CONSTRUCTION FOR DISASTER REDUCTION –

FLOOD MANAGEMENT IN MALAYSIA

Abstract:

Malaysia's main natural disaster is floods that occur annually to varying degrees of severity. The trend of major floods has shown a rise in frequency corresponding to the economic development and urbanisation of the country. After 1971, the government created proper machinery for flood response beginning with the formation of a Permanent Committee on Flood Control. Early actions include the commissioning of flood mitigation studies and implementation of engineering projects. Expenditure for flood mitigation has grown from RM14 million in 1971-1975 to RM5.2 billion in 2005-2010 exponentially. After 2000, significant changes were made as the government adopted Integrated Flood Management (IFM) as its underpinning strategy to mitigate floods. Under IFM, the emphasis is on addressing issues at the river basin level and involves participatory approach requiring public awareness to be raised and for the general populace to 'live and adapt' to floods.The introduction of the Urban Stormwater Management Manual for Malaysia as a guide for developers is a major component of the IFM strategy. Flood problems are hence solved holistically using a combination of structural and non-structural methods. While structural solutions are still key to solving chronic flood problems especially in the wake of climate change, their design can be optimised by non-structural means. Implementation of IFM is key towards reducing the nation's risk to disaster.

Introduction

Based on a history of causing the greatest economic damage, floods are Malaysia's biggest threat. In the last three decades, expenditure for flood mitigation has more than tripled from a mere RM14 million in the period 1971-1975 to RM5.3 billion in 2000-2005. From 2000 onwards, the government has actively promoted Integrated Flood Management in addressing flood-related disasters. Hence, from a purely structural approach, flood management in Malaysia has shifted towards a holistic approach where non-structural measures have been given equal emphasis. While the government continues in its traditional role as provider of structural solutions, flood mitigation is to be a collective and participatory approach with responsibilities shared by all stakeholders. This paper presents Malaysia's approach to flood management and how it has made the paradigm shift from the traditional curative approach to a more proactive and preventive one.

Climate

Annually, Malaysia gets most of her rain during the north-east and south-west monsoons. The north-east monsoon occurs from November to March and brings heavy rain spells to the east coast of peninsular Malaysia, north-eastern Sabah and western Sarawak. The south-west monsoon blows in from May till September and affects the west coast of the peninsular. Rainfall distribution in the south-west coastal areas is affected by squalls originating from Sumatera that contribute much rain. During the inter-monsoon period from September to November, cities in the west coast of Peninsular Malaysia are frequently affected by convectional thunderstorms.

The annual average rainfall is 2420 mm for Peninsular Malaysia, 2630 mm for Sabah and 3830 mm for Sarawak. Precipitation is recorded to be heavier in the east coast of Peninsular Malaysia and the coastal regions of Sabah and Sarawak. In extreme situations, 600 mm rainfall has been recorded in 1 hour and 100 to 200 mm of rainfall in 1 to 2 hours.

Flood in Malaysia

Definition and Types of floods

Floods occur whenever the capacity of the natural or man-made drainage system is unable to cope with the volume of water generated by rainfall. Resultant run-offs from rainfall over a catchment flow through ditches and channels to the river. If the rainfall duration is prolonged, the flow and water level in the river increases until it reaches a point beyond the capacity of the river channel to contain. The waters then overflows the banks and into the flood plain. In extreme cases, even the flood plain capacity is exceeded and river waters flood the adjacent land.

For management purposes, floods in Malaysia fall under two general types namely monsoonal floods and flash floods. Monsoonal floods occur as a result of rivers overflowing their banks following long duration rainfalls associated with monsoon periods. A flash flood is the type that occurs after a short duration, high intensity rainfall over a relatively small area. In major cities, flash floods can occur after one to three hours of rain and subside in less than six hours. Flash floods while prone to urbanised areas can actually occur in any low lying area especially those with bowl-shaped topography. It is often called 'nuisance' flood as it occurs almost without warning, disrupts economic activities and results in massive traffic jams in the city.

Flood History and Records

The first notable flood event in Malaysia's history was one that occured in the east coast (Peninsular Malaysia) state of Kelantan in 1886. This was followed by the flood of 1926 nicknamed the 'red flood' due to the reddish colour of sediment characterising the flood. In 1967, major floods raked havoc across the basins of three major rivers (Kelantan, Terengganu and Perak River) claiming 55 lives. This was surpassed by the great flood of 1971 that affected nearly all states throughout the country with Pahang taking the most damages. This flood caused 25 deaths and particularly, was the worst experienced in the center of the Federal capital of Kuala Lumpur.

Period	Year of Flood Occurrence
1920-1930	1926
1930-1960	1949
1970-198	1971
1980’s	1982, 1986, 1988
1990’s	1993, 1995, 1996, 1997
2000 to date	2000, 2001 (twice), 2002, 2003, 2004, 2006, 2007 (twice)

Table 1: Major flood Incidents in Malaysia

From the record of major flood incidents (Table 1), a rise in frequency of events can be observed beginning in the 1980’s, which coincided with the period of rapid economic development, and urbanisation in Malaysia. The past two decades have seen the increase in frequency of serious floods in major cities such as Kuala Lumpur, Penang and Kuching (Sarawak). From 2005 to 2009, thirty five (35) cases of serious flooding have been recorded. The worst amongst these were the Johor floods of 2006 which was the most devastating in recent history. The Johor floods were attributed to incessant rainfall over a period of 4 days from 18 to 21 December 2006 affecting the entire state (JPS, 2007).

Flood Areas

A total of 29,799 square kilometers equivalent to 9% of Malaysia’s total land area is considered flood prone (Figures 1 and 2). It affects 4.819 million people or 22.2% of the total population. These figures have risen from 1982 where the flood areas covered 29,021 square kilometers and affected 2.736 million people. Despite the increase in area, not every region is affected by floods each year.

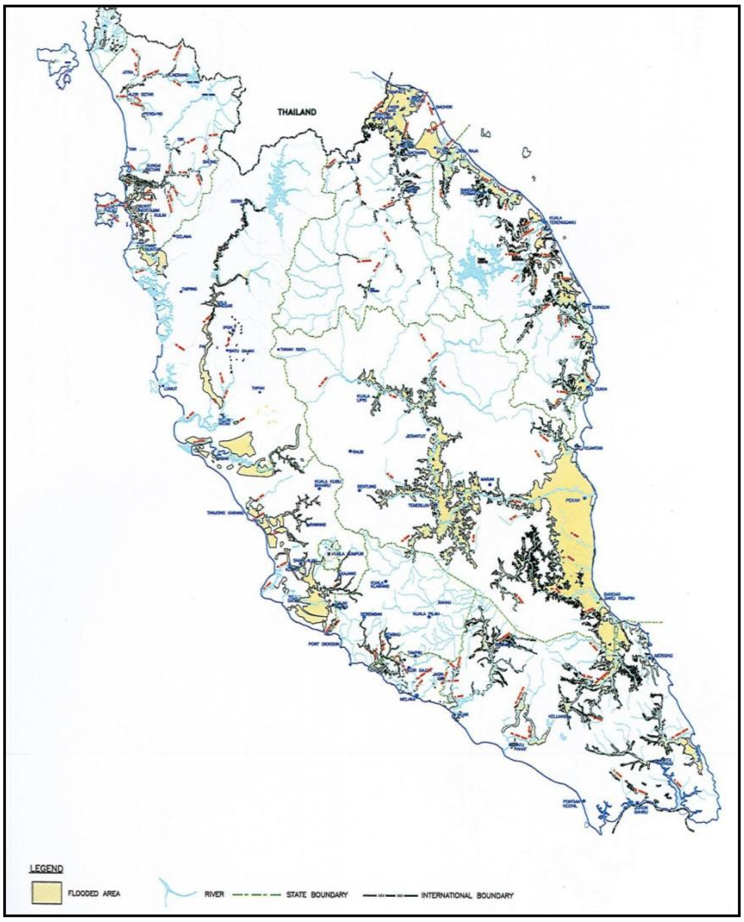

Figure 1: Flood Prone Areas Peninsular Malaysia

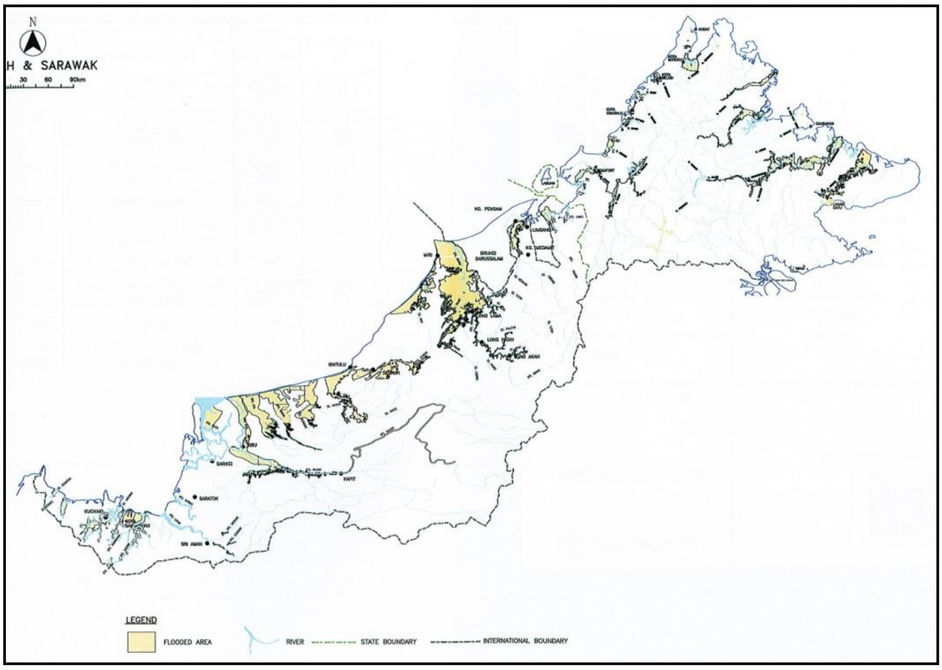

Figure 2: Flood Prone Areas - Sabah and Sarawak

Causes

Extreme rainfall events are capable of creating excessive surface run-off beyond the design capacity of existing drainage systems. Floods occur when flows in drainage channels and rivers exceed their conveyance capacity. The increasing run-off trend due to urbanisation has been evident based on a study of the mean flows in the Klang River in Kuala Lumpur. From 1910 to early 1980s, the mean annual flood flow was 148 cubic meters per second. In 1988, this flow increased three times to 440 cubic meters per second (Roseli, 1999). The main causes of flooding in Malaysia is summarised below:

i. increased run-off rates due to the urbanisation;
ii. loss of flood storage as a result of development extending into and taking over flood plains and drainage corridors;
iii. inadequate drainage systems or failure of localised drainage improvement works extended insufficiently downstream;
iv. constriction at bridges and culverts that are either undersized or partially blocked by debris buildup or from other causes;
v. siltation in waterway channels from indiscriminate land clearing operations;
vi. localised continuous heavy rainfall;
vii. tidal backwater effect;
viii. inadequate river capacity

The rising trend of flash flood events point to the fact that the rate of urbanisation has far exceeded our capacity to install flood mitigation measures. Climate change has been studied since 2000 and a growing frequency of high intensity rainfall events have been observed particularly in Kuala Lumpur.

Flood Damage

The 2006 Johor floods was estimated to cost RM1.5 billion in damages while floods in Kuala Lumpur city center has been estimated at RM112 million per year. The assessment of flood damage helps identify, predict and evaluate the benefits of flood control projects. Understanding the probabilities of damage and costs leads to better planning of the flood mitigation measures to undertake.

Damage due to floods is estimated based on tangible and intangible damage. Tangible damage can be a direct monetary value of properties, assets and inventories destroyed, the cost of repair and restoration. The indirect value of tangible damage is defined as loss of wages, projected sales and property value. The intangibles may include environment degradation, increase in cases of illness and weakening of social cohesion. If the damage associated with various annual events is plotted against their probability of occurrence, the average annual damage (AAD) is equal to the area under the consequence/probability curve. The AAD provides a basis for comparing the economic effectiveness of different management measures, i.e. their ability to reduce the AAD. Both actual and potential damages (related to a design flood scenario) are assessed to determine the AAD. The practise in Malaysia is to use both Rapid Assessment and Detailed Assessment methods depending on the availability of data.

Projects Implementation History

Urban areas were not the only ones which benefited from flood mitigation projects. To protect valuable agricultural land, projects were also implemented in fast growing agricultural areas such as the Integrated Agricultural Development Project (IADP) areas namely Perlis IADP, Western Johor IADP, Ketara IADP, Kemasin Semarak IADP and Samarahan IADP. Under the 2nd Malaysia Plan[1] (1971-1975), a sum of only RM14 million was spent for flood mitigation projects. This was followed by the 3rd Malaysia Plan (1976-1980) with an expenditure of RM56 million, the 4th Malaysia Plan (1981-1985) with RM141 million, the 5th Malaysia Plan (1986-1990) with RM155 million, the 6th Malaysia Plan (1991-1995) with RM431 million, the 7th Malaysia Plan (1996-2000) with RM845 million. The 8th (2001-2005) and 9th Malaysia Plans (2005-2010) were allocated RM2.7 billion and RM5.264 billion respectively.

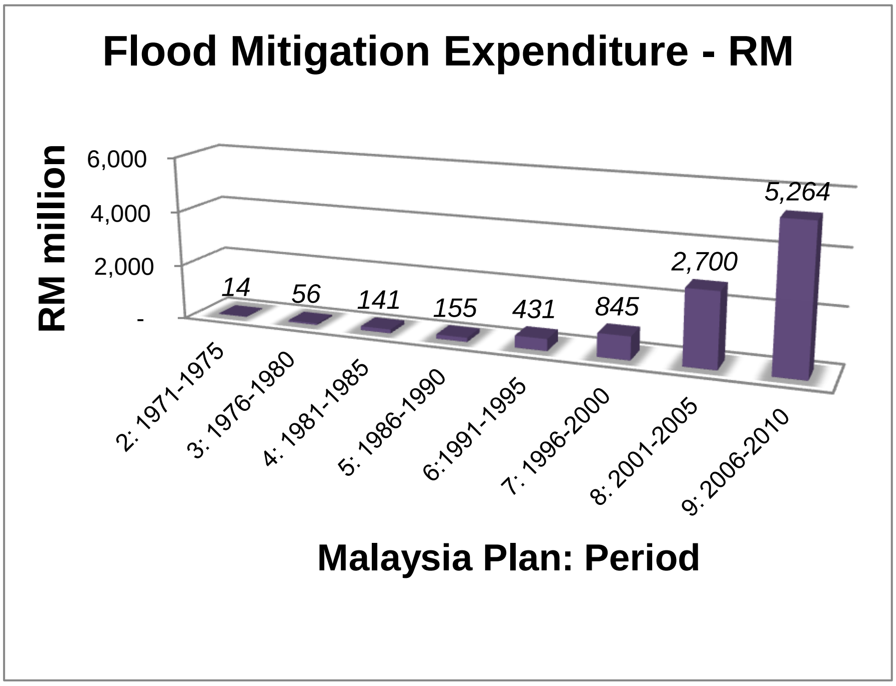

Figure 3: Flood Mitigation Expenditure 1971-2010

Flood Mitigation and Related Studies

Since 1972, a number of river basin studies have been carried out for rivers where major flood problems exist. The objective of these studies is to draw up master plans for water resources development and measures for flood mitigation form an important component. To date, more than 26 river basin studies have been completed, including Kuala Lumpur (1974 & 2002), Pahang River (1974), Kelantan River (1978 & 1989), Terengganu River (1978), Limbang River (1978), Kinabatangan River (1982), Samarahan River (1983), Batu Pahat River (1984), Johor River (1985), Golok River (1985), Besut River (1988), Klang River (1978,1989 & 1994), Menggatal, Sabah (1999), Miri Flood Diversion (2000), Linggi (2000), Selangor River (2000), and Bernam River (2001).

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[1] The 1st Malaysia Plan (1966 to 1970) was the first of the Government of Malaysia's 5-year development expenditure blueprints. The latest, the 10th Malaysia Plan will be in effect from 2011 to 2015.

Realising the need for a long-term water resources development strategy and master plan, the Government has carried out a National Water Resources Study (1982) to develop a comprehensive and coordinated water resources development programme for the country. The study has formulated a long-term plan for flood mitigation works in various flood-prone areas of the country. This includes improvement of 850 km of river channels, construction of 12 multi-purpose dams, 82 km of flood bypass, 12 ring bunds around urban centres, and resettlement of about 10,000 people in flood-prone areas. The whole plan was estimated to cost RM2.55 billion (1982 estimate) over a period of 20 years and will provide protection to some 1.8 million people.

A number of studies have also been carried out to alleviate flooding problems in major towns around the country. These include the Cukai Flood Mitigation Study, Lower Perak Flood Mitigation Study and the Kangar Flood Mitigation Study as well as drainage master plan studies for the towns of Butterworth and Bukit Mertajam, Kuala Lumpur, Alor Setar, Sandakan/Tawau/Kota Kinabalu, Bintulu, Johor Bahru, Kelang and Port Kelang, Seremban, Melaka, Kuantan, Kota Bharu, Kuala Terengganu, Port Dickson, Raub, Kerteh, Teluk Intan, Penang, Langkawi, Batu Pahat, Sungai Petani, Kuching, Ipoh and the Multimedia Super Corridor (MSC).

Costs and Returns

Project Outcome

The outcome of flood mitigation projects are evaluated based socio-economic factors. A reduction in flood area, frequency of flood occurrence, and numbers of populace effected are used as key performance indicators of flood mitigation projects. Flood mitigation project outcomes are determined from surveys part of which are garnered from flood damage assessment exercises. With the advent of Geographical Information Systems, flood hazard maps have become an important tool in evaluating the effectiveness of flood projects by way of comparing actual flood areas against the predicted flood areas under a given level of protection.

Future Investments

It is estimated that flood mitigation expenditure over the next 15 years for the outstanding flood prone areas would be around RM19 billion (USD5.94 billion).

Flood Management

Flood Management After 1971

Prior to 1971, the response by the Government to mitigate flood disasters were at best piece-meal and reactive. It was not until the aftermath of the great flood of 1971 that the Malaysian Government's flood mitigation strategy became properly framed and entrusted to the Department of Irrigation and Drainage (DID). Working with other agencies, the DID was responsible for implementing the engineering components under the following seven initiatives to address floods:

1. Formation of the Permanent Commission on Flood Control
2. Formation of a mechanism for flood disaster relief
3. Conduct studies on river basins and formulation of urban drainage master plans for major towns
4. Implement structural measures
5. Implement non-structural measures
6. Develop flood prediction and early-warning system
7. Develop network of hydrology and flood data collection stations

From the studies that have been carried out, various structural (curative) as well as non-structural (preventive) measures have been proposed to alleviate the flooding problem. Even in the early 1970s, it was realised that flood relief projects alone did not alleviate flood woes. Non-structural measures that controlled land development were needed. The flood problem had to be addressed from a river basin management perspective.

Structural Measures

Flood mitigation began with flood relief projects which were purely structural in nature and focused at local problems. Under structural measures, engineering methods are used to solve the flooding problem. The river capacity can be increased to accommodate the surplus runoff through channel improvement, construction of levees and embankments, flood bypasses, river diversions, poldering, and construction of flood storage dams and flood attenuation ponds, either singly or in combination. These are briefly described below:

(i) Flood Control Dams

Flood control dams are constructed to retain flood water in order to protect areas downstream. It is generally economically not viable to construct dams solely for flood control hence these dams serve other purposes such as power generation, domestic water supply or irrigation with a portion of their capacity allocated for flood detention. Among the dams specially constructed for flood mitigation are Batu Dam, Semberong Dam, Bekok Dam and Macap Dam while irrigation dams include Muda Dam, Pedu Dam, Timah Tasoh Dam, Bukit Merah Dam and Beris Dam. Hydro-electric dams built by Tenaga Nasional Berhad[2] include Kenyir Dam, Bersia Dam, Kenering Dam, Temenggong Dam and Sultan Abu Bakar Dam. The Klang Gates Dam in Kuala Lumpur is an example of a dam built for water supply but also serves as a flood mitigation dam.

(ii) Canalisation and Related Works

Canalisation works include the widening and deepening of channels as well as lining the banks and beds of the channels. They also include the replacement of undersized structures such as bridges. These works are necessary as the original channels have become undersized as a result of the increase in flood flows caused by development.

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[2] Tenaga Nasional Berhad (TNB) is Malaysia's largest electric utility company

(iii) Bunding of Rivers

Bunding of rivers reduces the chances of flooding of the low-lying adjacent areas. This option may give rise to problems of internal drainage as a result of the bunding. Bunding an urban area introduces a high flood damage potential as any occurrence of flooding as a result of flood water overtopping or breaching the bund would be very damaging.

(iv) Storage Ponds of Flood Attenuation

Ponds such as disused mining pools can be used for flood storage. The objective is to divert the flood water through such ponds and thus regulate the outflow so that the flood peaks[3] are attenuated. This strategy has been used in the case of Batu/Jinjang Pond Project in Kuala Lumpur where excess flood waters are diverted from Sg. Gombak to Batu Pond for temporary storage and from Sg. Keroh to Jinjang Pond. Water in the pond will be released slowly back to the river after the flood flow has subsided.

(v) Poldering (Ring Bund/Ring Embankment)

Poldering is the provision of a ring bund surrounding the area to be protected. This is normally carried out for an area which has high damage potential but for which the cost of overall basin-wide protection would be prohibitive. It includes the provision of internal drainage for the area to be protected and the evacuation of flood waters by pumping during periods of high river flows. This technique has been proven effective in controlling floods and is usually the only option available for built-up areas. However, structural measures usually incorporate "hard" engineering measures that result in bigger channels conveying high flows at high velocities. These measures incur high costs as well as require substantial land reserves for the channel.

(vi) Flood Diversion Channel or Tunnel

In major cities, rapid urbanisation causes tremendous increase in flood discharges which exceed river flow capacities. Extensive development adjacent to rivers however limit the space required for river widening projects. Under such circumstances, excess flood water has to be retained upstream in storage ponds or diverted downstream through a flood diversion channel or tunnel. Both concepts have been implemented in the Kuala Lumpur Flood Mitigation Project. A component of this project is the Stormwater Management and Road Tunnel (SMART) Project completed in 2007. The SMART system alleviates flooding in the Kuala Lumpur city centre by diverting large volumes of flood water from entering the city centre. The 9.7 km tunnel is designed to convey stormwater while a 3 km portion of it also serves as a motorway. The motorway eases daily traffic congestion at the southern gateway to KL City near Sungai Besi. This dual-purpose design is believed to be the first of its kind in the world.

[3] Flood peaks refer to maximum river flow levels at the peak of the flood event

Non-structural Measures

Non-structural measures are proposed where engineering measures are not applicable or viable or where supplemental measures are required. They include restriction of development in flood prone areas, land-use zoning, resettlement of population, flood proofing, and flood forecasting and warning systems. These measures are often installed to make-up for compromises in the design level of protection.

(i) Floodplain Management

The most important non-structural measure is floodplain management where development of land within or adjacent to flood plains are controlled (see Figure 4). The local government or district office is responsible for the development planning process and can restrict land-use within the flood plain or set specific requirements for approval.

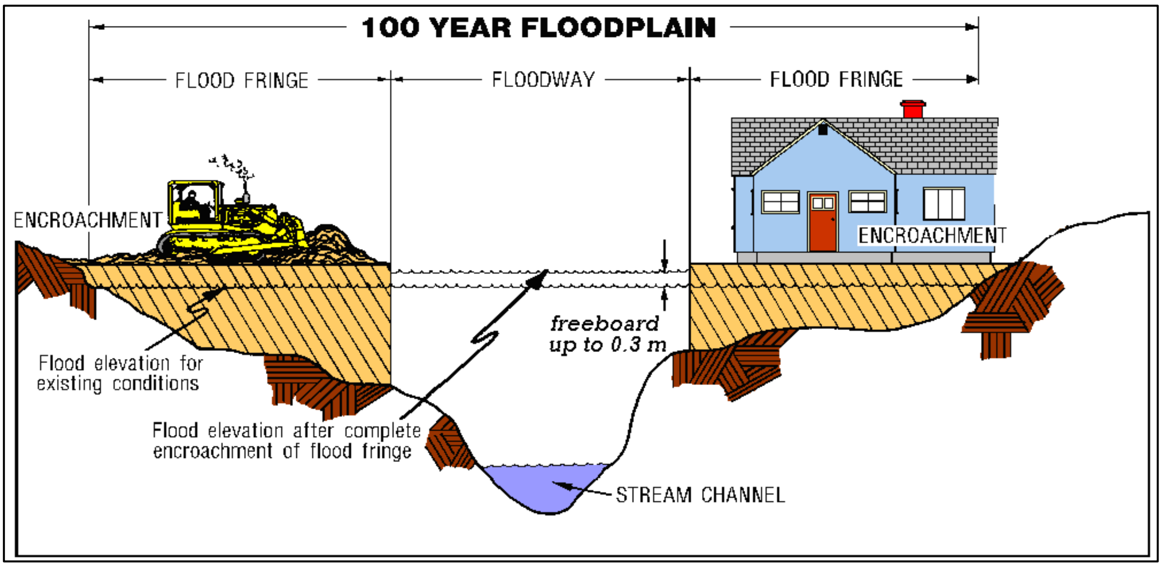

Figure 4: Encroachment of development into the 100-year flood plain

(ii) Early-warning Systems

Early flood warning systems were installed as far back as 1925 in Kelantan. After the 1971 floods, more advanced systems were installed. To date, DID has established about 335 telemetric rain-gauges and 208 telemetric water level stations in the vicinity of 40 river basins for real time flood monitoring. At these stations, three critical flood levels are designated, namely *Alert*, *Warning* and *Danger*. In addition, 400 river observation points are provided with manual flood gauges and more than 250 siren stations has been established.

(ii) Urban Stormwater Manual and Guidelines

The issuance of the *Urban Stormwater Management Manual for Malaysia* (elaborated further in later paragraphs) provided a guide to consultants and developers for drainage and environmental control for proposed development. Adherence to guidelines are monitored by local governments and technical agencies. Other than the above manual, specific guidelines such as for the prevention of flood in basement carparks and designing flood proofing for buildings have also been issued.

(iii) Risk Assessment and Flood Maps

In preparing the public for disasters, risk assessment is critical. Flood risk assessment requires the spatial aspect of floods to be clearly determined. Risk maps include inundation maps of historical events and flood hazard maps which are predicted scenarios derived from flood modelling. They facilitate the design of emergency evacuation plans.

Best Practise and Strategies

Flood Mitigation Design

Effective engineering solutions for flood mitigation must be supported by technical studies which detail flood hazard areas, modelled scenarios and potential damage assessments all resolved at the catchment level. The urban drainage master plans have been an effective management tool in guiding and refining structural engineering solutions. Flood mitigation design criterion considers many variables some of which are time-based and location specific. The level of protection in terms of the Average Recurrence Interval (ARI) is related to a hydrologic (rainfall, river flow) condition and based on historical data. The selected ARI frames a design to mitigate a rare event of considerable magnitude. Urban areas within agricultural regions are typically designed for 1:20 to 1:50 years ARI while a 1:100 years ARI is standard for densely populated urban catchments urban catchments. In all cases, the greater the ARI the higher the potential risk to human life and property, loss of income, damage to economy and societal cohesion. In reality, implementation of a project is constrained by land availability, social issues and monetary resources hence a compromised ARI design is eventually constructed. In most projects, a selected design level of protection is usually tested against a 1:100 ARI flood to ascertain the risk. Non-structural measures such as early-warning systems are then added to keep flood risks low.

Integrated Flood Management

A major shift in strategy took place in 2000 when the DID introduced the environmentally-friendly *Urban Stormwater Management Manual for Malaysia*. It signaled the beginning of Integrated Flood Management (IFM) as the underpinning strategy for flood mitigation. A subset of the Government's broader Integrated Water Resource Management initiative, flood management, like all other water resource issues, are to be addressed at the river basin level. In IFM, the river basin and flood plain is recognised as a dynamic environment where the management of land and water issues are integrated. IFM promotes a participatory approach and cross-sectoral interaction in decision-making adopting the best mix of strategies.

With the new manual in place, drainage control conditions are strictly imposed upon developers as a pre-requisite for development approval. Technically, the manual provides guidelines for control of erosion and sediment, stormwater quantity and stormwater quality. Key amongst this is that the estimated excess flows arising from new development are to be contained before being release into the main drainage system. Every new development is compelled to allocate land for flood detention. Structurally, IFM promotes a change in design concept – rapid-disposal, which was the primary design objective of earlier flood mitigation projects, have being replaced by storage, increased permeability and flow reduction.

IFM promotes public awareness of flood hazards and integrates its management together with other hazards such as bund breach and landslides. IFM, in tandem with other hazard management efforts are designed to create a high level of disaster preparedness and for the public to 'live and adapt' with floods as part of life. With climate change scenarios indicating higher annual rainfalls and more high intensity rainfall events in the future, IFM's proactive measures prepares the public with the knowledge of how disasters happen and how to reduce damages. This keeps in line with the National Climate Change Policy which is to "Ensure climate-resilient development to fulfill national aspirations for sustainability".

Recent Developments

Recently, much effort and advances have been made in raising awareness amongst the public. Websites with flood related information has been set-up where the public can access real-time flood information. Emergency messages via SMS have also been made available to residents of certain flood prone areas where there is insufficient lead time to warn of floods. Current and new projects include public awareness components and community programmes.

On the scientific aspect, the use of Supervisory Control and Data Acquisition (SCADA) and telemetery in the operations of flood mitigation structures and early-warning systems has been intensified to provide better control and efficiency. The government has also begun to incorporate atmospheric modelling elements in flood forecasting with the intent of acquiring more lead time to operate flood diversion structures as part of disaster response.

Conclusion

The flood phenomena is a permanent feature of the Malaysian landscape hence the current message to the general public is to live and adapt rather than to rely entirely on engineering intervention. A difference exists between flood control and flood management. The former is reactive while the latter is proactive. Engineering intervention should be part of a holistic solution to alleviate flood woes rather than a symptomatic cure for a local flood problem. Integrated Flood Management has become a key element in disaster management as its components encompasses preparedness, mitigation and response. In flood management, threat identification, inventoring, mapping and modelling are the non-structural elements that ascertain its risk level. The rising expenditure in flood mitigation reflects the seriousness of the government in managing floods effectively especially in urban areas where land is limited and solutions must be fitted around existing development. The greater emphasis on non-structural components is expected to lead to greater optimisation of the design of structural solutions. IFM therefore is key towards reducing the nation's risk from flood disasters.

Reference

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