SIMULATION OF SEA LEVEL RISE IN KLANG COASTLINES BY USING ARCGIS

SITI FATIHAH BINTI KAMARUDIN

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : SITI FATIHAH BINTI KAMARUDIN

Date of Birth : 02nd MARCH 1996

Title : SIMULATION OF SEA LEVEL RISE IN KLANG COASTLINES BY USING ARCGIS

Academic Session : 2018/2019

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☑	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

____
(Student's Signature)

960302-03-5582
New IC/Passport Number
Date: 31st MAY 2019

____
(Supervisor's Signature)

SHAIRUL ROHAZIAWATI BINTI SAMAT
Name of Supervisor
Date: 31st MAY 2019

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : SITI FATIHAH BINTI KAMARUDIN

ID Number : AA15136

Date : 31st MAY 2019

SIMULATION OF SEA LEVEL RISE IN
KLANG COASTLINE BY USING
ARCGIS

SITI FATIHAH BINTI KAMARUDIN

Thesis submitted in partial fulfillment of the requirements
for the award of the
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

Thanks to Allah S.W.T for His willing to give me the opportunity and good health for completing my final year project and so do the thesis report. The duration of completing the final year project filled with experiences and knowledge which I could not ask more.

My special thanks goes to my supervisor Pn. Shairul Rohaziawati binti Samat and my co-supervisor En. Norasman bin Othman for their valuable guidance and continuous support in helping me during this whole time. Thank you for all the knowledge, information and ideas given related to the field of study and ArcGIS software. Thank you also for being patient, caring and tolerate with my weakness through up the whole semester.

Last but not least, I am really grateful for having a very concern parent Kamarudin bin Awang and Rosnani binti Mustapha who always supports and advices me to do well through this period and thanks to the fellow friends especially Wan Ramizah binti Wan Salleh who has helped and guided me while finishing this final year project.

ABSTRAK

Peningkatan paras air laut telah dikenal pasti sebagai salah satu ancaman utama terhadap semua hidupan di persisiran pantai dan komuniti di seluruh negara. Peningkatan paras air laut yang ketara boleh menjejaskan kegiatan ekonomi, perdagangan, perlancongan, biodiversiti dan kehidupan seharian. Peningkatan paras air laut juga boleh mencetuskan banjir, hakisan pantai dan bahaya disebabkan angin kencang yang bakal memberikan kesan besar terutamanya terhadap penduduk di kawasan tanah rendah di persisiran pantai. Kajian ini telah dijalankan sebagai salah satu usaha untuk mengenalpasti kawasan berisiko tinggi yang bakal terjejas akibat daripada peningkatan paras air laut pada tahun 2030, 2050 dan 2100. Kawasan yang telah dipilih untuk kajian ini ialah Klang, Selangor. Fenomena air pasang, perubahan iklim global, faktor antropogenik (akibat perbuatan manusia) dan banjir pantai adalah antara faktor berlakunya peningkatan paras air laut. Kajian ini telah mengunakan aplikasi Arc Geographical Information System (ArcGIS) yang merupakan alat berasaskan komputer untuk menjana hasil pemetaan dan menganalisa sesuatu perkara yang wujud atau berlaku di bumi. ArcGIS menjana hasil peta banjir yang diakibatkan oleh peningkatan paras air laut menggunakan data topografi yang diperolehi daripada laman sesawang United States Geological Survey (USGS), data paras air laut daripada National Hydraulic Research Institute of Malaysia (NAHRIM) dan data air pasang daripada National Hydrographic Centre Malaysia (NHC). Pada akhir kajian, ArcGIS akan menyediakan hasil kawasan banjir akibat kenaikan paras air laut. Pada tahun 2030 dan 2050, jumlah kawasan yang banjir adalah sama kerana hanya terdapat sedikit perbezaan kenaikan paras air laut iaitu hanya 0.115 meter dibandingkan dengan tahun 2100 iaitu 0.320 meter. Oleh itu, jumlah kawasan banjir akibat peningkatan paras air laut pada tahun 2100 lebih besar. Kawasan yang berkemungkinan untu banjir di kawasan Klang ialah kawasan yang berkedudukan rendah seperti Pulau Ketam, Pulau Klang, Pulau Selat Gering, Teluk Gong, Pulau Mat Zain dan Port Klang. Pelan mitigatasi telah dicadangkan untuk mengatasi masalah kenaikan paras air laut iaitu pemulihan SAUH dan pemecah air terendam.

ABSTRACT

Sea level rise has been recognized as a major threat to coastal habitats and community worldwide. A significant increase of sea level would hamper the economy, trade, tourism, biodiversity, and livelihood. Sea level rise plays a role in flooding, shoreline erosion and hazard from storm which would give great impact especially to low-lying coastal area. In an effort, this study was carried out to identify the risky locations that were affected in year 2030, 2050 and 2100. The selected area was located in Klang, Selangor coastline. Tide events phenomenon, global climate change, anthropogenic factors and coastal flood were among the factors that contribute to the sea level rise. This study was implemented by using Arc Geographical Information System (ArcGIS) software which was a computer-based tool for mapping and analysing things that exist and events that happen on Earth. ArcGIS would generate the data collected from United States Geological Survey's (USGS) website, National Hydraulic Research Institute of Malaysia (NAHRIM) and National Hydrographic Centre Malaysia (NHC) which were topography Digital Elevation Model (DEM), sea level rise and high tides data. At the end of the study, ArcGIS has provided the result of inundation area due to sea level rise. In year 2030 and 2050, the total inundated area was same because there were only slightly difference in the increment of projection sea level rise which was 0.115 meter compared to year 2100 which was 0.310 meter. Thus, in year 2100, the total inundated area was bigger than the previous year. The potential inundated area in Klang coastline was mostly all the low-lying area such as Pulau Ketam, Pulau Klang, Pulau Selat Gering, Teluk Gong, Pulau Mat Zain and Port Klang. Mitigation plans were proposed to overcome the sea level rise risk in Klang area which were SAUH revetment and submerged breakwater.

TABLE OF CONTENT

DECLARATION		
TITLE PAGE		
ACKNOWLEDGEMENTS		**ii**
ABSTRAK		**iii**
ABSTRACT		**iv**
TABLE OF CONTENT		**v**
LIST OF TABLES		**ix**
LIST OF FIGURES		**x**
LIST OF ABBREVIATIONS		**xii**
CHAPTER 1 INTRODUCTION		**1**
1.1	Introduction	1
1.2	Problem Statement	4
1.3	Objectives	6
1.4	Scope of Study	6
1.5	Significant of Study	6
CHAPTER 2 LITERATURE REVIEWS		**8**
2.1	Introduction	8
2.2	Type of Sea Level Rise	11
	2.2.1 Global Sea Level Rise	11
	2.2.2 Relative Sea Level Rise	12
2.3	Factors Affecting Global Sea Level Rise	12

2.3.1 Global Warming 13

2.3.2 Anthropogenic Factors 14

2.3.3 Glaciers and Ice Melting Process 15

2.3.4 Thermal Expression 15

2.4 Factors Affecting Relative Sea Level Rise 16

2.4.1 Rise and Subsidence of Land 16

2.4.2 Tidal Phenomena 17

2.4.2.1 Spring Tide 18

2.4.2.2 Neap Tide 18

2.4.2.3 Supermoon Phenomenon 19

2.4.3 Storm Surge 21

2.5 Impact of Sea Level Rise 22

2.5.1 Physical Impacts 23

2.5.2 Economic Impacts 24

2.5.3 Social Impacts 25

2.6 Case Study 26

2.6.1 Sea Level Rise at Maldives 26

2.6.2 Sea Level Rise at Terengganu 27

2.6.3 Sea Level Rise at Perak 28

CHAPTER 3 METHODOLOGY 30

3.1 Introduction 30

3.2 Methodology Chart 31

3.3 Study Area 32

3.4 Data Collection 34

3.4.1 Tide Gauge Data 35

3.4.2 Topography Data 36

3.4.3 Sea Level Rise Data 37

3.5 Arc Geographical Information System (ArcGIS) 38

3.6 Data Analysis 42

3.6.1 ArcMap 42

3.6.2 Digital Elevation Model (DEM) 43

3.6.2.1 Space Shuttle Radar Topography Mission (SRTM) 44

3.6.3 Clipping Method 44

3.6.4 Mosaic Method 45

3.6.5 Hillshade 48

3.6.6 Spatial Analyst Tools 50

3.6.6.1 Map Algebra 50

3.6.6.2 Reclassify 51

3.6.6.3 Conversion Toolbox 52

3.6.7 Selection by Location 53

3.6.8 Export Data 54

CHAPTER 4 RESULTS AND DISCUSSION 56

4.1 Introduction 56

4.2 Sea Level Rise Projection in Klang 56

4.3 Simulation of Sea Level Rise 57

4.3.1 Simulation of Sea Level Rise Scenario in Year 2030 58

4.3.2 Simulation of Sea Level Rise Scenario in Year 2050 59

4.3.3 Simulation of Sea Level Rise Scenario in Year 2100 61

4.4 Total Inundated Area 62

4.5 Mitigation Plan 63

4.5.1 SAUH Revetment 64

4.5.2 Submerged Breakwater 66

4.6 Summary 68

CHAPTER 5 CONCLUSION **69**

5.1 Introduction 69

5.2 Conclusion 70

5.3 Recommendation 71

REFERENCES 72

LIST OF TABLES

Table 3.1	Increase of Sea Level Rise from Maximum Sea Level	38
Table 3.2	Functional Categories of Spatial Analyst Used in This Study	50
Table 4.1	Sea Level Rise Projection in Klang	57

LIST OF FIGURES

Figure 1.1	Sea Level Rise at Pantai Kelanang, Banting, Selangor	2
Figure 1.2	Sea Level Rise at Kampung Sungai Meriam, Kedah	3
Figure 1.3	Sea Level Rise at Sungai Petani, Kedah	3
Figure 1.4	Sea Level Rise Due to High Tide in Pangkalan Tok Muda Jetty, Kapar, Selangor	5
Figure 1.5	Damage Happened Due to Sea Level Rise at Tumpat, Kelantan	5
Figure 2.1	Hydrological Cycle	10
Figure 2.2	Global Warming Consequences	13
Figure 2.3	Spring Tide and Neap Tide	19
Figure 2.4	Distance Between Perigee and Apogee and Its Size	20
Figure 2.5	View of Supermoon at Cardoba	20
Figure 2.6	Formation of Storm Surge	22
Figure 2.7	Sea Level Rise at Kampung Sungai Meriam, Kedah	24
Figure 2.8	Sea Level Rise Affected Economy	25
Figure 2.9	Sea Level Rise at Maldives	27
Figure 2.10	Damage and Erosion of Main Road due to Sea Level Rise at Mengabang Telipot	28
Figure 2.11	Sea Level Rise at Pantai Remis, Perak	29
Figure 3.1	Methodology Chart of This Study	32
Figure 3.2	Map of Klang District	33
Figure 3.3	Map of Klang District	34
Figure 3.4	Tide Gauge Reading at Port Klang, Selangor	36
Figure 3.5	Comparison Between Raster Data and Vector Data	41
Figure 3.6	Real World in GIS Was Forms by Several Layers Data	41
Figure 3.7	Main Display of ArcMap	43
Figure 3.8	Earth Explorer Website	44
Figure 3.9	Process of Clipping Method	45
Figure 3.10	Pixel Type and Pixel Depth of Terrain	47
Figure 3.11	Process of Mosaic Method	47
Figure 3.12	Azimuth and Altitude Value	49
Figure 3.13	Hillshading Process Occur in Klang Boundary	49
Figure 3.14	Result from Map Algebra Process	51
Figure 3.15	Result from Reclassify Process	52
Figure 3.16	Result After Raster to Polygon Process	53

Figure 3.17	Location Selection in ArcGIS	54
Figure 3.18	Final Step After Export Data Process	55
Figure 4.1	Simulation of Sea Level Rise Scenario in Year 2030	58
Figure 4.2	Inundated Area in Klang Coastline by Sea Level Rise in Year 2030	59
Figure 4.3	Simulation of Sea Level Rise Scenario in Year 2050	60
Figure 4.4	Inundated Area in Klang Coastline by Sea Level Rise in Year 2050	60
Figure 4.5	Simulation of Sea Level Rise Scenario in Year 2100	61
Figure 4.6	Inundated Area in Klang Coastline by Sea Level Rise in Year 2100	62
Figure 4.7	Proposed of Protection Area in Klang	63
Figure 4.8	Example of Adaptation Approaches for Sea Level Rise	64
Figure 4.9	Proposed Location of SAUH Revetment Location for Klang Coastlines	65
Figure 4.10	Example of Existing SAUH Revetment at Sungai Burung, Selangor	65
Figure 4.11	Submerged Breakwater at Gold Coast, Australia	66
Figure 4.12	Example of Design for Submerged Breakwater Typical Type X-Secion at Gold Coast, Australia	67
Figure 4.13	Proposed Location of Submerged Breakwater at Klang Coastlines	67

LIST OF ABBREVIATIONS

GIS	Geographical Information System
ArcGIS	Arc Geographical Information System
NAHRIM	National Hydraulic Research Institute of Malaysia
NHC	National Hydrographic Centre Malaysia
USGC	United States Geological Survey
DEM	Digital Elevation Model
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
GoM	Gulf of Mexico
TIN	Triangulated Irregular Network
DTM	Digital Terrain Model
DSM	Digital Surface Model
SRTM	Space Shuttle Radar Topography Mission
SAUH	Simplified Armour Unit ‘H’ Revetment

CHAPTER 1

INTRODUCTION

1.1 Introduction

Klang was located in the eastern part of the Selangor which was facing the Straits of Malacca. According to the Department of Statistics Malaysia 2010, Klang has 861,189 number of population. Sea level rise has been recognized as a major threat to coastal habitats and communities worldwide (Nicholls *et al.*, 2007; Mohamad *et al*., 2018). A significant increase of sea level would hamper the economy, trade, tourism, biodiversity and livelihood. The height of the ocean surface at any given location or sea level was measured with respect to the surface of the solid Earth.

Sea level could be categorized into two parts which were global sea level rise and relative sea level rise. Global sea level rise was the average height of Earth's ocean combined or relative to the centre of Earth. The consequences of global sea level rise could be even scarier than the worst-case scenarios predicted by the dominant climate models, which do not fully account for the fast breakup of ice sheet and glaciers (Richardson *et al*., 2015). The changes in ocean volumes primarily occurred because of two factors which were ice melting and thermal expansion. Meanwhile, the local or relative sea level was affected by global sea level fluctuations, rise and fall of sea surface, rise and subsidence of land also on the erosion and accretion.

Besides, the probability of sea level to become rise was higher during raining season. The changes in ocean volumes and changes in water storage on land such as dams, wetlands and soil moisture were because of increase in amount of rainfall intensities. The combination of heavy rain and strong winds would make the amount of rainfall intensities increase dramatically and even worse could create a huge sea wave. Sea would overflow due to the gravity forces and this would affect all the low- lying areas and dry land areas flooded with water. Figure 1.1 shows sea level rise happened at Pantai Kelanang, Banting, Selangor in September 2016 by Kosmo’s newspaper. Meanwhile, Figure 1.2 shows the phenomenon of sea level rise at Kampung Sungai Meriam, Kedah in September 2016 by mStar’s newspaper and Figure 1.3 shows the sea level rise at Sungai Petani, Kedah by The Malaysian Times, on October 2016.

Figure 1.1 Sea Level Rise at Pantai Kelanang, Banting, Selangor

Source: Kosmo (2016)

Figure 1.2 Sea Level Rise at Kampung Sungai Meriam, Kedah

Source: mStar (2016)

Figure 1.3 Sea Level Rise at Sungai Petani, Kedah

Source: The Malaysian Times (2016)

1.2 Problem Statement

Sea level rise was very dangerous than thought. Sea level rise due to climate change was a serious threat to countries with heavy concentrations of population and economic activity as well as ecosystem in coastal regions (Sachs *et al*., 2001: Al *et al*., 2017). According to National Oceanic and Atmospheric Administration (NOAA), sea level rise could create more floods in coastal areas and all low-lying areas would be threatened by this increased flooding phenomenon.

Sea level rise would not only give a big impact towards human and society but also to the wildlife and entire ecosystems. Rising sea level was a threat to people who live near to the ocean. As sea level continues to rise, some low-lying areas would experience more frequent flooding, especially during high tides or large storms. The most low-lying land would be totally submerged during sea level rise. People need to be displaced when flood happen and cannot going through their livelihood as usual. Furthermore, all this flooding could destroy homes, businesses, facilities and infrastructures. Malaysia lose average RM 100 million per year of conservative estimation due to floods (Baharuddin, 2007). Obviously, this would result to the reducing of economic growth in a country. In addition, public authorities need to invest huge amount of money in order to repair and upgrade all the damage happen.

Kampong Tok Muda, Kapar in Klang has been encountered the sea level rise phenomenon in 2016. The sea has been overflowed due to the sea level rise and caused all the neighbourhoods and town nearby were flooded by water. The sea level had reach to 5.3 m and has affected about 236 people from Kampung Tok Muda. There are a lot of damage of properties and facilities due to the sea level rise. All of the evacuees had been transferred to a relief centres at community hall in Kapar.

Figure 1.4 shows the high tide events that lead to sea level rise at Pangkalan Tok Muda Jetty in Kapar, Selangor by News Straits Times in September 2018 and Figure 1.5 shows the damage happened at the villager’s houses and their main roads due to the effect of sea level rise at Tumpat, Kelantan by BH Online on January 2015.

Figure 1.4 Sea Level Rise due to High Tide in Pangkalan Tok Muda Jetty, Kapar Selangor

Source: New Straits Time (2018)

Figure 1.5 The Damage Happened due to Sea Level Rise at Tumpat, Kelantan

Source: BH Online (2015)

1.3 Objectives

The aim of this study is to determine the risky locations in Klang coastlines that were affected by sea level rise. The objectives of this study are as following:

i) To identify the risky locations in Klang coastlines that were affected by sea level rise in year 2030, 2050, and 2100.
ii) To propose the mitigation plan due to the effect of sea level rise risk.

1.4 Scope of Study

The scope of this study was focused on the location in Klang area that would be affected by the sea level rise. Klang was one of the flood vulnerable areas in Malaysia. There were many people who live along the coastal areas in Klang. In addition, Klang also have become a tourist city as there were many attractive beaches and place to be visited. Klang beaches areas consist of Tanjung Harapan, Pulau Ketam, Pulau Indah, Pantai Remis, Pantai Tanjung Piai, and many others which were vulnerable to the risk of sea level rise. Other than that, people used to visit Klang because of the popular accommodation, shopping complex and recreational places which were located near to the beach areas such as Dream Garden Hotel, Port Klang Cruise Centre, Wisma GM Klang Wholesales City, Aeon Bukit Tinggi Shopping Centre, Taman Pengkalan Batu, and Taman Rakyat. This study was going to be represented by using Geographical Information System (GIS). By generating data collected from United States Geological Survey's (USGS) website and National Hydrographic Centre Malaysia (NHC), the exact location in Klang coastlines that would be affected by sea level rise in year 2030, 2050, and 2100 were provided by GIS software at the end of this study. Google Earth software was able to identify the risky lowest land areas and potential land loss in Klang coastline that would be affected due to the sea level rise.

1.5 Significant of Study

The significance of this study was to enhance public awareness about sea level rise and its consequences. Public already know the dangerous of others flood such as flash flood and how it would effect in all aspect of life. However, they were not familiar with the tremendous impact of sea level rise could be. The study was focused on the area of Klang coastlines that would be affected by sea level rise in year 2030, 2050, and 2100. Thus, public would be more alerted and care with sea level rise in their area.

Other than that, the significance of this study was to help the effort of government in reducing the number of loss of life and properties. GIS software could produce a map based on the sea level rise data accordingly to the location. Therefore, this study can be as a preventive measure for the government and public to estimate when the sea level would be rises at their place. Adversely, loss of life and properties could be reduced and prevented.

Besides, this study was to encourage public on understanding sea level rise and the modelling of that sea level rise. This is because with the map of estimated sea level rise in a certain location, government and public could identify also planning for the adaptation measures of sea level rise and be well-prepared when the times comes. Adaptation measures were necessary to reduce the adverse impacts of sea level rise and to protect the resources also the livelihood of the coastal region. Thus, it was important to educate the public about how severe sea level rise could affects everything by which the informatics and modeling could produce better warnings and evacuations.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Earth was a truly unique in its abundance of water. Water was the only natural substance that could be founded with three physical states which were liquid, solid, and gas. According to the National Aeronautics and Space Administration (NASA, 2001), water was need to sustaining life on Earth and helps tie together the Earth's lands, oceans and atmosphere into an integrated system. Water was the most basic needs to every living such as human, plant, and animal. Water was never sitting still. Indeed, water supply was constantly moving from one place to another place and from one form to another form. Thus, it was important to understand the cycle of water because things would get pretty stale without it. Hydrological cycle consists of few processes like evaporation, transpiration, sublimation, condensation, precipitation and infiltration.

Based on Figure 2.1, it was clearly shows that evaporation of water from the surface of oceans, seas and other bodies of water like rivers, streams and lakes was a process of water changes from a liquid to a gas form. Evaporation contributes to the moisture in the atmosphere and then condenses of water would take place to form clouds. Evaporation also happened because of radiant energy from the sun that heats water. According to Northwest River Forecast Center by National Oceanic and Atmospheric Administration (NOAA, 2010), solar radiation and other factors such as air temperature, vapour pressure, wind and atmospheric pressure affect the amount of natural evaporation that takes place in any geographic area. This adversely makes the water molecule became active and some of the water molecule rise into the atmospheric in state of vapour. Other than that, transpiration occurs when plants were using their roots to take in water and released it through their leaves. Transpiration process could remove and eliminate contaminants and pollutions which may produce clean water.

Meanwhile, sublimation was a process where water changes it states from solid water such as ice and snow to water vapour form. Then, condensation was a process by which water would change their state from a vapour to a liquid. In this condition, warm and humid air would rise up while the cooler air would flow downward. When the warmer air rises, the temperature tends to drop. This is because the water vapour was losing their energy and would change into liquid or ice form.

After that, precipitation would occur when the condense water vapour in clouds become too heavy to remain in the air currents and falls. Latent heat was heat that obtained from water molecule as the transition process from liquid or solid to vapour and the heat was released when the molecules condensed from vapour back to liquid or solid form, then creating cloud droplets and various forms of precipitation (Bathelt *et al.*, 2004). Precipitations would take place when the conditions of clouds were suitable to release water such as rain, snow, sleet or hail to the ground. The release water would be added to the surface water like streams and lake or infiltrate the soil to become groundwater. Infiltration process happened when the release water from precipitation reaches the Earth's surface and seeps into the ground. Therefore, there would be more infiltrations if there were more openings in the surface like cracks, pores, or joints exist. Besides, there were some of the portions from precipitations that have reaches the Earth's surface but does not infiltrate the soil and have been known as runoff. Melted snow and ice were the main sources that lead to the runoff. However, soils may become saturated with the excessive water if there were many precipitations occur and this would eventually make the additional rainfall cannot seep through the ground anymore. In this condition, the runoff would be drained into the streams, creeks, and rivers. This indirectly would be contributed to a large amount of flow water due to the added runoff. Surface water tends to flow towards the lowest point which was usually the oceans. Thus, the hydrological cycle was an integrated system which managed the flow of water supply. However, with the excessive amount of water rainfall and runoff, melting of ice and snow, and surface water during the hydrological cycle could affect the livelihood with the sea level rise phenomenon.

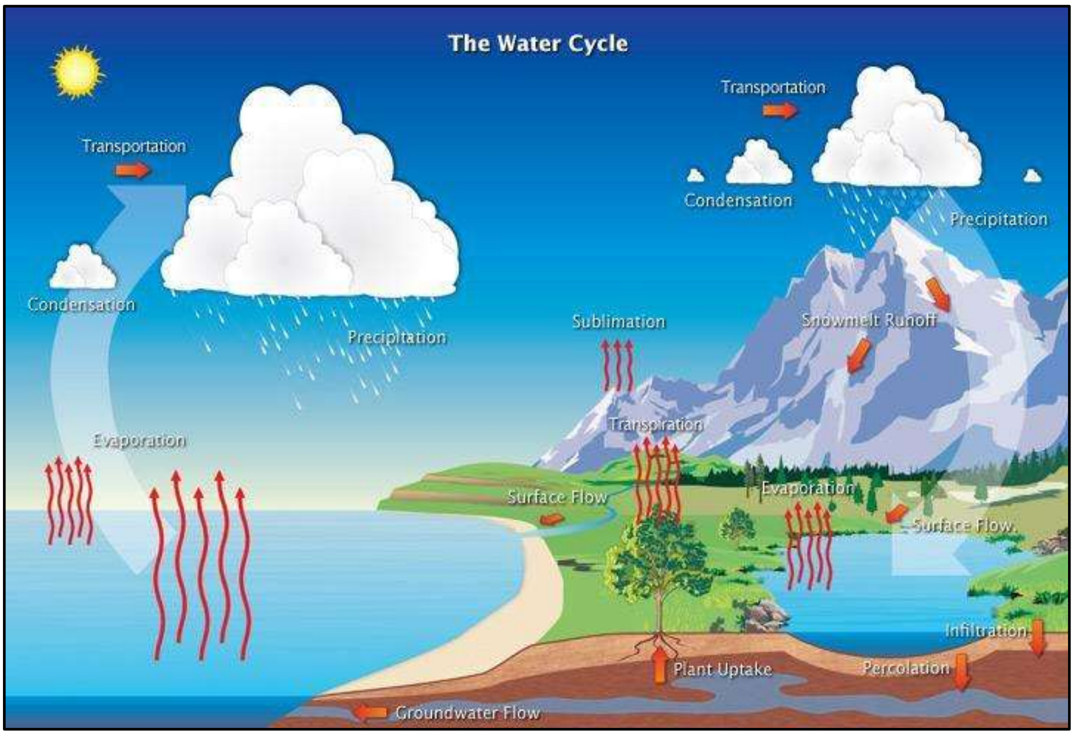

Figure 2.1 Hydrological cycle

Source: Northwest River Forecast Center by National Oceanic and Atmospheric Administration (NOAA, 2010)

Sea level rise was a situation in which most significant effects of climate change and other factors. Sea level rise in any amount would increase the frequency and duration of coastal flooding. Sea level was rising faster in recent decades. The level of the sea was varying with time and space due to the physical processes such as tides and waves. Over the Malaysia coastal lines, the sea level rise during the historical 1955-2003 period varies with location in the range 1.6-3.6 mm/yr. Meanwhile, examining the satellite altimetry data from 1993 to 2003, the sea level rise over Malaysia coastlines vary with location in the range of 3-9 mm/year (Bindoff *et al*., 2007; Taibi et al., 2019). Therefore, Malaysia was also one of the countries in the world that experiencing sea levels rise.

Rising of sea level have been recognized as a major threat to every living things and habitats in the worldwide. Coastal zones in Malaysia were used for a variety of purposes such as tourism, fisheries, transportation, mining and communication (Ramli., 2008). Sea level rise due to global warming would severely affect the coastal areas of many countries of the world through inundation of coastal areas and islands, shoreline erosion, and destruction of important ecosystems such as wetlands and mangroves. Sea level rise also could create more floods especially to those all low-lying coastal areas which definitely would affect human, flora and fauna within the flood areas nearby. Thus, all beaches activities were prohibited to all people either to local people, tourist and fisherman due to the tremendous effects of sea level rise.

2.2 Type of Sea Level Rise

Sea level rise may be classified into two categories which were global sea level rise and relative sea level rise. The Earth's surface was flat and same goes to the ocean. The ocean was never stops moving which by means the sea surface was not changing at the same rate globally. Sea level rise at certain locations was not fixed and may be more or less than the global average sea level rise. Changes in sea level occur over a broad range of temporal and spatial scales, with the many contributing factors making it an integral measure of climate change (Milne *et al*., 2009; Church *et al*., 2010). Therefore, both global sea level rise and relative sea level rise were different in measurements and factors affecting them.

2.2.1 Global Sea Level Rise

Global sea level was the average height of the Earth's ocean combined or relative to the center of the Earth. This was supported by measurements from tide gauges and satellites by which indicate that the best estimate for the average sea level rise over the last two decades was centered on 3.2 mm per year and 0.12 inches per year (Woodworth *et al*., 2015). Global sea level has risen by about 17 cm in between 1900 and 2005 which was faster rate than compared to previous 3,000 years. The rises per year may not be seemed like much but sea level was increasing over time and it adds up quickly. Since 1992, NASA has been collected data from satellites, uses tides gauges in many parts of the world in order to get a global average. In this context, the gauges block out the impact of waves and tides to get an accurate reading. The third method used by scientists was by reviewing the rock formations to determine the sea levels millions of years ago. They look for fossils of ocean organisms, sedimentary deposits, and even the actions of waves.

2.2.2 Relative Sea Level Rise

Relative sea level rise was the height of the ocean surface at any given location or sea water level which was measured with respect to the surface of the solid. Besides, the relative sea level change was the change that could be measured by a tide gauge at specific coastal locations. Relative sea level rise was the more relevant quantity when considering the coastal effects of sea level change, and it has been measured using tide gauges during the past few centuries (Cazenave *et al*., 2002). In this context, relative sea level was the most important measurement to assess the sea level rise on infrastructure, properties and ecosystems. Thus, the most vulnerable environments to the sea level rise are deltas, barrier islands, estuaries, and coral reef communities.

2.3 Factors Affecting Global Sea Level Rise

Fast development of industrial age was a phenomenon that recently occurs very rapidly and become the major cause of the global sea level rise by which increases of global warming. Rising sea level was caused by three main factors which were ocean thermal expansion, melting of the Greenland and Antarctica glacier and ice sheets and change in terrestrial storage with ocean thermal expansion as the dominant factor (Dasgupta *et al*., 2007; Parker *et al*., 2014)). Therefore, there were three factors that linked to the global warming and causes to global sea level rise which were anthropogenic factor, melting of ice sheets as well as glaciers, and the expansion of sea due to warming. The projected global warming could turn the sea level become rise through heating of ocean water which would then expand and by causing mountain of glaciers and parts of ice sheets in West Antarctica, East Antarctica, and Greenland to melt or slide into the oceans. Thus, the sea could reach to unexpected heights in the history of civilization. Therefore, this factors affecting global sea level rise need to give concern and it is important to be understand. Figure 2.2 shows the consequences of global warming.

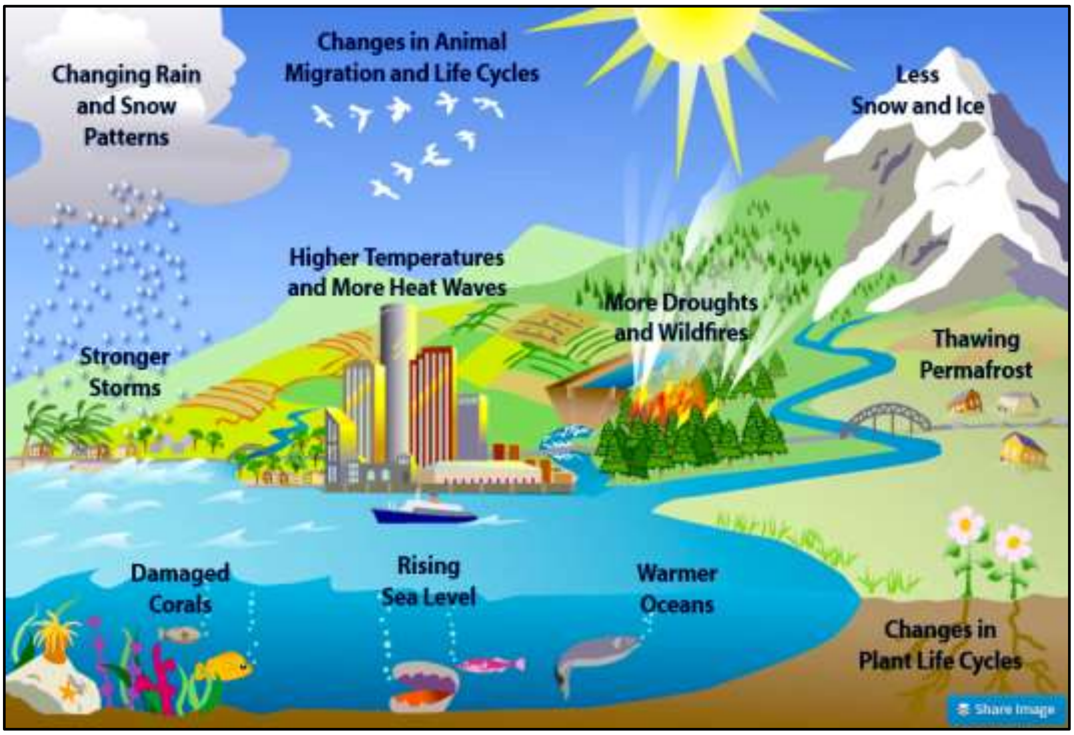

Figure 2.2 Global Warming Consequences

Source: National Aeronautics and Space Administration (NASA), Job One for Humanity (2016)

2.3.1 Global Warming

Global sea level rise occurred through the 20th Century and continued to rise due to the impacts of global warming. Based on historic data, global warming has led to a sea level rise at a mean rate of 1.8 mm/year for the past century (Douglas., 1997). Moreover, the expectation of sea level would increase during the 21st century and beyond (Meehl *et al*., 2007). Global warming refers to the rise in global temperatures because of the increasing concentrations of greenhouse gases in the atmosphere and usually happens because of anthropogenic process. Greenhouse gases were gases that trap heat in the atmosphere. This pollution of greenhouse gases usually came from cars, factories, homes, power plants that burn fossil fuels such as oil, coal, natural gas, and gasoline. In this context, carbon dioxide enters the atmosphere through burning of fossil fuels such as coal, natural gas and oil. Other than that, burning of solid waste, trees and wood products, and also as a result of certain chemical reactions like manufacture of cement. During the production and transport of the coal, natural gas and oil, gases that would be emitted were methane. Meanwhile, nitrous oxide was emitted during agricultural and industrial activities also on combustion of fossil fuels and solid waste. Each of these gases could remain in the atmosphere for different amounts of time and could be for a few years to thousands of years. However, global warming pollution knows no boundaries. Global warming not only causes the temperature on land to increase but also leads to an increase in sea warming. Therefore, the more time the gases take to remain in atmosphere, it would eventually increase the level of global warming. This is because some gases were more effective than others at making the planet warmer and thickening the Earth's blanket or ozone. Thus, global warming would make ocean gains heat and water became expanded by which contribute to global sea level rise.

2.3.2 Anthropogenic Factors

Anthropogenic effects, objects, processes, or materials were those that were derived from human activities and influences. There were many anthropogenic factors which may contribute to environmental pollution and degradation. Anthropogenic processes that influence the amount of water stored in the ground or on its surface in lakes and reservoirs, or cause changes in land surface characteristics that influence runoff or evapotranspiration rates which would perturb the hydrological cycle and cause sea level change (Wada *et al*., 2010). Such processes include impoundment in dams and reservoirs, irrigation schemes, and groundwater depletion. During industrial evolution, there were a lot of trees has been cut down and those anthropogenic activities increase the global warming and contribute to sea level rise. Other than that, burning of fossil fuels also one of the anthropogenic processes that could increase the level of global warming and the sea level. Anthropogenic factors cannot be taken lightly. This is because a worst case scenario shows sea levels rising so much that it would sink a significant portion of Malaysia. Sea level rise was a vital aspect of the environmental hazards due to its potential impacts on human population living in coastal regions and on islands. Sea level rise results in coastal floods, salt water intrusion, excessive erosion, soil salinization, deterioration of coastal ecosystems.

2.3.3 Glaciers and Ice Melting Process

More than 90 percent of the net energy increase of the climate system was stored in the ocean. Earth's oceans contain about 96.5 percent of all the planet's water and less than 3 percent of all water on Earth was freshwater that was usable for drinking. Thus, water on Earth was very abundant. According to National Aeronautics and Space Administration Earth Observatory (NASA, 2010), there were about 75 percent of the Earth's surface was covered by water. The large ice formations like glaciers and ice sheets would be naturally melt back a bit each summer which would add the sea level. Ice sheets also have long response times and so continue to respond to past climate change. According to Zhou Xiaoyin (2003), water freezes at 32° Fahrenheit (F) and boils at 212°F at sea level but 186.4° at 14,000 feet. Ice is floating because water was unusual in that the ice solid form because it was less dense than the liquid form.

Over the planet's history, Earth's sea levels have risen and fallen many times due to natural causes. During the last half-million years, Earth has gone through about half a dozen ice ages alternating with warmer periods called interglacial periods. During each ice age, water which was evaporating from the oceans would falls as snow on cold regions. Then, it would fall near to the poles and stay there becoming locked up in the form of land-based ice sheets. This causes the sea water level to drop. Thus, melting of ice sheets and glaciers would add up amount of water in the ocean adversely rising the sea level.

2.3.4 Thermal Expression

Sea level was affected by changes in the density of sea which was induced by temperature changes. When the ocean warms, sea becomes less dense and expands by means would contribute to rise of sea level. This is because at the same amount of heating, warm water would be expanded more than cold water. Besides, sea at higher pressure would be expanded more than sea at lower pressure. The primary contributors to contemporary sea level change were the thermal expansion of the ocean as it warms and the transfer of water currently stored on land to the ocean, particularly from land ice like glaciers and ice sheets (Church *et al*., 2011; Cazenave *et al*., 2014). Thus, the global sea level rise was depending on the distribution of ocean temperature change throughout the ocean. Therefore, global sea level rise due to thermal expansion was approximately proportional to the increase in ocean heat content.

2.4 Factors Affecting Relative Sea Level Rise

Factors affecting relative sea level rise consists of rise and subsidence of land, tidal phenomenon, and storm surge.

2.4.1 Rise and Subsidence of Land

Malaysia's coastline was over 4,809 km where more than 1,300 km of Malaysian beaches were experiencing erosion (Mohd *et al*., 2018). Malaysia coastal and marine areas would be affected by the sea level rise. This was due to the increase in sea surface temperature, changes in storm intensity and wave action that pose a serious threat to the society in the coastal areas. In this context, it could contribute to coastal erosion and inundation, storm surge flooding, loss and damage of physical property. According to Hari Prasad and Darga Kumar (2014), coastal erosion was recognized as the permanent loss of land and habitats along the shoreline which was resulting to the transformation of the coast.

The shoreline was the boundary of intersection between the coastal land and the surface of sea body. Due to the dynamic environmental conditions, the shape and position were keeps changing continuously. The change in shorelines were mainly occurred with waves, tides, winds, periodic storms and sea level change also on the human activities (Hussain & Yaakob., 1995). This was supported by Chang and Lai in 2014 that explained about the shoreline problems occur through decades of time scales which were related to daily, monthly, and seasonal variations in tides, currents, wave climate and anthropogenic factors. The problem of climate change especially sea level rise and its impacts on low lying coastal areas have caused worldwide attention to the management of coastal ecosystems nowadays (Cui *et al*., 2015).

Coastal erosion was always accompanied with a shoreward recession of the shoreline and the loss of land area which also largely depends on the nature of the waves. However, large waves pose a major threat to people and assets located close to the coastline, mostly due to their capability during storms (Wdowinski *et al*., 2016; Whittaker *et al*., 2016). Consequently, the impacts of coastal erosion and flood in closely populated and infrastructure rich coastal cities have received much attention. The shoreline changes its shape and size from time to time as a response to waves, currents and tides.

2.4.2 Tidal Phenomena

The tidal phenomenon was phenomenon of rise and fall of the oceans and seas. Tidal phenomenon was happening because of forces exerted by Moon and the Sun on the sea. Tidal effects have plays an important role in attempts to describe phenomenon in the solar system (Darwin, 1898; Joseph *et al*., 1975). Then, all those forces would combine with the rotation of the Earth and generates a centrifugal force. Besides, it also called as gravitational force which was varies depending on the position of the Moon and the Sun in relation of the Earth. There would be a strong tide if they were on the same side or opposite with each other. In this condition, the gravitational force of Moon and the Sun would pull the water in the oceans upwards making the oceans bulge. Meanwhile, it would be low tide when they were separated by 90°. The difference in height between the high tide and low tide was called the tidal range. The time that takes Earth to spin once around its own axis and return to the same point under the sun which lasts for 24 hours was known as solar day. Meanwhile, the time takes Earth to reach the same position in relation to the Moon which takes average of 24 hours 50 minutes was known as lunar day. Lunar day was longer than solar day due to the Moon revolves around Earth in the same direction as Earth rotates around its axis. The tides followed the lunar day since the tidal force of the Moon was more than twice as strong as the Sun’s. Tidal phenomenon could be divided into two categories which were spring tide and neap tide.

2.4.2.1 Spring Tide

Spring tide occurs when the Earth, the Sun and the Moon were in a line. The name of a spring tide comes from the notion of the tide ‘springing forth’. During full or new moons, average tidal ranges were slightly larger when the Earth, the Sun and the Moon were nearly in alignment. Spring tide has been occurred twice each month by which the Moon appears new or dark when it was directly between the Earth and the Sun. Meanwhile, the Moon appears full when the Earth was between the Sun and the Moon. However, in both cases, the gravitational pull of the Sun was added to the gravitational pull of the Moon on Earth which causing the oceans to bulge a bit more than usual. Therefore, high tides were a little higher and low tides were a little lower than average. These were called as “spring tides”, and it happen twice a month, when the Moon was full and when it’s new (Plait, 2016). Spring tides occurred twice each lunar month all year long without regard to the season.

2.4.2.2 Neap Tide

Neap tide occurs when the Sun, the Moon, the Earth were at the right angles to each other after seven days of a spring tide. According to National Oceanic and Atmospheric Administration (NOAA, 2010), the bulge of the ocean caused by the Sun partially would cancel out the bulge of the ocean caused by Moon which produces moderate tides. Therefore, in this state, high tides were a little lower and low tides were a little higher than average. Besides, neap tide occurs when the Moon appears half full which was during the first and third quarter of the Moon. Figure 2.3 shows the phenomenon of spring tide and neap tide.

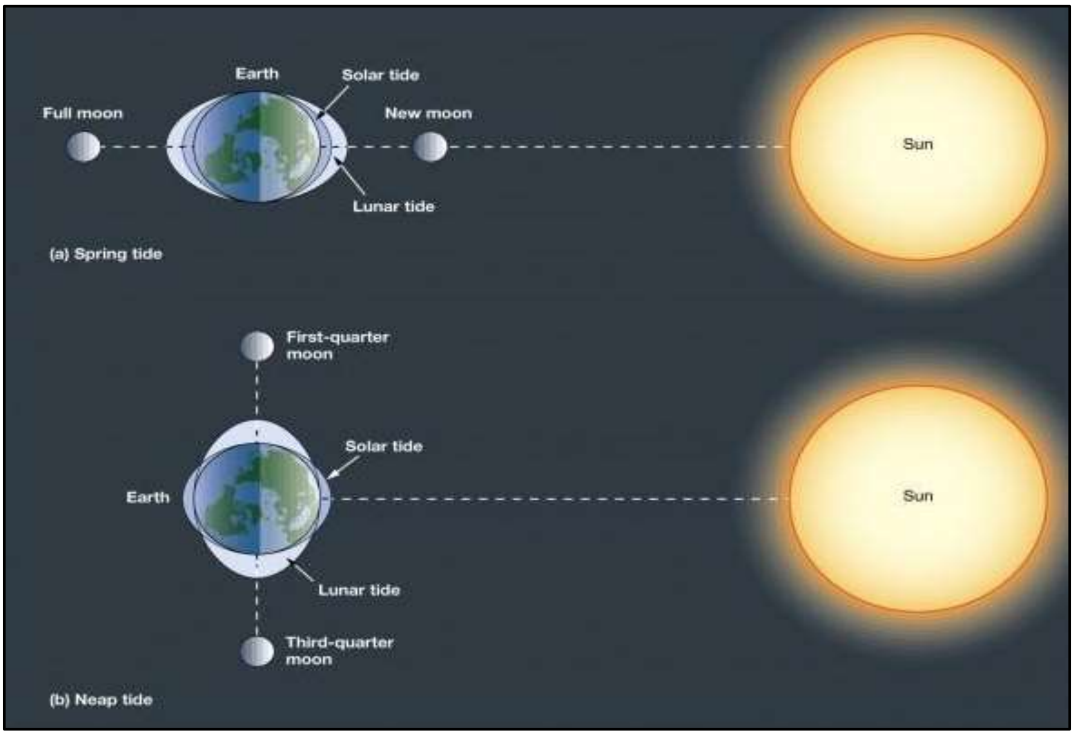

Figure 2.3 Spring Tide and Neap Tide
Source: Pearson Prentice Hall. Inc. (2004)

2.4.2.3 Supermoon Phenomenon

A supermoon was the Moon that was full when it was near its closest point in its orbit around the Earth. Moon could be categorized into two phase when it moving around the Earth which were perigee and apogee. During a full moon, the perigean spring tide pulls the slightly closer to the Earth, giving rise to a more appropriate moniker which was the supermoon (John O'Brien, 2017). Full Moon which was nearby perigee would appeared about 14 percent bigger and 30 percent brighter than full Moons that occur near apogee in the Moon's orbit. Figure 2.4 shows the distance between Perigee and Apogee and their size. Meanwhile Figure 2.5 shows the view of supermoon at Cardoba.

Figure 2.4 Distance between Perigee and Apogee and Its Size

Source: National Aeronautics and Space Administration (NASA, 2008), Popular Mechanics (2016)

Figure 2.5 View of Supermoon at Cardoba

Source: Arab News (2016)

2.4.3 Storm Surge

Storm surge was the rise in sea level caused solely by a storm. Storm surge was the abnormal rise of sea during a storm which the height of water was measured above the normal predicted astronomical tide. The storm surge was occurring because of the strong winds over the ocean combine with low pressure to push the water onshore. The amplitude at any given location of storm surge was based on the orientation of the coast line with the storm track such as the intensity, size and speed of the storm. Moreover, storm surge could produce sea levels much higher than normal high tide which would result in extreme coastal and inland flooding. Storm surges may cause severe damage to property and loss of live. In the Gulf of Mexico (GoM), a hurricane flooded Galveston Island, Texas in 1900 with the loss of over 6000 lives (Blake *et al.*, 2006; Chunyan *et al.*, 2009). Storm surge also could reach height up to 28 feet from the normal dry ground if the storm surges coincide with high tide (The Weather Channel,. 2016). Other than that, storm surges driven by strong hurricanes or extra-tropical storms could cause deaths and extensive of property loss. This was including of erosion of the beaches, damage to coastal habitats and damage of facilities and infrastructures. Figure 2.6 shows the formation of storm surge which was occurred because of climate change and lead to sea level rise.

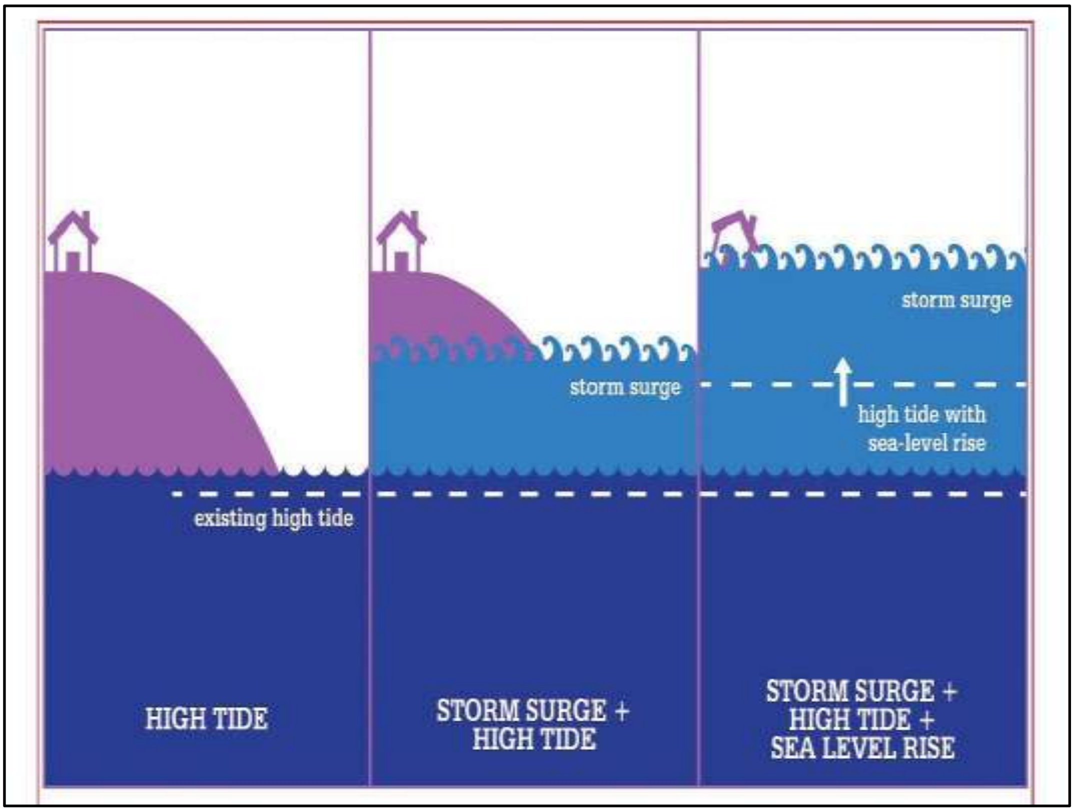

Figure 2.6 Formation of Storm Surge

Source: The New daily (2015)

2.5 Impact of Sea Level Rise

Sea level rise would severely affect the coastal areas of many countries of the world through inundation of coastal areas and islands, shoreline erosion, and destruction of important ecosystems such as wetlands and mangroves. Moreover, sea level would reduce the economy, trade, tourism, biodiversity, and livelihood and so on. Flooding and loss of land would give significant impacts on humans, economy, wildlife, and entire ecosystems. Malaysia was a coastal nation which would be faced several impacts due to the rise of sea level.

During the 20th century, there were increasing in number of populations, economies and urbanization in the coastal areas. Nowadays, low-elevation coastal zones below 10-m elevation contain about 10 percent of the world population (McGranahan *et al.*, 2007). In the 136 port cities around the world with more than 1 million inhabitants there was a total population of 400 million people, of which about 10 percent were exposed to a 1 in 100-year coastal flood event (Nicholls *et al.*, 2008).

2.5.1 Physical Impacts

Malaysia was already facing serious erosion problem where out of the 4800 km coastline, 1400 km which was 30 percent of the coastline was subjected to varying degrees of erosion. Sea level rise could create more flood areas. In addition, floods frequently happened in the southern states of Malaysia, including Selangor, Negeri Sembilan, Melaka, Johor and Pahang. About 9 percent of the land area in Malaysia was vulnerable to flooding affecting 3.5 million people (Kabir Sarkar., 2014). The flood proneness of these states could be increased due to sea level rise. Other than that, sea level rise could make damage in properties and infrastructure. Government and society need to spend a lot of money to repair all the damage happen such as bridge and road failure, facilities not functioning, and damage on houses. People who live in the flood areas also need to be transferred to other place which much more safe for them. In this case, they must follow and aware with the instruction given by the authorities because sea level rise can lead to loss of life. Figure 2.7 shows the sea level rise which had happened at Kampung Sungai Meriam, Kedah.

Figure 2.7 Sea Level Rise at Kampung Sungai Meriam Kedah
Source: mStar (2016)

2.5.2 Economic Impacts

The economic impacts could be much higher resulting in the consequences of sea level rise. Malaysia lose average RM 100 million per year of conservative estimate due to floods (Baharuddin., 2007). Sea level rise by 1 meter could flood and inundate about 100,000 ha of land planted with oil palm and 80,000 ha of land under rubber production (Chong, 2000). The main economic loss was projected to be the interruption of economic activities and principally agriculture production. The potential loss in terms of fisheries resources was related to a 20 percent loss of mangrove areas, which serve as habitat for fish juveniles (INC, 2000). This is because during sea level rise, all the beaches activities would be prohibited to all people either for fisherman, local people or tourist. According to Chamhuri *et al.,* (2009), climate change could influence food production adversely due to geographical shifts and yield changes in agriculture, reduction in the quantity of water available for irrigation and loss of land through sea level rise and associated salinization. Malaysia would be needing 5750 million US$

PPP as an additional economic cost per year for sea water level rise in 2030 (Climate Vulnerability Monitor, 2010). Coastal countries were highly prone to sea water level rise. This is because it could lead to salt-water intrusion and increased of salinity levels in agricultural land. Thus, sea level also could contaminate the drinking water sources. Figure 2.8 shows sea level rise affected the paddy field and inundated all the areas which adversely affected the economy.

Figure 2.8 Sea Level Rise Affected Economy
Source: Norwegian Institute of Bioeconomy Research (2017)

2.5.3 Social Impacts

Though it was difficult to measure the social impact of sea level rise but it was believed that many people of the coastal area would be displaced and their livelihood would be impacted. When sea level rise rapidly, even a small increase could have devastating effects on coastal habitats. People cannot go to other places because the road has been stuck and filled will water. As sea reaches farther inland, it could cause destructive erosion and wetland flooding and even worse powerful storm surges could strip away everything in path when large storms hit land. Therefore, their livelihood would be affected by sea level rise. As Malaysia has a long coastline of 4800 kilometres, some degree of sea level rise would inundate land and people of the low lying areas need to be shifted. It has been projected that 2500 people would be affected and 450 square kilometres additional land would be lost of Malaysia every year due to sea level rise by 2030 (Climate Vulnerability Monitor, 2010). A quantitative assessment of erosion on the mud coasts in Malaysia was beyond existing knowledge, but the nature of the impacts was expected to be severe. Destruction of coastal bunds could inundate 1000 km^2 of agricultural land (Midun and Lee., 1995).

2.6 Case Study

2.6.1 Sea Level Rise at Maldives

Maldives was a South Asian country which was located in the Indian Ocean. The Maldives was a tropical nation composed of 26 ring-shaped atolls which were made up of more than 1,000 coral islands. Therefore, it was known for its beaches, blue lagoons and extensive reefs. However, Maldives was the most high-risk country due to the sea level rise because it was surrounded by the beaches areas. The land area of this island country was about 300 kilometers square and none of Maldives islands has an elevation more than 3 meters above sea level rise (Tariq *et al*., 2010). Sea level rise in the major coastal cities would lead to higher costs for the city's economy. In addition, Maldives was the lowest country on Earth which had experienced the tsunami because of sea level rise on December 2004. Many islands in Maldives have been discovered by water and swallowed by the ocean due to the rising in sea level. There were 106 people had been died during the tsunami due to increase of sea level. Tsunami due to sea level rise also happened in other country like Thailand, Sri Lanka, Myanmar, Bangladesh and Indonesia. Figure 2.9 shows sea level rise that had happened at Maldives in 2004.

Figure 2.9 Sea Level Rise at Maldives

Source: National Oceanic and Atmospheric Administration (NOAA), Natty Hazards (2014)

2.6.2 Sea Level Rise at Terengganu

Terengganu was located at the east side of Malaysia which overlooks the South China Sea. Terengganu was known and popular for their tourism and ecosystem activities since they have a lot of beach that may be visited. According to the Department of Statistics Malaysia 2010, Terengganu has total area of 12,995 kilometers square. However, more than 70 percent of Terengganu was categorized as low-lying coastal area with an altitude of less than 200 meters altitude and 30 percent of the area was identified as vulnerable to flooded (Jumaat *et al.*, 2007). During December 2017, Mengabang Telipot has been encountered sea level rise due to the strong tidal waves. The Malaysia Meteorological Departments (METMalaysia) had issued a warning that Terengganu,Kelantan and Pahang would be whipped by strong north-easterly winds of up to 60 kilometers per hour which could generating waves of up to 4.5 meters and sea level rise. Consequently, almost half of 200 meters stretch of road fronting the beach at Mengabang Telipot in Kampung Kolam, Terengganu had eroded after being lashed by monsoonal tidal waves due to sea level rise. This adversely gave troublesome to the local people since the areas have been cordon off by authorities from motorist and general public to avoid any untoward incidents happened.

Figure 2.10 Damage and Erosion of Main Road due to Sea Level Rise at Mengabang Telipot, Terengganu

Source: National Hydraulic Research Institute of Malaysia (NAHRIM, 2014)

2.6.3 Sea Level Rise at Perak

Perak was a state in the Northwest of Peninsular Malaysia. Perak also one of the famous state in Malaysia that always be visited by local people and people from other countries. The capital city of Perak was known as Ipoh. In September 2016, Kampung Bagan Pancor, Pantai Remis which located in Ipoh, Perak was experienced the flooding due to sea level rise. The sea level tends to be high when the rainy season due to the increase in the number of exceptional rainfall. The existing bunds fill with sand damaged due to the risen of sea level effect. Adversely, this scenario caused the water to overflow to the nearest area. According to myMetro newspaper in September 2016, the main road of the area has been inundated to 300 meters and 15 out of 60 houses have been inundated to 0.730 meter. 76 persons have been move to the relief centre since their houses were inundated by water. There were many damage of property and facilities happens which make the villagers willingly stay awake over fears that a big flood might be happened. Figure 2.11 shows the house that has been inundated with water.

Figure 2.11 Sea Level Rise at Pantai Remis, Perak
Source: myMetro (2016)

CHAPTER 3

METHODOLOGY

3.1 Introduction

The study of sea level rise was implemented by using software known as Arc Geographical Information System (ArcGIS). ArcGIS was one of the products of Geographical Information System (GIS) by ESRI software which was include of ArcGIS Desktop 10, ArcGIS Server 10 and Image Server that have been used. ArcGIS was a computer-based tool for mapping and analysing things that exist and events that happen on Earth. ArcGIS technology could integrate common database operations with the unique visualization and geographic analysis were the benefits offered by maps. ArcGIS also was a system that could be connected with satellites and adversely could provide any data for user purposes such as elevation data and coordinate of the required data. In ArcGIS, the software already has their own map which known as a base map. This base map basically used to determine the location of a study at the first stage. However, user still can use another method that was link and could be used in ArcGIS such as Google Earth Pro Map and Earth Explorer.

Google Earth Pro Map was used in this study to determine the location of the study and also on the elevation height of the study area. For this study, Klang in Selangor was selected as the study area. Heavy concentration of populations in Klang was become one of the motivation in order to provide this flood prone map due to sea water level rise. Klang have a lot of industrial areas, development areas, residential areas, institution areas which was crowded with people. Klang also one of the areas in Malaysia that often encountered flood. Hence, sea level rise might give severe effect in Klang. Therefore, with the presence of the inundation map or flood map, the area in Klang that would be affected by sea water level rise could be identified. Government and public could use this as a preventive measure to be well-prepared and how to overcome it. Thus, at the end of this study, ArcGIS software could provide the result on which areas would have a significant potential to be flooded by the sea water level rise in year 2030, 2050 and 2100.

3.2 Methodology Chart

Methodology chart was one of the important elements in the field of study. Methodology chart acted as a guidance for all people during their accomplishment of work or study. In methodology chart would consist of selection of title study, identify the problem, study area, data collection, data analysis, results and discussion, and conclusion of the study. Thus, methodology chart would provide a clear vision on what task someone should have done. Therefore, many people or researcher found that methodology chart was very useful since it can be used as their strategy of study and help on complete the study or task within the time provided. Figure 3.1 shows the methodology chart for this study.

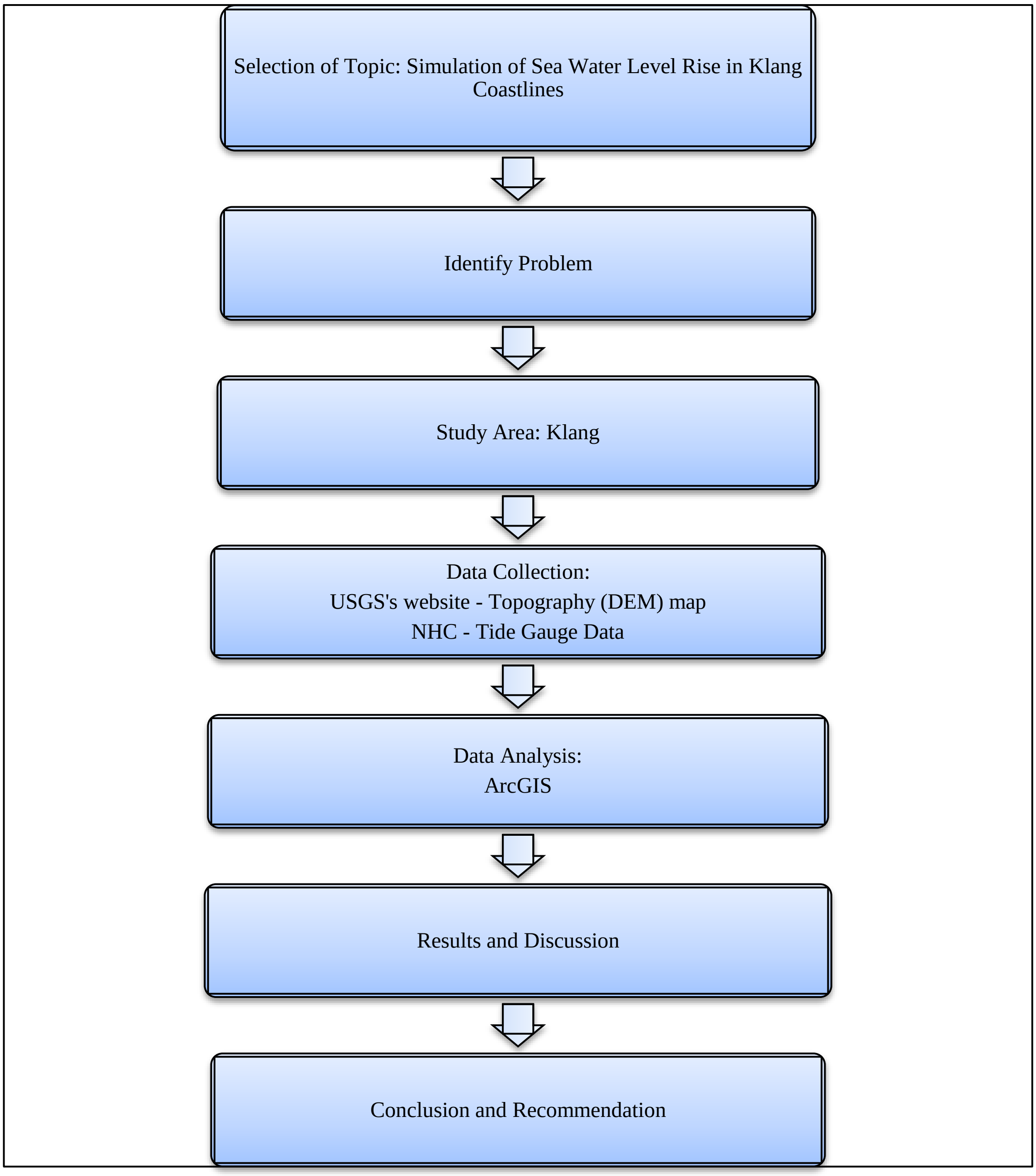

Figure 3.1 Methodology Chart of This Study

3.3 Study Area

Klang was a state of Selangor, located in the west coast part of the Malaysia. Klang consists of Mukim Klang, Mukim Kapar and Mukim Jugra. The study area falls in Klang coastal zone which extends further inlands, with total area coverage of 80,966 hectares and could be seen in Figure 3.2 and Figure 3.3. According to the Department of Statistics Malaysia 2010, Klang has 861,189 number of population. Klang was one of the flood vulnerable area in Malaysia. There were many people who live along the coastal areas in Klang. In addition, Klang also have become a tourist city as there were many attractive beaches and place to be visited. Klang beaches areas consist of Tanjung Harapan, Pulau Ketam, Pulau Indah, Pantai Remis, Pantai Tanjung Piai, Pulau Mat Zin, Port Klang, Kuala Langat, Teluk Gong and Bandar Sulaiman which were vulnerable to the risk of sea level rise.

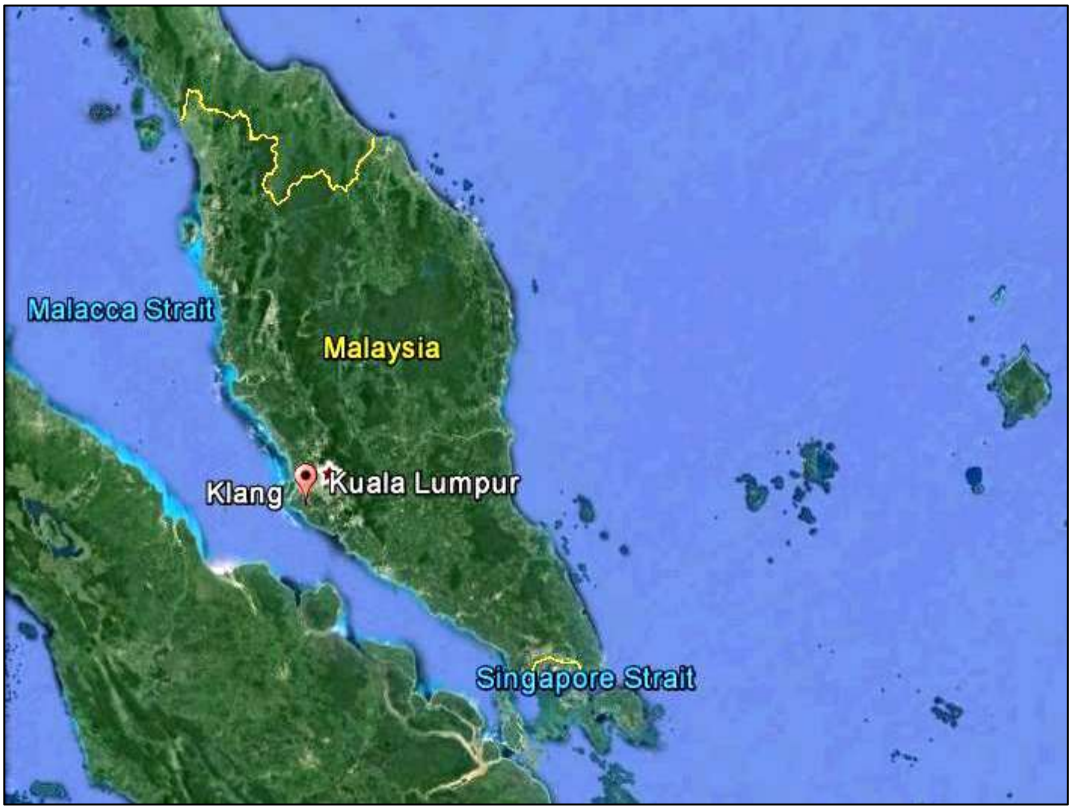

Figure 3.2 Maps of Klang District

Source: International Journal of Engineering and Technology, Vol. 10, No. 1 (2018)

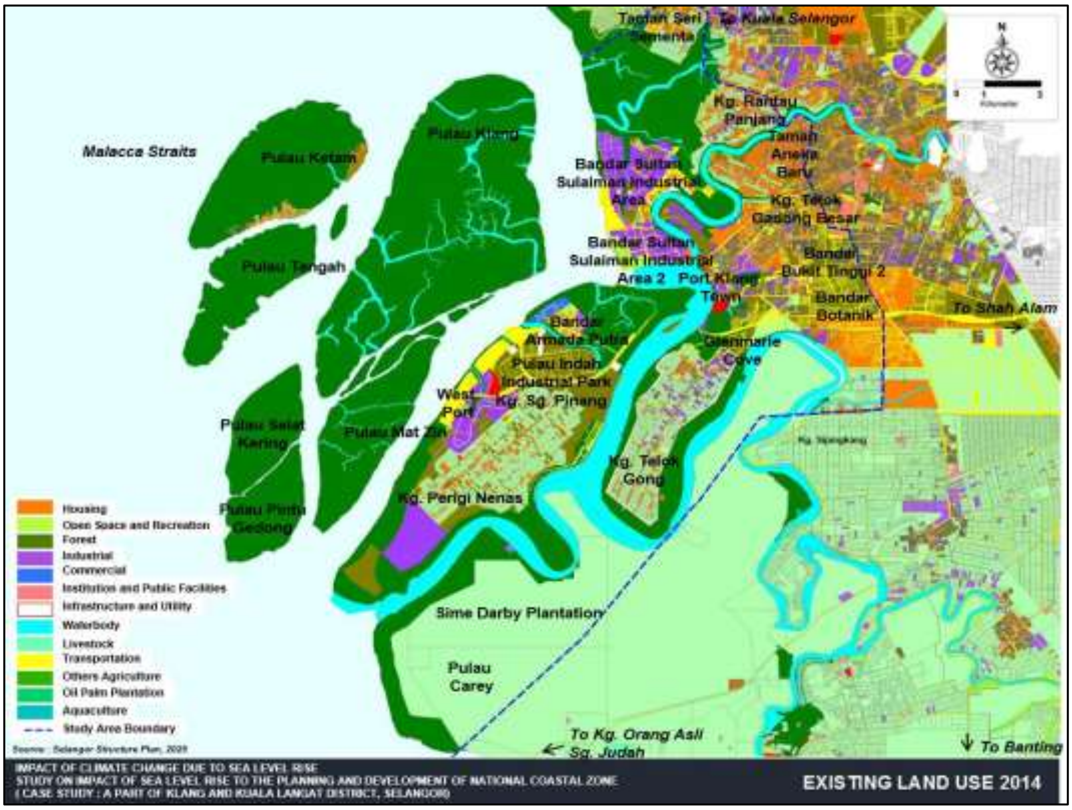

Figure 3.3 Maps of Klang District

Source: International Journal of Engineering and Technology, Vol. 10, No. 1 (2018)

3.4 Data Collection

Data collection was the systematic approach of gathering data and measuring information from variety of sources to get a complete and accurate picture of an area of interest. Accurate data collection was essential to maintaining the integrity of research, making decisions and ensuring quality assurance. There were several data that was required for this study which were related to the sources of sea level rise. The data that was needed were tide gauge data and topography map based on digital elevation model (DEM).

3.4.1 Tide Gauge Data

In this study, tide gauge data was collected from National Hydrographic Centre Malaysia (NHC). Tide gauge stations were normally installed along coasts or near islands to measure the sea level. National Hydrographic Centre Malaysia (NHC) had published Tide Tables 2017 as a guidance for researcher or local agencies to make a prediction about the current sea level especially in the monsoon season. The tide table consists of three to four readings of water reading range in the station which was recorded by days. In this study, Port Klang in Selangor was selected as a nearest tide gauge station in the Klang. The tide gauge data used in this study was the highest reading that has been identified from the tide tables. From the tide tables 2017 in the Figure 3.4, the highest tide gauge reading was recorded in 5.6 meters on 5^{th} November 2017. Thus, this value was selected as input data for maximum tide gauge reading in Klang area for this study.

Figure 3.4 Tide Gauge Reading at Port Klang, Selangor

Source: Tide Table 2017, National Hydrographic Centre Malaysia (NHC)

3.4.2 Topography Data

Topography data which was Digital Elevation Model (DEM) in Klang was collected from United States Geological Survey's (USGS) website. DEM was a numerical representation of the Earth's surface that contains the actual height points representing the topography. In addition, DEM also was a method to calculate elevations between the height points. DEM able to carry out the statistical analysis and simultaneously demonstrates the comparison of different terrain types at multiple scales of measurements (Abd Manap *et al*,. 2014). Typically, DEM was stored in a data system as a regular grid or a triangulated irregular network (TIN), digital terrain model (DTM) and digital surface model (DSM). The modelling of surface entities such as height and rainfall poses interest problems in ArcGIS. The abbreviation of DEM was used to describe a digital data set which was used to model a topographic surface since it was representing the height data. A DEM was a file rows (x) and columns (y) which was corresponding to the pixel location. The value assigned to each pixel was the z value or elevation.

3.4.3 Sea Level Rise Data

The sea level data was taken from a projection research that had been proposed by the National Hydraulic Research Institute of Malaysia (NAHRIM). The title of this research was Impact of Sea Level Rise Due to Climate Change: Case Study of Klang and Kuala Langat Districts. This research has been published on International Journal of Engineering and Technology, Vol. 10, No. 1 in February 2018. The numerical model software used in that research was MIKE 21 Flexible Mesh 2011 version with resolution of 30 meters Digital Terrain Model (DTM). The Table 3.1 shows the increase in sea level from maximum water level in year 2020, 2040, 2060, 2080 and 2100. In order to get the data of sea level rise in year 2030 and 2050, interpolation method has been used.

Table 3.1 Increase of Sea Level Rise from Maximum Water Level

YEAR	LEVEL(meter)
Baseline (2014)	X meter
2020	X + 0.06 meter (2.363 inch)
2040	X + 0.18 meter (7.086 inch)
2060	X + 0.29 meter (11.417 inch)
2080	X + 0.41 meter (16.141 inch)
2100	X + 0.53 meter (20.886 inch)

Source: International Journal of Engineering and Technology, Vol. 10, No. 1 (2018)

3.5 Arc Geographical Information System (ArcGIS)

ArcGIS was a system for capturing, storing, checking, manipulating, analysing and displaying data which were spatially referenced to the Earth. ArcGIS was a set of tools that would allow the visualization and management of geographic information, and also has an extensible architecture through which new functionalities could be added (Olaya, 2011). In this study, spatial data and spatial reference was used in ArcGIS. Spatial data generally was data that have some form of spatial or geographical reference that would enable them to be located in two or three-dimensional shape. Meanwhile, spatial reference was the reference for the spatial data that has been observed such as the location of the place.

Besides that, in order to generate data, ArcGIS required to be in a form of digital data. This is because ArcGIS does not have the 'local knowledge' regarding the location. Therefore, all of spatial data used in ArcGIS must be given a mathematical spatial reference. Almost all of the elements on the Earth's surface may be encoded so that a computer could understand them and depending on the type of information, one data model or another could be used. What was not so obvious was how to represent the real world in a digital medium (ESRI,.2010). In this context, both spatial data and spatial reference could be in a form of a pair of coordinate (x,y). The coordinate could use the value of longitude and latitude taken from the Google Earth Pro Map.

ArcGIS consist of three dimensions which were temporal dimension, attribute dimension and spatial dimension. Temporal dimension would provide a record of when the data have been collected. For example, it could be in a form liked 15:30 hours 14 February 2002. Meanwhile, attribute dimension or also known as thematic dimension was describing the characteristic of the real world features to which the data has been referred. Additional thematic data for the incidents might relate to the size and consequences. Attribute dimension often referred as non-spatial data. Then, spatial dimension could be regarded as the values, character strings or symbols that convey the user information about the location of the features being observed. Basically, spatial data structure could be constructed from three forms which were lines, points and polygons. Points was representing a pair of coordinate (x,y) and lines was a set of coordinate that define a shape. Meanwhile, polygon was a set of coordinate defining boundaries for that enclosed areas.

Spatial data model could be categorized into two parts which were in vector model and raster model. Vector model was one of the way to represent geographic phenomenon which was with point, line and polygon. Vector models were particularly useful for representing and storing discrete features liked buildings, pipeline or parcel boundaries. The vector data model was based on assumption that the Earth's surface was composed of discrete objects such as trees, rivers, lagoons and others (ESRI,.2010). In this model, there were no fundamental units that divide the collected area but the variability and characteristics of this area were collected by means of geometric entities. The coordinate has been used in the vector data to store the shape of spatial data object. It was performed in CAD Software, Shapefile, Map info table, delimited text file (with coordinates), Triangulated Irregular Network (TIN). Meanwhile, raster model was representing the geographical features by dividing the world into discrete square or rectangular cell laid out in a grid. Each of the cells described the phenomenon that have been observed and have its own values. In raster model, the world was represented as a surface that was divided into rectangular grid of cells. When at least one of the raster (x,y) grid was known, then it could be located in geographic space. Raster model were very useful for storing and analysing data that was continuous across an area. In addition, raster model could include images and grids such as satellite image, scanned map and topography. Grids represent derived data that often have been used for analysis and modelling. Grids also could store continous values such as elevation surface. Both data model was complementary and coexist within GIS, although each of them was more or less appropriate for studying a specific type of information (Del Bosque González et al., 2012).

ArcGIS could be used in many applications. In this context, ArcGIS could be used in resource survey when want to estimate the land use and forest development. Then, in change of monitoring where they want to identify the illegal constructions and coastal changes. In pollution monitoring also could use ArcGIS to know the waste emission. Besides that, ArcGIS could be used in hazard survey of landslide and also in cartography. Figure 3.5 shows the comparison between raster data and vector data. Meanwhile, Figure 3.6 represent the real world in GIS which was forms by several layers of data.

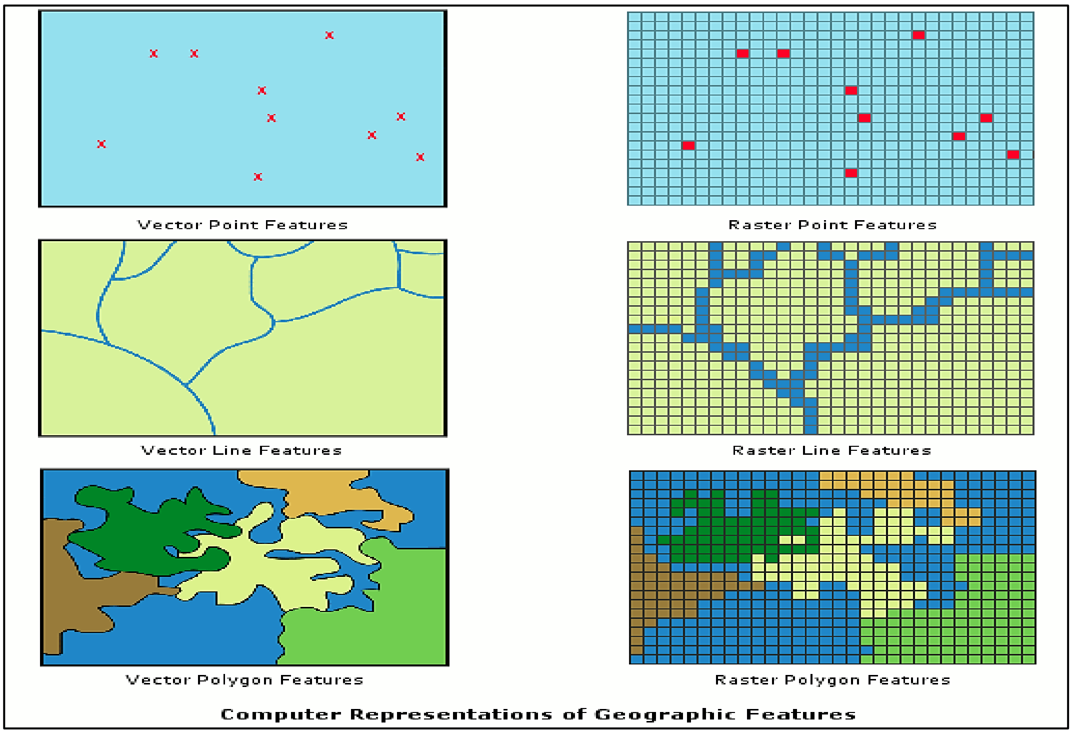

Figure 3.5 Comparison Between Raster Data and Vector Data

Source: Hertfordshire Country Council (2016)

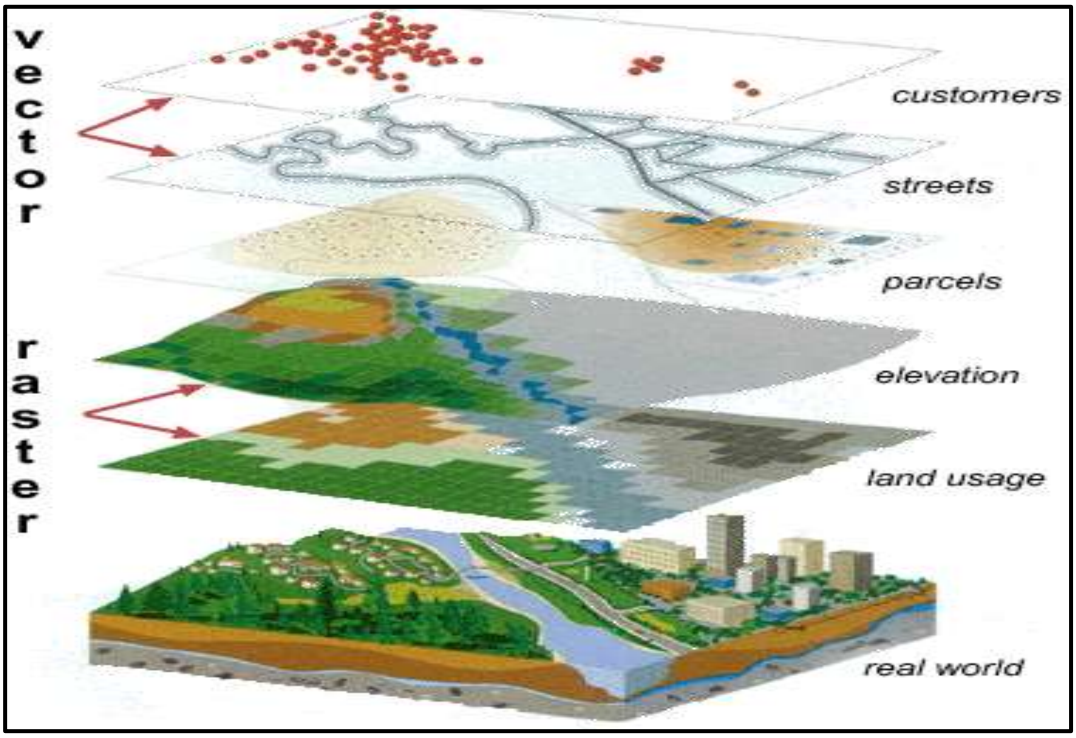

Figure 3.6 Real World in GIS was Forms by Several Layers Data

Source: Esri ArcGIS (2018)

3.6 Data Analysis

Data analysis was the process of evaluating data by using analytical and statistical tools to discover useful information and aid in decision making. Data analysis entails a process from exploring, understanding, cleaning, transforming, modelling, presenting and ultimately coming to a goal where translation of data into valuable information can be done analysis.

3.6.1 ArcMap

ArcMap was a platform that allow user to display and explore GIS datasets for their study area. ArcMap could provide function such as create map layouts, assign symbols, overlay map layers, editing map online, analysis for building services and maintenances and others. Such a tailored ArcMap environment would enable engineers with different level of knowledge of GIS, to investigate and compare results of applying different criteria, constraints and scoring schemes on the final suitability map for a landfill site in an area (Roozbeh et al., 2004). Figure 3.7 shows the ArcMap which was the central application used in ArcGIS.

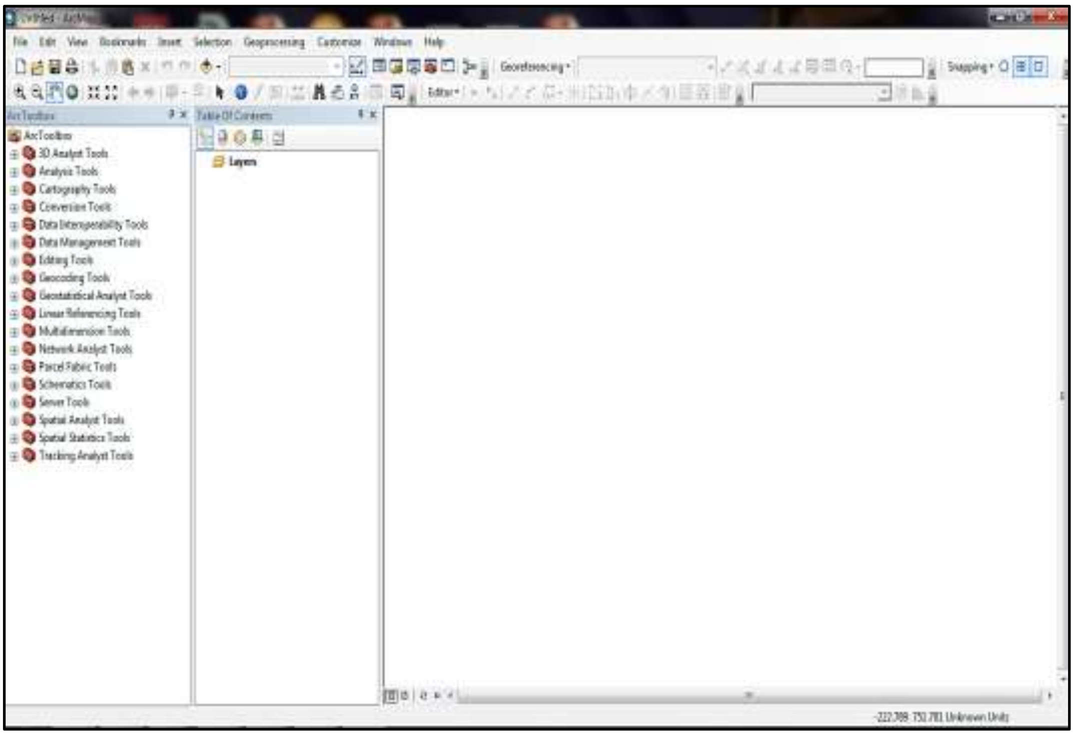

Figure 3.7 Main Display of ArcMap

Source: Geographical Infromation System (GIS), ArcMap

3.6.2 Digital Elevation Model (DEM)

A digital elevation model (DEM) was the most basic and interesting geographical data type. Digital Elevation Model (DEM) was a specialized database that represents the relief of a surface between points known elevation. ArcGIS software could use the DEM for 3D surface visualization, generating contours, and performing view shed visibility analysis. There were many types of DEM such as ASTER, LIDAR, SRTM, NED and so on. Each of the DEM have their own superiority and advantage. In this study, Space Shuttle Radar Topography Mission (SRTM) was used as a base terrain for the inundation map due to sea level rise in Klang coastlines. All the elevation value for this area also would be automatically downloaded concomitant with the DEM which already was in the TIFF file format.

3.6.2.1 Space Shuttle Radar Topography Mission (SRTM)

Space Shuttle Radar Topography Mission (SRTM) was a good source of DEM data for almost everywhere in the world which available at 90 meter and 30 meter resolution (Ramaraju et al., 2015). In this study, SRTM 1 Arc-Second Global which was resolution of 30 meters has been used as a raster data in ArcMap and altitude information of a location also was provided. The DEM data of SRTM was downloaded from United States Geological Survey's (USGS) website without any charges included. Figure 3.8 shows the main page of USGS's website.

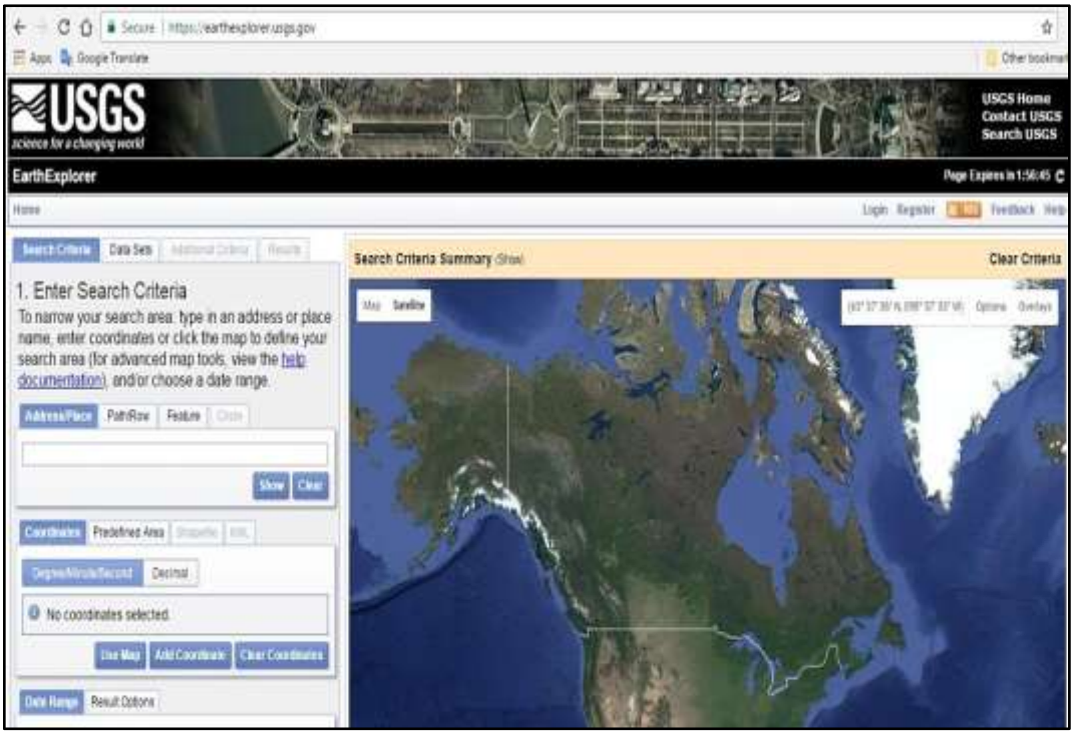

Figure 3.8 Earth Explorer Website
Source: United States Geological Survey (USGS)

3.6.3 Clipping Method

The Digital Elevation Model (DEM) which was Space Shuttle Radar Topography Mission (SRTM) 30 meters in Klang area have been used as the base terrain in one of the product in Arc Geographical Information System (ArcGIS) known as ArcMap. However, the area of the terrain need to be limited only in Klang region. Thus, shape polygon in Figure 3.9 was designed and sketch by using sketching method accordingly to the boundary line in the imagery base map. The polygon has been stored in ArcCatalog and save as a shapefile. This study was continued by using clipping method. Clipping method would be used when the situation required to overlay a polygon on one or more target features or layer. In this study, clipping method serves to clip only those terrain of DEM that overlay with the polygon designed before. All other area would be discarded and was no longer part of the polygon feature. The shapefile in the ArcCatalog has been created to become a mold in order to get a new DEM around Klang area. ArcToolbox could be found in the 'Geoprocessing' and could be dragged at the side of the ArcMap. In the ArcToolbox, click on Data Management Tools and Raster. Then, choose Raster Processing and Clip function would be appeared.

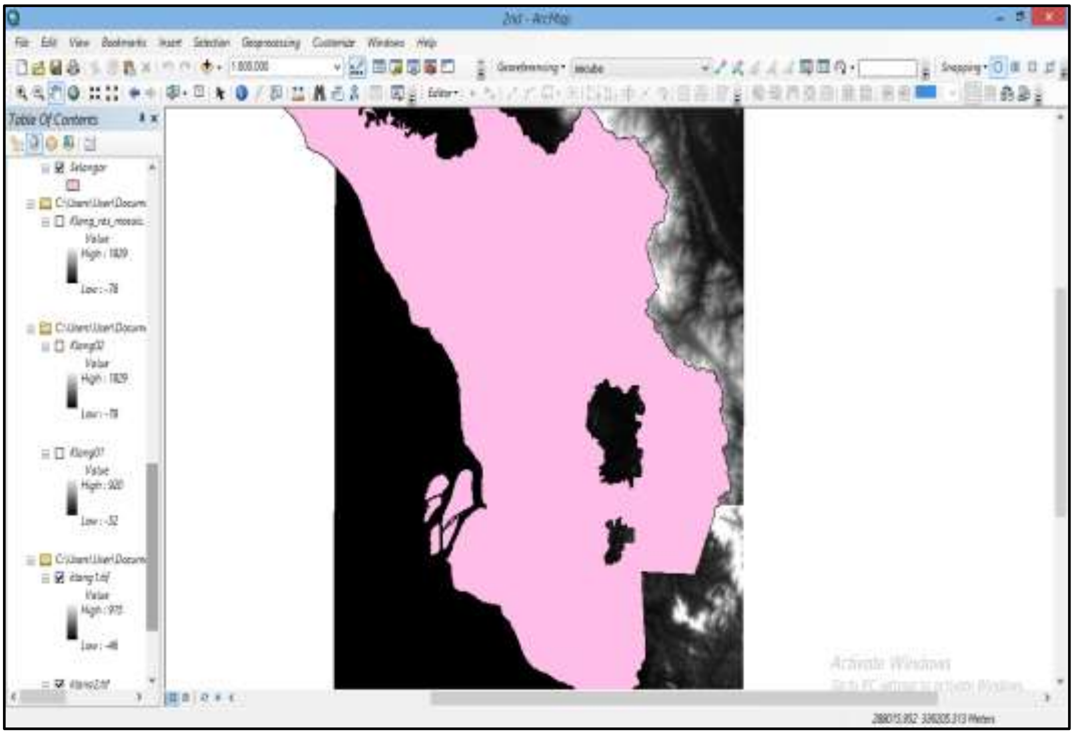

Figure 3.9 Process of Clipping Method
Source: Geographical Information System (GIS), ArcMap

3.6.4 Mosaic Method

Mosaic method was used to merge or combined the raster data. By using the tool of Mosaic to New Raster, the raster data which was the DEM terrain could be combined together and became a new raster output. In this study, there were two of terrain for the Klang area. Therefore, to merge the two terrain and became only one full terrain, mosaic method has been used. Before using mosaic method, make sure to check the Pixel Type and Pixel Depth. This could be done by checking the properties of the terrain. For this study, Pixel Type was signed integer and Pixel Depth was 16 Bit which could be seen in Figure 3.10. In the ArcToolbox, Raster Management Tools followed by Raster and Raster Dataset have been chosen. Then, run the tool of Mosaic to New Raster to do the mosaic method. The terrain that already combined together was shown in Figure 3.11.

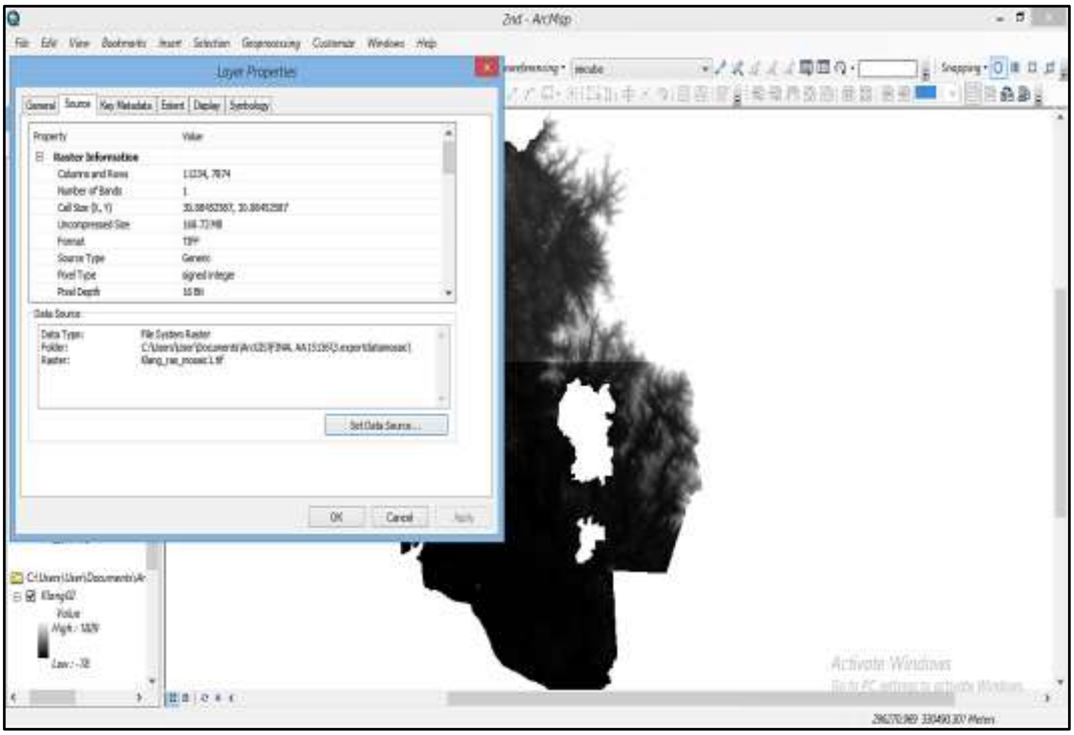

Figure 3.10 Pixel Type and Pixel Depth of Terrain

Source: Geographical Information System (GIS), ArcMap

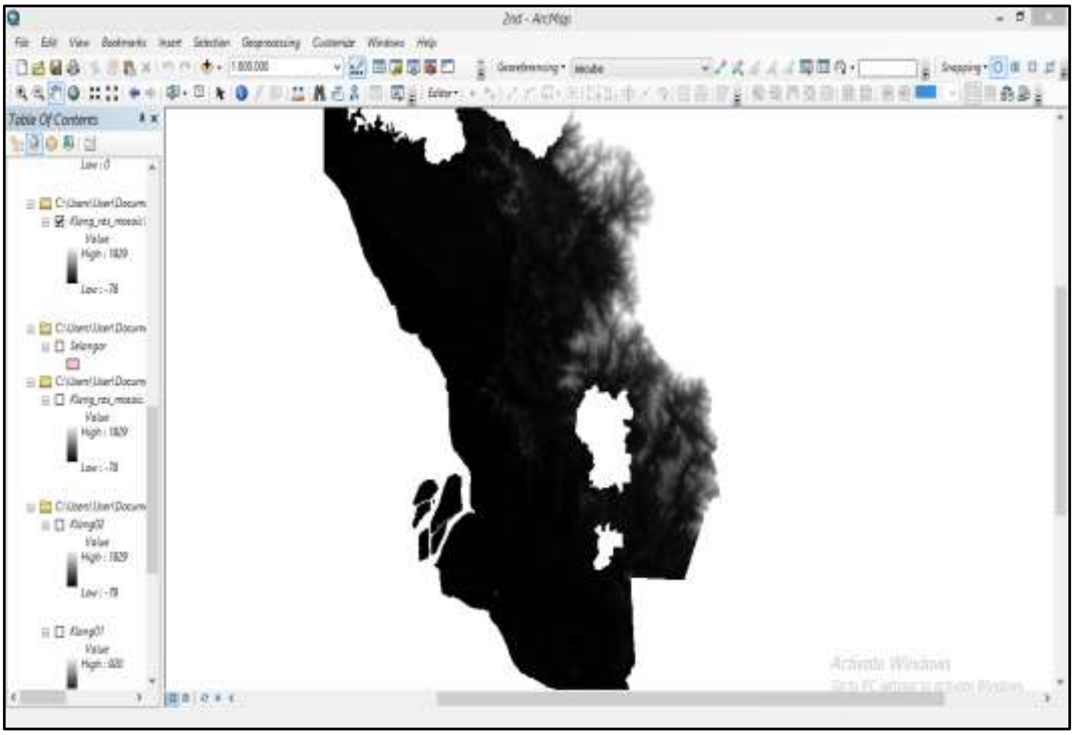

Figure 3.11 Process of Mosaic Method

Source: Geographical Information System (GIS), ArcMap

3.6.5 Hillshade

Hillshade was used in map-making process. From the raster data of terrain, a grayscale model of the terrain could be generated with sun's relative position taken into account for shading the terrain. Figure 3.12 shows the Azimuth and Altitude value used for this study which was determined relatively to the sun's position. Hillshade would produce the effect of 3D which represent the surface of the Klang area. Thus, location with high and low elevation in Klang area could be determined from the result of the hillshade. The section of hillshade also could be found in the ArcToolbox. Spatial Analyst and Hillshade has been clicked and the result shown in Figure 3.13.

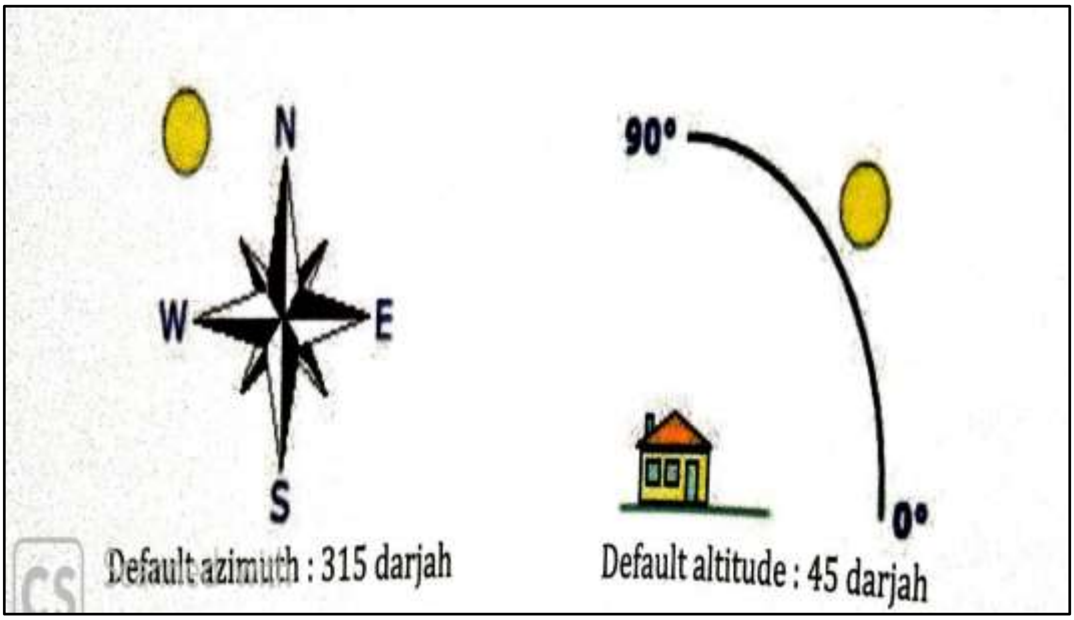

Figure 3.12 Azimuth and Altitude Value

Source: Seronoknya Belajar ArcGIS Jilid 1 (2017)

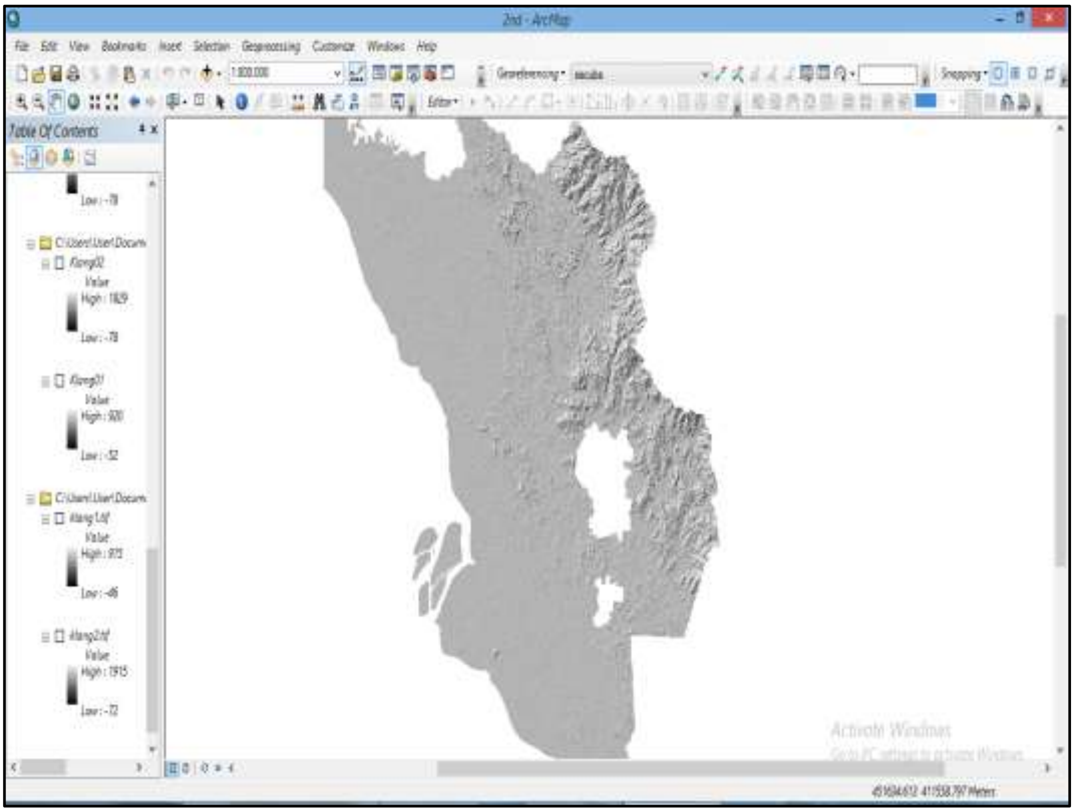

Figure 3.13 Hillshading Process Occur in Klang Boundary

Source: Geographical Information System (GIS), ArcMap

3.6.6 Spatial Analyst Tools

Spatial analyst tools consist of several different function. The ArcGIS Spatial Analyst extension provided many set of spatial analysis and modeling for both vector and raster data. With this extension, a wide range of data formats to combine datasets, interpret new data and perform complex raster operation could be employed. In this study, Spatial Analyst extension was used to derive new information from the existing data such as slope, hillshade, elevation raster and others. Table 3.2 shows the functional categories of spatial analyst used in this study.

Table 3.2 The Functional Categories of Spatial Analyst Used in this Study

Toolset	**Description**
Map Algebra	By creating expressions in an algebraic language, Map Algebra was a way that could be used to perform spatial analysis. Map Algebra expressions could be easily created and run by using the Raster Calculator.
Reclass	The Reclass tools provide a variety of methods that allow the user to reclassify or change input cell values to alternative values.
Surface	With the Surface tools, the user could quantify and visualize a terrain landform represented by a digital elevation model.

Source: ArcGIS for Desktop Website (2010)

3.6.6.1 Map Algebra

Map Algebra was a simple and powerful algebra which could executed all Spatial Analyst tools, operators, and function to perform geographic analysis. For this study, Map Algebra was a first stage to develop sea level rise model in ArcMap. Sea water may flow using the elevation data of study area if there were no such function as the extension provided. During this process, the flood happened was not involve of sea level rise. The section of Map Algebra could be found in the ArcToolbox with the parts of Spatial Analyst tools. Raster Calculator which was a subsection of Map Algebra was used to run the total projection of sea level rise at Klang coastlines. The result from this extension would show two different colour in the terrain data. The blue colour in Figure 3.14 indicate that the total region was calculated by the Map Algebra calculator. Meanwhile, the green colour represent the lower elevation area in Klang coastlines boundary that was exposed to the sea level rise risk.

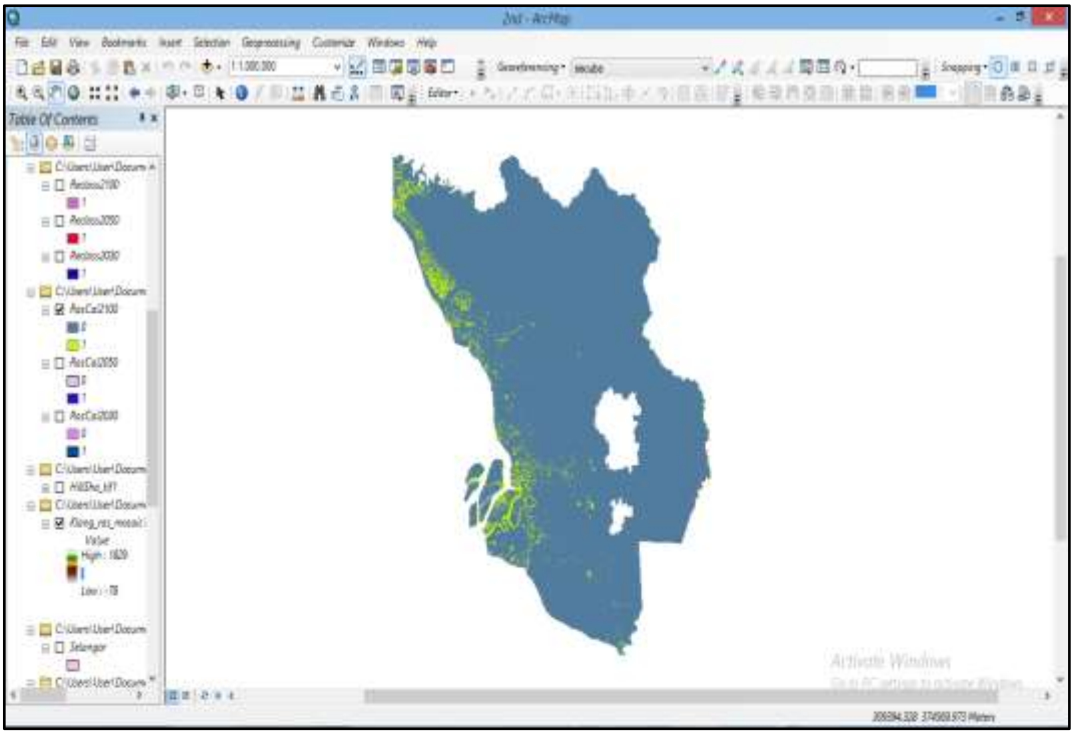

Figure 3.14 Result from Map Algebra Process

3.6.6.2 Reclassify

Reclassify was the process to reclass or change the values in a raster. In this study, reclassify was used to separate the terrain region between the flooded area due to sea level rise and the regions that does not flooded by sea level rise. Reclassify was used to create the model of inundation map by sea level rise. Reclassify could be found in the ArcToolbox within Reclass subsection in the Spatial Analyst Tools. In Figure 3.15, the pink colour was the result for the reclassify process which was represent the low-lying areas that have been submerged by sea level rise. Eventually, this process was related to the previous step of Map Algebra. Thus, the input raster data used in this reclassify process was based on the output results of Map Algebra.

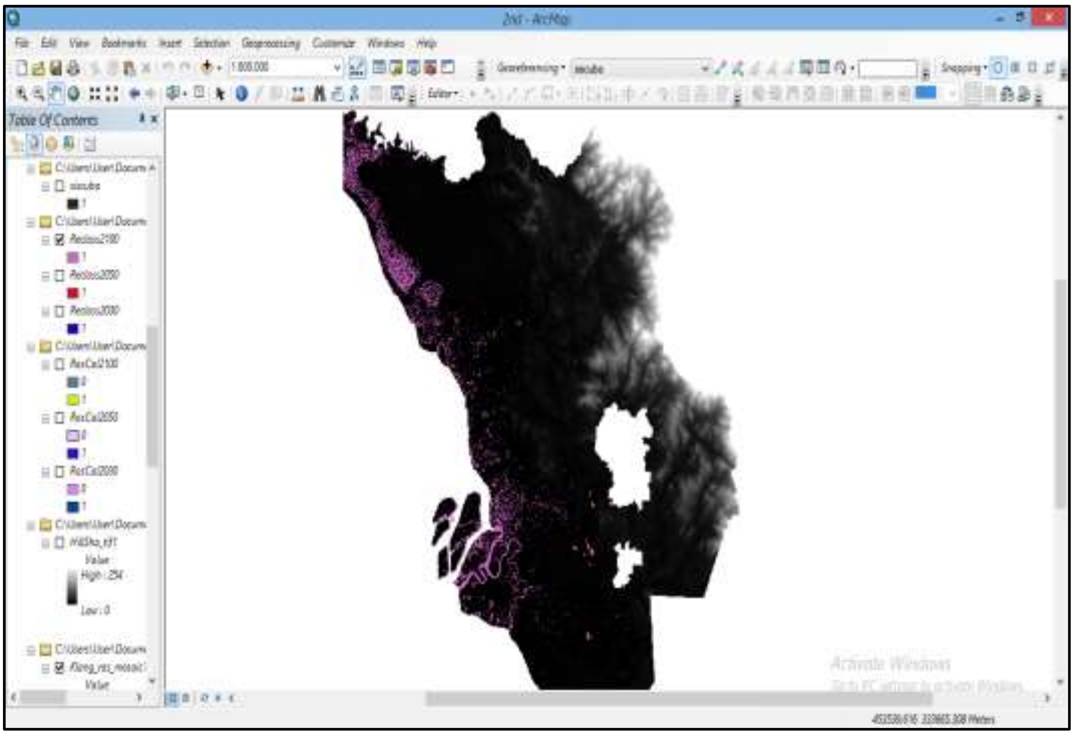

Figure 3.15 Result from Reclassify Process

3.6.6.3 Conversion Toolbox

Conversion Toolbox contain tools that could convert data between various formats. There were many toolsets provided such as Excel toolset, From GPS toolset, From KML toolset, From Raster toolset and others. In this study, From Raster toolset has been used with the function to convert the information in a raster dataset to a different type of data structures, such as a feature class or to a different type of file like binary or text file. This process would generate the output data from reclassify and produce a input of location that were only influenced by sea level rise in Klang area. Figure 3.16 shows the result after raster to polygon process for the projection of sea level rise in year 2100. The light blue colour was represent the risky location in Klang area that have the potential to be submerged by sea level rise in year 2100. This result could be concluded that the light blue colour was above the projection of sea level rise which was 3.116 meters.

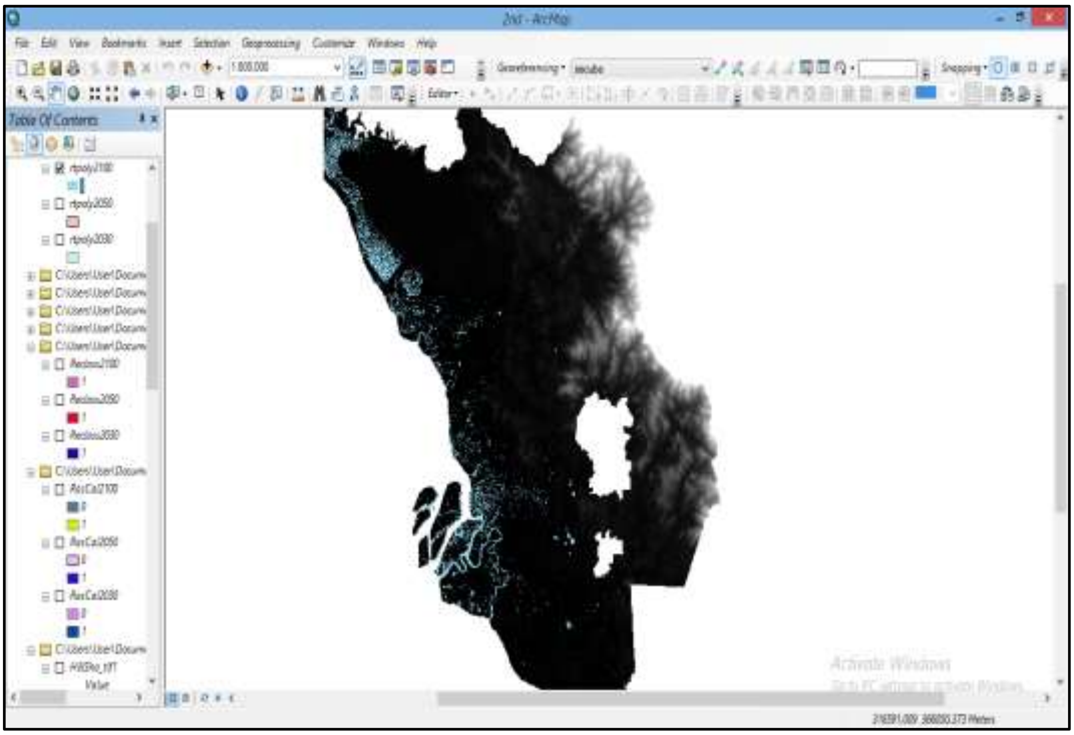

Figure 3.16 Result After Raster to Polygon Process

3.6.7 Selection by Location

The step to produce the inundation map due to sea level rise was continued with Selection by Location process. The Select by Location would allow the user to select features based on their location relatively to the features in another layer. For instance, this study only wants to know the exact location along Klang coastlines that was affected by sea level rise. Previously, the output data from Conversion Toolbox was saved as Flood2100. Therefore, Selection by Location was used in this study by selecting the output data from the Conversion Toolbox as the input data that fall within the boundary of Klang coastlines. This could be seen in figure 3.17. The spatial selection method must be ensured to select “are crossed by the outline of the source layer feature”.

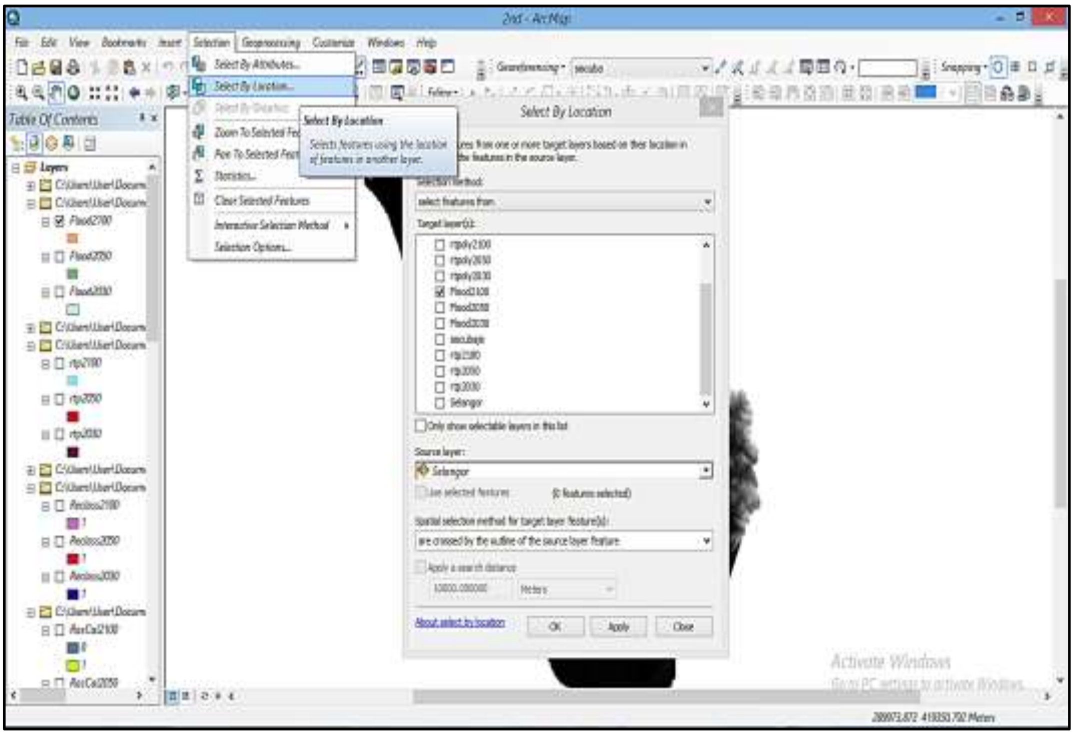

Figure 3.17 Location Selection in ArcGIS

3.6.8 Export Data

Export Data was the last step required to produce the inundation map by sea level rise. The data that need to be exported was the output data from Selection by Location. Thus, right click on the output data and choose the Data section. Export Data was selected and this result was saved in the personal geodatabase as “File and Personal Geodatabase feature classes”. Figure 3.18 shows the final step after export data process and the turquoise colour represented the fixed location which experienced sea level rise along the Klang coastlines.

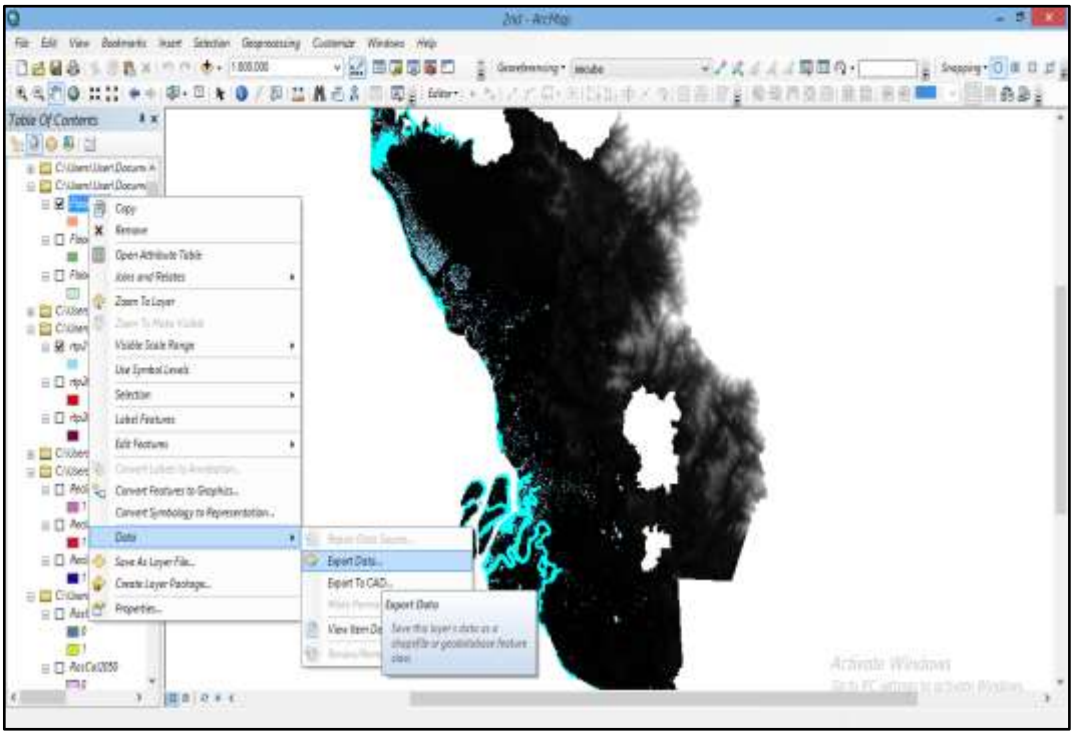

Figure 3.18 The Final Step After Export Data Process

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Climate change and sea level rise can give rise to high impacts such as destruction of assets and disruption to economic sectors, loss of human lives, mental health effects, or loss of plants, animals, and ecosystem and their severity depends on their extremes, exposure and vulnerability (R.McLean., 2009). Thus, it was important to know the exact location that may be affected by sea level rise. Klang known as royal city and former capital state of Selangor. According to the Department of Statistics Malaysia 2010, Klang has 861,189 number of population. Klang is one of the flood vulnerable area in Malaysia. There are many people who live along the coastal areas in Klang. In addition, Klang also have become a tourist city as there are many attractive beaches and place to be visited. Klang beaches areas consist of Tanjung Harapan, Pulau Ketam, Pulau Indah, Pantai Remis, Pantai Tanjung Piai, and many others which are vulnerable to the risk of sea level rise.

Arc Geographical Information Systems (ArcGIS) have been used in this study to identify the risky location in Klang coastline that would be affected by sea level rise in year 2030, 2050 and 2100. From ArcGIS, inundation areas due to sea level rise could be estimated and identified. In this chapter, the result of projection on the simulation of sea level rise in Klang coastline would be presented.

4.2 Sea Level Rise Projection in Klang

In this study, data collection of sea level rise and high tides have been collected by research done from National Hydraulic Research Institute of Malaysia (NAHRIM) and National Hydrographic Centre Malaysia (NHC). Table 4.1 shows the sea level rise projection in Klang. The total projection of sea level rise was the combination of sea level rise value and high tides value.

In year 2030, sea level rise data was 0.120 meters and high tides data was 2.586 meters. Thus, the total projection of sea level rise was 2.706 meters. For year 2050, sea level rise data was 0.235 meters and high tides data was 2.586 meters. In combination, the total projection of sea level rise during that year was 2.821 meters. Then, in year 2100, sea level rise data was 0.530 meters and high tides data was 2.586 meters. Hence, the total projected of sea level rise was 3.116 meters. All the data have been generated in the ArcGIS software to know the affected areas due to sea level rise risk.

Table 4.1 Sea Level Rise Projection in Klang

YEAR OF PROJECTION	**SEA LEVEL RISE (meter)**	**HIGH TIDES (meter)**	**TOTAL PROJECTION SEA LEVEL RISE (meter)**
2030	0.120	2.856	2.706
2050	0.235	2.856	2.821
2100	0.53	2.856	3.116

4.3 Simulation of Sea Level Rise

The simulation of sea level rise in ArcGIS were invented in three different files which were the sea level rise in year 2030, sea level rise in year 2050 and sea level rise in year 2100. By generating the data of total projection of sea level rise, ArcGIS have produced the results for the inundated area in Klang coastlines. Thus, the results were presented by Google Earth.

4.3.1 Simulation of Sea Level Rise Scenario in Year 2030

In year 2030, the predicted height of sea level rise was 2.706 meters. The Figure 4.1 and Figure 4.2 below shows that the mint-green colour serve as the inundation areas of sea level rise. As the result for this projection, in Figure 4.2 shows the low lying areas like Pulau Ketam, Pulau Klang, Pulau Selat Gering, Pulau Mat Zin, Pulau Pintu Gadong and Port Klang were the potential area that would be flooded due to the sea level rise. Furthermore, all of the location were located near to the sea which more exposed to be flooded. The seawater came from Straits of Malacca, hit all the coastlines area and overflow into the Klang river.

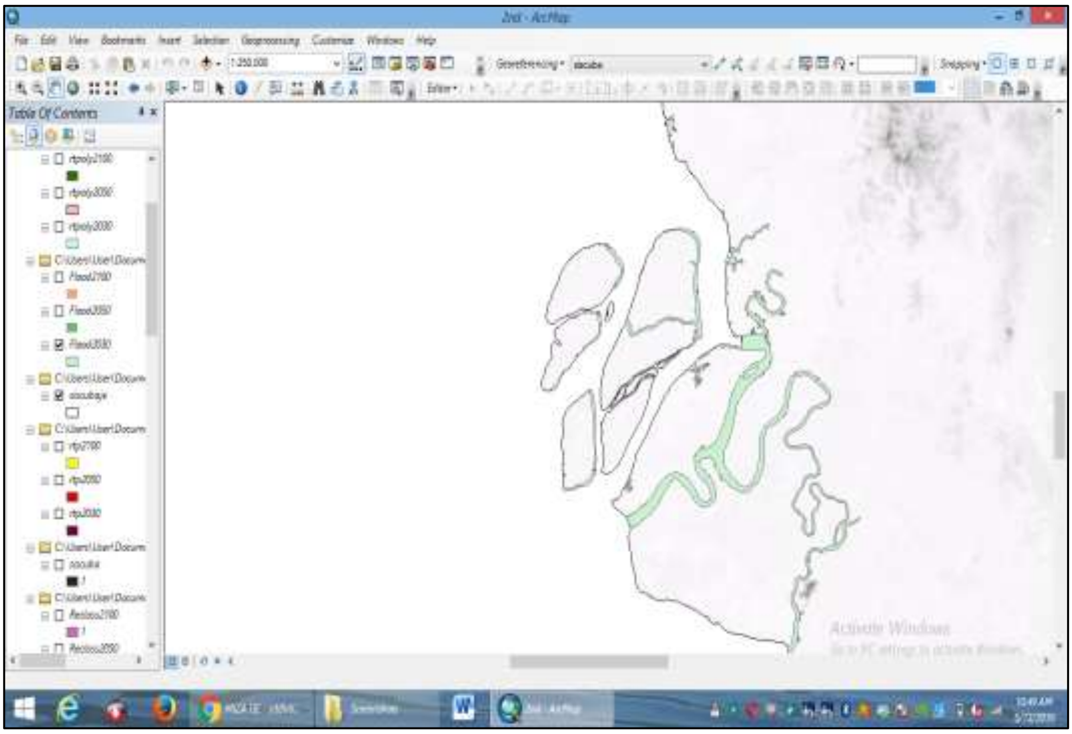

Figure 4.1 Simulation of Sea Level Rise Scenario in year 2030

Figure 4.2 Inundated Area in Klang Coastlines by Sea Level Rise in year 2030

4.3.2 Simulation of Sea Level Rise Scenario in Year 2050

For year 2050, the predicted height of sea level rise was 2.821 meters. The Figure 4.3 and Figure 4.4 below shows that the green colour serve as the inundation areas of sea level rise. In Figure 4.4 show the low lying areas like Pulau Ketam, Pulau Klang, Pulau Selat Gering, Pulau Mat Zin, Pulau Pintu Gadong and Port Klang were the potential area that would be flooded due to the sea level rise. Pulau Ketam and Pulau Klang which were rich with mangrove forest and wetland were the protected areas for mangrove. However, these areas were prone to sea level rise inundation due to very low lying.

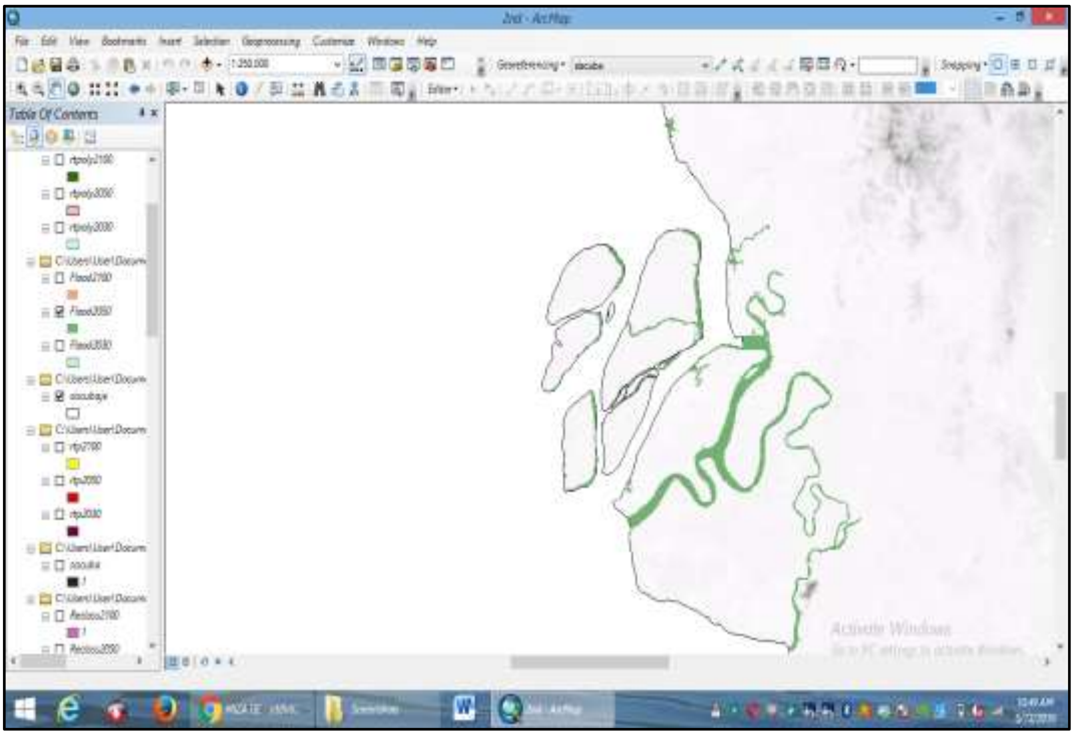

Figure 4.3 Simulation of Sea Level Rise Scenario in year 2050

Figure 4.4 Inundated Area in Klang Coastlines by Sea Level Rise in year 2050

4.3.3 Simulation of Sea Level Rise Scenario in Year 2100

In year 2100, the predicted height of sea level rise were 3.116 meters. The flood prone maps in Figure 4.5 and Figure 4.6 show some areas that would be inundated by sea level rise. The orange colour was indicate the overflow of sea level rise. In most of the inundated area, the topographic condition of the land along the coastline are higher compared to those areas near the river. Thus, the impact of sea level rise would mainly affect the areas along the river. The low lying areas like Pulau Ketam, Pulau Klang, Pulau Selat Gering, Pulau Mat Zin, Pulau Pintu Gadong and Port Klang would totally be inundated by sea level rise in year 2100. Other than that, the residential and industrial areas such as Bandar Sultan Sulaiman, Glenmarie Cove and Kampung Nelayan also would be affected due to sea level rise. The Port Klang which is located in Klang District is the 13th busiest trans-shipment port (M.F. Mohamad et al., 2018). Thus, if the areas like Port Klang and Bandar Sultan Sulaiman were inundated by sea level rise, the socio-economy of the area would be significantly affected as well since it was an important place for economic activities in Klang.

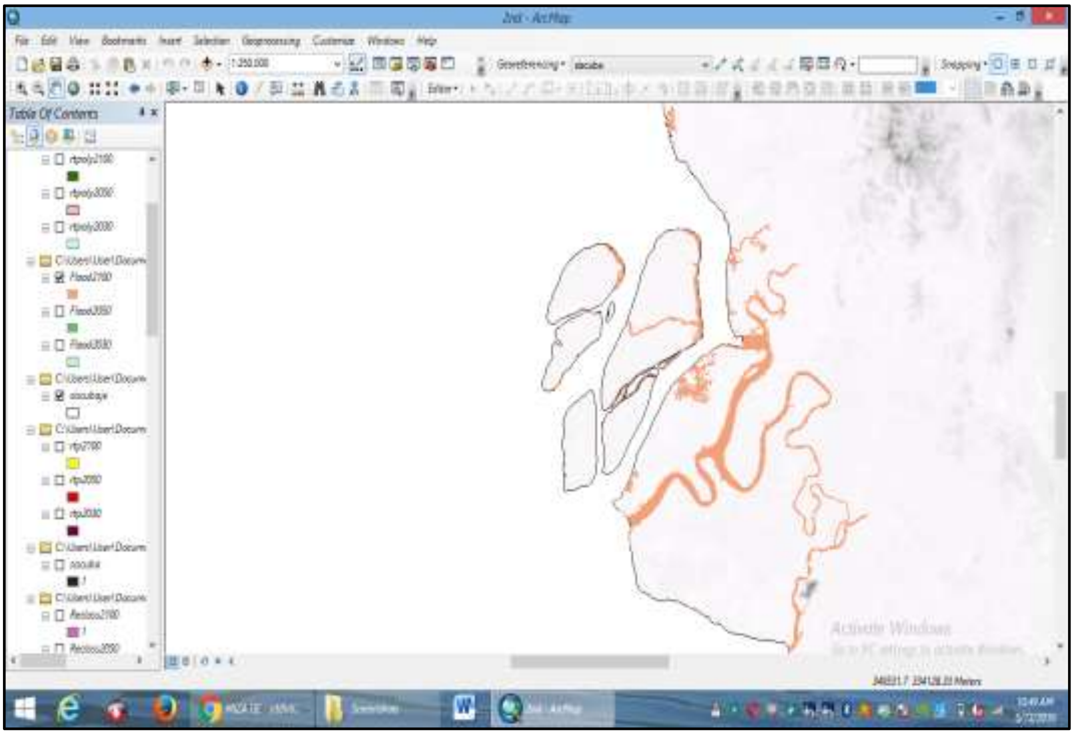

Figure 4.5 Simulation of Sea Level Rise Scenario in year 2100

Figure 4.6 Inundated Area in Klang Coastlines by Sea Level Rise in year 2100

4.4 Total Inundated Area

The inundated areas due to sea level rise in Klang coastlines could be calculated directly in the ArcMap. From the simulation results show that sea water level was slowly increasing from year 2030 to year 2100. The areas that will be affected by the flooding from sea level rise in year 2100 were mainly the existing flood prone areas which was the low lying areas along Klang river. The land use types of these areas were mostly residential and industrial areas. In year 2030 and 2050, the potential inundated areas were 49.229 square kilometre. The flooding area was same because there were only slightly different of total projection sea level rise which was 0.115 meter between year 2030 and 2050. Meanwhile for year 2100, the inundated areas were 72.631 square kilometre. This indicate that affected areas due to sea level rise in year 2100 was bigger compare to year 2030 and 2050. All of these values and result could be found in the data of Attribute Table in the ArcMap.

4.5 Mitigation Plan

Mitigation plan was one element of risk management. The implementation could reduce the probability of risk occurrence. Klang was a city which have a lot of mangrove forest or agriculture area, coastal protection structures, retreat inland and higher platform that must be protect from sea level rise and this can be seen in Figure 4.7. There were many adaptation approaches to sea level rise. In Figure 4.8 shows the alternative methods to mitigate the damage of coastal storms and forces such as accommodation, protection, beach nourishment, retreat, do-nothing, integrated shoreline management plan and refurbishment on coastal bund. In this study, the mitigation plans of protection have been proposed in order to reduce the impacts of sea level rise in Klang coastlines via behavioural changes. Simplified Armour unit 'H' or known as SAUH revetments and submerged breakwater have been chosen as the mitigation plans.

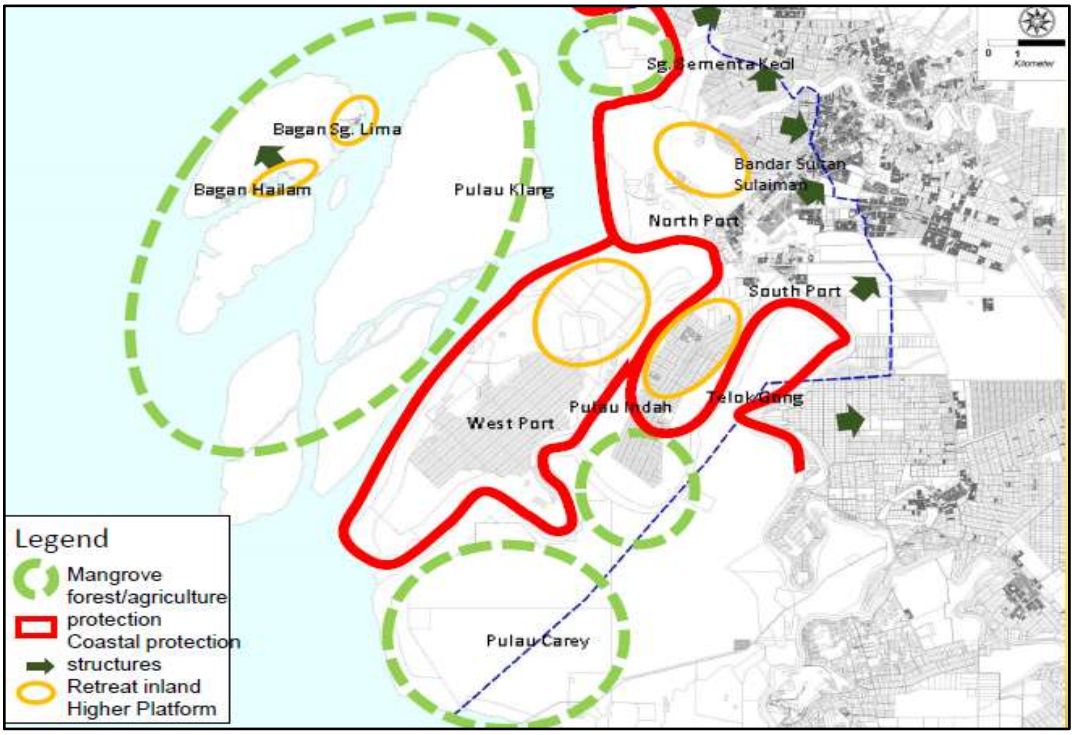

Figure 4.7 The Proposal of Protection Area in Klang

Source: National Hydraulic Research Institute of Malaysia (NAHRIM, 2017)

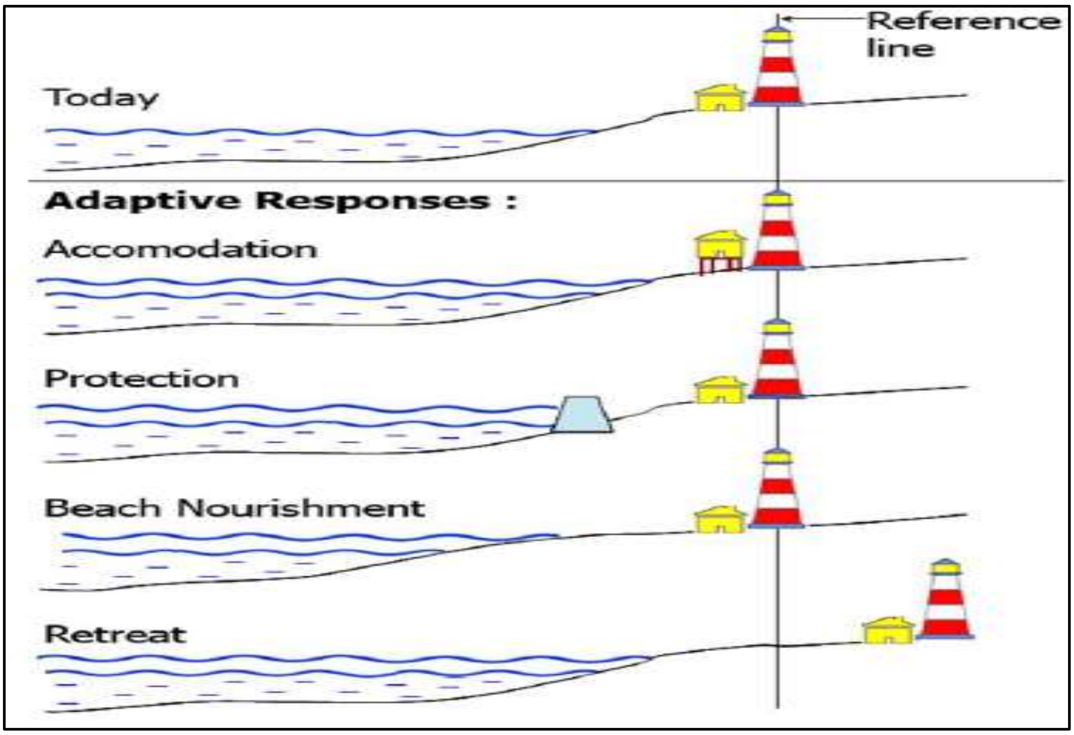

Figure 4.8 Example of Adaptation Approaches for Sea Level Rise

Source: Department of Irrigation and Drainage Manual (DID, 2009)

4.5.1 SAUH Revetment

Simplified armour unit 'H' or known as SAUH revetments was the concrete revetment that could be used as the bund protection along Klang coastlines. Among the advantages of this SAUH revetment was light but well interlocked structure which may performed well on the weak soils of Klang coastlines. This revetment were onshore structures with the principal function of protecting the coastline from erosion. Typically consist of armour rock or concrete block and were flexible. In this context, revetment structure would rest on the surface being protected and dependent on it to support. Voids within the revetment permit quick drainage over the surface of the slope and hence reduces wave run-up (Syed Amir Syahmi., 2017). The properly designed and constructed revetment could achieve long life structure with little maintenance required. In 1987 at Sungai Burung, Selangor, the DID have been produced SAUH revetment as an experimental concrete revetment for bund and escarpment protection. The revetment was used in combination of the mangrove re-planting which was the first attempt to combine a biological component and a structural coastal protection measure. SAUH revetment have been proven as good in quality and ability when they were performed well on the weak soils of the Selangor coastline up till now. In figure 4.9, the red lines show the proposed location of the SAUH revetment location for Klang Coatlines and in Figure 4.10 shows the example of existing SAUH revetment at Sungai Burung., Selangor.

Figure 4.9 Proposed Location of SAUH Revetment Location for Klang Coastlines

Figure 4.10 Example of Existing SAUH Revetment at Sungai Burung, Selangor

Source: Department of Irrigation and Drainage (DID, 2017)

4.5.2 Submerged Breakwater

Sea level rise could give impacts to visual appeal, access and recreational amenity which could be problematic and also need to be closely considered. Submerged breakwater was appropriate for all coastlines. They are often constructed for beach protection or to restore eroded beaches, being applied as a preliminary defence system to protect the principal coastal structures, redistribute sediment transport patterns, create desirable beach features and calmer zones in harbours, prevent siltation or alter the sediment deposition area in port access ways and navigation channel entrances (Amir Sharif, 2016).

A wide-crested submerged breakwater with crest at low tide has been proposed to mitigate effectively the wave energy during all events especially the most severe events. The breakwaters was served to reduce the incoming wave energy in protecting certain coastal areas from wave attack (Thaha *et al*,. 2015). The submerged breakwater would act as the wave buffer within the expected wave forces, toe scour and overtopping. In this context, armour rock would be placed and stockpile underwater to the required crest levels and the large voids would be filled with core rock.

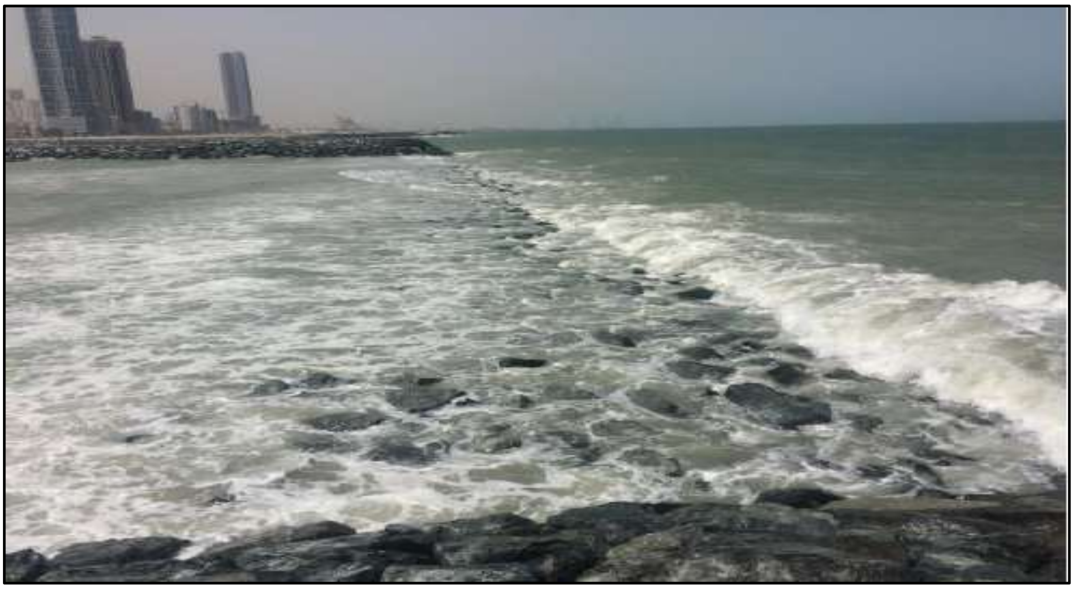

Figure 4.11 Submerged Breakwater at Gold Coast, Australia

Source: International Coastal Management, Australian Coasts & Ports Conference (2015)

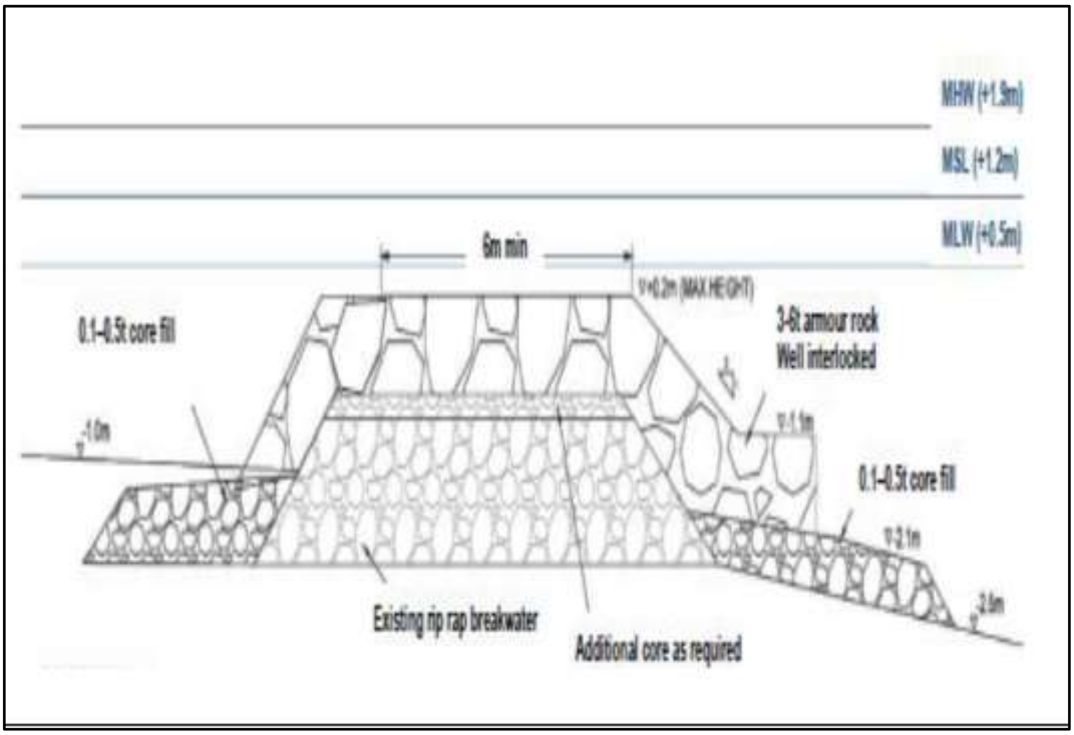

Figure 4.12 Example of Design for Submerged Breakwater Typical X-Section at Gold Coast, Australia

Source: International Coastal Management, Australian Coasts & Ports Conference (2015)

Figure 4.13 Proposed Location of Submerged Breakwater at Klang Coastlines

4.6 Summary

Sea level rise have been stimulated and the area of risky locations have been identified due to the inundation map in year 2030, 2050 and 2100. The simulation results show that sea level rise was slowly increasing from year 2030 to year 2100. The total inundated area in year 2030 and 2050 were 49.229 kilometers square and in year 2100 were 72.631 kilometers square. The total inundated area in year 2030 and 2050 was same because there was only slightly difference in the increment of projection sea level rise during that year which was 0.115 meter compared to year 2100 which has larger increment. Meanwhile, the potential inundated area in Klang coastline was mostly all the low-lying area such as Pulau Ketam, Pulau Klang, Pulau Selat Gering, Teluk Gong, Pulau Mat Zain and Port Klang. The land use types of these areas were mostly residential and industrial areas. Mitigation plans could be used to overcome the sea level rise risk in Klang area such as SAUH revetment and submerged breakwater.

CHAPTER 5

CONCLUSION

5.1 Introduction

Klang plays a key role in industrial development of Selangor. Port Klang and Bandar Sultan Sulaiman Industrial Areas were the important places that became main contributor to Selangor. Besides, Klang consists of coastal protection structures, retreat inland and high platform areas. Mangrove forest and agriculture also one of the attraction in Klang which were located in Pulau Klang, Bagan Sg. Lima, Bagan Hailam, Pulau Carrey, Pulau Indah and Sg. Sementa Kecil. Sea level rise poses a major threat to mangrove ecosystems through sediment erosion, inundation stress and increased of salinity at landward zones (NAHRIM.,2017). Therefore, all of these places which were the assets of Klang and vulnerable to the sea level rise risks need to be safe.

As a first step of precaution to avoid the sea level rise risk that could contribute to lots of damage such as failure of buildings, bridges and roads collapse, and even worst could lead to loss of life, inundation map of Klang was required. With the presence of inundation map, public and authorities would be more alerted and care with sea level rise in their area. Adaptation measure could be figured out since the inundation map would show the affected location due to sea level rise.

Arc Geographical Information System (ArcGIS) was used as a method to construct and produce the inundation map based on the sea level rise data accordingly to the location. The inundation map was useful to help the effort of government in reducing the number of loss of life and properties. By developing the inundation map in ArcGIS software, public could be educate about how severe sea level rise could affects everything by which the informatics and modeling may produce better warnings and evacuations.

Nowadays, there were some studies and research related to sea level rise which have been done by National Hydraulic Research Institute of Malaysia (NAHRIM). As a additional precaution step other than the goverment, the result from this study could also be applied in Malaysia to reduce the percentage of losses by sea level rise.

5.2 Conclusion

Climate change and global warming, anthropogenic factors, tides events, and melting of glaciers and ice sheets were among the factors that could cause the sea level to become rise. Unfortunately, these factors would contribute a lot of severe impact to human, wildlife and entire ecosystem in Klang coastline especially all those low-lying areas.

This study was successfully in identified the risky location in Klang coastlines that would be affected by sea level rise in year 2030, 2050 and 2100. All the risky location could be seen in the inundation map in the Figure 4.2, Figure 4.4 and Figure 4.6. The risky locations due to sea level rise were included all those low lying areas and the industrial development areas in Klang coastlines which were Pulau Ketam, Pulau Klang, Teluk Gong, Port Klang up to Bandar Sultan Sulaiman Industrial Areas. The inundated areas because of sea level rise also were provided in this study. The total inundated areas by sea level rise in year 2030 and 2050 in Klang coastline were 49.229 square kilometre. The flooding area was same because there were only slightly different of total projections sea level rise which was 0.115 meter between year 2030 and 2050. Meanwhile, the total inundated areas in year 2100 were 72.631 square kilometre which was bigger than the previous years. Thus, authorities could determine the affected areas cause by sea level rise based on the inundated area and plan for the better future.

This study also has been successful to answer the second objectives which was proposed for the mitigation plans by sea level rise risk. There were two mitigation plans that had been proposed in this study. SAUH revetment and submerged breakwater have been chosen as the mitigation plans. Every options for the mitigation plans have their own specialities and good in performances in order to prevent sea level rise especially in Klang coastlines.

As a conclusion, the result of inundation map due to sea level rise that was produced from Arc Geographical Information System (ArcGIS) in this study could prevent the risk of sea level rise event in the future. The inundation map was useful for the government and public to estimate when the sea level will be rises at their place and be well-prepared when the times comes. Actions may be taken by authorities to avoid the sea level rise. Adversely, loss of life and properties can be reduced and prevented.

5.3 Recommendation

Sea level rise has the potential to change coastal natural processes, marine habitats and ecosystems which may give impact toward the infrastructure and socio-economy in Malaysia. From this study, the suggestion for the recommendation was all those low-lying areas and locations that were involved in the inundation map due to sea level rise would found a way on how to overcome it. In this context, government and local authorities could give more attention to these locations because natural disaster could not be handled and may occurs anytime. Some action could be taken such as used the mitigation plan to avoid the severe impact of sea level rise. Adversely, loss of life and properties could be prevented.

Besides, Arc Geographical Information System (ArcGIS) was highly recommended to be used in this field of study since it could effectively produce the result with regard the data provided. This system also may be used to develop and estimate any other natural disasters such as coastal flood, earthquake event, tsunami and others. ArcGIS was a user-friendly which could be managed and used easily by anyone either in technical or non-technical field.

REFERENCES

Abd. Razak Idris, (2016). Air Pasang Besar Akibat Pemanasan Global (Global Warming Causes Sea Level Rise). Utusan Online. Retrieved from http://www.utusan.com.my/rencana/utama/air-pasang-besar-akibat-pemanasan-global-1.385366

Al, Y. Y. (2017). Sea Level Change, Sea Water Intrusion, and Coastal Land Subsidence. *Marine Geo-Hazards in China*,587-656. doi:10.1016/b978-0-12-812726-1.00014-0

Audrey Vijaindren , (2018). 6.6 Million Mangrove Trees Planted Nationwide. New Straits Times. Retrieved from https://www.nst.com.my/news/nation/2018/07/394778/66-million-mangrove-trees-planted-nationwide-says-xavier

Baharuddin, M.K. (2007). Climate Change - Its effects on the agricultural sector in Malaysia. National Seminar on Socio-Economic Impacts of Extreme Weather and Climate Change, 21-22 June, 2007 Malaysia. Online access from http://www.met.gov.my/index.php?option=com_content&task=view&id=110&Itemid=147.

Bathelt, A., & Viskanta, R. (1980). Heat transfer at the solid-liquid interface during melting from a horizontal cylinder. International Journal of Heat and Mass Transfer,23(11), 1493-1503. doi:10.1016/0017-9310(80)90153-2

Cazenave, A. (2002). Sea level variations in the Mediterranean Sea and Black Sea from satellite altimetry and tide gauges. *Global and Planetary Change*,*34*(1-2), 59-86. doi:10.1016/s0921-8181(02)00106-6

Cazenave, A., & Le Cozannet, G. (2014). Sea level rise and its coastal impacts. *Earth's Future*, *2*(2), 15-34.

Cerovski-Darriau, C., & Roering, J. J. (2016). Influence of anthropogenic land-use change on hillslope erosion in the Waipaoa River Basin, New Zealand. *Earth Surface Processes and Landforms*,*41*(15), 2167-2176. doi:10.1002/esp.3969

Daljit Singh, (2017). Deforestation Kills Our Future. The New Straits Times. Retrieved from https://www.gogle.com/amp/s/www.nst.com.my/node/240624/amp

Deng, M., Mace, G. G., Wang, Z., & Berry, E. (2015). CloudSat 2C-ICE product update with a newZeparameterization in lidar-only region. *Journal of Geophysical Research: Atmospheres*,*120*(23). doi:10.1002/2015jd023600

ESRI, (2019). An Overview of the Spatial Analyst Toolbox. ArcGIS Desktop. Retrieved from http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/an-overview-of-the-spatial-analyst-toolbox.htm

ESRI, (2019). What is ArcMap. ArcGIS Desktop. Retrieved from http://desktop.arcgis.com/en/arcmap/10.3/main/map/what-is-arcmap-.htm

ESRI, (2019). What is Map Algebra. ArcGIS Desktop. Retrieved from http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/map-algebra/what-is-map-algebra.htm

Esterson, K., and S. Gorlachev (2010). *The Sea Level Projections of USACE EC 1165-2-211 in Context.* Paper presented at the Greater Everglades Ecosystem Restoration Conference, Naples, FL, July 12-16.

Hadinata, (2016). Banjir Akibat Air Pasang Besar (Flooding Due to Sea Water Level Rise). The Harian Metro. Retrieved from https://www.hmetro.com.my/node/167574

Joa˜o L.R, Chunyan Li (2009). On the importance of the forward speed of hurricanes in storm surge forecasting: A numerical study. Geophysical Research Letters, VOL. 36, L07609, doi:10.1029/2008GL036953, 2009

Jumaat H. Adam, MB Gasim, Mohd Ekwan H.T., Sahibin A.R., Hafizan H.J., (2007). Coastal Flood Phenomenon in Terengganu, Malaysia : Special Reference to Dungun. Reasearch Journal of Environmental Sciences, 1: 102-109. doi: 10.3923/rjes.2007.102.109

Mohamad, M. F., Hamid, M. R., Awang, N. A., Shah, A. M., & Hamzah, A. F. (2018). Impact of Sea Level Rise Due to Climate Change: Case Study of Klang and Kuala Langat Districts. *International Journal of Engineering and Technology,10*(1), 59-64. doi:10.7763/ijet.2018.v10.1035

Mohd, F. A., Maulud, K. N. A., Begum, R. A., Selamat, S. N., & Karim, O. A. (2018). Impact of Shoreline Changes to Pahang Coastal Area by Using Geospatial Technology. *Sains Malaysiana*, *47*(5), 991-997.

NAHRIM (2010). *The Study of the Impact of Climate Change on Sea level Rise in Malaysia*, Final Report, December 2010.

Nicholls, R.J. (2004). Coastal flooding and wetland loss in the 21st century: Changes under the SRES climate and socio-economic scenarios. *Global Environmental Change*, 14(1): 69-86.

Parker, A. (2014). Present contributions to sea level rise by thermal expansion and ice melting and implication on coastal management. *Ocean & Coastal Management,98,* 202-211. doi:10.1016/j.ocecoaman.2014.05.026

Richardson, K., Steffen, W., & Liverman, D. (n.d.). Sea-level rise and ice-sheet dynamics. *Climate Change: Global Risks, Challenges and Decisions,*50-74. doi:10.1017/cbo9780511973444.006

Ruwaida Md Zain , (2018). Fisherman Carry on Daily Routine Despite High Tide Phenomenon. New Straits Times. Retrieved from http://www2.nst.com.my/news/nation/2018/09/410362/fishermen-carry-daily-routine-despite-high-tide-phenomenon

Shamil Norshidi , (2018). Climate Change in Malaysia: Floods, Less Food, and Water Shortages-Yet Its People are Complacent. South China Morning Post. Retrieved from https://www.scmp.com/lifestyle/article/2164866/climate-change-malaysia-floods-less-food-and-water-shortages-yet-its

Taibi, H., & Haddad, M. (2019). Estimating trends of the Mediterranean Sea level changes from tide gauge and satellite altimetry data (1993–2015). *Journal of Oceanology and Limnology*. doi:10.1007/s00343-019-8164-3

United State Geological Survey (USGS)(2010). Earth Explorer. Retrieved from https://earthexplorer.usgs.gov/

Wong, P.P., Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y.Saito, A. Sallenger, (2006): Coastal Systems and Low-Lying Areas in: Climate Change 2014: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361-409.

Woodworth, P. L., Pugh, D. T., & Plater, A. J. (2015). Sea-level measurements from tide gauges. *Handbook of Sea-Level Research,*555-574. doi:10.1002/9781118452547.ch35

Zakri Abd.Hamid , (2018). Global Warming: Malaysia Needs a Strategy. New Straits Times. Retrieved from https://www.nst.com.my/opinion/columnists/2018/10/423458/global-warming-malaysia-needs-strategy

Zhou, X. (2003). *Fast fluid simulation and its applications*(Doctoral dissertation, University of Hong Kong).