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# FLOOD HAZARD ANALYSIS IN FLOODPLAIN OF BEAUFORT, SABAH, MALAYSIA

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**Abstract**

The level of comfort of a home or residential area is important to everyone. The intended connotations of comfort include being safe and free from natural hazards such as floods, landslides and earthquakes. However, there is not one area on this earth that is completely free of natural hazards. Highland areas, for example, are more likely to experience landslides while lowlands are more likely to experience floods. Beaufort District flood plain is one of the most frequently flooded lowlands, especially in Bekalau, Bingkul, Mempagar and Malalugus. Therefore, this study aims to analyze the flood risk level in all four villages. Hydrological data integrated with field measurement data in the field is used to determine flood hazard levels. The duration of the hydrological data is 10 years from 2009 to 2018. Total sample size (to measure strandline) was 241 households. The data were then analyzed using Anaconda Python version 3.7 software through the Pandas application. The findings show that the level of exposure to flood hazards at the study site varied. Nearly 90 per cent of the total sample (residential) is exposed to high flood risk (Area B and Area C). These include the frequency, duration and depth of the flood.

**Keywords :** Hydrology, flood risk assessment, flood exposure, flood management, Padas Basin

## Introduction

A house is a basic human needs to be used as a shelter (Mohd Nazaruddin Yusoff et al., T th). In fact, the assessment of a community's life quality can be determined based on the level of a house or residence's comfort, among others (Haryati Shafii et al., 2018). Therefore, a residence that is safe and free from any natural hazards such as floods, landslides and earthquake is a dream of every indidivual. This is in line with the 11$^{th}$ Sustainable Development Goals (SGDs) which is to develop comfortable, safe, resilient and sustainsable cities and settlement areas (United Nations, 2015).

Even so, in reality, not one area is completely free from the occurrence of natural disasters or hazards. Every inch of of areas on earth has the potential to be exposed to natural hazards. The only difference is in the types of hazards. Upland areas, for example, have high possibilities of experiencing landslide hazard (Chan et al., 2013) while lowland areas are more likely to experience flood hazard (Noorazuan Md Hashim et al., 2011). One of the lowland areas that are prone to experiencing floods is the floodplain in Beaufort (Waidi Sinun & Jadda Suhaimi, 1996; Jafar et al.,2020a; Jafar et al., 2020b; Jafar et al., 2021; Jafar et al., 2022).

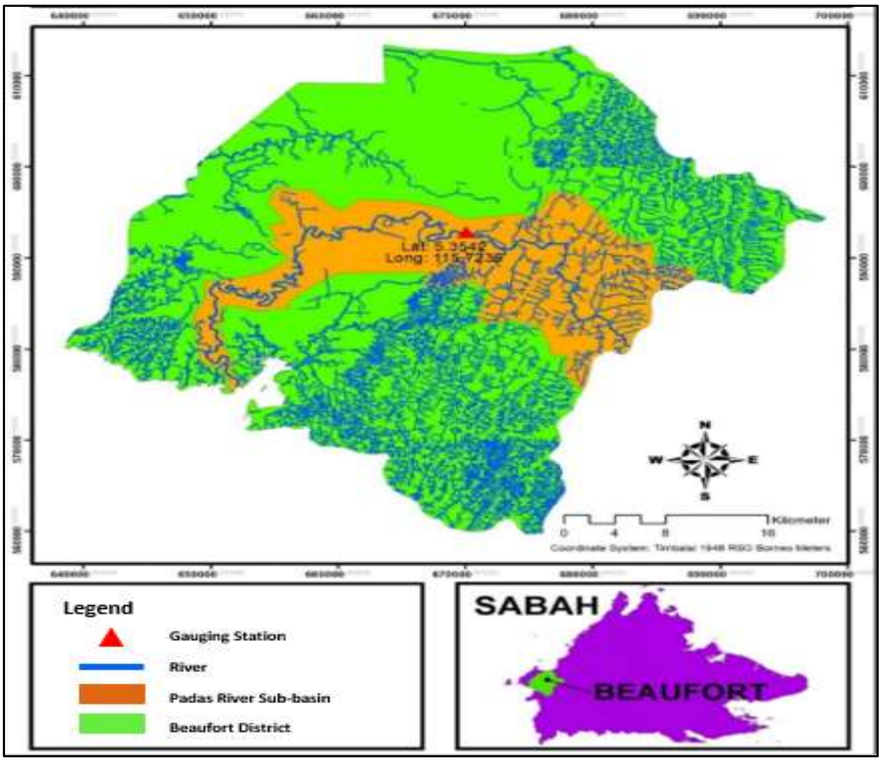
Flood events in that area have submerged dozens of villages, affecting the lives of residents (Mohd Izham Unnip Abdullah, 2017). Among those affected are electricity and water supply sources (Berita Harian, 2010). A series of floods in the area have also caused the closure of main roads (Sinar Harian, 2011). Other impacts of flood hazard include damage of residential structures (Choirul Nanang, 2009), casualties, injuries and disease infections (Zhang et al., 2002). This shows that the level of risk of loss or negative impacts experienced as a result of flood events is one of them influenced by the level of flood hazard itself (White et al., 2005). Hence, the objective of this study is to analyse the level of flood hazard in the floodplain of Beaufort. This is because, by understanding the level of flood hazard in a certain area, it facilitates the work of flood disaster management so that it can be carried out more efficiently.

## BEAUFORT DISTRICT AS A FLOODPLAIN AREA

This study was specifically conducted in four villages comprising Bekalau, Bingkul, Malalugus and Mempagar. These four villages are adjacent with each other (refer to Figure 3) and are flood hotspot areas (Berita Harian, 2014; Mohd Izham Unnip Abdullah, 2017). These villages are located within the administrative jurisdiction of Beaufort district. This district is situated in the downstream area of Sg. Padas and is located close to the Brunei Gulf which is the outlet and last point of the Sg. Padas river flow. Apart from the Sg. Padas sub-basin, there are also several other sub-basins that are located within the Beaufort district area (refer to Figure 1). The position of the Beaufort district which is located in the downsteam area of Padas River and several other sub-basins makes it a floodplain area.

According to Eldawaty Madran & Felix Tongkul (2011), a large part of the topography of the Beaufort district area is more sloping, low, and almost flat. This is evidenced when approximately 70 per cent of the whole Beaufort district area has a height below 10 metres, while the rest (30 per cent) is located 10 metres to 174 metres above sea level. This situation causes most of the Beaufort district area to have almost the same height with the sea level during the occurrence of high tide phenomena (Johan Aziz, 2016). Therefore, it is not suprising when Beaufort district often experiences flood incidents (Waidi Sinun & Jadda Suhaimi, 1996).

Figure 1: Position of Beaufort district boundary




## LITERATURE STUDY

## CONCEPT OF HAZARD

Hazard is defined as a physical event that has the potential to cause fatalities, injuries, property damages, social interuption, economic disruption and environmental degradation (UNISDR, 2004). Generally, hazards can be classified into three categories consisting of natural hazards, technological hazards and environmental degradation hazards (Tarbotton et al., 2015). However, this article only focuses on the natural hazard, which is flood. The cause of natural hazards occurrence can be due to hydrometeorological, geological or biological factors (refer to Table 1). For example, the occurrence of floods, tropical cyclones and sandstorms belongs to hydrometeorological hazard while the occurrence of earthquakes, volcanic activities and landslides are caused by geological factors. The spread of disease on plants and animals, on the other hand, is a result of biological hazards.

**Table 1: Categories of Natural Hazards of Disasters Based on Their Causes**

| Causes | Phenomena |
|---|---|
| **Hydrometeorology:** Natural phenomena or process of the atmosphere, hydrology and oceanography | Floods, tropical cyclones, storms, rain, blizzards, droughts, extreme temperatures, sandstorms and landslides |
| **Geology:** Endogenous and exogenous natural phenomena or processes such as tectonic plate movement and mass movement | Earthquakes, volcanic activities, landslides, tsunami and rock ruins |
| **Biology:** Processes derived from organics or biological vectors including exposure to pathogens, microorganisms, toxins and bioactive substances | Outbreaks of disease, transmission of disease infections from animals and plants |

Source: Modified from Tarbotton et al. (2015)

## CONCEPT OF FLOOD HAZARD

Flood phenomena is classified in the category of natural hazards or hydrometeorological hazards (Dickson et al., 2012; Tarbotton et al., 2015). There are several variables that can be used to determine the level of flood hazard. The flood hazard variables are determined based on the characteristics or nature of floods (Tincu et al., 2018). The characteristics of floods comprise the depth level (Cancado et al., 2008), duration and frequency of occurrence (Wika Ristya, 2012), velocity (Albanoa et al., 2017), amount of discharge (Messner & Meyer, 2005), and so on. However, flood depth is the most influential flood hazard variable towards damages of residential building structures and business disruption (Kreibich & Thieken, 2009; Neto et al., 2016).

The level of flood hazard can be classified into three levels, namely low, moderate and high (Wika Ristya, 2012; Cancado et al., 2008). Flood depth level of less than 0.5 metres can be categorised as low hazard level. When the flood depth level is 0.5 metres to 1.5 metres, it is categorised as moderate hazard level. Flood depth level of more than 1.5 metres, on the other hand, is classified in the high hazard level category (cancado et al., 2008). From the aspects of incident duration, floods that happen less than 24 hours is classified in the low level. Moderate and high flood hazard levels, respectively, are when the time period of a flood event happen for 24 hours to 48 hours, and more than 48 hours. Wika Ristya (2012) also explained that the frequency of flood events less than six times a year is classified in low hazard. Moderate and high hazard levels would occur when the frequency of flood events are six to eleven times a year, and eleven times a year, respectively (refer to Figure 2).

Table 2: Classification of Flood Hazard Levels

| **Characteristics of Flood** | **Criteria** | **Level** | **Reference** |
|---|---|---|---|
| Flood Depth | <0.5 metres | 1 (low) | Cancado et al., (2008) |
| | 0.5 – 1.5 metres | 2 (moderate) | |
| | >1.5 metres | 3 (high) | |
| Frequency of floods in one year | <6 occurences | 1 (low) | Wika Ristya (2012) |
| | 6–10 occurences | 2 (moderate) | |
| | >11 occurences | 3 (high) | |
| Duration of flood event | <24 hours | 1 (low) | Wika Ristya (2012) |
| | 24-48 hours | 2 (moderate) | |
| | >48 hours | 3 (high) | |

Source: Modified from Wika Ristya (2012) and Cancado et al., (2008)

## INFLUENCE OF FLOOD HAZARD LEVEL ON RISK OF LOSS OF PROPERTY, DEATH, ACCESSIBILITY AND ECONOMY

According to Cancado et al., (2008), flood depth level of 0.5 metres to 1.5 metres (moderate hazard level) can cause damage to properties in the house in addition to causing stranded movement. Flood depth level of more than 1.5 metres (high hazard level), on the other hand, has the potential to cause minor damage to the frame structure of a house. At this stage, the risk of casualties is also high. Low flood hazard level will only occur if the flood depth is less than 0.5 metres. At that depth level, on-foot actitvity to weather the flood can still be done by adults (refer to Table 3).

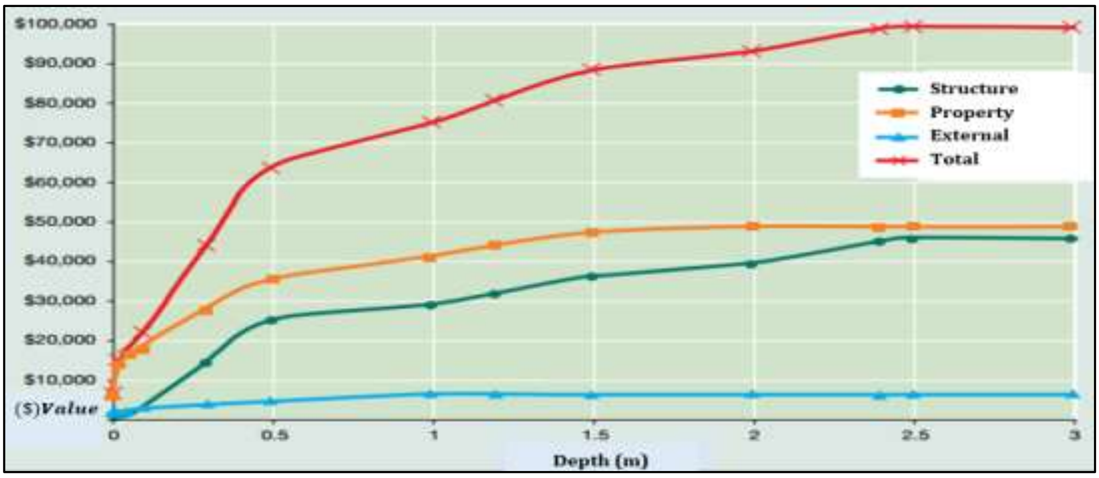
Besides that, losses due to floods can be measured based on economic value. A modern single-storey house that is flooded at the depth level of less than 0.5 metres (low hazard) has the potential to cause losses worth no more than $64,000 (Australian Dollars). On the other hand, floods with a height of 0.5 metres to 1.5 metres (high hazard) can cause losses worth $64,000 to $88,000. The value of loss can reach up to $100,000 if the level of flood stagnation exceeds 2.5 metres. The amount takes into account losses in the form of property (carpets, furniture items and electrical appliances), external losses (gardens, fences and garages), and damage to home structure (refer Figure 2).

Table 3: Risk of loss based on the factors of flood's Depth and Velocity

| **Hazard Level** | **Depth level** | **Risk** |
|---|---|---|
| High | D>1.5 | Minor damage to the frame structure of a house and risk of death is high if the velocity is in the range of 1.51 m/s - 1.99 m/s |
| Moderate | 0.5 <D< 1.5 | Damage to property and action to wade through floodwater is not possible if the velocity is halaju 0.5m m/s – 1.49 m/s |
| Low | 0.1< D< 0.5 | Flooded areas can be weathered by adults if the velocity is in the range of 0.1 m/s - 0.49 m/s |

(Source: Modified from Cancado et al., 2008)

Figure 2: Influence of Flood Depth Level from the aspect of Economic Loss




Source : Modified from Hawkesbury-Nepean Floodplain Management Steering Committee (2007)

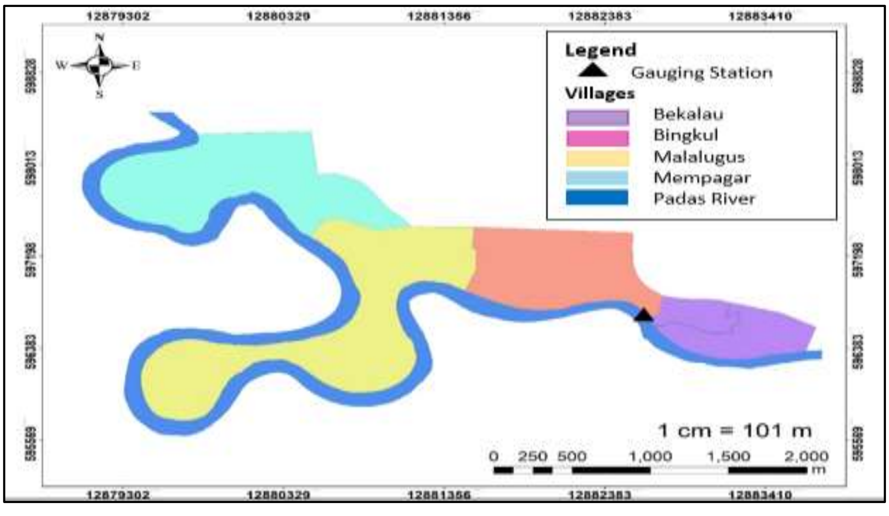
## RESEARCH METHODOLOGY

The level of flood hazard in this study was determined through the process of analysis of several variables such as frequency, duration of incident (Wika Ristya, 2012) and flood depth (Cancado et al., 2008). However, before the variables of frequency and duration of incident were obtained, one must first know the level of flood depth. Therefore, to determine the level of flood depth over a period of 10 years, the use of hydrological data in the form of water discharge level is necessary. The value of water discharge level was observed through the Beaufort Discharge Station (refer to Figure 3). The data period used is from 2009 to 2018. This is because, according to Nur Hamiza Adenan (2015), the time-series data period of 10 years was found to be sufficient for forecasting purposes. Apart from that, the data period used is also updated and still suitable to represent the current state of water discharge. The hydrological data in the form of water discharge level of Padas River in this study were obtained from the Department of Irrigation and Drainage (DID), Inanam branch.

The analysis process of the flood hazard level in this study does not only use hydrological data. This is because in order to know the flood depth level in the study location, the hydrological data obtained must be intergrated with the height level of the site of houses. Hence, on-site level measurements process (of past flood events) were conducted using a measurement tape. The purpose is to find out the height level of the site of the houses found at the study location. The level measured are the effects formed from the flood incident on January 21, 2015. The flood incident on that date was one of the largest flood cases in the period of 10 years from the date this article was written. The height value of the site was obtained by substracting the value of the level measurement from the result of peak discharge reading on January 21, 2015. The total samples in this study are 241 houses. The determination of the sample size was based on the equations gazetted by Yamane (1967).

In this study, the data of discharge level obtained were analysed using the microsoft excel software. Through the analysis process, the findings on the frequency and duration of flood events based on the depth level over a period of 10 years have been obtained. The analysis results were presented descriptively in the form of frequency and percentage values. The classification on the flood hazard level in this study is based on Cancado et al., (2008) and Wika Ristya (2012) (refer to Table 2).

Figure 3: The location of the discharge station situated in Bingkul Village



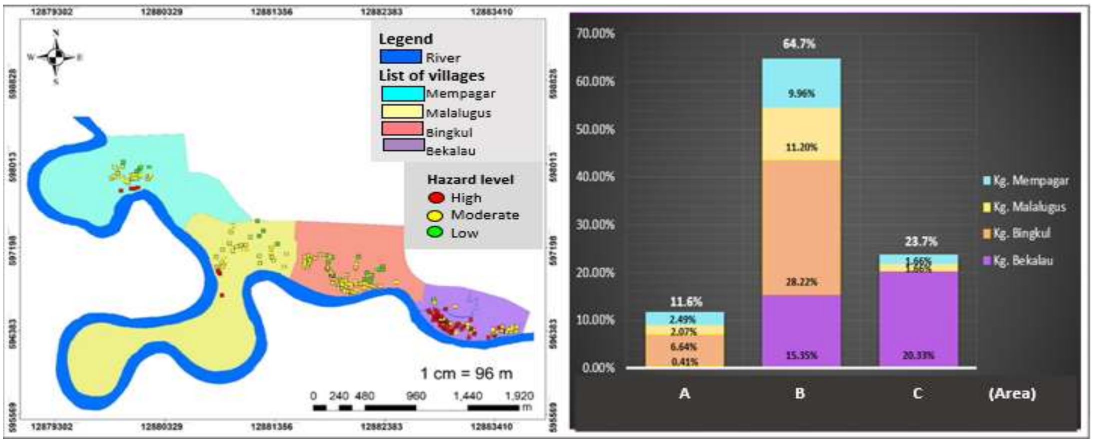
## RESEARCH FINDINGS

### EXPOSURE LEVEL OF FLOOD HAZARDS TO THE POPULATION AT THE STUDY LOCATION

The level of exposure to flood hazards in each area varies. It depends on several factors such as the distance of the house from the river bank and the height of the house's site area. This study found that a large number of the houses at the study location have a distance of less than 400 metres from the banks of Padas River. The distance of the position of a house that is less than 400 metres is exposed to flood hazard. Figure 4 shows three categories of the height of site area placement, namely Areas A, B and C. Each category of the site area has varying position or height level.

The lowest height position of the site is in Area C which is 6.27 metres from the minimum reading level of the discharge station. Area A has the highest topographic condition of 9.02 metres from the minimum reading level of the discharge station. Area B which has a height of 8.02 metres from the minimum reading level of the discharge station is higher than Area C but lower than Area A. The analysis found that most (64.7%) of the total population at the study location built their houses in Area B. While only 11.6 per cent and another 23.7 per cent live in Area A and Area C, respectively.

Figure 4: Height Level of the House's Site Area at the Study Location



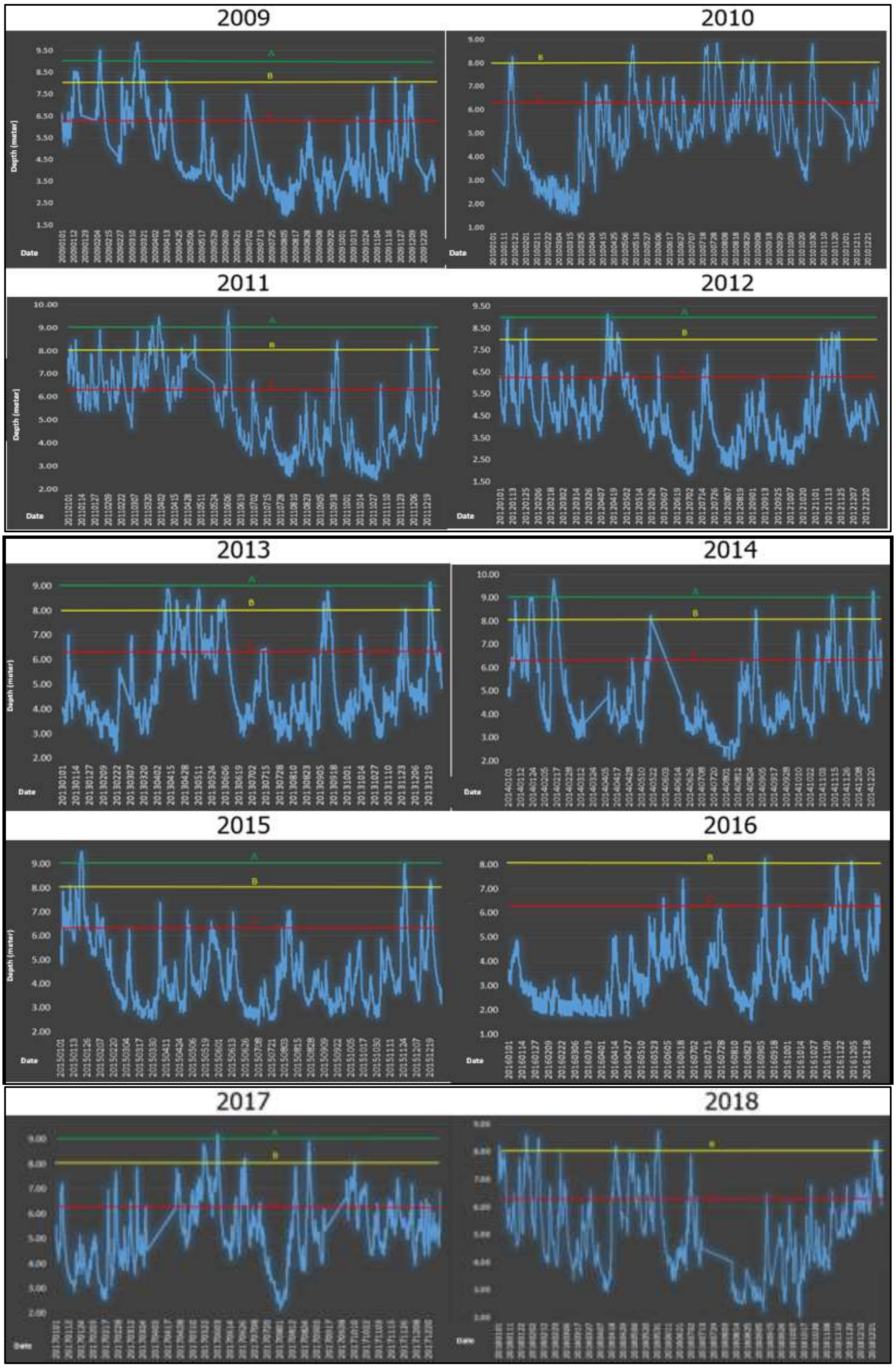

### Annual Analysis of Flood Hazard Based on Area Category

Figure 5 shows the hydrograph of the water discharge at the study location over the period of 10 years. This study found that the measurements of peak discharge varied every year. Different measurements of peak discharge will also result in different depth measurement and duration of flood events. The highest peak discharge was in the year 2009 with a measurment of 9.88 metres from the minimum reading level of the discharge station. The peak discharge with that height resulted in flood depths of 3.61 metres, 1.86 metres and 0.86 metres in Areas C, B and A, respectively. The duration of flood events in Area C was 16 days while Area B experienced six days of floods.

The second highest peak discharge was in 2014 (9.76 metres) which caused floods with depth level reaching 3.49 metres, 1.74 metres and 0.74 metres in Areas C, B and A, respectively. The flood event that happened in Area C at that time took nine days to recede while it took five days for Area B. In 2018, the highest peak discharge was only 8.76 metres deep. The discharge water with that height caused floods with a depth of 2.49 metres in Area C and 0.74 metres in Area B, respectively. The duration of floods produced was six days for Area C and two days for Area B, respectively.

In 2015, the highest peak discharge was measured at 9.52 metres from the minimum reading level of the discharge station. The peak discharge reading was observed from January 21 at 11.30pm. The peak discharge with the depth measurement was the third highest during the period of this study (2009 to 2018). The height measurement of the peak discharge has caused flood occurrence in Area A with a depth of 0.5 metres. The depth of flood level in Area B at that time, on the other hand, was 1.5 metres while Area C had a depth flood level of 3.25 metres. The peak discharge with the height measurement was found to have caused flood events in the duration of eight days for Area C and three days for Area B.

Figure 5: The hydrograph of water discharge over the period of 10 years (2009-2018)




## LEVEL OF FLOOD HAZARD IN BEAUFORT FLOODPLAIN

Figure 6 shows the average annual flood frequency for the categories of Areas A, B and C. This study found that the level of flood hazard varies for each area category. The total frequency of annual flood events in Area C from the year of 2009 to 2018 is in the high hazard level category. The highest total frequency of flood incidents for the area category was in 2011 which is 46 cases.

However, in 2016 the total frequency of flood incidents showed a decrease to 13 cases, then increased again to 42 cases in 2018. On average, the total frequency of floods in Area C is 35 cases per year.

On the other hand, Area B shows a relatively unique trend in flood frequency. In the year 2011 to 2014 and 2018, the flood hazard level fell into the high category. In contrast to the years of 2009, 2010, 2015 and 2017. The total of flood frequency was at a moderate hazard level. Only in 2016 that the total of flood frequency fell in the low category. Even so, overall, the total of flood frequency in Area B is dominantly still at high and moderate hazard levels. Area A still shows flood situations that are under control. The total annual flood frequency was largely at a low hazard level except for 2011 and 2014. In those years, the flood hazard level was classed in the moderate hazard category.

Figure 6: Annual Flood Frequency in Areas A, B and C

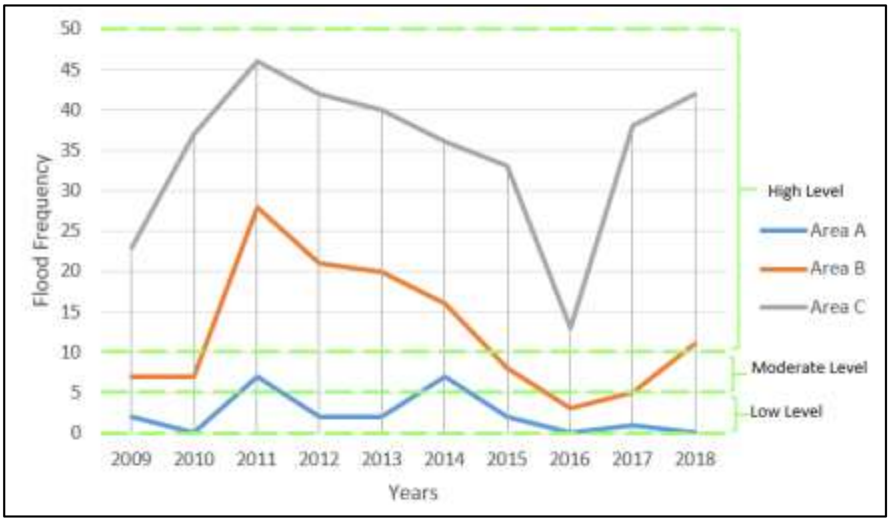



Figure 7 shows the average frequency of floods that occurred in Area B based on the depth level and duration of the incident. The average number of floods that occured in the area reached 12 to 13 cases per year (high hazard level). Of that number, 59 per cent were less than half a metre deep. If converted to the form of frequency, the number of flood incidents is equivalent to seven to eight times a year. The number of flood incidents that occured at a depth of 0.5 metres to 1.5 metres (moderate hazard) is four to five cases (37%) in a year. The remaining four per cent is more than 1.5 metres deep. In other words, flood events at high hazard levels occured once every two years.

From the aspect of duration of incident, 67 per cent from the flood incident series was at a low hazard level. The analysis also found that flood incidents that happened less than 24 hours are eight to nine cases (8.5 times) a year. Apart from that, it was found that a total of 18 per cent from the series of flood events overall occurred in a time period of more than 48 hours (high hazard). The total percentage is equivalent to two cases (2.2 times) a year. Meanwhile, the number of floods that occurred in a period of 24 hours to 48 hours (moderate hazard) is almost two cases (1.9 times) a year.

Figure 7: The Depth and Duration of Flood Incidents in Area B

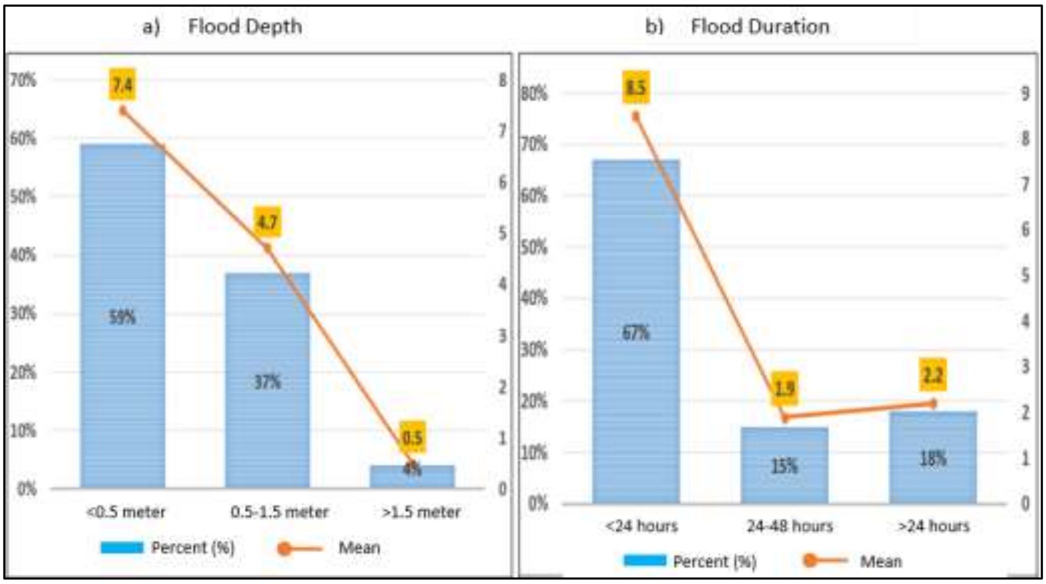
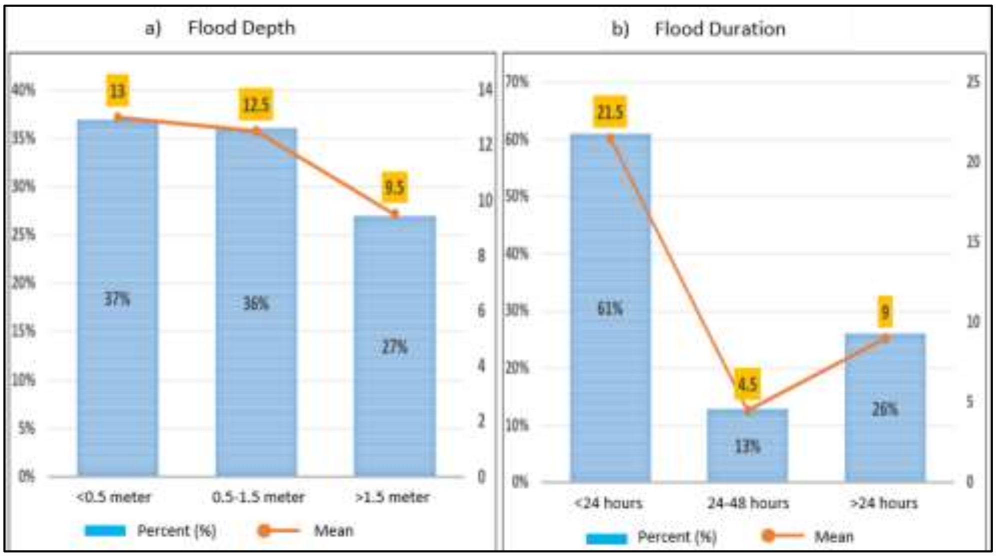


Figure 8 shows the average frequency of floods that happened in Area B based on the duration of event and its depth. Of the total average flood frequency (35 cases) in a year, 36 per cent (12 to 13 cases) had a depth range of 0.5 metres to 1.5 metres. Meanwhile, another 27 per cent occurred at a depth level of more than 1.5 metres (high hazard). The percentage value is equivalent to nine to 10 times a year. On the other hand, the total of flood events that happened at a depth level of less than 0.5 metres is 13 times in a year (37 per cent).

Meanwhile, in terms of flood duration, more than half (61%) from the total of flood incidents that happened every year occurred less than 24 hours (low hazard). The total percentage is equivalent to 21 to 22 times of flood events per year. This study found that 13 per cent of the total of flood incidents that occurred in a year is in a duration of 24 hours to 48 hours (moderate hazard) or equivalent to four to five times per year. Meanwhile, flood events that happened in a duration of more than 48 hours (high hazard) were nine times in a year (26 per cent). The total frequency of the floods is twice as large compared to the total percentage of floods that happened at moderate hazard levels.

Figure 8: Depth and Duration of Flood Events in Area C




## DISCUSSION

In general, it can be explained that the level of flood hazard at the study location varies. It depends on the site position of the resided house. Area A, for example, is less exposed to flood hazard as it has a higher position compared to the two other areas. It is this situation that causes the flood hazard in Area A to still be under control. However, the number of respondents living in Area A is only 11.6 per cent compared to the total of study samples. Most of the other 88.4 per cent reside in Area B and Area C (refer to Figure 4).

The number of flood incidents that happened in Area B at a depth level of 0.5 metres to 1.5 metres (moderate hazard) is four to five times in a year (refer to Figure 7). For Area C, the number of flood events that occurred at that depth level is 12 to 13 cases per year (refer to Figure 8). On average, the flood incidents at a moderate hazard depth level in Area C is equivalent to one case per month. The number is almost three times higher compared to Area B. This matter should not be taken lightly because according to Cancado et al., (2008), flood events at that depth level could cause damage to households. If the flood velocity is high (0.5m/s to 1.49 m/s), the act to wade through the water is not possible. Other than that, the potential for death or injury in the affected areas is also quite high (Komi et al., 2016). From the aspects of economy, flood events at that depth level could cause losses worth $64,000 (Australian Dollar) to $88,000 (Hawkesbury-Nepean Floodplain Management Steering Committee, 2007).

The average number of flood events that occurred at a depth level of more than 1.5 metres (high hazard) in Area B is once in two years (refer to Figure 7). In contrast to Area C, the number of flood events that happened at that depth is nine to 10 cases per year (refer to Figure 8). The number is almost 20 times higher compared to Area B. This shows that the potential of losses faced by residents in Area C is much higher compared to residents in Area B. According to Cancado et al.,(2008), moving activities using trucks may unlikely succeed in a flood situation with a depth of more than 1.5 metres. The potential for casualties and damage to the frame structure of a small house is also high. Other than that, Komi et al., (2016) found that flood incidents at that depth level could cause broad damage to properties. If measured based on economic value, the potential of loss can reach up to $100,000 for a house (Hawkesbury-Nepean Floodplain Management Steering Committee, 2007).

The flood hazard level from the aspect of duration also has a high frequency at the study location, particularly Area B and Area C. On average, the number of flood events that occurred in Area C in a duration of more than 48 hours (high hazard) is two cases per year (refer to Figure 7). Water stagnation in the area sometimes even takes up to six days to fully recede (refer to Figure 5). The total average of flood frequency at that hazard level was found to be higher for Area C (9 cases) (refer to Figure 8). The duration of water stagnation in that area could even last for more than two weeks before it fully recedes (refer to Figure 5). According to FEMA Gov (t th), this situation is common in the context of a floodplain. Even in some other places, the duration of floods is longer that it could reach up to one month (Norazuan Md Hashim & Siti Aisah Shamsudin, 2006).

There are seveal negative impacts as a result of the long period of floods. Apart from the impacts toward health, the long period of floods has the potential to cause damage to a house's structural components. This is because, a house structure that uses building materials such as fiberboard, gympsum and wood when exposed to floods over a long period will be more prone to molding, rotting and damage that could cause health problems. (FEMA Gov, t th). Other than that, Penning Rowsell et al., (2005) found that the potential to develop Hypothermia disease is even higher if an individual is trapped indoors for a long time (several days) during a flood.

However, the potential of risk of losses is not only influenced by the flood hazard element alone. This is because, the risk of flood losses can also be minimised by increasing the level of coping capacity even in situations where the hazard level is high (White et al., 2005; Djati Mardiatno et al., 2012). The low vulnerability level among the residents is also a crucial factor in minimising the level of risk of loss (ISDR, 2004, Birkmann et al., 2013). Therefore, by increasing the level of coping capacity and minimising the level of vulnerability, it could balance the levels of flood hazard so that the risk of loss can still be under control.

## Conclusion

In conclusion, most of the areas in the study location is extremely vulnerable to flood hazard, especially for the Area A and Area B categories. Not only on the aspect of frequency, the flood occurrence in these areas sometimes lasts for a long period of time and reaches depth levels of more than 1.5 metres. This situation, if not efficiently and systematically managed, will surely cause risk of loss to the local residents. The types of risk of loss include property damage, house structure damage, health disruption, interuption to accessibilty, and more. Hence, to minimise the risk of loss, measures to increase the level of coping capacity should be carried out.

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