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# GIS-based River Flood Hazard Mapping in Rural Area: A Case Study in Dabong, Kelantan, Peninsular Malaysia

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**Abstract:** Flooding is the most serious natural disaster and often happens in many countries around the world. Dabong Town which is located in the southern district of Kuala Krai, Kelantan was the case study of this research. Floods occur periodically at Kampung Dabong Hulu, Kampung Dabong Hilir and Kampung Chegar Lapan because of the heavy rainfall during the monsoon season. The main objective of this study is to determine which areas are exposed to floods and characterizing the flood zones in the Dabong Town by using Geographic Information System (GIS). Secondary data was gathered from the Department of Irrigation and Drainage while field investigations were conducted at the flooded area. Several questionnaires were distributed to the respondents in order to identify the extent of floods and depth of flooded areas. The results show that three parameters of flood hazards level which are low, medium and high have significant influences on the river flood hazard maps pattern. The area along the Galas River possessed high risk to flood and the total of the high hazard area is 378.39 hectares. Medium hazard area is shown as 57.11 hectares while low hazard area is 37.63 hectares.

**Key words:** GIS, flood, hazard mapping.

## Introduction

Many countries suffer death, trauma, damaged properties, monetary and interpersonal disturbance due to the natural disasters. Natural disasters, such as earthquakes, tornados, floods, volcanic outbreaks, together with landslides always make up issues in most developing and developed countries. Floods are among Earth's most common and most destructive natural hazards. There are few places on Earth where people need not be concerned about flooding. Any place where rain falls is vulnerable, although rain is not the only impetus for flood.

According to Malczewski (2004), since 1973, the floodwater control in Malaysia becomes a concern between authorities, researchers and non-public sector due to the national flood catastrophe. Flooding is defined as the amount of water in a river which exceeds the capacity of the channel causing it to burst its banks onto the flood plain. According to Aurora (2003), for more than thirty-five years the acceleration of flood level to land clearing is triggered by the man-made action. Urbanization or agricultural activities, construction of structures such as highways, roads together with bridges, became activities which often reverse the trend of flooding. Flooding associated with flash flood commonly occurred in Malaysia. Flash floods are among the most typical threats after monsoon floods, with serious rainfall between 2000 mm and 3000 mm. Many large urban areas faced flash floods, usually

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within a monsoon period from November to March (North-East monsoon) and from May to September (Southwest Monsoon). Works by Petry (2002) have shown that the occurrences of serious monsoon rainfall as well as the resultant huge concentration of runoff can cause river system exceeds. According to Borneo Post Online (2015), Malaysia flood hazard in Kelantan has affected a total of 11,099 hectares of agricultural land involving 6,309 farmers, breeders and fishermen and the destruction of infrastructure and agricultural assets.

Location map of Dabong is shown in Figure 1. Study area consists of a main river namely Sungai Galas. The study area is aligned at 10159′36.733″° East and 523′59.096″° North. Figure 2 shows the base map of Pekan Dabong Kelantan. There are also several kinds of villages such as Kampung Batu Sawa, Kampung Rambai, Kampung Dabong Hulu, Kampung Dabong Hilir and Chegar Lapan. Dabong experienced massive flood during 2014 and the main contributor to the flood is excessive rainfall. The second factor that contributes to the water depth increment at Galas River, Dabong is due to the anthropogenic and natural hazard. The anthropogenic hazard induced by human had changed the pattern of topography of Dabong. Activities such as sand mining, deforestation and unplanned agricultural system has led to the flooding events. These kinds of activities have been actively operated at catchment area of Dabong such as Pergau River, Nenggiri River and Galas River.

Pergau River also has experienced anthropogenic hazards where it becomes one of a chosen site for sand mining activity (Figure 3). This activity contributes to the flood occurrence in Dabong, since this activity

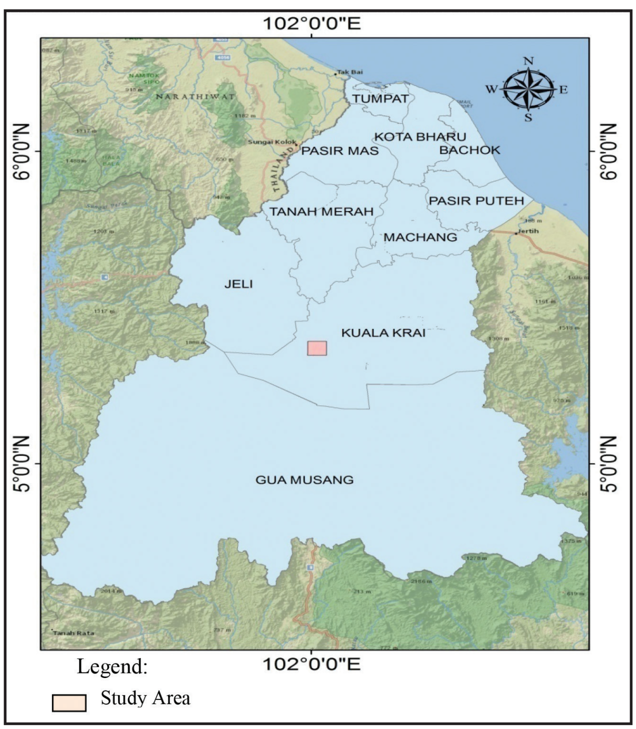


**Figure 1: Location map of Dabong Kelantan. (http://www.mddabong.gov.my).**

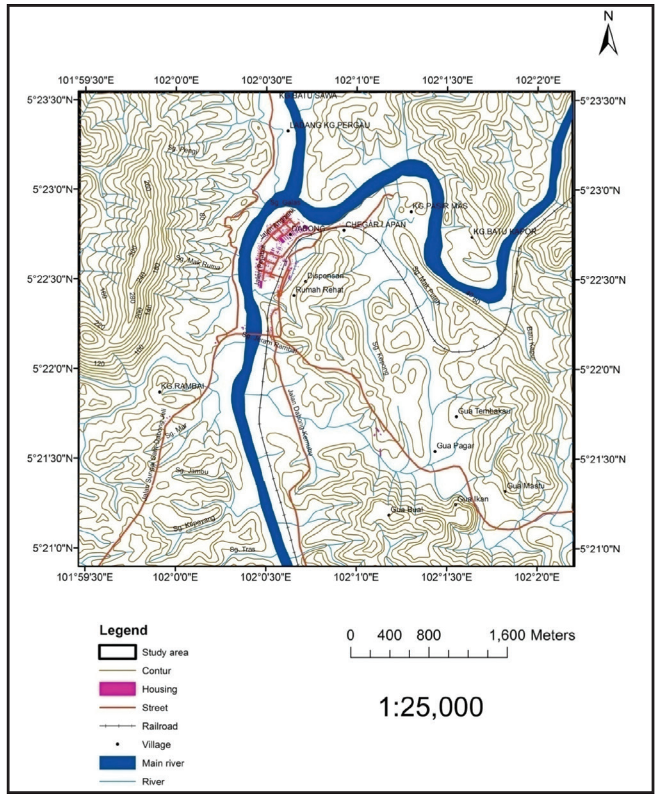


**Figure 2: Base map of Dabong Kelantan.**

**Figure 3: Sand mining activity at Pergau River.**

**Figure 4: Logging activity at Sungai Nenggiri.**

causes the rapid erosion and degradation of rivers and had changed the morphology of river. Apart from that, Nenggiri River located in the middle of forest area was also exposed to the anthropogenic hazards by unplanned agricultural and deforestation activities (Figure 4).

As agriculture is one of the major consumers of freshwater, more yield or output using same or less amount of water has become the global interest (Hossain et al., 2016). There is an oil palm plantation and also oil palm factory that operates near Nenggiri River. Logging activities reduce the rate of water infiltration into the soil and thus reduce the level of water in the soil (Hogan and Joseph, 2014**).** When there is continuous heavy rainfall, soil at the area becomes saturated and thus is not able to absorb excess water and finally flowed into the river (Alex, 2011). This also contributes to the rate of surface water runoff that carries a lot of silt and mud into the river. Therefore, the catchment area of Nenggiri River will lead to the increase of flood depth of water level and contribute to the flood occurrence in Dabong.

Flood hazard mapping is an essential component for proper land use in flood areas. According to Bapalu and Sinha (2005), the potential risk areas and to prioritize the effects of mitigation was identified by using a map of flood hazard. This kind of map can facilitate in easy reading, quickly in access chart and maps. In order to produce a flood hazards map, GIS is a vital and powerful tool for identifying the flood prone areas in the society. Through GIS, all geographical information is stored in a database which can be displayed in graphic for analysis. The database of the GIS maps give information about villagers, the agencies and organizations which are related to the particular place where it gives an excellent view of the real condition and situation in rural areas. In addition, by differentiating the area either safe or prone to natural disasters, it facilitates the emergency plans for evacuation.

## Methodology

Methodology for conducting flood hazard involves a few procedures which are data collection, data processing and data analysis (Figure 5).

### Data Collection

Data was collected by using primary sources and secondary sources. Primary sources included flood hazards mapping, interview the local people living at sub-area along Galas River and distribute questionnaires to local people. A few sessions of structured questionnaire and face to face interview were conducted with one

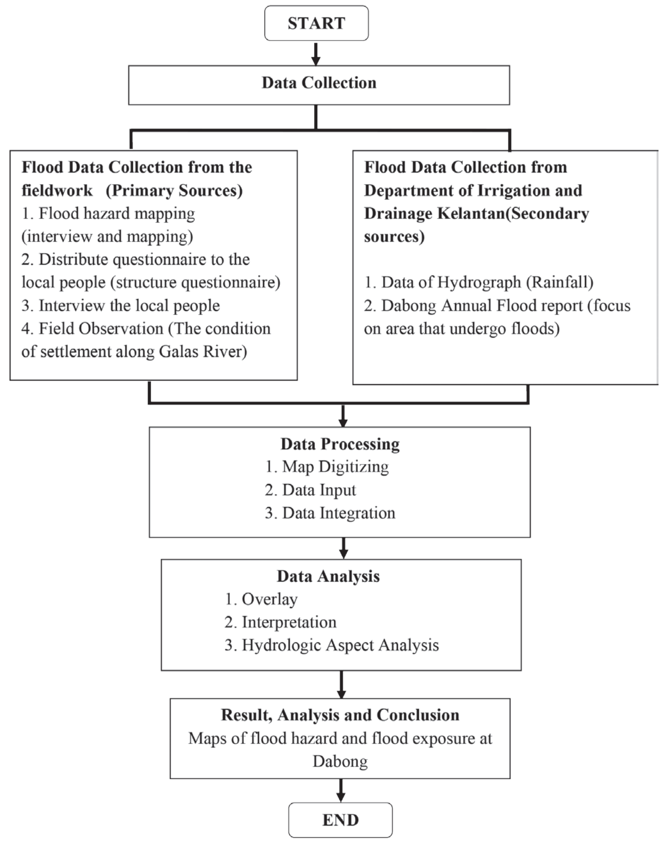


**Figure 5: Research flow chart of flood hazards at Dabong.**

hundred local people in the study area at different locations. The survey was conducted on October 2015 after the flood event in 2014. The questionnaires were developed based on flood exposure where proximity to river, location in or closeness to flood plain was examined. Meanwhile flood hazard questionnaires were developed based on depth of flood level besides general information about the respondent including name, age, period of residence and also broad information about the flood in their residential area. The people were asked about the extent and depth of flood level just after the flood to analyse flood hazard level based on three parameters, which is low, medium and high.

In order to conduct flood hazard mapping, GPS was used to mark the specific location of extension area which is affected and surrounded by overflow of water. This research was focused on Galas River in order to find general impression of the natural geological problem in terms of drainage pattern. For secondary sources, the data was gathered from Department of Irrigation and Drainage, Kelantan. This process was done by interviewing the authorities of the department by asking several questions regarding the distribution of monthly and annual report of rainfall in Dabong, the factor of flood, the maximum depth of flood and identifying the overflow of river basin that contribute to the flooding.

**Data Processing**

The second step is data processing which involves maps digitizing, data input and data integration. Map digitizing is divided into three parts which are: digitizing sub-area along the Galas River in Dabong, digitize the flood exposure and digitize flood hazard at Dabong. Sub-area along Galas River was digitized using Arc-GIS 10 software and then the layer of the sub-area was added along Galas River. Second phase is digitizing the flood exposure. In this phase, flood data was analyzed from all data collection and Arc-GIS 10 software was used to generate the map of flood extension of the study areas. The factor of the flood occurred in the study area has been compared with the rainfall event of the study area. Therefore, this map shows the extension of the flood and the name of the area which is involved during floods due to the overflow of Galas River. The third phase is digitizing the flood hazard at Dabong by creating the layer of extension and refers to the sampling map of sub-area along Galas River in Dabong. Apart from that, the base map is also used as a reference for digitizing the extension of flood area.

**Data Input and Data Integration**

For input data, it involved the data of sub-area effected by flood and data zone of flood risk. Data integration is a combination of primary sources and secondary sources. After data processing was completed, data analysis was done by overlapping the maps and interpretation. In term of analysing questionnaire, it was done through descriptive statistics data using Microsoft excel. By this analysis, the frequency and percentage of the questions can be identified. Department of Irrigation and Drainage Kelantan provided rainfall data to analyse hydrologic aspects. Some parameters were used as an indicator in analysing flood hazards such as sedimentation load, duration of velocity and depth of water based on low, medium and high. Lastly, maps of flood hazard and flood exposure at Dabong were produced by using Arc-GIS 10 software.

## Results and Discussion

**Hyetograph for Galas River at Dabong Kelantan**

Figure 6 shows the Hyetograph of Galas River at Dabong Kelantan. The hyetograph showed the highest peak of the rainfall distribution of Galas River from 15 December to 24 December. From the graph, the highest peak is on 22 December where it showed a drastic rainfall distribution which is 235 millimetre at 11 pm. The minimum of rainfall is 11 millimetre during 19 December at 9 pm. On 15 December the rainfall is 65 millimetre at 6.00 pm and increased to 101 millimetre on 16 December at 11 pm. The rainfall distribution then rose up to 70 millimetre on the 21 December at 11 pm and 90 millimetre on 24 December at 7 pm.

**Flood Exposure in Pekan Dabong**

Flood exposure describes whom and what may be harmed by the flood hazard including the measure of the

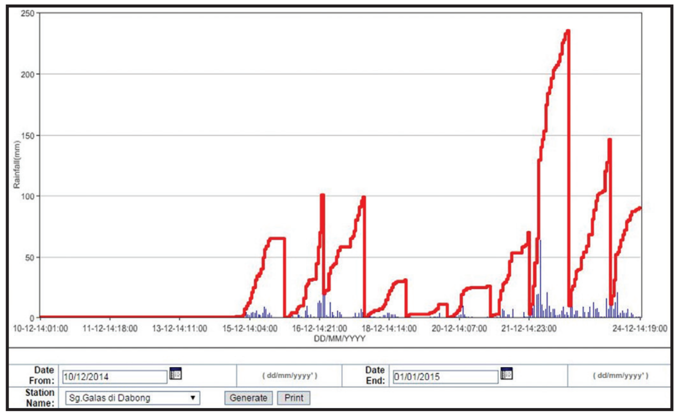


**Figure 6: The hyetograph for Galas River at Dabong Kelantan.**

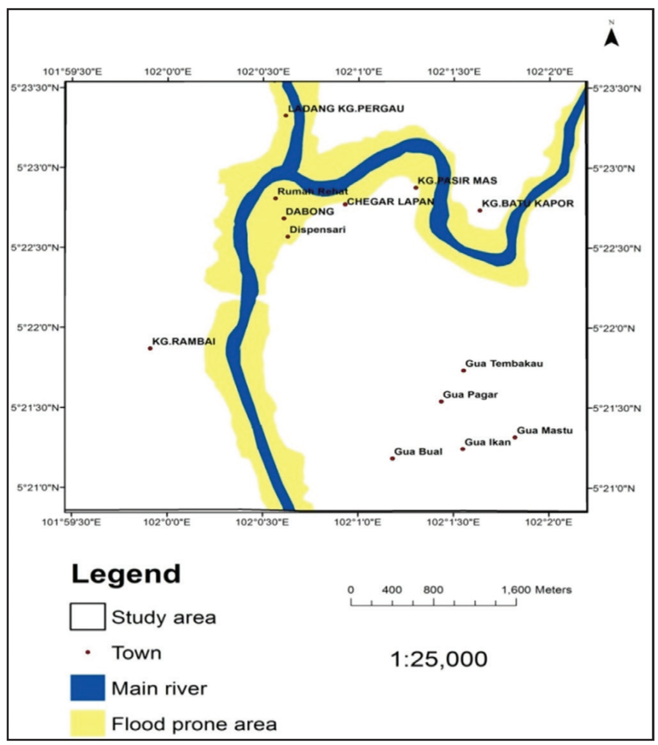


**Figure 7: The map of town affected by flood at Pekan Dabong.**

human population, land use and infrastructure located in flood zones. A common method of measuring flood exposure is to determine the number of different types of properties which occupy a floodplain or other flood risk area. In Dabong, major population of residents are located at floodplain area that is close to the main river namely Galas river. Furthermore, there is a merger of rivers between Galas River and Pergau River at the location of human residence. The length of Galas river is 178 km and the catchment area is about 7,770 $km^{2.}$ while Pergau River has been found with basin length of 99.74 km. This river can be a potential location of flood occurrence at the nearby area since these rivers are merging in each other. Besides that, in terms of topography, the lowest contour is 40 metre where it became residential area at the Pekan Dabong.

Figure 7 shows the map of town affected by flood at Pekan Dabong whereby there are several villages which are located on floodplain and affected by flood at the end of 2014. It was including Ladang Kampung Pergau, Kampung Chegar Lapan, Kampung Hilir Dabong and Kampung Hulu Dabong. These villages have possible risk to flood exposure because of the geomorphology of river. There were about 412 buildings out of 456 within Kampung Chegar Lapan, Kampung Hilir Dabong and Kampung Hulu Dabong in the Dabong town affected by the flood.

Figure 8 shows the map of road connections affected by flood at Pekan Dabong. The main road at Pekan Dabong consists of Jalan Pengkalan Bot Dabong, Jalan Sungai Sam-Dabong Jeli and Jalan Dabong-Kemubu. There are several main roads surrounded by flood, namely Jalan Pengkalan Bot Dabong and Jalan Dabong-Kemubu. Table 1 shows the road affected by flood in metres. There are ten roads flooded by water and the maximum road inundated by flood is Jalan Chegar Lapan which is 1737 metres. The minimum road width flooded is Jalan Melor which is 144 metres but for Jalan Padang Belakang Sekolah, the width is slightly high which is 182 metres.

Figure 9 refers to the map of land use affected by flood at Pekan Dabong. Land use in Pekan Dabong is mostly covered by the rubber plantation and forest. The most affected by the floods is rubber plantation, where the affected area is 202.79 hectare out of 1374 hectare. Second land use that has greater contribution is river and irrigation canal which is as much as 159.91 hectare affected by floods out of 161.16 hectare. The forest is the third large land use which is 983.64 hectare and 96.11 hectare has been inundated by the flood. This followed with the urbanization at Pekan Dabong where

**Table 1:** The road affected by flood at Pekan Dabong

| *Name* | *Area affected by flood (metres)* |
|---|---|
| Railroad | 8111 m |
| Jalan Chegar 8 | 1737 m |
| Jalan Pejabat | 294 m |
| Jalan Hilir Dewan Dabong | 302 m |
| Jalan Anggerik | 255 m |
| Jalan Melor | 144 m |
| Jalan Dabong-Kemubu | 697 m |
| Jalan Pengkalan Bot Dabong | 1706 m |
| Jalan Padang Belakang Sekolah | 182 m |
| Jalan Seroja | 403 m |
| Jalan Masjid | 268 m |
| Jalan Stesen | 234 m |

it covers the land use at almost 39.74 hectare and the affected area is 37.48 hectare. For the road and streets, the affected area is 30.67 hectare out of 59.16 hectare. The total of land use inundated by the floods is 541.89 hectare including mix crops, grass, grove and former crops.

**Flood Hazard Map of Pekan Dabong**

Flood hazard map that has been produced encompass of flood water depth level and flood risks based on three parameters, namely low, medium and high that were shown in Figure 10. The low parameter of flood hazard includes the area as much as 37.62 hectare, followed with the medium hazard as 57.10 hectare and high hazard as 378.38 hectare. Table 2 represents the number of buildings affected by flood based on flood hazard level and flood depth at Pekan Dabong by carrying out one hundred questionnaires. Based on the table, flood hazard level can be classified into three parameters which are high, medium and low. In terms of high flood hazard level, the depth of the flood is five metres above causing ninety seven of buildings affected by floods, including Kampung Dabong Hilir, Kampung Dabong Hulu, and Chegar Lapan. Ninety six of buildings were affected by massive floods, sixty buildings from Kampung Dabong Hilir, thirty six buildings from Kampung Dabong Hulu and one building from Chegar Lapan. In terms of medium flood hazard level, only two buildings were affected by floods which are buildings of Chegar Lapan. These two buildings have experienced flood depth as much as 2.5 metres to 5 metres. For low parameter of flood hazard level, the depth of the flood is one metre or below and it includes only one building of Chegar Lapan.

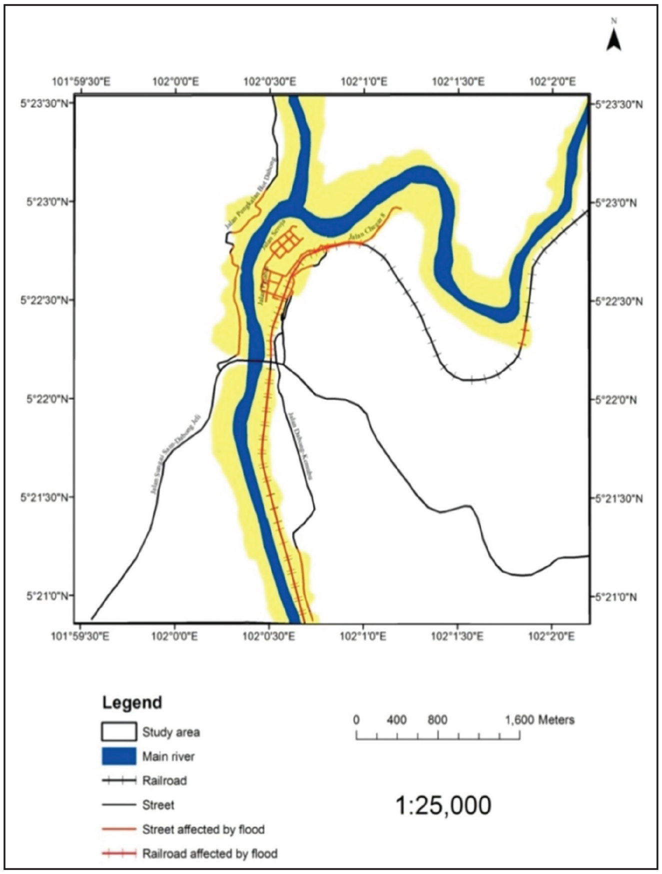


**Figure 8: The map of road connections affected by flood at Pekan Dabong.**

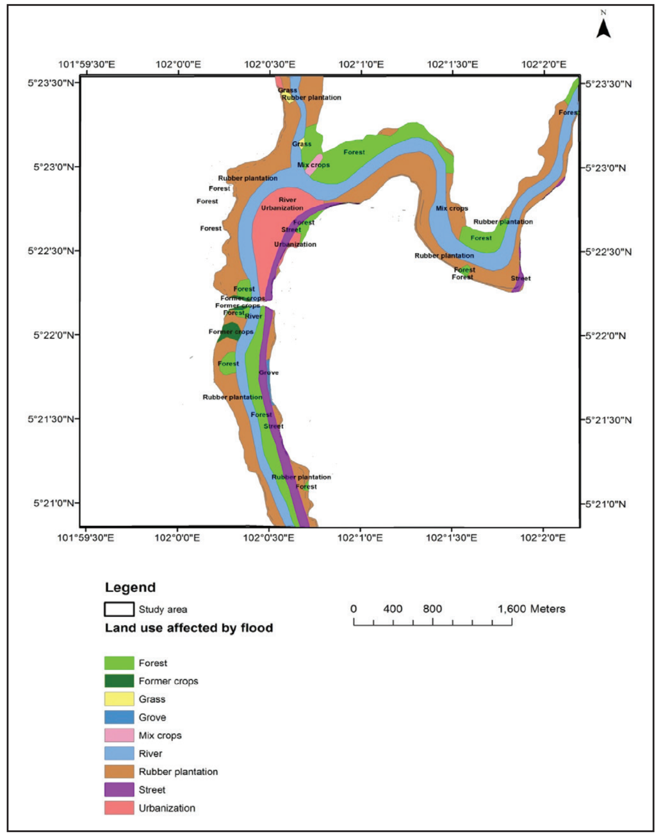


**Figure 9. The map of land use affected by flood at Pekan Dabong.**

**Table 2: Number of buildings affected by flood based on flood hazard level and flood depth at Pekan Dabong**

| *Name of villages* | *Number of buildings* | *Flood hazard level* | *Flood depth* |
|---|---|---|---|
| Kampung Dabong Hilir | 60 | High | 5 metres and above |
| Kampung Dabong Hulu | 36 | | |
| Chegar Lapan | 1 | | |
| Chegar Lapan | 2 | Medium | 2.5 metres-5 metres |
| Chegar Lapan | 1 | Low | 1 metre and below |

Figure 11 represents the percentage of flood hazard level based on three measurements of flood depth which are five metres and above, 2.5 metres to 5 metres and 1 metre and below. According to Figure 11, the dominant percentages of flood hazard level is five metres and above when 96% number of buildings were affected by flood at that level. Majority of the buildings that were inundated by flood at five metres and above were located at floodplain area. The second dominant percentage of flood hazard level is 2.5 metres to 5 metres where it is categorized as medium hazard level and affects 3% number of buildings at Chegar Lapan. The main factor that caused the flood occurrence is the distance of building from the river adjacent to it and the elevation of contour is quite high compared to the elevation at high hazard level. The area affected by the medium flood hazard level is 57.10 hectares. The least percentage of flood hazard level is 1 metre and below where it is classified as the low hazard level. Low hazard level has affected 1% of buildings since the distance of building was far from the river and has high elevation of contour. The area affected by the low hazard level is 37.62 hectares. As a conclusion, the probability to flood occurrence is low if the building is not located at flood prone area, far from the river, and has high elevation of contour. Meanwhile, the probability to flood occurrence is high if the building is located at the flood prone area, adjacent to the river and has lower elevation of contour.

**Hydrograph for Galas River at Dabong Kelantan**

Figure 12 represents the hydrograph for Galas River at Dabong Kelantan. The trends show the fluctuation of water level within 49 days from December 2014 to January 2015. From the hydrograph, it shows the three parameters of water level which is danger level, alert level and normal level. The danger level was labelled as a red line, while alert level is orange line and normal level is green line. The normal hydrograph reading at Galas River is 25 metres while for alert level is 33 metres and for dangerous level is 38 metres. The water depth was recorded at every twelve hours from 10 December 2014 to 1 January 2015. The highest record of water depth level within that period is 46 metres which exceeded the dangerous level and caused the water river to overflow the flood plain area in Dabong. Therefore, the probability of flood occurrence was high due to the increase of water depth level and prolonged heavy rainfall.

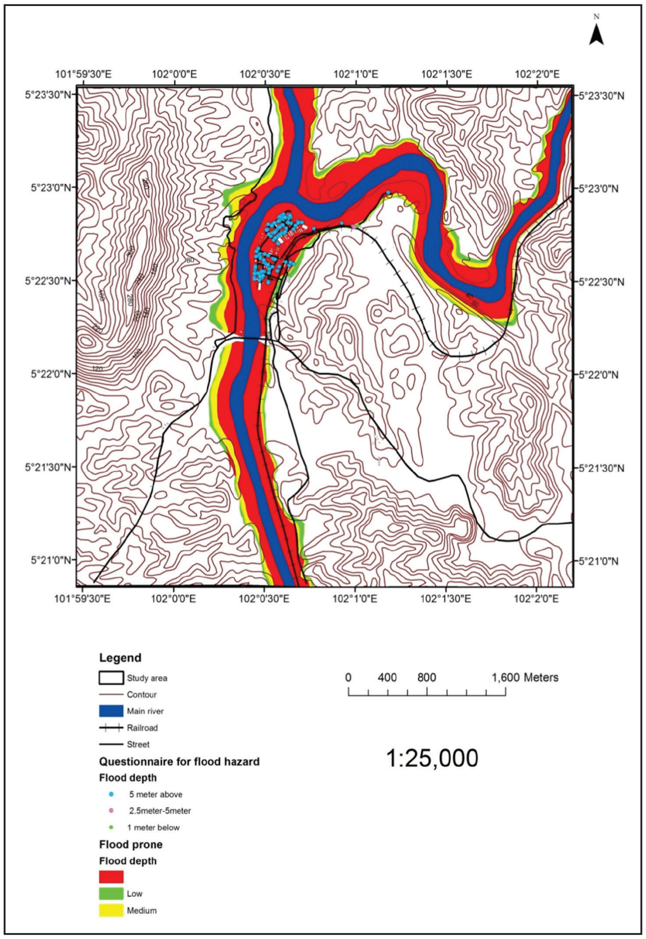


**Figure 10: Flood hazard map of Pekan Dabong.**

**Result of Questionnaire**

*(a) The Survey of General Information about Respondent*

The survey for questionnaire based on one hundred respondents is shown in Table 3. The respondents in the

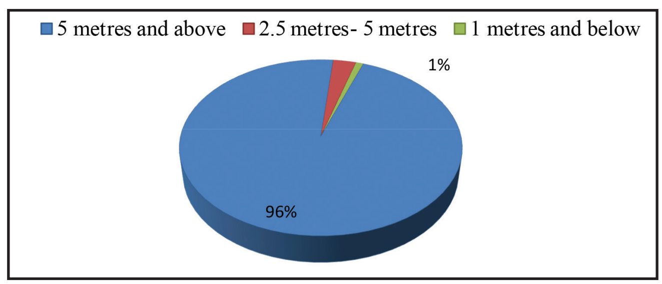


**Figure 11: The percentage of flood hazard level.**

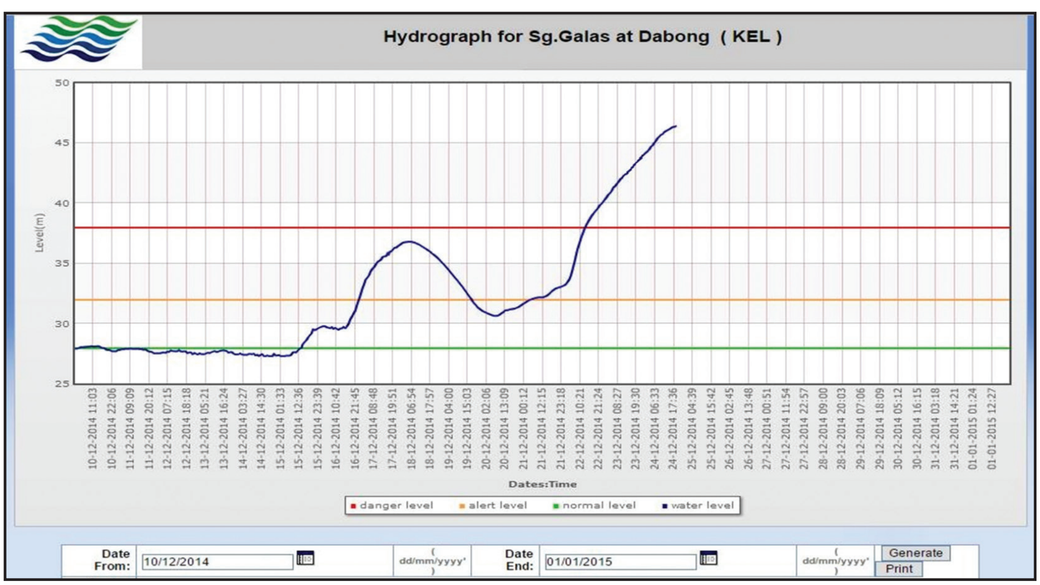


**Figure 12: Hydrograph of Galas River at Dabong.**

**Table 3: Questionnaire survey based on one hundred respondents**

| Types | Classification | Respondents | |
|---|---|---|---|
| | | *n* | *%* |
| Gender | Male | 56 | 58 |
| | Female | 44 | 42 |
| Race | Malay | 98 | 99 |
| | Chinese | 2 | 1 |
| | 20 years old and below | 3 | 2 |
| Ages | 21-39 years old | 37 | 35 |
| | 40-60 years old | 14 | 45 |
| | 61 years old and above | 46 | 18 |
| | Business | 6 | 7 |
| Occupation | Unemployed | 25 | 27 |
| | Government | 12 | 13 |
| | Freelancer | 45 | 26 |
| | Private work | 12 | 7 |
| | 1-3 years | 2 | 2 |
| Settlement duration | 3-6 years | 5 | 4 |
| | 6-9 years | 10 | 16 |
| | 9 years and above | 83 | 78 |
| | Rainfall and nearby | 82 | 75 |
| Causes of flood | river | 5 | 6 |
| | Drainage system | 11 | 18 |
| | Low ground level | 2 | 1 |
| | Land use | | |
| Water depth level during flood | 1 metre and below | 1 | 1 |
| | 2.5-5 metres | 2 | 2 |
| | 5 metres | 97 | 97 |
| Distance of building from the river | 0-20 metres | 1 | 1 |
| | 80-100 metres | 14 | 12 |
| | 100 metres and above | 85 | 87 |
| Effect changes of terrain after flood | River become wide | 67 | 62 |
| | Landslide | 33 | 38 |
| | Hill | 20 | 35 |
| Place transfer during flood | Hall | 16 | 8 |
| | School | 38 | 41 |
| | Other | 26 | 16 |
| | House | 73 | 75 |
| Types of loss due to floods | Transport | 16 | 24 |
| | Livestock | 6 | 13 |
| | Crops | 5 | 10 |

study area comprise 58% male and 42% female while the race is dominated by Malay which is 99% and 1% is Chinese. In terms of age it is ranging between 20 years old and below to 61 years old and above. The highest group of age ranged from 40 to 60 years old with the percentage of 45%; followed by the group age of 21 to 39 years old with the percentage of 35%. The respondents in the study area also can be categorized based on their occupation which shows that 27% of all respondents are unemployed while 26% and 13% are free-lancer and government employees. 78% of the respondents have lived in the study area for nine years and above while 16% of them lived for the range of 6 to 9 years. The others lived there for 3 to 6 years and 1 to 3 years is only 4% and 2%.

*(b) Flood Survey through Descriptive Analysis*

One hundred questionnaires were distributed to one hundred local people in the study area. 82 respondents (75%) out of 100 people stated that the causes of flood is rainfall and about 18% of the respondents stated the areas were observed to be at low-lying areas. Analysis on other causes of flood also shows that drainage system and land use give the values of 6% and 2% respectively. In terms of flood depth, all the respondents agreed that their houses submerged by flood up to 2.5 m to 5 m due to their location nearby to Galas River.

## Conclusion

Flood exposure and flood hazard maps of Pekan Dabong were produced by using GIS software with the three particular levels of hazard. The maps were produced based on secondary data from the Department of Irrigation and Drainage and also field investigations at the flooded area. There is also several questionnaires carried out with respondents to identify the extent of flooded and depth of flooded areas.The results show that the area susceptible to flood are based on three parameters, namely low, medium and high. Analysis of flood exposure at PekanDabong Kelantan shows that human population, land use and infrastructure located in flood zone area have a high possibility to floods phenome. In terms of land use, rubber plantation with an area 202.79 hectare is the most affected by floods. There are total ten roads exposed to flood. The highly exposed to flood is Jalan Chegar Lapan with an area as much as 1737 metres. Based on flood hazard maps, it showed that the areas along the Galas river of Dabong possessed high risk of flood with the total of the high hazard area being 378.39 hectares. For medium hazard area is 57.11 hectares and low hazard area is 37.63 hectares.

## Acknowledgement

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