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**GEOLOGY AT KAMPUNG KUALA GERIS,  
DABONG AND SPATIO-TEMPORAL ANALYSIS  
OF RAINFALL DATA IN KUALA KRAI,  
KELANTAN**

by

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

**FACULTY OF EARTH SCIENCE  
UNIVERSITI MALAYSIA  
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**2023**

## DECLARATION

I declare this thesis entitled “Geology at Kampung Kuala Geris, Dabong and Spatio-Temporal analysis of rainfall data in 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 hereby declare that I have read this thesis and in our opinion, this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honors”

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**Geology at Kampung Kuala Geris, Dabong and Spatio-Temporal Analysis of  
Rainfall Data in Kuala Krai, Kelantan**

**ABSTRACT**

This research is about geology and Spatio-temporal analysis of rainfall data to determine the rainfall pattern related to the occurrence of flooding in Kuala Krai, Kelantan. The study area of Kampung Kuala Geris is located at Dabong with coordinates 5°21'53" N to 5°24'20" N and 102°1'50" E to 102°4'50" E. The study area consists of phyllite, slate, quartzite, and alluvium unit from Gua Musang Formation and Stong Migmatic Complex Formation. The study area was dominated by plain, low land, low hill, and hill topographic. The objective of this study is to update the geological map in Kampung Kuala Geris with a scale of 1:25,000 and to identify the rainfall distribution patterns in Kuala Krai. For mapping, the method used to collect the data was by performing the preliminary research related to the area and conducting the geological mapping that consisted of observation and measurement in the field, taking samples, and doing the petrography of the sample to identify the rock type. Besides, the monthly precipitation amounts for water level and rainfall data from the year 2009 to 2020 were obtained from the Department of Irrigation and Drainage (DID). The collected precipitation data were analysis using Mann Kendall Test to see the trend pattern of the data. In addition, interpolation data and Arithmetic Average was used to fill up the missing data. From that analysis, it can be concluded that the huge amount of rainfall intensity is the factor that contributes to the flood event in Kuala Krai, Kelantan.

Keywords: Geological mapping, Spatio-Temporal, Mann Kendall Test, Interpolation data

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# **Geologi di Kampung Kuala Geris, Dabong dan Analisis Spatio-Temporal Data**

## **Hujan di Kuala Krai, Kelantan**

### **ABSTRAK**

Penyelidikan ini adalah mengenai geologi dan analisis Spatio-temporal data hujan untuk menentukan pola hujan yang berkaitan dengan kejadian banjir di Kuala Krai, Kelantan. Kawasan kajian Kampung Kuala Geris terletak di Dabong dengan koordinat 5°21'53" N hingga 5°24'20" N dan 102°1'50" E hingga 102°4'50" E. Kawasan kajian terdiri daripada unit batuan phyllite, batu sabak, batu kuarza dan mendapan alluvium Formasi Gua Musang dan Formasi Stong Migmatik Komplek. Kawasan kajian didominasi oleh topografi dataran, rendah, bukit rendah, dan bukit. Objektif kajian ini adalah untuk mengemaskini peta geologi Kampung Kuala Geris dengan skala 1:25,000 dan mengenal pasti corak taburan hujan di Kuala Krai. Bagi pemetaan, kaedah yang digunakan untuk mengumpul data adalah dengan melakukan penyelidikan awal berkaitan kawasan dan menjalankan pemetaan geologi yang terdiri daripada pemerhatian dan pengukuran di lapangan, mengambil sampel, dan melakukan petrografi sampel untuk mengenal pasti jenis batuan. Selain itu, jumlah hujan bulanan bagi data paras air dan hujan dari tahun 2009 hingga 2020 diperoleh daripada Jabatan Pengairan dan Saliran (JPS). Data kerpasan yang dikumpul adalah analisis menggunakan Ujian Mann Kendall untuk melihat corak aliran data. Selain itu, data interpolasi dan Purata Aritmetik digunakan untuk mengisi data yang hilang. Daripada analisis tersebut, dapat disimpulkan bahawa jumlah intensiti hujan yang besar merupakan faktor yang menyumbang kepada kejadian banjir di Kuala Krai, Kelantan.

Kata kunci: Spatio-temporal, Ujian Mann Kendall, Data interpolasi

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## TABLE OF CONTENT

<b>DECLARATION</b>	<b>i</b>
<b>APPROVAL</b>	<b>ii</b>
<b>ACKNOWLEDGMENT</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>ABSTRAK</b>	<b>v</b>
<b>LIST OF TABLES</b>	<b>ix</b>
<b>LIST OF FIGURES</b>	<b>x</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xii</b>
<b>LIST OF SYMBOLS</b>	<b>xiii</b>
<b>CHAPTER 1</b>	
<b>INTRODUCTION</b>	<b>1</b>
<b>1.1 General Background</b>	<b>1</b>
<b>1.2 Study Area</b>	<b>2</b>
a) Location	2
b) Road Connection	5
c) Demography	6
d) Land use	6
e) Social Economic	7
<b>1.3 Problem Statement</b>	<b>7</b>
<b>1.4 Objectives</b>	<b>8</b>
<b>1.5 Scope of Study</b>	<b>8</b>
<b>1.6 Significance of Study</b>	<b>9</b>
<b>CHAPTER 2</b>	
<b>LITERATURE REVIEW</b>	<b>10</b>
<b>2.1 Introduction</b>	<b>10</b>
<b>2.2 Regional Geology and Tectonic Setting</b>	<b>10</b>
<b>2.3 Stratigraphy</b>	<b>14</b>
<b>2.4 Structural Geology</b>	<b>14</b>
<b>2.5 Historical Geology</b>	<b>15</b>
<b>2.6 Research Specification</b>	<b>17</b>
<b>2.6.1 Flooding in Kuala Krai</b>	<b>17</b>
<b>2.6.2 Spatio-temporal analysis of rainfall data</b>	<b>18</b>
<b>2.6.3 Trend Analysis and Mann Kendall</b>	<b>18</b>

<b>2.6.4 Interpolation data and Arithmetic Average</b>	19
<b>CHAPTER 3</b>	
<b>MATERIALS AND METHODS</b>	20
<b>3.1 Introduction</b>	20
<b>3.2 Materials</b>	20
<b>3.3 Methods</b>	22
<b>3.3.1 Preliminary Studies</b>	22
<b>3.3.2 Field studies</b>	23
<b>3.3.3 Laboratory analysis</b>	23
<b>3.3.4 Data Collection</b>	23
<b>3.3.5 Data Analysis and interpretation</b>	24
<b>3.3.6 Research Flow Chart</b>	28
<b>CHAPTER 4</b>	
<b>GENERAL GEOLOGY OF KAMPUNG KUALA GERIS, DABONG, KELANTAN.</b>	29
<b>4.1 Introduction</b>	29
<b>4.1.1 Accessibility</b>	29
<b>4.1.2 Settlement</b>	32
<b>4.1.3 Forestry</b>	33
<b>4.1.4 Traverse and Observation</b>	35
<b>4.2 Geomorphology</b>	37
<b>4.2.1 Geomorphological classification</b>	37
<b>4.2.2 Weathering</b>	40
<b>4.2.3 Drainage Pattern</b>	42
<b>4.3 Lithostratigraphy</b>	43
<b>4.3.1 Stratigraphic Position</b>	44
<b>4.3.2 Unit Explanation</b>	47
<b>4.4 Structural Geology</b>	55
<b>4.4.1 Lineament analysis</b>	56
<b>4.4.2 Joint</b>	59
<b>4.5 Historical Geology</b>	61
<b>CHAPTER 5</b>	
<b>RESULT AND DISCUSSION</b>	64
<b>5.1 Spatial Analysis of Rainfall Data</b>	64
<b>5.2 Trend analysis of rainfall data</b>	67
<b>5.2.1 Descriptive statistic of rainfall stations and dataset from 2009 to 2020</b>	67

5.2.2 Total of annual rainfall for 2009-2020	68
5.2.3 Average rainfall in month	69
5.2.4 Trend analysis using Mann-Kendall (MK)	70
5.3 Trend analysis of water level	72
5.3.1 Descriptive statistic of water level station and dataset from 2009-2020	72
5.3.2 Total water level for 2009-2020	72
5.3.3 Average water level in month	73
5.3.4 Trend analysis using Mann-Kendall (MK)	74
5.4 Interpolation Data	75
5.4.1 Descriptive statistic of rainfall stations and dataset from 2009 to 2020	75
5.4.2 Total annual rainfall for 2009-2020	76
5.4.3 Average rainfall in month	77
5.4.4 Trend analysis using Mann-Kendall (MK)	78
5.5 Discussion	80
<b>CHAPTER 6</b>	
<b>CONCLUSION AND SUGGESTION</b>	82
6.1 Conclusion	82
6.2 Recommendation	83
<b>REFERENCES</b>	84

## LIST OF TABLES

NUMBER	TITLE	PAGE
3.1	Material and its function	20
4.1	Geomorphological unit classification	38
4.2	Weathering profile of the rock mass in the study area	40
4.3	Stratigraphy column of the study area.	44
5.1	Descriptive analysis rainfall stations	67
5.2	Summary statistics of Mann Kendall	70
5.3	Mann-Kendall analysis	71
5.4	Descriptive analysis of water level	72
5.5	Summary statistics of Mann Kendall	74
5.6	Mann-Kendall analysis for water level data	74
5.7	Descriptive analysis	75
5.8	Summary statistics of Mann Kendall	78
5.9	Mann-Kendall analysis	79

## LIST OF FIGURES

NUMBER	TITLE	PAGE
1.1	Kuala Krai Base with rainfall and water level stations plot	3
1.2	Base map Kampung Kuala Geris, Dabong, Kuala Krai	4
1.3	Federal Route 66 from Jeli to Kampung Kuala Geris	5
2.1	Geological map of Peninsular Malaysia	12
2.2	Geological map of Kelantan	13
4.1	Accessibility map of Kampung Kuala Geris, Dabong Kelantan	31
4.2	Sekolah Kebangsaan Kuala Geris	32
4.3	Masjid Mukim Kuala Geris	32
4.4	Landuse map of the study area consisted of rubber plantation, forestry, and settlement.	34
4.5	Traverse map of study area	36
4.6	Topography map of Kampung Kuala Geris, Dabong	39
4.7	Hill topography at the study area	39
4.8	Drainage map of Kampung Kuala Geris	43
4.9	Geological map of Kampung Kuala Geris, Dabong, Kelantan	46
4.10	a) Hand specimen of greenish grey phyllite b) Outcrop of greenish grey phyllite on the ground.	48
4.11	Petrographic analysis of green phyllite in PPL and XPL. Quartz (Qtz), Opaque minerals (Op), Silica clay (Si)	49
4.12	a) Hand specimen of slate b) Slate outcrop for slate at near distance c) Slate outcrop at far distance.	50
4.13	Petrographic analysis of slate in PPL and XPL. Silica clay (Si), Quartz (Qtz), Opaque minerals (Op).	51
4.14	a) Hand specimen of metaquartzite b) Outcrop of metaquartzite.	52

4.15	Petrographic analysis of metaquartzite in PPL and XPL.	53
4.16	a) Alluvium deposit at Galas River b) Alluvium deposit at riverbank c) alluvium deposit at stream contains sand and gravel.	54
4.17	Lineament map from terrain map (RGB analysis).	57
4.18	Lineament map from topography analysis.	58
4.19	Lineament analysis of the study area	58
4.20	Rose diagram for joint data	60
4.21	Joint structure on the slate rock.	61
5.1	Distribution of rainfall by year with missing data	65
5.2	Distribution of rainfall by year without missing data	66
5.3	Graph of total annual rainfall (2009-2020).	68
5.4	Graph of average rainfall in month	69
5.5	Graph of total annual water level (2009-2020).	72
5.6	Graph of average water level in month	73
5.7	Graph of total annual rainfall (2009-2020)	76
5.8	Graph of average rainfall in month	77

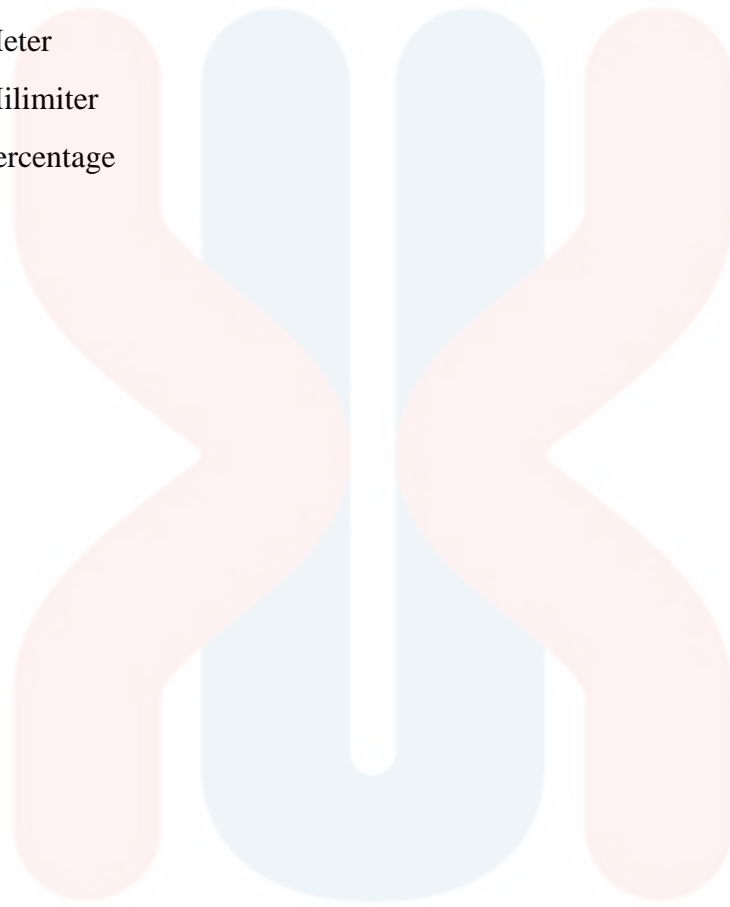
## LIST OF ABBREVIATIONS

DID	Department of Irrigation Drainage
E	East
GIS	Geographic Information System
N	North
MK	Mann-Kendall
S	South
W	West

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## LIST OF SYMBOLS

km	Kilometer
m	Meter
mm	Milimiter
%	Percentage



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# CHAPTER 1

## INTRODUCTION

### 1.1 General Background

This research was carried out to determine the trend of rainfall data in Kuala Krai, Kelantan. This study aims to do some geological mapping in Kampung Kuala Geris, Dabong, Kuala Krai to fulfil the requirement of Geoscience students. Geological mapping is essential to determine the composition and structure of geologic materials of the Earth's surface and depth. Geological mapping includes studying several types of rock and their structure, geomorphology characteristic, and rock lithology. Depending on the scale and extent of the mapping, it may take a few days to several months to complete.

A flood is an overflow of water that submerges the ground due to heavy rains that continue for three or four days. They are the most widespread natural occurrence of severe weather. Kelantan has experienced enormous floods since 1927, with a rainfall return period of about 1:1000 years (Hanan et al.2020). Rainfall in Malaysia is caused by convectional rain, which has its pattern and is mainly affected by changes in the climate (Irwan et al., 2017). Rainfall is expected to be more intense in the future due to global warming. This will increase the flood peak, volume, and duration. Furthermore, the rate of sea level is expected to increase and will exacerbate the effects of floods (Sa'adi et al.,2022).

Kuala Krai was a flood-prone area because there was a collision between two main tributaries, Sungai Lebir and Sungai Galas, upstream of Kuala Krai. Therefore, Kuala Krai is easily impacted by the flood if heavy rain occurs for a few days. So, this study was conducted to look at daily and monthly rainfall data for 12 years (2009-2020) to see the pattern and distribution of rainfall. Water levels from two stations at Kuala Krai also were recorded. Then, the data flow pattern was determined using the Mann-Kendall Test. The analysis revealed whether heavy rains caused floods in Kuala Krai or not. The use of ArcGIS software is also required to compare the distribution of rainfall data in Kuala Krai, Kelantan.

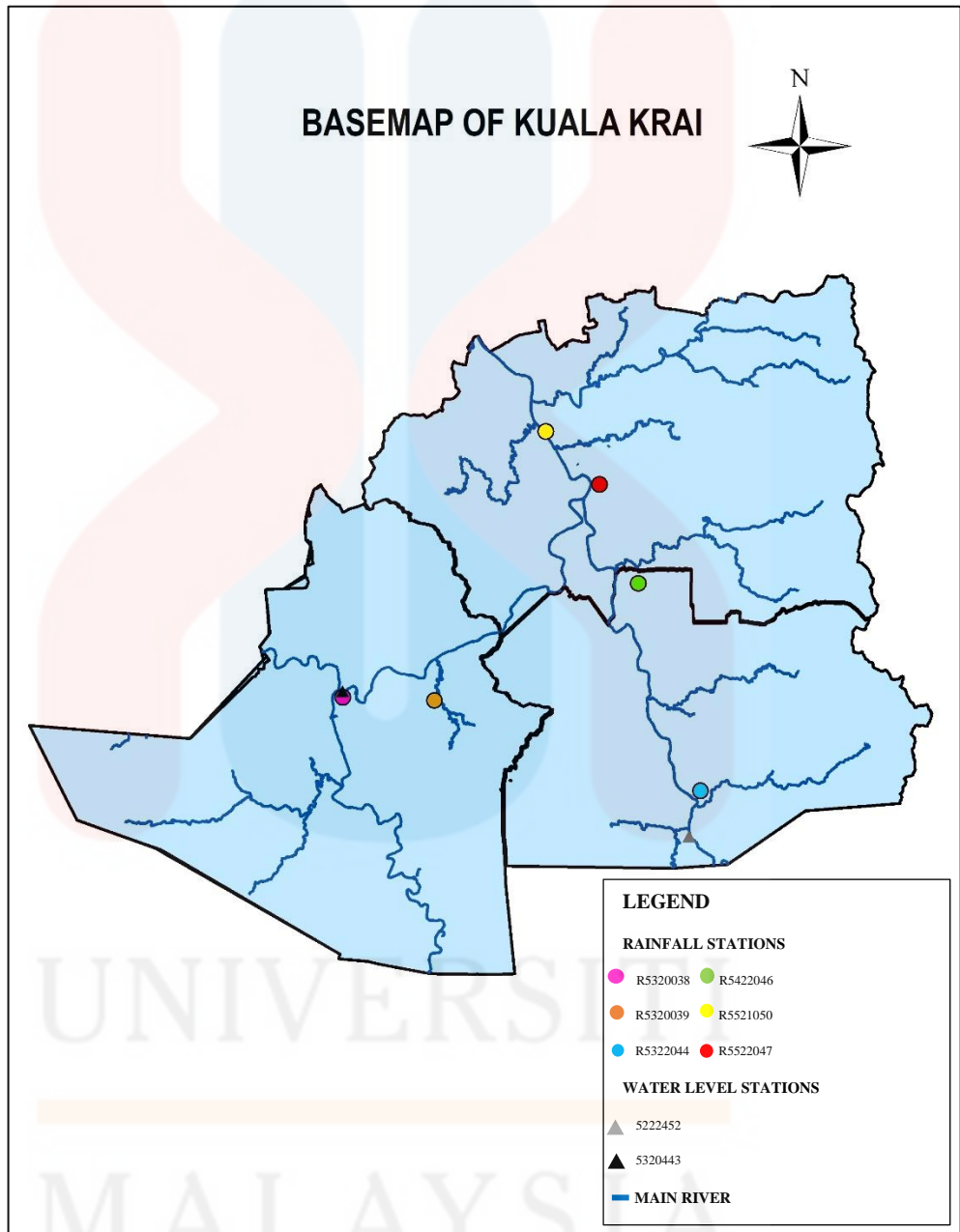
## 1.2 Study Area

### a) Location

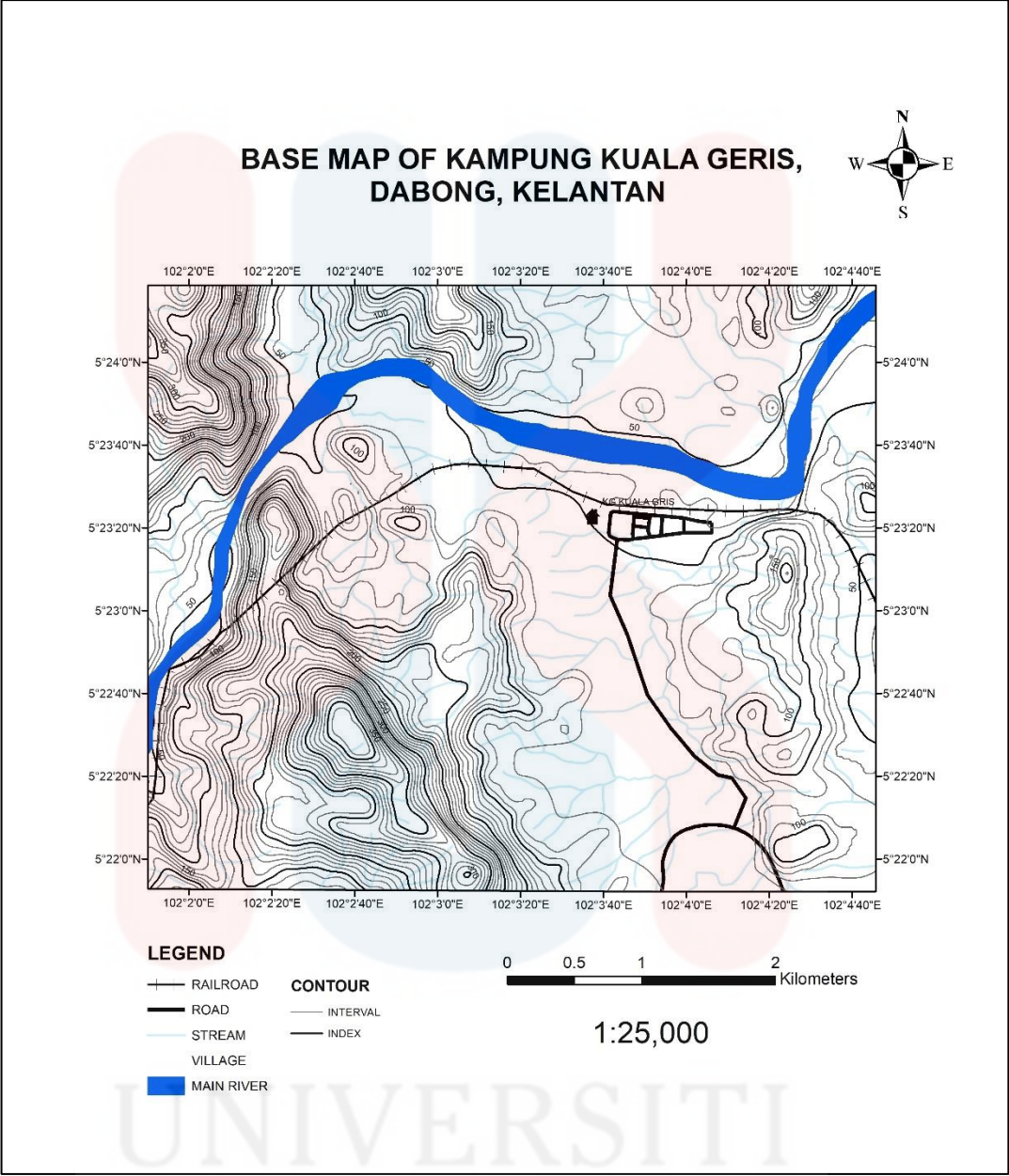
This research was conducted at Kuala Krai, which is in the southern-central of Kelantan, Malaysia. The terrain is hilly, and the entire region was covered with tropical rain forests before the 20<sup>th</sup> century. Kuala Krai shares borders with Machang in the North and Gua Musang in the South, and it shares an eastern border with Sabah. Kuala Krai is an appropriate place to conduct this study because the area is often hit by floods, especially in the village area near the main river of Kelantan. This study was carried out to assist in updating geological data in Kuala Krai, Kelantan, and prevent flood hazards that could harm those living there. **Figure 1.1** shows the base map of Kuala Krai with plotted rainfall and water level stations.

Meanwhile, Kampung Kuala Geris, Dabong has been chosen to do the geological mapping. The coordinate for this study area is 5°21'34.70"N, 101°58'45.41"E, 5°21'34.43"N, 102° 1'49.38" E, 5°19'10.70"N, 101°58'44.68"E,

5°19'11.74"N, 102° 1'48.46"E. Dabong is situated in the lower part of Kuala Krai with 84,007.06 hectares. The base map of Kampung Kuala Geris is shown in **Figure 1.2**.



**Figure 1.1** Kuala Krai base map with rainfall and water level stations plot.

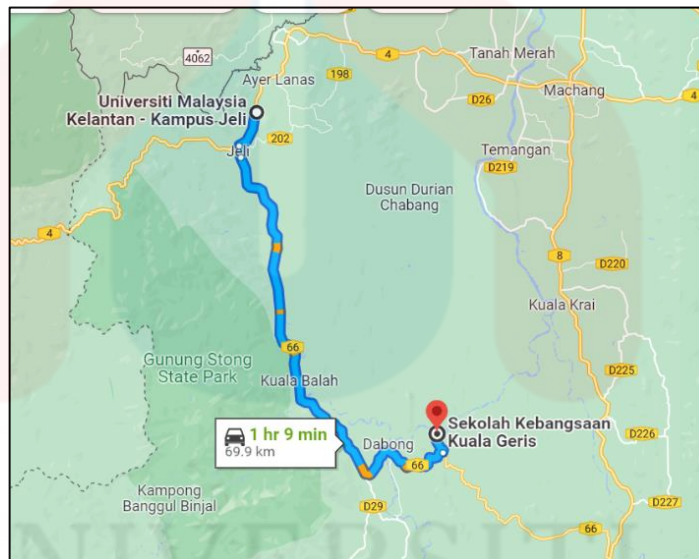


**Figure 1.2** Base map Kampung Kuala Geris, Dabong, Kuala Krai

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## b) Road Connection

In Kuala Krai, the main roads used to the study area were Federal Route 66 and Kota Bharu-Kuala Krai Expressway. Federal Route, also known as Kuala Lumpur-Kota Bharu, is a 402.7 km federal highway in Malaysia. It connects Bentong in the South to Kota Bharu. Next, Kota Bharu-Kuala Krai Expressway is a 73 km expressway connecting the city of Kota Bharu and Kuala Krai. Besides, the main road to the study area was connected to Dabong and from Jeli or Gua Musang. **Figure 1.3** shows Federal Road 66 from Jeli to Dabong.



**Figure 1.3** Federal Route 66 from Jeli to Kampung Kuala Geris (Source: Google Map,2022)

### c) Demography

Kuala Krai district is the second largest after Gua Musang, with three sub-districts: Olak Jeram, Batu Mengkebang, and Dabong. Olak Jeram with 67 villages. Batu Mengkebang with 122 villages and Dabong with 27 villages. According to the Department of Statistics Malaysia (2020), Kuala Krai has a land area of 2,275 km<sup>2</sup> with a population density of 60 km<sup>2</sup>. In 2020, the number of residents in Kuala Krai was estimated at 136 thousand, with an annual population growth rate of 0.7%.

The male population of Kuala Krai in 2020 was 51.5 %, and females 48.5 %. There are 29.0 thousand residential places with 25.4 thousand households, and the average household size is 5.1 people. The population of Kuala Krai consists of 95.1 % of citizens, and the rest are not citizens.

Besides, the population of Dabong was 17.4 thousand with a population density of 17 km<sup>2</sup>. The area for Dabong was 1031 km<sup>2</sup>. The population in the area consists of 95.2% of citizens and 4.8% of non-citizens.

### d) Land use

Land use and land cover changes show there is a change in development that occurs in a place. For example, when a forest area changes to a different type of land use such as settlement, industry, farm, or tourist spot. These changes can affect the quality of the environment. Samsurijan et al., (2018) stated that the land use Kelantan basin development in 1984 was less, with only a few types of land use with only a few types of land use, like rubber, coconut, oil palm, plants, and so on, were allowed. The average patterns of how land is used show that Kelantan Basin is not as developed as it was in the 1980s.

The land use in Kuala Krai is mostly used by rural and urban developments as the area is near the town and village. The development in Kuala Krai includes the infrastructure of schools, malls, hospitals, public libraries, and other places that growing up well. Besides, the land use in Kuala Krai also uses for agriculture activities. In the study area, most of the land use area is covered with plantations such as palm oil and rubber tree plantation area. In the East, there was a city area and a main river.

#### **e) Social Economic**

The economic activities of Kelantan mainly focused on business, agriculture, manufacturing, the agro-industrial sector, and tourism. Most of the residents in Dabong are involved in agriculture, forestry, and fishing business. Besides, there was also the establishment of manufacturing, construction, and services businesses. Thus, the palm oil plantation was the primary source of income in Dabong. Next, as observed the residents also work under the government as the government sector could provide many facilities to people.

### **1.3 Problem Statement**

Climate change and extreme weathering can change the geomorphological settings of an area. Natural phenomena caused by climate change and global warming changed the local conditions of the soil, resulting in high rates of weathering and mass transport of sediments. Therefore, geological mapping needs to be conducted to provide fresh and updated information on the geological settings of the affected area.

Besides, Kuala Krai had a problem identifying the flood-prone zone due to the lack of information about flood vulnerability. The updated information about the flood

is essential for the community to understand the flood risk and making more informed decisions about how to manage it. In addition, it is crucial to relate the current flood incidents to historical rainfall records to offer information on the rare and intense level of rainfall that caused the flood.

From the previous research, some statistical models are still not accurate in predicting the occurrence of floods, and further research is required to improve flood forecasting accuracy in the future. It is expected that integrating watershed feature factors into flood modelling and forecasting will improve prediction accuracy and model dependability, respectively. The updated information about the flood is vital for the community in understanding the flood risk and making more informed decisions about how to reduce or manage it.

#### **1.4 Objectives**

This research was conducted based on a few objectives which are:

- i. To update the geological map in Dabong, Kuala Krai with a scale of 1:25,000.
- ii. To identify rainfall distribution patterns in Kuala Krai using Spatio-temporal analysis.

#### **1.5 Scope of Study**

The scope of this study was focused on the geology of Kuala Krai, Kelantan, especially at Kampung Kuala Geris, Dabong. Geological mapping including investigating the petrographic properties of rock samples that be collected from fresh outcrops. In addition, this research was conducted to study the lithology, structural geology, stratigraphy, and geomorphology of Kampung Kuala Geris, Dabong.

Besides, this study aims to analyse the Spatio-temporal pattern of rainfall intensity in Kuala Krai. Daily and monthly data from 6 rainfall stations and 2 water level stations in Kuala Krai (2009 - 2020) were collected from the Department of Irrigation and Drainage (DID). Then, the existence of the rainfall intensity was analysed using a non-parametric test which is the Mann-Kendell test.

### **1.6 Significance of Study**

The significance of this research is to update the geological map of Kampung Kuala Geris, Dabong on a scale of 1:25000. Geological map will show the geological features of the study area. These features include rock types, faults, minerals, and groundwater. It may help the community to understand natural disasters and climate change. In addition, it will be a valuable reference for other companies to further the project including development, sustainability, soil and water resource management, and many other geological purposes. Geological maps use letters, colours, lines, and symbols to help and ease people learn more about how the Earth is arranged.

Besides, this study was conducted to get a better understanding of the level of floods that commonly occur in the study areas. This study hopes to consequently reduce the destructive impacts in the flood-prone area. The latest and precise information is essential in decision-making (Farhadi & Najafzadeh., 2021). The present study of rainfall distribution in Kuala Krai will help to understand and evaluate the rainfall trend analysis and possibly predicting the flood future event.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter covers the regional geology and structural geology of Kampung Kuala Geris, Dabong. This part also will discuss the Spatio-temporal analysis based on the previous study and research article. All contents from the secondary data such as journals, articles, and others would contribute as sources to this research.

#### 2.2 Regional Geology and Tectonic Setting

Bentong Raub Suture Zone (BRSZ) is a part of the main Devonian to Middle Triassic Palaeo-Tethys Ocean. It is a primary structural zone in Peninsular Malaysia (**Figure 2.1**). It forms the western boundary of the Sibumasu terrane and the eastern boundary of the Sukhothai Arc/East Malaya block (Indochina terrane), which is derived from the eastern margin of the supercontinent Gondwana. (Pour et al., 2016). Peninsular Malaysia was formed from two Gondwana-derived terranes, the western Sibumasu terrane and the eastern Sukhothai Arc/East Malaya block (Indochina terrane). Both of those terrains were assembled in the Late Triassic. Peninsular Malaysia is a part of Sundalian continental core in Southeast Asia. According to Pour et al. (2016), Bentong Raub Suture Zone marks the boundary between Sibumasu and Indochina Gondwana-derived continental fragments in Peninsular Malaysia.

Kelantan is in the north-eastern part of Peninsular Malaysia. **Figure 2.2** shows the geological map of Kelantan. The regional geology of Kelantan is made up of a central zone of sedimentary and meta-sedimentary rocks that are surrounded on the

west and east by the Main Range and Boundary Range. In the west and central Kelantan, the belts continue to the north into southern Thailand. Thus, in the east, the Boundary Range granite is covered by the alluvial flat of Sungai Kelantan. The oldest rock in this state is in the lower Palaeozoic rocks. They form a belt that runs north to South along the foothills of the Main Range and east to Sungai Nenggiri. They are mostly made of metapelites, with some smaller pieces of volcanic rock and lesser amounts of arenaceous and calcareous material (Heng et al., 2006).

In the Southwest of Kelantan, there were a lot of Permian volcanic-sedimentary rocks. The Taku Schist, whose age is still unknown but is older than the Triassic, makes up most of central and northern Kelantan. Most of the Triassic rocks are in the central and southern parts of Kelantan. These rocks are mostly made up of argillo-arenaceous sediments, with bits of volcanic rock and limestone in between. The youngest rock is from the Jurassic-Cretaceous continental rocks.

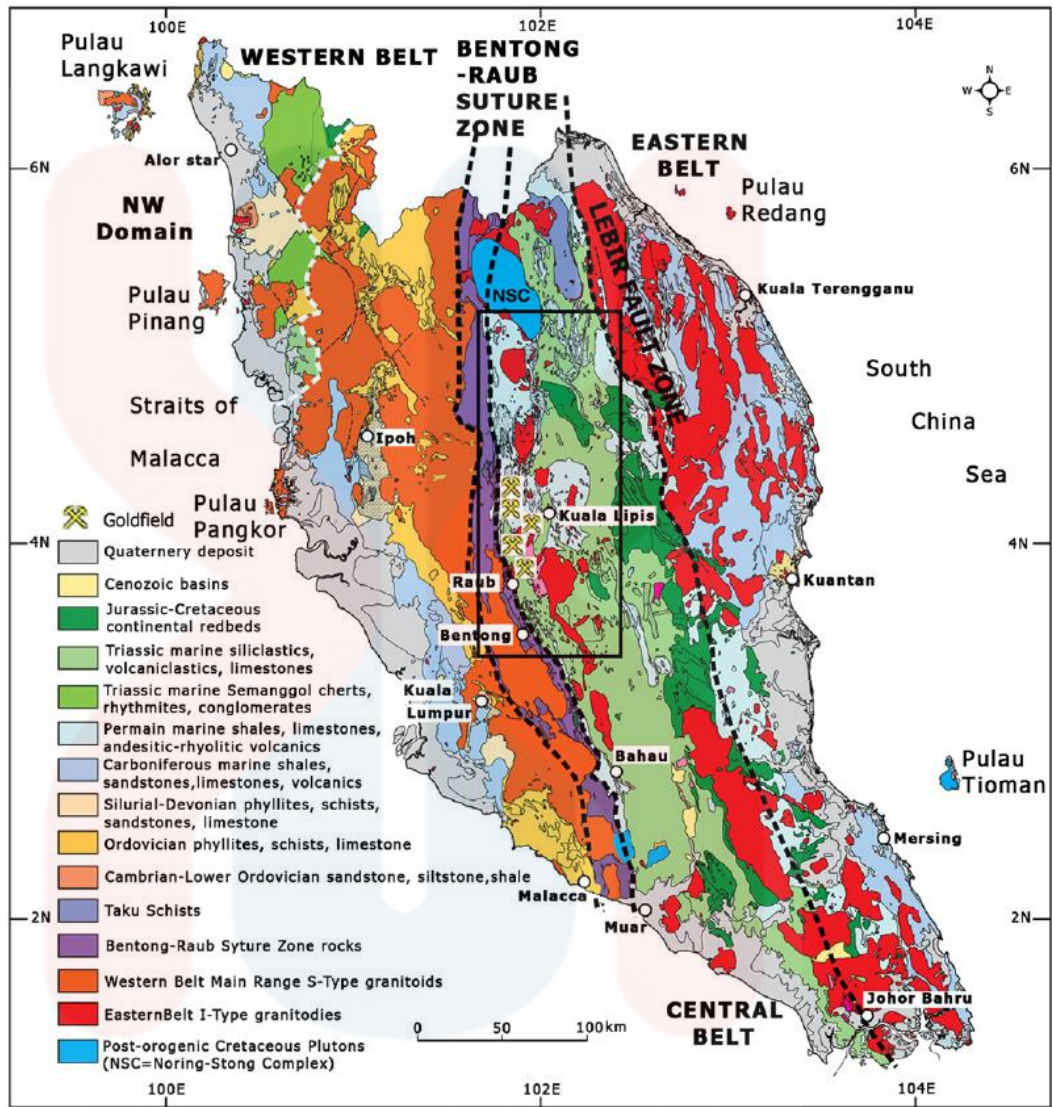


Figure 2.1 Geological map of Peninsular Malaysia (Source: Mazlan, 2013)

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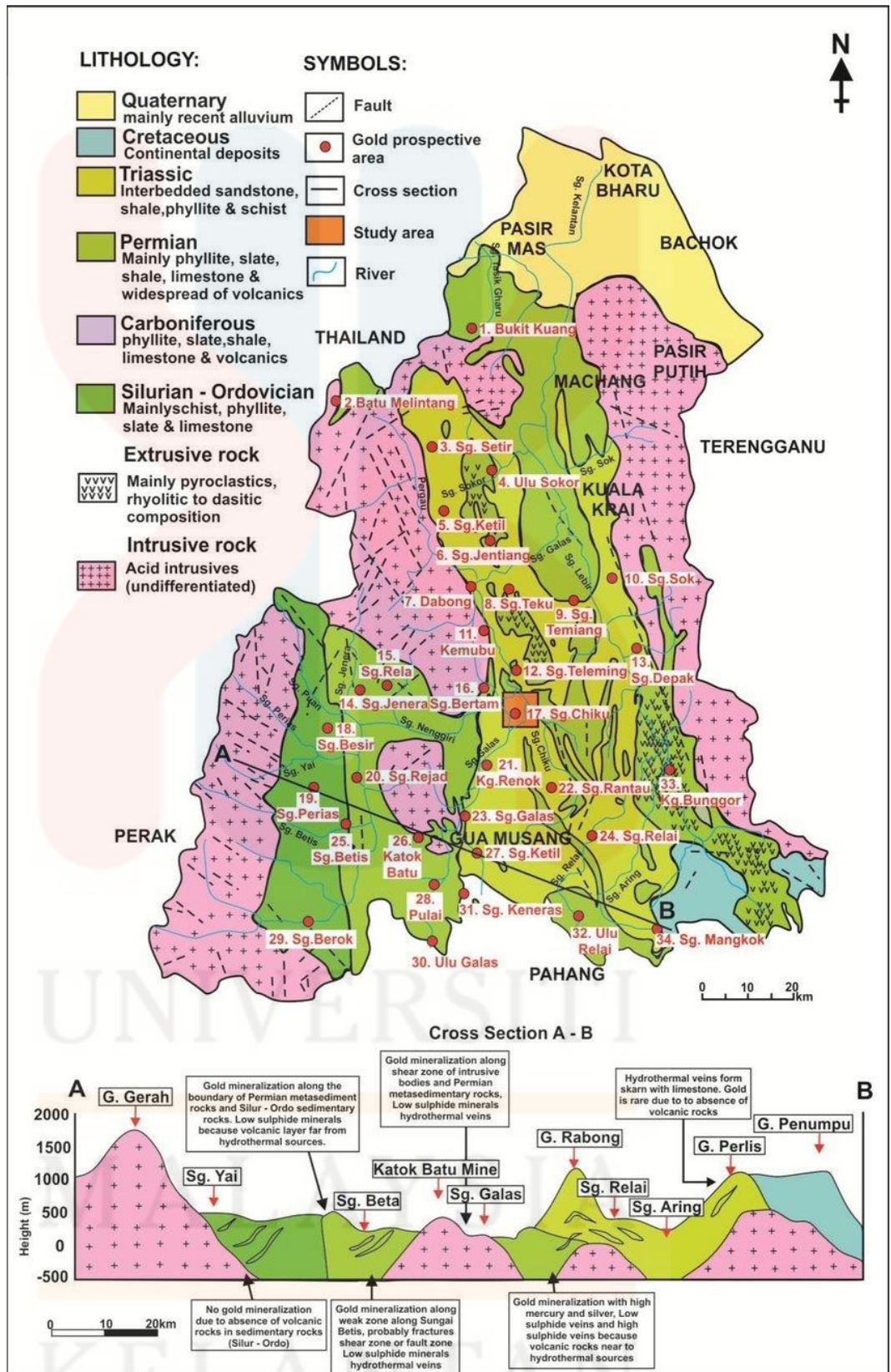


Figure 2.2 Geological map of Kelantan (Source: Arifin et al.,2019)

### 2.3 Stratigraphy

Dabong is a town located in the southern part of Kelantan. Dabong is a part of Gua Musang Group which consists of Permian to Triassic rocks (Sulaiman et al., 2020). Gua Musang formation and Gunung Rabong formation are included in the Gua Musang Group. The top part of the Gua Musang formation interferes with the Semantan formation, the Telong formation, and the Gunung Rabong formation. The Gua Musang Group comprises four different types of rock called "facies." These are calcareous, argillaceous, arenaceous, and volcanic. This formation was made on a shallow shelf in the ocean where there were active volcanoes. The thin bedded, laminated, and fissile shale is usually grey, but when carbonaceous, it turns black. But sometimes it's found in chert beds that are dark grey to black.

The Gunung Rabong Formation is a layer of argillaceous rock that dates from the Middle Triassic to the Upper Triassic and can be seen between Gua Musang and the upper reaches of the Sungai Relai and Sungai Aring rivers. The Gunung Rabong formation comprises a sequence of crystal tuff, shale, quartzite, and a small amount of conglomerate (Sulaiman et al., 2021).

### 2.4 Structural Geology

The Geological of Kelantan consists of west Kelantan olistrostrom, Taku Schist, and Gua Musang formation. The structure of Kelantan is the boundary by an olistrostrom in the west and the Lebir Fault zone in the East. Gua Musang formation is mainly separated in Kelantan. In the middle part towards north-south up to north-northwest-south-southeast, there was the prominent fold of Gua Musang formation. In the northern part of this main fold turned by granite intrusion and diorite porphyry

towards NE-SW. The main fault in Gua Musang Formation is the dextral fault with strike N30-45 and dipping 60-70 to SE and the sinistral fault with strike N330-340 E and dipping 60-8- to ENE-WSW. In the area boundary by igneous granite intrusion and near the main fault, Gua Musang Formation formed the compact and strong folding. The intrusion of diorite porphyry towards NE-SW must turn the main fold of Gua Musang formation to follow this intrusion.

## **2.5 Historical Geology**

Kelantan is a state in Peninsular Malaysia that may be found in the upper left-hand corner of the peninsular. The Kelantan River is the most important in this part of Malaysia. 'Sungai Galas' and 'Sungai Lebir' are main river in Kelantan. It emerges at the point where that two rivers converge, close to Kuala Krai, and then winds its way through the coastal plain before finally emptying into the South China Sea. The Kelantan River basin extends over an area of 923 km<sup>2</sup>, which is equivalent to approximately 85% of the total surface area in Kelantan state. The northern half of the river basin is placed with a gentle to moderate slope, and in the southern part are areas with sharp scraps and high slopes.

Kelantan has various types of rocks including igneous, sedimentary, and metamorphic. These rocks are laid out in a north-south direction. Granitic rocks, sedimentary and metasedimentary rocks, extrusive rocks (volcanic rocks), and unconsolidated sediments are the four types of rocks that are typically classified in this area. In the granitic rocks, there is faulting and jointing, while in the sedimentary rocks, there is folding, faulting, and jointing. Granitic rocks can be found along the western border of the state of Kelantan (known as the Main Range granite), as well as the eastern border of the state (known as the Boundary Range granite).

The Main Range Granite can be found in the western part of the state and stretches from the western part of Kelantan to the boundary between the states of Perak and Pahang, as well as Thailand. The Main Range Granite can be found along the western boundary of the Bentong–Raub Suture Zone (BRSZ), and it can be traced to Thailand in the north. The Bentong–Raub Suture is roughly 13 kilometres wide and stretches from Thailand through Raub and Bentong to the east of Malacca in Peninsular Malaysia.

The Lebir Fault Zone is in the eastern section of Kelantan state, which is one of the major lineaments in Peninsular Malaysia and is thought to be post-Cretaceous and a sinistral strike-slip fault. In addition, the Lebir Fault Zone is regarded to be a sinistral strike-slip fault. Mountainous regions, hilly regions, plain regions, and coastal regions make up the four different types of terrain that can be found in the state of Kelantan. Mount Chama, also known as Gunung, is at an elevation of 2171 meters and is the highest peak in the state of Kelantan. It can be found in the Gua Musang district in the state's western region, close to the boundary with the state of Perak. Alluvium deposits, also known as unconsolidated sediments, are what make up Quaternary deposits. Other types of sedimentary rocks, such as Triassic marine siliciclastic and volcanoclastics, as well as sandstone and limestone, can be discovered in Kelantan (Nazaruddin et al.,2014).

## 2.6 Research Specification

### 2.6.1 Flooding in Kuala Krai

Peninsular Malaysia located at latitude ranges from about 1°0'0''N to 7°0'0''N and 100°0'0''E to 105°0'0''E. Malaysia has a climate with consistent temperatures and high humidity. It is because Peninsular Malaysia is close to the equator and surrounded by the South China Sea to the East and the Malacca Strait to the West. Rainfall distribution on the East and West coasts of Peninsular Malaysia is influenced by the Northeast monsoon which occurs from November to March and the southwest monsoon which occurs from May to September (Alias et al., 2016).

Historically, the east coast of Peninsular Malaysia has been hit by several major floods. In Kelantan, a flood is considered an annual disaster. The first major flood in Kelantan was in 1967 with the percentage of the affected population was 70 percent. However, in 2014, Kelantan was attacked by a major flood, and it was the most significant flood ever recorded in Kelantan history. It was classified as a "tsunami-like disaster," with 202,000 people displaced. The flood is called 'Bah Kuning (yellow-coloured flood) because it has a high mud content (Bharuddin et al. 2015).

In 2014, Kuala Krai was one of the worst affected areas with a total of 16, 734 families being evacuated to 83 relief centers (Irwan et al., 2017). From the 21<sup>st</sup> to the 23<sup>rd</sup> of December 2014, Gua Musang was hit by continuous heavy rain with a record-setting 1:295 mm, which is the equivalent amount of rain that usually falls in 64 days. Therefore, the water levels in three major rivers, Sungai Galas in Dabong, Sungai Lebir in Tualang, and Sungai Kelantan, rise dramatically exceeding the danger level. According to Bharuddin et al. (2015), the highest level of the Sungai Galas, Dabong

was 46.47 meters. Meanwhile, the highest level of Sungai Lebir in Tualang, Kuala Krai, was 42.17 meters.

### **2.6.2 Spatio-temporal analysis of rainfall data**

Flooding in Kelantan can be classified as the seasonal monsoon floods characterised by low-intensity long duration rainfall. Continuous heavy rain will drastically rise the water level. Rainfall is a critical index of climatological inquiry. It has significant consequences for the flora and fauna, as well as any area's ecological setting and water resource management. Spatio-temporal data analysis is a growing field of study with the development of powerful computers such as graphics processing units (GPUs), which are used to analyze big data. Spatio-temporal databases store information about phenomena in a particular place and time collected according to space and time. Therefore, this research work on Spatio-temporal analysis of time series rainfall data in Kuala Krai Kelantan aims to characterise and determine the behaviour and pattern of the data.

### **2.6.3 Trend Analysis and Mann Kendall**

The trend is the general movement of the series over a long period. It shows the relationship between two variables and how fast it changes to determine rainfall trends. Then, the trends are derived and evaluated using Mann – Kendall (MK) test. It is imperative to look at the long-term trends and changes in rainfall for sustainable water resources management. Researchers can learn a lot about the spatial and temporal variation of water resources and how to manage them by looking at how rainfall and temperature change over time.

Mann Kendall is a nonparametric statistical test that is often used to look at trends in climate and rainfall. This test is acceptable because it is not a parametric test, so the data will not spread out normally for it to work. The Mann-Kendall statistical test is used to figure out if a set of data values is getting to increase over time or decreasing over time, and if either change is statistically significant.

#### **2.6.4 Interpolation data and Arithmetic Average**

The arithmetic average (AA) method is a simpler approach to fill the missing data of meteorological and hydrological data. Interpolation data could be done by using the data at the neighbouring station and the mean on the same day and month but at different years of the selected neighbouring station. According to Norliyana and Zawiah (2017), the missing values of rainfall and water level can be predicted using temporal interpolation, which takes the mean of corresponding months to fill in the blanks. If data are still missing and information from neighbouring stations cannot be used due to data scarcity, the mean on the same day and month but in a different year estimates the missing values for that date.

## CHAPTER 3


### MATERIALS AND METHODS

#### 3.1 Introduction





This part discusses materials and methodologies that were used to complete the present study. Most of the data used in the study about flood risk analysis are secondary data from authoritative organizations such as the Department of Irrigation and Drainage (DID) and spatial datasets from satellite images. Therefore, this study used both primary and secondary data from statistical and spatial analysis to make sure that the results are reliable and can be trusted.


#### 3.2 Materials

**Table 3.1** Materials and its function

<b>Materials</b>	<b>Function</b>
1) Geological hammer 	Used to break the outcrop when doing the rock sampling.

*Table 3.1 (Continued)*

<p>2) Global Positioning System (GPS)</p> 	<p>It is used to mark the coordinate when doing the traverse and determine the elevation.</p>
<p>3) Optical microscope</p> 	<p>Used to do the petrography analysis.</p>
<p>4) Brunton compass</p> 	<p>Used to take the direction (azimuth) and to measure the strike and dip.</p>
<p>5) Microsoft Excel (XLSTAT)</p> 	<p>Used to extract the rainfall data and analyse the Mann-Kendall test.</p>

<p>6) ArcGIS software</p> 	<p>To process and analyse spatial data. To process the rainfall distribution data and base map.</p>
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### 3.3 Methods

Methods are important because it shows how researchers design a study systematically to ensure valid and reliable results that address the goals and objectives of the research.

#### 3.3.1 Preliminary Studies

Preliminary studies for this case are more focused on desk study. In general, a desk study is likely to be less time-consuming and less expensive than a physical investigation. Desk study can provide a basic understanding of research and help plan the details, scope, and methods for future investigations. For this research, the desk study started by reading basic literature such as books, and journal articles related to the research. Next, identify the rainfall and water level stations in Kuala Krai. The information about the stations can be accessed online. Then, overlay the stations with Kuala Krai base map by plotting the coordinates. In addition, general geology in Kuala Krai is done by reviewing journals and previous articles. In addition, the related data from related organizations and websites were explored.

### **3.3.2 Field studies**

Field studies for this research were done by doing the geological mapping at Kampung Kuala Geris, Dabong, Kuala Krai. Observing, measuring, and sampling is essential aspects that should be considered when conducting geological mapping. Geological mapping involved all the information regarding geomorphology, lithology, structural geology, and stratigraphy of the study area. Geomorphology aspect including the landscape and the process that formed the landform. In structural joints, fracture, fault will be observed, and their orientation will be measured. In lithostratigraphy, the observation of the rock unit in term of colour, structure and grain size will be done. For further identification of the rock name, petrography analysis of the rock sample needed. During the field studies, every outcrop and important geological information are sketched and taken photograph with appropriate scale. All the samples are labeled and put in the sample bags.

### **3.3.3 Laboratory analysis**

Laboratory analysis was conducted by looking the thin section of the rock samples under an optical microscope. The minerals, fragments, and their coverage percentage in the rock can be identified from the petrographic analysis. It is important to work on petrography analysis to see the features of the rock, such as mineral composition, texture, grain size, and signs of formation or deformation.

### **3.3.4 Data Collection**

In this study, both primary and secondary data were included in the data collection. Primary data was obtained by performing the geological mapping. The information taken when doing the mapping is geographical information such as

topography, land use, river morphology, and demographics of the study area. Elevation and ground clearance value data were collected and marked using GPS during mapping. This also includes the parameters to conduct the flood risk area.

Secondary data was obtained from authoritative organisations such as the Department of Irrigation and Drainage (DID). This study required rainfall distribution and water level data to be processed in producing a map. This study analyses data from 6 rainfall stations and 2 water level stations in Kuala Krai, Kelantan. The data was collected from 2009-2020. The United States Geological Survey (USGS) website was used to get satellite images and land use data. DEM was also used to look into the influence of geology on the geomorphological features of the land. All elevation data and subsequent derivations like slope and aspect were calculated from the created DEM.

### **3.3.5 Data Analysis and interpretation**

#### **a) Geological mapping**

The data collected during the field study was recorded and processed using Geological Information System (ArcGIS) software to produce a map. The maps that can be produced during mapping are geological maps, geomorphological maps, and drainage pattern maps. Geological maps help solve problems related to hazards, the environment, and mineral and earth resources. The DEM was processed using elevation data. The topographic map of the study was analyzed during the field work. DEM was processed using the elevation data. The topographic map of the study was analysed during the fieldwork.

### b) Mann-Kendall test

The rainfall series will be processed using the Mann-Kendell test. The Mann-Kendall test statistic is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(x_j - x_i), \text{sign}(x_j - x_i) = \begin{cases} +1 & (x_j - x_i) > 0 \\ 0 & (x_j - x_i) = 0 \\ -1 & (x_j - x_i) < 0 \end{cases} \quad (3.1)$$

A positive S value shows that the trend is going up, while a negative value shows that the trend is going down. The difference in the amount of rain is considered to get the Z value. Variance (S) is worked out by:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)}{18} \quad (3.2)$$

A tied group (m) is a group of rainfall data with the same value when the number of samples is more than 10. The equation below shows how to figure out the normal Z-test statistic:

$$Z = \frac{S \pm 1}{\text{Var}(S)^{1/2}} \quad (3.3)$$

If  $S > 0$ , this equation uses  $S-1$ , if  $S < 1$ , it uses  $S+1$ ; and if  $S=0$ , it uses 0. A positive value for  $Z$  shows that the trend is going up.

**c) Interpolation method – Arithmetic Average Method**

The arithmetic average (AA) method is the simplest method typically used to fill in the missing meteorological and hydrological data. Rainfall and water level data missing from a particular station can be recovered by taking an average over a group of stations geographically closed on the same date as the station of interest but from different years. In this case, the missing value is estimated as:

$$p_t = \frac{1}{n} \sum_{i=1}^n x_i \quad (3.4)$$

where  $p_t$  is the estimated value of the missing data.  $T$  is the target station/date,  $x_i$  is the observed data at the  $i$ th nearby station or the date of the same date with different years, and  $n$  is the number of nearby stations or years.

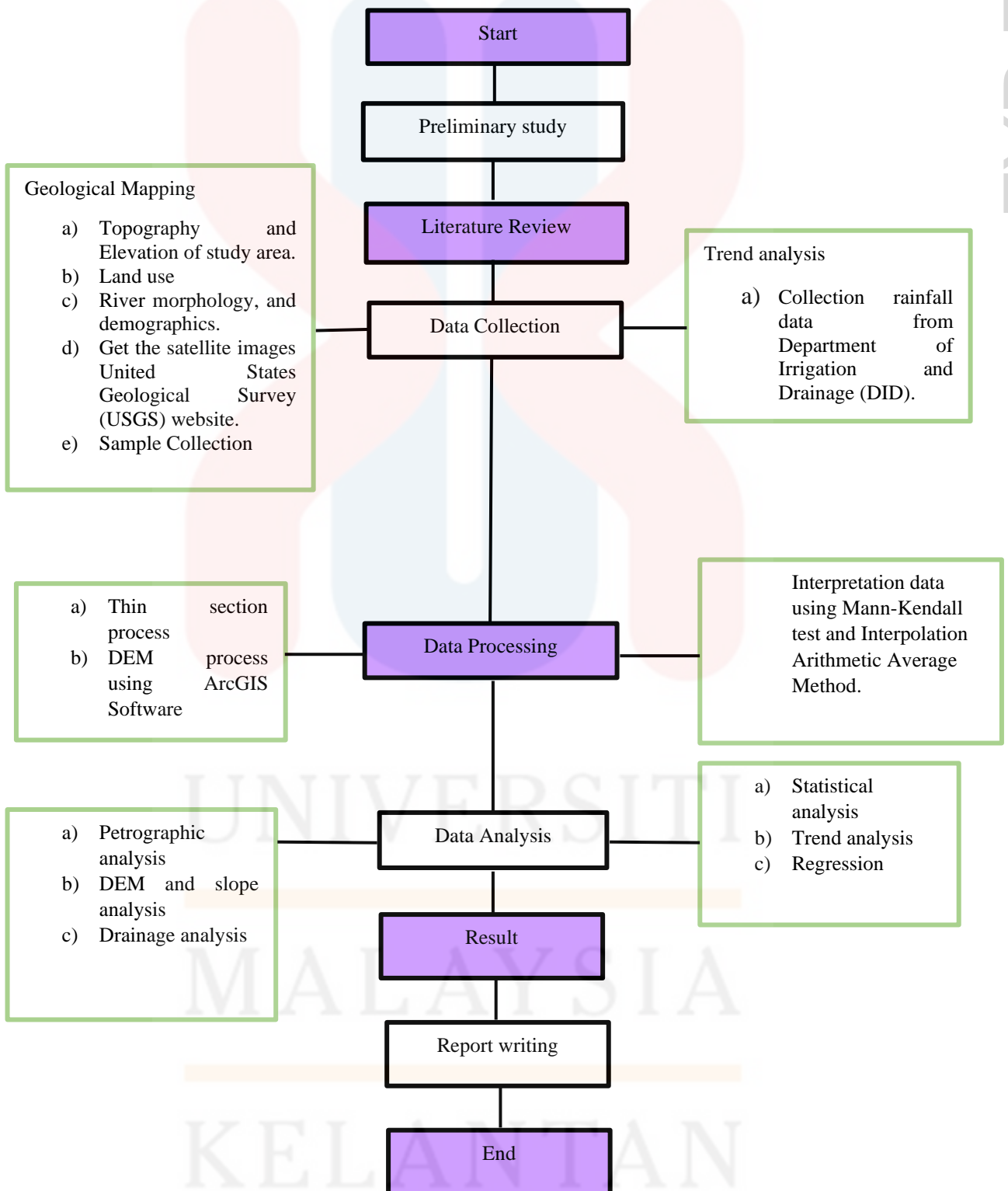
**d) DEM and Slope Analysis**

The DEM data was analysed to identify the morphology such as the land surface that is used to represent the hydrological process. DEM also can create a slope analysis. The overall procedures were evaluated using a GIS environment. The slope of the land in the river flow area plays an important role in determining the water velocity. Moreover, the steeper the slope, the higher the run and consequently, the higher the peak discharge.

### e) **Drainage Analysis**

Flow accumulation is one of the methods of determining the drainage network and area. All the depressions in the DEM will be conducted using a spatial analysis tool to ensure that the data is perfect. This method was developed to identify water accumulation points using the flow accumulation tool and a flow direction raster as input. For areas with concentrate flow, output cells with a high accumulation will be identified and used to create stream channels or networks.

### 3.3.6 Research Flow Chart



## CHAPTER 4

### GENERAL GEOLOGY OF KAMPUNG KUALA GERIS, DABONG, KELANTAN

#### 4.1 Introduction

This chapter discusses the general geology in Kampung Kuala Geris, Dabong, Kelantan. Study general geology including determining the geomorphology, stratigraphy, geological structure, and historical geology. All data can be taken while in the field as well as data analysed in the lab. In addition, all findings during mapping were explained more detail for geological understanding. Besides, all the geological data and maps will be combined to generate a geological map of Kampung Kuala Geris, Dabong, Kelantan.

##### 4.1.1 Accessibility

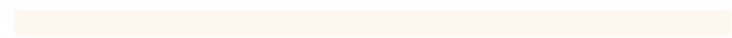
Kampung Kuala Geris is a small town in the district of Kuala Krai. This town can be reached in several ways. Based on **Figure 4.1**, the study area can be accessed through Road 66 from Jeli to Dabong and cross the bridge. Besides, from Kuala Krai-Gua Musang Highway can use Jalan Sungai Sam to reach Dabong. Kuala Geris is about 40 km away, and it takes about an hour and a half to get there. Kampung Kuala Geris can also be reached by boat, which takes about an hour and a half from 'Tangga Krai'. Tangga Krai was located at Sungai Kelantan near a Kuala Krai bridge.

Additionally, the study area can be accessed by train. The train line starts from Pasir Mas Station, Tanah Merah station, Kuala Krai station and ends at Dabong. Then, can drive from Dabong to Kampung Kuala Geris. There were also small stations

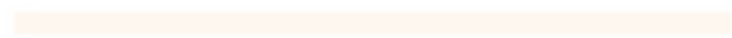
between the trips. Tanah Merah to Dabong takes 2 hours. The western part of the study area is covered by thick forests and a hilly area. It is impossible to access that part as there is an unavailable road to reach there.



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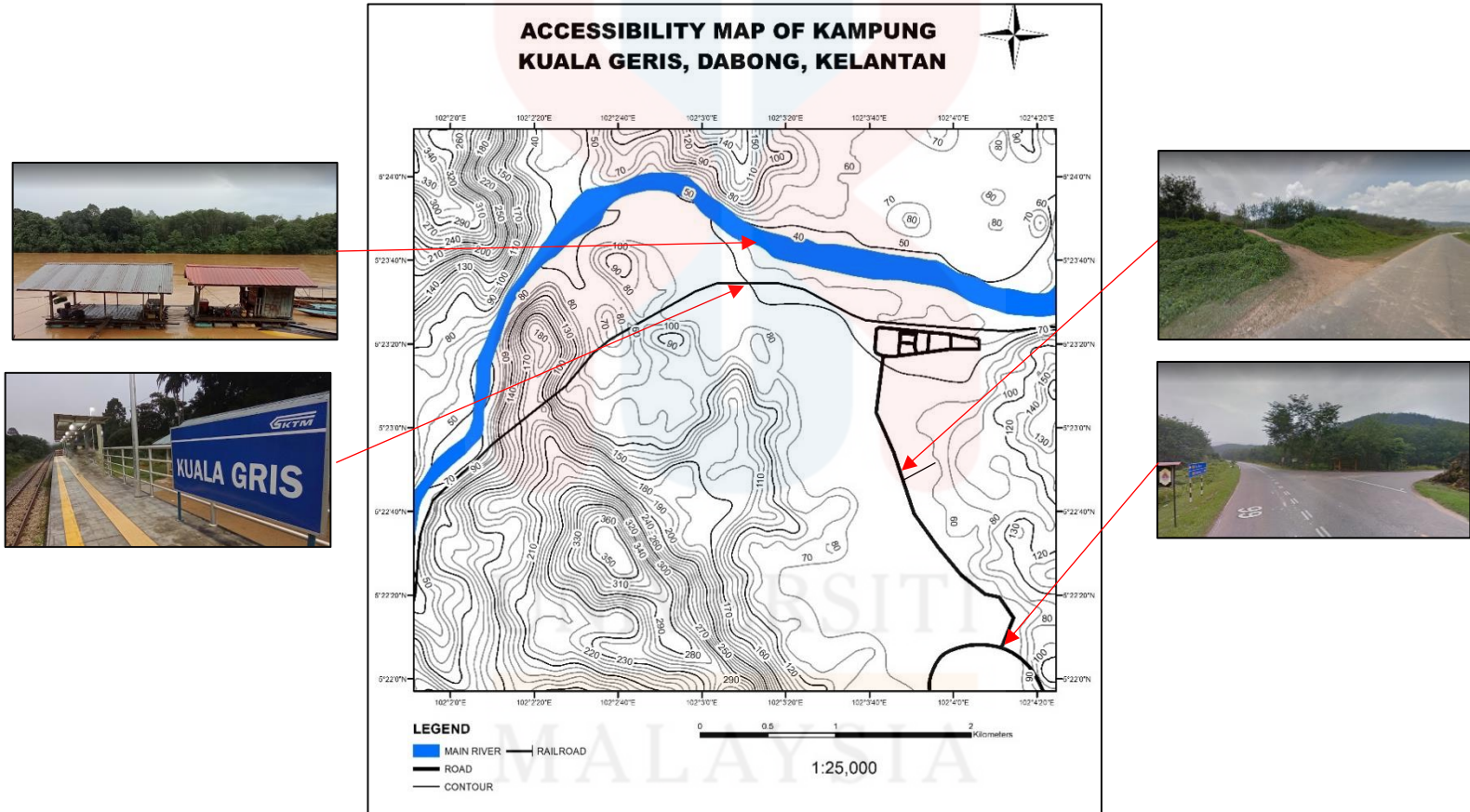


Figure 4.1: Accessibility map of Kampung Kuala Geris, Dabong Kelantan

#### 4.1.2 Settlement

Kampung Kuala Geris is a rural area located near Sungai Galas. From the observation in the study area, most of the people in this area live on their land and do agriculture. Most of them are rubber tappers and fishermen. Others are involved in small businesses such as food stalls and grocery stores.

The village is complete with basic facilities such as a rural clinic, mosque, food stalls, and schools. **Figure 4.2** shows Sekolah Kebangsaan Kuala Geris located at the center of the village. Besides, **Figure 4.3** shows the Masjid Mukim Kuala Geris located in front of the school. In addition, there is also a small jetty and boats for fishermen to go fishing. The residents there also have a boat rental service to cross the river.



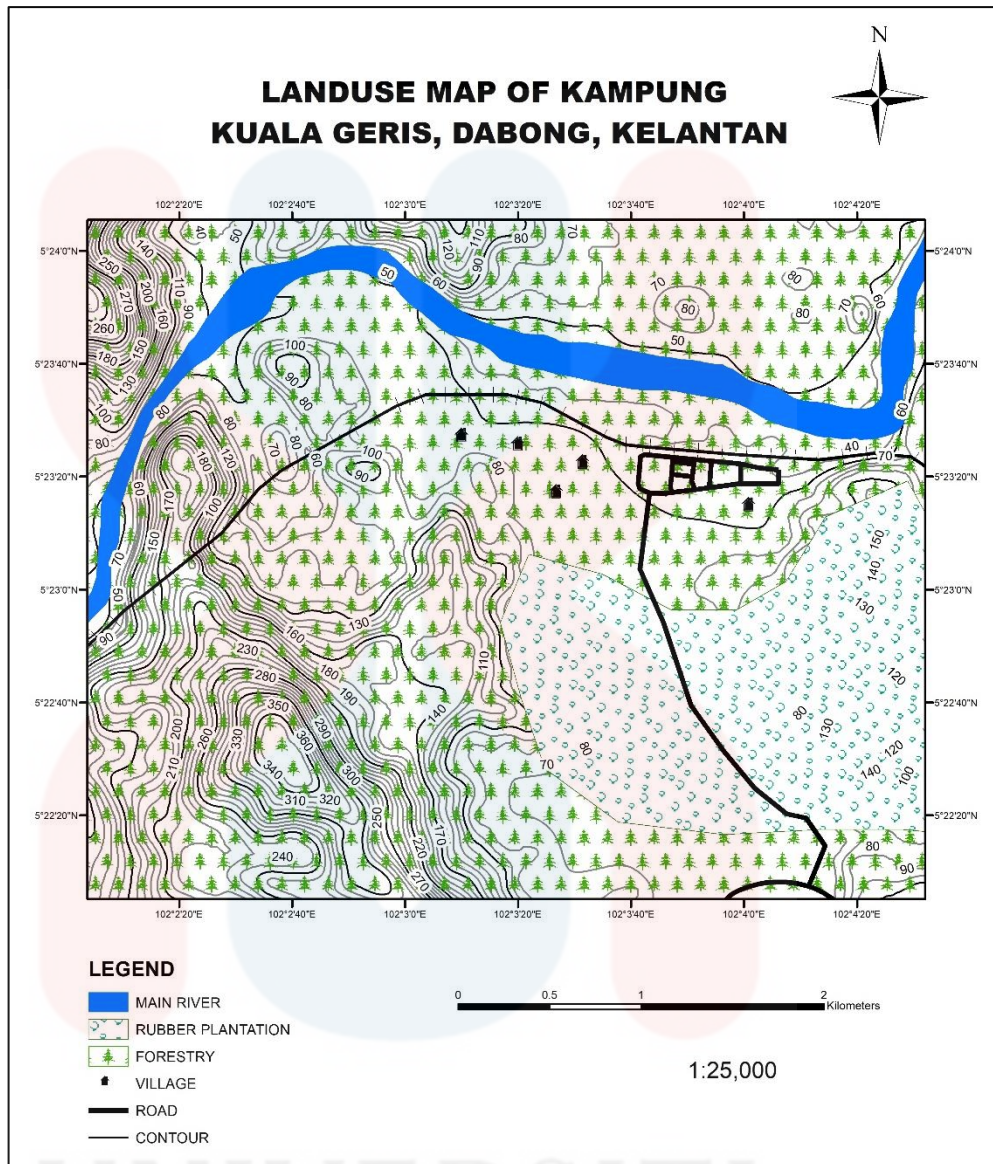
**Figure 4.2:** Sekolah Kebangsaan Kuala Geris



**Figure 4.3:** Masjid Mukim Kuala Geris

### 4.1.3 Forestry

The study area consisted primarily of forested areas and rubber plantations. **(Figure 4.4)**. Kampung Kuala Geris is a rural area with a small population. The land is mostly made up of hills, and it can be seen in the background. The highest elevation of this study area was 383m and covered by natural forest. Rubber plantations are mainly planted in flat and low-hill areas. The villagers mostly work as rubber tappers. The main activities among the villagers in the study area are the vegetation which is also their main source of income.



**Figure 4.4:** Landuse map of the study area consisted of rubber plantation, forestry and settlement.

#### 4.1.4 Traverse and Observation

Geological mapping is a systematic investigation to observe the structure and geology of the study area. Surveys are performed to prepare a geological map. Method for geological mapping including traverses, walk-over surveys, and studying the exposures of outcrops and landforms.

A topography map is essential before starting the traverse. The purpose of the traverse is to see the geomorphology and landforms in the study area. In addition, to make a preliminary interpretation of the type of rock. Contour lines that are close together show the elevation is changing in a short distance. So, the terrain is quite steep as the elevation changes more slowly. Widely separated contour lines indicate a gentle slope.

**Figure 4.5** represents a traverse of the study area. The route covers river areas, rubber plantation areas, and hill areas. The tracks and waypoints along the traverse were marked in the GPS. Based on the map, each outcrop checkpoint is marked with a yellow dot. However, in the west part, the area is filled with thick forests and high elevations. Therefore, there is no paved road to enter the area.

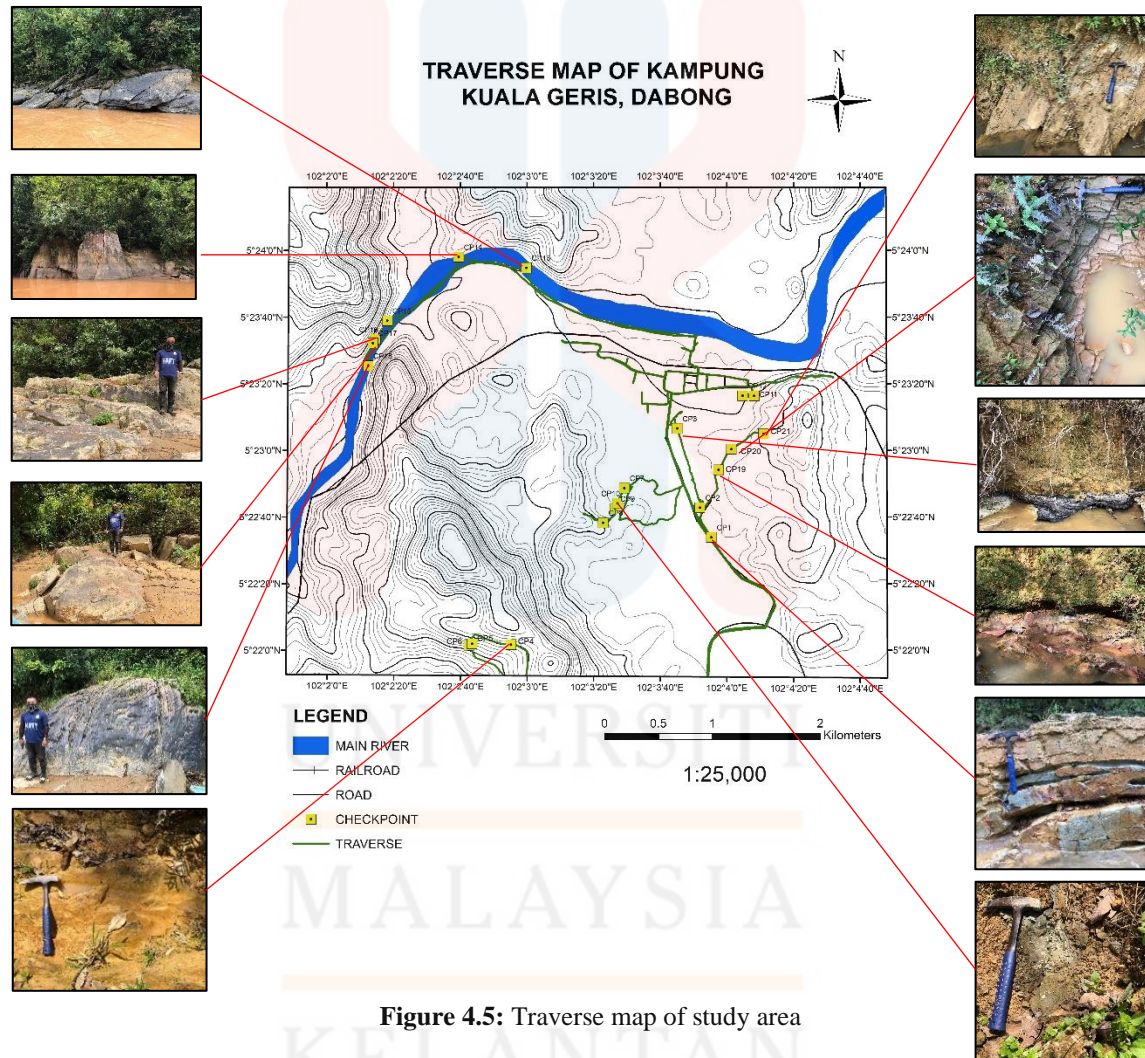


Figure 4.5: Traverse map of study area

## 4.2 Geomorphology

Geomorphology is the study of landforms and landscapes including hills, valleys, floodplains, and fluvial. Geomorphology is one of the geological aspects. In this study, geomorphology focused on geomorphologic categorisation, weathering process, and drainage pattern of the study area. Geomorphology is about the history related to the earth's surface that forms from a geological process like deposition, erosion, and weathering. The geomorphological observation could help to determine the type of rock in this study area.

### 4.2.1 Geomorphological classification

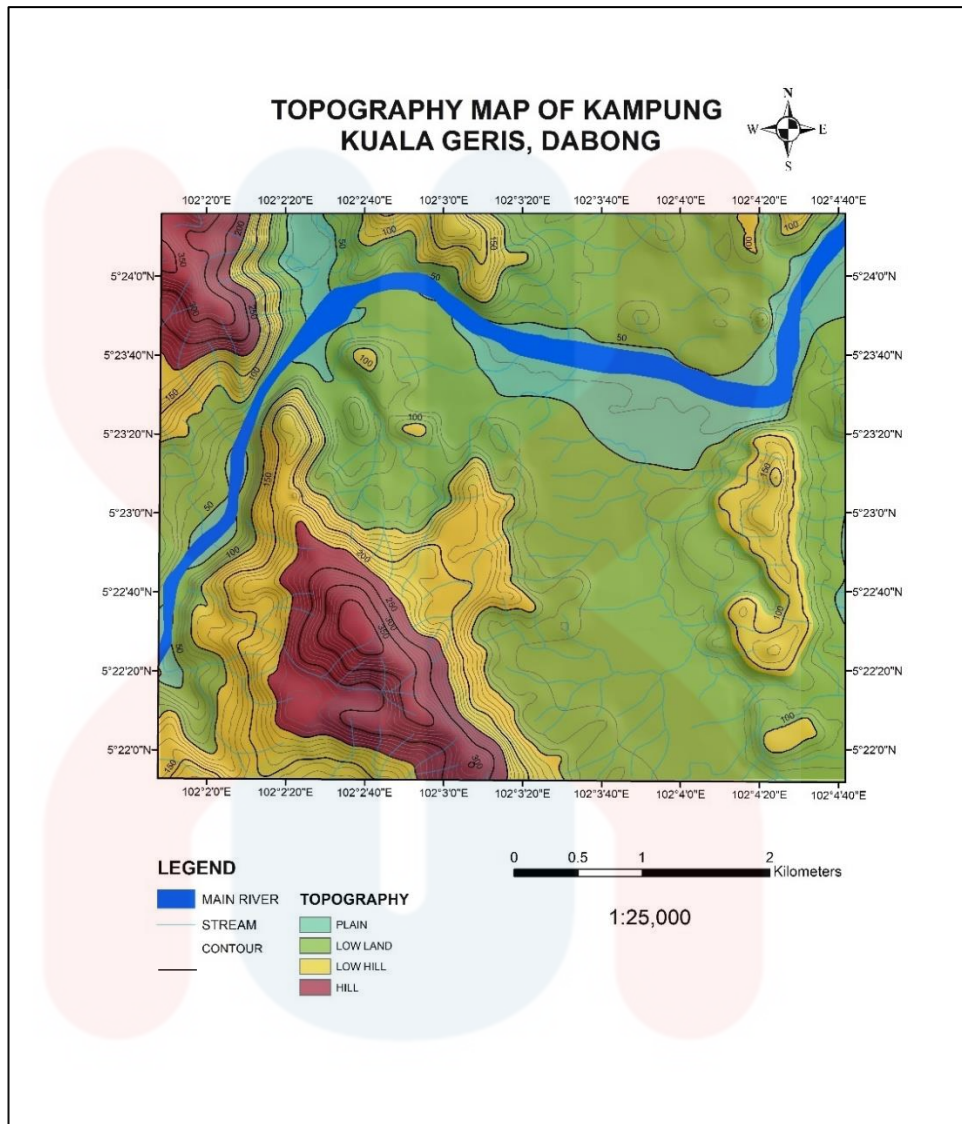
Geomorphology explains more about the processes that cause and alter landforms. Geomorphological processes are divided into two: exogenic process and endogenic process. The endogenic process works within the Earth to change the Earth's surface. An example of an endogenic process is volcanic and tectonic activity. Exogenic process work at Earth's surface. Example of the exogenic process is weathering, erosion, and the aeolian process.

The geomorphology classification can be determined from the contour line pattern and the elevation of the area. From **Table 4.1**, there are four geomorphological units in the study area. It is divided into a very gentle slope, gentle slope, moderate slope, and strong slope.

**Table 4.1:** Geomorphological unit classification

<b>Class</b>	<b>Geomorphological Unit</b>	<b>Landform</b>	<b>Elevation (Above sea level)</b>
1	Very gentle slope	Plain	25-50
2	Gentle slope	Low land	50-100
3	Moderate slope	Low hill	100-200
4	Strong slope	Hill	200-500

From **Figure 4.6**, the study area was dominated by low land and then low hill topographic. The first geomorphological unit is a very gentle slope with a plain landform. The elevation is between 25-50m, and it's covered the area near the river. Second is a low land landform with a gentle slope and an elevation of about 50-100m. The third class is low hill landforms with moderate slopes and the last class is hill landforms with strong slopes. **Figure 4.7** shows the hill in the study area. The formation of hill landforms resulted from the movement of tectonic plates, which caused faulting processes. Erosion also contributed to the formation of the hill, which occurs when particles of rock, soil, and silt are washed away and deposited elsewhere.



**Figure 4.6:** Topography map of Kampung Kuala Geris, Dabong



**Figure 4.7:** Hill topography in the study area

### 4.2.2 Weathering

Weathering is an exogenic process. Weathering can be described as the disintegration of rock. The rock with low resistance can easily be weathered which is the process that comes from the erosion and transportation of the losses particle from the rock after being weathered. The properties of the parent rock will affect the rate of the weathering process. It is because the structure and mineralogy of the rock affect its susceptibility to weathering. Next, rainfall and temperature can increase the rate of chemical weathering.

In Kuala Geris area, due to the area that was located near the Galas River and often flooded, the rock body is highly exposed and had a high rate of weathering. From the observation, the rock is mainly affected by physical and biological weathering. The main agent for physical weathering is water, ice, and temperature changes. **Table 4.2** represent the weathering grade and its description for each rock.

**Table 4.2:** Weathering profile of the rock mass in the study area




Rock	Grade symbol	Rock Mass Weathering Grade	Description
a) Slate 	IV	Highly weathered	The top colour is brown and followed by grey colour at the bottom. Slate has a very fine grain. It has a weak strength and can break it by hand. When hit with a geological hammer, it makes a dull sound. More than half of the rock has broken down into the ground.

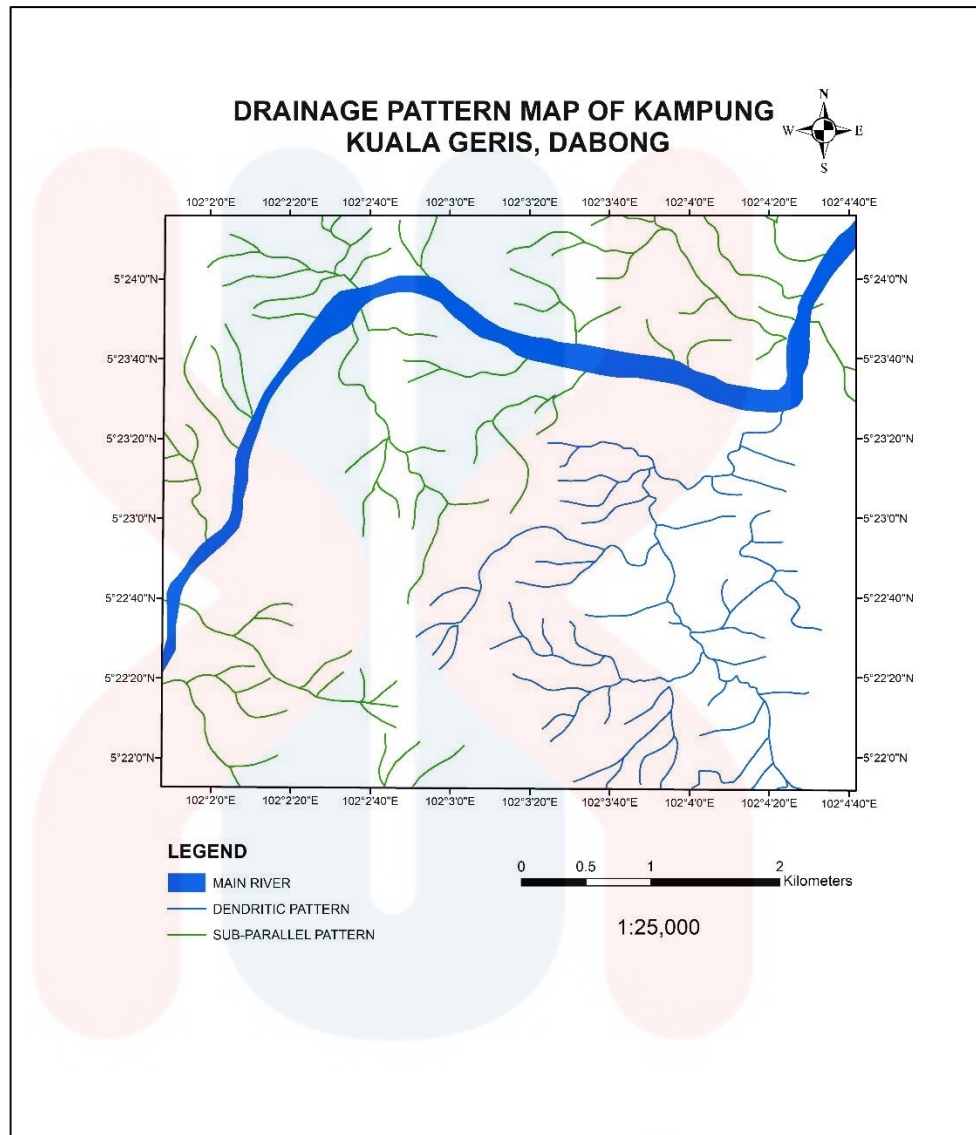
Table 4.2 (Continued)

<p>b) Phyllite</p> 	<p>III</p>	<p>Moderately weathered</p>	<p>The colour of the rock is light grey and it has a fine grain. It has a moderate strength which cannot usually be broken by hand but is easily broken by a geological hammer. Less than half of the rock material is disintegrated into the soil.</p>
<p>c) Quartzite</p> 	<p>II</p>	<p>Slightly weathered</p>	<p>The colour of the rock is black and has a medium-grain size. The strength is still strong and not broken easily by a geological hammer. It makes a ringing sound when struck by a geological hammer.</p>

### 4.2.3 Drainage Pattern

The drainage pattern is one of the geomorphology features. The drainage pattern is the pattern formed by the streams, rivers, and lakes in a specific drainage basin. The pattern made by stream erosion can determine the type of rock and geological structure in the study area. Topography and slope affect the drainage pattern. Based on **Figure 4.8**, the study area comprises two types of drainage patterns: dendritic and sub-parallel.

Dendritic patterns form in places where the rock or loose material under the stream does not have a specific shape or structure and can be eroded in any direction. Generally, the characteristic of a dendritic pattern is soft rock, and massive crystalline and flat-lying beds. Dendritic pattern form when the river channel follows the slope of the land. Example of rock that may occur at the dendritic pattern probably sedimentary rock, granite, gneiss, and volcanic rock. Next, rivers often flow in a sub-parallel pattern due to the presence of intermediate slopes or control by sub-parallel landforms. In the study area, the rock occurred along the dendritic pattern is phyllite, slate and quartzite.



**Figure 4.8:** Drainage map of Kampung Kuala Geris.

### 4.3 Lithostratigraphy

Lithostratigraphy is a subdivision of rock successions into units based on lithology or rock type. This part is divided into subfields such as lithostratigraphy, biostratigraphy, sequence of rock, and chronostratigraphic. The lithology of the study area is composed of metamorphic rock. These types of rock were classified into four main lithology units which were the phyllite unit, slate unit, quartzite unit, and alluvium unit. All the units were named based on their dominance in lithology. The

most common rock in the study area was phyllite. **Figure 4.9** shows the geological map of Kampung Kuala Geris, Dabong, Kelantan.

#### 4.3.1 Stratigraphic Position

**Table 4.3:** Stratigraphy column of the study area.

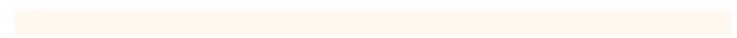
Formation	Era	Period	Stratigraphy	Description
	Cenozoic	Quaternary	Alluvium	Alluvium contains clay, silt, sand, and gravel. Non-consolidated into solid rock
Stong Migmatic complex	Mesozoic	Triassic	Quartzite	Non foliated metamorphic rock composed mostly quartz. Dark grey colour with medium-grained size.
Gua Musang Formation	Paleozoic	Permian	Phyllite	Phyllite is greenish colour with slaty minerals and show a medium grade of foliation textures.
Gua Musang Formation	Paleozoic	Permian	Slate	Slate is a very fine grain with medium grade of foliation textures. Mainly composed of silica clay.

The study area is a part of Gua Musang formation consist of phyllite and slate, and quartzite is from the Stong Migmatic Complex formation. From the stratigraphy column in **Table 4.3**, the oldest unit is the slate unit and followed by phyllite and quartzite. The alluvium is a relatively young geological formation. Most of it was put there during the most recent time in the Cenozoic era, which is the time we are in now.

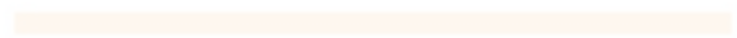
Also, this stuff is loose and hasn't been around long enough to have hardened into stone. Instead, it sits on top of the bedrock, covering the solid rock below.



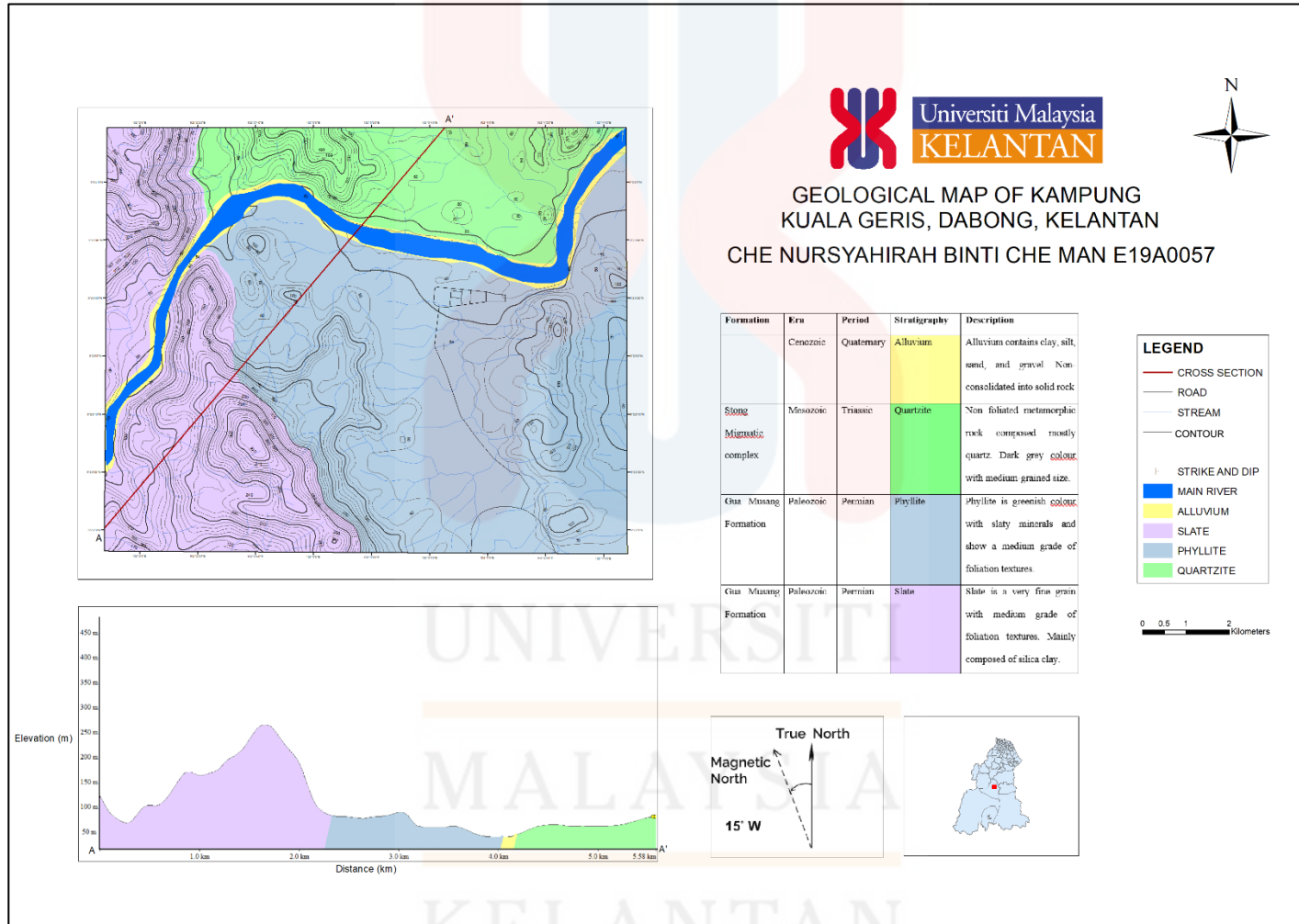
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**Figure 4.9:** Geological map of Kampung Kuala Geris, Dabong, Kelantan

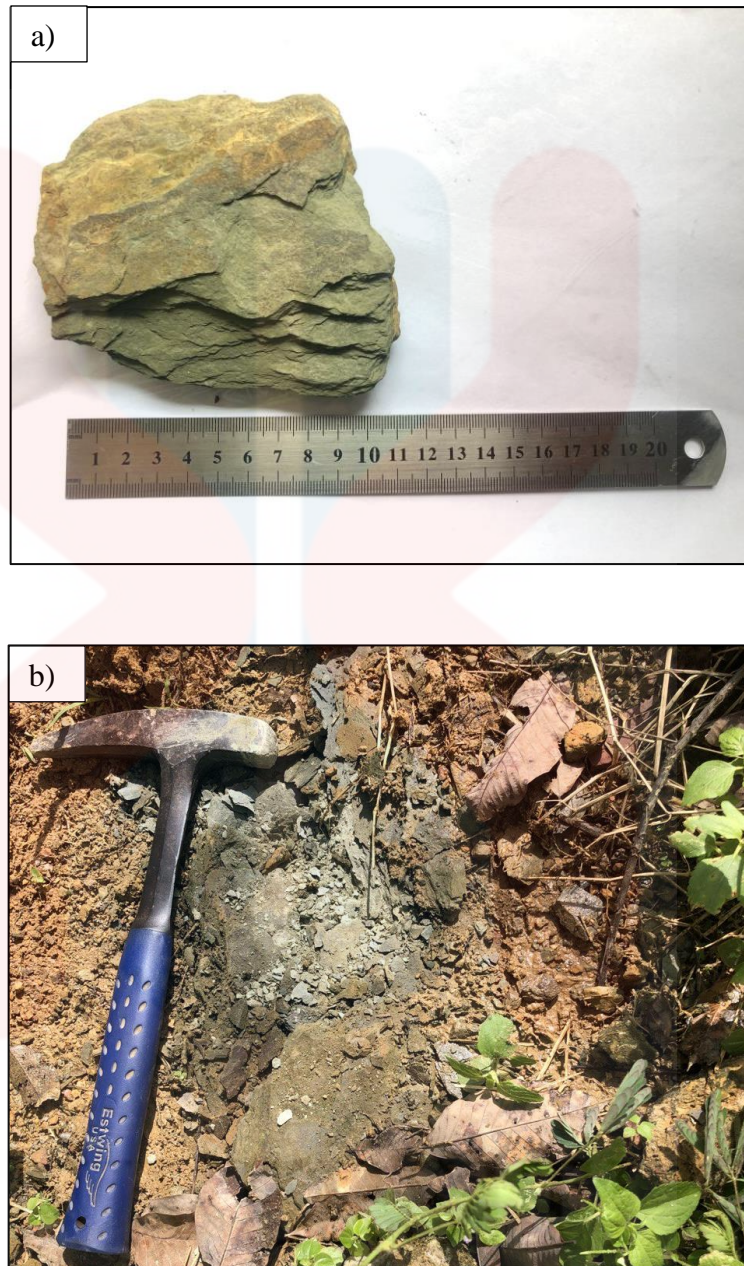
### 4.3.2 Unit Explanation

#### a) Phyllite unit

Phyllite has covered almost 60% of the study area. The outcrops were found near the river, at the stream, at the plain area, and the hill area. Most of the outcrop was exposed to moderate to high weathering. It is because the area is constantly hit by the flood. Water and rainfall are the main agent for weathering. The colour of this rock varies between black and grey to greenish grey. Phyllite has a fine grain and has a smooth surface when cut in a half. This show that the outcrop had undergone a low degree of regional metamorphism.

Regional metamorphism occurs over large areas, such as two continental masses colliding to form mountain ranges. Compressive stress due to the collision folds the rocks in between and thickens the crust, pushing the rock deeper and subjecting it to higher temperature and pressure. The increased pressure results in partial melting and recrystallization of minerals in metamorphic rocks, such as phyllite.

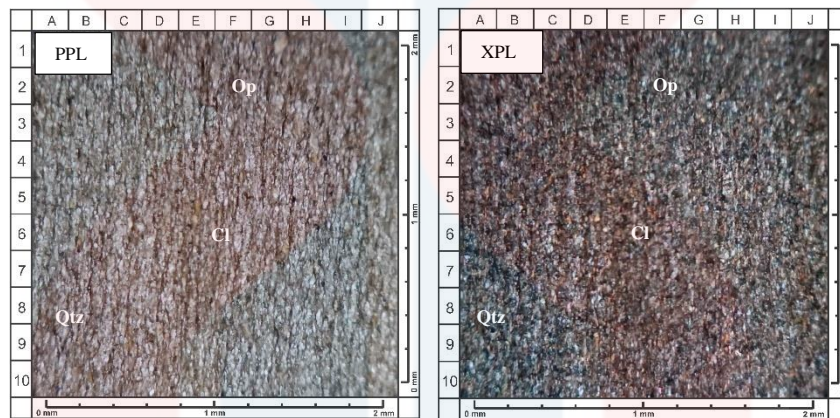
An increasing grade in metamorphism is observed when slate, an initially fine-grained metamorphic rock, turns into phyllite, schist, and eventually gneiss. Although phyllite and slate have the same mineral composition, minerals in phyllite are slightly larger than that of slate and have already been subjected to higher temperatures and pressure. **Figure 4.10** shows an outcrop and hand specimen of phyllite. The outcrop was found in the rubber plantation area with an elevation of 35m. The outcrop was found at checkpoint 2 with coordinates N05°22'48.6", and E102°03'29.3".



**Figure 4.10** a) Hand specimen of greenish grey phyllite b) Outcrop of greenish grey phyllite on the ground.

**Figure 4.11** shows the petrographic image of phyllite. Phyllite has an aphanitic texture. The petrographic analysis was carried out at 10x magnification. From the observation, the grain size ranges from  $<1/256 - 1/32$  mm and has good sorting. Phyllite contains quartz, mica, chlorite, and an opaque mineral. From the petrography analysis, phyllite includes almost half the amount of quartz mineral in its composition.

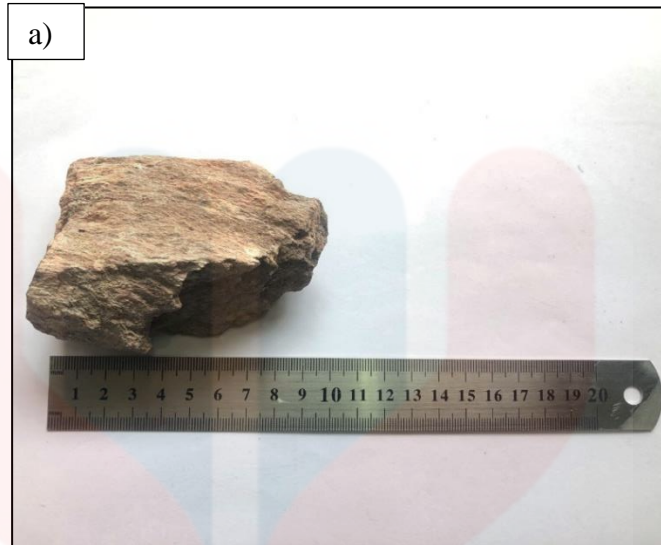
Quartz and chloride are found in large quantities in phyllite. In PPL, quartz is colourless with low relief. In XPL, the interference colour is in order 1 which was grey and white, and there is no twinning. Mica is colourless in PPL and dark grey in XPL. Opaque minerals in PPL have a euhedral-anhedral crystal form. At XPL, the black interference colour of the 1st order. Chloride has a weak pleochroism in both PPL and XPL.



**Figure 4.11** Petrographic analysis of green phyllite in PPL and XPL. Quartz (Qtz), Opaque minerals (Op), Chloride (Cl)

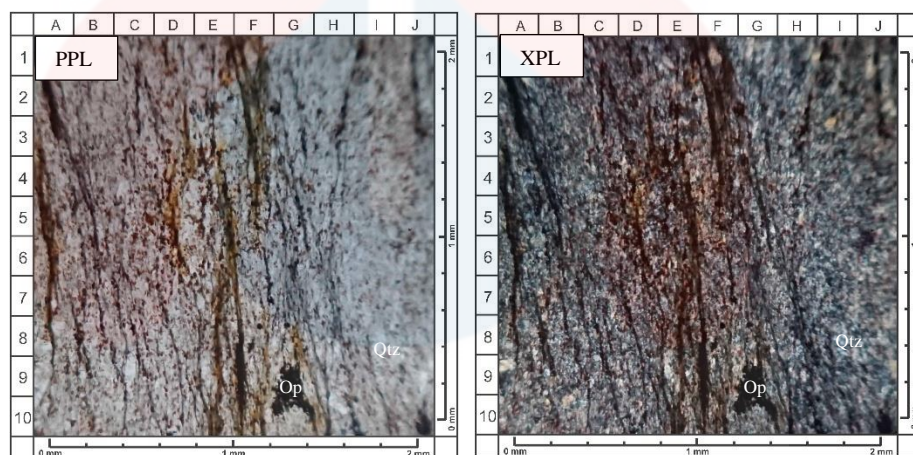
#### b) Slate unit

Next, slate is a very fine grained, foliated metamorphic rock with aphanitic texture. Because of its texture, the crystals not visible to the naked eye. Slate is created by the alteration of shale mudstone by low grade metamorphism. Slate is composed of clay minerals or micas, depending upon the degree of metamorphism to which it has been subjected. The colour of the slate was brown to pink colour. The hardness is hard and brittle. The outcrop was found at the riverbank with an elevation of 38m. The coordinate for this outcrop was N05°23'32.2", E102°02'13.8". **Figure 4.12** shows the hand specimen and outcrop of slate rock.



**Figure 4.12** a) Hand specimen of slate b) Slate outcrop for slate at near distance c) Slate outcrop at far distance.

**Figure 4.13** shows the petrographic analysis of the slate sample under 10x magnification. From the observation, the mineral's size ranges from  $<1/256 - 1/16$  mm and has good sorting. From the petrographic analysis, slate contains quartz, silica clay, and opaque minerals. Quartz minerals are colourless in PPL, low, and have an anhedral crystal form. In XPL the interference colour is ordered 1 grey to white. Next, in PPL, silica clay is colourless to brown. In XPL the interference color is dark grey. Besides, for the opaque minerals, the colour is black in PPL. It has low relief and no pleochroism. The shape is euhedral to anhedral crystal form. In XPL, the color is black which is in order 1 and there is no twinning.

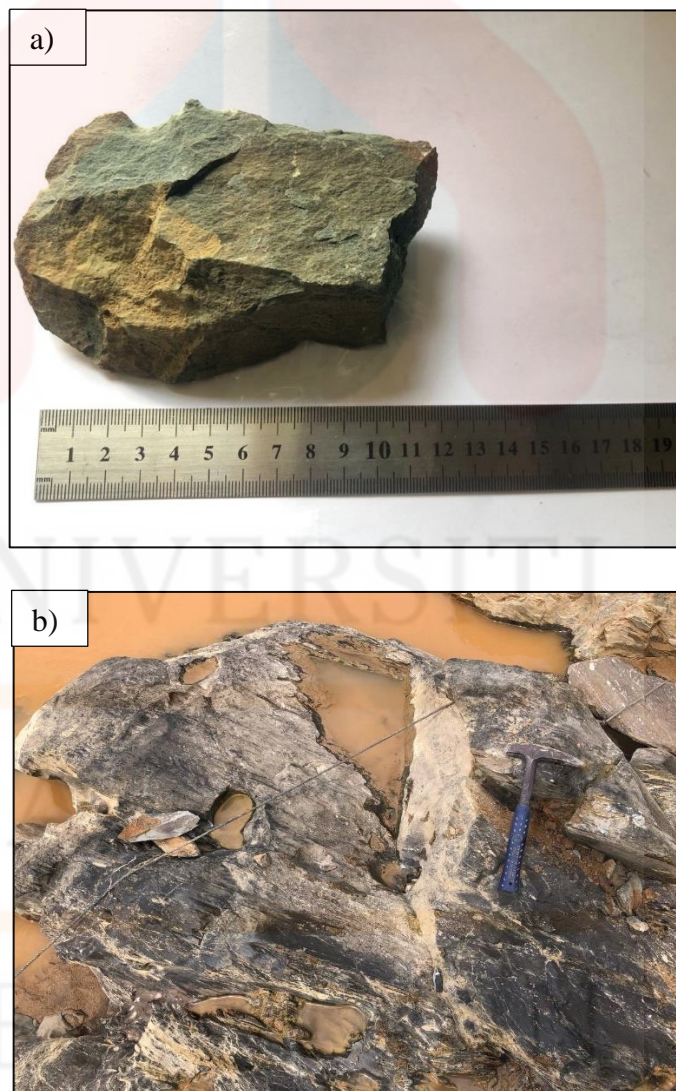


**Figure 4.13:** Petrographic analysis of slate in PPL and XPL. Quartz (Qtz), Opaque minerals (Op).

### c) Quartzite unit

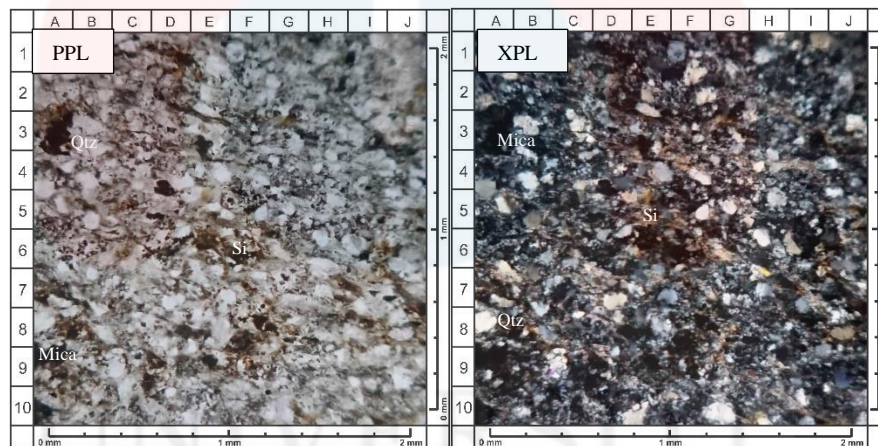
Quartzite is non-foliated metamorphic rock that used to be pure quartz sandstone and was changed into quartzite by heat and pressure. This usually happens in orogenic belts where tectonic plates squeeze together. The original individual quartz grains recrystallize along with the former cementing material to form an interlocking mosaic of quartz crystals. The metamorphism wipes out most of the sandstone's

original texture and sedimentary structures. During recrystallization and metamorphism, small amounts of former cementing materials like iron oxide, silica, carbonate, and clay often move. This makes the quartzite get streaks and lenses. Samples come in card trays that are labelled and come in different sizes. Quartzite has a granular texture, and the hardness is hard. The outcrop was found at the riverbank with an elevation of 33m. The coordinate for this outcrop was N05°23'54.8", E102°02'59.9". **Figure 4.14** shows the hand specimen and outcrop of metaquartzite rock.



**Figure 4.14** a) Hand specimen of metaquartzite b) Outcrop of metaquartzite.

**Figure 4.15** shows the result of quartzite petrography analysis in PPL and XPL. The observation used 10x magnification and revealed a massive structure. Quartzite covering grain size  $<1/256 - 1/8$  mm. It has good sorting. The minerals composition of quartzite predominantly quartz (quartz content in the rock reaches 88-98%) with silica clay, and mica. Quartzite looks similar to its parent rock, but it is much harder than sandstone. Quartz in PPL is colourless, low relief, and has an anhedral crystal form. In XPL the interference colour is grey to white. Silica clay at PPL is colourless to brown. In XPL, the colour is dark grey. Consists of micron-sized silicate material. For mica, the colour in PPL is black, low relief, no pleochroism, and euhedral–anhedral crystal form. In XPL, the colour is black.

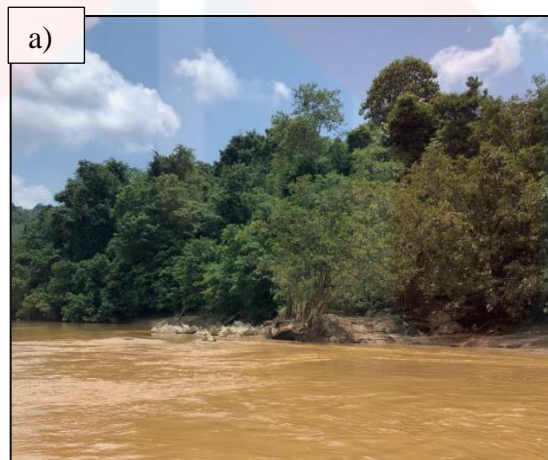


**Figure 4.15** Petrographic analysis of metaquartzite in PPL and XPL.

#### d) Alluvium unit

The alluvium is a deposit of loose clay, sand, or gravel that moves by flowing water, in a stream bed, on a floodplain, river valley, or delta. The alluvium was located alongside the Pergau River and at the riverbank. **Figure 4.16 (a)** shows the sediments deposited at Pergau River and the stream bed. Rivers carry sediment along their paths,

which is usually caused by erosion. Most of these materials are collected in parts of the river where water flows very quickly. A river can deposit alluvium at any point along its course. However, these deposits are typically concentrated in locations where water flow is reduced. Over time, the flow of the water changes and wears down the sediment until it is loose and almost like mud, as depicted in **Figure 4.16 (b)**. Most of this alluvium is found where rivers empty into lakes or where riverbanks are washed away by floods, making floodplains and deltas. From **Figure 4.16 (c)**, there are rubber plantations around the river which show that the land is fertile for agricultural activities.





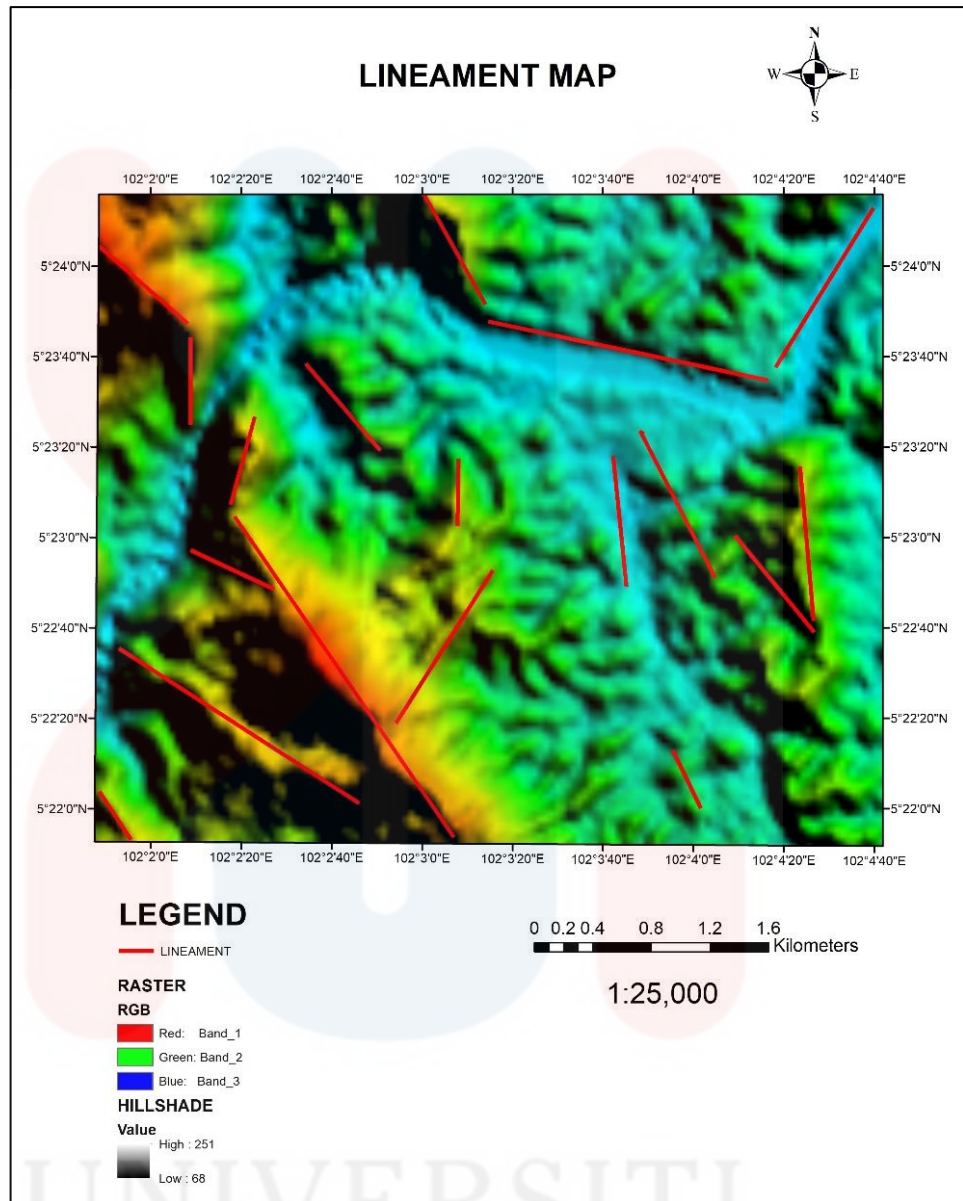
**Figure 4.16** a) Alluvium deposit at Galas River b) Alluvium deposit at riverbank c) alluvium deposit at stream contains sand and gravel.

#### 4.4 Structural Geology

Structural geology is a deformation process and an integral part of tectonics, particularly in deformation history over the year. There are two types of structural geology which are primarily structural and secondary structural. The primary structure is the structures that occur during the process of rock formation, such as bedding, ripple marks, and cross-bedding in sedimentary rocks. Primary structures indicate the local environmental conditions within which rocks originate. Secondary structure is the structures that develop in rocks after their formation. In sedimentary and igneous rocks, the structure occurred after lithification, and in metamorphic rocks during or after formation. Examples of secondary structures are joints, fractures, cleavage, faults, folds, and foliation. The structure observed in the study area was the bedding plane and joints.

#### 4.4.1 Lineament analysis

Lineament is the geological feature that represents a geological structure of discontinuity in the rock mass. Several structural geologies that can interpret from the lineament map is a fault, joint, and bedding. Lineament analysis is a primary step before starting the mapping. **Figures 4.17** and **Figure 4.18** indicate the lineament map of the study area using a terrain map and topography map. Lineament can interpret by using a terrain and topography map which will appear as a structure of hills, valleys, ridges, and rivers. There are two types of lineaments which are positive and negative. Positive lineament can be identified from ridges or hills meanwhile negative lineament can be identified from valleys or rivers. **Figure 4.19** shows the lineament analysis with the major force coming from the North-East part.



**Figure 4.17** Lineament map from terrain map (RGB analysis).

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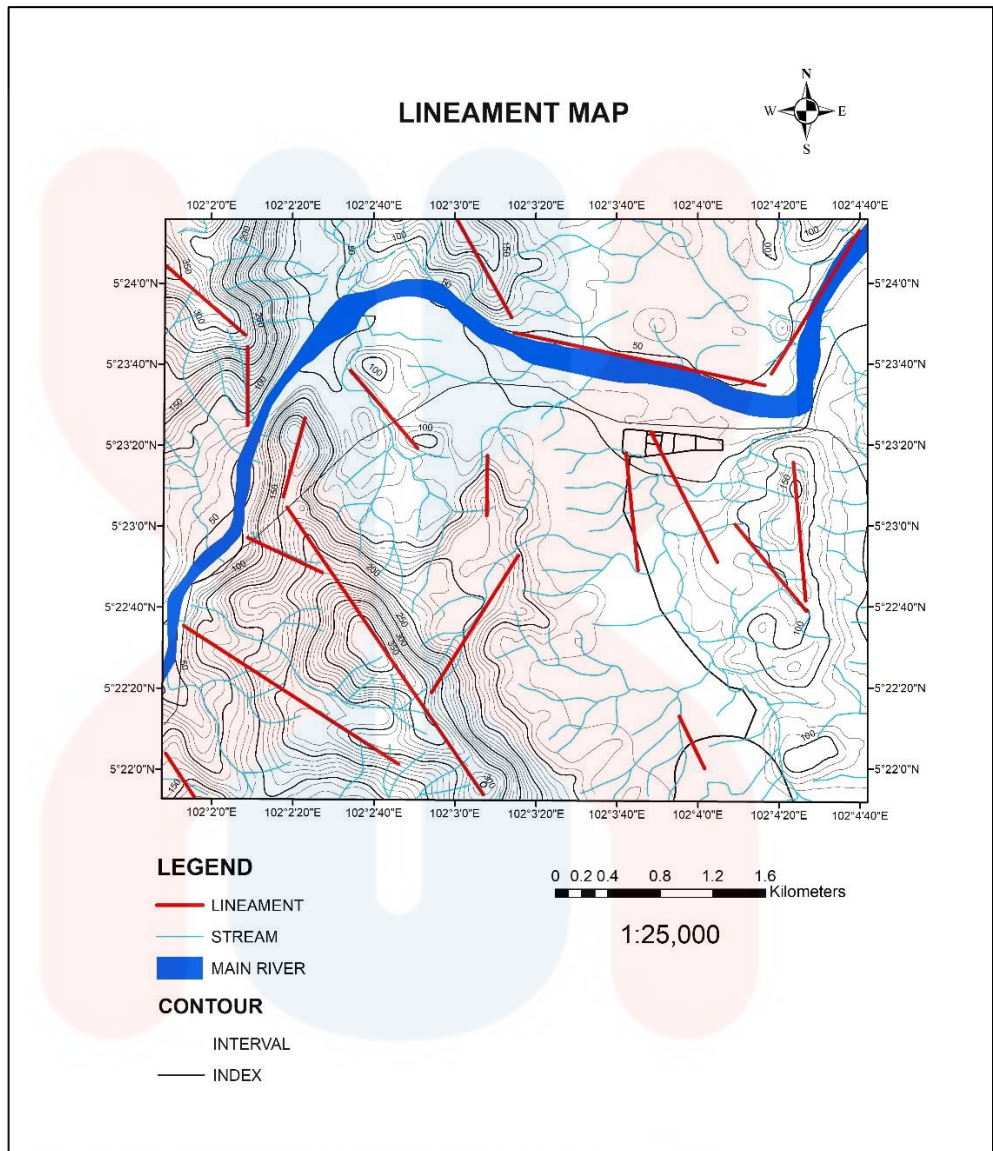


Figure 4.18: Lineament map from topography analysis.

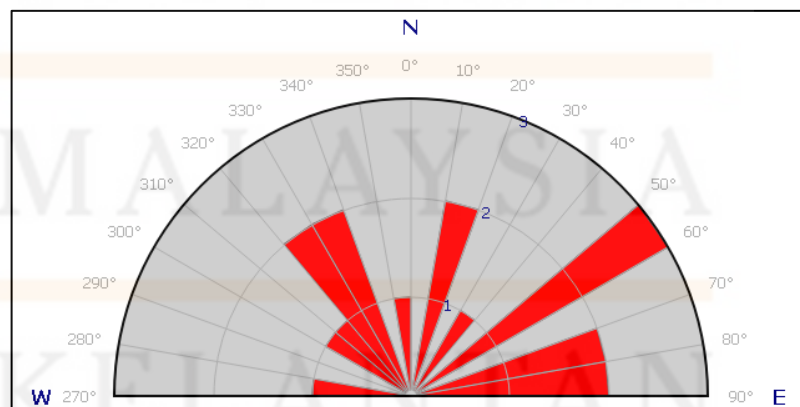


Figure 4.19: Lineament analysis of the study area

#### 4.4.2 Joint

Joint is classified as a secondary geology structure. Joints are cracks or fractures that divide the rocks into parts of blocks and there is no relative displacement. They are like cleavage in minerals. The result of tensile stresses and compression stresses can form joints. **Table 4.4** show 20 readings of joint data in the study area. Based on the joint analysis in **Figure 4.20**, shows that the major force ( $\delta_1$ ) comes from the north-south direction. The maximum force is the force that tends to make the rocks slightly break or fracture. Meanwhile, the minor force ( $\delta_3$ ) comes from the east-west direction. **Figure 4.21** shows the joint structure at the slate outcrop. The joint data were analysed using Georose software. From the analysis, the force and direction can be determined.

**Table 4.4** Strike and dip reading for joints data.

No	Strike	Dip
1	6	158
2	10	80
3	10	180
4	10	250
5	12	315
6	13	94
7	14	165
8	20	85
9	25	170
10	21	181

Table 4.4: (Continued)

11	40	185
12	40	184
13	41	185
14	50	255
15	36	240
16	12	250
17	20	245
18	10	270
19	22	185
20	10	160

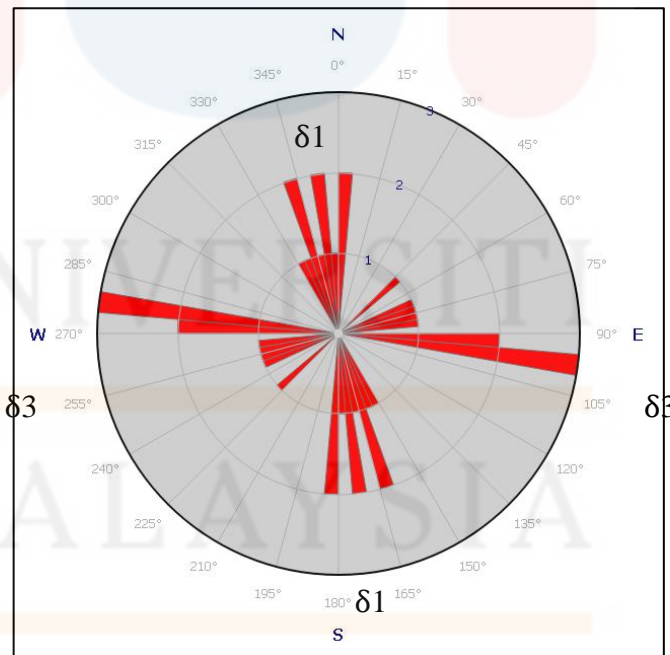


Figure 4.20: Rose diagram for joint data



**Figure 4.21:** Joint structure on the slate rock.

#### **4.5 Historical Geology**

Dabong is a part of Gua Musang Formation. Dabong was located at the central belt of the peninsular. According to Mohamed et al., (2016), the formations within the study area were deposited in a warm, shallow marine environment within the Paleotethys Seaway of the Central Belt during the Permo-Triassic time. This is because, in the study area, there were argillite units that slightly metamorphosed to slate and phyllite. The age of the study area was from Permian to Quaternary. The shallow marine depositional exists between the landward effect of marine processes and the seaward influence of continental, primarily fluvial (river). Waves, storms, tidal currents, and river-derived flows are the primary physical forces functioning in shallow marine environments. The lithology and texture of the rock in the study area comprise primarily of sand, mud, and gravel that is moderate to well-sorted. It is indicated that the area is from a shallow marine deposit.

Gua Musang Formation was introduced informally by Yin E.H. (1965) for a predominantly argillaceous and calcareous sequence interbedded with volcanic and arenaceous rocks in the Gua Musang area of south Kelantan. The unit extends to north Kelantan and southwards to north Pahang. Fossils of ammonoids and pelecypods indicate a middle Permian to middle Triassic age. It is unconformably overlain by the Gunung Rabong Formation. To the east of the Gua Musang Formation is another Triassic rock formation which is Gunung Rabong Formation. The upper part of Gua Musang formation interfingers with Semantan Formation, Telong formation, and Gunung Rabong formation. Gunung Rabong Formation was predominantly an arenaceous-argillaceous sequence with subordinate calcareous, rudaceous, and volcanic bands in the Gua Musang area of south Kelantan.

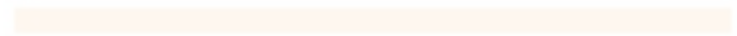
In addition, the study area consists of rock from Stong Migmatic Complex which was quartzite. The Stong Magmatic Complex is in the northern part of Peninsular Malaysia and is divided into three main plutons in order from oldest to youngest, namely Berangkat Tonalite, Kenerong Leucogranite and Noring Granite. Kenerong Leucogranite rocks consist of three types of rocks, which are medium-grained granite, a sequence of interlayered metasediments, and dark grey microgranite. Light grey medium-grained granite is leucorate with a mineral composition dominated by quartz. This unit is also foliated and contains garnet metamorphic minerals. Metasedimentary rock units interlayered with outcrops show a variety of thicknesses.

In conclusion, the geology of Kampung Kuala Geris can be classified as a flood-prone area because the location is near the main river, Galas River. The study area has a high tendency for river flow because of the rainfall. Moreover, the height elevation of this study area is 386m, and is considered a hill. Most of the area is covered

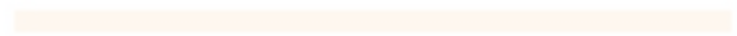
by plains and low-hill areas. The high precipitation of rainfall has the possibility of overflow occurring. So, the analysis of precipitation of rainfall and water level of Kuala Krai was analysed and discussed in the next chapter.



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## CHAPTER 5

### RESULT AND DISCUSSION

#### 5.1 Spatial Analysis of Rainfall Data

Spatial analysis was conducted by producing 12 rainfall distribution maps in Kuala Krai, Kelantan from 2009-2020. The average rainfall data be used and classified by year. **Figure 5.1** shows the map of the distribution of rainfall by year with missing data. Meanwhile, the change in size is perpendicular to the average rainfall in a year. During the year 2009 until 2011, Ladang Kuala Nal highly received precipitation. In the year 2012, Laloh received high rainfall while Dabong received the least precipitation of rainfall. From the map rainfall distribution in the year 2013, 2014, 2016, and 2017, JPS Kuala Krai and Ladang Lepad Kabu received the highest precipitation of rainfall respectively. Next, during the year 2015, Ladang Kuala Geris and JPS KK had mostly the same average rainfall. During the year 2018 until 2019, Dabong received the highest precipitation of rainfall.

**Figure 5.2** shows the map of the distribution of rainfall by year without missing data. Based on the map, Ladang Kuala Nal received high precipitation during the year 2009 until 2013. In the year 2014, Ladang Lepad Kabu received high rainfall while JPS Kuala Krai received the least precipitation of rainfall. From the map rainfall distribution in the year 2015, JPS Kuala Krai received the highest precipitation of rainfall. Next, during the year 2016 until 2020, Ladang Lepad Kabu and JPS KK had mostly the same average rainfall. During the year 2018 until 2019, Dabong received the highest precipitation of rainfall. Overall, there is a significant change between data with missing and without missing data.

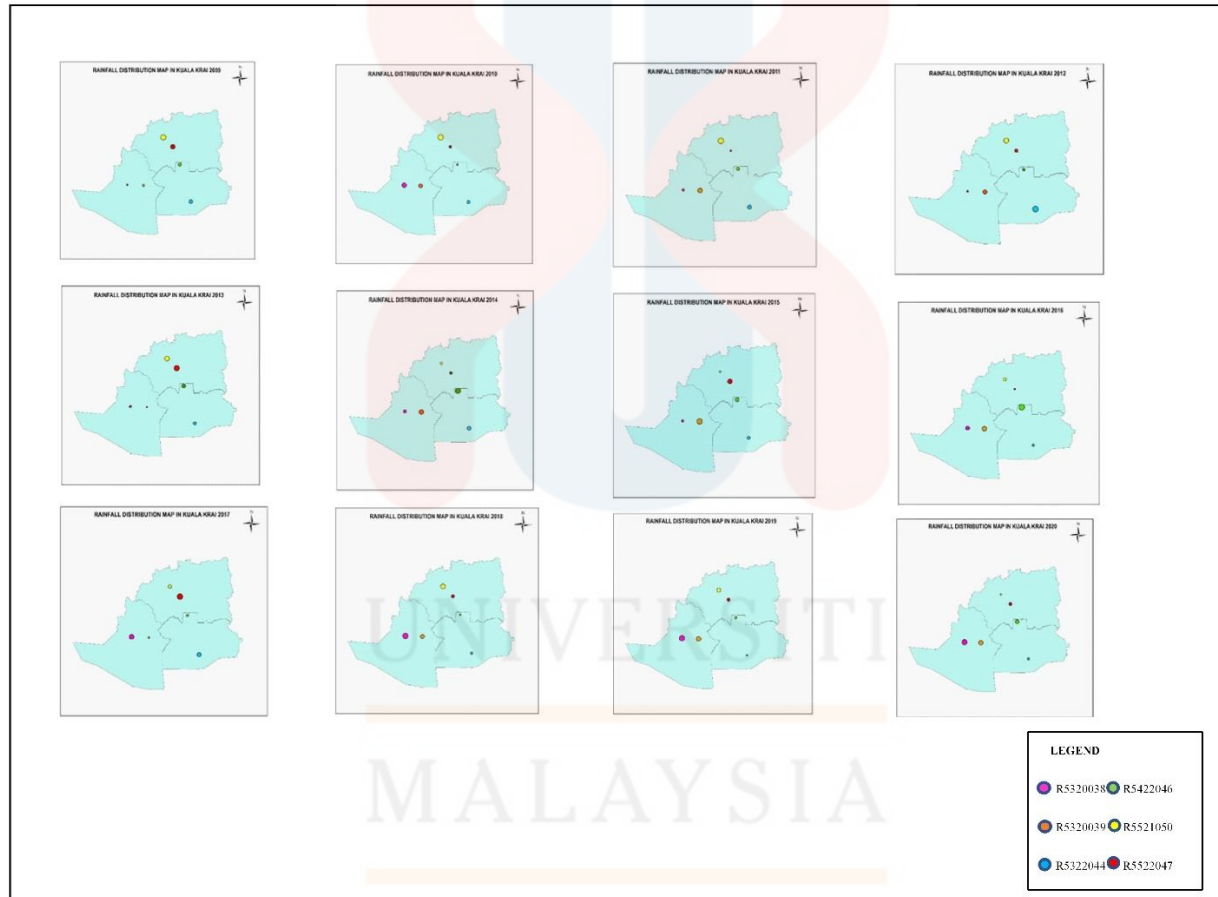
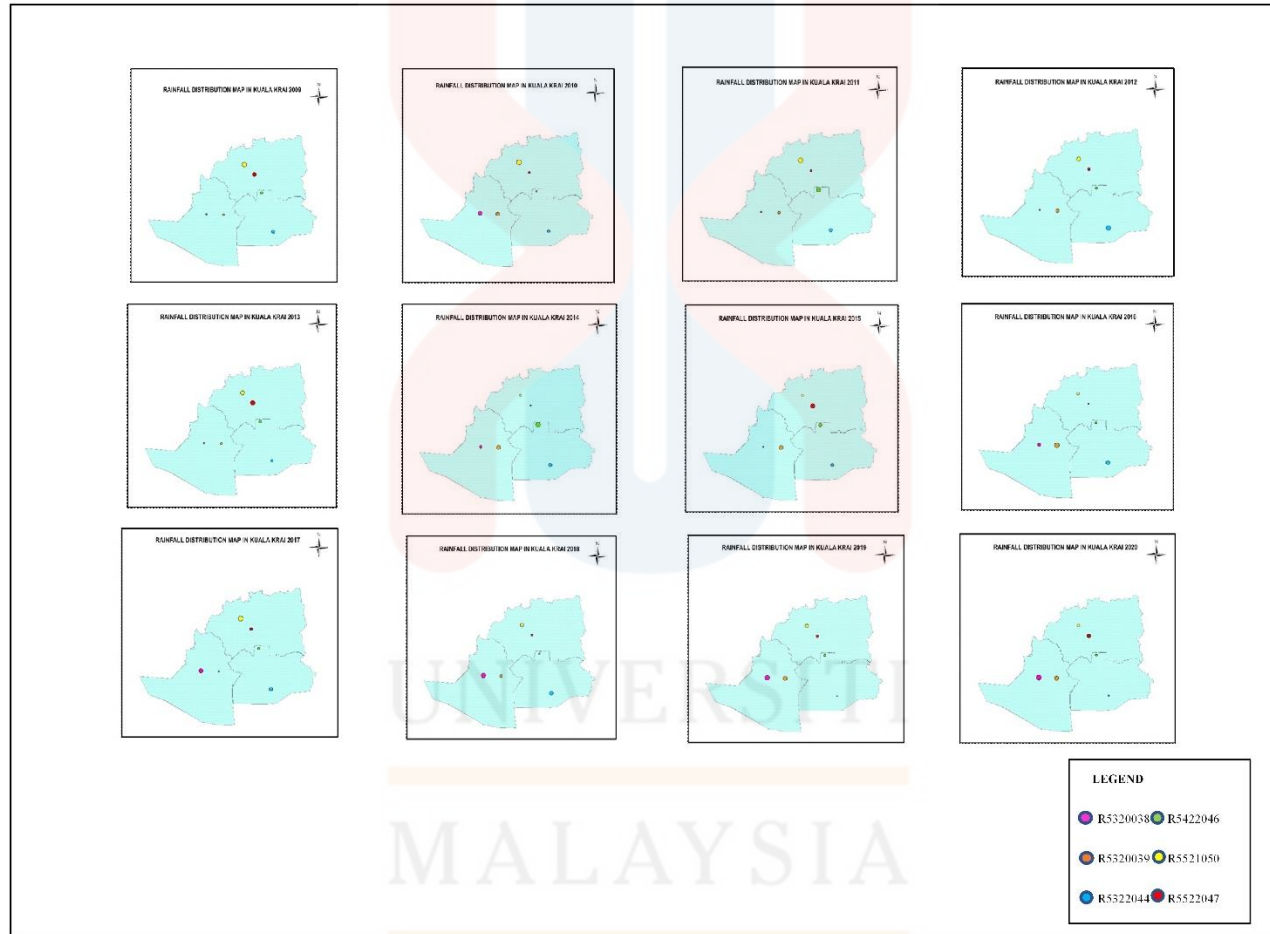


Figure 5.1: Distribution of rainfall by year with missing data



**Figure 5.2:** Distribution of rainfall by year without missing data

## 5.2 Trend analysis of rainfall data

### 5.2.1 Descriptive statistic of rainfall stations and dataset from 2009 to 2020

**Table 5.1:** Descriptive analysis

Station	Latitude (N)	Longitude (E)	Average (mm)	Maximum (mm)	Total (mm)	Standard Deviation (mm)
Dabong	5.378	102.015	212.572	1340.1	30610.4	173.759
Ldg Kuala Gris	5.375	102.082	208.240	1177.0	29986.5	150.632
Kg Laloh	5.308	102.275	199.294	1254.5	28698.3	162.242
Ldg Lepad Kabu	5.460	102.231	199.767	1338.0	28766.5	184.043
Ldg Kuala Nal	5.571	102.164	210.868	1414.5	30365.0	191.328
JPS Kuala Krai	5.532	102.203	200.815	1208.4	28917.4	186.827

**Table 5.1** shows the descriptive statistic of six rainfall stations in Kuala Krai from 2009 to 2020 with missing data. The rainfall data were analysed for descriptive statistics such as average, maximum, total, and standard deviation. Descriptive statistics of the data were carried out as an essential step before further analysis because wrongly placed outliers can have a big impact on the trends (Abdulkareem et al., 2016). The total range value for Dabong, Ldg.Kuala Gris, Kg.Laloh, Ldg.Lepad Kabu, Ldg.Kuala Nal, and JPS Kuala Krai is from 28698.3mm to 30610.4mm. The average rainfall was observed higher at station Dabong (212.572 mm) and followed by station Ldg.Kuala Nal (210.868 mm). The highest standard deviation was 191.328 which was recorded by station Ldg.Kuala Nal.

5.2.2 Total of annual rainfall for 2009-2020

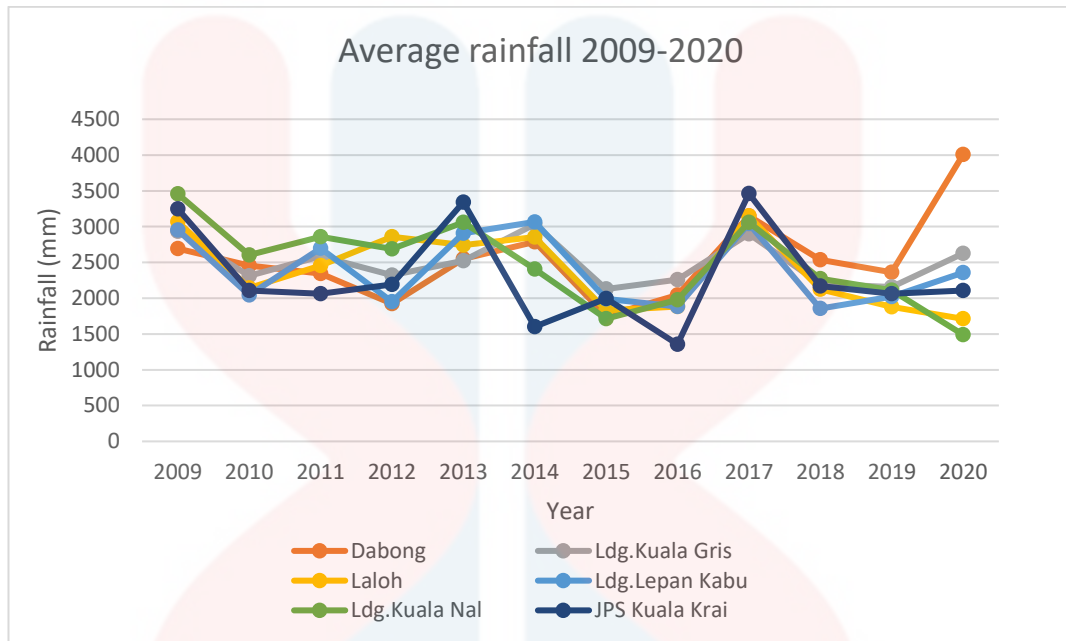
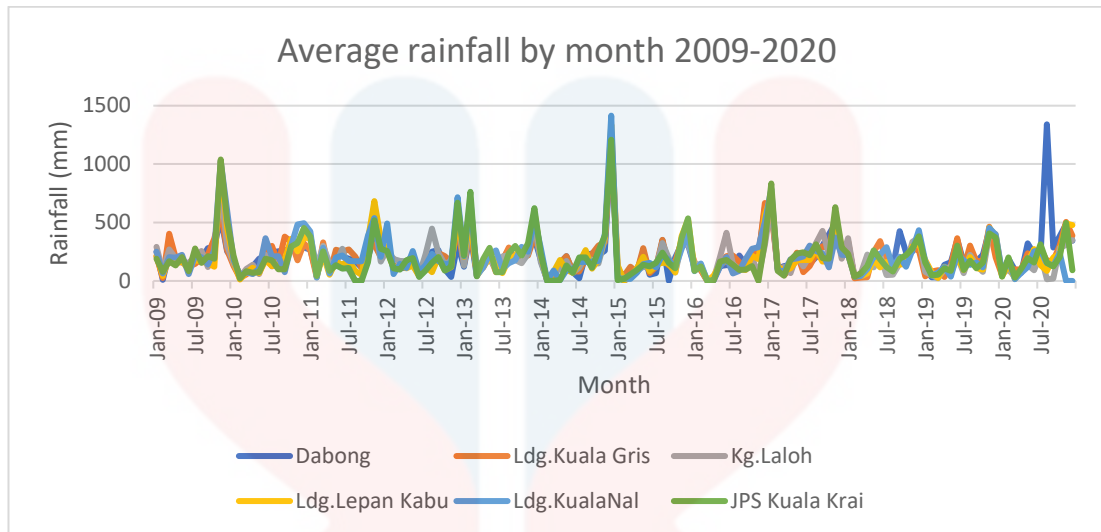


Figure 5.3: Graph of total annual rainfall (2009-2020).

Figure 5.3 represents the graph of the total annual rainfall amount for 12 years for six stations in Kuala Krai, Kelantan. Furthermore, the result revealed that the maximum rainfall occurred during the year 2020 at Dabong station. On the other hand, the year 2009, 2013, and 2017 also reported a high amount of precipitation amount compared to the other year.



### 5.2.3 Average rainfall in month



**Figure 5.4:** Graph of average rainfall by month 2009-2020

**Figure 5.4** shows the trends for monthly rainfall from 2009 to 2020 with maximum total rainfall occurrence in December 2014 (1414.5 mm). It was recorded at Ladang Kuala Nal station. An extreme rainfall that occurred in 2014 resulted in overflowing water in Sungai Kelantan, Sungai Galas, and Sungai Lebir in Kuala Krai. Besides, Dabong station also shows high precipitation of rainfall that can be observed in August 2020 (1340.1mm).

### 5.2.4 Trend analysis using Mann-Kendall (MK)

**Table 5.2:** Summary statistics of Mann-Kendall analysis

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Dabong	144	0	144	0.000	1340.100	212.572	174.264
Ldg.Kuala Gris	144	0	144	1.000	1177.000	208.240	150.632
Kg.Laloh	144	0	144	0.000	1254.500	199.294	162.242
Ldg.Lepan Kabu	144	0	144	0.000	1338.000	199.767	184.043
Ldg.Kuala Nal	144	0	144	0.000	1414.500	210.868	191.328
JPS Kuala Krai	144	0	144	0.000	1208.400	200.815	186.827

**Table 5.2** represents the summary statistics of the Mann-Kendall analysis that contains minimum, maximum, mean, and standard deviation. 144 monthly data from 2009-2020 for each station were recorded. The minimum value for each station starts from 0 except at station R320039 (1.000 mm). Ldg Kuala Nal has a high maximum value (1414.5) while Ldg.Kuala Gris recorded the least maximum value (1177mm). The high mean shows 212.572 mm which was recorded at Dabong station while station Ldg.Kuala Nal had a high standard deviation (191.328 mm).

**Table 5.3** Mann-Kendall analysis

Series/Test	Kendall's tau	S	Var(S)	p-value (Two-tailed)	Alpha
Dabong	0.062	637	335182.3	0.272	0.05
Ldg.Kuala Geris	-0.016	-165	335178.3	0.777	0.05
Kg.Laloh	-0.102	-1049	335177.7	0.070	0.05
Ldg.Lepan					
Kabu	-0.004	-44	335176.0	0.941	0.05
Ldg.Kuala Nal	-0.079	-814	335181.3	0.160	0.05
JPS Kuala Krai	0.013	130	335168.7	0.824	0.05

The result of the Mann-Kendall analysis was represented in **Table 5.3**. Dabong and JPS Kuala Krai stations had a positive S value (637,130) which indicates an upward trend. Meanwhile, the other 4 stations show a downward trend with their respective S values being negative. Besides, the p-value is higher than the alpha value. A p-value that is higher than 0.05 indicates the analysis has a trend and if less than 0.05 there was no trend. Based on the table, all 6 rainfall stations a trend but not significant.

### 5.3 Trend analysis of water level

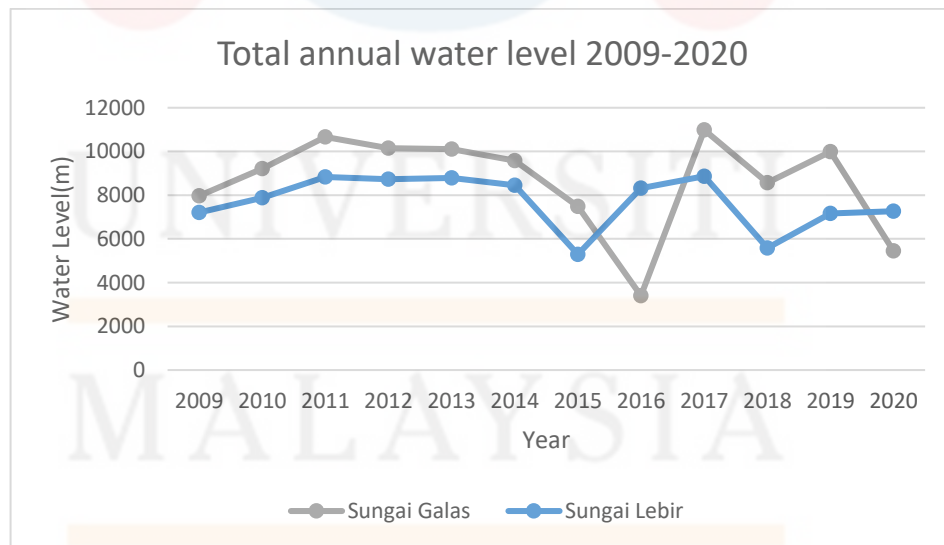
#### 5.3.1 Descriptive statistic of water level station and dataset from 2009-2020

**Table 5.4** Descriptive analysis of water level

Station	Latitude (N)	Longitude (E)	Average (m)	Maximum (m)	Total (m)
Sungai Galas	5.3819	102.015	719.159	1351.24	103558.93
Sungai Lebir	5.275	102.267	641.752	842.34	92412.34

A descriptive analysis was performed in **Table 5.4**. Water level data at two stations were analysed for descriptive statistics such as latitude, longitude, average, maximum and total. Range value for Sungai Galas and Sungai Lebir stations were 842.34 and 1351.24 respectively. Sungai Galas water level had a high average and high maximum than Sungai Lebir. The difference in total annual water level for these two stations is very significant.

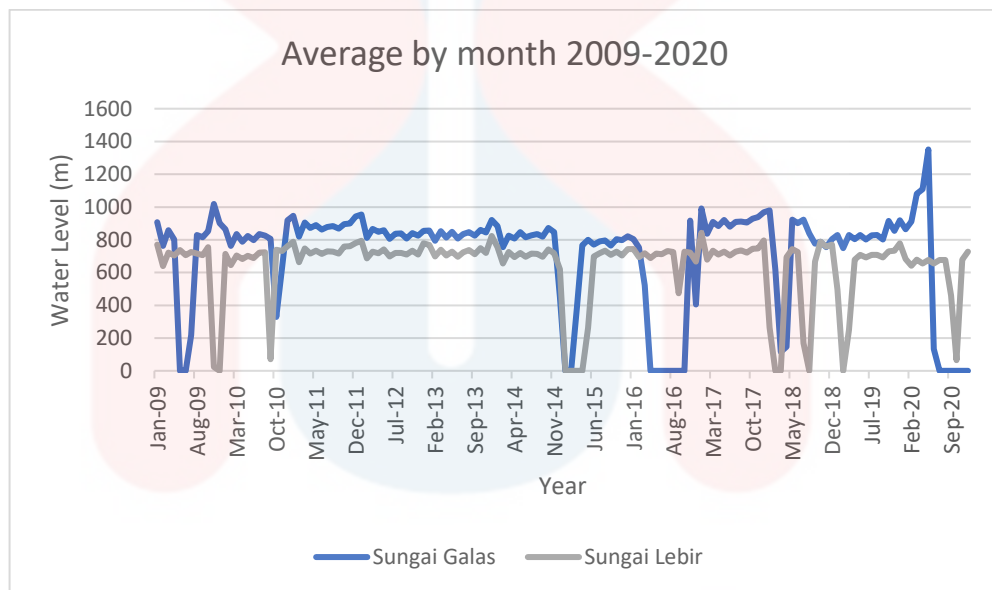
#### 5.3.2 Total water level for 2009-2020



**Figure 5.5:** Graph of total annual water level (2009-2020).

**Figure 5.5** represents the graph of the total annual water level for 12 years in Kuala Krai, Kelantan. The results as represented in the figure above indicate that the maximum water level occurred during the year 2017 at Sungai Galas station (10982.2). Overall, Sungai Galas had a higher water level than Sungai Lebir except for the year 2016. At Sungai Lebir, the water level rise till 2011 and slowly decreased until 2014 before drastically decreasing in 2015.

**5.3.3 Average water level in month**



**Figure 5.6:** Graph of average water level in month 2009-2020

**Figure 5.6** shows the pattern for monthly water level from 2009 to 2020 with the highest water level occurring in May 2020 (1351.24 m). It was recorded at Sungai Galas station. The water level pattern for both stations was mostly the same.

### 5.3.4 Trend analysis using Mann-Kendall (MK)

**Table 5.5:** Summary statistics of Mann-Kendall analysis

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Sungai Galas	144	0	144	0.000	1351.240	719.159	307.700
Sungai Lebir	144	0	144	1.000	842.340	641.752	211.564

**Table 5.5** represents the summary statistics of the Mann-Kendall analysis that contains minimum, maximum, mean, and standard deviation. 144 monthly data from 2009-2020 for each station were recorded. The minimum value for Sungai Galas was 0 and for Sungai Lebir started with 1. Sungai Galas have a high maximum value (1351.24) than Sungai Lebir (842.43). Mean for Sungai Galas was 719.159 and for Sungai Lebir was 641.752. Next, Sungai Galas have a highest standard deviation than Sungai Lebir. Overall, Sungai Galas have a higher water level than Sungai Lebir.

**Table 5.6** Mann-Kendall analysis for water level data

Series/Test	Kendall's tau	S	Var(S)	p-value (Two-tailed)	Alpha
Sungai Galas	-0.071	-724	334602.667	0.211	0.05
Sungai Lebir	-0.141	-1452	335100.000	0.012	0.05

The result of the Mann-Kendall analysis was represented in **Table 5.6**. The S and Kendall's tau value for both stations were negative. It indicates a downward trend. The p-value for Sungai Galas was higher than the alpha value. The p-value below 0.05 tells that there is a no trend. A p-value higher than 0.05 indicates the analysis has not significant trend. But the p-value for Sungai Lebir is less than 0.05. It shows that Sungai Lebir not has a trend.

## 5.4 Interpolation Data

### 5.4.1 Descriptive statistic of rainfall stations and dataset from 2009 to 2020

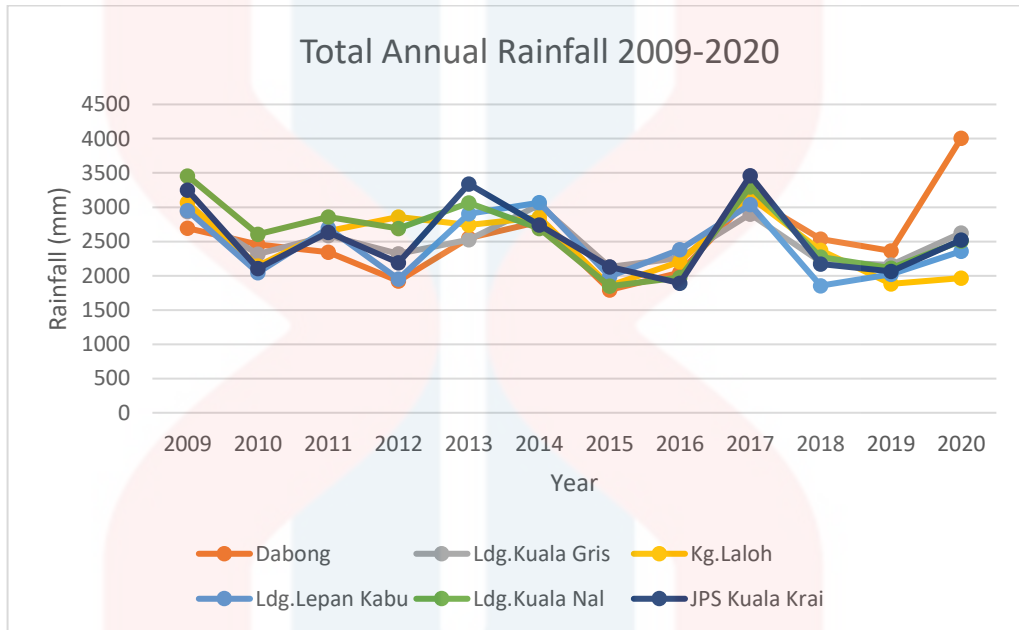
**Table 5.7:** Descriptive analysis

Station	Latitude (N)	Longitude (E)	Average (mm)	Maximum (mm)	Total (mm)	Standard Deviation (mm)
Dabong	5.378	102.015	212.858	1340.1	30651.6	173.494
Ldg.Kuala Gris	5.375	102.082	208.240	1177.0	29986.5	150.632
Kg.Laloh	5.308	102.275	206.581	1254.5	29747.6	159.875
Ldg.Lepan Kabu	5.460	102.231	199.767	1338.0	28766.5	184.043
Ldg.Kuala Nal	5.571	102.164	217.848	1053.0	29844.5	180.518
JPS Kuala Krai	5.532	102.203	207.253	1054.0	28917.4	174.554

**Table 5.7** shows the descriptive statistics of six rainfall stations in Kuala Krai from 2009 to 2020 with missing data. The rainfall data were analyzed for descriptive statistics such as average, maximum, total, and standard deviation. Descriptive statistics of the data were carried out as an essential step before analyses because wrongly placed outliers can have a big impact on the trends (Abdulkareem et al, 2016). Range values for 6 rainfall stations are from 1052mm to 1340.1mm. The average rainfall was observed higher at Ldg.Kuala Nal station (217.848 mm) and followed by Dabong station (212.858 mm). The highest standard deviation of 184.043mm was recorded by Ldg.Lepan Kabu. Next, Ldg.Kuala Nal station has a high maximum

(1053.0mm) compared to other stations. Dabong station has a high total of 30651.6mm while Ldg.Lepan Kabu station has least total with 28766.5mm.

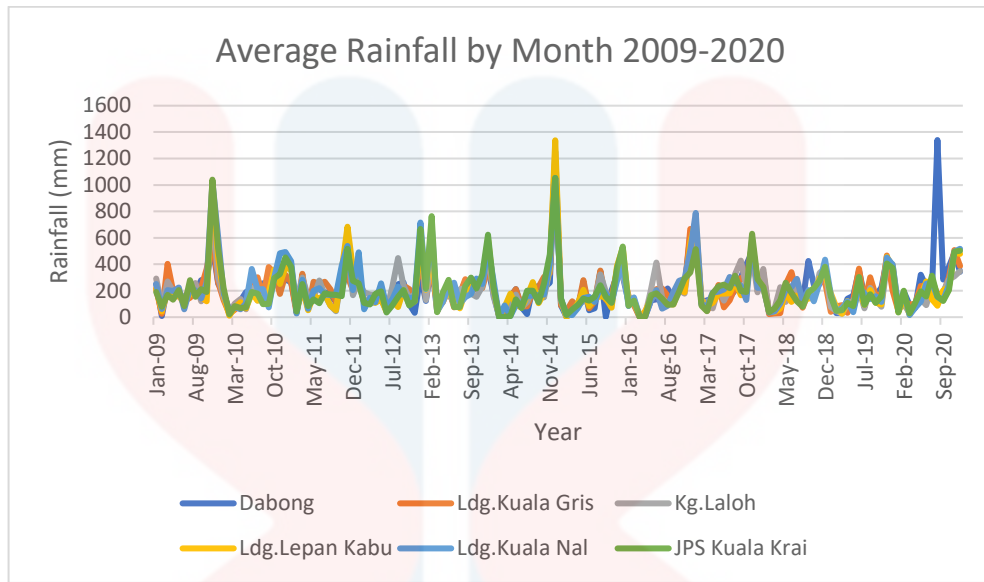
**5.4.2 Total annual rainfall for 2009-2020**



**Figure 5.7:** Graph of total annual rainfall (2009-2020)

**Figure 5.7** represents the graph of the total annual rainfall amount for 12 years for six stations in Kuala Krai, Kelantan. The results as represented in the figure above indicate that the maximum rainfall occurred during the year 2020 at Dabong. On the other hand, the years 2009, 2013, and 2017 also had a high precipitation amount of rainfall compared to other years. During the years 2010, 2012, 2015, 2016, and 2018, most of the stations experienced decreasing in precipitation compared to other years.

### 5.4.3 Average rainfall in month



**Figure 5.8:** Graph of average rainfall in month

**Figure 5.8** shows the pattern for monthly rainfall from 2009 to 2020 with maximum total rainfall occurrence in December 2014 (1338mm). It was recorded at Ldg.Lepan Kabu station. An extreme rainfall that occurred in 2020 resulted in overflowing water in Sungai Kelantan, Sungai Galas, and Sungai Lebir where these three main rivers are in Kuala Krai. The analysis showed that each station received a high rainfall from the 14th to the 28th of December. They occurred almost daily. Besides, November 2009 and December 2014 received high precipitation compared to other months.

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#### 5.4.4 Trend analysis using Mann-Kendall (MK)

**Table 5.8:** Summary statistics of Mann-Kendall analysis

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Dabong	144	0	144	0.000	1340.100	212.858	173.494
Ldg Kuala Gris	144	0	144	1.000	1177.000	208.240	150.632
Kg.Laloh	144	0	144	0.000	1254.500	206.581	159.875
Ldg.Lepan							
Kabu	144	0	144	0.000	1338.000	199.767	184.043
Ldg.Kuala Nal	144	0	144	1.000	1053.000	217.848	180.518
JPS Kuala Krai	144	0	144	0.000	1054.000	207.253	174.554

**Table 5.8** represents the summary statistics of the Mann-Kendall analysis that contains minimum, maximum, mean, and standard deviation. 144 monthly data from 2009-2020 for each station were recorded. The minimum value for each station starts from 0 except for Ldg.Kuala Gris and Ldg.Kuala Nal stations (1.000). Dabong station has a high maximum value (1340.1) while Ldg.Kuala Nal recorded a minimum value of 1053mm.

**Table 5.9** Mann-Kendall analysis

Series/Test	Kendall's tau	S	Var(S)	p-value (Two-tailed)	Alpha
Dabong	0.059	608	335179.3	0.294	0.05
Ldg.Kuala Gris	-0.016	-165	335178.3	0.777	0.05
Kg.Laloh	-0.075	-767	335185.0	0.186	0.05
Ldg.Lepan Kabu	-0.004	-44	335176.0	0.941	0.05
Ldg.Kuala Nal	-0.028	-287	335185.0	0.621	0.05
JPS Kuala Krai	0.020	206	335177.3	0.723	0.05

The result of the Mann-Kendall analysis was represented in **Table 5.9**. Dabong and JPS Kuala Krai stations had a positive S value (608 and 206) and which indicates an upward trend. Meanwhile, the other 4 stations show a downward trend with their respective S values being negative. Besides, the p-value is higher than the alpha value. A p-value that is higher than 0.05 indicates the analysis has a trend and if less than 0.05 it refers to no trend in this analysis. Based on the table, all 6 rainfall stations have a trend but are not significant.

## 5.5 Discussion

In this chapter, descriptive analysis of rainfall data and water level data were analysed. The descriptive analysis was analysed with the missing data and without missing data. Then, the trend by year and month was presented in graphs to see their pattern. To fill in the missing data, the interpolation method, the arithmetic average was used by considering the neighboring data. Neighboring means using the data from nearby stations on the same day and month in different years. Next, to analyses the trend of rainfall and water level, Mann Kendall Test was used.

Overall, from the result with missing data, the year 2020 received the highest precipitation of rainfall at Dabong station. The water level was also high in the year 2020 at Sungai Galas station. **Figure 1.1** stated that Sungai Galas station and Dabong station was at the same coordinate. The result of the Mann-Kendall test with and without missing data has a trend but is not significant. The result without missing data shows the highest total annual rainfall is in the year 2020 at Dabong station. The difference between before and after interpolation methods is significant at JPS Kuala Krai station.

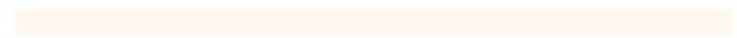
The interpolation data for the water level station could not be analysed due to a lack of data. This is because in Kuala Krai there are only two stations and both data are incomplete. So, the arithmetic average interpolation method cannot be used because the two adjacent data are missing.

Most rainfall data is troubled due to a lack of continuous data. The outcome of data analysis is contingent on the data's quality and completeness. The absence of high-quality precipitation data will have negative effects on the analytical process and lead to skewed outcomes. So, spatial interpolation techniques are commonly used to fill

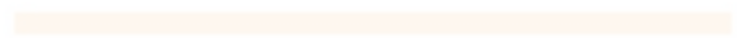
gaps in daily rainfall series by predicting the unknown rainfall quantity for a point based on the known rainfall amounts at surrounding stations.



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## CHAPTER 6

### CONCLUSION AND SUGGESTION

#### 6.1 Conclusion

For this study, the first objective was accomplished. A geological map of Kampung Kuala Geris, Dabong, Kelantan has been produced. Based on the mapping, the study area consists of four rock unit which are phyllite unit, slate unit, quartzite unit, and alluvium unit. Dabong is under Gua Musang Formation with the age Permian to Quaternary. Phyllite was categorized as the oldest rock followed by metaquartzite and alluvium. Quartzite was under Stong Migmatic Complex formation dated from Triassic period.

The second objective is to identify rainfall distribution patterns in Kuala Krai using Spatio-temporal analysis. From the Mann-Kendall test, the result shows that all the stations have a trend but not significant. The highest rainfall distribution mainly occurred in the year 2020 and year 2014. It proves that high rainfall intensity causes a flood.

The results of this study showed that the pattern of rainfall changes by month, season, and year. The total amount of rain that fell each year was very different from every year. But when the amount of rain in three years was more than the average amount of rain in seven years, the amount of heavy rain on Peninsular Malaysia's east coast got worse. So, this information led to the conclusion that extreme floods are hard to predict, but they may happen more often because of how the pattern of extreme rainfall events has changed in recent years. But more analysis of Spatio-temporal of

rainfall data is needed to make sure that extreme rain patterns can be predicted accurately so that floods can be prevented.

## 6.2 Recommendation

For recommendations, the quality of the data from each station needs to be complete because it will affect the decision to interpret the rainfall intensity. One of the methods to fill in the missing data is the regression method. This method aims to find out missing precipitation values. Regression models use climate data, altitude, terrain, and distance from the coast as explanatory variables to estimate missing data (Lebay & Le, 2020). Regressive methods like simple substitution, parametric regression, ranked regression, and the Theil method has been used to fill in missing daily rainfall series. In addition to spatial interpolation and regression, neural network algorithms are also used to try to figure out what precipitation values are missing. The weighted interpolation method from nearby stations is used by the neural network algorithms. Regression-based methods also undercount the number of dry days. In addition, the normal ratio method can be used if the normal annual precipitation of any nearby gauges is more than 10% of the considered gauge. This gives weight to each station in the area.

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