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Analysis of Thirty Years Recurrent Floods of the Pahang River, Malaysia

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ABSTRACT

Pahang River flows from its upstream at Cameron highlands to its downstream at Pekan into the South China sea. The hydrodynamics of Pahang river as well as data on the long term variation of its water level, rainfall and river flow from the year 1980 to 2009 have been identified based on analysis at three gauging stations, namely the Sg. Yap, Temerloh and Lubuk Paku Gauging Stations. The highest of the total rainfall was triggered by the Northeast Monsoon which occurs from November to March yearly. The average monthly water level of the Pahang River at Sg. Yap ranged from 43.49 m (July) to 45.36 m (Dec.), at Temerloh from 24.73 m (August) to 26.71 m (Dec.) and at Lubuk Paku from 12.70 m (July) to 15.23 m (Dec.). The recorded monthly rainfall at Sg. Yap was from 106.67 to 254.01 mm, while at Temerloh it was from 93.75 to 219.83 mm and at Lubuk Paku from 79.81 to 324.57 mm. The average monthly discharge of the Pahang River at Sg. Yap was 845.78 m^3 sec^{-1}, while at Temerloh it was 1008.50 m^3 sec^{-1}. At Lubuk Paku, the recorded monthly discharge was 1184.46 m^3 sec^{-1}. At least five critical points coincided with the flood events along Pahang River from the year 1980 to 2009.

Key words: Pahang river, discharge, northeast monsoon, hydrodynamics, flood hazard

INTRODUCTION

Being one of the tropical countries, Malaysia gets heavy rainfall all the year round; therefore, flood is a very common disaster in Malaysia. Nevertheless, Malaysia is free from huge natural disasters such as volcano eruptions, earthquakes, tsunamis and many others. In Malaysia, flood often occurs particularly during the wet season in the east coast area which is mostly influenced by the northeast monsoon (Gasim *et al.*, 2007).

Monsoons influence many parts of the world including Malaysia (Wang *et al.*, 2003; Kale and Hire, 2004; Sultan *et al.*, 2005; Colin *et al.*, 2010; Pal and Al-Tabbaa, 2010; Pattanaik and Rajeevan, 2010). The inter-annual variations of monsoon are often shown in the variation of the climatic trend that exist in the year-to-year variation of the seasonal transition and the inter-annual variation of the amplitudes of the intra-seasonal oscillations (Chen *et al.*, 1992). The factors which cause inter-annual variations of the monsoon are air-sea interaction, land surface effects and other external forces.

In Peninsular Malaysia, the climate is mainly affected by four seasons, namely two monsoons (the northeast and southwest monsoons) and two inter-monsoon seasons (Suhaila *et al*., 2010). The influence of the monsoons in the Peninsular is characterised by higher total monthly rainfall. Pahang Basin receives high total rainfall during the northeast monsoon period amounting to almost 40% of Pahang's total annual rainfall (Suhaila *et al*., 2010). The consequence of the extreme rainfall has an impact on Pahang River where it results in higher river flow and water level and finally contributing to serious flood events along the river in the basin (DID, 2005, 2009).

Pahang river is the longest river in Peninsular Malaysia with a length of 459 km. The upstream of this river is located at the Titiwangsa Main Range. Pahang River starts with two rivers, namely the Tembeling and Jelai rivers which meet at a confluence in Kuala Tembeling located 300 km away from the estuary of Pahang River (Kuala Pahang). The river meanders through townships such as Jerantut, Temerloh, Maran, Bera, as well as Pekan and lastly flows into the South China Sea which is located on the east coast of Peninsular Malaysia (Lun *et al*., 2011). Pahang River plays the role as the main drainage system that drains off water flowing from its upstream at Cameron Highlands into its downstream at Pekan, Pahang, particularly during the wet season. The overflowing water results in inundation within the basin area and this happens almost every year in particular from November to December, or sometimes extending into January (Lun *et al*., 2010).

Extreme rainfall has often resulted in the spilling over of the Pahang River leading to the overflow phenomenon especially at lowland areas. Normally, due to its dynamic system, a river would undergo the process of river evolution (Camporeale *et al*., 2007; Robert, 2003). However, climatic condition, especially rainfall as well as anthropogenic activities in the form of exploitation of natural resources and developments are the external factors which would always affect, increase and stimulate the dynamic process in rivers (Andersson *et al*., 2006; Singh *et al*., 2011). The landscaping measures would affect the flow patterns and peak water levels (Straatsma *et al*., 2009) and these changes may continue to result in river degradation (Jackson *et al*., 1995) through the sedimentation processes (Toriman *et al*., 2009a). In terms of Pahang River, its natural condition has been altered with the intensive developments in the basin area and is regulated by the weir structures-water impoundment at the upstream area in Cameron Highlands (Gasim *et al*., 2009a, b; Jaafar *et al*., 2010).

Although the monsoon rainfall is the main cause of flood events along Pahang River and thus far has been giving impact to flow pattern changes, anthropogenic factor could not be neglected (Fu and Wen, 1999; Fu, 2003; AlSaqoor *et al*., 2010). Urban climate is normally controlled by the regional natural climate system but in some cases it is affected by local urbanization (Ntelekos *et al*., 2010). Urbanization could significantly affect the precipitation climatology relating to flood events (Shepherd, 2005; Tuncay and Esbah, 2006). Archer *et al*. (2010) and Baris and Karadag (2007) believe that there is a relationship between timing of land use and hydrological change. Jung *et al*. (2011) mention that in 2050, changes in flood frequency will be more sensitive to climate change rather than land use change.

The biogeo-morphological function of lowland floodplains will strongly be altered because of future landscaping measures that are necessitated by climate change (Straatsma *et al*., 2009). Climate change prediction based on the General Circulation Model (GCMs) suggested that a 1.5-4.5°C rise in global mean temperature would increase global mean precipitation at about 3-15% (Sen, 2009). An analysis based on 33 years of daily temperature from selected areas in the Peninsular showed that the daily temperature fluctuated between 26.3 to 28.5°C in the lowland areas and between 17.8 to 19.8°C in the highland areas (Gasim *et al*., 2009a). All the activities of land use change have led to a physical impact on the ecosystem of Pahang River, particularly increase in soil erosion and higher sedimentation rate along the river. These have thus made the river shallower. Finally, Dastorani *et al*. (2010), Toriman *et al*. (2009b, c) and Hosseinpourtehrani and Ghahraman (2011) studied the flood prone in their study areas by using 1D water management models to determine precise mitigation measure for the future flood.

Having presented the background information, the objectives of this study are: (1) to determine the flow and water level pattern of the river due to extreme rainfall and (2) to evaluate the flow and water level pattern and its relation to the history of flood events of Peninsular Malaysia and (3) to estimate the impact of land use cover changes on flood frequency.

MATERIALS AND METHODS

Thirty years of hydrological data (1980-2009) of the Pahang River Basin including river discharge, water level and rainfall which have been recorded by gauging stations belonging to the Department of Irrigation and Drainage Malaysia (DID) have been used in this analysis. Available daily and hourly stage data were compiled from the records at the gages operated by DID in the upper Pahang River from Sg. Yap to Lubuk Paku Stations (Fig. 1). Meanwhile the statistical

Fig. 1: The location of Pahang river

analysis of data was carried out by using the co-relation method to analyze the relationship between the hydrologic and climatic factors. Establish hydrograph then was developed using simple discharge vs time for all gauging stations. The generated hydrographs were used to construct the of rating curve among the three stations in the study area. The water levels which were beyond the danger level (as proposed by DID) along with the highest discharges have also been identified. The 26 years of land use change (1984-2006) have been derived from the Malaysian Department of Agriculture. The thirty years of population growth (1990-2010) have been derived from the Department of Statistics, Malaysia.

RESULTS AND DISCUSSION

In this study, Pahang River's hydrological data for thirty years (1980-2009) were plotted and analyzed. Figure 2, 3 and 4 show the comparisons between the monthly water level and total rainfall at three gauging stations. The figures show that the average of the water level at Sg. Yap (Fig. 2) reached its highest (45.36 m) in December and reached its lowest level (43.49 m) in July while the average of the total rainfall at Sg. Yap reached its highest (254.01 mm) in October and its lowest (106.67 mm) in February. At Temerloh (Fig. 3), the water level reached its highest (26.71 m) in December and its lowest (24.73 m) in August, while the total rainfall reached its highest (219.83 mm) in November and the lowest (93.75 mm) in February. At Lubuk Paku (Fig. 4), the highest water level (15.23 m) was recorded in December and its lowest (12.70 m) in July, while the highest total rainfall (324.57 mm) was recorded in December and the lowest (79.81 mm) in February.

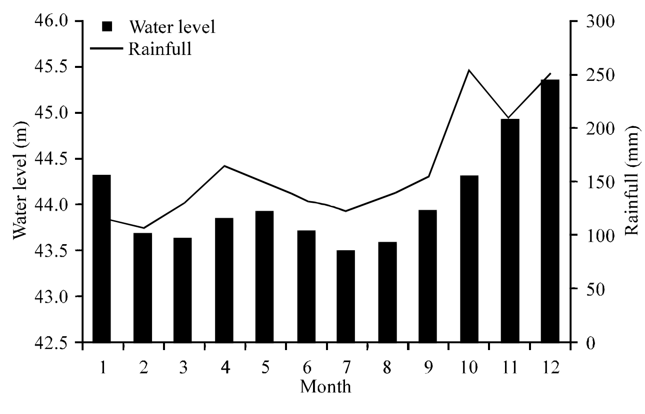

Fig. 2: Comparison of water level and monthly rainfall at Sg. Yap station (1980-2009), Source: DID Malaysia (DID, 2009)

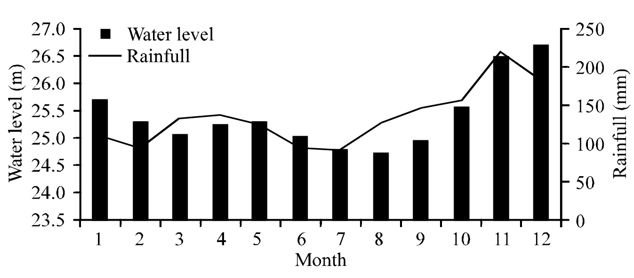

Fig. 3: Comparison of water level and monthly rainfall at Temerloh station (1980-2009), Source: DID Malaysia (DID, 2009)

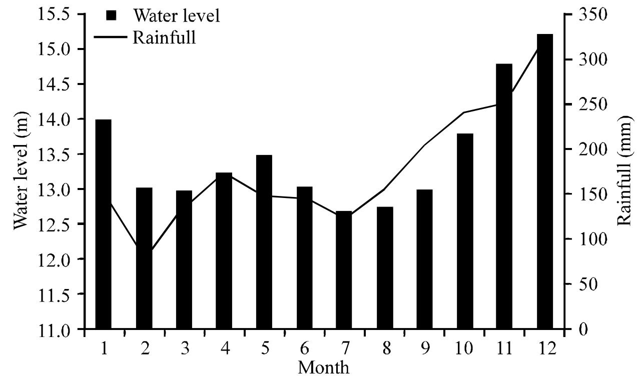

Fig. 4: Comparison of water level and monthly rainfall at Lubuk Paku station (1980-2009), Source: DID Malaysia (DID, 2009)

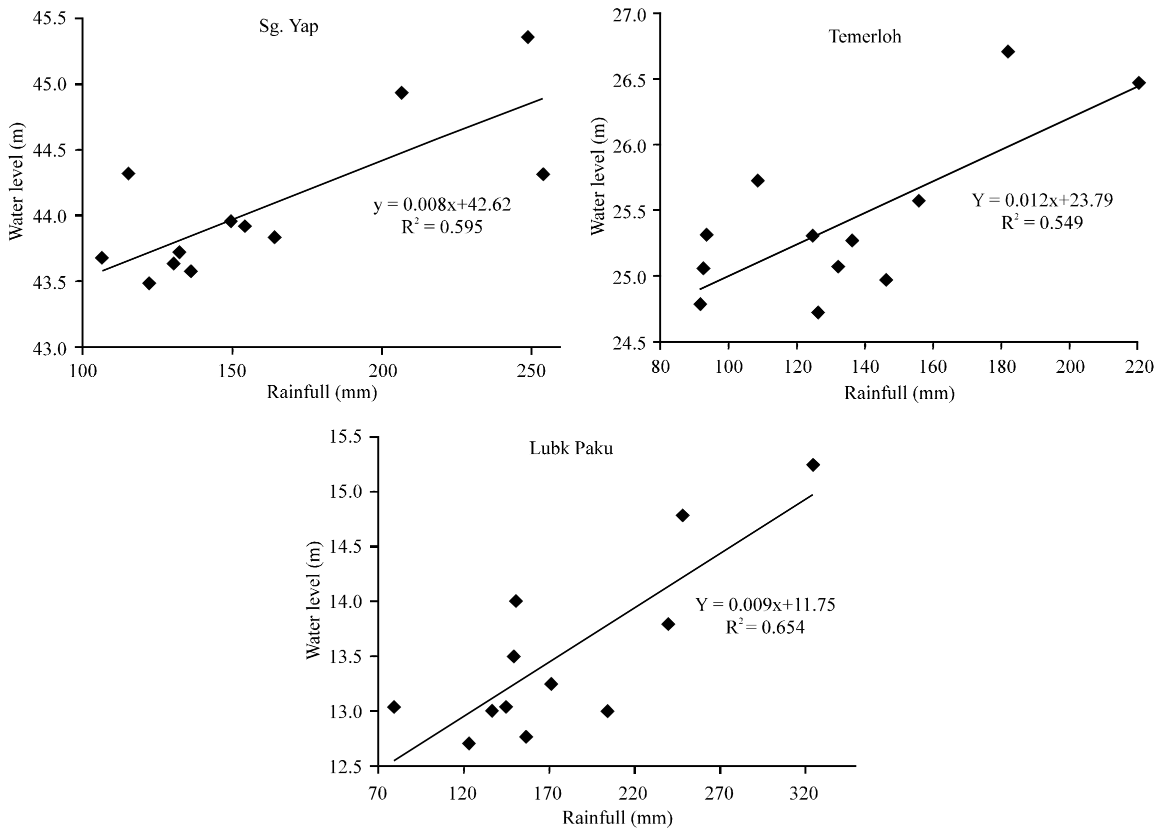

Fig. 5: Relationship between water level and rainfall for the three gauging stations at Pahang river

From the findings, the rainfall stations at Sg. Yap, Temerloh and Lubuk Paku received higher rainfall starting from October to December annually which resulted in the higher water level of the Pahang River. All of the gauging stations recorded the highest water level in December. The higher total rainfall received was triggered by the northeast monsoon occurring from November to March every year and this resulted in the overflowing of the Pahang river.

Figure 5 shows the positive relationship between water levels and rainfalls at the three gauging stations where the increase of rainfall had resulted in the increase of the water level. Similarly,

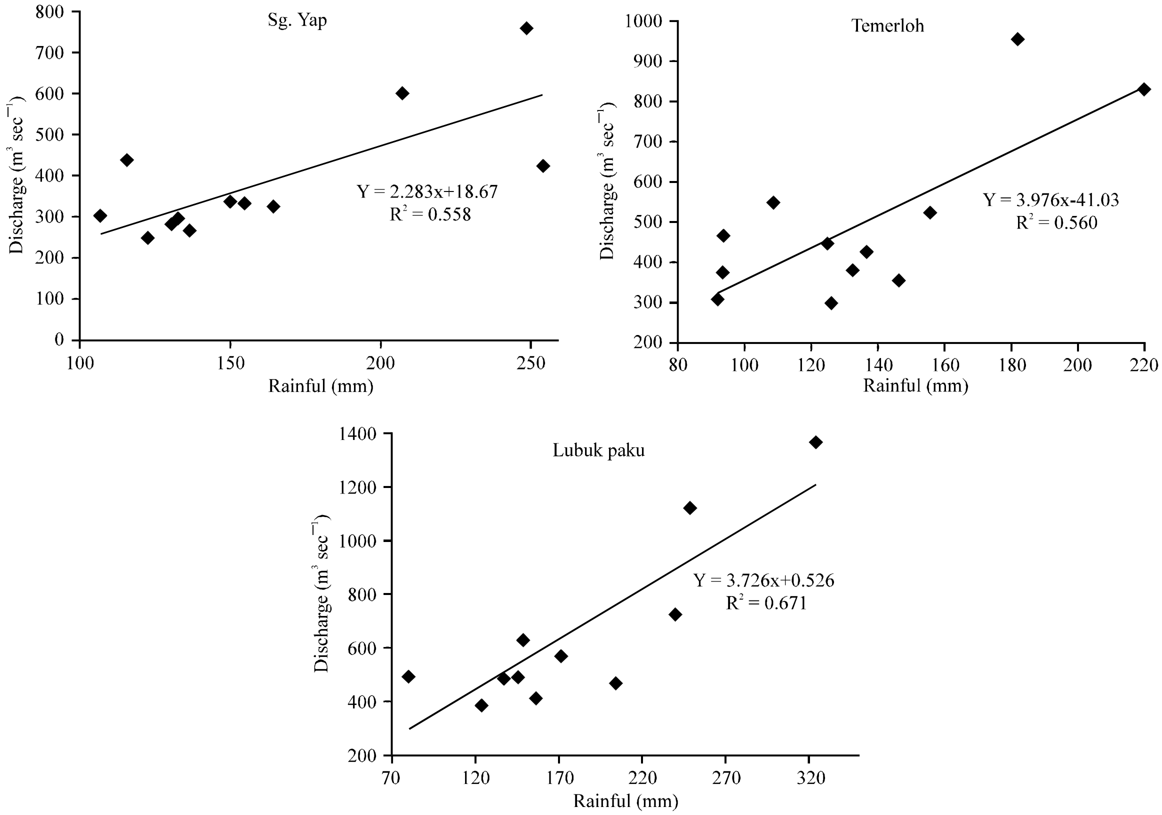

Fig. 6: Relationship between water discharge and rainfall for the three gauging stations at Pahang river

Fig. 6 shows the direct relationship between rainfall and water discharge where the increase of rainfall had caused higher volume of river discharge. The results show that rainfall has directly affected the Pahang river causing it to overflow. Additionally, it is also a significant factor that has led to the flood event.

Hydrologic data series: Hydrological data for the time span of thirty years was analyzed in the form of rating curve between discharge and water level. The results of the correlation study show that there are positive relationships among Sg. Yap ($R^2 = 0.851$), Temerloh ($R^2 = 0.873$) and Lubok Paku ($R^2 = 0.928$) (Fig. 7-9). These relationships indicate that the increase of water level has resulted in the increase of the discharge. Mean discharge of Pahang River at Sg. Yap was 845.78 m^3 sec^{-1} (Fig. 7), whereas at Temerloh it was 1008.50 m^3 sec^{-1} (Fig. 8) and at Lubuk Paku the mean was 1184.46 m^3 sec^{-1} (Fig. 9). High water discharges that reached and went over the danger level proposed by DID Malaysia for the three gauging stations over the period of thirty years (1980-2009) have been recorded and have been identified. At the gauging station in Sg. Yap (Fig. 7), water level and discharge that went over the danger level (52.0 m; 3600 m^3 sec^{-1}) were recorded on these dates: 6/12/1983 (52.12 m; 3610.3 m^3 sec^{-1}), 22/11/1988 (56.21 m; 6154.5 m^3 sec^{-1}), 2/12/1988 (52.24 m; 3671.6 m^3 sec^{-1}), 12/12/1991 (52.58 m; 3868.8 m^3 sec^{-1}), 19/12/1993 (54.28 m; 4860.4 m^3 sec^{-1}), on the 24/12/2001 (55.24 m; 5456.0 m^3 sec^{-1}) and 13/2/2006

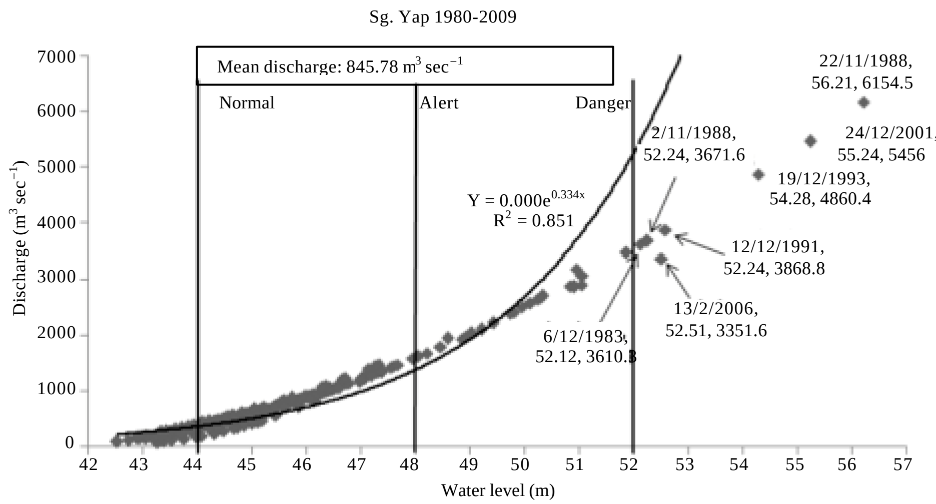

Fig. 7: Rating curve of Pahang river at Sg. Yap (1980-2009), Source: DID Malaysia (DID, 2009)

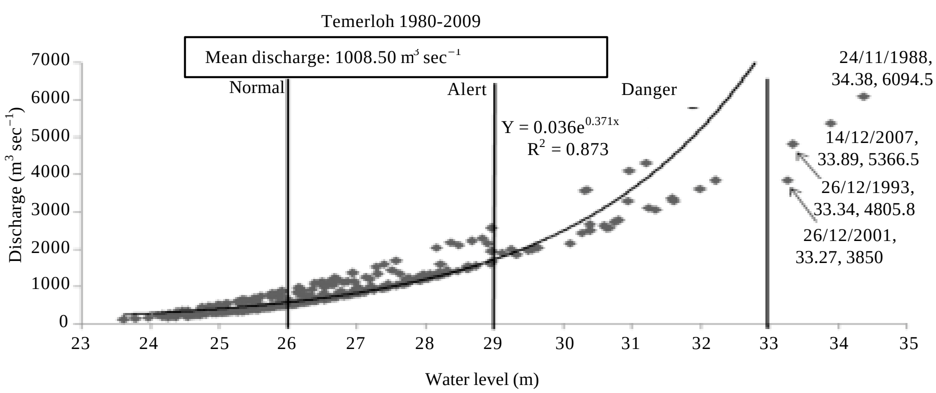

Fig. 8: Rating curve of Pahang river at Temerloh (1980-2009), Source: DID Malaysia (DID, 2009)

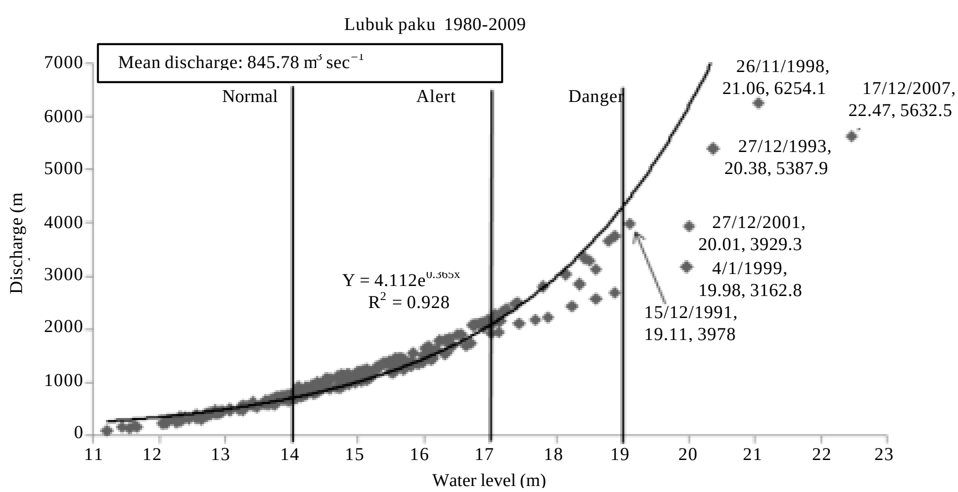

Fig. 9: Rating curve of Pahang river at Lubuk Paku (1980-2009), Source: DID Malaysia (DID, 2009)

(52.51 m; 3351.6 m^3 sec^{-1}). At Temerloh (Fig. 8), water level and discharge that went over the danger level (33.0 m; 6000 m^3 sec^{-1}) were recorded on 24/11/1988 (34.38 m; 6094.5 m^3 sec^{-1}), 26/12/1993 (33.34 m; 4805.8 m^3 sec^{-1}), 26/12/2001 (33.27 m; 3850.0 m^3 sec^{-1}) and 14/12/2007 (33.89 m; 5366.5 m^3 sec^{-1}). Water level and discharge that exceeded the danger level (19.0 m; 3900 m^3 sec^{-1}) at Lubuk Paku's gauging station (Fig. 9) occurred on 26/11/1988 (21.06 m; 6254.1 m^3 sec^{-1}), 15/12/1991 (19.11 m; 3978.0 m^3 sec^{-1}), 27/12/1993 (20.38 m; 5387.9 m^3 sec^{-1}), 4/1/1999 (19.98 m; 3162.8 m^3 sec^{-1}), 27/12/2001 (20.01 m; 3929.3 m^3 sec^{-})^1 and 17/12/2007 (22.47 m; 5632.5 m^3 sec^{-1}). The results show that the increase in water level was followed by higher water discharge. Extreme rainfall is the main cause of Pahang River overflowing which resulted in the flood events in the Pahang river basin.

Based on the rating curve analysis, rainfall is the main input as the runoff supplement that caused the overflowing of Pahang river. The higher amount of rainfall received increased the water level of Pahang river and resulted in the overflow of the river banks and inundation of the lowland areas along the river. The areas involved are Temerloh district, Bera district, Jerantut district, Maran district, Lubuk Paku district and Pekan district (DID, 1989, 1993, 1996, 1999, 2001, 2002, 2003, 2006, 2009). The higher water level was followed by higher water discharge and this phenomenon occurred during the northeast monsoon (October-March). It is believed that big flood events would occur at lowland areas and floodplains along the Pahang river during these days. The results also show that the highest water discharge during flood events was three to seven times higher than the normal discharge and it is also believed that the discharge of Pahang river during flood events is tremendously faster and would cause extreme river bank erosion.

CONCLUSIONS

The last 30 years of observation shows that flood events have been identified at least 5 times along Pahang River. Occurrence of storms during the monsoon season has resulted in the overflow as well as inundation of the lowland and floodplain areas. Change of river flow dynamics from the upstream seems to be influenced by land use changes. Anthropogenic activities in the basin due to the impact of population increase such as urban development, rubber and oil palm plantations and sand mining along the river have been identified as factors that have worsened the stability of the basin. Loss of forest covers and turned by another land use categories to be another factor that contributed to the rise of daily temperature in the country. This is expected to lead to more evaporation coupled with more precipitation where flooding is likely to become a larger problem in this region. Finally, these hazards have resulted in the government suffering revenue loss due to the large compensation given out to flood victims and repairing costs of the damaged infrastructures after the flood events.

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