APPLICATION OF HEC-RAS HYDRODYNAMIC FLOOD MODELLING FOR RIVER: A STUDY CASE OF BERTAM VALLEY, PAHANG.

ANDREW LEE KWAN YEE

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

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by

ANDREW LEE KWAN YEE

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

August 2021

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: "APPLICATION OF HEC-RAS HYDRODYNAMIC FLOOD MODELLING FOR RIVER: A STUDY CASE OF BERTAM VALLEY, PAHANG."

Name of Student: ANDREW LEE KWAN YEE

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Date : 4 August 2021

Endorsed by:

(Signature of Supervisor)

Name of Supervisor: Dr. MOHAMAD FARED MURSHED, School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia

Date: 4.8.2021

Approved by:

(Signature of Examiner)

Name of Examiner: Dr Rozi bin Abdullah, School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia

Date: 04/08/2021

ACKNOWLEDGEMENT

First of all, I would like to express my profound honour for being able to do the study which might help contributing to the society. I am deeply grateful to my supervisor, Dr Mohamad Fared Murshed for his guidance, patience and assistance throughout the project. I feel myself really fortunate to have the opportunity to work with such a thoughtful and inspiring lecturer. Furthermore, I would like to thank Muhammad Kashfy Zainalfikry, who gave me a lecture tutorial about the operation steps of the software HEC-RAS right before I began my work. Yet, the work wouldn’t be done if I didn’t acquire the Digital Elevation Model (DEM) for the study area from Siti Multazimah Binti Mohamad Faudzi. The DEM that served as the topography input of the project, eased my work from further searching for a suitable DEM that might had costed me extra time.

I owe many thanks to my classmate and all of my friends, especially Khor Cheng Yi and Ching Meng Xuan that had given me a hand during my hard time. They always assist me in discussing ideas and provide a pleasant learning environment. They literally enlightened my life in Universiti Sains Malaysia and their friendships are precious to me.

Last but not least, I am most grateful to my family who cheered me up when I was in tension. They've always loved me and backed me up in all I've done. Cheerio!

ABSTRAK

Empangan adalah sebuah kawasan tadahan air dan berfungsi sebagai penjana kuasa hidroelektrik dan merupakan satu sumber tenaga boleh diperbaharui yang paling berkesan. Pada masa linkungan air sudah hampir penuh atau melebihi kemampuan, empangan akan dibuka untuk melepaskan air. Walau bagaimanapun, sejumlah besar pelepasan yang dikeluarkan dari limpahan bendungan berpagar akan membawa kepada kerosakan besar di kawasan sungai hilir. Oleh sebab itu, kajian ini telah dijalankan untuk mengenalpasti pelepasan air maksimum pada aliran air di hilir Lembah Bertam. Objektif kajian ini juga turut mensimulasikan kawasan yang mungkin dihanyut banjir menggunakan model HEC-RAS dan mengesahkan serta membandingkan model HEC-RAS berdasarkan nilai pelepasan dan ketinggian air. Dalam kajian ini, kadar pelepasan air yang digunakan dalam simulasi adalah 10, 27.5, 75, 230 dan 300 m^3/s berdasarkan cadangan pelepasan empangan oleh Tenaga Nasional Berhad (TNB). Hasil kajian menunjukkan bahawan air melai untuk melimpah dari tebing apabila pelepasan maksimum 27.5 m^3/s dan merupakan kadar alir maximym yang boleh dilepaskan berdasarkan simulasi HEC-RAS. Pada kadar alir ini, kedalaman, halaju, dan masa larian air sungai adalah 2.66 m, 1.33 m/s, dan 0.22 jam. Berdasarkan keputusan ini diharap dapat memberikan amaran kepada penduduk tempatan dan membantu pihak pengurusan empangan dalan pengawalan jumlah pembuangan maksimum dari empangan.

ABSTRACT

Dams are built to store water to adapt for changes in the catchment region, and they are undeniably one of the most efficient renewable energy sources. The dam will open the sluice gate to discharge certain amount of water when the level of water is almost exceeding the safety level of it. However, an overwhelming amount of discharges discharged from the dam's gated spillways would cause egregious damage to the downstream area. As a result, a study was conducted on the effects of various maximum discharges on the flow along a segment of the downstream river in Bertam Valley. The highlighted objectives for the study were to simulate a flood inundation of Bertam Valley using HEC-RAS model and to have validation and comparison of HEC-RAS model based on discharge value and water level. With HEC-RAS, a computer simulation was run to examine various maximum discharges released from the dam's gated spillway. The amount of water release used in the simulation were 10, 27.5, 75, 230 and 300 m^3/s based on the recommendation dam release by Tenaga Nasional Berhad (TNB), according to a previous study. The result shows that the safest maximum release was 27.5 m^3/s, that is when water started to overflow from the bank. The water depth, and velocity, as well as the travel time of the water flow at the discharge of 27.5 m^3/s are 2.66 m, 1.33 m/s and 0.22 hour respectively. The study could be useful for warning to local inhabitants and to help dam management in controlling the amount of maximum discharge level from the dam.

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CHAPTER 1

INTRODUCTION

1.1 Simulation of Hydrodynamic Model

In this modern era, there is a lot of things still unpredictable. Recent generations are lucky to live on with these peaceful and harmonious lives compared with the previous generations. There are more safety assurances nowadays to avoid preventable risks. For instance, flash flood is considered predictable despite of the fact of being spontaneous. In the process of predicting a flood, there is actually various types of data needed for the analysis, i.e., rainfall data of a particular area; the rate of change of river stage on real-time basis *(how are floods predicted - Google Search, no date)*; and a tool for the mapping system and demonstration of flood (Snead, 2000). With the help of modern tool like computer software, it is for sure going to ease the prediction of flood. Hydrodynamic flood model could be simulated through the computer in ordered to mimic the real-life situation of the runoff in rainy days. Floods are happening quite often in Malaysia, as we could hear the news of flood occurrence in different districts or states all year long. Bertam Valley is an agricultural-based village that located close to Ringlet, Malaysia. Ringlet is the southernmost town of the Cameron Highlands, Pahang, Malaysia, which is a hub of Malaysia's agriculture and international flower farming sector. Cameron Highlands land extent occupies an area of 712 square kilometres. The place located at an altitude of 1135 meters above sea level and the population of Cameron Highlands consists of roughly around 34,510 people up to 2010. There was a serious flood once happened in Bertam Valley back in 2013, after the downpour of water from Sultan Abu Bakar Dam. The flood killed 3 people and destroyed almost 10 houses located at the banks of Sungai Bertam (Kaur, 2013). The Cameron Highlands has a climate that is somewhere between tropical rainforest and subtropical highland, with annual precipitation exceeding 2,700 mm. The average rainfall for each month differs with a range from 109.5 mm to 334.7 mm in 2017.(*Climate Change and the Green House Effect)*

There are two types of preventive methods which often being applied by the government, that is structural and non-structural flood mitigation planning. Both methods are necessary in the way of coping with each other which could bring on a more optimum outcome (Kubal *et al.*, 2009). Yet, non-structural mitigation plan is said to be easier to carry out and lesser in costing. One of the examples of non-structural flood mitigation plan is the preparation of hydrodynamic flood model through simulation process of computer process to find out the peak water level according to the data input we acquired for a study area. The definition of hydrodynamics is a study of motion of fluids and the forces applying on solid bodies submerged in the fluids and in the motion corresponding to them (Merriam-Webster, 2020), hence that is basically the mechanism used in the analysis. We could choose to input the past rainfall data or the forecast rainfall data to obtain the peak water level on study site according to our requirements of either for validation or prediction purpose. The peak water level from prediction is important and could be useful as evacuation warning sign for residents living in the study area. An earlier evacuation before a catastrophe happened is undoubtedly a good act to be applied to ensure that the amount of injury and death could be minimized.

To achieve the aims, we would design a sensible framework with the usage of HEC-RAS (Hydrologic Engineering Center's River Analysis System) software. The project focuses on showing one-dimensional (1D) hydrodynamic modelling of Sungai Bertam in Bertam Valley regarding the changes of water discharge from Sultan Abu Bakar Dam. Throughout the study, we would mainly use the software to estimate the river water level to identify any flash flood occurrence probability. Hence, the seasonal update of rainfall data and the water level of river of the particular time being are fairly important to carry out the simulation.

1.2 Problem Statement

The occurrence of floods in Bertam Valley back in 23th October of 2013 was disastrous. If floods could not be prevented, at least some actions should be taken in order to send out warning signs right before floods. The simulation of hydrological model is useful to forecast the flood inundation area that could be affected by the floods. By observing the outcomes of the simulation with several necessary inputs, we could be able to stay alert and evacuate the inhabitants of that area right before the floods happen.

Furthermore, validation of the model is important for proving the accuracy of the system. There must always be a proof for everything in order to enhance the affirmative of it. In order to prove that the outcome of the analysis is trustworthy, a comparison could be made between the outcome such as water level produced by the simulation with the actual water level at that particular moment.

1.3 Research Aim

The aim of this project is to look for the final water level of the observe point with the simulation run. The project's results are simulated peak water level based on historical data and projected peak water level based on forecast data. The prediction of the highest water level of the channel points allows for the find out of the potential inundation of floods, hence able to raise awareness of the residents around.

1.4 Objectives of Running Hydrodynamic Model

1.4.1 To simulate a flood inundation of Bertam Valley using Hec-Ras model.

1.4.2 To validate and compare Hec-Ras model based on discharge value and water level.

1.5 Scope of Works

In this project, an analysis run to obtain the water profile, water depth and water velocity of a specific location which located in Sungai Bertam. With the provided water release information from TNB, we are able to identify the flow hydrograph to be input in the study. With each variation of the flow, the respective expected outcomes from the analysis are being obtain and being compared with each other.

The project is not an overcomplex hydraulic modelling that could provide detailed flood profile and accurate affected flood area. However, the study could help to determine if the water level would exceed the riverbanks and overflow to nearby residency. A precise flood inundation map would require further study and research onto this topic in the future.

1.6 Summary of Following Chapters

Chapter 2 is mainly about the literature review of related articles referred to. It indicates how well a subject at the moment including main facts and how to carry out the study.

Chapter 3 shows a detailed methodology that describes the procedures and frameworks for the research. Furthermore, it contains strategy to complete the research.

Then, we would have Chapter 4 which shows the analysis and results that had been obtained from the research done. The results allowed us to make some discussion and make validation for the accuracy of the analysis.

Lastly, Chapter 5 is to show conclusion of the whole research. The conclusion should tell if the aim and objectives of the study have been achieved or not.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, there is an inclusion of various aspects related to floods. The chapter includes explanation of river basin system, strategies and mitigation for floods, risk and hazard of floods, flood modelling as well as the elaboration of the data and materials needed.

In view of the article journals of similar topic with this study, it was shown that researchers are doing the simulations of real-life possible flooding situations because of the demand of the integrated flood risk management approach. Certainly, flood hazard is a potential threat to human life and property. Extreme floods have occurred in various parts of the world in recent years, including Malaysia, have already attracted a great number of attentions. Floods account for about a third of all natural disasters worldwide; they kill more than half of all people; they cause a third of all economic losses; and their share of insured losses is comparatively small, at less than 10% on average (Berz, 2001; Petry, 2002). Over the last ten years, communities all over the world have had to bear losses of total more than US$250 billion to compensate for the effects of floods (Berz, 2001). Economically, floods are like earthquakes and hurricanes, are a leading cause of losses from natural events; it may not be seemed important, but the combined impact of the losses from the many small and medium-sized events is significant (Berz, 2001). Despite significant investments made in a number of countries to improve flood protection in flood-prone areas such as river basins and coastal ranges, the global image of flood losses and damages has not changed much (Petry, 2002). No human place on the planet is safe from flooding; the flood threat has a much wider base of risk than any of other threats (Berz, 2001). Houses, buildings, roads, and utilities built near flood-prone areas are particularly being more vulnerable to flooding.

Some communities have learned to deal with floods and are prepared for them, while others are caught off guard when a local stream or water pond rises to a level that residents have never seen before (Berz, 2001). In this context, three factors are critical: (1) the rapid rise in the world's population, which necessitates settlement in hazardous areas; (2) refugee migration to unfamiliar environments; and (3) increased population mobility and people's desire to live in areas with a good natural environment and a desirable climate (Berz, 2001). When people first arrive at places they don’t familiar with, they tend to be not aware of possible crisis over there and will most of the time panic if nature strikes. Even if they do, people tend to forget about any incidents in any vicinity in just a short period.

Malaysia's population of over 31.8 million people contributes to the country's rich traditions, which encompass the country's diverse cultures (Martin, 2019). Malaysia is prone to flooding due to its location in monsoon zone near the equator of the earth. Flooding has the potential to threaten food production, water supply, ecosystems, infectious disease outbreaks, and vector-borne diseases (Martin, 2019). There are a few common types of flooding which could be seen more easily, that are river floods, flash floods, coastal floods, and surface floods (Maddox, 2014). There are many challenges in the access of proper management, protection and development of the water resources due to increase of population and the rivalry of usage between water and land resources (The World Bank, 2019). The hydrology of a region is defined by the accumulation, flow, and storage of water through drainage basins

(Booth, 1991). Floods are either consequences of natural phenomenon or human-related factors. Floods are said to be caused by extreme branch of meteorology associated with hydrological cycle, and they are also depend onto the permeability of soil and the geometric characteristics of the river basins (Shahzad Khattak *et al.*, 2016).

Yet, the factors that could cause floods are not only in the aspects of meteorology and hydrology but also human factor. Hydrological factors include rainfall, cyclonic storms, cumulonimbus, temperature, snowfall and snowmelt (Alaghmand, 2014). Secondly, hydrological factors comprise of soil moisture level, groundwater level prior to storm, natural surface infiltration rate, impervious layer of soil, channel cross-sectional roughness and shape, presence or absence of channel network, synchronization of run-offs from various parts of watershed and level of tide (Alaghmand, 2014). For human factors, they mean the consequences or effects caused by human activities which promote the happen of floods. For example, the sealing of ground pervious surface due to urbanization, obstruction to the flows of flood plain, poor land use practices, quarrying activity that leads to removal of trees and shrubs that increase the surface runoff (Office of Disaster Preparedness and Management - ODPM, 2017). Most of the time, flooding occurs after excessive rain on the earth surface, causing the runoffs to flow to the streams of river nearby and eventually overflow from there. The severity of flooding also depends on the period of the rising and falling of tides as the overflow from the stream or river would be harder to be extracted to the sea during high tide and of another way around during low tide. In recent years, problems related to flooding and vulnerability of the population have spiked due to numerous of factors including changes in land-use, urbanization of flood-prone sites, squatter possession of land which causes settlements and the rising number of households (Weng, 1996).

Other than that, climate change is undeniable one of the catalysts for the frequent occurrences of floods. One of the major impacts of climate change is the phenomenon of extreme precipitation which causes more and more extreme events like droughts and floods to happen (Shahzad Khattak *et al.*, 2016). This is because the increased humidity levels caused by higher temperatures and the resulting higher rates of evaporation would have an especially negative impact on the amount of precipitable water as well as the troposphere convection processes (Sherwood *et al.*, 2010). In short, we can know that there will be a noticeable rise in rainfall on a regional scale. The climate change also increases the rate of the large floods to occur more because the rain intensity might be varied throughout the process of climate change. The consequences of a flood are well-known, hence there are many countries been working hard onto the research of mitigation of flood. If a country that is located near to another cold country, the winter storms from the cold country can penetrate far into the neighbouring places (Berz, 2001). If the climatological predictions are confirmed, storm surge risk will rise along many coasts, as increasing sea levels combined with an increase in storms will increase the number of storm surges (Berz, 2001). Flood loss is expected to increase due to the uncontrolled urbanization, insufficient drainage and siltation of the water discharge points (Faiqah Maruti *et al.*, 2016). In conservative, floods are said to have claimed countless lives and adversely causing trouble to approximately 2billion people worldwide from 1998 to 2017 according to World Health Organization. More attention must be paid to flood control and damage minimization or mitigation in all practicable ways as part of the ongoing efforts to tackle climate change (Berz, 2001).

By looking at Figure 2.1, the numbers of catastrophe caused by floods are increasing by year from 1975 to 2001. The increase inclination of the numbering could be caused by various factors mentioned previously such as deforestation and overexploitation of land.

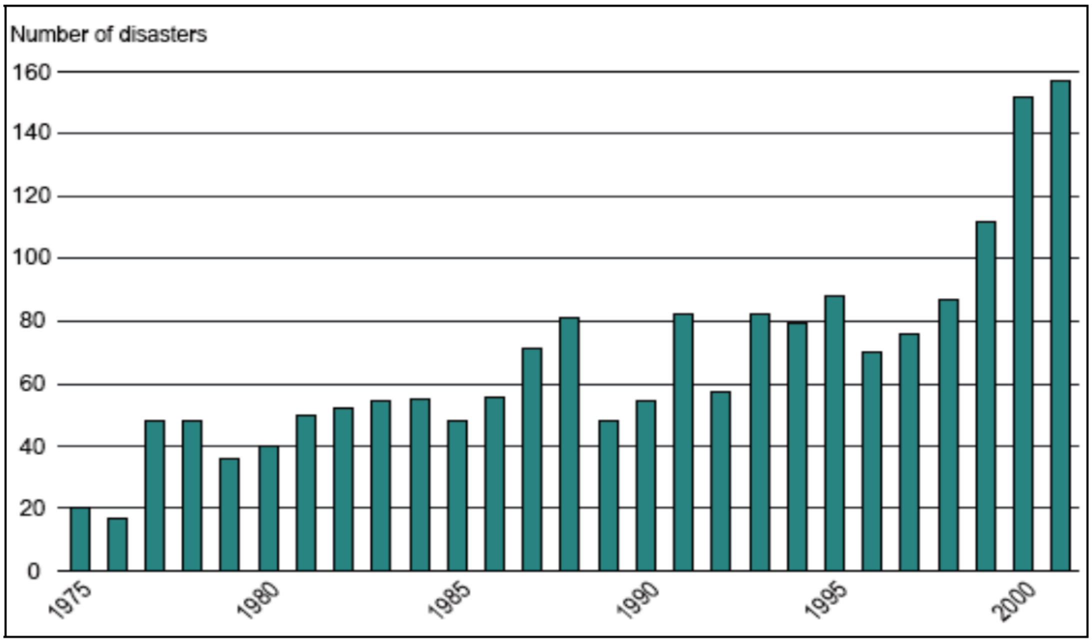

Figure 2.1 Number of Disasters Attributed to Floods from 1975 to 2001(Source: Alaghmand, 2014)

2.2 Drainage Basin System

In most cases, the frequent occurrences of floods may be caused by development of human activity as in land reconstruction or demolition of old structures which may left with solid wastes that cause difficulty for dissipation of runoff. One of the effects of development is causing changes to hydrologic condition such as reduce in drainage basin. Another impact of urbanization is that it restricts the flow of floodwaters during the occurrence of flood as the structures which covering large surface area obstruct the natural channels. Hence, drainage system is undoubtedly important to human as it provides a way for the water to travel. Drainage systems are made up of all the elements of the landscape that enable water to flow through (Booth, 1991). Natural drainage system includes the soil and the vegetation that grows on it, geologic materials underneath the soil, stream channels that bring water on the surface, and areas where water is retained in the soil and passes beneath the surface (Booth, 1991). Natural drainage system is the best drainage system in the world as the structures of it are natural and it provides the most stable hydrologic condition. There is a limitation for natural drainage system. That is, altering a natural drainage basin, whether by forestry, agriculture, or urbanization, will result in significant changes in water flow and storage (Booth, 1991). The precipitation process and the natural drainage system could be seen in the figure below.

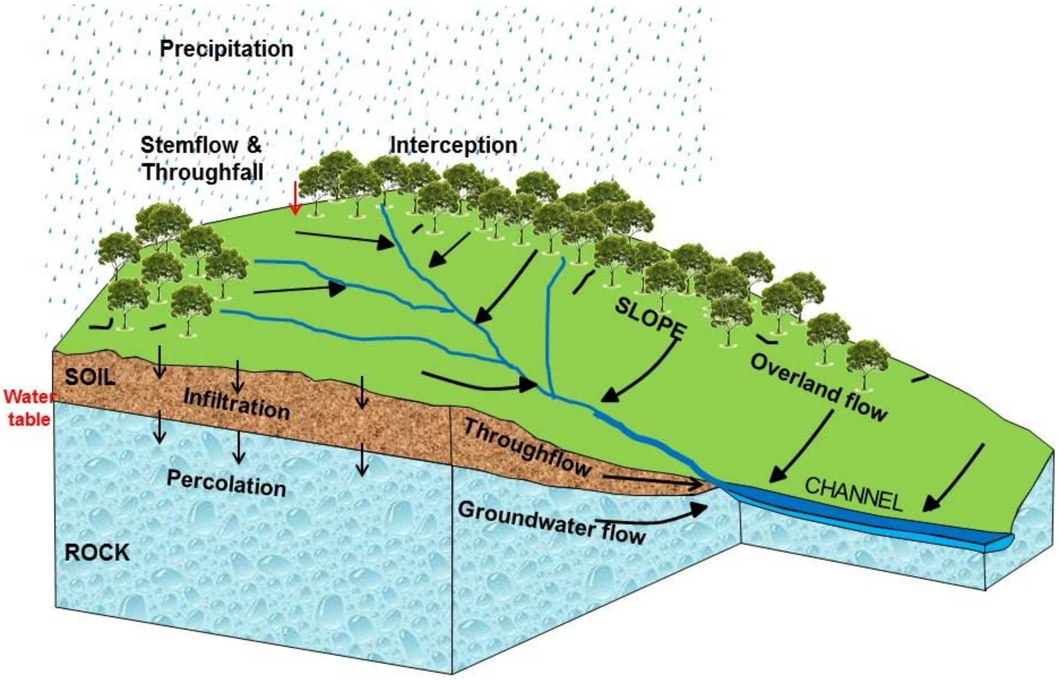

Figure 2.2: A simple drainage basin (Source: Gregory *et al.*, 2014)

A drainage basin system is said to be able to allow the flow and storage of water. This is so much efficient as the storage system of it helps to prevent or delay the occurrence of floods because it provides more time for the water to flow to the sea when large precipitation is happening. The water is travelling in stem flow, overland flow, infiltration, throughflow, percolation and groundwater flow before it reaches the temporary storage. At the final stage, the water is either being transferred to sea or lake or undergo evapotranspiration. Evapotranspiration can be said as the combination of water evaporation and transpiration from an open space to the atmosphere, where the evaporation involves the movement of water to the air from source like the soil while transpiration is the discharge of water through stomata in the plant leaves. A detailed drainage basin system process is being shown below in the Figure 2.3. The overall drainage basin system shows the paths of precipitation to transform to evaporation and sea or lake. The drainage basin system is working under atmospheric system where the water transmit from one vicinity to another beneath the atmosphere.

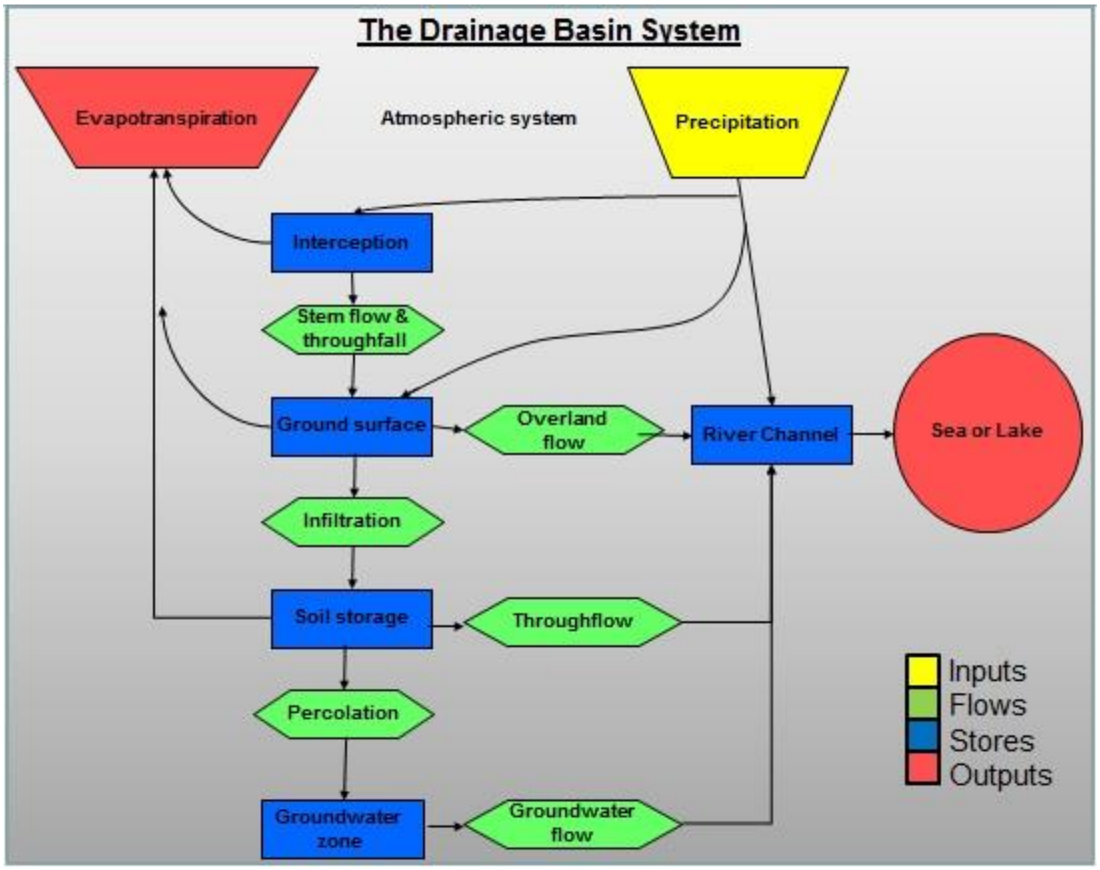

Figure 2.3: The drainage basin system (Gregory *et al.*, 2014)

In terms of reducing flood risk, there are four different methods to consider. The first strategy is called “Keep the Flood Away from People”, and it employs both structural and non-structural interventions (Alaghmand, 2014). The building of more drains in urban area causes the rate of water to travel to rivers higher than it did with natural aspects and conditions (Douglas *et al.*, 2008). As the discussion earlier did mention that, a non-structural flood mitigation plan is legitimately important and an easier method to handle with the risk. Study had shown that structural flood control is only partially effective because it was not able to overcome the floods effectively, hence there should be application of non-structural flood control plan to ensure the compensation of both sided. This is because structural flood control would cause high flows in rivers indirectly because of the massive runoff from structure surfaces and drains. The smooth surface of most of the concrete structure is one of the factors that speed up the flow of water during precipitation. The flow of water through a series of culverts and drains couldn’t varies with respect to the variable of rain intensity, but natural streams do (Douglas *et al.*, 2008). The rapid flow of water towards the rivers would increase the water level in short time. Storm runoff is a significant phenomenon that describes rainfall that enters a stream channel quickly—within a day or so of first landing on the ground (Booth, 1991). Storm runoff occurs as precipitation falls on the soil surface faster than the soil can absorb it, allowing excess precipitation to flow off the land's surface (The World Bank, 2019). Horton first identified the process in 1945, then it’s now known as “Horton Overland Flow” (HOF) and it is most common in regions of intense rainfall like tropical countries (Booth, 1991). When there is a continuous storm happening, flow patterns and runoff quantities will not be the same as it was before the storm happened as the major change is a rapid reduction in soil infiltration capacity compared with the ground when it first gets wet. Hence, water flows rapidly from the hillslopes into the river, and all parts of the drainage basin leads to the storm runoff in the channel (Hallema *et al.*, 2016). Once the capacities of the rivers reach the safety level, the water might outflow from the channel and causes floods around the area. Even if we said so, we couldn't deny the importance of a drains to humanity.

2.3 Strategies and Mitigations for Flood Handling

Most of the recent experience of flood management in urban areas provides clear examples of the need to combine structural and non-structural interventions to cope with floods, as well as the benefits of doing so (Petry, 2002). Many metropolitan communities have examples of attempts to incorporate, at least to some degree, the full variety of possible alternatives (Petry, 2002). The fact that urbanisation has, in most cases, been a phase of historical growth driven by tendencies and driving forces that have not resulted in fair use of space or coordinated planning effective solutions (Petry, 2002). In many cases, as cities grew, highly complex problems emerged, exacerbated by the need to fix adverse conditions, upgrade and restore rundown and non-operational infrastructure, build and encourage zoning concepts, and fair use of urban space in a never-ending race against time (Petry, 2002). Hence, through the study or Petry's paper, we can see that how much proper planning from time to time should be underscored in order to come up with a satisfied flood management mitigation in urban areas.

Figure 2.4 shows how devastating the flood was in Penang during the occurrence on the beginning of September of 2018 and November of 2017. The water level almost reached the engine of the car, which could be very dangerous to be drive on, as the car could run out at any time causing undesired accident. From both the events can tell that northeast part of Malaysia tends to have floods during the northeast monsoon from October to March.

Figure 2.4: Flood image in Penang on 7th September 2018 (Source: TheStar, 2021)

Figure 2.5 is showing the location of flash floods in Penang, where the submersion of roads can be seen at Georgetown and ferry being washed ashore at Butterworth on 5th November of 2017. The water only retreat after the ebb of tide happened, and at the moment, traffic at Georgetown was paralyzed due to the road being submerged in water.

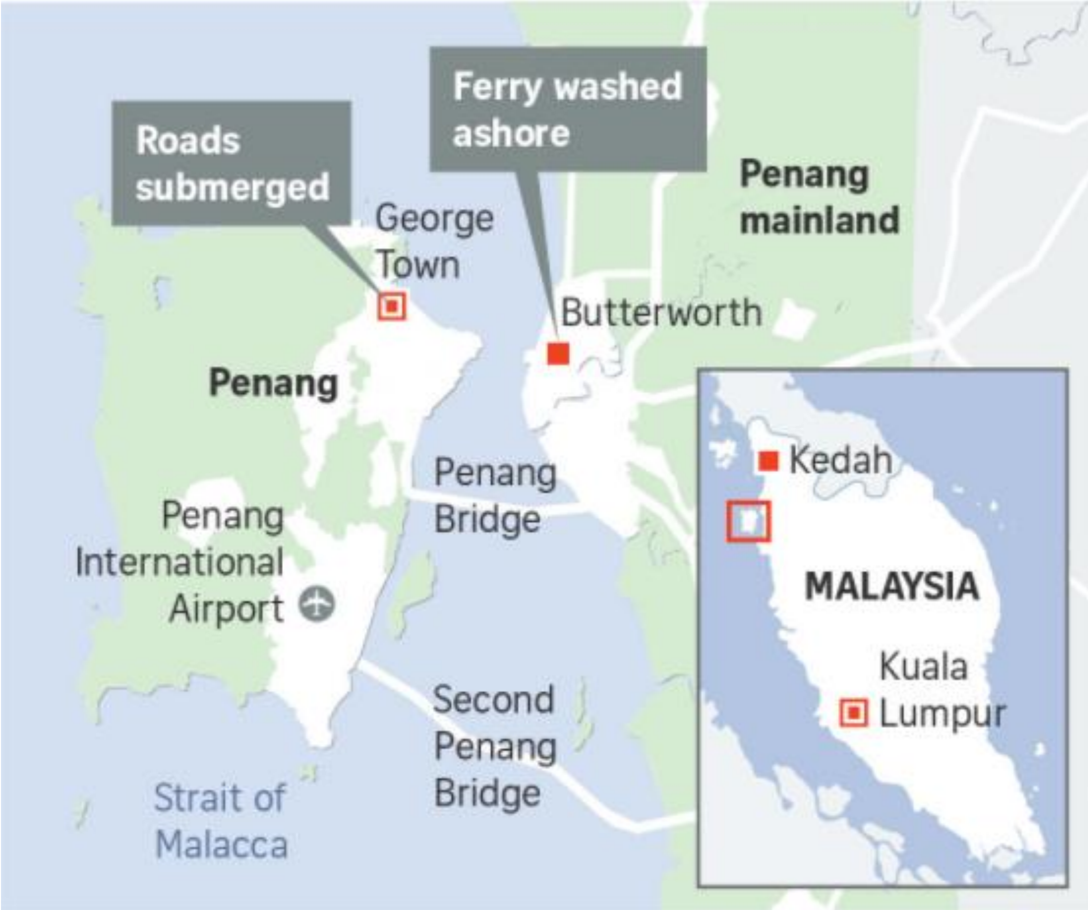

Figure 2.5: Location of Flash Floods hit in Penang on 5th November 2017 (Source: Straits Times, 2021)

As non-structural flood mitigation plan is currently still having a lot of prospects that are yet to be developed, hence usually there would be more focus to be put onto the domain of the city, giving priority to the main enterprise and administrative offices. Rather than just implement all kind of mitigation plans, public information and awareness are crucial and should be putting more attention on. The purpose of public awareness is not only to advise individuals and community basically about the possible hazards and hazardous areas but also to implant mitigation techniques onto them. Encouragement of public education for crisis mitigation could implant knowledge onto citizens as early as possible. As a democratic country, advices from all sources should be welcomed as involvement of citizens in hazard mitigation planning process. We will have to live with the catastrophe whereas reducing the flood's effects. If we could come up with more research corresponding to this field, truly it is going to be beneficial to us as in helping us to predict more preventable floods. Example of structural and non-structural hazard mitigation strategies are being shown in Table 2.1.

Table 2.1: Structural and non-structural hazard mitigation strategies (Source: Alexander, 1997)

	Structural	Non-structural
Concept	- Control over hazard - Protection of human settlement	- Hazard mitigation/ avoidance - Adjustment of human activities
Measures	- Sea walls, levees, structure of dams, break water, flood storage reservoirs, dikes, pumps, channel improvements and diversions, and groins - Strengthening buildings through building codes - Building shelters	- Land use management by planning tools (comprehensive plan, zoning, ordinance, incentives) - Infrastructure policy - Insurance - Awareness (education, information dissemination) and partnership - Protect natural areas (dunes, wetland, maritime forests, vegetation etc.) - Risk reduction and preparedness policies

The second strategy, known as "Keep people away from floods", aims to prevent the development at flood-prone areas (Alaghmand, 2014). Developers should avoid developments at low spots which are probably most of the places with low elevation of sea level height. It is smart to not stay at a place which is known likely a flood-prone area. This is because people don't wish to end up in a flood later at any time when there is a big rainfall. Hence, evasion of the selection of low spots for inhabitation in the first place is undeniably the best decision.

The third strategy, also known as “Allow floods and clean up afterward”, involves acknowledging flooding as a normal occurrence and remaining put, recognising that it will happen again in the future (Alaghmand, 2014). Sometimes, when we can’t do anything to change the situation much, the only thing we could do is to have disaster preparedness and coping with disaster once it has struck again. At the same time, what we could do is the preparation in term of psychology so that the impact that is going to land on would not be as much severe. Then, when the next disaster hits on, at least we would know what to do, as regards to the previous experiences.

The last strategy would be the combination of the three approaches mentioned formerly, which could be applied based on the real-time situation (Petry, 2002; Alaghmand, 2014). The combination of various approaches could always make a better one which comprises all the advantages of each approach respectively. The so-called ultimate approach would be showing more obvious result and it is more effective than the application of only either one of the approaches alone. As long as the approach is effective and will lead to developments from which all those concerned, the flood-prone population, in particular, can be benefited.

By using the 1D hydrodynamic model as simulation is said to be economical, and it could provide useful information on water profile properties and is a well-known preferred alternative as long as we have the identified flow paths (Ahmad and Abu, 2011) (Leow *et al.*, 2009). There is actually a numerous of thesis showing the simulation of hydrodynamic model according to the past hydrological data for validation of the accuracy of the study. As we can see how important it is for the past hydrological data, World Meteorological Organization (WMO) has been giving supports for data rescue activities in many countries all around the world (Organization, 2014). The hydrodynamic model of the past could give us a lead towards understanding and handling the flood behavior of a particular area. This can be said so because it provides a thorough outframe of the location of the study. Therefore, more information about the flood mapping could be acquired and knowing where the flash floods areas located (Zainalfikry *et al.*, 2020). Unexpectedly, there will be more flooding in larger scale in the near future. By looking into the past flood behavior of the area is probably going to ease the job during the preliminary desk study. As the purpose of preliminary desk study is usually to obtain the useful data and parameters that could probably be used in the middle of progress, a detailed flood mapping of the study area is certainly one of them. Yet, more focusses could be applied onto the inundation areas only, which further increase the effectiveness of the study. Appropriate steps are needed desperately without delay.

2.4 Risk and Hazard

Risk is what we cannot predict about, and it means the possibility of something dangerous or something that might causes harm to human being. Technically, risk is saying the uncertainty, often to be said as undesirable consequences, that are about to affect human as in health, wealth or possession. It is almost impossible to live in a world with total assurance and without any risk. Sometimes, hazard is considered to be a subset of risk (UNISDR, 2015). Risk may occur in many different forms and the risks we are about to face depends on the nature and complication of the situation, from natural disaster to consequences after human mistakes.

Next, the definition of hazard could be the source of any potential damage, destruction or adverse health effects on anything. It includes circumstances, events or substances that could cause crisis even when there is only a slight possibility. Hazard also refers to a dangerous phenomenon that is potential to happen in a given place within a specified duration of time (Alexander, 2001).

For risk and hazard related to floods, they included hydro-meteorological incidents, technological circumstances or geophysical events that could bring up failures in residential and industrial activities (Alaghmand, 2014). As the development and advances of technology of human are speeding up in recent centuries, the hazard occurring are more and more correlated to the mankind's decision. The human activities which alter the shape of geometry of natural drainage, damage of natural environments and anything that could change the water table level may radically alter the hazard's behavior pattern (Otieno, 2004). Afterall, if we are unable to prevent risk or hazard, what we could only do is to determine the possibility of it to happen in order for us to assess implication on time before things getting worse. This is in hope that the mitigation on time could help to relieve the severity of hazard that is going to happen and minimize the possible loss as much as possible.

Risk management is a strategic decision-making mechanism for minimising and managing risks in the most effective and productive ways imaginable. Countries have started to pay attention to emergency management problems in the hopes of establishing a comprehensive emergency management system that can rationally coordinate the application of people, assets, money, and associated expertise, thus reducing catastrophe losses (He and Zhai, 2021). In the late 20th century, countries like the United States (Labadie, 1984), South Korea (Kim and Lee, 1998) and Canada

(Caro and Angelis, 2001) had begun to underscore the disaster emergency management (He and Zhai, 2021). Many foreign countries have been focusing on the emergency management system's coordination and collaboration between different organization (Wenger, Quarantelli and Dynes, 1986); (Sylves and Waugh, 1990); (He and Zhai, 2021). Malaysia has recently established a new disaster management structure, the National Disaster Management Agency (NADMA) in 2015. In the Eleventh Malaysia Plan 2016-2020, Malaysia has adopted many policies and introduced a mechanism to counter natural hazards and plan economic and civil development at the same time (Martin, 2019). There is a need for Malaysia to implement disaster management plan even though it is considered as one of the safest countries from natural disasters. Floods, landslides, haze, earthquakes, and other man-made disasters, as well as some unusual cases of drought and tsunami, are the most common natural disasters in Malaysia (Martin, 2019). It has become increasingly clear that the mission to find out for more reliable and optimized ways to deal with floods requires a more holistic and broadly focused response from society as a whole, or, in other words, flood management must be the concern of everyone who lives in flood-prone areas (Petry, 2002).

2.5 Application of HEC-RAS in River Flood Modelling

A typical flood map is one of the valuable tools that could provide flood information and early warning. A flood threat map was created using a simulation of flood events based on rainfall and streamflow data in order to gain a better understanding of the effects of flooding (Faudzi, 2019). River flood hazard mapping is an unexpectedly complicated process, with substantial of uncertainties due to complications in the hydrological or hydraulic models used, the availability and quality of data, and the ambiguity of man-made judgement in the process (Moore and Jones, 1996). In order to analyse and understand the factors and impacts of flood, researchers used a number of models such as MIKE, HEC-RAS, Info Work, SWMM, and others (Faudzi, 2019). River flood model could predict future peak water level by simulate according to the forecast hydraulic data. The method of assessing flood inundation area and depth by comparing river water levels to ground surface elevation is known as river-flood-extent mapping (Alaghmand, 2014). Flood hazard maps created may give us water depth, flood covered area, flow velocity and flood duration which are basic and necessary indicators for the flood plain land-use development planning and legislation (Walesh, 1989); (Alaghmand, 2014). There are some vital data required during flood hazard mapping, that are past and former discharge records, geometry data and manning's roughness, channel hydraulic structure and historical flood inundation area (Alaghmand, 2014). Additional of aerial photos, topography, on-site photos and survey data could be helpful in the process to enhance the accuracy of the result. If the findings have been calibrated and compared to real evidence, they would be more reliable (Walesh, 1989). The Hydrologic Engineering Centre (HEC) of the US Army Corps of Engineers pioneered flood danger mapping in the United States in 1988 (Smith, 1997); (Brunner, 2010). Floodplain mapping is often used when deciding on land use in areas, assessing where there is water in a drainage basin, and determining how to disperse water in the basin (Sharkey, 2014).

The aim of the study for the creation of flood hazard maps to be used by National Insurance Program (NFIP) because private insurance industry was reluctant to give insurance policies after the losses during catastrophe (Smith, 1997). Some insurance companies might require a detailed data analysis of exact loss during the happen of natural disaster in order to fulfill the requirement of the policy of compensation to be able to redress the compassionate. In the loss analysis phase, insurers must meticulously review their claims data and draw conclusions from these evaluations in order to calculate risk-commensurate ratings (Berz, 2001). Gathering necessary data, hydrologic analysis, hydraulic analysis, and floodplain mapping using output data sets and base maps are all part of the Floodplain Mapping Process (FMP) (Alaghmand, 2014).

Hydrologic Engineering Centres-River Analysis System (HEC-RAS) is a comprehensive bundle of hydraulic analysis programs by allowing the user to interact with the system through the use of graphical user interface (GUI) (ShahiriParsa *et al.*, 2016). The software not only capable of performing steady flow analysis but also unsteady flow analysis onto water surface profile with much integrated hydraulic design calculation. HEC-RAS can also perform river simulation study onto mixed flow regimes (Agrawal and Regulwar, 2016). There are actually numerous of HEC-RAS model, flood plain zoning simulation models with dimensional approach, all sorts of governing rules of models and data requirements to be obtained from many manuals (Brunner, 2010). HEC-RAS is a famous one-dimensional (1D) software that is used to simulate floodplain (Heydari *et al.*, 2013). Despite the availability of two-dimensional models, HEC-RAS is still commonly used due to its accuracy in modelling natural streams and its low cost. (Castellarin *et al.*, 2009). HEC-RAS was previously compared to two other models, LISFLOOD-FP and TELEMAC-2D, in a report, but it was determined that HEC-RAS was the overall best modelling system among the three choices (Horritt and Bates, 2002). HEC-RAS employs a typical direct phase procedure for water surface profile calculations, assuming a one-dimensional, gradually varied and steady flow (Gharbi *et al.*, 2016). We can conduct determination of the water surfaces as either subcritical flow profile or a supercritical profile by using the computer program (Faudzi, 2019). The mixed subcritical and supercritical profiles are not calculated at the same time, which means that if the computations show that the profile should cross critical depth, the critical water surface elevation should be used to continue the computations to the next cross section (Faudzi, 2019).

Figure 2.6 shows an example of HEC-RAS 1D model of a river. The turquoise colour shades are actually indicating the water surface elevation. The red dot in the middle of the stream indicating the centre of the river. The numbering beside the river border line is used to show the ground level of each section cut.

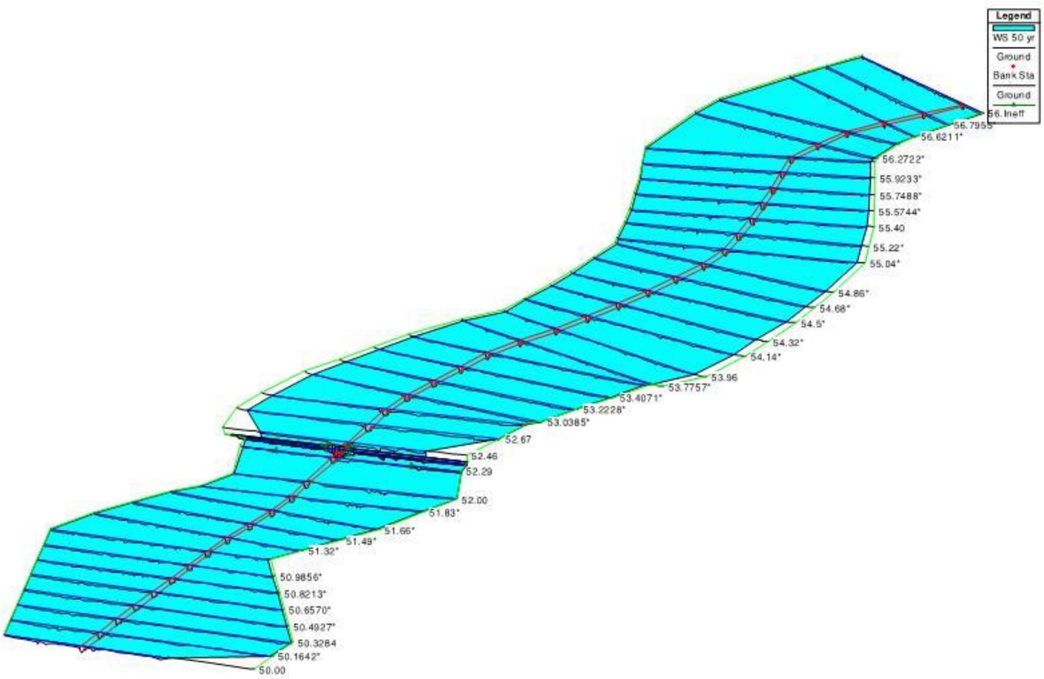

Figure 2.6: Example of HEC-RAS 1D model (Source: HEC-RAS, 2021)

Hence, HEC-RAS could predict the inundation area of floods for even 100-year return period and could indicate the location of the maximum depth too (Masood and Takeuchi, 2012). The extent of a flood area is determined by the frequency of