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**GEOLOGY AND GIS – BASED FLOOD
VULNERABILITY ASSESMENT IN KAMPUNG
LALOH, KUALA KRAI, KELANTAN**

by

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A report submitted in fulfilment of the requirements for the degree of
Bachelor of Applied Science (Geoscience) with Honors

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DECLARATION

I declare that this thesis entitled “GEOLOGY AND GIS – BASED FLOOD VULNERABILITY ASSESSMENT IN KAMPUNG LALOH, KUALA KRAI, KELANTAN” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

“I/ We hereby declare that I/ we have read this thesis and in my/our opinion this is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours”

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Geology And GIS – Based Flood Vulnerability Assessment In Kampung Laloh, Kuala Krai, Kelantan

ABSTRACT

The research mainly focuses on geological mapping in Kampung Laloh Kuala Krai, Kelantan. The total study area is approximately 28 km² using measurement dimension of 7km×4km, within the coordinate ranging from latitude 5° 22' 10" N to 5° 18' 30" N and longitude 102° 19' 10" E to 102° 21' 20" E. This area has a mountainous, hilly, and flat topography. Kampung Laloh, Kuala Krai require sufficient geological mapping, structure, and lithology data. The aim of the research is to create a geological map of the area in a scale of 1:25000. In order to accomplish the objective, the geological mapping component of this research relied on fieldwork inputs including collecting samples from fresh outcrops, identifying structural trends in rocks, and making other observations like geomorphological characteristics, drainage pattern, and others. The oldest sediments in the Eastern Belt of Peninsular Malaysia are predominantly Carboniferous and Permian clastic, limestones, and volcanics. Western Kuala Krai is composed of granite Stong Complex and the Gua Musang and Taku Schist rock formations. Moreover, dendritic and trellis drainage patterns were found in the research area. Dendritic patterns form on consistently strong bedrock, while parallel patterns formed where there is a slope and rectangular pattern exist in areas that have experienced faulting. All this field data, including petrographic studies, was processed in a GIS-based platform in order to create geological and other thematic maps. The lithology of the study area is phyllite, granite and meta mud rock. ArcGIS's Weighted Overlay Method (WOM) was used to create the flood hazard map by layering all relevant parameters based on the area's influences. Before applying the overlay technique, it was necessary to transform all parameters into raster data. The findings reveal that the flood hazard map was divided into five distinct classes based on the varying heights of the water which is very high, high, moderate, low, very low. As a conclusion, the local populace must be better informed and made aware of the risks associated with floods, therefore this is crucial. A major cause of flooding is the heavy rain that occurs naturally every year, especially during the northeast monsoon seasons of November through March. In addition, logging operations contribute to the rapid drainage of water into rivers, most notably the Sungai Kelantan.

Geologi dan Penilaian Kerentanan Banjir Berasaskan GIS di Kampung Laloh, Kuala Krai, Kelantan

ABSTRAK

Penyelidikan ini tertumpu terutamanya kepada pemetaan geologi di Kampung Laloh Kuala Krai, Kelantan. Jumlah kawasan kajian adalah lebih kurang 28 km² menggunakan dimensi ukuran 7km×4km, dalam julat koordinat dari latitud 5° 22' 10" N hingga 5° 18' 30" N dan longitud 102° 19' 10" E hingga 102° 21 ' 20" E. Kawasan ini mempunyai bentuk muka bumi yang bergunung-ganang, berbukit dan rata. Kampung Laloh, Kuala Krai memerlukan data pemetaan geologi, struktur, dan litologi yang mencukupi. Matlamat penyelidikan adalah untuk mencipta peta geologi kawasan dalam skala 1:25000. Untuk mencapai objektif, komponen pemetaan geologi penyelidikan ini bergantung kepada input kerja lapangan termasuk mengumpul sampel daripada singkapan segar, mengenal pasti aliran struktur dalam batuan, dan membuat pemerhatian lain seperti ciri geomorfologi, corak saliran, dan lain-lain. Sedimen tertua di Jalur Timur Semenanjung Malaysia kebanyakannya adalah Karbon dan Klastik Permian, batu kapur dan gunung berapi. Kuala Krai Barat terdiri daripada Kompleks Stong granit dan formasi batuan Gua Musang dan Taku Schist. Selain itu, corak saliran dendritik dan trellis ditemui di kawasan penyelidikan. Corak dendritik terbentuk pada batuan dasar yang kukuh secara konsisten, manakala corak selari terbentuk di mana terdapat cerun dan corak segi empat tepat wujud di kawasan yang mengalami sesar. Semua data medan ini, termasuk kajian petrografi, telah diproses dalam platform berasaskan GIS untuk mencipta peta geologi dan tematik lain. Litologi kawasan kajian ialah batuan phyllite, granit dan meta lumpur. Kaedah Tindakan Berwajaran (WOM) ArcGIS digunakan untuk mencipta peta bahaya banjir dengan melapis semua parameter yang berkaitan berdasarkan pengaruh kawasan tersebut. Sebelum menggunakan teknik tindakan, adalah perlu untuk mengubah semua parameter menjadi data raster. Penemuan menunjukkan bahawa peta bahaya banjir dibahagikan kepada lima kelas berbeza berdasarkan ketinggian air yang berbeza-beza iaitu sangat tinggi, tinggi, sederhana, rendah, sangat rendah. Kesimpulannya, penduduk tempatan mesti lebih bermaklumat dan menyedari risiko yang berkaitan dengan banjir, oleh itu ini adalah penting. Punca utama banjir ialah hujan lebat yang berlaku secara semula jadi setiap tahun, terutamanya semasa musim tengkujuh timur laut bulan November hingga Mac. Di samping itu, operasi pembalakan menyumbang kepada pengaliran air yang cepat ke sungai, terutamanya Sungai Kelantan.

KELANTAN

TABLE OF CONTENT

	PAGE
DECLARATION	i
APPROVAL	ii
ACKNOWLEDGMENT	iii
ABSTRACT	iv
ABSTRAK	v
LIST OF TABLES	ix
LIST OF FIGURES	xi
LIST OF ABBREVIATION	xv
LIST OF SYMBOLS	xvi
CHAPTER 1	1
INTRODUCTION	1
1.1 General Background	1
1.2 Study Area	3
1.2.1 Location	5
1.2.2 Road Accessibility	5
1.2.3 Demographic	6
1.2.4 Land Use	6
1.2.5 Social Economic	7
1.3 Problem Statement	7
1.4 Objective	8
1.5 Scope of Study	8
1.6 Significance of Study	9
CHAPTER 2	11
LITERATURE REVIEW	11
2.1 Introduction	11
2.2 Regional Setting	12
2.3 Stratigraphy	13

2.4	Structural Geology	13
2.5	Historical Geology	15
2.6	Research Specification	16
2.6.1	Flood in Malaysia	16
2.6.2	The Causative Factors that Influence Flooding	17
2.6.4	Flood Vulnerability Analysis by Using GIS Analysis Tools	18
CHAPTER 3		21
MATERIALS AND METHODS		21
3.1	Introduction	21
3.2	Materials	22
3.2.1	Google Earth	23
3.2.2	ArcGIS Software	23
3.2.3	Data	23
3.3	Methodology	25
3.3.1	Preliminary Studies	26
3.3.2	Field Studies	26
3.3.3	Laboratory Work	27
3.3.4	Data Processing	27
3.3.5	Data Analysis and Interpretation	29
CHAPTER 4		30
GENERAL GEOLOGY		30
4.1	Introduction	30
4.1.1	Brief Content	30
4.1.2	Accessibility	31
4.1.3	Settlement	33
4.1.4	Forestry	33
4.2	Geomorphology	34
4.2.1	Geomorphologic Classification	34
4.2.2	Weathering	37
4.2.3	Drainage Pattern	37
4.3	Lithostratigraphy	40
4.3.1	Stratigraphy Position	40
4.3.2	Unit Explanation	43

4.4	Structural Geology	50
4.4.1	Fault	52
4.4.2	Fold	53
4.4.3	Mechanism of Structure	53
4.5	Historical Geology	55
	CHAPTER 5	56
	LANDSLIDE VULNERABILITY ASSESMENT BY USING GIS	56
5.1	Introduction	56
5.2	The cause of Flooding	57
5.2.1	Rainfall Distribution	58
5.2.2	Hyetograph of Annual Rainfall area at Kuala Krai, Kelantan	67
5.2.3	River Catchment	70
5.3	Parameter of Flood Hazard Analysis	73
5.3.1	Flow Accumulation	74
5.3.2	Elevation	76
5.3.3	Land Use	79
5.3.4	Slope Stability Analysis	80
5.3.5	Lithology	83
5.3.6	River Distance	84
5.4	Flood Hazard Map	87
5.5	Flood Hazard Analysis	88
	CHAPTER 6	90
	CONCLUSION AND SUGGESTION	90
6.1	Conclusion	90
6.2	Suggestion	91
	REFERENCE	93

LIST OF TABLES

NO.	TITLE	PAGE
3.1	Characteristic of DEM data	24
4.1	Topographic unit based on mean elevations	35
4.2	Stratigraphy column of study area	40
4.3	Mineral Composition and Description	44
4.4	Mineral composition and Description	46
4.5	Mineral composition and Description	48
5.1	Rainfall distribution at the rain measure stations	59
5.2	Rainfall distribution at Dabong Kuala Krai of May 2021	63
5.3	Average Rainfall Dabong 2022	64
5.4	Average rainfall day	65
5.5	Rainfall distributions at Kampung Laloh of 2020.	66
5.6	Weightage of parameter of flood hazard analysis	73
5.7	Weightage and rating for flow accumulation	76
5.8	Weightage and rating for elevation	77
5.9	Geomorphological unit and its elevation	77
5.10	Weightage and rating of land use	79
5.11	Weightage and rating of slopes	80
5.12	Weightage and rating of lithology	84
5.13	River distance distribution	84
5.14	Weightage and rating of river distance	84
5.15	Reclassify data with influence	88

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KELANTAN



UNIVERSITI

LIST OF FIGURES

NO.	TITLE	PAGE
1.1	Base map of Kampung Laloh, Kuala Krai	4
2.1	Geologic map of Kelantan state	14
2.2	Location of Kelantan in Peninsular Malaysia	15
2.3	Flood Vulnerability Map in Sidoarjo Regency	19
2.4	Flood Vulnerability Analysis	20
3.1	Research flow chart	22
3.2	The DEM data information of the study area	24
4.1	Accessibility Map of Kampung Laloh, Kuala Krai, Kelantan	30
4.2	Lebuhraya Kota Bharu- Gua Muang is the main road to study area at of Kampung Laloh, Kuala Krai, Kelantan.	31
4.3	The main river, Lebir River in Kuala Krai, Kelantan	32
4.4	The population of Kampung Laloh, Kuala Krai, Kelantan	33
4.5	Landform map of Kampung Laloh, Kuala Krai, Kelantan	35

4.6	The drainage pattern map in the study area	38
4.7	Geological map of study area	41
4.8	The observation of the enormous structure, phaneritic texture and coarse – medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification	43
4.9	The International Union of Geological Science (IUGS) volcanic rock classification. Rock name is quartz rich granitoid	44
4.10	The observation of the enormous structure, phaneritic texture, and coarse-medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification.	45
4.11	Granite outcrop with hammer as scale	46
4.12	The observation of the enormous structure, phaneritic texture, and coarse-medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification.	47
4.13	The International Union of Geological Sciences (IUGS) volcanic rock classification. Rock name is Granodiorite.	48
4.14	The Granodiorite outcrop with human scale.	49
4.15	Rose diagram of the study area located at the north part.	50
4.16	The lineament map	50
4.17	The Fault at the study area.	51
4.18	The Fold at the study area.	52
4.19	Different shapes and orientations 4.19 due to chemical weathering by rainwater and physical weathering by running water form a joint	52
4.20	Sediment is eroded and carried by rivers and streams.	53
5.1	Average rainfall distributions at Ladang Kuala Nal of 2019-2020	60
5.2	Average rainfall distributions at Sek. Men. Teknik Kuala Krai of 2019-2020	62
5.3	Rainfall at Dabong area on 2022	63
5.4	Rainfall days at Dabong area	64
5.5	Average rainfall distributions at Dabong of 2020-2022	65
5.6	Average rainfall distributions at Kampung Laloh for year 2020.	66
5.7	Kampung Laloh hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.	67
5.8	Dabong hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.	68
5.9	Kuala Krai hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.	68
5.10	Kampung Laloh hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.	69

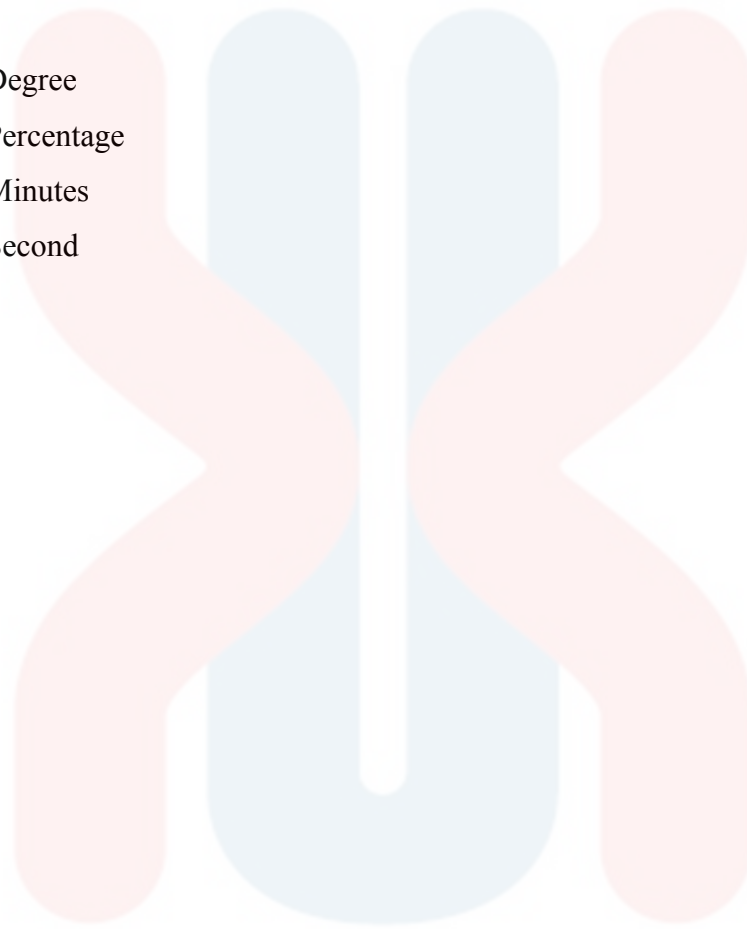
5.11	Dabong hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.	70
5.12	Kuala Krai hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.	70
5.13	River Catchment area in Kuala Krai Town, Kuala Krai, Kelantan.	72
5.14	Flow accumulation map of the study area.	75
5.15	Elevation Map of study area	78
5.16	Land Use Map	81
5.17	Slope map of the study area	82
5.18	Stratigraphy and lithology column	83
5.19	Lithology map of the study area	85
5.20	River distance map of the study area	86
5.21	Flood hazard map at Kampung Laloh, Kuala Krai, Kelantan	89

LIST OF ABBREVIATION

DEM	Digital Elevation Model
GIS	Geographical Information System
GPS	Global Positioning System
USGS	US Geological Suervey Earth Resources and Science Centre
WOM	Weighted Overlay Methods

LIST OF SYMBOLS

°	Degree
%	Percentage
'	Minutes
”	Second



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CHAPTER 1

INTRODUCTION

1.1 General Background

This research entitled 'Geology and GIS- Based Flood Vulnerability Assessment in Kampung Laloh, Kuala Krai, Kelantan'. Geology is Earth science and is the study of the planet and its environment. Geology is the fundamental Earth science that investigates the planet's formation, structure, and composition as well as the various processes that shape it. Geologists have been studying Earth's past for the past 4.5 billion years. Learning about the Earth's internal makeup is the key to understanding its history and making predictions about its future. (R Cavicchioli, 2019).

Geologic mapping is fundamental for education, science, business, and a wide range of public policy issues. Geologic maps, for example, assist us in predicting, preparing for, and mitigating the effects of natural disasters such as flooding. People rely on geologic maps to locate flood basins, which are usually swampy, and flood plains, which are sometimes rich in sediment deposition. Geohazard is one of the geology branches and flood is an example of geohazard. Data sets from geological mapping can be used to illustrate how new information is being created. (Wynn Tranfield, 2019).

Vulnerability is related to disaster risk. In other words, a hazard's impact on a society or an element at risk is defined by the hazard's vulnerabilities (Birkman, 2007; Lauire, 2003). A hazard is a natural occurrence that may have a harmful effect on humans as well as the environment. Geological and biological hazards are two of the most common types. There are a variety of natural disasters, including floods, landslides, earthquakes, sinkholes, and more. Meanwhile, vulnerabilities are "an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbation". Due to these aspects this research must include the structural geology, geomorphology, stratigraphy, and sedimentology in order to observe and gain data within study area.

Kelantan which is located on the east coast of Peninsular Malaysia, is one of Malaysia's worst - hit areas when it comes to massive flooding. Intense floods are now occurring due to localized physical and climate factors, posing risks to the environment and people. Flood is one of the natural disasters that is not just cause by climatic factor, human also can be the main reason for this disaster keep recurring every year and regularly. Human population growth, low drainage control systems, and other anthropogenic activities have a significant impact on this disaster. People in Kelantan are particularly vulnerable to flooding during the northeast monsoon seasons November–March (Abdul Latif ,2018).

When rainwater levels are high enough and discharged more frequently into the channel, flooding occurs quickly. It was caused by heavy rain that caused the Galas and Lebir rivers to overflow, resulting in the flooding. When it reaches the Kelantan River, it will overflow its banks and flood the area around Dabong, Gua

Musang, Manik Urai and Kuala Krai. Therefore, this researched was conducted to update geological mapping and to determine flood hazard and vulnerability of the research area. Besides, the impact of a disaster to the community and surroundings can be determined.

1.2 Study Area

The research mainly focuses on geological mapping in Kampung Laloh Kuala Krai, Kelantan. The total study area is approximately 28 km² using measurement dimension of 7km×4km, within the coordinate ranging from latitude 5° 22' 10" N to 5° 18' 30" N and longitude 102° 19' 10" E to 102° 21' 20" E. This area has a mountainous, hilly, and flat topography.

The highest elevation is in the east part of the area which is dominated by many hills. Based on Figure 1.1, there is a main river which is Kelantan River that become source to the nearest village at the centre and South part of the location. It has lots of village around Kuala Krai district and human activities also one of the main factors that cause the flooding in the area.

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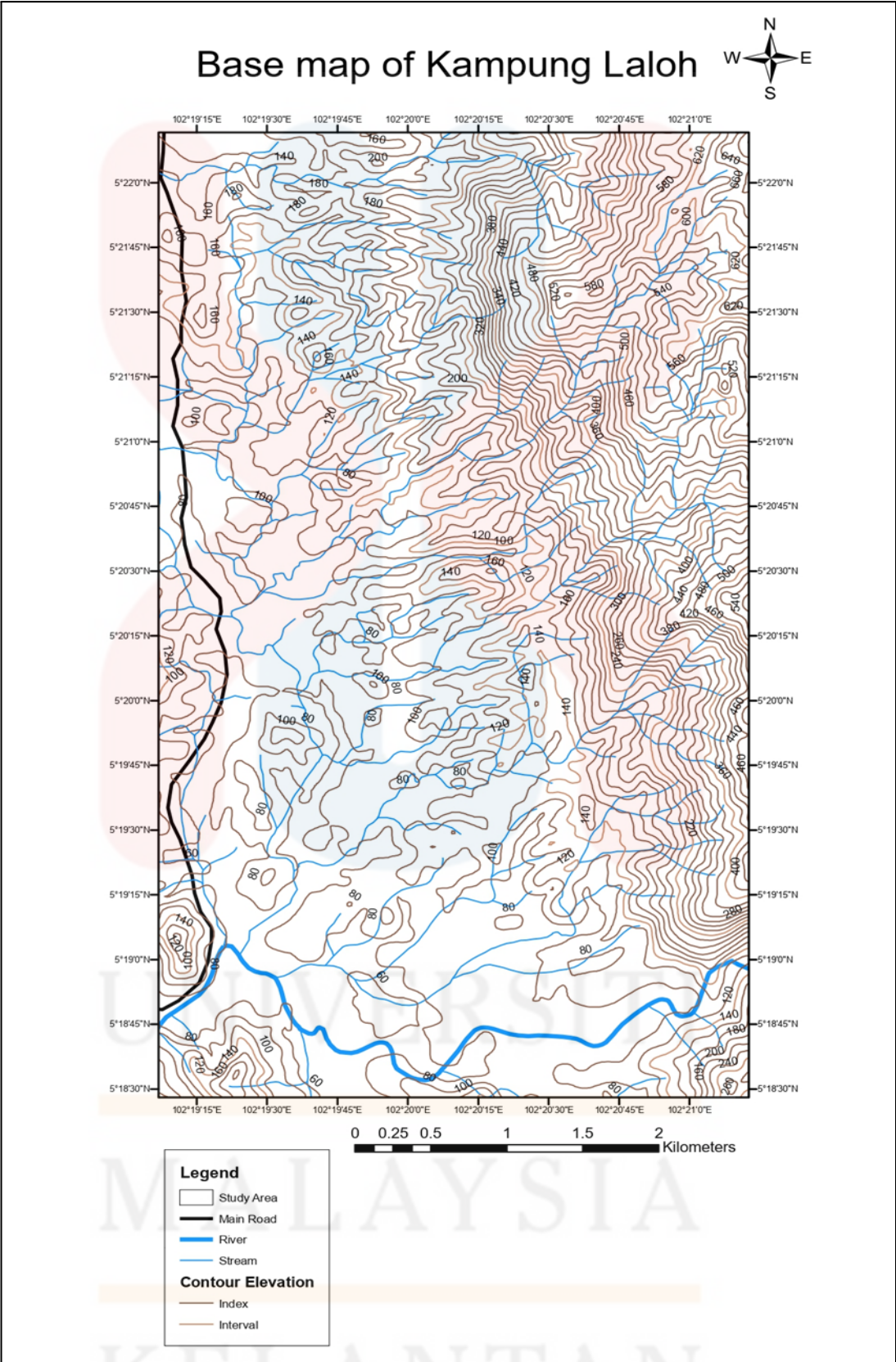


Figure 1.1: Base map of study area.

1.2.1 Location

The location is in Kuala Krai, which is in the central region of Kelantan and is the second largest district after Gua Musang. Kuala Krai shares borders with Machang in the north and Gua Musang in the south, while Terengganu is to the east and Jeli is to the west. Kuala Krai was originally known as Kuala Lebir.

The study area is relevant for conducting research, which is general geology and flood hazard analysis, because the area is prone to flooding, particularly in the village area close to main Kelantan River. Kuala Krai undergone flooded annually, and it has been designated as one of Kelantan's top five flood-prone districts. Due to the heavy rainfall, Kelantan is at danger of severe flooding (State Drainage and Irrigation Department (DID) 2022).

1.2.2 Road Accessibility

Road access to Kuala Krai is by two major roads: Federal Route 8 and the Kota Bharu-Kuala Krai Expressway. Firstly, Federal Route 8, popularly known as Kuala Lumpur-Kota Bharu, is a 402.7 km long Malaysian federal highway. It connects Bentong to Kota Bharu in the south and Kota Bharu to the north.

The Kota Bharu-Kuala Krai Expressway is a 73-kilometer (45-mile) expressway that connects the cities of Kota Bharu and Kuala Krai in Kelantan. Because the study location is close to the city of Kuala Krai, it is much easier to

reach there due to various transportation options available, including vehicles, buses, and trains. There is also a boat service that can assist in crossing the Kelantan River.

1.2.3 Demographic

Agriculture provides the most significant source of revenue in the study area. At the period, rubber manufacturing was becoming increasingly significant throughout Malaysia, and many rubber-tree plantations were established in this area. Later, oil palm plantations were established in the territory, some of which replaced rubber. Most of the people who live in the area are either self-employed or work as laborer.

1.2.4 Land Use

Land use is the process of managing and modifying the natural environment to create a new built environment. It may take a long time to complete. The overall arrangements, activities, and input that people undertake in a specific land type constitute natural environment alteration. The land use in Kuala Krai is dominated by rural and urban development's due to its proximity to the town and village. Today, progress can be witnessed in Kuala Krai, such as hospital facilities, public libraries, schools, shopping malls, and other locations that are flourishing.

Furthermore, land in Kuala Krai is used for agricultural purposes. Agriculture is the most important land use, accounting for half of the world's habitable land. The extensive land use has a major impact on the earth's environment as it reduces wild

mess and threatens biodiversity. The research area in Kuala Krai area is mostly covered by plantation areas such as palm oil and rubber tree plantation areas. Aside from it, the city area covers the north coast area.

1.2.5 Social Economic

The primary source of social economic income in the research area is agriculture, as well as government employees and self-employment. The government sector is large and includes numerous residents such as state or local government and all units of federal government that can give many services to people. Furthermore, most people in the area work as contractors or labourer's due to the study area's proximity to palm oil plantations in the north and rubber tree plantations in the south.

1.3 Problem Statement

The weakness of outdated geological maps in the research area is the neglect of low-lying locations that are likely to flood but there is no geological evidence of flooding. Geological maps basically can show where all the floodplains are located as well as the main areas at greatest risk of flooding. The map had been based on observations of the many types of geological deposits found in the area and did not account for any man-made influences such as house construction or flood controlled planned. Therefore, it is a necessity to produce or update the geological map of Kampung Laloh, Kuala Krai considering that geological factors are one of the most important elements related to flood disasters.

Floods can be interpreted using geological maps, which can explain why flooding does not occur in every region of a valley bottom. Tectonic activities, weathering processes, and other processes had an impact on the geology of Kuala Krai, Kelantan. The geological chart must be updated because the geological data has changed. Even if the flood happens regularly in the Kelantan region, the impacts of the flood cannot be mitigated or diminished. Hence, this research was carried out in order to identify the causative factors that contribute to the disaster's impact on the community and the surrounding environment.

1.4 Objective

The objectives of the research are as follows:

1. To update the geological map of the study area in 1:25,000 scale measurement
2. To determine the parameter of flood hazard analysis
3. To produce a flood hazard map by identifying the flood hazard zones in the study area

1.5 Scope of Study

This research will focus on the geology of Kuala Krai, Kelantan especially in the Kampung Laloh. This study will be done through the interpretation of the study area by using some software such as Google Earth, GIS software with the help of secondary data and previous research. Besides, this study area focusing on flood hazard analysis by doing a map that shows an area that exposed to flood hazards. This map will categorize into low, medium and high of water depth in the area.

Floods were the most common typed of natural hazard that occurs in most areas. The expected results of a flood risk area map which consists of different levels had been produced based on a few parameters such as accuracy of digital elevation model (DEM), land use and amounts of rainfall. Beneficiaries of flood hazard and vulnerability studies can expand variables knowledge of flooding, anticipation of future flooding, and willingness to accept adjustments for better flood management plan in the Kuala Krai.

1.6 Significance of Study

Structure, processes, depositional settings, and surface and subsurface aspects of the Earth can all be obtained through geological maps. It provides essential information for establishing outcrop, slope, and drainage area. Human alteration of the physical landscape can also be depicted on geologic maps so that is why geological map with 1:25000 scale must be created.

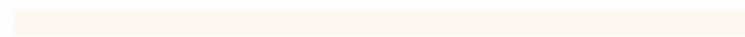
Next, in order to determine which areas are most at danger of flooding, flood hazard mapping is a vital component of flood assessment. So, it is important to determine the parameter of flood hazard analysis.

This researched would add to our understanding the cause of flooding from a geological standpoint. The final outcome of flood hazard map would assist the government in reducing flood risks by delivering early alerts to citizens in flood-prone areas through Jabatan Pengairan dan Saliran. The studied would aid in the development of a better understanding of flood conditions in the area, which

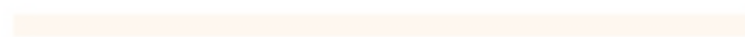
would aid in the development of economic sector and the improvement of the living standards of the area's resident.



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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, all prior researched had been summarized in terms of how it relates to the current studied. The literature review must include the important contents, such as the objectives, problems, and methods previously used. This research would aid in obtaining all the general geological information about Kuala Krai, Kelantan, through a comprehensive studied of the area.

Geological studies are important because they can help identify the types of rock, its distribution, and the overall structure of the area studied. A geological map can be created using this information. All secondary data, such as books, journals, and articles, would serve as sources for this studied. Researched on the studied area of Kuala Krai district and its title by previous researchers had been discussed in more detail in this discussion.

Based on previous research, floods contribute to the risk of human life and property damage because it is difficult to identify flood-prone areas. Urban flood vulnerability varies over time due to society's culture in the face of threats (Ahmad and Simonovic 2013). In Kuala Krai, a lack of environmental disaster management and information led to this incident. It is important to have accurate information

about both physical and climatic risks and vulnerable areas in order to successfully mitigate the effects of a flood disaster. Because the vulnerability is the root cause of catastrophe, more information is needed. If a flood occurs, low-lying areas are more at risk than higher ones depending on the location and metrology. The risk of flooding can increase as a result of new, unplanned development, which can lead to increased runoff.

According to previous study (Takemoto, 2011), there has been an increase in the amount of damage caused by flooding over time. A flood vulnerability map for Kuala Krai can provide protection against flooding. This goal can be achieved by reducing vulnerability. A GIS is essential to flood mapping because it can predict flood vulnerability and help manage flooding more effectively. Identifying vulnerable areas and implementing effective measures is one of the most important steps in this process.

2.2 Regional Setting

Sibumasu and Indochina or East Malaya, which were both formed by the Late Triassic period, are the two continental terraces that make up Peninsular Malaysia (Pour and Hashim, 2015). The western tin belt, the central gold belt, and the eastern tin belt were all based on stratigraphy and mineralization.

As a follow-up, it can be dividing the country into two regions: the northwest and the Kinta-Malacca sectors identified four structural domains in Peninsula, one of which is Northwest. Eastern, Western, and Central. With all the above statement,

Lebir Fault zone is known as the boundary between eastern and central belts while boundary between central and western belts is taken as Bentong-Raub.

2.3 Stratigraphy

As a branch of geology, stratigraphy studies the order and position of layering strata and their relation to the geological time scale. This research primarily utilized sedimentary and layered volcanic rocks. Schist is also present, but it's of a lower grade. There is a dearth of evidence for the presence of Triassic sediments. There are continental deposits from the Jurassic to the Cretaceous era that are unconformable with the older Carboniferous and Permian sediments. Western Kuala Krai is dominated by the granite Stong Complex and the Gua Musang and Taku Schist rock formations. The most extensive product of deep-seated regional metamorphism as product of Indosinian Orogeny in Peninsular Malaysia is the Taku Schist. The Taku Schist is exposed as a body elongated along a NNW-SSE trend with an anticlinal dome shaped structure that plunges toward the southern end.

2.4 Structural Geology

Because the study location is close to the city of Kuala Krai, it is simpler to get to because there are various transportation options available, including vehicles, buses, and trains. There is also a boat service that can assist in crossing the Kelantan River, which is a deep river. The Central Belt rocks that surround the Main Range Granite are also metamorphic, including polytropic schist, phyllites and amphibole schist.

The Taku Schist in north Kelantan is known as the greatest tract of regional metamorphic rocks in the Central Belt area. The terrain is substantially larger if the low grade phyllites bordering the Taku Schist are included. According to MacDonald (1967), serpentinite was also found in the Late Triassic period. Because the Taku Schists were metamorphosed in the Late Triassic, it must be an older group of rocks.

Based on Figure 2.1, the Kelantan region contains four types of rocks: granitic rock, sedimentary or metasedimentary rock, extrusive rock (volcanic rock), and unconsolidated sediment. There are also faulting and joints in granitic rocks, as well as folding, faulting, and joints in sedimentary rocks. Granitic rocks are found in the west (the Main Range granite) and east (the Boundary Range granite) borders of the state of Kelantan.

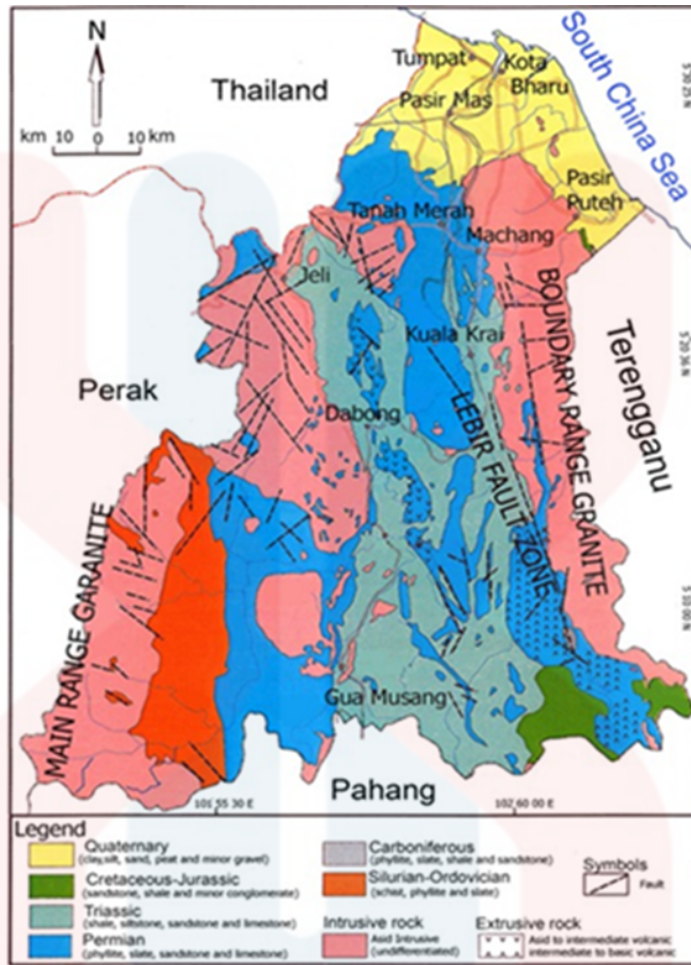


Figure 2. 1: Geologic map of Kelantan state

2.5 Historical Geology

Kelantan is located in the north-eastern part of Peninsular Malaysia (Figure 2.2). The Kelantan River is the region's main river, originating at the confluence of the Galas and Lebir rivers. The location is close to the Kuala Krai district region and meanders through the coastal plain before dissolving into the South China Sea. The Kelantan River basin comprises 923 km², accounting for approximately 85 percent (%) of the state's surface area. It is made up of flat to moderately sloping sections in the north and steep scrapes and high slopes in the south of the river basin.



Figure 2. 2: Location of Kelantan in Peninsular Malaysia

In the state of Kelantan, a wide variety of rocks, including igneous, sedimentary, and metamorphic rocks, are scattered in a north-south trend. Kuala Krai is a district in Kelantan and is known as the second largest district after Gua Musang. Kuala Krai borders Machang in the north and Gua Musang in the south, while the east is adjacent to Terengganu and the west is adjacent to Jeli. Kuala Krai was formerly known as Kuala Lebir.

2.6 Research Specification

2.6.1 Flood in Malaysia

Floods are Malaysia's most frequent and devastating natural disaster, causing billions of dollars in damage each year. Flash floods and monsoon floods are two types of floods. About 3000mm of rainfall is produced each year by the heavy

monsoon rains, which creates an enormous flood prone area with a high risk of flooding. Kelantan is prone to flooding due to the country's proximity to the South China Sea, which causes flooding on a regular basis. In the northeast monsoon seasons of November to March, an abundance of rains causes flooding until it reaches a certain level and discharges into the channel in the Kuala Krai district area. Monsoon and flash floods are the most severe climate-related natural disasters in Malaysia, with a flood prone area of about 29,000 km² affecting more than 4.82 million people (22% of the population) and inflicting annual damage of USD 298.29 million (Asian Disaster Reduction Centre (2005) Mitigation and Management of Flood Disasters in Malaysia).

2.6.2 The Causative Factors that Influence Flooding

Several factors in Malaysia contribute to the country's high risk of flooding. Physical and human geography are intertwined, and they influence each other. Human geography, such as settlements and land use, as well as natural geography, such as topography and drainage, have all contributed to a variety of floods, including monsoons and tides.

As examples at the Kampung Baru. Kampung Baru district is located in the central area of Kuala Lumpur enclosed between the Klang River in the south - east and the Sungai Bunus in the north - west. Kampung Baru is prone to both river flooding and flash floods, partly due to the poor drainage system (D'Ayala et al., 2020). The floods were caused by the existing drainage system to be unable to contain the high-water flow capacity.

Works by (Sugianto, 2022) surface overflow and the infiltration capacity of a land surface are both affected by the change in land use and land cover in upstream watersheds, which is a contributing factor to flooding. The primary goal of this research is to map the flood hazard in the Teunom watershed by identifying flood-prone locations and evaluating their causes using ground-based measurement, remote sensing data, and GIS-based flood risk mapping techniques.

Another example is in Pahang (Safiah Yusmah,2020). The annual flooding phenomenon brought on by the periodic monsoon causes huge losses in Malaysia. Poverty and vulnerability are on the rise as a result of rising flood risk, exposure, and

possible destruction. Because the risk of flooding occurs annually, people have learned to take preventative measures that make it easier to resume their normal lives afterward. The purpose of the research was to learn more about how flood victims in Kuantan, Pahang, react to disasters and how prepared they are for future floods.

2.6.4 Flood Vulnerability Analysis by Using GIS Analysis Tools

Flood vulnerability analysis can show that researchers are increasingly using multi- criteria decision-making tools (MCDT) to assess the risk of flooding. For example, GIS has been used to compute flood vulnerability index based on social and physical criteria in several urban areas (Figure 2.3) (Dano et al., 2019).

By combining spatial and non-spatial data, GIS analysis has the potential to produce high-quality insights within the framework of a comprehensive analysis strategy. In the 1970s, more people started using GIS, although most were still employing mainframe-based methods at that time. The Harvard Laboratory for Computer Graphics and Spatial Analysis was among the leading academic organisations in the 1970s working on producing widely accessible mapping software, while having its origins in the 1960s (Chrisman, 2005).

ArcGIS software is used to create flood maps by applying the weighted overlay method in GIS tools (WOM) and assigning weighting and scoring to each parameter as shown in Figure 2.4. This approach is a function that overlays all the parameters that influence flooding based on the effect of each parameter on flooding. Several criteria, including river distance, flow accumulation, rainfall intensity, land

use, slope, elevation, and lithology of the area, must be thoroughly investigated. According to Suhardiman (2012), in the GIS analysis section, the weight for each thematic map is determined by the likelihood of flooding caused by each geographical characteristic.

Furthermore, scoring is vital in assigning a score to each class in parameter since it is based on the class's influence on events. The stronger the effect on the events, the higher the parameter's score (Anas Sudijono, 2007). According to the influence of the class, the total influence of the parameters must be 100%. The influence value can be bigger or lower depending on the parameter and the study region. The values assigned to each parameter are the same, namely 1-5, but weighting is determined by the influence of each parameter on the level of flood vulnerability (Matondang J.P. 2013).

Based on Purnawali (2017), the vulnerability of flood zones in the mainland area of Sidoarjo Regency is classified into five (five) categories which is "very highly vulnerable," "highly vulnerable," "moderate vulnerable," "low vulnerable," and "very low vulnerable" as indicated in Figure 2.3.

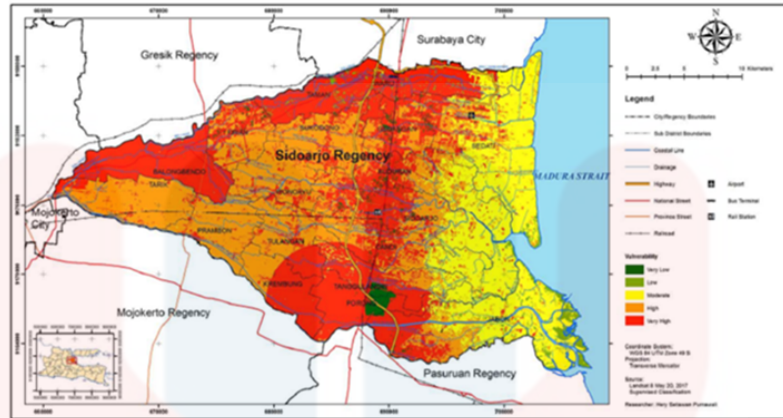


Figure 2. 3: Flood Vulnerability Map in Sidoarjo Regency

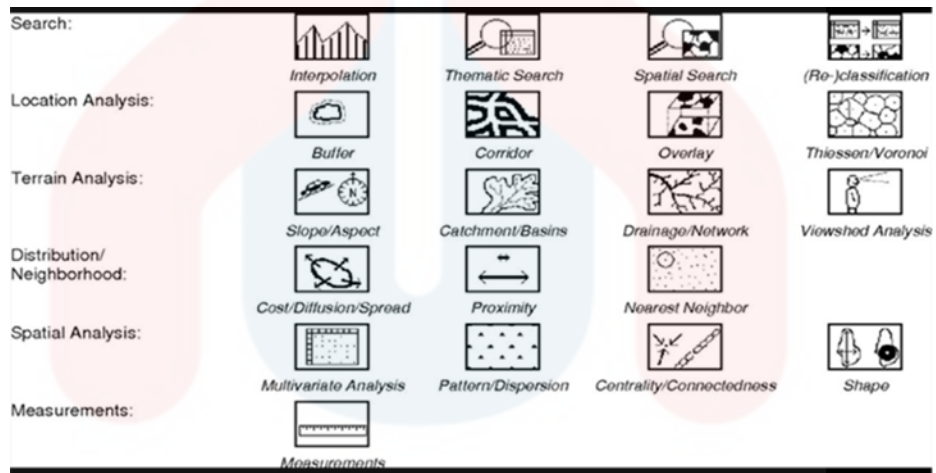


Figure 2. 4: Flood Vulnerability Analysis

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CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This section describes about materials and techniques that were used to complete the process of data collection and analysis for geological interpretation and vulnerability assessment of flood. The result should be easier when use the proper techniques and methodologies. Research flowchart of overall methodology is indicated in Figure 3.1.

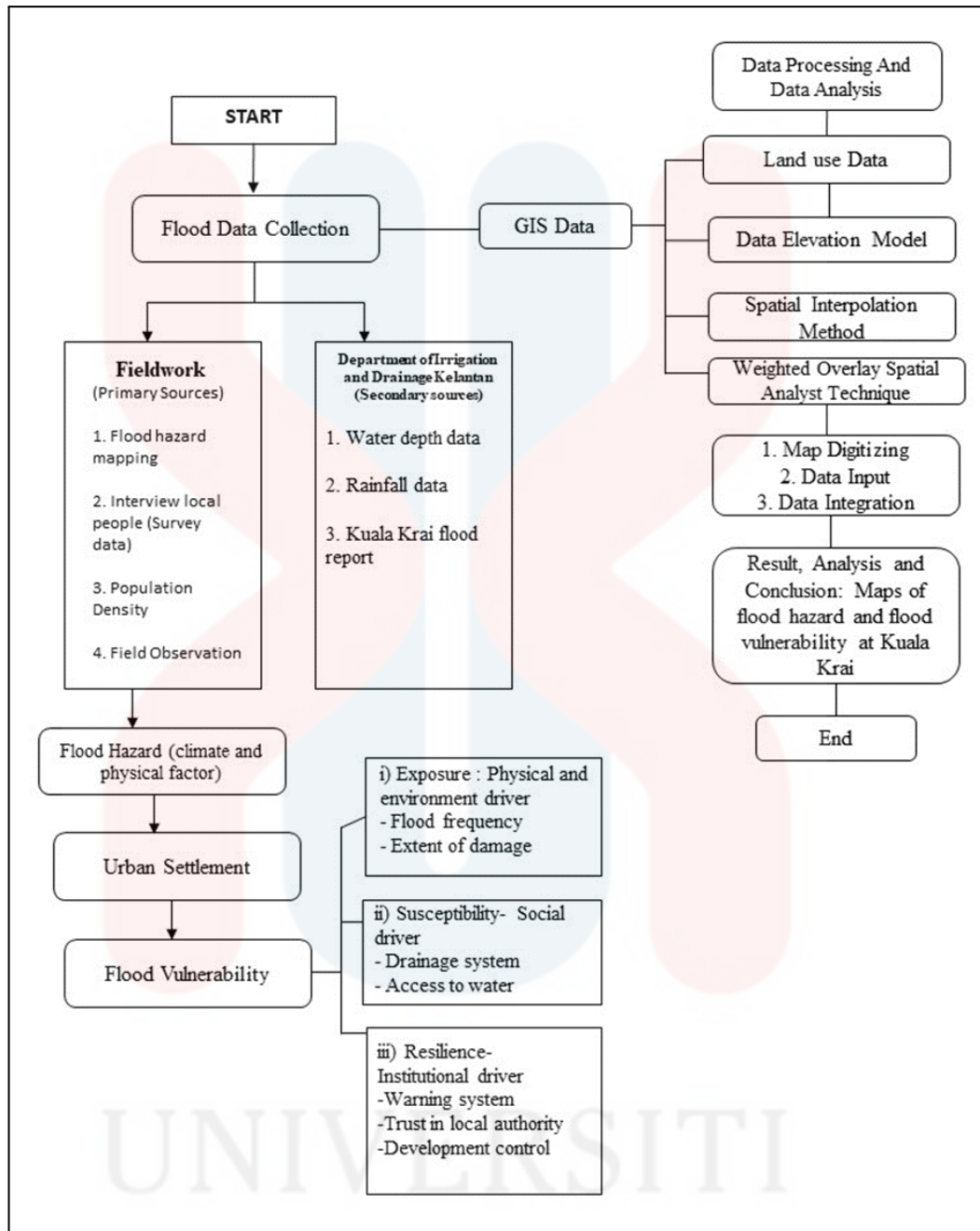


Figure 3. 1: Research flow chart

3.2 Materials

To conduct this research, two types of materials were divided which is for geological mapping and for flood vulnerability assessment. In geological mapping

scope, the mapping equipment is needed such as, compass, measuring tape, stationery, and GPS

3.2.1 Google Earth

A computer software that represents the 3D effect of the Earth using satellite photos. It allows users to view the terrain from multiple perspectives by superimposing aerial imagery, satellite images, and GIS data onto a 3D globe.

3.2.2 ArcGIS Software

ArcGIS is required to create the research area's base map. All primary and secondary data were used to create a geology and flood hazard map of the research area. Flood hazard maps are created in ArcGIS software using the Weighted Overlay Method tool.

3.2.3 Data

Secondary data such as Digital Elevation Model (DEM), flow accumulation, slope and rainfall data were gathered from available website such as United States Geological Survey (USGS) and Department of Drainage & Irrigation (DID).

As the most critical and direct cause of a flood disaster, rainfall has a major impact on a flood hazard study, especially intense rainfall over a short period of time. Gauge observations and satellite estimations of rainfall levels (low, medium, and

high) are currently the primary sources of information used in flood danger analyses. Rainfall data can be obtained from Jabatan Pengairan dan Saliran (JPS) from 2018-2020 at Dabong and Kampung Laloh rainfall station.

Meanwhile, slope data is important because water volume, flow rate, and inertia force all increase as the slope lengthens. If you move away from a watershed's boundary, the flow's kinetic energy and velocity will increase, making floods more likely.

And lastly, Flow Accumulation. In runoff simulation, the flow accumulation is generated by determining the flow direction. The number of cells that pass through a certain cell determines the flow accumulation for that cell; a higher flow accumulation value means that runoff may be formed more easily in that location.

Table 3.1: Characteristics of DEM data

Entity ID :	SRTM3N05E102V1
Publication Date :	2005-02-01 00:00:00-06
Resoloution :	3-ARC
Coordinates :	5 , 102

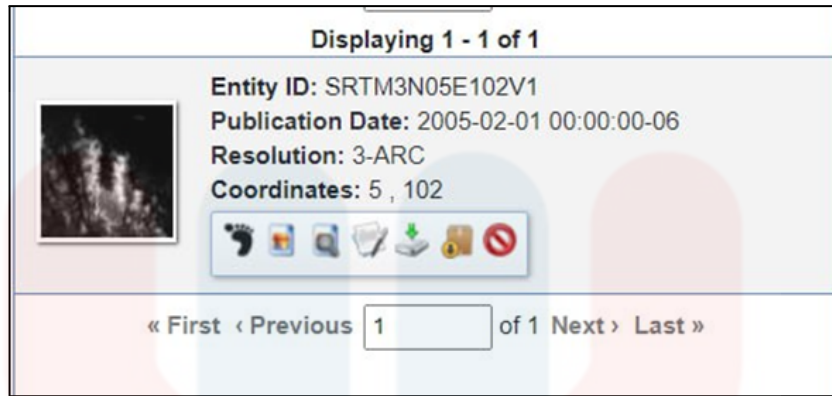


Figure 3. 2: The DEM data information of the study area

3.3 Methodology

The methodology plays a crucial role since it elucidates the process by which this study is being conducted using secondary sources of information. The geological component of the study region and its definition in flood hazard assessments can be better understood with the use of secondary data and prior research. Changes in water level, flood depth, and rainfall had been identified for flood vulnerability assessments. By weighting the parameter and causative factor in the researched region, the potential flood area could be determined.

To determine the distribution of the parameters, the flood vulnerability map and geological map were constructed using ArcGIS software. The weighted overlay technique is an important GIS strategy because it allows to create a flood vulnerability map by superimposing one map picture over another, and the results were displayed on a graph (Muhamad Azahar Abas,2020). This analysis was conducted using a scale of 1 to 5, with 1 representing low vulnerability and 5 representing high vulnerability to flooding. (Nur Aniza Mohammd Hanan,2020).

3.3.1 Preliminary Studies

Previous research must be thoroughly understood before conducting a research study since research began in this phase by studying a literature review related to the background study. Previous publications, journals, and other flood danger reports are essential for a researcher to find information. Data obtained from articles, websites, or books were examples of sources used in the literature review.

The preliminary investigation is also very useful because it provides an overview of the study region and assists researchers in developing a plan for doing the research. Furthermore, data from the base map, such as lineament and geomorphology, can be acquired using the ArcGIS software.

3.3.2 Field Studies

Geological mapping was conducted to analyse the study's features. To figure out the causes of flood, it is important to find out the structural geology, weathering, and geomorphology of the study area. Primary data was collected from geological mapping while secondary data was gathered from the previous geology study in that area. A field study was conducted to gather all significant information on previous flood operations in the region. Additionally, it assists in the evaluation of numerous causative factor maps created during pre-field work. At the completion of the mapping, a geological map was designed.

3.3.3 Laboratory Work

Meteorological data was collected within study area from Department of Drainage and Irrigation (DID) for analysing average amount of rainfall purposes, which was represented in the form of a point shapefile that included the longitude and latitude of each station (Nur Aniza Mohamad Hanan,2020). As a result, accurate data was obtained by doing laboratory work.

For the rock identification, there will be a laboratory work to create a thin section. In the fields of geology, minerology, and petrography, a frequent form of laboratory preparation is a thin section, sometimes known as a petrographic thin section. Rock, mineral, and even metal may all be examined through a thin slice.

3.3.4 Data Processing

This study makes use of both primary and secondary data, either as part of geological mapping data or in the definition of flood hazard assessments. All secondary data either in geological data or flood data that have been collect are process by using specific software such as ArcGIS. These data needed in order to update and produce the new geological map of the study area. Secondary data can be gathered from sources such as papers, journals, books, and the Internet, which include the results of past research. The parameter focuses on the factor, which is flow accumulation, elevation, river distance, slope, land use, and lithology.

In addition, part of it, including the Digital Elevation Model (DEM), is accessible through the at the USGS website. The DEM was used to build further themed maps referring to slope map, aspect map and lithology map. Data are necessary for performing geology and flood vulnerability evaluations in the Kuala Krai, Kelantan study area.

a. Weighting

A color ramp was assigned to the data in order to reveal the inundation area layers, which were used to graphically depict the areas that are most vulnerable to flooding. Using weight overlay analysis, this methodology was represented on a scale that represented the relative vulnerability of the Kuala Krai district based on expert opinions, and the results were displayed on a graph (Muhamad Azahar Abas,2020). Weighting provides each topic map prominence (parameter). The weight of each thematic map is determined by the extent to which each GIS analysis-relevant geographical parameter effects flood probability (Suhardiman, 2012).

b. Weighted Overlay Spatial Analyst Technique

A measurement scale and the raster layer of the parameter used, such as slope, vegetation, drainage density and aspect, were produced. It overlays several rasters and weight each one according to its influence by using a common classification scheme, each raster has been assigned percentage of overall impact. The values of the cells are multiplied by the percentage influence of the cells, and the resulting sums are calculated. The weight evaluation was done based on the reclassified

weight by using reclassify tools in ArcMap. As a result, the flood vulnerability map was generated.

3.3.5 Data Analysis and Interpretation

In the general geology aspect, the geological mapping that includes the traversing and sampling is a severe matter where all the geological characteristics and elements are observed and recorded. The data from the satellite imagery such as slope, lineament and land use were compared with the collection of data from geological surveys and mapping. The data was analysed during the observation of the research area to update the outdated one.

GIS was also used to create a flood vulnerability map in order to extract facts that needed to be explained further. The flood vulnerability map was constructed by collecting and evaluating data on all flood-related factors, such as flow accumulation, elevation slope, land use, and lithology.

As for flow accumulation factor, there is a scale to determine the vulnerability area. Based on a scale of 0 (zero vulnerability), 1 (low vulnerability), 2 (modest vulnerability), 3 (moderate vulnerability), and 4 (very high in vulnerability) (Nur Aniza Mohamd Hanan,2020). If an area was very near to water sources or water bodies, it will show that the area is more vulnerable than other areas. This is how it work. Flooding is when the water increased flow capacity of water body's surface level. It makes the surrounding environment increase in order of vulnerable from this point of view.

CHAPTER 4

GENERAL GEOLOGY

3.1 Introduction

All the specifics of geology, including geomorphology, lithostratigraphy, structural geology, and historical geology, need to be set in a general geology chapter. The information described in this section comes from three sources: a previous study, an assessment of remote sensing data, and the use of a geographic information system.

3.1.1 Brief Content

Landforms and physical features of Earth's surface are studied and named according to their physical characteristics, such as rivers, hills, plains, beaches, and sand dunes. The study area's landform and the processes that act upon it were analysed with attention and consideration. Understanding landform's history requires a focus on form, process, and the connections between them.

Geomorphology is defined in this chapter as the study of the Earth's surface, drainage, contour pattern, weathering, and processes contributing to the formation and development of the Earth. Additionally, the topography and drainage pattern are highlighted in the study.

3.1.2 Accessibility

The term “accessibility” refers to the availability of several means of entering, approaching, or otherwise reaching the designated region of study. Figure 4.1 is an accessibility map of the Kuala Krai Town area, showing the various road and river access points. Since it is inside a highly developed city, the area under study has easy access to major roads and is centrally located.

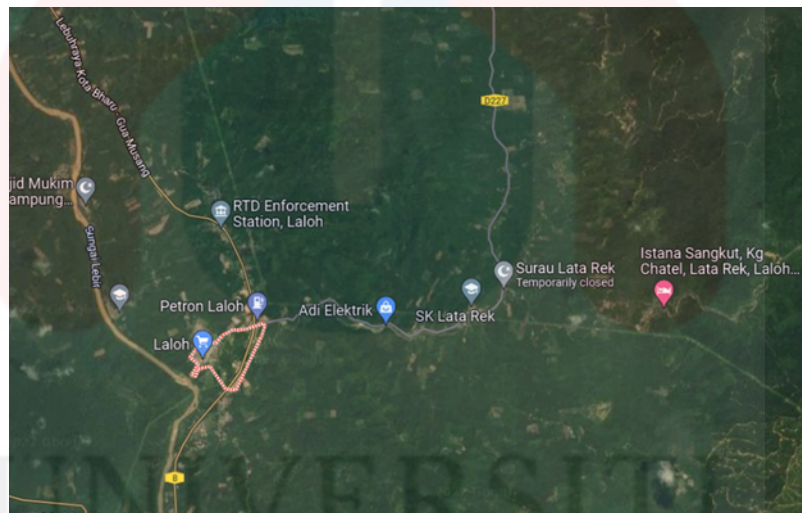


Figure 4. 1: Accessibility Map of Kampung Laloh, Kuala Krai, Kelantan

The study was carried out in the town of Kuala Krai, which can be located at latitude $5^{\circ} 22' 10''$ N to $5^{\circ} 18' 30''$ N and longitude $102^{\circ} 19' 10''$ E to $102^{\circ} 21' 20''$ E. From Kota Bharu, a key route that leads to Gua Musang, Kuala Lumpur, and other major cities can be used to reach this research area. Kuala Krai, Kelantan’s major road, as seen in Figure 4.2, is the most travelled route in the region.



Figure 4. 2: Lebuhraya Kota Bharu- Gua Muang is the main road to study area at of Kampung Laloh, Kuala Krai, Kelantan.

The study location can be accessed by four-wheel drive, vehicle, motorbike, or by foot over unpaved roads in environments like rubber plantation, farm, or forest. The main river in the area is Lebir River (Figure 4.3).

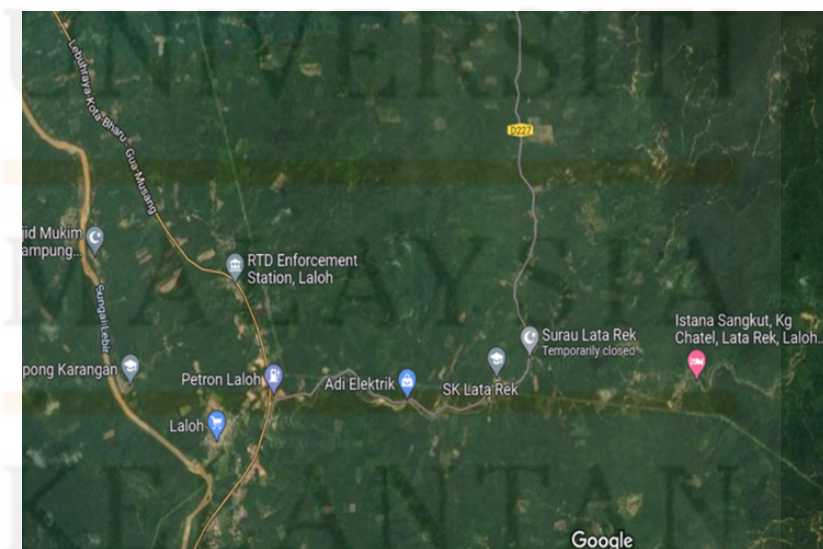


Figure 4. 3: The main river, Lebir River in Kuala Krai, Kelantan

3.1.3 Settlement

Settlement is a place where community in which people live. Given its central location within Kuala Krai, the town's settlement covers a significant geographical area. Kampung Laloh are part of the research area's human population. Figure 4.4 shows the total estimation population of Kuala Krai in 2020 is 19,573.

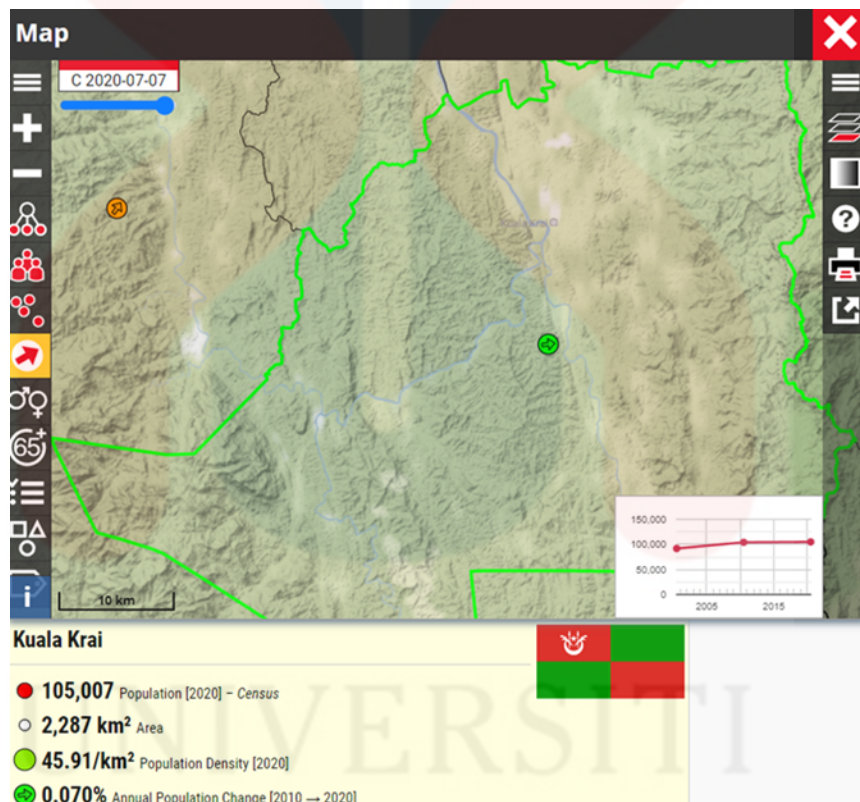


Figure 4. 4: The population of Kampung Laloh, Kuala Krai, Kelantan

3.1.4 Forestry

Kampung Laloh is surrounded by a diverse range of plant life, including rubber trees, forests, and gardens. The main activities within Kampung Laloh are

focused on agriculture and plantations which contribute to the community's economic sector.

3.2 Geomorphology




The term “geomorphology” comes from the Greek for “the Earth,” “form,” and “discourse.” So, it’s a talk on the forms of Earth. Due to its potential to characterise the physical structure of the Earth’s landforms (rivers, hills, plains, etc.), geomorphology is an important consideration in the assessment of geological maps. Studying the history and mechanisms behind the formation of various landforms is a major focus of current study.

3.2.1 Geomorphologic Classification

The purpose of geomorphology is to categorise geomorphological characteristics according to their nature, where they originated, and how often they occur. In geomorphic categorization, the four primary categories that are employed are landforms, morphometry, geomorphic generation, and geomorphic processes. Morphometry is the study of the relationships between landforms. As shown Figure 4.5 refers to Landform Map of the study area while Table 4.1 indicates Topographic unit based on mean elevations. There is four colour which indicate as light green as low land, dark green as low hill, orange as hill and red as mountain. The green symbol show that there is slightly sloping plain and the red symbol is the steep hills.

The topography of the Earth's surface was moulded by geological forces, including endogenic, exogenic, and extra-terrestrial activities. These geological forces were responsible for the physical and chemical processes. These transport and transformation processes may take place in a variety of ways, including via weathering, gravity, water, wind, and ice.

Table 4.1: Topographic unit based on mean elevation

No	Geomorphological Unit	Symbol	Landform	Elevation (M)
1	Slightly sloping plain		Low Land	0-100
2	Sloping hills		Low Hill	200-400
3	Steep hills		Hill	500

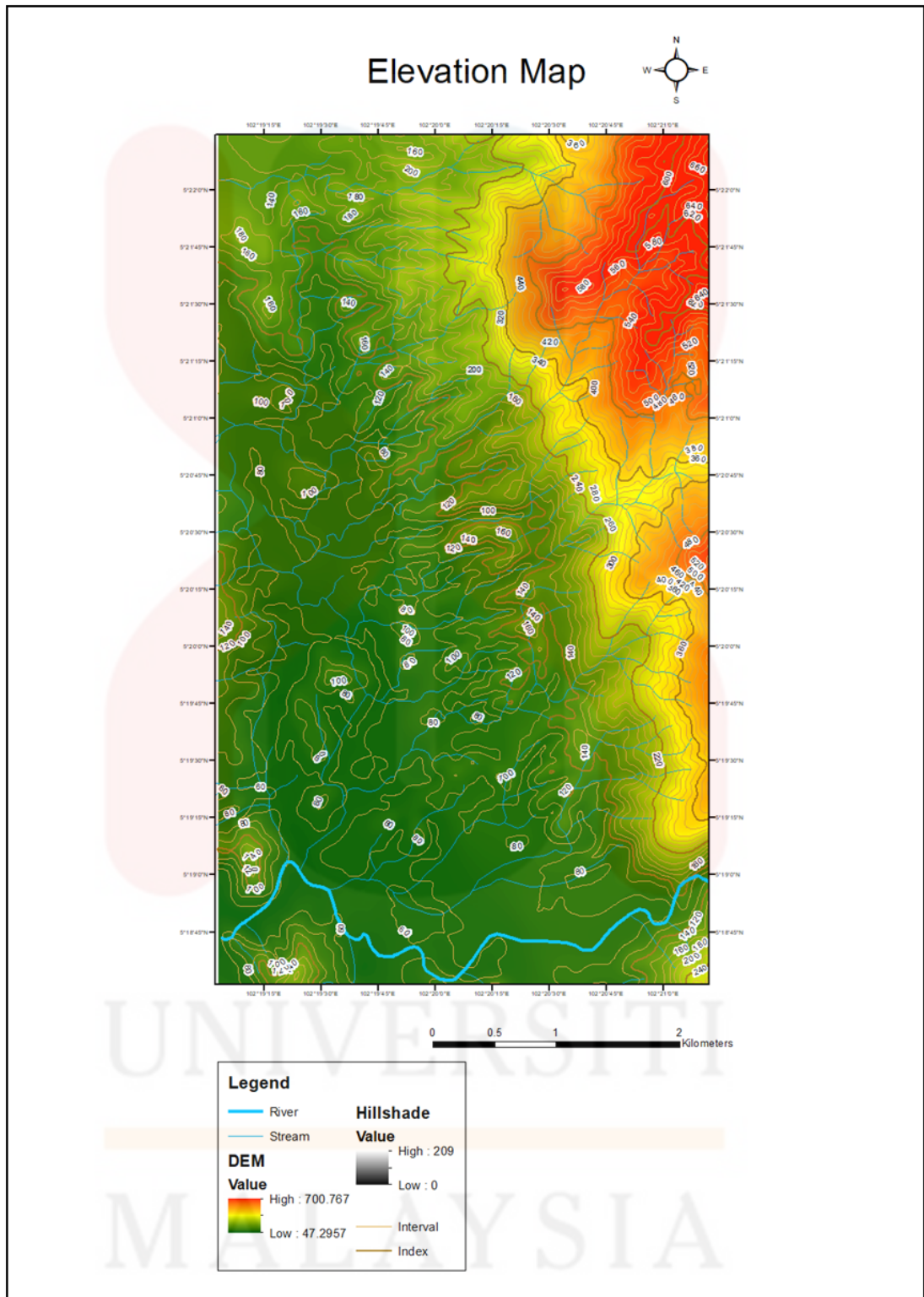


Figure 4. 5: Landform map of Kampung Laloh, Kuala Krai, Kelantan

3.2.2 Weathering

Soil development relies heavily on the process of weathering, and healthy soil is essential to human survival on Earth. About half of soil is composed of inorganic minerals, while the other half is mostly air and water in variable proportions. Soils have a wide range of mineral compositions, although clay minerals and quartz predominate, with feldspar and other rock fragments making up the rest.

3.2.3 Drainage Pattern

It is essential to know the local drainage pattern for both GIS and topography analysis. In geomorphology, a drainage pattern is a system of waterways and bodies of water that flow into and out of a certain basin. In GIS databases, river networks are shown as lines, which not only indicate their positions but also their topographical connections. The networks make it easier to see patterns and how they link to the world around us. Charlton (2008) claims that topography, soil types, bedrock type, climate, vegetation, water and sediment transport, and many other factors all have an impact on drainage basins. The drainage system can be digitised in a Geographic Information System (GIS) either manually or via extraction from a DEM by calculating the flow direction and accumulation on the terrain (Ortega and Rueda, 2010).

A stream's drainage pattern is its physical arrangement on Earth's surface as a result of the Earth's drainage system. The drainage basin is a unique ecosystem that has developed due to the presence of streams, rivers, and lakes. Dendritic, parallel,

trellis, rectangular, radial, centripetal, and reticulate drainage patterns are the seven types identified by Ritter (2003).

Based on the list given, there is three type of drainage pattern which is dendritic, parallel and rectangular pattern. Figure 4.6 shows all the drainage pattern in the study area. Lambert (1998) stated the dendritic pattern is the most common form of river system and the river system, tributaries of a main river join together in a shape liked tree or V-rule or V-shaped valley.

Secondly, parallel drainage pattern is developing in regions of parallel and elongate landforms like outcropping resistant rock bands. Lastly, rectangular pattern its occurs when the rock structure steers streams into a parallel course with tributaries joining at almost right angle. Sometimes, the joint pattern in the rocks create rectangular drainage.

Figure 4.6 shows the drainage pattern map of the study area where there is rectangular, parallel and dendritic pattern. The elevation, slope and lithology of the area play important roles in forming the drainage pattern.

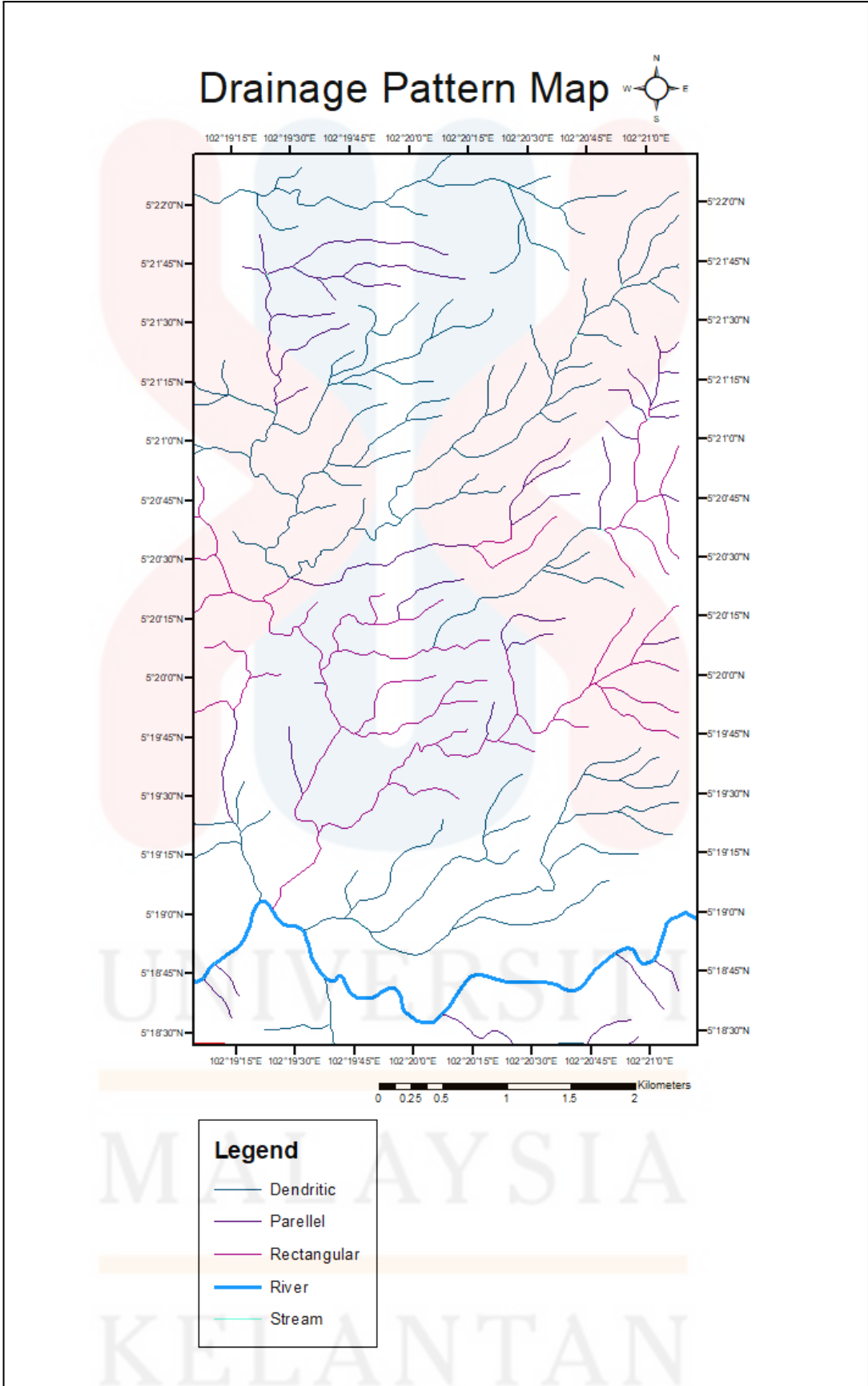


Figure 4. 6: The drainage pattern map in the study area

3.3 Lithostratigraphy

3.3.1 Stratigraphy Position

The study of stratigraphy, a branch of geology, sheds light on how rocks are formed and the relationships between different types of rock layers. The characteristics of the layered rock and their relationship to the formation time have been analysed and established. Stratigraphy allows geologists to rapidly evaluate the state of the Earth at any given location.

That's why more information about the area's geology, like its structures, geological age, depositional environment, and history and evolution, needs to be made public. Lithostratigraphy, a subfield of stratigraphy, is the study of rock strata and their interrelationships. Based on the data shown in Table 4.2, it clearly shows that determining the age of the rock unit and elucidating the link between the different strata in the region under study requires knowledge of the stratigraphic column.

Table 4.2: Stratigraphy column of study area

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	The main features consist of quartz and sericite with accessory mineral biotite	Granodiorite	Cretaceous	Mesozoic
	Major felsic mineral is quartz with minor mafic minerals such as biotite and chlorite	Granite	Precambrian	Paleozoic

Superposition, the fundamental principle of stratigraphy, dictates that sedimentary rocks should be placed with the oldest on the bottom and the most recent on the top.

Elevation, cross section, and lithology rocks in the study area are represented in a geological map (Figure 4.8). According to the map, the rocks in the area studied include granite and granodiorite. The varying colors indicate the various types of lithology. Kampung Laloh is located on igneous rock, which consists primarily of granite and granodiorite. The lithology colours from the USGS website were used to determine the geological map's colours.

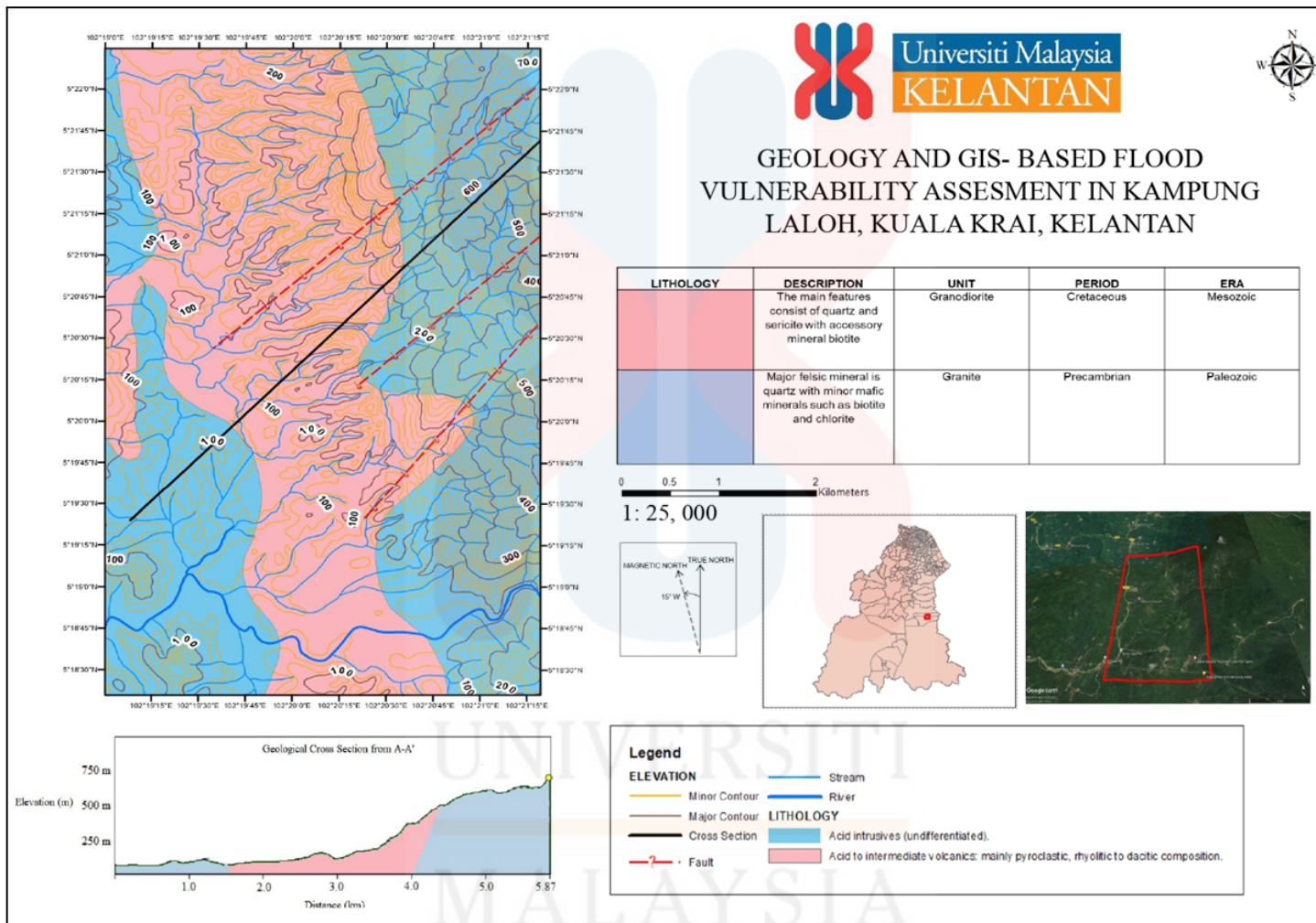


Figure 4. 7: Geological map of study area

3.3.2 Unit Explanation

The research region contains two major types of lithologies. Here are some examples of the lithology that was found in the study area.

a. Granite

Most igneous rocks are phaneritic in texture, and granite is one of the most frequent types of phaneritic intrusive igneous rock. Quartz, mica, feldspar, and ferromagnesium are only few of the minerals that make up granite. Granitoids are sometimes referred to as granite or granitic rock, while granite is merely one kind of granitoid.

The research area includes a section of granite that lies to the west, beneath the Stong Complex (Kuala Krai Area). This can be proven by petrography analysis result shown in Figure 4.9 and Figure 4.11. Table 4.3 and Table 4.4 Mineral composition and description. As can be seen on Figure 4.9 the black and white colour and no cleavage are mostly identify as quartz. From PPL, there is about 67% of white colour on thin section. But there is only 2% of Biotite, usually the black colour on XPL is identify as biotite but when it is under PPL it is in white so it is quartz. Meanwhile in Figure 4.11 the quartz mineral composition is 50% which obviously show under the PPL where there is a lot of white in colour mineral(quartz) but the biotite is more visible compare to Figure 4.9 where Figure 4.11 has 20% of biotite.

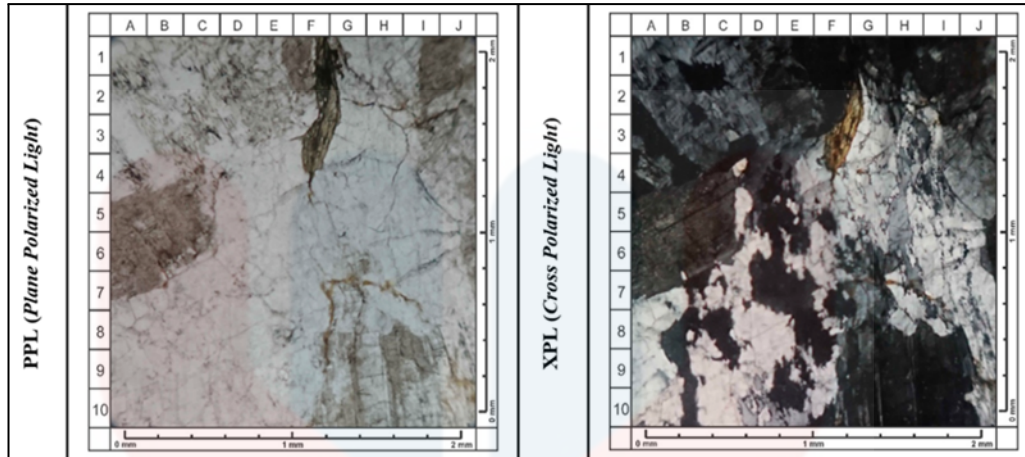


Figure 4. 8: The observation of the enormous structure, phaneritic texture and coarse – medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification

Table 4.3: Mineral Composition and Description

Mineral Composition	Description
Quartz (A10) – 67%	At PPL the absorption colour is colourless, low relief, no pleochroism, anhedral crystal form, no cleavage. In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.
Microclin (H10) – 30%	In PPL, the absorption color is colorless, low relief, no pleochroism, subhedral – anhedral crystal form, 1-way cleavage. In XPL the interference color is order 1 gray – white, the dark angle is slanted, polysynthetic twinning
Biotite (F3) – 2%	At PPL absorption color is brown – greenish, moderate relief, strong pleochroism, subhedral – euhedral crystal form, 1 way cleavage. In XPL, the interference color is green – orange order 3, there are no twinning parallel dark angles.
Opaque Mineral (F1) – 1%	At PPL the absorption color is black, low relief, no pleochroism, euhedral – anhedral crystal form. In XPL color interference black order 1, there is no twinning.
<p>Classification of plutonic rocks: Mineral composition is the primary criterion for categorising plutonic rocks (or mode). All rocks having phaneritic, holocrystalline, and coarse-grained (> 3 mm) textures must be considered plutonic rocks according to the International Union of Geological Sciences (IUGS). The classification is centered on the QAPF diagram, developed by Streckeisen (1973).</p>	

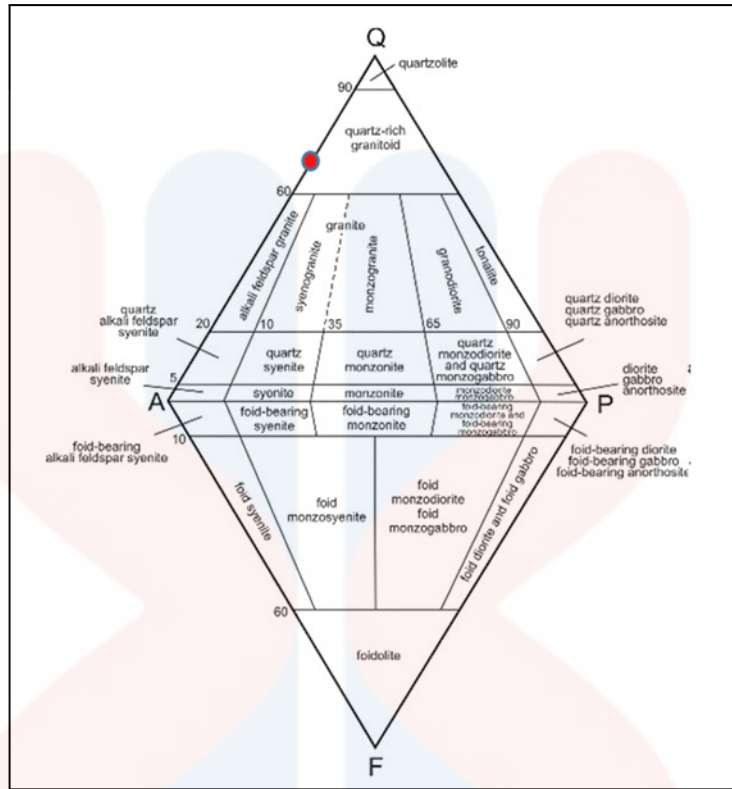


Figure 4. 9: The International Union of Geological Science (IUGS) volcanic rock classification. Rock name is quartz rich granitoid

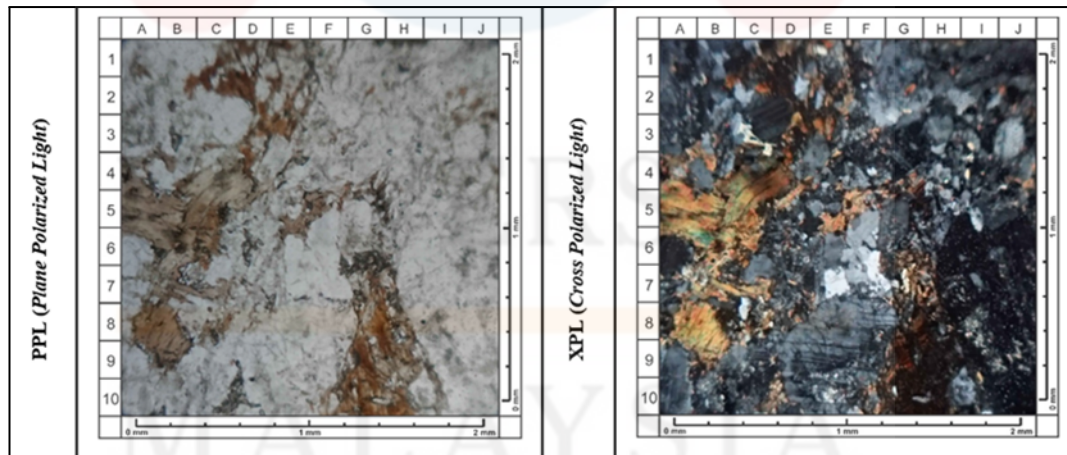


Figure 4. 10: The observation of the enormous structure, phaneritic texture, and coarse-medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification.

Table 4.4: Mineral composition and Description

Mineral Composition	Description
Quartz (G1) – 50%	At PPL the absorption color is colorless, low relief, no pleochroism, anhedral crystal form, no cleavage. In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.
Microclin (E8) – 29%	In PPL, the absorption color is colorless, low relief, no pleochroism, subhedral – anhedral crystal form, 1-way cleavage. In XPL the interference color is order 1 gray – white, the dark angle is slanted, polysynthetic twinning.
Biotite (A5) – 20%	At PPL absorption color is brown – greenish, moderate relief, strong pleochroism, subhedral – euhedral crystal form, 1 way cleavage. In XPL, the interference color is green – orange order 3, there are no twinning parallel dark angles.
Opaque Mineral (E1) – 1%	At PPL the absorption color is black, low relief, no pleochroism, euhedral – anhedral crystal form. In XPL color interference black order 1, there is no twinning.



Figure 4. 11: Granite outcrop with hammer as scale

b. Granodiorite

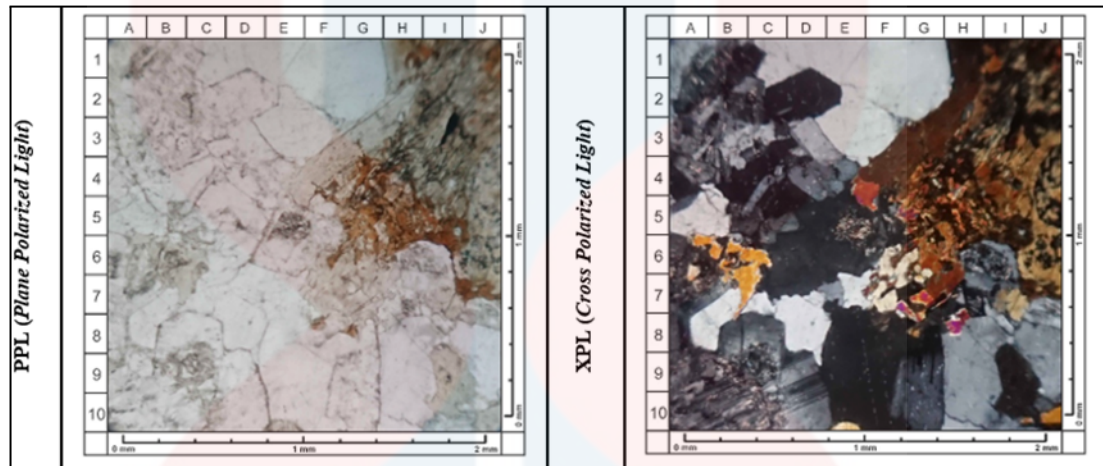


Figure 4. 12: The observation of the enormous structure, phaneritic texture, and coarse-medium mineral size was done under a microscope with 10x ocular magnification and 5x objective magnification.

Table 4.5: Mineral composition and Description

Mineral Composition	Description
Plagioclase (D10) – 20%	Some begin to turn into sericite. In PPL, the absorption color is colorless, low relief, no pleochroism, euhedral – anhedral crystal form, 1-way cleavage. In XPL the interference color is gray – white order 1, dark angles are parallel, albite – Carlsbad-albite twinning, A value is 24 (oligoclase).
Microclin (G10) – 7%	In PPL, the absorption color is colorless, low relief, no pleochroism, subhedral – anhedral crystal form, 1-way cleavage. In XPL the interference color is order 1 gray – white, the dark angle is slanted, polysynthetic twinning
Sanidine (C4) – 3%	In PPL, the absorption color is colorless, low relief, no pleochroism, subhedral – anhedral crystal form, 1-way cleavage. In XPL the interference color is order 1 gray – white, the dark corners are parallel, the Carlsbad twin.
Quartz (F1) – 44%	At PPL the absorption color is colorless, low relief, no pleochroism, anhedral crystal form, no cleavage.

	In XPL the interference color is order 1 gray – white, the dark corners are wavy, there is no twinning.
Biotite (I4) – 25%	At PPL absorption color is brown – greenish, moderate relief, strong pleochroism, subhedral – euhedral crystal form, 1 way cleavage. In XPL, the interference color is green – orange order 3, there are no twinning parallel dark angles.
Opaque Mineral (I3) – 1%	At PPL the absorption color is black, low relief, no pleochroism, euhedral – anhedral crystal form. In XPL color interference black order 1, there is no twinning.

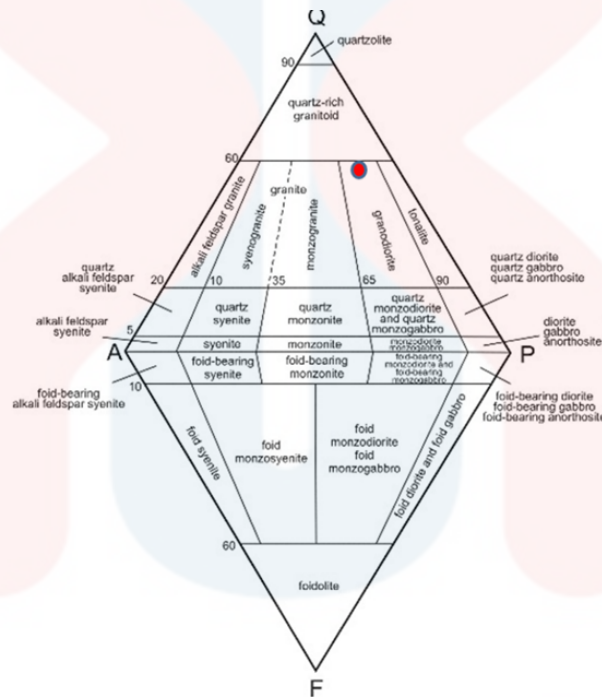


Figure 4. 13: The International Union of Geological Sciences (IUGS) volcanic rock classification. Rock name is Granodiorite

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Figure 4. 14: The Granodiorite outcrop with human scale.

3.4 Structural Geology

This lineament analysis was performed with the help of the GeoRose programme. When you see a lineament in the landscape, it's a sign that there's a fault or other underlying geological structure. Using the topographical map, it can determine if the area is hilly, flat, or mountainous, and whether the coastline is rocky or smooth. Google Maps' landscape may be interpreted in terms of lineaments, as seen in Figure 4.16.

RGB stand for Red, green and blue. A RGB lineament map, the red dotted line is the lineament. A lineament is a linear feature in a landscape that is an expression of an underlying geological structure such as a fault, fracture, or joint. And this one is lineament RGB. After analysing the lineament map, the data was utilised to generate the rose diagram shown in Figure 4.15. The greatest forces are clustered along the rose diagram's longest petal, which points north-east and south-west.

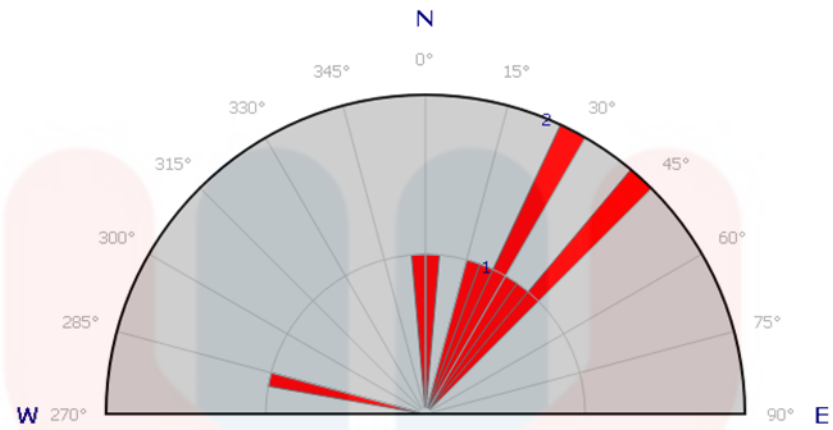


Figure 4. 15: Rose diagram of the study area located at the north part.

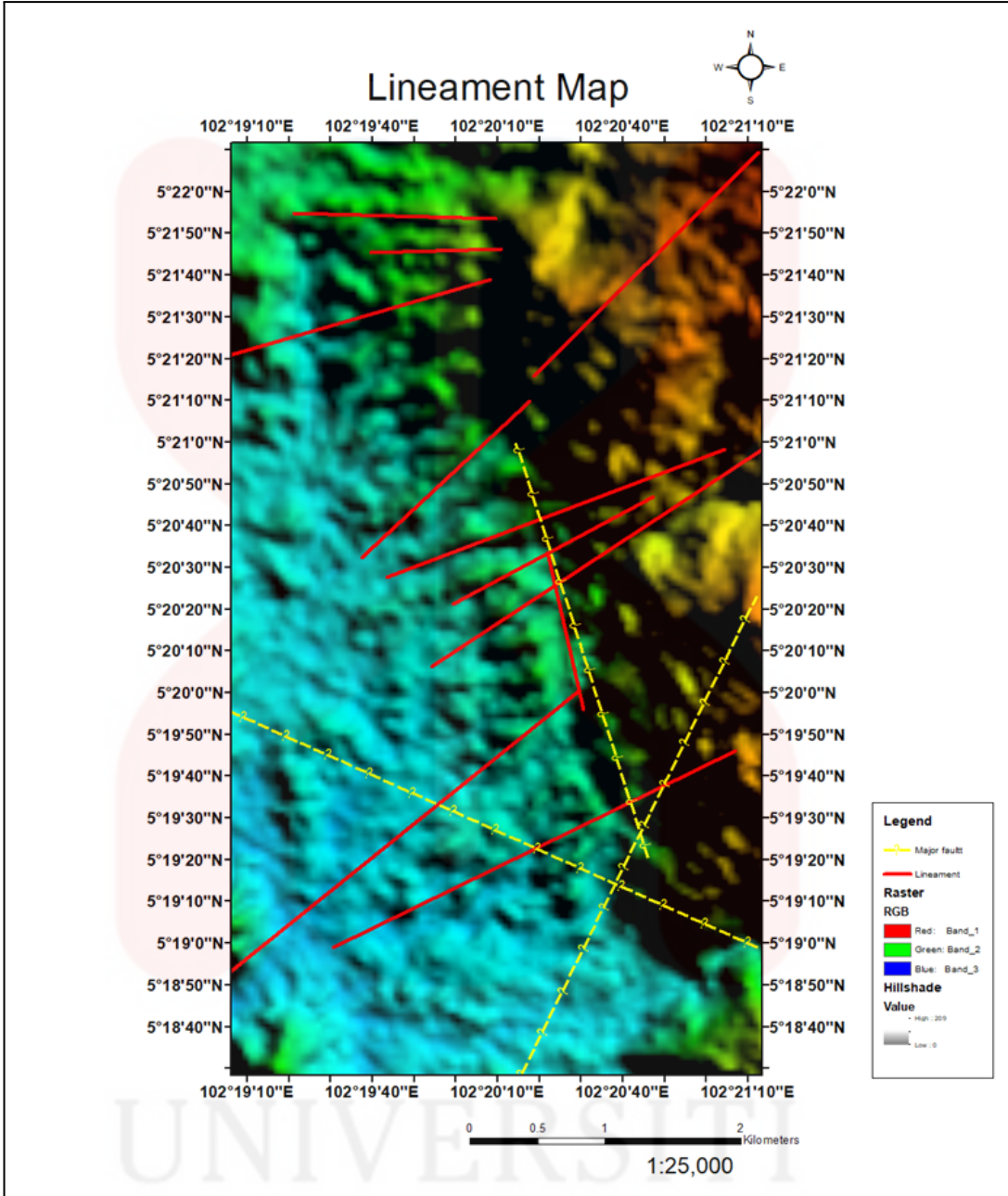


Figure 4. 16: The lineament map

3.4.1 Fault

A fault is a crack or region of cracks that separates two rock blocks. The blocks might move in relation to one another due to faults. This movement may happen suddenly, like an earthquake, or it may happen gradually, like creep. From a few millimetres to thousands of kilometres, faults can vary in length.



Figure 4. 17: The Fault at the study area

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3.4.2 Fold

Structured geologists define a fold as a series of curved or bowed surfaces that were formerly flat, like sedimentary layers. Rock folds may range from little creases to massive mountain ranges. Each fold can be found on its own, or they can be found in sets at regular intervals.



Figure 4. 18: The Fold at the study area.

3.4.3 Mechanism of Structure

The mechanism of structures may take on many different shapes, such as folds, faults, and joints, and they can be created by a wide variety of phenomena, including tectonic pressures, earthquakes, and fluid movement. Figure 4.19 show how chemical weathering have changed the structure and orientation of Granodiorite to form a joint. Meanwhile in Figure 4.20 show that the sediment is eroded and carried by rivers and streams.



Figure 4. 19: Different shapes and orientations due to chemical weathering by rainwater and physical weathering by running water form a joint.



Figure 4. 20: Sediment is eroded and carried by rivers and streams.

3.5 Historical Geology

Permian, Triassic, Jurassic, and Quaternary geologic time periods all apply to the region under investigation. Examining the stratigraphy of Kuala Krai Town, Kuala Krai, Kelantan, makes this point quite clear. Kuala Krai is a lower area, or lower altitude, in which sand, silt, and clay are the predominant lithologies, and it is located close to populated areas like Lata rex.

The sandstone, siltstone, and shale that make up the Telong Formation are clastic sedimentary rocks, and their interbedded structure is a result of their deposition in a shallow marine environment. The Triassic Telong Formation that lies above the Permian Taku Schist is responsible for the metamorphism that transformed the schist into medium-grade metamorphic rocks.

A significant portion of the Peninsula's freshly formed land mass was raised up and left above sea at the beginning of the Mesozoic Era. This is evident from naval sedimentation. The stratigraphy of Kuala Krai Town in Kuala Krai, Kelantan, makes this very obvious. The Permian-Triassic border in Lata Rek, south of Kuala Krai, is covered with phyllite, slate, sandstone, and limestone. Some of these rocks are found in the Boundary Range Granite, which is primarily composed of intrusive rock like granite. The granite exposure and Gua Musang Formation are separated by the Lebir Fault Zone at Lata Rek, south of Kuala Krai.

CHAPTER 5

LANDSLIDE VULNERABILITY ASSESMENT BY USING GIS

5.1 Introduction

This section discussed on the flood risk map that was generated for the area of Kampung Laloh in Kuala Krai, Kelantan. Using the Weighted Overlay Method in GIS, this map displays the areas classified as low, medium, and high flood risk. In this section, few variables that must be correct before creating the flood risk map were examined.

Nearly half of the state's population was impacted by a massive flood in Kelantan in 1967. At the time, it was estimated that 70% of the village population was displaced. In 2014, the worst flood on record caused a "tsunami-like tragedy" that affected 202,000 people. This flood, which was given the name "Bah kuning" because of the high mud content that gave it a distinctive yellow hue, was commonly associated with a major agricultural disaster. Flash flooding in Kuala Krai began on December 17th, 2014, forcing 3,390 residents to evacuate their homes.

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5.2 The cause of Flooding

The occurrence of flooding can be caused either by natural processes or by human activities. Natural floods are a type of natural catastrophe that may be caused by things like excessive precipitation, a tropical cyclone's storm surge, quick snowmelt, or a tsunami in coastal areas. After the mishap, the soil was already too wet to hold any more water. Floodwater that has been absorbed by the ground begins to pool on the surface and spread to other places. Too much water might cause flooding if the ground is too dry.

Second, human activity contributed to floods, especially in human-developed places where ecosystems' inherent resilience has been diminished. It is possible for this flood to cause widespread damage, including the destruction of buildings and infrastructure, the destruction of crops, the spread of waterborne illnesses, and even human casualties. Industry, water supply, transportation, education, sewage treatment, and other economic activities are all vulnerable to floods.

Extreme rainfall, typical of the region during the northeast monsoon season (November–March), is the primary source of flooding in the study area. By analysing the geomorphology, the study region has geological features that make it vulnerable to rising water levels and flooding. The town of Kuala Krai, Kelantan, is distinguished by its undulating, mountainous, and rolling topography. The South China Sea shoreline is particularly vulnerable to floods due to the country's geological make-up.

Unorganized logging is another contributor to the severe flooding in Kuala Krai, Kelantan. Since the hills have been stripped of their trees, the landscape has become desolate. Because of this, water flows quickly into rivers, notably the Sungai Kelantan. Flooding is exacerbated by deforestation because forests absorb and store more water than agricultural land or grassland. Because their live and decaying roots create a network of well-connected, microscopic pathways in the soil, trees help bring rain into the ground. Such canals increase the rate at which rainwater percolates into the ground by a factor of several hundred compared to soil that lacks such features.

When land is covered with trees, the amount of water pouring over the surface when it rains is reduced. The amount of water that may enter rivers and streams is reduced as a result. Alluvial deposits as far as 1000 metres from riverbanks found after a flood is evidence that logging or land clearance caused the greatest floods in Kelantan. Acres of sandbars formed in Sungai Kelantan as a result of rapid erosion upstream is more proof of this. Rainfall increases when land clearance and logging operations alter the hydrologic cycle, research by the Institute of Infrastructure Engineering and Sustainable Management (IIESM) of Malaysia found.

Since the Kelantan region received the equivalent of its annual rainfall in just 10 days, the massive deluge that hit the area that year can be attributed to the clearing of tens of thousands of hectares of forest the same year.

5.2.1 Rainfall Distribution

Kuala Krai Town, Kuala Krai, Kelantan, has experienced flooding on several occasions, therefore understanding the patterns of rainfall is crucial. From November through March, Kelantan often experiences floods.

The data in Table 5.1 collected from the Portal of the Department of Irrigation and Drainage, demonstrates that heavy rain is the source of the floods. From the 17th of December 2014 until the 25th, rainfall was reported at 13 different locations around Kelantan. In terms of time, the heaviest rainfall was reported at the Kusial Tanah Merah station (414 mm) on 17 December 2014, with a total of 2596 mm recorded across all 13 stations.

Table 5.1: Rainfall distribution at the rain measure stations

Analisis Sukatan Turunan Hujan di Pusat-pusat Sukatan Turunan Hujan Negeri Kelantan, 17-25 Disember 2014																	
Tarikh	Gua Musang		Kuala Krai		Gua Musang		Jeli		Kuala Krai			Tanah Merah	Kota Bharu	Tanah Merah	Pasir Mas	Pasir Putih	Jumlah
	Gunung Gagau	Kg. Aring	Kg. Laloh	Gua Musang	Kg. Jeli	Dabong	Tualang	Kuala Krai	Kusial	Jeti Kastam	Jenob	Rantau Panjang	Pasir Putih				
17/12/2014	164	135	121	85	192	146	127	140	414	223	291	273	285	2596			
18/12/2014	71	47	52	7	74	33	45	48	58	101	77	51	77	741			
19/12/2014	40	19	1	1	20	12	2	10	22	3	6	1	44	181			
20/12/2014	36	19	17	13	106	24	16	38	121	84	110	58	105	747			
21/12/2014	302	128	77	65	70	78	82	78	99	32	96	59	23	1189			
22/12/2014	478	294	208	212	130	243	227	155	83	12	70	20	29	2161			
23/12/2014	515	13	0	116	39	154	164	24	27	5	46	13	4	1120			
24/12/2014	159	0	0	0	160	101	112	211	261	40	181	77	60	1362			
25/12/2014	32	0	0	0	60	0	8	22	18	6	15	17	10	188			

*** sumber: Portal e-Barajir Negeri Kelantan.

(Source: Portal of Department of Irrigation and Drainage, 2015)

a. Station: Ladang Kuala Nal (5521050) 2019

The greatest monthly total for 2019 rain falls in December at 171.5 mm. The below data shows that the heavy rainfall that occurred practically every day began in September 2019 and will last until December 2019. The majority of January 2019's precipitation fell in the first two weeks of the month, from days one through eighteen, before gradually tapering off beginning on day nineteen.

b. Station: Ladang Kuala Nal (5521050) 2020

The Jabatan Pengairan dan Saliran (JPS), will only have data on the distribution of rainfall from January to June of 2020. According to records kept at the Ladang Kuala Nal weather station, 70 mm of rain fell in June. In March, the month with the fewest rainy days, only four such days happened.

c. Station: Ladang Kuala Nal (5521050) 2019-2020

An average rainfall distribution graph for Station of Ladang Kuala Nal, based on the data presented in Figure 5.1 shows that the northeast monsoon season in the Kelantan region begins in this month, with the maximum rainfall distributions occurring in November and December.



Figure 5. 1: Average rainfall distributions at Ladang Kuala Nal of 2019-2020

d. Station: Sekolah Menengah Teknik Kuala Krai (5522047) 2019

Sekolah Menengah Teknik Kuala Krai is the second station in close proximity to the Kelantan River where Kelantan River is also divided into Lebir River. In order to determine whether or not rainfall has increased or decreased from one year to the next, it can be consulted the rainfall distribution data which received from the Jabatan Pengairan dan Saliran (JPS).

The monthly breakdown of precipitation for 2019, with November recording 76 mm and December registering 183 mm as the rainiest months. There was no precipitation in the research area at the end of December, so the river’s water level might not rise too quickly. A scant seven days of precipitation in February show the lowest rainfall distribution of any month.

e. Station: Sekolah Menengah Teknik Kuala Krai (5522047) 2020

Jabatan Pengairan dan Saliran (JPS) rainfall for the year 2020, but only includes precipitation totals for the months of January through June of that year. In 2020, the only two days with larger rainfall distribution are February 10 and 12, with a value of 77 mm and 61.5 mm, respectively. This period covers January through June.

f. Station: Sekolah Menengah Teknik Kuala Krai (5522047) 2019-2020

An average rainfall distribution graph for Station of Sekolah Menengah Teknik Kuala Krai, based on the data presented in Figure 5.2 shows that the northeast monsoon season in the Kelantan region begins in this month, with the maximum rainfall distributions occurring in November and December.

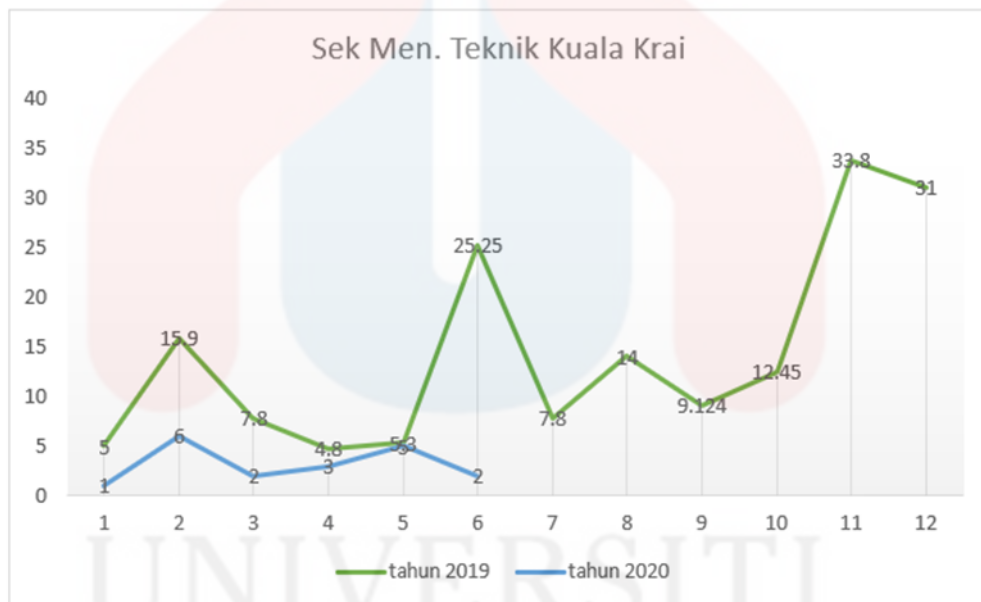


Figure 5. 2: Average rainfall distributions at Sek. Men. Teknik Kuala Krai of 2019-2020

g. Station: Dabong (5320038) 2020

Dabong, the third station near the study area, is located at the point where the Kelantan River splits into the Lebir River. Rainfall distribution data from the Jabatan Pengairan dan Saliran, which may be used to establish whether or not rainfall has risen or decreased from one year to the next (JPS).

The annual distribution of rainfall for 2020, the rainy month will be August, with precipitation totals of 201.6 mm, 248.1 mm and 404 mm. As of late December, the Dabong region had not received any significant precipitation, suggesting that the river level might not rise too rapidly. Two weeks without rain in April is indicative of the month’s lower rainfall distribution compared to others.

h. Station: Dabong (5320038) 2021

In terms of precipitation, JPS only provides up-to-date information from January through April approximately half of the months of March and April do not have their data updated. Due to the fact that there is no evidence of activity after May Table 5.2, it appears to be outdated and incomplete.

Table 5.2: Rainfall distribution at Dabong Kuala Krai of May 2021

No	Date	DRF	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000
1	31/05/2021																									
2	30/05/2021																									
3	29/05/2021																									
4	28/05/2021																									
5	27/05/2021																									
6	26/05/2021																									
7	25/05/2021																									
8	24/05/2021																									
9	23/05/2021																									
10	22/05/2021																									
11	21/05/2021																									
12	20/05/2021																									
13	19/05/2021																									
14	18/05/2021																									
15	17/05/2021																									
16	16/05/2021																									
17	15/05/2021																									
18	14/05/2021																									
19	13/05/2021																									
20	12/05/2021																									
21	11/05/2021																									
22	10/05/2021																									
23	09/05/2021																									
24	08/05/2021																									
25	07/05/2021																									
26	06/05/2021																									
27	05/05/2021																									
28	04/05/2021																									
29	03/05/2021																									
30	02/05/2021																									
31	01/05/2021																									

(Source: JPS Kelantan Telemetry System,2021)

i. Station: Dabong (5320038) 2022

Based on Figure and Table 5.3 on 2022, the wettest month (with the highest rainfall) is November (274mm). The driest month (with the least rainfall) is February (60mm).

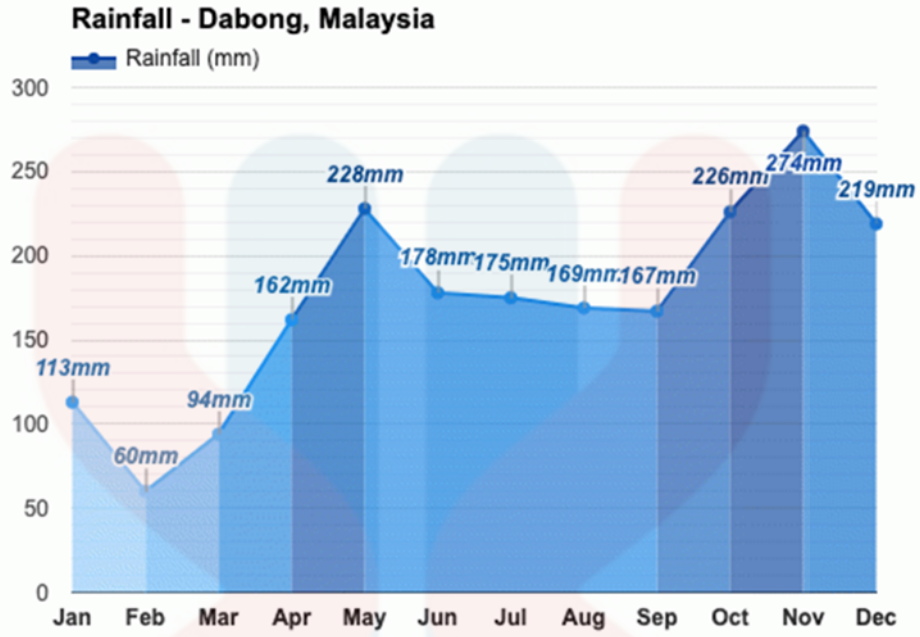


Figure 5. 3: Rainfall at Dabong area on 2022

Table 5.3: Average rainfall Dabong 2022

Month	Average rainfall (mm)
January	113
February	60
March	94
April	162
May	228
June	178
July	175
August	169
September	167
October	226
November	274
December	219

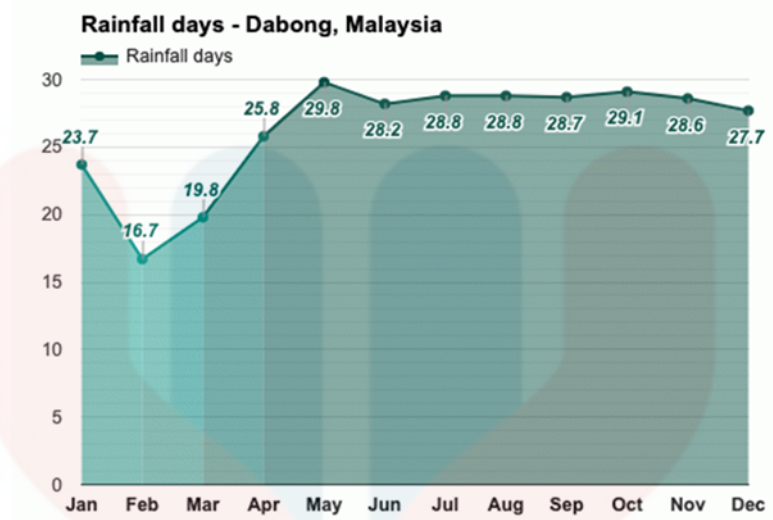


Figure 5. 4: Rainfall days at Dabong area

Figure and Table 5.4 show the month with the highest number of rainy days is May (29.8 days). The month with the least rainy days is February (16.7 days) on 2022.

Table 5.4: Average rainfall day

Month	Rainfall days
January	23.7
February	16.7
April	25.8
May	29.8
June	28.2
July	28.8
August	28.8
September	28.7
October	29.1
November	28.6
December	27.7

j. Station: Dabong (5320038) 2020-2022

An average rainfall distribution graph for Station of Dabong, based on the data presented in Figure 5.5 shows that the northeast monsoon season in the Kelantan region begins in this month, with the maximum rainfall distributions occurring in August, November and December.

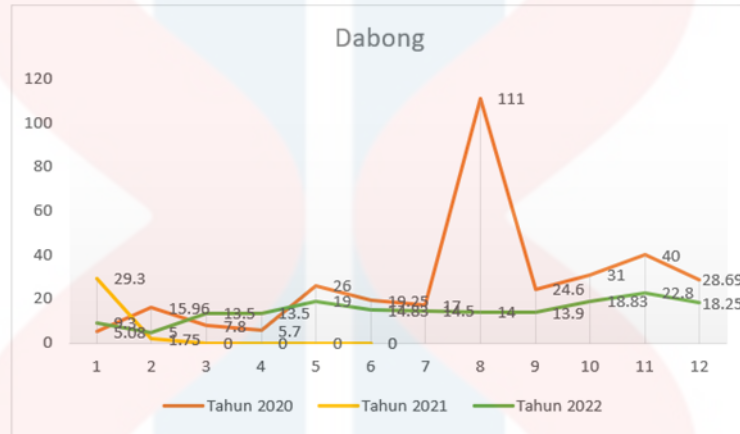


Figure 5. 5: Average rainfall distributions at Dabong of 2020-2022

The only rainfall distribution data at Kampung Laloh that have on the study area from Jabatan Pengairan dan Saliran for the year 2020 can be seen in Table 5.5. And Figure 5.6 is the average rainfall distribution at Kampung Laloh for 2020.

k. Station: Kampung Laloh (5320038) 2020

Table 5.5: Rainfall distributions at Kampung Laloh of 2020.

Year 2020												
KG. LALOH AT KELANTAN (5322044)												
Rainfall.Primary (mm)												
Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	2.5	1.5	0	0	0	6	0	11	11	0	2.5	0
2	0.9	3.5	0	13.5	0	0	10.5	0.4	0	13.5	0	3.9
3	0.1	0	0	18.5	0	2.5	0.5	2.6	0	0	12.2	4.4
4	0.5	0	0	6.5	1.5	0	0	0	0	0.5	7.3	15.2
5	1.5	0	9.5	1.5	3.5	1.5	0	0	0	39	0	0
6	0	2.5	0	0	0	0	0	0	0	33.4	0.5	0
7	0.9	0	0	0	8.5	2.5	0	0	0	20.6	8	0.5
8	1.1	0	0	4	3	20	1	0	0	19	1.3	0
9	1.1	4	0	0	1	0	25	0	0	0	2.7	0
10	4	28.5	0	0	0.5	2	3.5	0	0	15.3	0	0
11	0	10.5	0	0	6.5	0	58.4	0	0	0.2	1.8	0.5
12	0	3	0	3.5	1.5	0.5	42.4	0	0	12	5.2	7
13	0	0	0	0.5	0	0	21.2	0	0	1	0	1
14	0	0	0	0	0	0	0	0	0	0	1	0.5
15	0	1	0	0	0	24.5	0	0	0	0	0	17.5
16	0	0	0	0	9	0	0.5	0	0	0	0.4	23.7
17	0	16.5	0	0	0	0.5	16.3	0	0	0.5	28.4	100.5
18	6	0	0	0	5.5	0	5.2	0	0	0	28.8	96.1
19	13.5	1	0	0	10	0	0	0	0	0	0.5	36.4
20	10	0	0	0	0.5	2.5	3	0	0	0	0	16.1
21	0	0.5	0	0	23.5	0	0	0	0	0	2.5	0.6
22	8	0.5	0	0	0	2.7	0.5	0	0	3.5	11.2	0
23	0	5.5	24	5	7.5	0.3	8.5	0	2.5	1.5	35.6	0
24	0	2	0	2.5	1.5	3	1	0	0	45.5	75.7	10.7
25	0	0	0	9	2.5	0	0	0	6.3	50.6	6.7	4.8
26	0	0	0	0.5	14.5	0	0	0	3.7	0.9	4.7	1.9
27	0	0	0	0.5	0	0.5	0.5	0	0	0	68.9	1.6
28	0.5	0	0	3.5	22	0.5	11.2	0	0	0	4.7	0
29	0.5	0	0	0	3.5	0	4.3	0	0.5	0	0	0
30	1	0	0	6	0	0	5.7	0	7.5	1	0	1
31	9.5	0	0	0	2	0	0.3	0	0	24	0	1

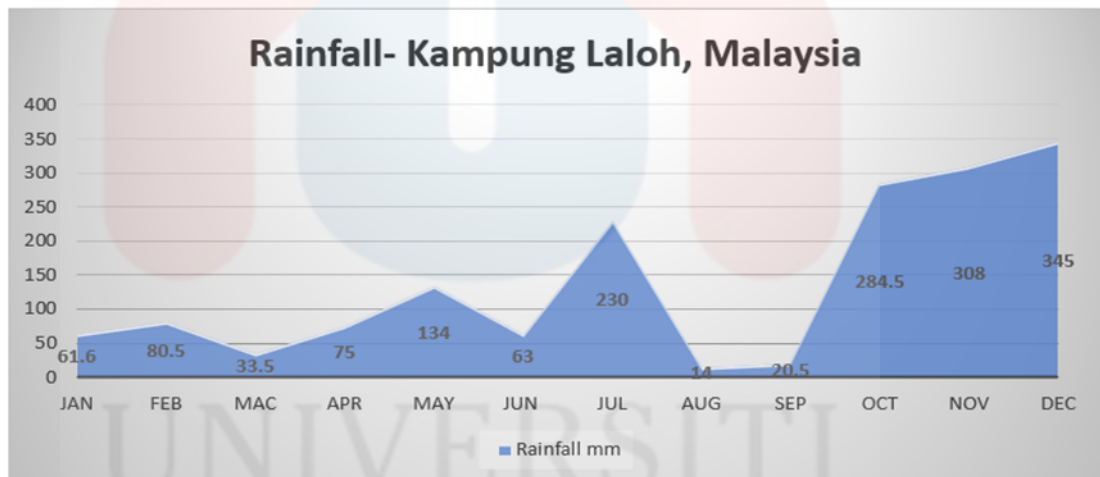


Figure 5. 6: Average rainfall distributions at Kampung Laloh for year 2020.

5.2.2 Hyetograph of Annual Rainfall area at Kuala Krai, Kelantan

The Department of Drainage and Irrigation developed the hyetographs in Figures 5.7, 5.8, and 5.9, which depict the distribution of hourly rainfall intensity over time at various locations from December 18, 2020, to December 21, 2020, as

represented on a graph. These three locations will often provide information on the distribution of precipitation in Kuala Krai Town, Kuala Krai, Kelantan.

In Figure 5.7, Kampung Laloh, which is in the research area, and figure 5.8 Dabong on the 18th of December indicate the heaviest rainfall recorded at 11 a.m., which is 15 mm. Figure 5.9 depicts the peak precipitation intensity on the 18th of December in Kuala kra i at 2:00 p.m. approximately 22 mm.

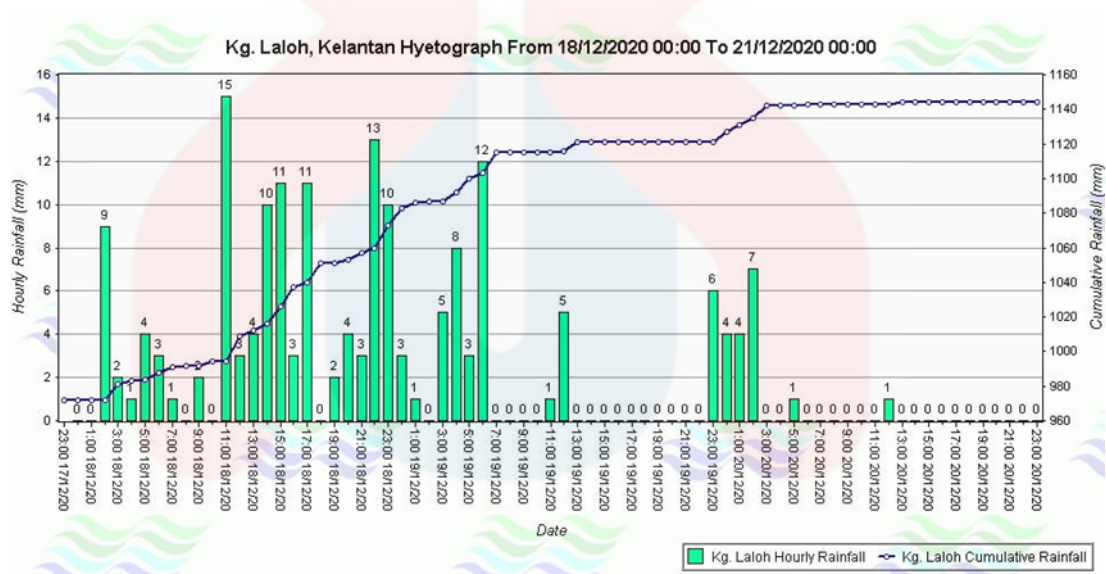
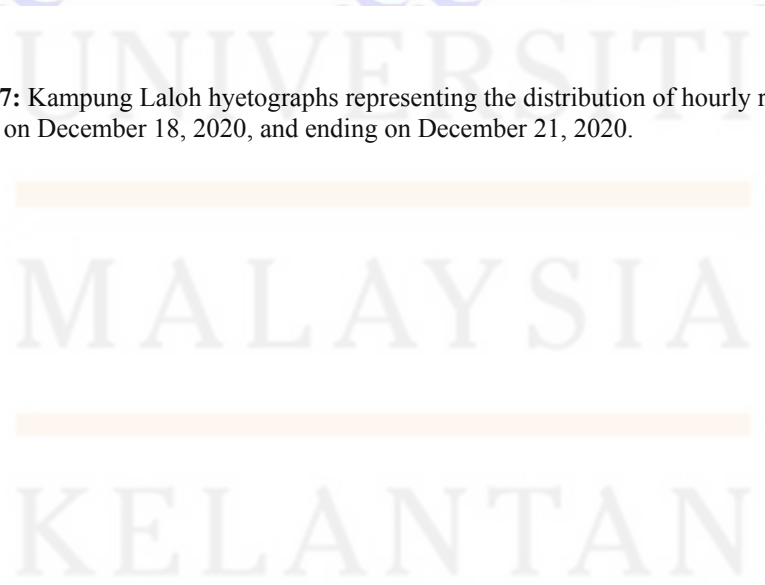


Figure 5. 7: Kampung Laloh hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.



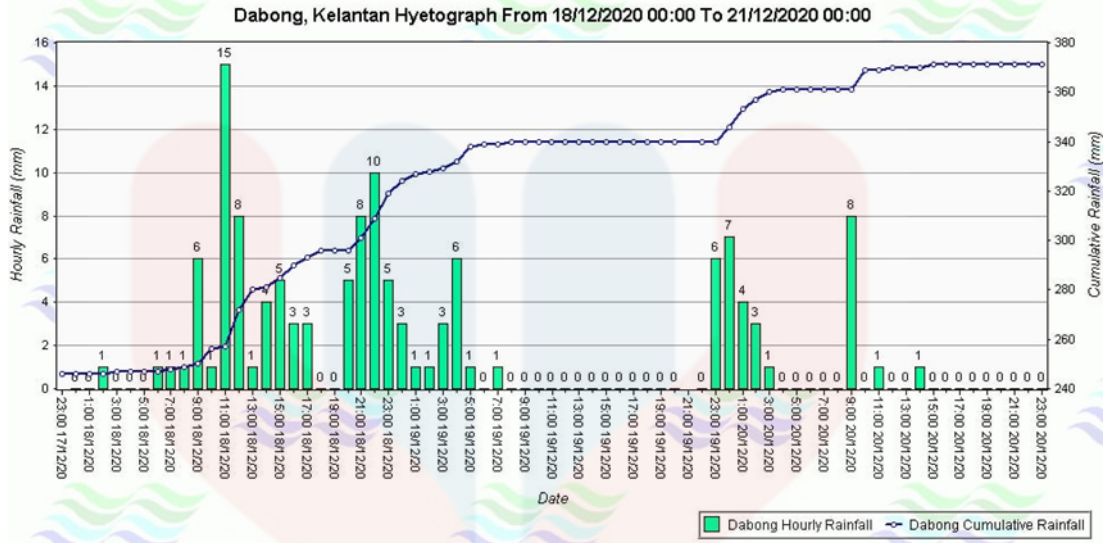


Figure 5. 8: Dabong hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.

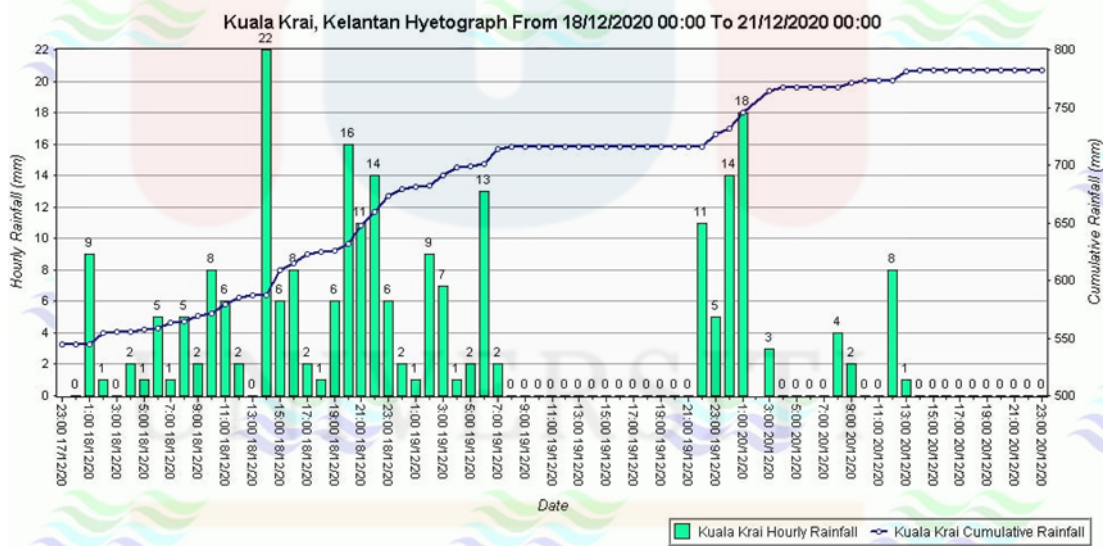


Figure 5. 9: Kuala Krai hyetographs representing the distribution of hourly rainfall intensity beginning on December 18, 2020, and ending on December 21, 2020.

The Department of Drainage and Irrigation developed the hyetographs in Figures 5.10, 5.11, and 5.12, which depict the distribution of hourly rainfall intensity over time at various locations from December 18, 2020, to December 21, 2020, as

represented on a graph. These three locations will often provide information on the distribution of precipitation in Kuala Krai Town, Kuala Krai, Kelantan.

In Figure 5.10, Kampung Laloh, which is in the research area, has the greatest daily rainfall of 111 mm on the 18th of December, while in figure 5.11, Dabong has the highest daily rainfall of 78 mm on the same day. Figure 5.12 displays the greatest precipitation intensity on the 18th of December in Kuala Krai, which was around 134 mm.

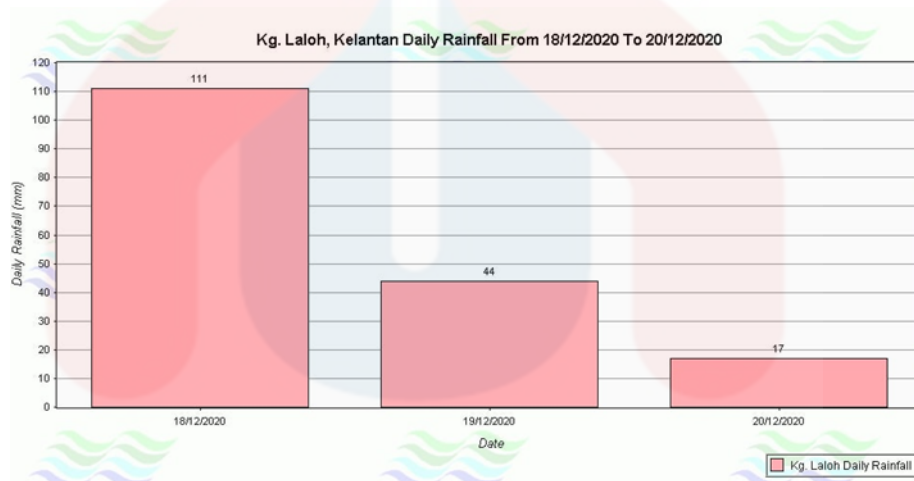


Figure 5. 10: Kampung Laloh hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.

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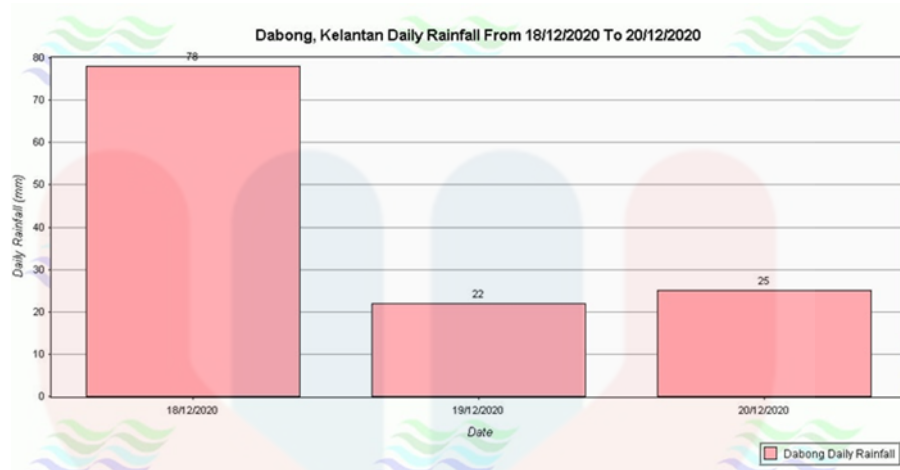


Figure 5. 11: Dabong hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.

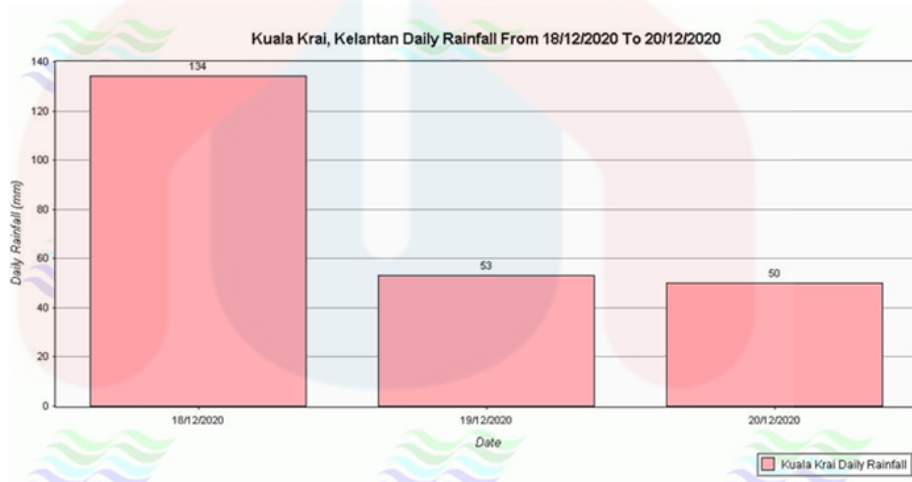


Figure 5. 12: Kuala Krai hyetographs representing the distribution of daily rainfall intensity data beginning on December 18, 2020, and ending on December 21, 2020.

5.2.3 River Catchment

The term “river catchment” refers to the area of land that collects rainwater and is typically surrounded by hills. The river is fed by water that has made its way over the landscape and into the soil via the streams. Water that falls to the ground as

precipitation is collected by a catchment, and then transported by a drainage system to a major river's mouth.

Besides the Kelantan River basin, the Pahang River basin, and the Terengganu River basin are the three largest basins in Malaysia. These three basins are located in and grouped together as part of the monsoon catchment area, where the northeast monsoon's high rainfall acts as the driving force from November through March. Those living in the floodplains along the Kelantan River in Malaysia are often the first to hear of a natural disaster. When it rains a lot, it floods a lot, and that has a negative impact on the economy and agriculture. Annual precipitation varies from zero millimetres during the dry season to seventeen hundred and fifty millimetres during the monsoon. About 500 m³/s is the average discharge rate in the Kelantan River basin.

Catchment area for the Kelantan River, shown in Figure 5.13, is located between 4°40'N and 6°12'N, and 101°20'E and 102°20'E. The largest possible dimensions of the catchment are 150 km in length and 140 km in width. About 248 kilometres long, the Kelantan River drains an area of 13,100 km², making it the state's primary water source. Galas, Nenggiri, Pergau, Guillemard Bridge, Kuala Krai, and Lebir are the names of the six subbasins of the Kelantan River.

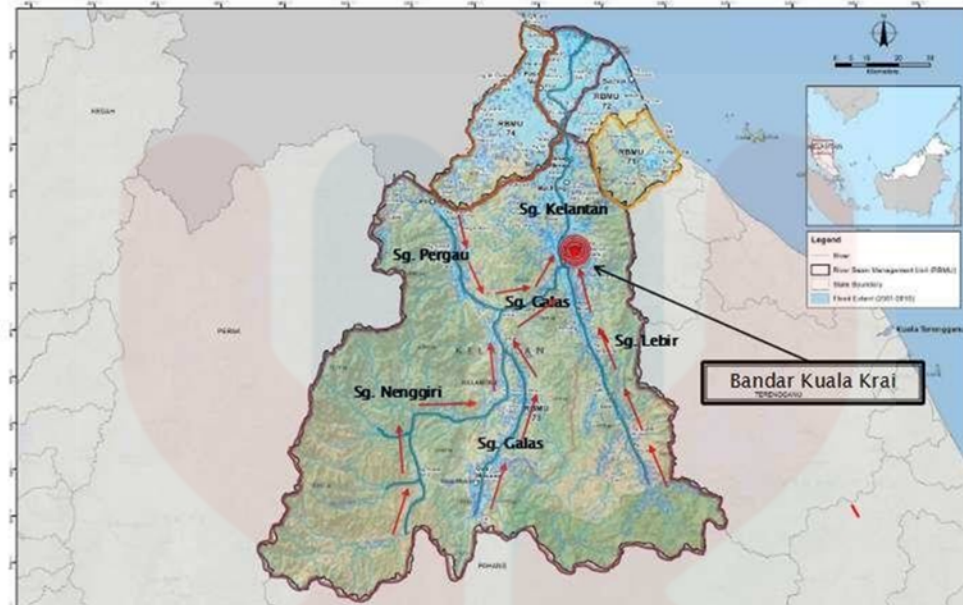


Figure 5. 13: River Catchment area in Kuala Krai Town, Kuala Krai, Kelantan (Source: Google Image, 2018)

In the study region, the Kelantan River is the primary river basin, while the Galas River and the Lebir River are the southernmost tributaries. It is at the confluence of the Nenggiri and Pergau rivers that the Galas begins its life. It is from the middle mountain range's southwestern corner that the Nenggiri River flows (Main Range). Tahan mountains are the source of the Lebir River. The Sungai Lebir catchment region, with a total catchment area of around 2500km², may be found in the southern part of the state of Kelantan, which is located in the far northern section of Peninsular Malaysia.

5.3 Parameter of Flood Hazard Analysis

In flood hazard analysis, flow accumulation is the most crucial aspect despite requiring only a few factors. The second and third parameters to be used are the slope and elevation, respectively. When employing the Weighted Overlay Method, it is necessary to assign weights and scores to each parameter that affects flooding (WOM). It considers the impact of every variable on the occurrence of flooding.

Table 5.6 shows the parameter selected in determining the flood hazard analysis by using GIS. The paper Analysis of Flood Hazard Zones Using Overlay Method with Figured-Based Scoring Based on Geographic Information Systems served as the basis for all parameters, weights, classes, and ratings (2019).

Table 5.6: Weightage of parameter of flood hazard analysis

No	Parameter	Weightage
1	Flow Accumulation	0.6122
2	Elevation	0.2944
3	Land use	0.0697
4	Slope	0.2944
5	Lithology	0.0053
6	River Distance	0.2944

(Source: Adlyansah et al, 2019)

5.3.1 Flow Accumulation

Flow accumulation is the most critical parameter of flood hazard in the weighted Overlay Method (WOM). Flow accumulation is regarded as the zone of accumulation of water flow into a basin; hence, its weighting is set at 10 percent. This data was processed using the Demographic data, and then it was generated to provide a flow accumulation map with several classes and a value range from 0 to 31,971.

When the value of flow accumulation is greater, so is the amount of water accumulated in the area. In addition, river order influences flow accumulation. Consequently, when the stream or river's order value is high, the flow accumulation is also high. The drainage pattern helps determine the flow accumulation's distribution. Figure 5.14 dendritic pattern indicates, based on the research region, that the area closer to the river's mouth has bigger flow accumulation values. The weighting and score for flow accumulation are shown in Table 5.7.

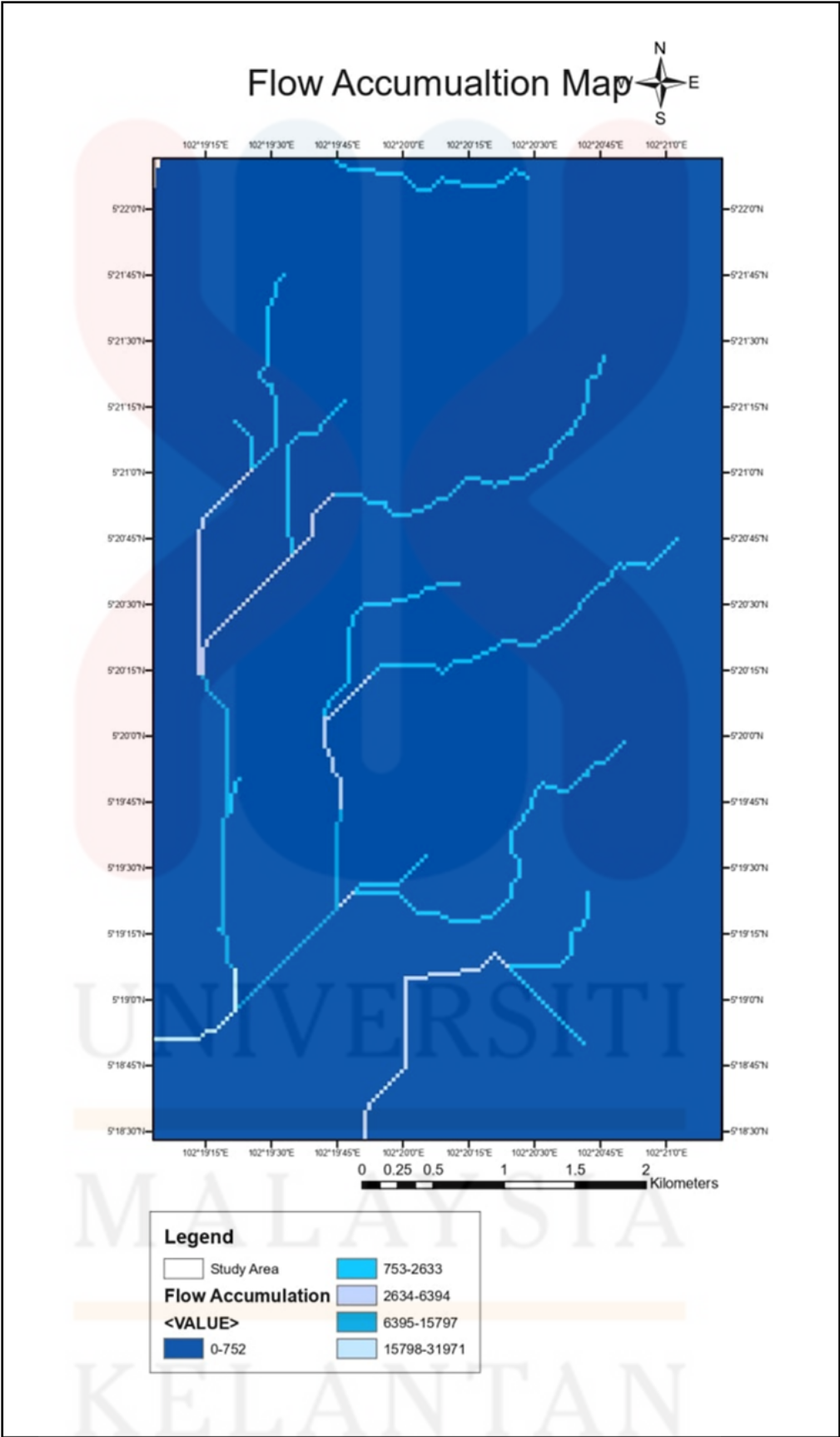


Figure 5. 14: Flow accumulation map of the study area

Table 5.7: Weightage and rating for flow accumulation

No	Range of Flow Accumulation	Weightage	Rating
1	0 – 752	0.6122	1
2	752 – 2633	0.6122	2
3	2633 – 6394	0.6122	3
4	6394 – 15797	0.6122	4
5	15797 – 31971	0.6122	5

(Source: Adlyansah et al., 2019)

5.3.2 Elevation

The elevation data was processed with DEM data until a map with values between 20 and 240 metres was generated. Due to the flow of water from higher altitudes to lower altitudes, low-elevation areas have a greater likelihood of flooding. The following Table 5.8 outlines the weighting and score for the criterion of elevation. Figure 5.15 depicts the elevation map of the research region. Table 5.9 is the geomorphological unit and its elevation where the green symbol is low land and the red symbol is the mountain.

Table 5.8: Weightage and rating for elevation (Adlyansah et al., 2019)

No	Elevation Class	Weightage	Rating
1	0-81	0.2944	5
2	81 – 190	0.2944	4
3	190 – 353	0.2944	3
4	353- 550.2	0.2944	2
5	550 – 787	0.2944	1

Table 5.9: Geomorphological unit and its elevation

No	Geomorphological Unit	Symbol	Landform	Elevation (M)
1	Slightly sloping plain		Low Land	0-100
2	Sloping hills		Low Hill	101-400
3	Steep hills		Hill	401-500
4	Mountain		Mountain	501-700

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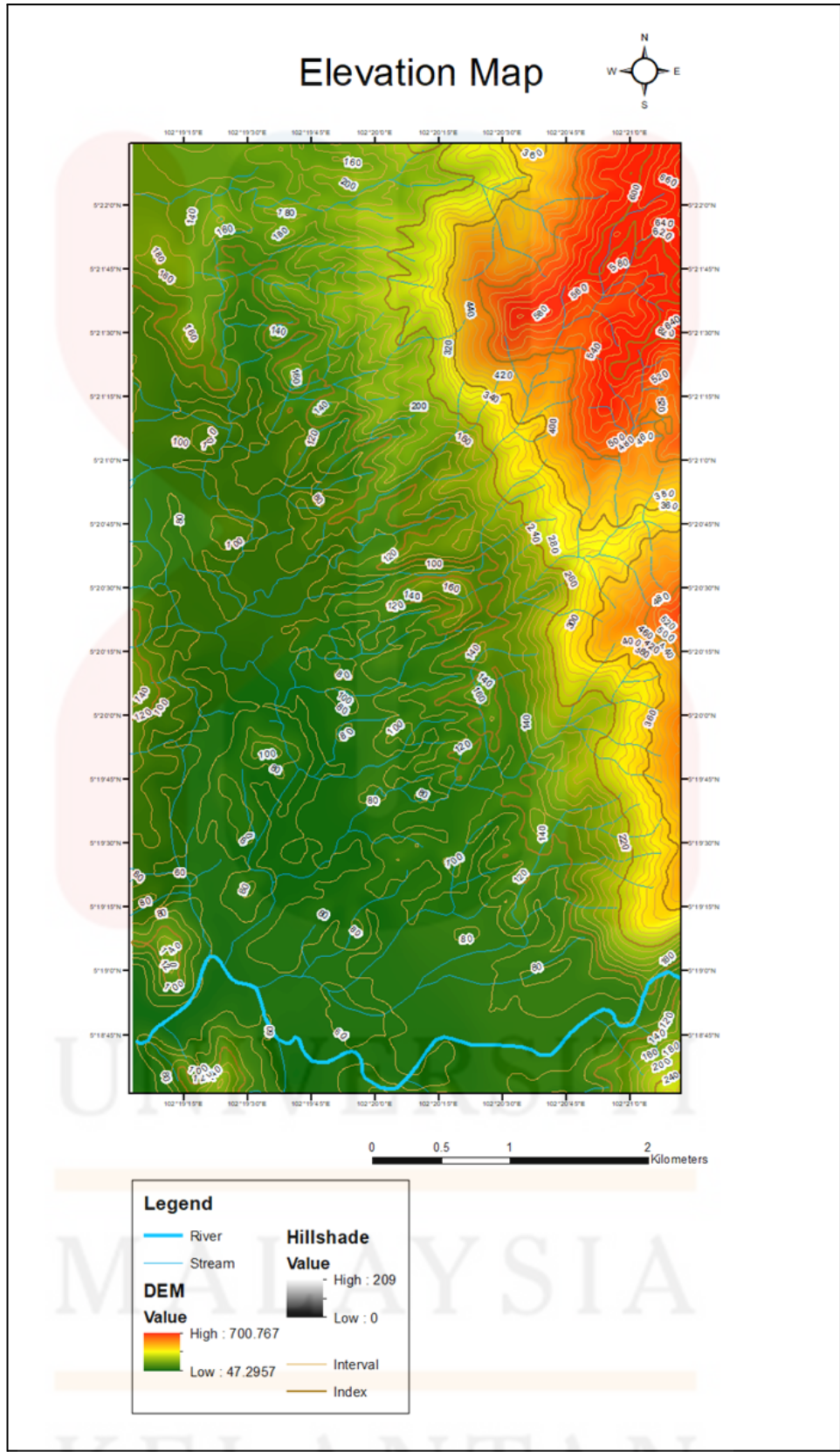


Figure 5. 15: Elevation Map of study area

5.3.3 Land Use

Land use referred to the land uses that characterise the studied area. It entails the management of natural environment within the constructed environment. For example, agricultural, forest, and lake-based communities. Due to the area's capacity for water penetration, land usage might affect the likelihood of flooding. This parameter's data were extracted from a 1:25000 scale land use shapefile containing geospatial data.

Land uses with a high degree of similarity share some features, including a limited capacity for infiltration that promotes flooding. In the presence of dense vegetation, such as a forest, the ground will be able to absorb surface water, hence reducing the likelihood of floods. The land use parameter's weighting and score are displayed in Table 5.10. Figure 5.16 depicts a land use map of the research region.

Table 5.10: Weightage and rating of land use

No	Class	Weightage	Rating
1	River	0.0697	5
4	Town	0.0697	4
8	Road	0.0697	3
10	Forest	0.0697	1
11	Rubber	0.0697	3

(Adlyansah et al., 2019)

5.3.4 Slope Stability Analysis

This slope's parameter is derived from demographic data and is measured in degrees ($^{\circ}$). Based on the study region, the slope parameter ranges from 0° to greater than 35° . East of the study area, a steep slope with a value more than 35° was discovered. There is a slope range of 0° to 5° , indicating that the area is a plain with low altitude of elevation and has a higher flood risk than areas with steep slopes and high altitude of elevation. Table 5.11 displays the weighting and score of the slope parameter. Figure 5.17 depicts a slope map of the area under examination.

Table 5.11: Weightage and rating of slopes

No	Class	Weightage	Rating
1	0 - 5 $^{\circ}$	0.2944	5
2	5 - 10 $^{\circ}$	0.2944	4
3	10 - 15 $^{\circ}$	0.2944	3
4	15 - 25 $^{\circ}$	0.2944	2
5	25 - 35 $^{\circ}$	0.2944	1
6	>35 $^{\circ}$	0.2944	1

(Source: Adlyansah et al., 2019)

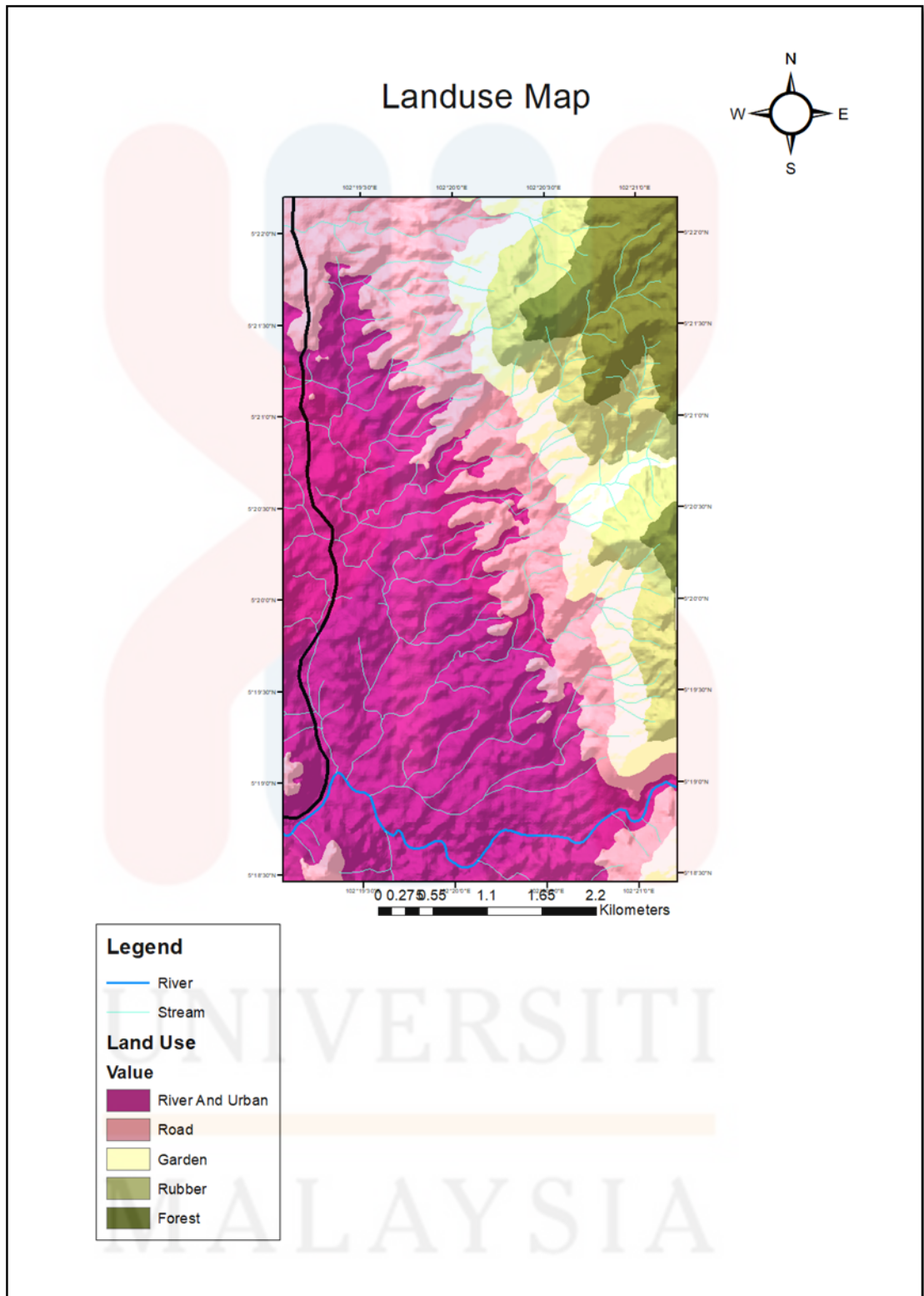


Figure 5. 16: Land Use Map

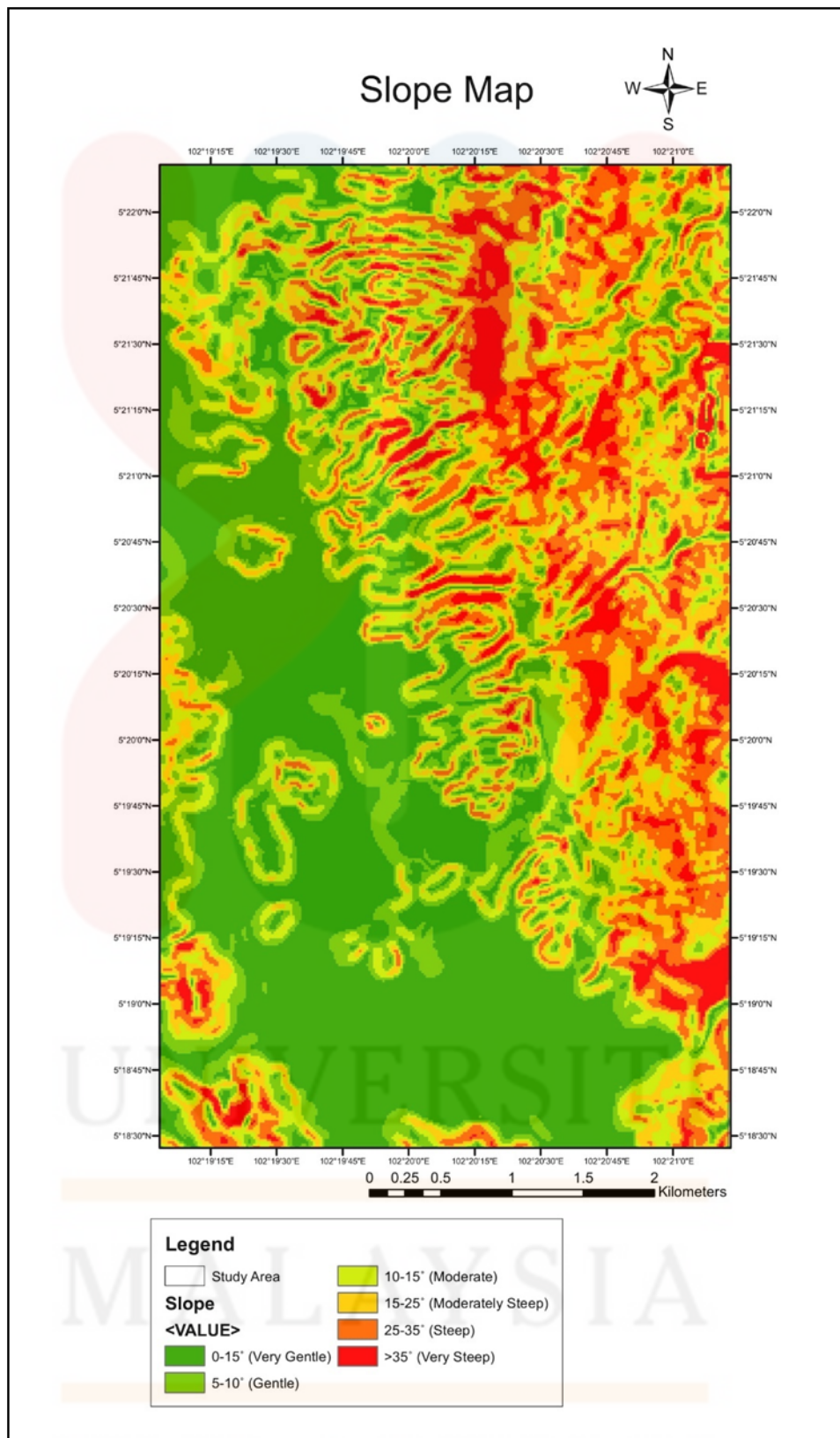


Figure 5. 17: Slope map of the study area

5.3.5 Lithology

The lithology of the studied area affects the intensity of flooding. When the rock is unconsolidated, permeable sediments such as alluvial will support water, percolation, and groundwater infiltration, whereas impermeable rocks support surface flow. If the lithology of the rock is permeable, the potential for the area under study to become inundated is diminished. Table 5.12 displays the weighting and score for lithology rock. The Figure 5.18 show the stratigraphy and lithology column and Figure 5.19 depicts a lithology map of the study region.

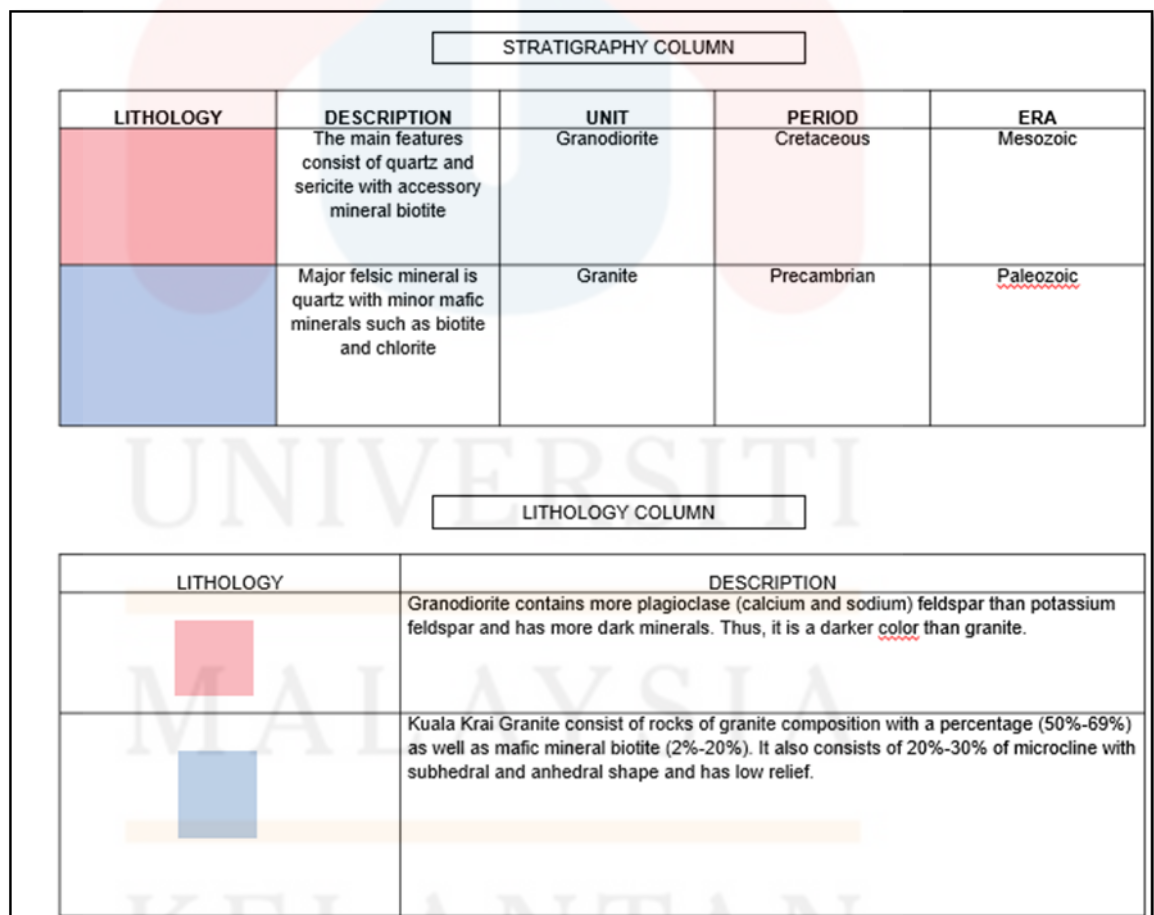


Figure 5. 18: Stratigraphy and lithology column

Table 5.12: Weightage and rating of lithology

No	Lithology Class	Weightage	Rating
1	Granite	0.0053	1
2	Granodiorite	0.0053	1

(Source: Adlyansah et al., 2019)

5.3.6 River Distance

The distance factor from the river and the height of the area are considered to have parallel levels as the second parameter because flood areas are often at low altitudes and close to the river. Nearly all of the villages in the study region are within 200 metres of a river, putting them at risk of flooding as indicated on Figure 5.20. Table 5.14 displays the weighting and score for river distance and Table 5.13 show river distance distribution.

Table 5.13: River distance distribution.

	Safe Zone	Low Hazard zone	High Hazard zone
Distance	More than 975m	250m-975m	0 – 570 m; but dominant in 0 – 250 m

(Source: Adlyansah et al., 2019)

Table 5.14: Weightage and rating of river distance

No	Class	Weightage	Rating
1	0-250	0.0971	5
2	250-570	0.0971	4
3	570-975	0.0971	3
4	975-1465	0.0971	2
5	1465-2000	0.0971	1

(Source: Adlyansah et al., 2019)

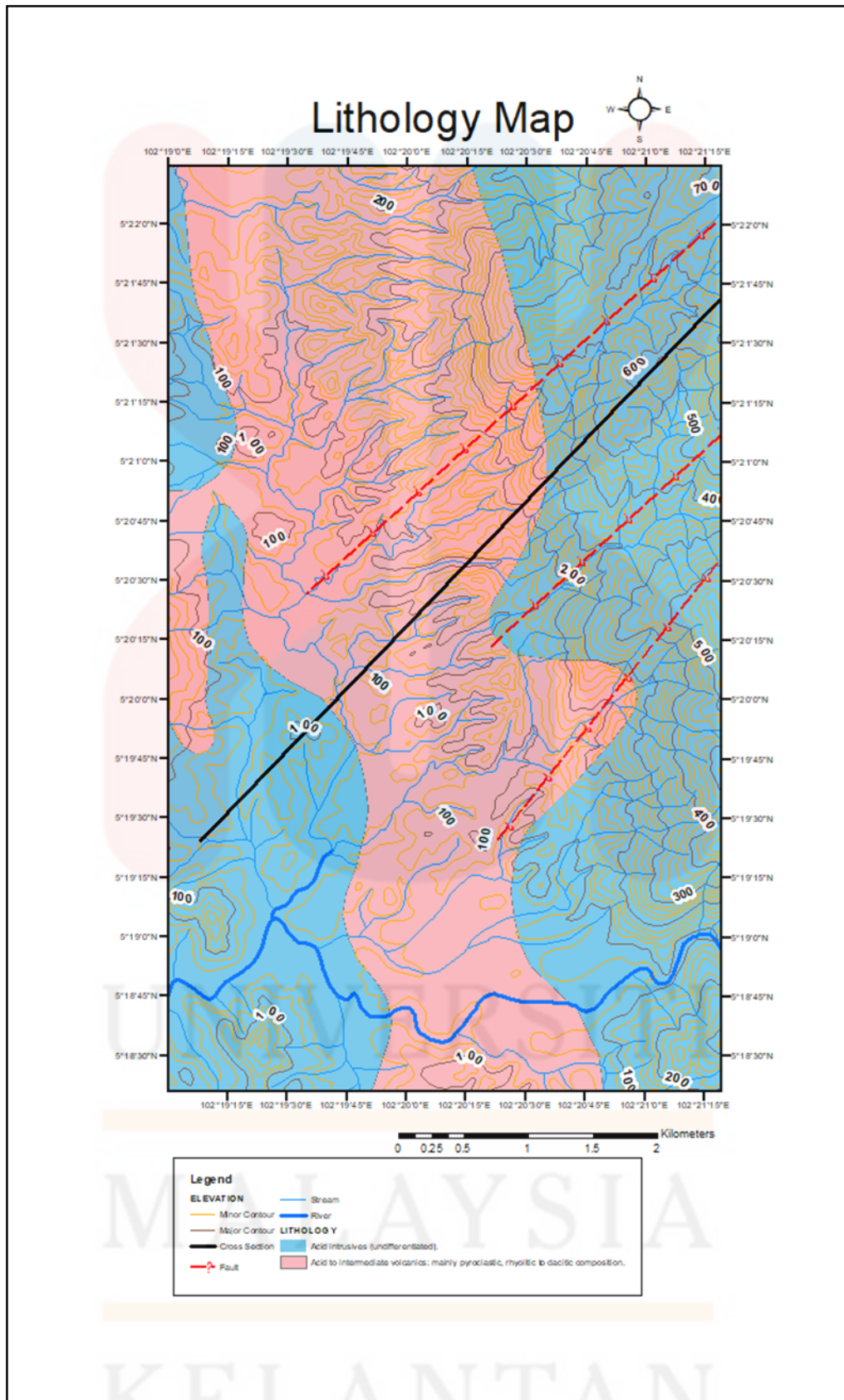


Figure 5. 19: Lithology map of the study area

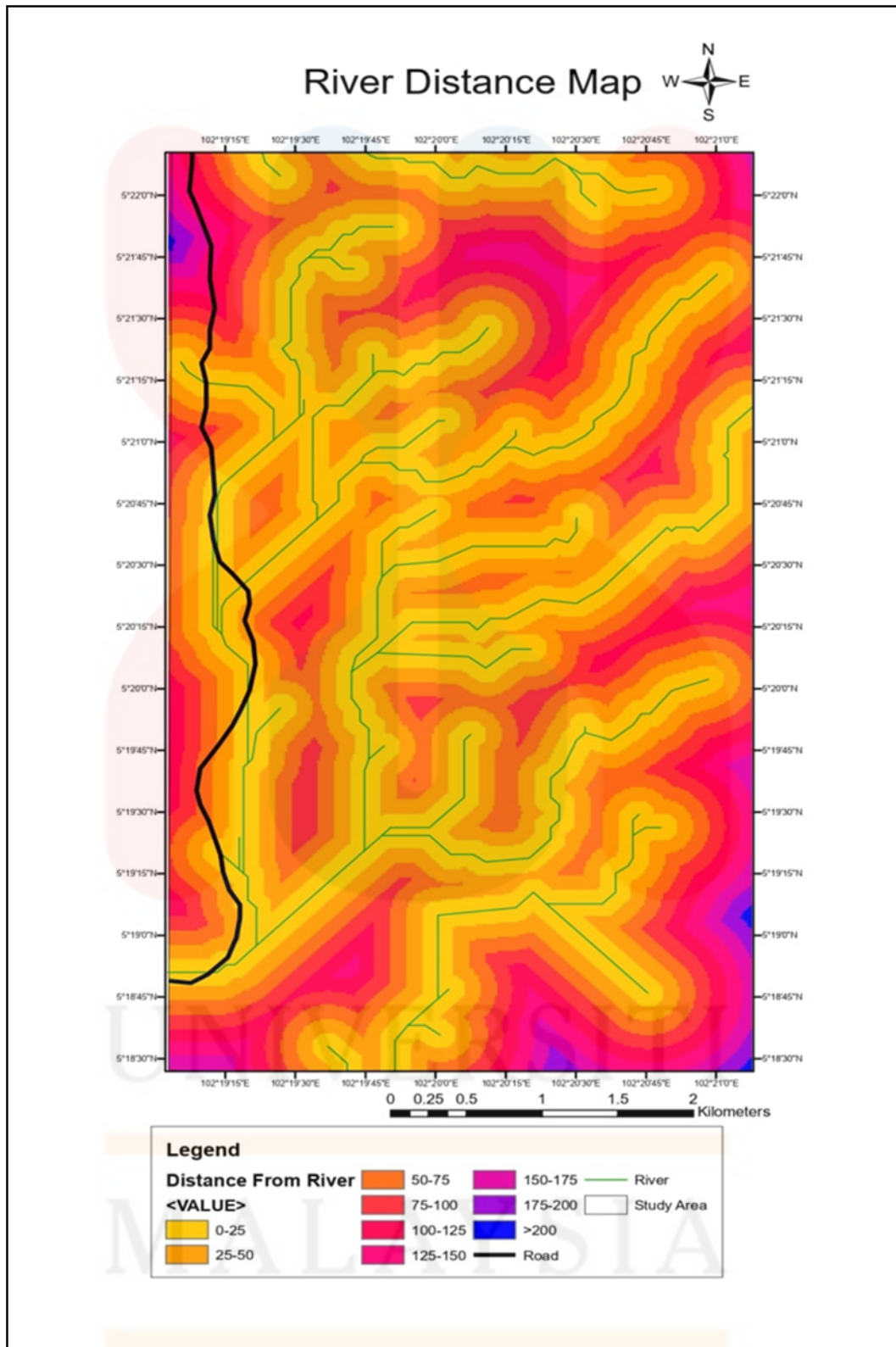


Figure 5. 20: River distance map of the study area

5.4 Flood Hazard Map

Before reclassification, each parameter must be present in raster data to construct and generate the flood vulnerability map of Kuala Krai Town, Kuala Krai, Kelantan. Then, all parameters were superimposed using the WOM in ArcGIS. In this study region, the following factors must be selected: flow accumulation, elevation, land use, slope, and lithology. Table 5.15 displays reclassification data influenced by flooding for each parameter.

In this study, a flood vulnerability map was created using ArcGIS Software and the hydrograph data of the Kelantan River in Kuala Krai, Kelantan. Figure 5.21 depicts the hydrograph data of the Kelantan River in Kuala Krai, Kelantan, which assist in identifying flood-prone areas based on water depth.

Additionally, flood hazard refers to the likelihood of occurrence with varying degrees of severity. In order to define the level of flood risk encountered by residents, the created map is separated into three levels: low, medium, and high. The flood hazard is emphasised based on observable indicators such as flood depth and flood duration derived from the hydrograph and hyetograph analyses. The water level, duration, depth, and exposure are crucial physical factors that must be analysed with the response variable in order to evaluate the severity of a flood occurrence.

Table 5.15: Reclassify data with influence

No	Raster Datasets	Influence
1.	Flow Accumulation Very Low (0-752) Low (752-2633) Moderate (2633-6394) High (6394-15797) Very High (14797-31971)	30
2.	Elevation 0-100 101-400 401-500 501-700	20
3.	Land Use River Garden Town Road Forest Rubber	20
4.	Slope 0-3 3-10 10-20 20-30 30-50	10
5.	Lithology Granite Granodiorite	10
6.	River Distance	10

5.5 Flood Hazard Analysis

Six parameter components flow accumulation, elevation, land use, slope, river distance and lithology were used in a Weighted Overlay Method (WOM) to generate a flood vulnerability map. Supporting this approach were factors such as depth and duration for this flood hazard.

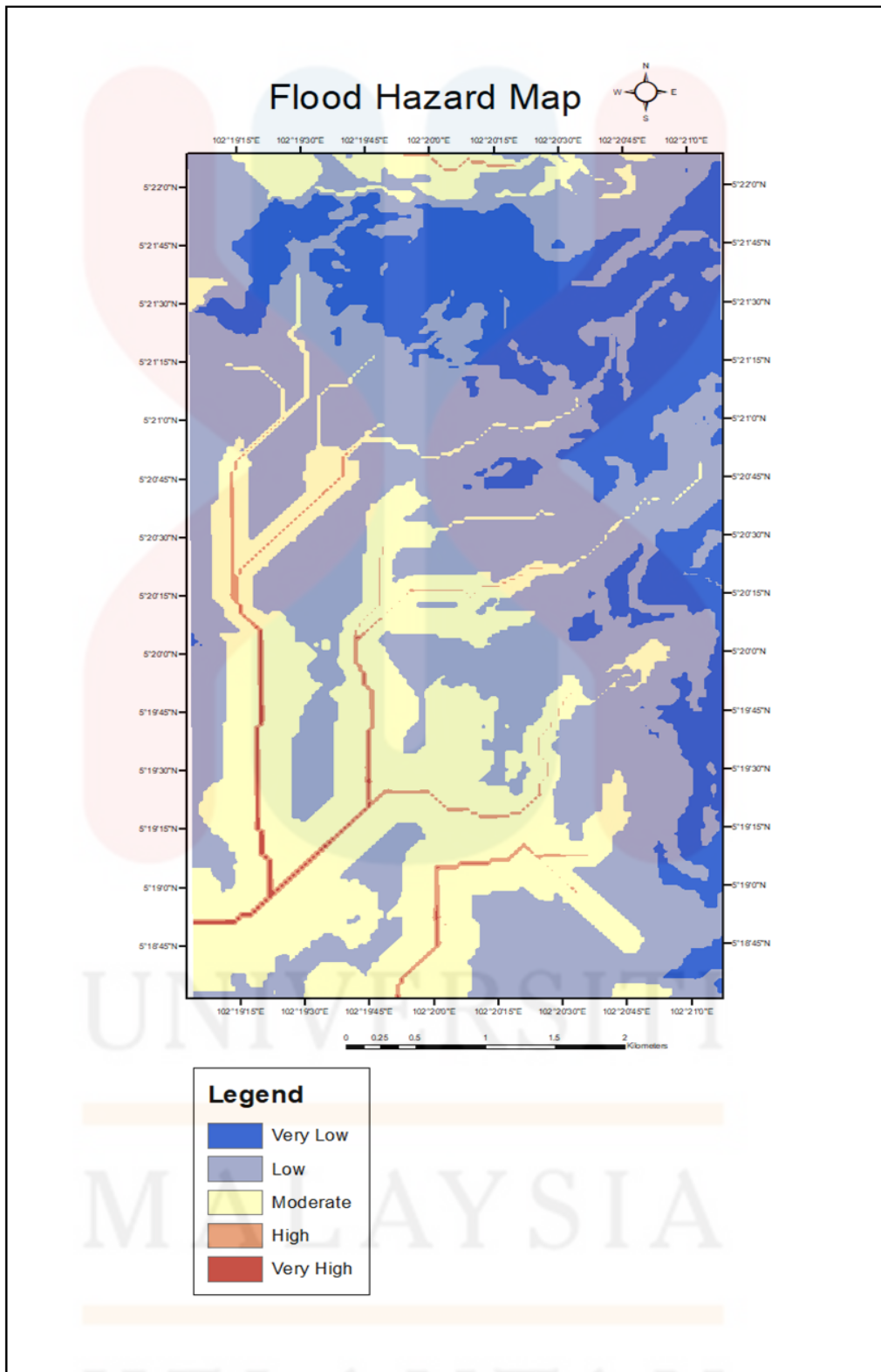


Figure 5. 21: Flood hazard map at Kampung Lahoh, Kuala Krai, Kelantan

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

In conclusion, all research objective stated in 1.4 were achieved. A geological map of Kuala Krai Town, Kuala Krai, Kelantan was updated with more details in scale of 1:25000. The lithology of the research region was studied in the stratigraphy research, and it was determined that the region was composed of two distinct kinds of rock: granite and granodiorite and it is proven by thin section. It is explained where in the formation's stratigraphy the Granite and Granodiorite rocks lie, with Granite being the oldest of the two. The research area's maximum height is found to be 700 m in the east, while its lowest elevation or altitude is found to be 100 m, particularly in urban areas.

The final output in the forms of flood hazard map was generated by identifying the flood zones in the study area by determining the parameter of flood hazard analysis. There are six parameters component were gathered and processed into GIS and remote sensing program such as flow accumulation, elevation, land use, slope, lithology and river distance. These parameters were then reclassified and overlaid by using Weighted Overlay Method (WOM) in GIS software.

The highest elevation at Kampung Laloh is 700m in the east area while the lowest elevation or altitude is 100m located at residential area. The generated flood

hazard map was classified into three flood zone areas which is low, medium and high. In general, the study area has the potential for flood hazards with a percentage of 30% high, 50% medium and 20% low. The parameters for flood hazard analysis were discussed and the factors for flood hazard were also determined. The main factors for flood hazard analysis in the study area are rainfall intensity and logging activities.

6.2 Suggestion

As a suggestion for future research, I would emphasise the significance of mapping in the geosciences, particularly in determining the outcome and collecting sample hand specimens for the evidence to update geological map of study region. Insufficient information exists for reliable interpretation of the terrain map alone. It is recommended that appropriate parameters should be selected for promising better flood hazard analysis map in particular research area. Because of this, a thorough comprehension of the procedure is required prior to the preparation of appropriate parameters. In order to gather more precise data and to compare the new data with the existing data, it is suggested to use different approach in creating flood danger map is. Another technique is the Analytic Hierarchy Process (AHP).

Finally, flood mitigation aids in reducing the flood occurrence through the management and control of flood water movement. To prevent floods in Kelantan from getting worse in the years to come, at least a few actions need to be taken. First, logging and land removal should be halted or at least brought under control. In any case, it needs to be handled properly. Next, construct upstream water containment

infrastructure, such as a dam, to collect and store water during times of high precipitation, such as the monsoons. Finally, floods can be mitigated by actively silting and deepening rivers downstream. The activity has to be taken at both the headwaters and the lower reaches of the Kelantan River basins.



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