, Sungai Labu begins in Territorial division Labu, Seremban and flows through the town of Nilai. The river finally meets Langat main tributary at about 3 km south of Dengkil town. Figure 1.3 shows the upper part of Sungai Langat is being studied in this research.

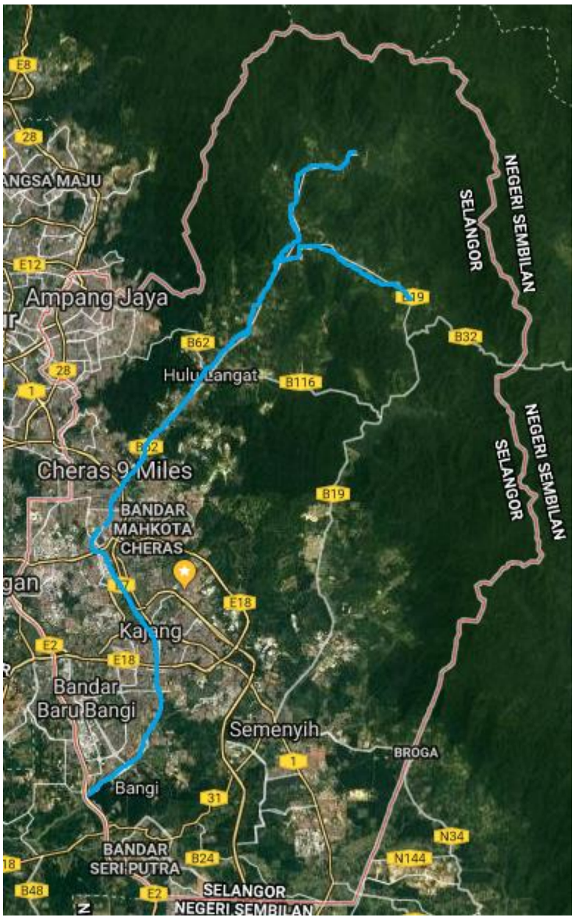

Figure 1.3 Study area in Sungai Langat, Hulu Langat

1.6 Thesis Organization

The research project consist of five chapters and are divided as the follows:

Chapter 1: The first chapter gives a general description of the background, problem statement, objectives, scope of study as well as study area.

Chapter 2: Chapter two is the literature review that covers the following topics:

- Upper Sungai Langat watershed
- Rainfall intensity
- Urbanization
- Deforestation
- Land use change

- Flood Simulation

Chapter 3: Chapter three explains the methodology which covers the data collection and the process in order to get output result.

Chapter 4: Chapter four which is the main chapter in this research shows the result of difference six simulation cases and the findings of the simulation analysis are interpreted as the map that produce flood map.

Chapter 5: Chapter five is the last chapter. It includes the conclusions and recommendations of the research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Climate change, population growth, land use change, deforestation and urban development are causing floods to become increasingly severe and more frequent in flood plains (Huong and Pathirana, 2013; Apollonio et al., 2016). As mentioned by Vijayalakhsmi and Jinesh (2010), extreme flood events could cause severe damages to property, agricultural productivity, industrial production, communication networks and infrastructure, especially in the downstream parts of catchments.

2.2 Study Area

Natural disaster such as landslide, flood, drought and storm has been hitting Malaysia years ago. Climate-related natural disasters had costed Malaysia RM 8 billion in the last 20 years (Malaymail, 2018). A study by Zairol (2018) revealed that since 1985-1999 to 2000-2014, occurrence of cases related to natural disasters had increased by 63.43% from 3981 to 6506 reported cases. The number of death from these cases in the year 1985-1999 was 687633 while in 2000-2014 the number increased by 85.11% contributing to 1272868 deaths. In terms of economic damage, approximately $800 million was lost in 1985-1999 and rose up to $1777 million in the consecutive years, showing a 122.07% increment. This proves that natural disaster inflicts a bad impact on Malaysia in terms of cost, loss of life and economy.

Malaysia is located near the Equator and experiencing hot and humid conditions throughout the years. A study by TAM and Ibrahim (2014) stated that the averages annual rainfall and temperature in Malaysia are 2500 mm and 27℃ respectively. Selangor has the highest case reported on flash flood (Department of Statistic Malaysia, 2010).

Figure 2.1 reveals the difference in the frequency of natural disasters occurred in Malaysia in terms of percentage. The most striking truth revealed from this figure is the highest frequency of flood of 62.5% in comparison to landslide and drought of only 8.3% and 4.2% respectively. This proves that flood is the major natural disaster occurs in Malaysia and this is expected to inflict more harm to lives and increase the possibility of damages to properties in the future. Citizens living in the inundated areas have to face these problems regularly as no prevention can be done since rainfall events occurrence is beyond our control.

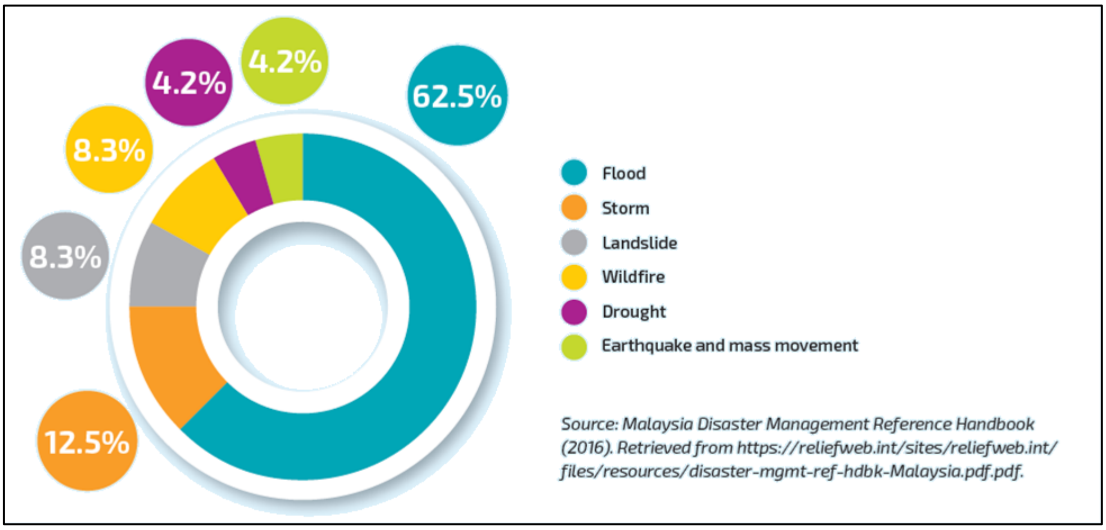

Figure 2.1 Frequency of natural disasters occurrence in Malaysia (1990-2014) (Source: Malaysia Disaster Management Reference Handbook, 2016)

2.2.1 Upper Sungai Langat

The geographical coordinates of Hulu Langat are of 3°7’0” North and 101°49’0” East. The location of Upper Sungai Langat originates from coordinates 2.917855, 101.757210 and ends at coordinates 3.210618, 101.880231. Sungai Langat has several tributaries including Sungai Semenyih, Sungai Lui and Sungai Beranang (Juahir, 2009). The upper part of Sungai Langat watershed measures from Gunung Nuang towards Bangi.

From Figure 2.2, it can be clearly seen that Selangor is ranked first in population distribution with 5.46 million people compared to other states. According to the Population and Housing Census Malaysia 2000, Hulu Langat's population increased from 177,900 in 1980 to 413,900 in 1991; 864,451 in 2000 and 1,067,744 (excluding foreigners) in 2010 (Yaakob at al., 2012). Figure 2.3 reveals Selangor as the third top state in Malaysia with high percentage of urbanization of 91.4%.

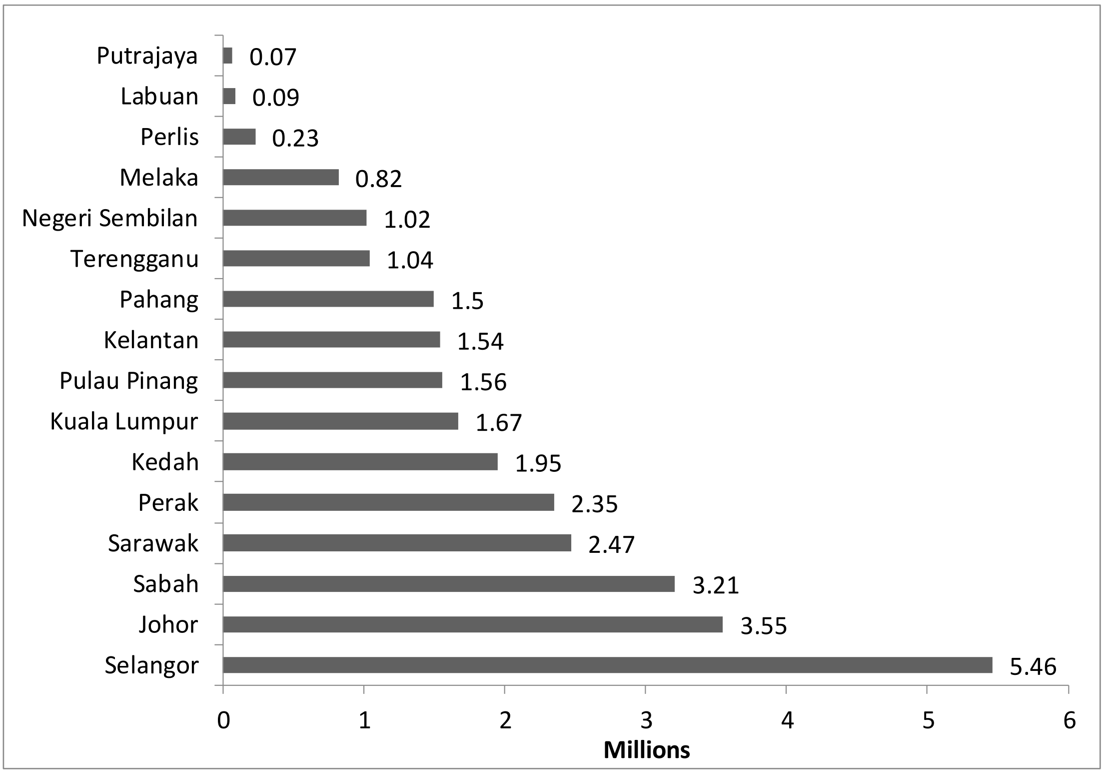

Figure 2.2 Population distribution by state in Malaysia, 2010
(Source: Department of Statistics Malaysia, 2010)

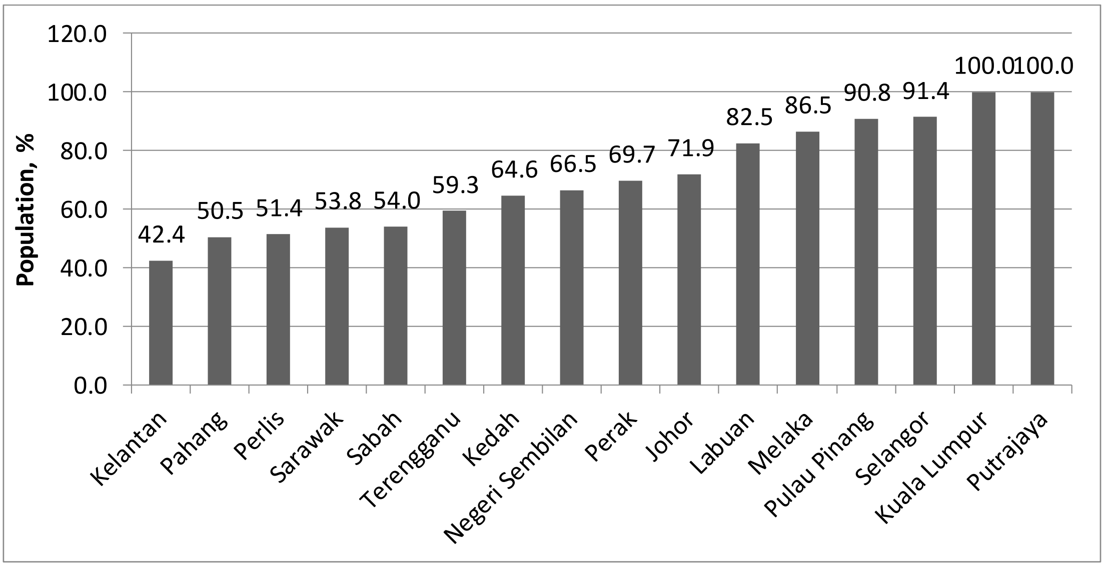

Figure 2.3 Level of urbanization by state in Malaysia, 2010
(Source: Department of Statistics Malaysia, 2010)

A report by Amran (2017) had described the worst flood ever happened in Malaysia in the past years and the impacts in terms of death and cost in flood mitigation plan.

The report is summarized in Table 2.1 which is categorized based on year, flooding areas, factors of occurrence and loss generated from the flood. In 2015, flash flood occurred in Selangor caused by an increase in sea level and poor drainage system. The cost spent for flood mitigation plan during this event was RM 121 million which was a huge amount (Amran, 2017).

Table 2.1 Worst flood events reported in Malaysia (Source: Amran, 2017)

Year	Flood event	Factors	Losses of properties and lives	Flood mitigation plan cost
2014	Yellow Flood in Kelantan	Monsoon 'New Moon'	RM200 million & 10 deaths	NA
2016	Banjir Termenung in Terengganu	Clash of water from river and sea	RM100 million	RM 1 million
2010	Flood in Kedah and Perlis	'La Nina' - strong wind and heavy rain	RM50 million & 6 deaths	RM1 billion
2015	Flash flood in Selangor	Increase in sea level and poor drainage system	NA	RM121 million
2009	Flood in Sabah and Sarawak	Heavy rain	RM300 million	NA
2017	Flood in Pulau Pinang	Fujiwara phenomenon	7 deaths	NA

Based on Figure 2.4, the highest accumulated rainfall was in 1995 and the lowest was in the year 1990. The bar graph shows irregular pattern of rainfall as the precipitation values had fluctuated since 1990. The data collected from the Department of Irrigation and Drainage Malaysia (DID) show that the lowest rainfall recorded was 1381.2 mm and the highest was 3098.6 mm. The mean precipitation collected at the gauging station was 2548.2 mm, which was higher than the average rainfall in Malaysia of 2500 mm as stated by TAM and Ibrahim (2014). This proves that the watershed in upper Sungai Langat had experienced high precipitation for years.

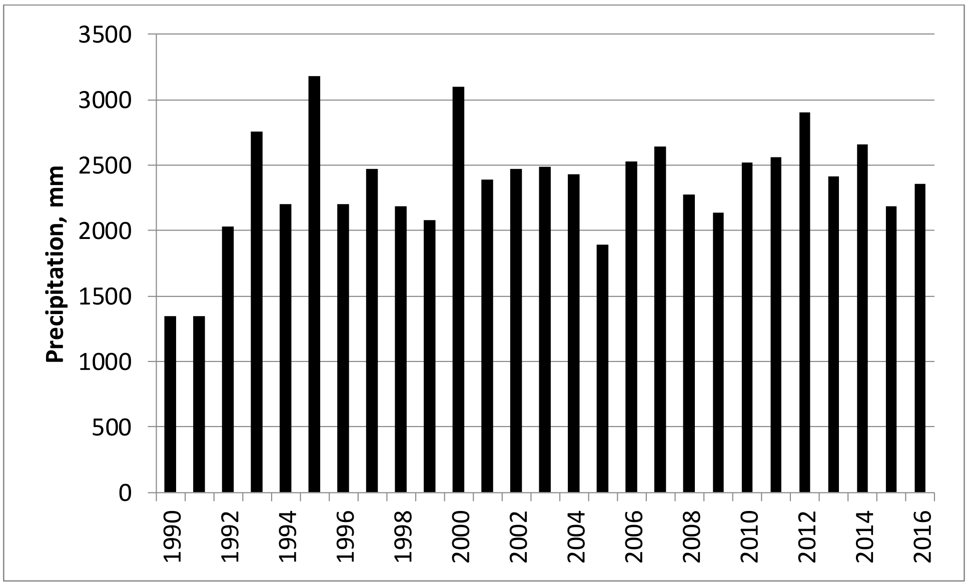

Figure 2.4 Total precipitation at gauging station 2917001 (RTM Kajang) from 1990-2017
(Source: Department of Irrigation and Drainage, 2017)

Sungai Langat flows along the urban areas such as Ampang, Bangi, Kajang and Petaling Jaya. These urban areas had experienced several flood events due to the rise in the water level of Sungai Langat (Kandari et al., 2018) and the scenario keeps on repeating till present. In order to reduce damage inflicted from flood, flood hazard map is one of the tools that can be used to help authorities to control as well as predicting flood events in future. Thus, the upper Sungai Langat catchment area was chosen as the study area of flood inundation.

Many studies had been conducted by researchers and students regarding flood occurrences in Malaysia. A recent case study by Samsuri et al., (2018) had also supported that rapid development and urbanization are the main causes of floods. A study by Sadatkhah et al., (2016) on extreme flood occurrence in Kelantan using a hydrological model had proved that land cover and land use change posed a great impact on flood occurrences. Hulu Langat as well had been experiencing rapid urbanization, land use change and rampant deforestation activities, which are further explained in the following sections. Thus, the factors for flood occurrence in the upper Sungai Langat area are heavy rainfall, urbanization, deforestation and land use change.

2.3 Heavy Rainfall

One of the factors affecting the local climate is the mountain ranges present in Malaysia which can be divided into highland, lowland and coastal area (Wong et al., 2016). Highland is usually recognized as wetter and cooler region compared to lowland and coastal area due to its high level of humidity as mentioned by Cleavitt (2004). Large amount of clouds covering highland areas eventually affects the amount of rainfall produced in those areas.

Evaporation process happens when water on the surface is heated by the sun and rises up into the air as water vapors (Newsela, 2017). The temperature of air in highland is lower than that of lowland areas. The water vapors cool and condense into droplets (Saraireh, 2012). The droplets then form clouds as a water storage in the atmosphere. Upper air wind keeps the clouds afloat and moving along the wind current and eventually change in shape. Water will fall back down onto the surface through rain which is known as the precipitation process. This process occurs when the condensation process reaches its maximum limit as the clouds can no longer hold its content of water vapors as stated by Metal Building Manufacturing Associations (2010). Since the temperature in highland areas is cooler, the rate of condensation in these areas is higher. This will eventually increase the rate of precipitation as the amount of water vapors stored in the clouds is higher.

Ali et al. (2012) mentioned that the upstream of the river starts at the highest point which is at 1493 meter above sea level. Precipitation in the upper Sungai Langat accumulates in a catchment area of 477 km^2. River flows in the catchment area for a 34 km distance. The river originates from a highland area, passing through rural area and ends in Bangi, which is an urban area.

Most flood occurrences in Hulu Langat was recorded and reported by DID Malaysia. The most frequent areas affected by flood are Bangi, Ampang and Kajang. These areas are situated along Sungai Langat. Table 2.2 shows the summary of flood events reported in Hulu Langat.

Table 2.2 Reports on flood event in Hulu Langat (Source: DID 2017)

Date	Inundated area	Maximum rainfall (mm)	Flood level (m)
26th February 2013	Bangi Lama	98	0.3 - 0.5
12th October 2014	Kg Sg Serai	74	0.5
24th November 2014	Kg Pasir	125	0.15
4th October 2014	Batu 12	72	0.5
1st November 2015	Kg Sg Jernih	96	0.2 - 1.0
24th August 2015	SMK Abdul Jalil	126	0.6
7th November 2016	Tmn West Country	93	0.3
19th June 2016	Kg Sg Kantan	80	0.3
3rd June 2016	Kg Pasir	100	0.2
7th May 2016	Kg Sg Tangkas	142	1.0

According to the Department of Irrigation and Drainage (DID), the number of reports on flood events is increasing each year. Figure 2.5 shows the trend of flood occurrences in Hulu Langat. There were 23 cases of flood events reported in the year 2013. The number of flood events increased to 46 and 82 cases in the year 2014 and 2015 respectively. However, the graph shows a decrease in the number of reported flood events in the year 2016 which was 59 cases. This shows that the areas located near Sungai Langat are prone to flood and the number of reported cases are increasing each year.

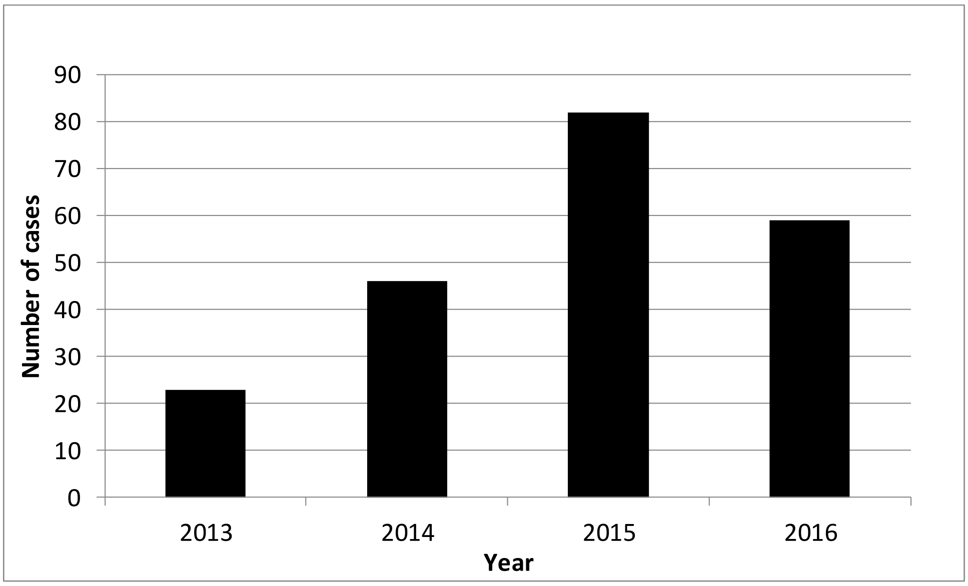

Figure 2.5 Graph of year versus number of cases of flood
(Source: Department of Irrigation and Drainage, 2016)

Figure 2.6 shows the most frequent areas (marked with red dots) reported by DID that are affected by flood events. Most of the areas are located at the downstream of upper Sungai Langat, which is an urban area instead of the upstream area. Urban area such as Bangi, Kajang and Ampang Jaya have a higher population density compared to rural area (Rural Development Institute, 2014). Thus, it consists more housing areas, buildings, paved roads as well as other infrastructures.

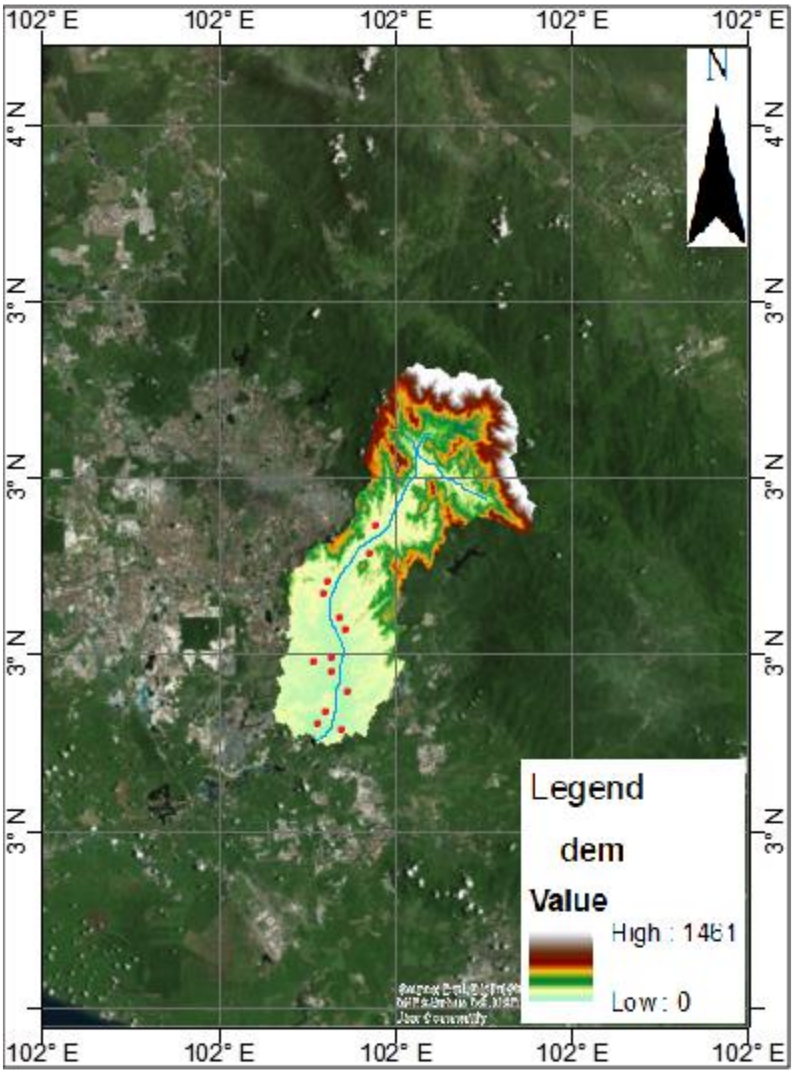

Figure 2.6 Map of Sungai Langat showing the inundated areas along the river (Source: Esri, DigitalGlobe, Geo Eye, Earthstar Geographics)

2.4 Urbanization

Urban area is created through years of urbanization. Bapari et al., (2016) stated that an area originally consists of plants and forests but with passing time, the demand for a more comfortable life has led to urbanization. Urbanization is the population of human live in an urban area (Andrea, 2015). According to Abas and Hashim (2014), a rapid increase in population has caused an increase in urbanization and land cover change. Increasing demand for a better life has improved the human civilization as well as urban planning. Urban revolution has increased the human activities and led to natural resources exploitation. Yang et al., (2014) proved in their study that this phenomenon had inflicted negative impact on environment. In order to meet this demand, deforestation activities are increased. This causes urban area to have less pervious area and higher percentage of impervious area (McGrane, 2016). Urbanization influences deforestation activities which causes reduction in time of concentration, decrease in storage water capacity, changes in land use, increase in water level and increase of surface runoff (Gholami, 2013).

2.5 Deforestation

Deforestation is carried out when a new area is needed to develop housing area, new roads are paved for transportation and trees are cut down to produce daily use equipment such as toilet paper, paper, furniture and et cetera (Fearnside, 1987). In order to fulfill the increasing demand in urban development, human began to exploit the earth natural resources such as trees, hills, water and soils (Aubell and Mensah, 2007). The Star Online (2014) had published about deforestation which had caused flood that claimed three lives. A research by Gholami (2013) had concluded that the effects of cosmopolitan area growth are increases in surface flow, annual runoff and peak discharge. As a conclusion, deforestation affects the time of concentration of surface runoff, the water level of river channels and the water storage in soil after rainfall.

2.5.1 Time of Concentration and Surface Runoff

Figure 2.7 shows an illustration of the comparison between pervious and impervious areas in terms of percentage of infiltration, runoff and evapotranspiration. Pervious area has high percentages of evapotranspiration and infiltration but low percentage surface runoff. Vice versa, the percentages of infiltration and evapotranspiration in an impervious area are low but with high percentage surface runoff.

Pervious and impervious areas have a huge impact on surface runoff and streamflow (Boyd et al., 1994). Pervious area is porous and permeable for water to infiltrate through while impervious area is the opposite, as mentioned by Brabec et al., (2002). Rain falls on surfaces of either ground, road, concrete or roof. Kaspersen (2014) stated that water on ground infiltrates into pervious soil layer while water on impervious surfaces such as roofs, concretes and roads do not infiltrate. The runoff flows along the surfaces down to lower areas. As a result, high volume of surface runoff is generated. The time needed for water to flow from the highest point toward the outlet of a catchment is known as the time of concentration. Xu and Zhao (2016) proved that an increase in surface runoff causes a reduction in the time of concentration of a watershed. The water volume flows toward rivers rapidly and causes an increase in streamflow. It will result in increasing peak discharge and causes flash flood.

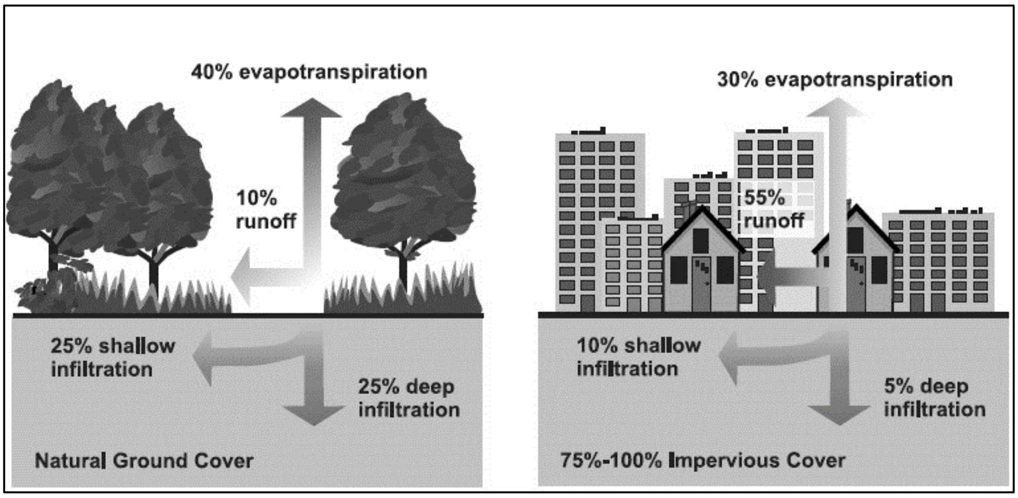

Figure 2.7 Comparison between natural ground cover and impervious cover (Source: Beachapedia, 2016)

2.5.2 Infiltration

Plants play a big role in an infiltration process. Big trees with branches help to filter rain than falls directly onto soil surface (Ekhuemelo, 2016). This will reduce the time for rainfall to reach ground and eventually helps in a smooth infiltration process. As mentioned by Li et al., (2015), the process of rainfall being temporarily held on tree leaves and stem surfaces before dripping and flowing down is known as interception. Only a certain volume of water is able to penetrate into ground at a certain time, as the rate of infiltration decreases with time (Gundalia, 2018). Thus, leaves and stems on trees help in prolonging the time taken for rainfall to reach ground as well as for soil to adsorb sufficient amount of water penetrates through it.

Figure 2.8 shows an illustration of an infiltration process. Balasubramaniam (2017) mentioned that infiltrated water gradually moves vertically and horizontally through rocks and soil particles in an unsaturated zone. Based on a study conducted by Easton et al., (2016), the time taken for subsurface water to reach a seepage is determined by the ability of soil to store water. If a soil has a high capability to store infiltrated water, then the time required for the water to reach river channel is longer. This will help in reducing the volume of water flowing into the stream channel and thus controling the water level.

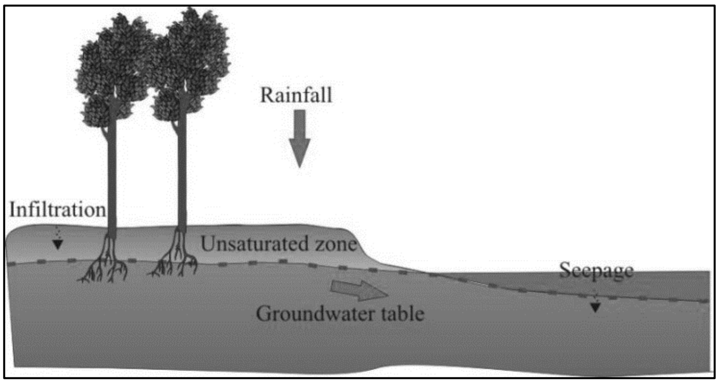

Figure 2.8 Infiltration process from precipitation onto ground surface (Source: Civil Digital, 2013)

2.5.3 Water Surface Elevation

Root of a tree or vegetation functions as a soil grip as it helps to hold soil particles from getting loose (Saifuddin and Normaniza, 2016). Bengough et al., (2005) had also stated that the removal of roots will disturb the arrangement of soil particles and eventually loosen it making it less strong. Soil erosion will occur during a rainy day when water falls on ground and flows to a lower area carrying along the loosen soil particles as runoff (Balasubramaniam, 2017). The runoff together with soil particles will then reach the lowest area which is the river. The suspension of soil particles in water will eventually settle down at the bottom of the river as sediments. Consequently, the depth of river channel will decrease and this will result in the rise in water level.

2.6 Land Use Change

One of the negative impacts of urbanization is changes in land use. A study by Zhao et al., (2011) revealed that soil properties change due to vegetation and soil removal as well as the grading of land surface. Land use can be categorized into water body, built-up area, commercial agriculture, forest etc.

A study by Muhamad et al., (2015) revealed that the upper Sungai Langat has gone through changes especially in its land use. The changes in land use since the year 1988 until 2014 can be observed in Figure 2.9. Based on the map, upper Sungai Langat was once occupied with commercial agricultural land in 1988. The commercial agricultural land had slowly changed into built-up area in the downstream part of upper Sungai Langat from 1996 till 2005. Eventually in the year 2014, the commercial agricultural land had been replaced almost entirely by built-up area. The percentage of built-up area back in the year 1988 was approximately 5% occupying the downstream area. Built-up area in 2014 showed a huge difference in percentage of approximately 95%. The changes from commercial agricultural into built-up areas had resulted in an increase in impervious area due to urbanization.

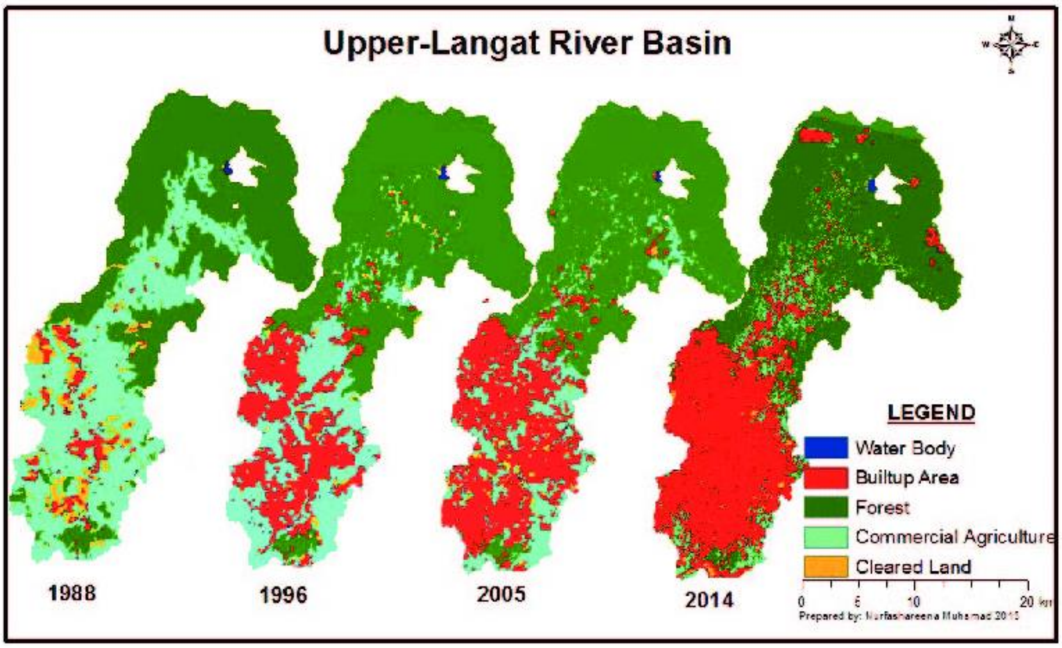

Figure 2.9 Land use map of the Upper Sungai Langat
(Source: Muhamad et al., 2015)

2.7 Flood Simulation

In order to grasp a better understanding on the impact of flood, a simulation of flood events based on the rainfall and streamflow data was done to produce a flood hazard map. Benito and Hudson (2010) defined flood hazard as a potential threat to human life and property. Flood hazard map gives a clearer view of the intensity of rainfall on the inundation of an area and provides awareness to those staying near the flood-prone areas. This will help authorities to alarm an early warning to citizens before a flood event occurs and provide ample time for them to prepare from any disasters. Thus, the two-dimensional simulation can be very useful in producing flood maps.