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Research paper

Assessment of Flood Risk Analysis in Selangor

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Abstract

Flood events occur every year especially during the monsoon season. Although its consequences are not as disastrous as other natural disasters such as earthquakes and tornado storm, but it still gives off a great deal of destruction towards social, operational and financial sectors. Recently, most of the events occurred are not happened at the common marked areas and seasons. It happened anywhere and anytime. Hence, it is not surprise that at any time, any place could be affected by flood incidents. Therefore, an analysis on flood incident is crucial in mitigating the flood risk and at the same developing the flood safety measures. This study aims to analyse the flood frequency and flood magnitude of all nine districts in Selangor. Data is gathered from the Department of Irrigation and Drainage (DID) Selangor, from 2008 to 2017. Petaling Jaya posted the highest number of flood cases at 249 cases out of 1,161 cases in Selangor throughout the period of 2008 to 2017. Poisson distribution was used to estimate the probability of flood occurrence, and the results show that Petaling Jaya has recorded the highest probability of flood occurrence with at least one event in a day. For severity analysis, Gumbel distribution was used to estimate the magnitude of flood occurrence and flood frequency through the evaluation of flood risk from the annual maximum number of rainfall data. Results indicate that Sabak Bernam recorded the biggest magnitude of severity with moderate flood as compared to other districts. It is also estimated that Sabak Bernam has the biggest magnitude of flood recurring as early as two years return period. To conclude, authorities must work vigorously towards an efficient flood risk management and effective flood safety measures. The establishments of flood forecasting and warning system are crucial in minimising the flood losses.

Keywords: *Flood Occurrence; Rainfall; Insurance; Poisson; Gumbel.*

1. Introduction

Situation nowadays has been improved tremendously, especially when it comes to precautions and safety measures of new development projects. Most of the developments and constructions now, have deployed the highest level of safety measures and environmental friendly aspects as their standard operating procedures. However, as they have put much awareness on these aspects, this effort is still lacking in addressing the flash flood issues. Flood issue is one of the problems that has not been completely resolved and become rampant despite many precautions have been undertook by the developer. These issues are worsening as they involve injuries as well as loss of lives and damage of properties.

This study focuses on the flood occurrence in Selangor only. Selangor is one of the most populated states in Malaysia with flood issues become one of the main problems recently. The event is caused by either a natural phenomenon such as heavy rainfall, or by manmade contributions from the misuse of land and rubbish disposal near water reservoir and waterways. As the natural causes of flood can be considered as the act of God that cannot be changed, however, the manmade causes that contribute to the flood are manageable and controllable. Under the risk management regime, such events can be controlled and monitored by the authority as to mitigate the number of events and at the same time to minimise the amount of the loss. Risk management is the process of identifying, evaluating and prioritizing the risks through the systematic and economic application of resources in minimising, monitoring and controlling the probability and magnitude of the occurrences. Risk management is widely used in many sectors including financial [1], operational [2] and technological [3]. Related studies on flood events have been conducted earlier by many researchers. For example, [4] carried out a study on finding the appropriate number of temporary relief centres for flood evacuees. [5] conducted a study on tracing changes of dry spells in Peninsular Malaysia based on the daily rainfall collected from 36 selected rainfall stations all over Peninsular Malaysia.

In May 2016, the state government of Selangor has identified 37 spots around Selangor that are affected by flood. In the recent statistics, the flood evacuees in Selangor reached 497 people from 119 families in October 2016. The highest water level recorded during the mishap was 5.7 meters. This shows that flood is not only damaging the properties but also threatening our lives. The earlier occurrence of flood in December 2006, has alarmed the authorities that preventive measures have to be taken appropriately to avoid losses of lives and properties. The flood that strike four states in the Peninsular Malaysia which are Melaka, Johor, Pahang and Negeri Sembilan has caused more than 100,000 people to be relocated and 18 fatalities was reported [6].

Therefore, a statistical study of flood risk analysis is deemed crucial to avert the event from raking such high losses and to mitigate the flood risks. The aims of this study is to analyse the pattern and to estimate the probability of flood occurrence in Selangor. Consequently, this study aims to determine the severity of flood occurrence event through the establishment of flood risk analysis model. The efficient

and effective solutions may resolve the situation. A proper and scientific study on flood occurrence may reduce the risks of flood and increase the quality of the society, as well as our government authorities in improving the management and implementation of flood control measures in order to provide a safer environment for everyone.

2. Literature review

Flood happens when there are overflowing of water from water stream to the dry land. According to DID, Department of Irrigation and Drainage, there are 3 categories of flood in Malaysia. These types of flood are categorized as monsoonal, flash or tidal flood and its occurrences and durations are based on the location, characteristic, causes and time of the day. Monsoon flood occurs when monsoon rain continues to pour nonstop and it usually occurs in November and December. Flash flood happens when there is sudden change in temperature that leads to heavy rainfall while tidal flood occurs in areas that are near sea level such as street during high tide.

When land that is usually dry has been submerged by overflow of water, the event is known as flood. According to Department of Irrigation and Drainage, there are two main causes that can lead to flooding event, either naturally or induced by human. Flood always happen naturally when there is a sudden change in temperature that lead to high intensity rainfall making the dry land become inundated. Act of disposing solid waste as well as construction development sediment that stays in the waterways and drainage are induced by irresponsible humans. This leads to flood event occurring even if the intensity of rainfall is less than what can usually trigger the event.

This issue regarding flood is crucial since the social disturbance caused by flood has seriously undermined the quality of life. Thus, this research could greatly benefit government sector. Our analysis will provide the information regarding flood risk in Selangor. This could help the government to review current regulations regarding this matter. Also, in order to minimize the losses in the future, new alternatives should be contributed. It might also be useful for the future scientists to dive further into this issue.

In Malaysia, flood management is focusing on the urgency to provide immediate flood relief works as well as to implement flood risk mitigation to curb with the continuous urban development.

The Department of Irrigation and Drainage (DID) of Malaysia has introduced the new non-structural measures that is in line with the requirement under Manual Saliran Mesra Alam that has been enacted as a mandatory requirement to be complied by all new urban development projects since 2001. Under this regime, two approaches have been adopted, namely, Integrated River Basin Development and the Integrated Flood Management as part of the flood management programs. These programs provide a balanced approach between structural and non-structural measures as well as higher levels of public participation.

Above all, issues pertaining to flood risks are manageable if proper action is taken to monitor and maintain the waterways and drainage system. The government should also take more aggressive action to control manmade causes of flood and to address the situation extensively to prevent from any loss due to flood. It is also public responsibilities to work hand in hand in properly disposing the rubbish as to not let the drainage system get clogged. Participation from public is also vital in creating awareness to the society on the precautions and preventive measures as well as flood management approach.

3. Methodology

3.1. Data collection

The data of number of flood cases based on nine districts (Petaling Jaya, Klang, Sepang, Hulu Langat, Hulu Selangor, Kuala Langat, Kuala Selangor, Gombak and Sabak Bernam) in Selangor for the year 2008 until 2017 and annual rainfall data for the year 2008 until 2017 were used to analyse the pattern of flood events whereas, the data of number of flood cases based on districts in Selangor for the year 2008 until 2017 were used to find the probability and severity of flood occurrence. All data was collected from Department of Irrigation and Drainage (DID) in Ampang.

3.2. Poisson Distribution

The probability of flood occurrence in Selangor is estimated using Poisson distribution. [7] in their studies, applied the Poisson distribution on the peaks-over-threshold sampling method to model the flood occurrence within each season. [8] applied the Mixed Geometric Poisson distribution on studying the distribution of dry and wet spells in Peninsular Malaysia. A year later, [9] have extended other probability distribution like Log Series distribution, Compound Geometric distribution and Mixed Two Geometric distribution, Polya distribution, Mixed Two Geometric distribution and Modified Log Series distribution on their study on the spatial distribution of wet and dry spells at ten selected rainfall stations in Peninsular Malaysia. In their study, they found that Mixed Two Geometric distribution was best fits the distribution of wet and dry spells respectively.

Since the flood events occur randomly and independently due to their nature as a natural disaster, the probability of an event occurring in a given time interval does not vary with time. In this study, we apply the Poisson distribution to estimate the number of flood occurrence in a day. The probability of observing x events in a given interval is given by;

$$P(X = x) = \frac{e^{-\lambda}\lambda^{x}}{x!}, x = 0,1,2 \quad (1)$$

where:

X = The number of flood occurrences in a day
λ = The average number of flood occurrences per day
P (X = x) = The probability that there are x flood occurrences in a day
In this study, the yearly data on number of flood cases in Selangor for 10 years is therefore;

$$\lambda = \frac{Total\ number\ of\ flood\ cases\ per\ year}{365\ days} \quad (2)$$

3.3. Gumbel Distribution

Gumbel distribution is a statistical technique that frequently applies for foreseeing natural disaster events [10]. [11] found that the frequency analysis is depending on the extreme values which is applied in Gumbel method that can be developed for theoretical distribution. Hence, this study uses Gumbel method to find a frequency factor by relating the flood discharge values to the return periods in order to provide an intense measurement of flood event.
The equation of Gumbel distribution in recognising whether the data is fitted or not at different return periods, T is;

$$Q_t = Q_{av} + K_\sigma \tag{3}$$

where:
Q_t denotes the magnitude of the T-year flood event
K is the frequency factor
Q_{av} is the mean of the annual maximum number of rainfall
σ is the standard deviation of the annual maximum number of rainfall
and K is expressed as;

$$K = -\frac{\sqrt{6}}{\pi}\{\lambda + \ln(\ln T - \ln(T-1))\} \tag{4}$$

where:
π =3.14
λ is the Euler constant (=0.5772)
ln is the natural logarithm

4. Results and discussions

4.1. Analysing pattern of flood occurrence

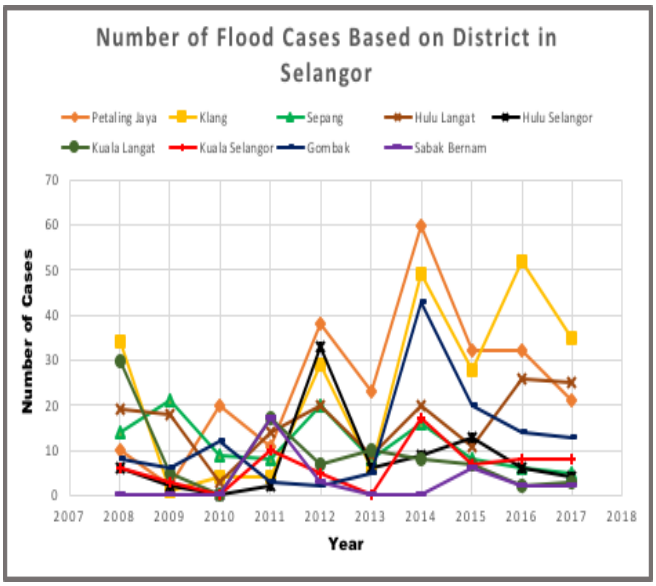

Fig. 1: Number of Flood Cases Based on Districts in Selangor

Petaling Jaya is reported to have the highest number of flood cases totalling 249 cases out of 1,034 cases. According to the report given by the Department of Irrigation and Drainage, flood cases are prone to happen in district of Petaling Jaya were due to its geographical landscape of the area. As the district has many lowlands area, in the event of heavy rain the location is highly exposed to flood. Besides that, Klang, Hulu Langat, and Gombak also reveal higher number of flood cases as compared to remaining districts raking up to approximately more than 500 cases.
On the lower side, Sabak Bernam has only 30 flood cases reported for the period under study. And other district reported to have low cases amounting to 234 are among district of Hulu Selangor, Kuala Selangor, and Kuala Langat. The area is reportedly to have highlands making it hard for them to encounter any flood problem.
The contributing factors that may lead to flood occurrence in Petaling Jaya are heavy and continuous rainfall, also the condition of its drainage and irrigation system. The loss values estimated for the flood event are vary, depending on the magnitude of each event.

4.2. Analysing annual maximum rainfall

The maximum rainfall data was sorted out by extracting the highest number of rainfall and the lowest number of rainfall from the rainfall data. In this study, we focus on districts of Petaling Jaya and Sabak Bernam as they are reported to have the highest and the lowest number of flood cases in Selangor.

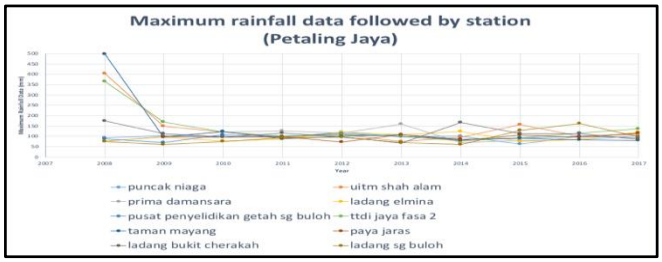

Fig. 2: Maximum Rainfall data followed by Stations (Petaling Jaya)

Figure 2 shows the annual maximum number of rainfall throughout 2009 until 2017 of Petaling Jaya. Concernedly, in 2008, Taman Mayang station was recorded the highest annual maximum number of rainfall at the level of 498.5mm followed by UiTM Shah Alam station at 402.9mm and TTDI Jaya Fasa 2 station at 366.1mm. In contrast, Ladang Sungai Buloh station was recorded lowest annual maximum number of rainfall followed by Pusat Penyelidikan Getah Sungai Buloh, Ladang Elmina and Puncak Niaga stations.
As reported by the Department of Irrigation and Drainange (DID), factors contributing to the flood in Petaling Jaya are due to heavy rain that lasted more than four hours, overflowing water from Sungai Buloh, Sungai Kuyoh and Sungai Pelumut, and also due to 'back water' system that is not well-functioned that blocked the water to flow back into the river.

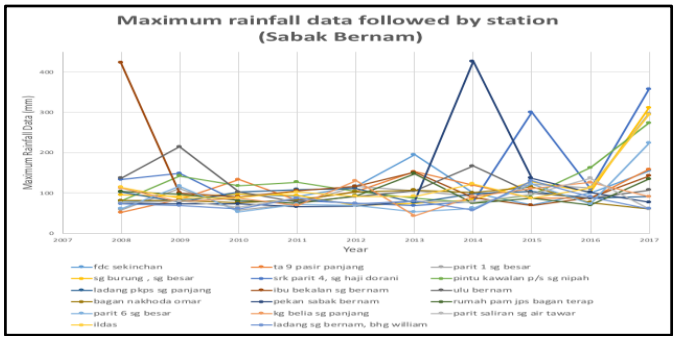

Fig. 3: Minimum Rainfall data followed by Stations (Sabak Bernam)

Figure 3 shows the annual maximum number of rainfall throughout the year of 2008 until 2017 for Sabak Bernam. The range of the movement of annual maximum number of rainfall is widely spread from 40 mm to 350 mm. Concernedly, Ibu Bekalan Sungai Bernam and Pekan Sabak Bernam stations recorded the highest annual maximum number of rainfall at the level of 422.4 mm in 2008 and 426 mm in 2014 respectively. Besides that, Parit 4 Sungai Haji Dorani station also recorded highest annual maximum number of rainfall at 357.5 mm in 2017 followed by Sungai Besar station at 311 mm, ildas station at 294 mm and Pintu Kawalan Sungai Nipah station at 273 mm. In contrast, most of the record of annual maximum number of rainfall from 2010 until 2012 for all stations are at the range between 50 mm until 150 mm with the lowest at Parit 6 Sungai Besar station at 53 mm in 2010.
As reported in the annual flood report by the Department of Irrigation and Drainage (DID), factors contributing to the flood in Sabak Bernam are due heavy rain that lasted more than two hours which resulting in flash flood to occur, water overflowed, overflowing water from the river, lowlands at the rainfall reservoirs, the drainage system and 'back water' system is not functioning properly obstructing rainfall to flow back into the river.

4.3. Probability of flood occurrence

In order to estimate the probability of flood occurrence, it is necessary to evaluate the annual data for different district with similar flood risk. Besides, it is vital to observe and compare the probability of flood occurrence by considering different locations of rainfall station for each year. In this analysis, data of flood statistics based on rainfall stations in Selangor is required to determine which location contributes higher probability of flood occurrence in a particular year.

Table 1: Probability of Flood Occurrence Throughout year 2008 until 2017 for each district

	Year									
District	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Petaling Jaya	0.02703	0.00546	0.05332	0.02969	0.09887	0.06107	0.15158	0.08394	0.08394	0.05591
Klang	0.08894	0.00274	0.01090	0.01090	0.07638	0.01630	0.12563	0.07384	0.13278	0.09144
Sepang	0.03763	0.05591	0.02436	0.02168	0.05332	0.02168	0.04289	0.02168	0.01630	0.01361
Hulu Langat	0.05072	0.04812	0.00819	0.03763	0.05332	0.02436	0.05332	0.02969	0.06875	0.06620
Hulu Selangor	0.01630	0.00546		0.00546	0.08644	0.01630	0.02436	0.03499	0.01630	0.01090
Kuala Langat	0.07890	0.01361		0.04551	0.01900	0.02703	0.02168	0.01900	0.00546	0.00819
Kuala Selangor	0.01630	0.00819		0.02703	0.01361		0.04551	0.01900	0.02168	0.02168
Gombak	0.02168	0.01630	0.03234	0.00819	0.00546	0.01361	0.11113	0.05332	0.03763	0.03499
Sabak Bernam				0.04551	0.00819			0.01630	0.00546	0.00546

highest probability of flood occurrence
lowest probabilty of flood occurrence

Assumption: Based on the rainfall data only

From the Table 1, it shows the probability of flood occurrence throughout the year of 2009 until 2017 for each district in Selangor. Petaling Jaya dominated the highest probability there will be at least one flood occurrence in a day as compared to other districts. Petaling Jaya holds the 5 years record of flood occurrence in 2010 and 2012 - 2015. Meanwhile, Klang district recorded the highest probability that there will be at least one flood occurrence in a day for the year of 2008 and also for years 2016 and 2017. For Sepang, Kuala Langat, and

Sabak Bernam, each of these districts holds record for one year only. Sepang holds the record in 2009 while Kuala Langat and Sabak Bernam both share the record for 2011 respectively.
As such, Department of Irrigation and Drainage (DID) and National Disaster Management Agency (NADMA) should step up their management and enforcement upon the irrigation and drainage system on the location that are prone to flood occurrence especially lowlands areas in Petaling Jaya.

4.4. Analysis of flood risk

Gumbel distribution was used to predict the magnitude or estimation of the T-year flood event at different return periods of T, the estimation of how frequent at a certain event the flood occurrence will occur.

Table 2: Magnitude of Flood Event

No Flooding	Minor Flooding	Moderate Flooding	Major Flooding
0	1 to 2	3 to 4	>5

Results conclude that the highest magnitude of flood for different return period, T selected, is reaching approximately 500 and the lowest amount was zero indicating there are no flood occurrence. As the flood magnitude were measured in percentage (%), all the value of the magnitude of flood should be divided by 100.

Table 3: Magnitude of Flood Event

	District								
Return Period, T	Petaling Jaya	Klang	Sepang	Hulu Langat	Hulu Selangor	Kuala Langat	Kuala Selangor	Gombak	Sabak Bernam
2	1.6445	1.6238	1.2938	1.7522	1.6355	1.7185	1.6186	1.8753	2.2792
5	2.5900	2.3950	1.4922	2.5912	2.3410	2.4753	2.2243	2.9036	3.2869
10	3.2160	2.9057	1.6236	3.1467	2.8081	2.9763	2.6253	3.5845	3.9541
15	3.5692	3.1938	1.6977	3.4601	3.0717	3.2590	2.8515	3.9686	4.3305
20	3.8165	3.3955	1.7496	3.6795	3.2562	3.4569	3.0099	4.2375	4.5941
25	4.0070	3.5509	1.7895	3.8486	3.3983	3.6094	3.1320	4.4447	4.7971

From here, there are several possible explanations for this result. A possible explanation for this might be that Sabak Bernam had the highest flood magnitude as compared to other areas for all the selecting years in return period. The result above indicates that the flood magnitude for 2-year and 5-year return periods for all districts except Sabak Bernam on 5-year return period, are minor as they stand within the range of 1 to2. For 10-year return period, only Klang and Sepang recorded a minor flood occurrences. The rest of the districts posted a moderate magnitude with the highest score is recorded by Sabak Bernam.
Geographically, Sabak Bernam landscape is considered highland area that is potential to get higher annual number of rainfall among other districts and most of the populations in Sabak Bernam are working in an agricultural sector.
Contrary, according to the geographical landscape in Sepang, that is located between Kuala Lumpur and Negeri Sembilan to the west and east respectively, and Petaling Jaya to the north and Hulu Langat to the northeast, this has resulted Sepang to receive a minimum annual number of rainfall throughout the period under study.

5. Conclusion

As a conclusion, Petaling Jaya recorded the highest number of flood cases and probability of flood occurrence with at least one flood occurrence in a day. In contrast, Sabak Bernam had the lowest number of flood cases but in case of floods, the flood magnitude for Sabak Bernam is the most severe. Meanwhile, Sepang is considered the safest area in Selangor with the lowest flood magnitude ranging from 1 to 2.
Authorities must work together toward a better flood risk management and flood safety system in Malaysia. The provision of a flood forecasting and warning system is crucial to minimise the losses from flood. Early flood prediction helps people living in flood-prone areas to be warned and prepared for evacuation. This can considerably reduce flood loss and damage especially on human death. Therefore, the installation of flood warning sirens, which will automatically activate once the water level reaches a critical and danger point need to be done at the strategic locations. The installation aims to minimise flood damage should be install along certain urban rivers to alert the local residents of impending floods.
Among other natural hazards and possible disasters to be considered, floods are no longer a surprise in Malaysia. It is important for the authorities such as the Meteorological Department and the Department of Irrigation and Drainage (DID) have the systems to foresee such disasters and provide forewarning to the people for precaution and evacuation purposes. For instance, the Flood and Water Management Act 2010 was one of the solutions to prevent or reduce flood risks.
Furthermore, the Department of Irrigation and Drainage (DID) must regularly update and improve their data keeping system since it is crucial for researchers to further conduct studies on flood. In order to produce a more accurate and reliable flood forecasts for river flow and waterways, a long-term historical related data is important to measure the past rainfall and flood events. [12] stated that, "By combining historical information and real-time knowledge about the volumetric capacity in catchment areas, more accurate flood forecasts can be made". Currently, the data that we received from the department are limited. Other methods of flood risk analysis required more variety of data.

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