The development of flood map in Malaysia

Cite as: AIP Conference Proceedings **1903**, 110006 (2017); https://doi.org/10.1063/1.5011632
Published Online: 14 November 2017

Siti Fairus Zakaria, Rosli Mohamad Zin, Ismail Mohamad, et al.

The Development of Flood Map in Malaysia

Siti Fairus Zakaria[1, a)], Rosli Mohamad Zin[2, b)], Ismail Mohamad[3, c)], Saeed Balubaid[1, d)], Shaik Hussein Mydin[4, e)], EM Roodienyanto MDR[5, f)]

[1] Candidate of Engineering Doctorate Studies, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM)
[2] Faculty of Civil Engineering, Construction Research Centre, Universiti Teknologi Malaysia (UTM)
[3] Faculty of Science, Mathematical Science Department, Universiti Teknologi Malaysia (UTM)
[4] Penang Regional Development Authority (PERDA); Deputy Chairman
[5] UMW Toyota Motors Sdn. Bhd; Director

[a)] Corresponding author: sitifairus@water.gov.my
[b)] roslizin@utm.my
[c)] immathematics@gmail.com
[d)] b2003alubaid@yahoo.com
[e)] shm878@gmail.com
[f)] roodienyanto@toyota.com.my

Abstract. In Malaysia, flash floods are common occurrences throughout the year in flood prone areas. In terms of flood extent, flash floods affect smaller areas but because of its tendency to occur in densely urbanized areas, the value of damaged property is high and disruption to traffic flow and businesses are substantial. However, in river floods especially the river floods of Kelantan and Pahang, the flood extent is widespread and can extend over 1,000 square kilometers. Although the value of property and density of affected population is lower, the damage inflicted by these floods can also be high because the area affected is large. In order to combat these floods, various flood mitigation measures have been carried out. Structural flood mitigation alone can only provide protection levels from 10 to 100 years Average Recurrence Intervals (ARI). One of the economically effective non-structural approaches in flood mitigation and flood management is using a geospatial technology which involves flood forecasting and warning services to the flood prone areas. This approach which involves the use of Geographical Information Flood Forecasting system also includes the generation of a series of flood maps. There are three types of flood maps namely Flood Hazard Map, Flood Risk Map and Flood Evacuation Map. Flood Hazard Map is used to determine areas susceptible to flooding when discharge from a stream exceeds the bank-full stage. Early warnings of incoming flood events will enable the flood victims to prepare themselves before flooding occurs. Properties and life's can be saved by keeping their movable properties above the flood levels and if necessary, an early evacuation from the area. With respect to flood fighting, an early warning with reference through a series of flood maps including flood hazard map, flood risk map and flood evacuation map of the approaching flood should be able to alert the organization in charge of the flood fighting actions and the authority to undertake the necessary decisions, and the general public to be aware of the impending danger. However this paper will only discuss on the generations of Flood Hazard Maps and the use of Flood Risk Map and Flood Evacuation Map by using geospatial data.

INTRODUCTION

Floods are natural disasters that have been affecting human lives ever since the beginning of time. There are only few places on earth where people need not be concerned about flooding. Any place where rain falls is vulnerable, although rain is not the only impetus for flood. A flood occurs when water overflows a river bank and / or inundates land that is normally dry. This can happen in a multitude of ways. Most commonly is when rivers or streams overflow their banks. Excessive rain and a ruptured dam or levee, can overwhelm a river and send it spreading over the adjacent land, called a floodplain. Meanwhile, coastal flooding occurs when a large storm or tsunami causes the sea to surge inland.

Proceedings of the 3rd International Conference on Construction and Building Engineering (ICONBUILD) 2017
AIP Conf. Proc. 1903, 110006-1–110006-8; https://doi.org/10.1063/1.5011632
Published by AIP Publishing. 978-0-7354-1591-1/$30.00

Most floods take hours or even days to develop, giving residents ample time to prepare or evacuate. Others generate quickly and with little warning and are normally called flash floods. These flash floods can be extremely dangerous, instantly turning a babbling brook into thundering wall of water and sweeping everything in its path downstream.

Disaster experts classify floods according to their likelihood of occurring in a given time period. A hundred-year flood, for example, is an extremely large, destructive event that would theoretically be expected to happen only once every century. But this is a theoretical number. In reality, this classification means there is a one-per cent chance that such a flood could happen in any given year. Over recent decades, possibly due to global climate change, hundred-year floods have been occurring worldwide with frightening regularity. Moving water has awesome destructive power. When a river overflows its banks or the sea drives inland, structures poorly equipped to withstand the water's strength are no match. Bridges, houses, trees, and cars can be picked up and carried off. The erosive force of moving water can drag dirt from under a building's foundation, causing it to crack and tumble. When floodwaters recede, affected areas are often covered by silt and mud. The water and landscape can be contaminated with hazardous materials, such as sharp debris, pesticides, fuel, and untreated sewage. Residents of flooded areas can be left without power and clean drinking water, leading to outbreaks of deadly waterborne diseases like typhoid, hepatitis A, and cholera. But flooding, particularly in river floodplains, is as natural as rain and has been occurring for millions of years. Most flood destruction is attributable to humans' desire to live near coastlines and in river valleys. Aggravating the problem is a tendency for developers to backfill and build on wetlands that would otherwise act as natural flood buffers.

Many governments have been given a mandate to build flood-resistant structures. Massive efforts to mitigate and redirect inevitable floods have resulted in some of the most ambitious engineering efforts ever seen. Highly advanced computer modelling and effective flood mapping now provide disaster authorities to predict with amazing accuracy where floods will occur and how severe they're likely to be.

FLOOD EVENTS IN MALAYSIA

In Malaysia the earliest recorded major flood was back in 1926. Other major floods occurred in 1949 and 1971. Over the years, flood events keep continuing and the occurrence seems to increase. It is most probably attributed to the progressive change in land use as the country developed while the drainage system remains inadequate with only little upgrading. As for the year 2000, the reported flood affected or flood prone areas in Malaysia are about 30,000 km2 or about 9% of total land mass of Malaysia while the number of people affected was close to 5 million. Typically, floods occur when flows in rivers and drainage channels overtop the banks and inundate the surrounding areas or flood plains. Generally in Malaysia there are 3 types of flooding which are: flooding due river bank overflow, high tides and flash floods. The basic cause of river basin flooding is heavy rainfall. In low-lying areas near the sea, the flood may become more severe or it may take a longer time to subside when coincide with high tide.

Floods are prevalent during the north-east monsoon season. The east coast and southern states are especially vulnerable to flooding during this period. Based on the facts presented, there is a dire need to understand the issues that arise from these annual floods and to develop counter-damage measures and methods; or to manage these issues in such a way that the floods do not become an obstacle to the economic and social development of the country and its citizens. Recurring floods are deemed by the public – rightly or wrongly - as inefficiencies of the local council, the government and the other relevant parties that may be involved. Therefore, comprehensive studies, proper implementation and better flood management projects are vital in reducing the impact faced by all sectors, which include reducing the costs of damage and compensation. A thorough study can develop counter-damage methods - or at least manage floods at a rational and tolerable state - to prevent or minimize damage and therefore reduce recurring costs and compensation.

It is important to note that most of the economic centers in Malaysia are located in low-lying terrain and near the coastline. As such, these economic centers are vulnerable to flooding and are therefore at high risk to significant structural damage and economic loss in the event of a major flood occurring. Some examples of large-scale flooding in Malaysia include a series of floods that hit the state of Johor particularly during December 2006 to January 2007, and also recently in January 2011. Throughout the week that started on 18 December 2006, a series of floods hit Johor, Melaka, Pahang and Negeri Sembilan. During this period, these southern Malaysian states - along with Singapore - experienced abnormally high rainfall which resulted in massive flooding. The rainfall recorded in the city of Johor Bahru on December 19 alone was 289 mm when the annual rainfall of the city was 2,400 mm. By the third week of January 2007, Johor was hit again by a larger flood. This flooding began when torrential downpours caused the rivers and dams to overflow. Weather officials described flooding in the area as the worst in a century. Both waves of these disasters were considered to be the costliest floods in Malaysia's history, with a total cost of RM1.5 billion. In January

2011, some urban areas in Johor - including Segamat, Johor Bahru, Kluang, Kota Tinggi, and Muar - were flooded and completely cut off. In this state alone, between 40,000 - 70,000 people were evacuated, and at least two people died in this particular occurrence.

Flood management measures are typically described as either structural or non-structural. Structural measures aim to reduce flood risk by controlling the flow of water both outside and within settlements. They are complementary to non-structural measures that intend to keep people safe from flooding through better planning and management of development. A comprehensive integrated strategy should be linked to existing development planning and management policy and practices. Structural and non-structural measures do not preclude each other, and most successful strategies will combine both types. It is also important to recognize the level and characteristics of existing risk and likely future changes in risk to achieve the balance between the required long and short term investments in flood risk management. But as both urbanization and climate change accelerate, there may well be the need to move away from what is often call today an overreliance on hard-engineered defenses towards more adaptable and incremental non-structural solutions. One of the non-structural solutions is through flood mapping.

THE DEVELOPMENT OF FLOOD MAP IN MALAYSIA

Malaysia is not left behind in applying this method of flood management in our country. In 2008, the National Water Resources Council (MSAN) has given its blessing for the Department of Irrigation and Drainage Malaysia (DID) to develop flood maps as an effort towards providing the country's non-structural solutions to support the structural measures which have been carried out throughout the country. A year later, DID was given the mandate by the Cabinet to continue in developing effective flood maps as one of the essential element in flood management. DID take this matter seriously and started to form a team of trained personnel to study the available and effective methodology in carrying out the tasks. Info Works RS and CS are used to carry out the flood map development. Within the same year DID has started with the Hydrodynamics Modelling and included Flood Hazard Maps as one of the scopes in the Flood Mitigation Master Plan Studies. In 2010, twelve (12) flood hazard maps from different flood prone locations have been completed where two (2) maps was developed in-house. Another four (4) flood hazard maps were developed in 2011 while fourteen (14) in 2012. In 2013, the flood hazard map for one of the largest river basin in Malaysia, Pahang River basin has been completed.

FLOOD MAP

Flood mapping is a crucial element of flood risk management. There are three common types of flood maps as shown in Figure 1.

1. Flood inundation maps, drawn based on observations of flooding which has occurred, normally shown on base maps such as satellite images ;
2. Flood hazard maps, shows the extent and expected water depth/level of a flooded area in three scenarios: a low probability scenario, a medium probability scenario, and a high probability scenario; and can be equipped with information such as the type of flooding, flooded area and water depth; if required information on water level, flow velocity or direction of water flow can also be included ; and
3. Flood risk maps, shows the combination of the probability of a flood event and the pshownotential adverse consequences to human health, the environment and economic activities associated with the flood

Hazard mapping reveals the areas that are particularly susceptible to floods. Information is needed both in spatial and temporal terms and includes location, frequency of occurrence, duration and severity. Production of hazard maps is the first step towards flood risk assessment. Their purpose is to better understand and communicate flood extent and flood characteristics such as water depths and velocity. Multiple stakeholders such as city managers, urban planners, emergency responders and the community at risk can use hazard maps in planning long term flood risk, mitigation measures and the appropriate actions to be taken in an emergency. Flood hazard maps provide a good foundation for efficient flood management. Flood hazard maps can be used as a decision making tool in preventing flood damages, land use planning, providing information on floods, in rescue operations and in determining a safe platform level from flooding for various types of development.

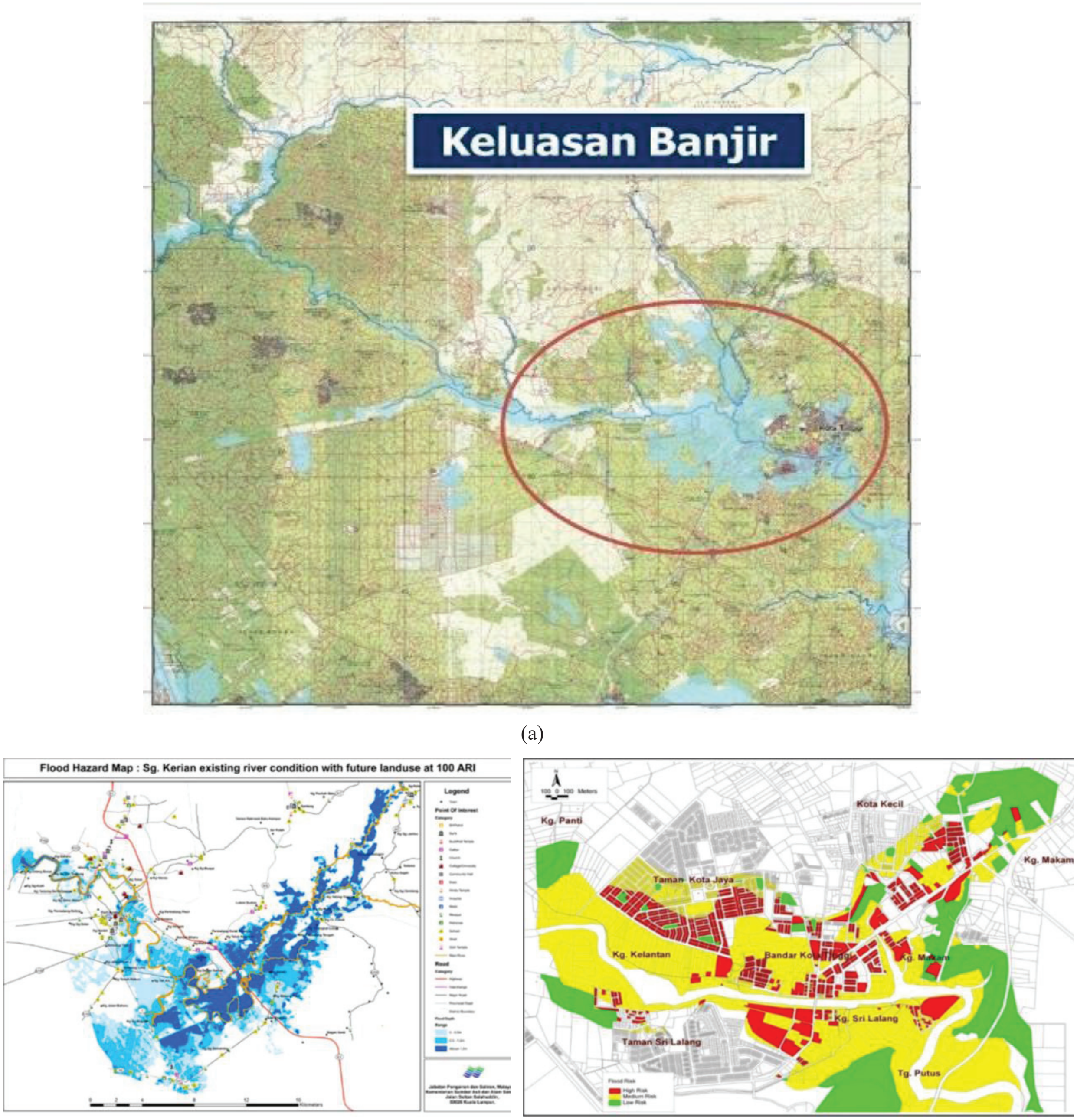
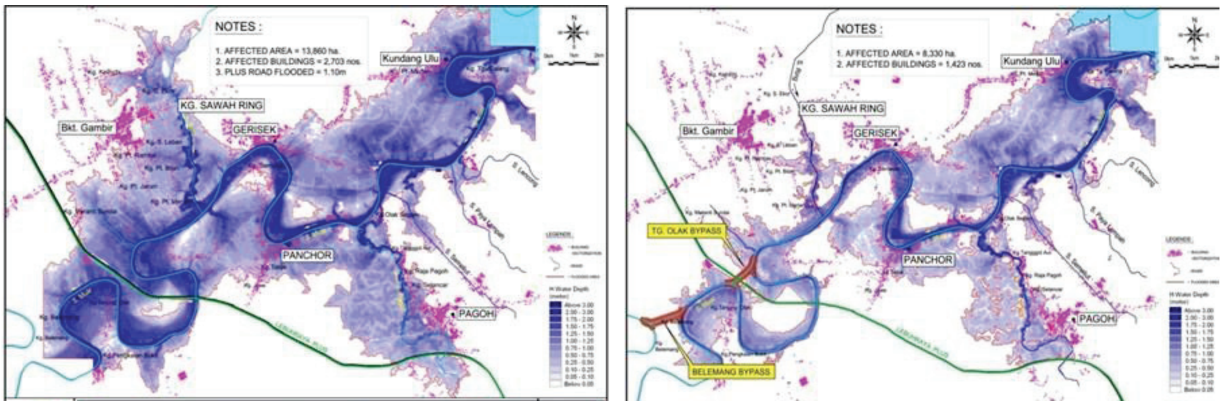


FIGURE 1. Various Type of Flood Hazard Map; (a) Flood inundation map; (b) Flood hazard map; (c) Flood risk map

Flood hazard map is an important tool to understand the hazard situation in an area. Hazard map is important for planning development activities in an area and can be used as supplementary decision support system (DSS). It should therefore be easy to be interpreted and the aim should be the generation of simple hazard map which can be read and understood by both technical and non-technical individuals. Therefore, there is a need to generate maps based on user-specific requirements, whether for individual or institutional purposes. Flood hazard maps are characterized by type of flooding, depth, velocity and extent of water flow, and direction of flooding.

The map can be prepared base on specified flood frequencies or return periods, for example, 1:10 years, 1:20 years, 1:100 years, or to more extreme events such as the 1:200 year return period for different scales (Fig. 2). Flood hazard is determined by the conjunction of climatic and non-climatic factors that can potentially cause a flood. The magnitude of a fluvial flood will depend on physical factors such as intensity, volume and timing of precipitation. The antecedent conditions of the river and its drainage basin will also have an impact on the development of the event, as will human-made factors such as the existence of dykes, dams and reservoirs, or the loss of permeability caused by development expansion into floodplains.



(a) (b)

FIGURE 2. Example of Flood hazard maps generated for Muar river; (a) Existing condition; (b) With 2 lower bypasses

In the mapping of flooded areas, attention must be paid to the reliability and accuracy of the source information. The historic flood maps are based on observations and thus they are reliable, especially if the observed flooded area is derived from accurate aerial photographs or satellite images or from the field markings. However, there is often no afore-mentioned source information available or the observed flood extent does not stand for a flood of a magnitude that has been chosen. Flood hazard maps are produced by combining the flooded areas, flood depths and flow velocities generated from the 2D hydrodynamic models for several different return periods with a digital terrain model (DTM). Inundated areas and water depths were digitally modelled with the above-mentioned information using Geographic Information System (GIS) software by reducing the digital elevation model of the earth's surface from the digital elevation model of the water surface (Fig. 3).

Typically, for public access purposes, general maps with limited information are produced using GIS software, showing only the flood extent and perhaps protection measures where these exist. For use by local authorities for decision making more detailed information will be required, such as municipality level maps with real estate data. For professional bodies, maps with more detailed supplementary data can be generated, going down to individual household plot level if required. Flood hazard maps must be updated regularly with both field information (for example, major building developments or road construction that significantly alter the terrain) as well as other relevant data, such as any changes in the peak recorded flows from gauging stations following extreme events. Monitoring of the hazard map's performance in use is also required (for example, where data from actual events following map production are found to exceed the modelled predictions). Known uncertainties in the model need to be incorporated into the decision making processes of the local authorities. Revisions to the maps following any amendments to input data will also be required. A process to ensure that the superseded copies are taken out of use is further needed, such that future decisions are made on the basis of the updated information. As of today, thirty one (31) flood hazard maps have been completed for this country. The location of this flood hazard maps are shown in Table 1.

FLOOD RISK MAP

When all flood hazards' information becomes available it is possible to develop contours which indicate the severity of risk. A flood risk map has several direct economic effects, since it causes revision of all planning maps for the area. On the negative side, it may lower property value in the flood prone areas and may stop development but on the positive side, the maps initiate the construction of flood loss prevention structures, alerts prospective land and property owners, as well as provide new developing ideas to the local planning authorities.

Flood risk is the combination of the probability of a flood event and the potential adverse consequences to human health, the environment and economic activities associated with a flood event. Risk can be assessed using the following equation (1)

$$R = Psi \times Aoj \times Poj.si \times Vojsi \quad (1)$$

Where:
R = Risk
P_{si} = Probability ofscenario i
A_{oj} = Value at risk of object j
$P_{oj.si}$ = probability of exposure of object j to scenario i
V_{ojsi} = Vulnerability of object j, dependent on scenario i

There are many factors that can be categorized as risk. In case of Flood Risk Map, only information of risk in socio economic and environment will be taken into consideration. For socio economic factor, the information will be gathered from the population and the related asset and economic activities. While for the environmental issues, the elements that will be integrated included agricultural areas and individual farm estates, dispersed settlements and small villages and city centers and industrial zones (Fig. 4).

TABLE 1. Completed flood hazard maps in Malaysia

2010	2011	2012	2013
JOHOR 1. Kluang 2. Simpang Renggam 3. Batu Pahat 4. Muar 5. Mersing 6. Sg. Johor SELANGOR 1. Sg. Buloh 2. Sg. Damansara 3. Sg. Kuyoh KELANTAN 1. Pasir Mas 2. Tanah Merah	SABAH 1. Beaufort 2. Tenom 3. Sook KEDAH 1. Lembangan Sg. Muda	MELAKA 1. Lembangan Sg. Melaka 2. Lembangan Sg. Kesang SELANGOR 1. Lembangan Sg. Selangor 2. Lembangan Sg. Labu, Sepang PERAK 1. Lembangan Sg. Kerian 2. Lembangan Sg. Kinta PERLIS 1. Lembangan Sg. Perlis & Sg. Arau NEGERI SEMBILAN 1. Lembangan Sg. Linggi JOHOR 1. WPI-Skudai 2. WPI-Sg. Plentong 3. WPI-Sg. Melayu TERENGGANU 1. Lembangan Sg. Setiu	PAHANG 1. Lembangan Sungai Pahang

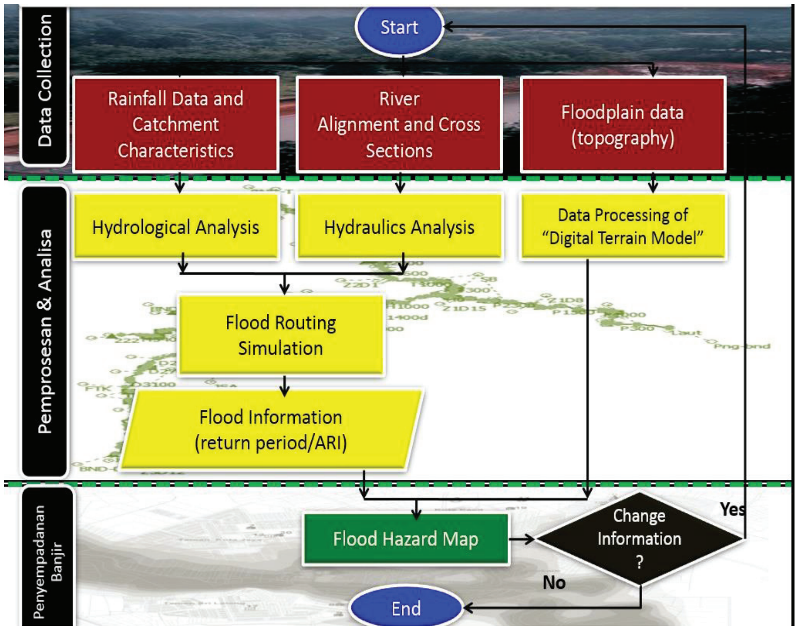


FIGURE 3. Processes in producing flood hazard map in Malaysia

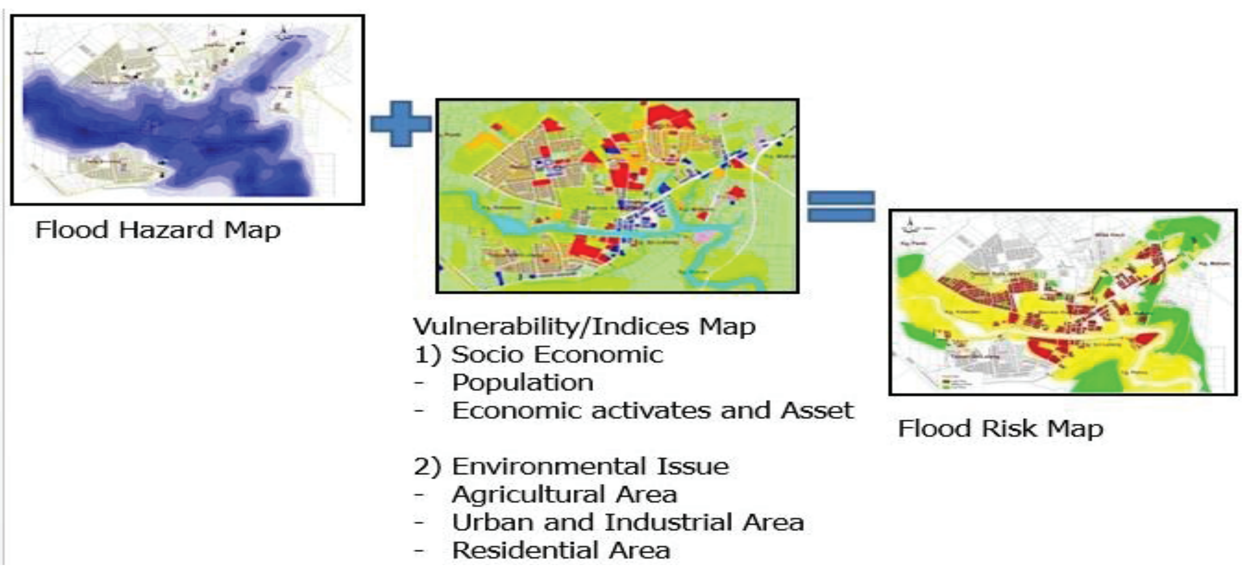


FIGURE 4. Elements in flood risk map

As a way forward, the objective of flood-risk mapping is to assist local citizens and governments to develop effective methods of reducing flood-related damage in the community over the long term. It is clear that the least costly and most effective solution is to adopt a preventive approach which emphasizes longer range planning in flood-prone areas. Measures such as zoning by-laws, building codes and subdivision regulations can be used to control and direct land use within the flood hazard areas. Flood damages can thus be limited by reserving the flood plain for uses that are less vulnerable to damage from flooding, such as agriculture, parks, recreation areas and parking lots. Regulations may require that certain conditions are met before development is permitted. Flood-proofing techniques such as construction without full or finished basements are examples of such requirements. It may also be decided to develop public ownership of lands which are susceptible to severe damage. However, before a local authority can effectively manage the flood plain, a great deal of information on flood-vulnerable areas must be collected. Flood risk maps, together with supportive material and more detailed technical maps, will be prepared by DID to facilitate the preventive approach. These maps cover parts of the areas known to be especially at risk from river flooding.

CONCLUSION

Integrated participation from various agencies will lead to a successful flood risk management. Moving from the current situation to the integrated ideal will often involve a painful process necessitating changes of mind-sets and motivations for multiple stakeholders, and balancing of their relative needs and priorities. The benefits of the integration of flood risk management into wider development management, urban planning and climate change adaptation are clear. It must be recognized that even repeated awareness campaigns, flood warnings and general advice will not always generate the required actions. Inertness is common to institutions and populations at risk and the situation is made worse by the future uncertainty which is perceived to dominate decisions in this area. There is a need to strike a balance between structural and non-structural measures in order to gain the most successful long-term flood risk management strategies. Understanding the required resources, the best and worst case scenarios is pertinent in making better decisions. In addition acknowledging those actions which will simply never be feasible can help in producing real practical solutions in the future.

REFERENCES

1. K. J. Abhas, B. Robin, L. Jessica, Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century (The World Bank Washington, USA, 2011).
2. G. V. Bapulu, R. Sinha, GIS in Flood Hazard Mapping: a case study of Kosi River Basin, India. Noida: GIS Development (2005).
   Available from: http://home.iitk.ac.in/~rsinha/PDF's/2006_FloodGISdevelopment.pdf [Accessed: 21/07/10].
3. Environment Agency, *Flood Map - your questions answered* (Rotterdam: Environment Agency, 2010)
   Available from: www.environment-agency.gov.uk/homeandleisure/31662.aspx [Accessed: 21/07/10].
4. P. Prinos, FLOODsite Project Report, T03-07-01 (2008).
5. M. Linham, R. J. Nicholls, in *Technologies for Climate Change Adaptation: Coastal Erosion and Flooding*, edited by Xianli Zhu (Magnum Custom Publishing, New Delhi, 2010).
   Available from: http://tech- action.org/Guidebooks/TNAhandbook_CoastalErosionFlooding.pdf.
6. S. Masatoshi, Science Direct – Urban Water, **1** (2), p.125-129 (1999).
7. M. Mazzoleni, B. Bacchi, S. Barontini, G. Di Baldassarre, M. Pilotti, R. Ranzi, J. Hydrol. Eng, **19** (4), p.717-731 (2014).
8. PFRA European Overview, Member State Report UC10508 (2014).
9. S. Neelz, G. Pender, Environment Agency Report SC080035/R2 (2009).
10. K. Spachinger, W. Dorner, R. Metzka, K. Serrhini, S. Fuchs, IOP Conf. Ser.: Earth Environ. Sci., **4** (012043) (2008).
11. FEMA Flood Maps, The National Academies of Science Report, 20001 (2009), see http:// nationalacademies.org/besr
12. World Meteorological Organization, *Comprehensive Risk Assessment for Natural Hazards* (Hydrology and Water Resources Department, Geneva, 2006). reprinted