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The physical geography and flooding of Peninsular Malaysia

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Abstract This paper demonstrates that, in Peninsular Malaysia, floods are the most common natural hazard, largely created and perpetuated by various aspects of its physical geography. The peninsula is located in the wet equatorial tropics where seasonal monsoon winds bring heavy rain spells which often result in widespread monsoon flooding, particularly along its entire east coast region. More than any other factor, the geography of the peninsula is probably the key reason why many regions are highly flood-prone. The peninsula's many physical characteristics are highly conducive to flood hazard creation. Its exposure to cold monsoon surges and depressions leading to heavy seasonal rainfall, intense convectional rainstorms, low-lying topography, poor drainage and other local factors are responsible for high flood risk in many parts of the peninsula. Low lying and flat riverine and coastal areas are flooded annually, with many places being flooded more than once a year. Although inadvertent and deliberate human use of flood plains—such as for agriculture, tin mining, industrialization, urbanization and others—have also contributed to increased flooding, the extent, magnitude and duration of such flooding (usually flash flooding) is small compared to monsoon floods.

La geografía física de Malasia Peninsular y las inundaciones

Resumen Este trabajo demuestra que en la Malasia Peninsular las crecidas contituyen el riesgo natural más común ocasionado principalmente y perpetuado por variados aspectos de su geografía física. La península se sitúa en el trópico ecuatorial júmedo donde los monzones estacionales traen intensos períodos lluviosos que a menudo resultan en severas inundaciones, particularmente en toda la región de la costa oriental. Más que cualquier otro factor, la geografía de la península es probablemente la razón fundamental por la que muchas regiones son altamente susceptibles a la inundaciones. Las diversas características físicas de la península provocan riesgos de crecidas. Su exposición al oleaje y depresiones causados por los monzones fríos conducen a fuertes precipitaciones estacionales, lluvias de alta convección, topografía plana, drenaje pobre y otros factores locales que son responsables del alto riesgo de crecidas en muchas partes de la península. Las áreas costeras y ribereñas bajas se inundan anualmente, y algunas de ellas más du una vez al año. Aunque la utilización accidental o deliberada de las llanuras de inundación por parte de hombre, ya sea para agricultura, minería, industrias, urbanización y otros fines también ha contribuido a aumentar las inundaciones, la extensión, magnitud y duración de las mismas (usualmente crecidas repentinas) es pequeña en comparición con las crecidas generadas por los monzones.

INTRODUCTION

Floods, as hazards, are often viewed in two extremes. They may be seen as all powerful and their creation solely attributed to the work of the natural event system

(Semple, 1911). In contrast, another extreme views floods as increasingly a product of human society (Blaikie *et al.*, 1994). It is only when humans choose to locate properties and live in areas affected by extreme natural processes that hazards exist. In reality, however, it is often difficult to distinguish between a flood that is attributed to nature from one that is attributed to humans. In fact, the same flood in one area may be more directly attributable to nature but can be largely created in another area by humans. In Peninsular Malaysia, although floods are caused by a combination of natural and human factors, monsoon floods which are more common and severe, can be largely attributed to the physical geography (i.e. natural factors) of the peninsula. On the other hand, flash flooding, which occurs mostly in highly urbanized catchments, is largely due to human factors. As this paper mainly concerns monsoon floods, the natural factors responsible for their occurrence are emphasized.

Flooding is the most common natural hazard in Peninsular Malaysia. Annually, it accounts for a significant number of casualties, disease epidemics, property and crop damage and other intangible losses. The peninsula is geographically located in the wet equatorial tropics where seasonal monsoon winds bring forth heavy rain spells generating extensive seasonal monsoon floods. This is especially so in the peninsula's East Coast region where the occurrence of such floods is considered a way of life (Chan, 1995). More than any other factor, the geography of the peninsula is the key reason why many regions are highly flood-prone. Major monsoon flooding is a serious natural hazard in Peninsular Malaysia. It is frequent and widespread, often escalating into disasters which cripple the economy, communications, public services and result in property damage and loss of life (Chan, 1996). Major monsoon floods have occurred regularly once every few years. Major floods in 1926, 1954, 1967, 1970, 1971, and 1988 have caused havoc in affected areas resulting in significant loss of life and damage to property, crops and livestock, businesses, industry and public amenities (Table 1).

The annual occurrence of seasonal monsoon floods has been shown to put a tremendous strain on the country's resources. For example, seasonal monsoon floods account for almost the entire reported annual national cost for disaster preparedness, mitigation, relief and rehabilitation. Smith (1985) has shown that household flood damage and its effects are significant when compared to mean household incomes of flood plain dwellers. Damage to building contents and structures, crops and livestock, and vehicles were the main categories of flood loss suffered by individual households. Intangible effects such as stress, worry and health were also shown to be important. Damage to commercial properties and their businesses, especially in large urban centres such as Kuala Lumpur and Georgetown are also substantial. Similarly, industrial damage is also expected to be substantial and currently under-reported (Chan, 1995).

MONSOON AND FLASH FLOODS

There are two main types of floods, viz. monsoon floods and flash floods. Monsoon floods are brought by monsoon winds which deposit heavy rainfall during both the southwest monsoon season (May–September) and the northeast monsoon season (November–March) (Fig. 1). They are seasonal in nature, of longer duration and are

Table 1 Official flood loss estimates for selected floods in Peninsular Malaysia.

Flood event Year	Place	Damage (US$ $\times 10^6$ at 1993 prices)	Deaths	Persons evacuated
1967	Kelantan R. basin	199.3	38	320 000
1967	Perak R. basin	154.5	0	280 000
1967	Terengganu R. basin	40.2	17	78 000
1971	Pahang R. basin	93.1	24	153 000
1971	Kuala Lumpur	84.7	24	NA
1979	Peninsular Malaysia	NA	7	23 898
1982	Peninsular Malaysia	NA	8	9 893
1983	Peninsular Malaysia	NA	14	60 807
1984	Batu Pahat R.	20.3	0	8 400
1986	Peninsular Malaysia	NA	0	40 698
1988	Peninsular Malaysia	NA	37	100 755
1988	Kelantan R. basin	33.0	19	36 800
1991	Peninsular Malaysia	NA	11	NA
1992	Peninsular Malaysia	NA	12	NA
1993	Peninsular Malaysia	NA*	22	17 000
1995	Peninsular Malaysia	NA	0	14 900

NA = not available.

* In the state of Kelantan, a total of 200 schools were closed during the 1993 flood resulting in 113 000 students missing school for 6–11 days.

(Source: DID Malaysia, Malaysian National Security Council and major newspapers).

generally more extensive and severe, especially during the northeast monsoon. Consequently, monsoon floods are the main natural hazard affecting a greater section of the Malaysian population, especially those whose livelihood depends on fertile alluvial soils, irrigation, fishing, river transportation, and surface water supply, and who therefore live in rural flood plain regions. Monsoon flooding is also largely due to occurrence of cold surges and depressions which generate sustained spells of heavy rains during the monsoon season, the low lying nature of many of the peninsula's coastal plains, the impedance of natural drainage as a result of the abundance of swamps, and the effect of high tides in estuary and coastal areas. As such, the high frequency of monsoon flooding in Peninsular Malaysia can be largely attributed to its physical geography rather than to human activities.

Monsoon floods occur almost annually in Malaysia. It is useful to distinguish between "normal" and "major" monsoon floods. "Normal" monsoon floods are seasonal floods which occur annually, usually during the northeast monsoon season. During these floods the waters do not normally exceed the stilt height of traditional Malay houses (Fig. 2). As such, people living in stilt houses are well adapted to normal monsoon floods. It is the "major" monsoon floods, termed "extreme events" and occurring once every few years, that render flood victims helpless. These floods are extensive, severe and often last for several weeks. They result in significant loss of life, damage to crops, livestock, property, and public infrastructure. Some examples of major monsoon floods are the great flood of 1926, the 1971 flood, and the 1988 flood. During major monsoon floods, a flood depth of 3 m is not uncommon.

In comparison, flash floods are of less significance in Peninsular Malaysia because of their small extent, short duration and lesser damage caused. Flash floods

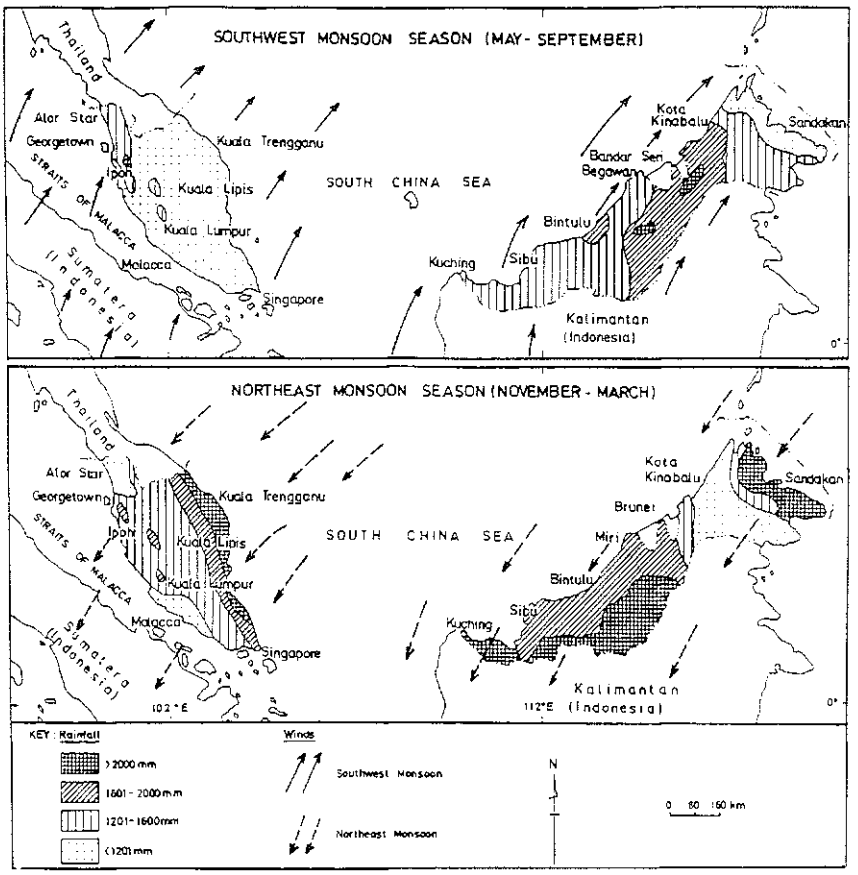

Fig. 1 Seasonal rainfall distribution in Malaysia during both the southwest monsoon season (May–September) and the northeast monsoon season (November–March).

Fig. 2 Traditional Malay stilt houses built in the shallow waters of the Pahang River near Pekan, Pahang.

are swift and localized but highly unpredictable. Compared to monsoon floods, flash floods are largely attributed to human interference with the natural hydrological cycle. In Peninsular Malaysia, flash floods are mainly due to use changes induced by rapid urbanization and economic development in major cities. Flash flooding is an ephemeral form of inundation usually caused by convectional storms accompanied by torrential rainfall over a short period of time. These storms occur most frequently during two relatively short inter-monsoon seasons around April and October. The duration of such storms is usually less than 24 h, and the resulting high intensity rainfall greatly exceeds soil infiltration capacity. This condition is common in urban areas where much of the land surface is made up of impermeable materials. As a result, a greater portion of the rainfall flows as surface runoff entering the river system in double-quick time. The river's capacity to carry the discharge is quickly exceeded giving rise to flash flooding (Fig. 3).

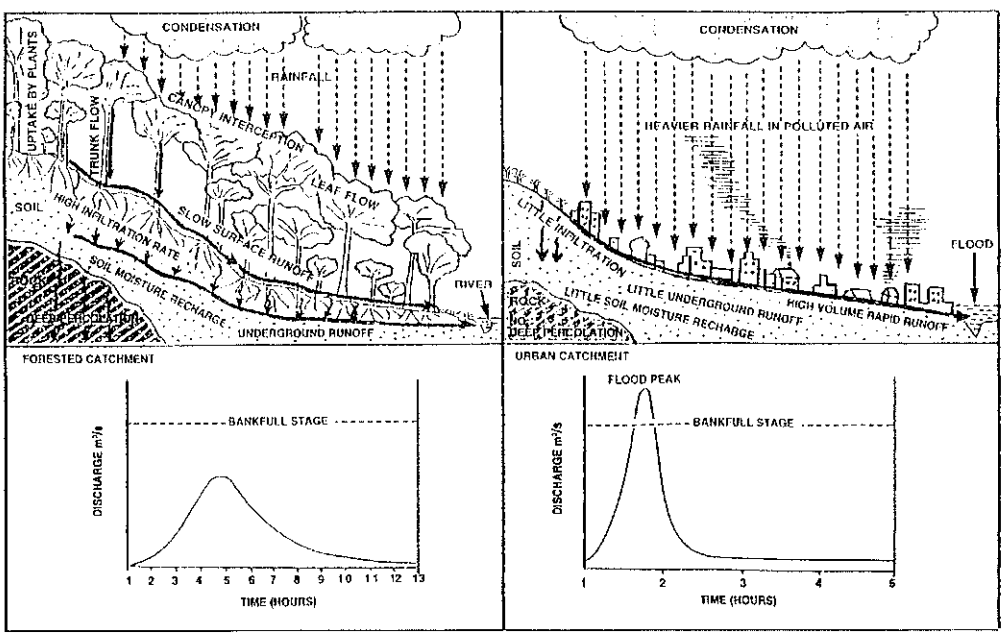

Fig. 3 Left: In a natural forest drainage system, absorption of rainfall by vegetation and soil is high, giving rise to a much reduced and slower rate of runoff into rivers. Right: In a city, the lack of vegetation and an impervious surface has given rise to a significant increase in the rate and volume of runoff, reduced lag time, and a higher incidence of flash flooding.

THE PHYSICAL GEOGRAPHY OF FLOODING

Peninsular Malaysia possesses wide coastal flood plains which are highly flood prone. Between the east and west coasts and the interior mountain ranges are gently rolling country known as the "foothill regions". From the foothills to the coasts are flat coastal plains on both the east and west of the peninsula. These coastal plains contain the bulk of the peninsula's population, economic activities, infrastructure,

and natural resources (Chan, 1995). The coastal plains on the west coast are generally wider than those on the east coast. In general, the western coastal plain is about 60 km wide while the eastern coastal plain is between 20 and 40 km wide. The average heights of coastal plains in the peninsula are not more than a few metres and most of the plains coincide with the flood plain regions of the peninsula. Consequently, the coastal plains are highly susceptible to monsoon flooding.

The two predominant wind systems which contribute significantly to flooding in many parts of the peninsula are the northeast and southwest monsoons. The former is responsible for floods which occur every year, especially in the east coast of the peninsula. In many cases, extreme conditions due to cold monsoon surges and depressions have deposited rainfall exceeding 600 mm within a 24 h period (Cheang, 1987). In general, the east coast region receives more than 2000 mm of rain during the northeast monsoon season while areas on the west coast receive less than 1000 mm of rain during the same period (Chan, 1990).

In contrast, the other predominant wind, the southwest monsoon (May–September), does not normally cause widespread floods because the peninsula is sheltered by the Indonesian island of Sumatra. However, heavy rains do occur in many parts of the west coast during the period of the southwest monsoon which may lead to localized floods. Also, during this same period, small intense and short-lived squalls called "sumatras" move across the Melaka and Johor coasts, on the southern parts of the west coast. In many instances, especially in the more developed urban areas, flash floods usually accompany these squalls. The average southwest monsoon season rainfall is between 1000 and 1500 mm.

Rainfall intensities in the peninsula are generally high, especially during convectional rainstorms which are of short duration. The intensity of a particular rainfall is important as it determines the rate of splash erosion and the rate of surface runoff (which in turn determines land surface erosion and flooding). In general, average rainfall intensities are around 150 mm h^{-1}. The rainfall intensity during an unstable rainstorm in Kuala Lumpur was found to be around 203 mm h^{-1}. With such high rainfall intensities and the subsequent high runoff rates, the occurrence of flash floods is therefore a common phenomenon, especially in urban areas.

The abundant water resources and wet equatorial climate of the peninsula support a perennial network of rivers and streams. The largest, the Pahang River, with a catchment area of 29 300 km^2 is only about 430 km long. The other major rivers are the Perak (14 000 km^2), the Kelantan (13 100 km^2), the Muar (6595 km^2), the Terengganu (4650 km^2) and the Kelang (1425 km^2). There are more than 100 river systems in Peninsular Malaysia. Since independence in 1957, indiscriminate use of rivers and a combination of rapid deforestation, agriculture and uncontrolled urban development of flood plains have disrupted the natural regime of rivers and resulted in the deterioration of rivers as natural means of drainage. Frequently, this has resulted in an increase in the frequency and magnitude of flooding as well as a corresponding increase in flood losses.

In the east coast, the rivers are more frequently flooded than their counterparts in the west coast, due mainly to the effects of the northeast monsoon. Quaternary changes in sea level and progressive sedimentation have also given rise to most rivers taking on a typically vertical profile in the upper stretches to a flattened appearance in the middle to lower stretches. This is because when the river beds were raised, the

rivers' erosive and transportation capacities were reduced but the rate of deposition correspondingly increased. This has given rise to the formation of extensive flood plains with the typical fluvial formations such as meanders, ox-bow lakes, natural levees and swamps. In the estuaries, the rivers deposit their loads into the sea and cause progressive sedimentation along the coasts. In the sheltered west coast, fluvial deposition has given rise to large tracts of tidal and freshwater swamps which further impede drainage. Many rivers flowing westwards often disappear into such swamps before they re-emerge and flow into the sea. On the east coast, there are few such swamps (due to the exposed coastline to the South China Sea) but flood plains are built around the estuarine areas and all along the major rivers. On both coasts, the rapid physical development and occupation of such flood plains have increased human vulnerability and damage potential of flooding in such plains (Chan, 1995).

HUMAN FACTORS AND FLASH FLOODING

While natural conditions are shown to foster and create monsoon floods, the incidence of flash floods, particularly in urban areas is largely the consequence of human action. Human activities interact with the natural system to produce flash floods. Flood plains have always been preferred settlement locations of human civilization and their lure and attractiveness as a places of occupancy is well documented (White *et al.,* 1958; Parker, 1976; Smith, 1992). In Peninsular Malaysia, many cities are now frequently affected by flash floods. Some recent examples are the June 1991 flood in Georgetown, the September 1995 flood in Penang, and the December 1995 flood in Shah Alam.

The main characteristic of a flash flood is its rapid onset and equally rapid subsidence. During flooding, the hydrograph shows a rapid attainment of the peak flow (flood peak) over a very short period, usually within half an hour from the onset of rainfall but often within minutes in the case of highly urbanized catchments. As a result, flash floods are difficult to predict and warning lead times are at best within minutes of the onset of flooding.

In Peninsular Malaysia, it has been estimated that approximately 2.5 million people live in flood plains and of these, more than half reside on urban flood plains which are susceptible to flash flooding (JICA, 1982). Flood plains are also regions where a significant proportion of the peninsula's population and much of the economic activity are concentrated (Leigh & Low, 1978). Table 2 indicates the extent to which populations have settled on urban centres in the flood plain regions in the peninsula. The three largest urban centres in the peninsula are located on flood plains and are susceptible to frequent flooding. In addition, five of the top ten urban centres and more than half of all urban centres are located on flood-prone areas. Rapid post-1970 urbanization has led to further swelling of urban population, thereby exacerbating the pressures for flood plain encroachment in urban centres located on or adjacent to flood plains. The rate of urbanization in the peninsula has increased more than four fold from 10.7% in 1911 to 44.7% in 1990 and the number of urban centres has also increased more than eight fold.

Despite susceptibility to frequent flooding, flood plain occupation has continued to increase. This is because the social, economic and other benefits of inhabiting and

Table 2 Rate of increase between 1957 and 1990, in the population of major urban centres located on the banks of major rivers in Peninsular Malaysia.

Centre	River	1957 population	1990 population	% increase
Kuala Lumpur (1)*	Kelang	316 200	919 600	190.8
Ipoh (2)	Kinta	125 800	293 849	133.6
Georgetown (3)	Pinang	234 900	248 241	5.7
Johor Bahru (4)	Johor	75 100	246 395	226.6
Kelang (6)	Kelang	75 600	192 080	154.1
K. Terengganu (7)	Terengganu	29 400	180 296	513.3
Kota Bharu (8)	Kelantan	38 100	167 872	340.6
Kuantan (11)	Kuantan	23 100	131 547	469.5
Melaka (12)	Melaka	69 900	87 494	25.2
Alor Setar (15)	Kedah	52 900	69 435	31.3
Muar (16)	Muar	39 100	65 151	66.6
Batu Pahat (17)	Batu Pahat	40 000	64 727	61.8
Keluang (20)	Mengkibol	31 200	50 315	61.3
Teluk Intan (21)	Perak	37 000	49 148	32.8
Sungai Petani (22)	Merbok	22 900	45 343	98.0
Dungun (29)	Dungun	12 500	28 903	131.2

* Figures in brackets indicate the ranked position of urban centre in terms of total population.
(Source: Karim, 1990 pp. 78–79).

using flood plains are often perceived to outweigh the negative effects of flooding. Flood plain encroachment has become more and more difficult to control. For example, deforestation has been a long standing issue alleged to be responsible for increased incidence of flash flooding. Forest cover is a natural form of flood prevention. In Peninsular Malaysia, deforestation is a controversial issue. Toebes & Goh (1975) showed that logging activities caused significant changes in flood peaks, flood volumes and flood frequencies. Human activities such as tin mining have also contributed to flash flooding. Other factors contributing to flash flooding are: excessive improvements of river channels which overtax the discharge capacity of downstream stretches; floating logs and vegetation debris from logging and related activities which block the free flow of water; indiscriminate disposal of rubbish into drains and rivers causing blockage; siltation of river beds due to soil erosion and other sediment runoff from slopes and housing schemes; low bridge crossings with insufficient clearance impeding high flow; and the formation of spits and sand bars at river estuaries due to coastal development.

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