5 YEARS AFTER SEVERE FLOOD IN 2014: A BETTER FLOOD FORECASTING SYSTEM



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Flooding is a natural way to discharge occasional large rainfall in the river eco system. However, with rapid urbanisation, natural floodplains have been sacrificed for socio-economic activities; we now realise that we need protection against inundation.

In Malaysia, flooding is the most severe natural disaster and it affects 18% of the country annually. There have been records of major floods: 1926 (whole country), 1963 (Sarawak), 1967 (Kelantan), 1970 (Kuala Lumpur), 1971 (whole country), 1976, 1996 (Sabah), 1998 (Penang), 2000 (Shah Alam), 2001 (Kuantan), 2003 (Kuala Lumpur/ Sarawak), 2004 (Kelantan), 2005 (Kedah/Perlis), 2006/2007 (Johor/Melaka), 2007 (Kuala Lumpur), 2007/2008 (Pahang), 2013 (Cameron Highlands, Kuantan, Kemaman) and 2014 (Kelantan, Terengganu, Pahang).

Meanwhile, with urbanisation and an increasing population, flash floods occur more frequently now, especially in city areas. For example, the population in the Klang Valley (less than 500,000 in the 1970s) is more than 3 million today and, to accommodate the need for housing, public facilities, utilities, businesses, recreational parks and others, new land areas have been opened up. The change from natural land surface to hard surface reduces the ability of rainwater to infiltrate the soil. The rainwater turns to surface runoff in a shorter time and so, more areas will be flooded at the downstream lower ground level.

After the catastrophic flood of 1971, the government set up The Permanent Flood Control Commission to look into long-term solutions to mitigate flooding. The National Disaster Relief Committee was also tasked with reducing losses in the event of impending flooding. One of its roles was to establish rainfall and water level stations to measure and deliver the information as quickly as possible to obtain flood forecasts. The flood forecast model was introduced as a function to predict river water level at any particular location. The forecast lead time depended on the time lag of surface runoff from upstream at higher levels flowing to inundation areas at lower level and finally to dissipate into the sea.

With the latest technologies in rainfall forecast and higher accuracies of surface topographic data, the flood forecasting model has made significant advances by using sophisticated and people-oriented models to achieve better and more accurate flood forecasts.

Floods in Kelantan in 2014

After the severe flooding on the east coast of the peninsula in December 2014, the government realised there was a need for non-structural measures in flood mitigation programmes. The flood hit Kelantan, Terengganu and Pahang and over 500,000 people were evacuated with 25 casualties and RM2.85 billion in losses (not including intangible losses). Victims also voiced out their dissatisfaction over the following:

1. Delay in early flood warning, especially for upstream areas such as Kuala Krai and Kuala Tahan, particularly during the second wave of flooding
2. Delay in evacuation response for rescue and location of flood victims at evacuation centres
3. Shortage of flood relief assistance such as clothing, food, medicine etc at evacuation centres.

In response, the government took the initiative to strengthen the institutional framework by establishing the National Disaster Management Agency (NADMA). Previously, NADMA was managed by a section under the National Security Council where the scope of work was limited to coordination and supervision of agencies related to natural disasters. With NADMA, coordination between agencies improved significantly, providing for more comprehensive flood assistance and response.

To improve flood early warning, the government, through the Department of Irrigation & Drainage (DID) and the Malaysian Meteorological Department (MMD), implemented a new flood forecasting project, the National Flood Forecasting & Warning Programme (Program Ramalan & Amaran Banjir Negara or PRAB). The idea of PRAB was mooted as the existing flood forecasting and warning system had limitations in terms of forecast location, lead time and flood warning coverage.

CURRENT FLOOD FORECAST SYSTEM

The flood forecasting system began in 1971, with the first telemetric water level station established at the Sulaiman Bridge on the Klang River. The number of rainfall and water level telemetric stations has increased tremendously since, from less than 20 locations to 800 stations currently. In-situ flood siren warning systems have been established in areas affected by frequent flooding, mainly to provide early alerts of rising flood water.

Flood modelling is defined as "the process of imitating a real phenomenon or a process with a set of mathematical formulae". The purpose is to provide as much advance notice as possible of an impending flood to the authorities and the public, which is to deliver reliable and timely information with enough lead time to allow people to take measures to protect themselves and to take appropriate actions.

In Malaysia, the first mathematical model, called Sacramento Model (1973), was used to estimate water level at Sungai Pahang. Since 1981, the Sugawara Tank Model was used at the Kelantan River, with very reliable forecasts. The series of the usage flood forecast models is shown in Figure 1 (refer to next page).

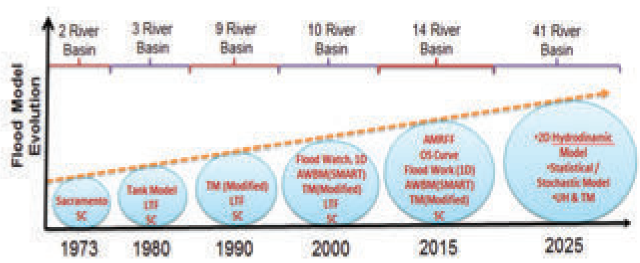

Figure 1: The evolution of flood forecast models in Malaysia

MAIN OBJECTIVES OF PRAB

PRAB refers to Program Ramalan & Amaran Banjir (in Malay) or National Flood Forecasting & Warning Programme (in English). Its three keywords represent:

- Forecasting which means how the system is able to calculate or estimate future conditions in particular water level forecast
- Warning which means dissemination tools or information to alert people so that early action can be taken
- National means the importance of the PRAB programme as a national agenda which will benefit many people.

PRAB has two main objectives:

1. To develop a system which can forecast monsoon floods 7 days in advance, based on weather forecast data from the Malaysia Meteorological Department
2. To increase the capacity of the existing system for warning and dissemination of information about monsoon floods from 6 hours to 2 days earlier for the benefit of related agencies and population affected by the flood.

To achieve its objectives, there are 4 components to be implemented in an integrated manner using the latest technology (see Figure 2). These are:

1. Hydrological Data Detection System
2. Database and ICT Infrastructure System
3. Flood Modelling and Forecasting System
4. Flood Warning and Dissemination System.

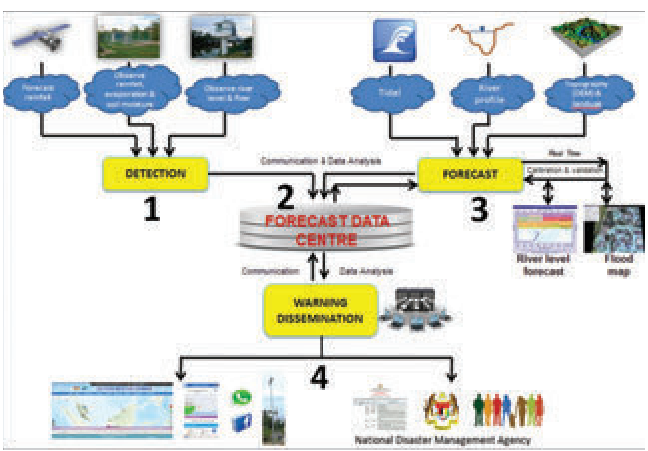

Figure 2: Main components of PRAB

A typical hydrological station

Since 2000, the Department of Irrigation & Drainage has developed a telemetry system to monitor real time rainfall and water levels from hydrological stations. Under PRAB, hydrological stations will be increased to up to 2,000 stations to make sure there's enough data and coverage to complement flood model requirements as well as to monitor flood conditions. Several stations will be equipped with new sensors for rainfall, water level, river flow, soil moisture and evaporation. The telemetry station has a compact and robust design to deliver accurate measurements and is powered by a solar panel at 15 minutes interval data transfer.

The Forecast Data Centre (FDC), a database and ICT system, was developed based on high performance and system redundancy platform. Currently, Terabyte Server and Virtualisation are used to store big sets of data from the DID telemetry system, geo-informatics data, weather forecast data and model simulation output. Centralising all data in one location in an integrated manner will improve the performance and time consumed for each component to complete the processing. FDC system also has a data cleaning system which will improve the quality of real-time hydrological data that could occur due to circumstances or conditions including sensor damage, communication breakdown and lack of power supply.

The FDC system links rainfall forecast data and hydrological measurement data to the National Flood Forecast & Warning System (NaFFWS), a modelling system that is able to process complex mathematical calculations consisting of hydrological, hydrodynamics and 2D mapping for flood hazard areas. NaFFWS will be developed for 41 river basins or almost 70% of flood prone areas. The flood modelling system will generate more than 20,000 points of interest, including the location of villages, towns, evacuation centres, mosques, main roads, government buildings, etc.

Public Infobanjir is a primary website medium for displaying and disseminating flood information to the public in real time. The website, developed in 2000, is being continuously improved to meet the needs of current expectations and to suit the latest technology. In principle, it displays more than 800 rainfall stations and water level data from hydrological stations in remote and urban areas. It can provide early warning for different levels of rainfall and water level conditions, based on the threshold.

PRAB will be improving its website capability through two new elements. The first is to develop a more informative and public user base interface. Simple web display and accurate information for rainfall and water level data are carefully developed.

The second element is to include an early flood warning bulletin containing a 7-day flood forecast to agencies and a 2-day flood forecast to the public. This information will be displayed in interactive ways, combining location maps of stations and locations of forecast flooding. Other than the *Public Infobanjir* website, other tools for disseminating flood forecast information include Facebook, Twitter, mobile apps, email, WhatApps and control flood sirens.

IMPLEMENTATION

The PRAB programme, divided into Phase 1 and Phase 2, will be implemented over 10 years, from 2015 to 2025. Phase 1 has been implemented for 3 major river basins: Sungai Kelantan, Sungai Terengganu and Sungai Pahang.

Phase 2, started in 2018, is expected to be completed by 2025. It will involve flood forecasting models and setting up new hydrological monitoring stations in 38 river basins in the peninsula, Sabah and Sarawak.

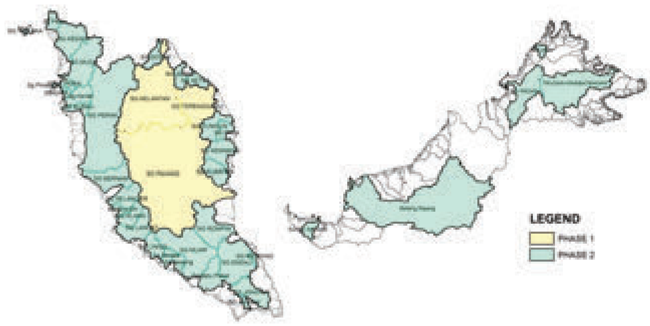

Figure 4: PRAB coverage area for 41 river basins

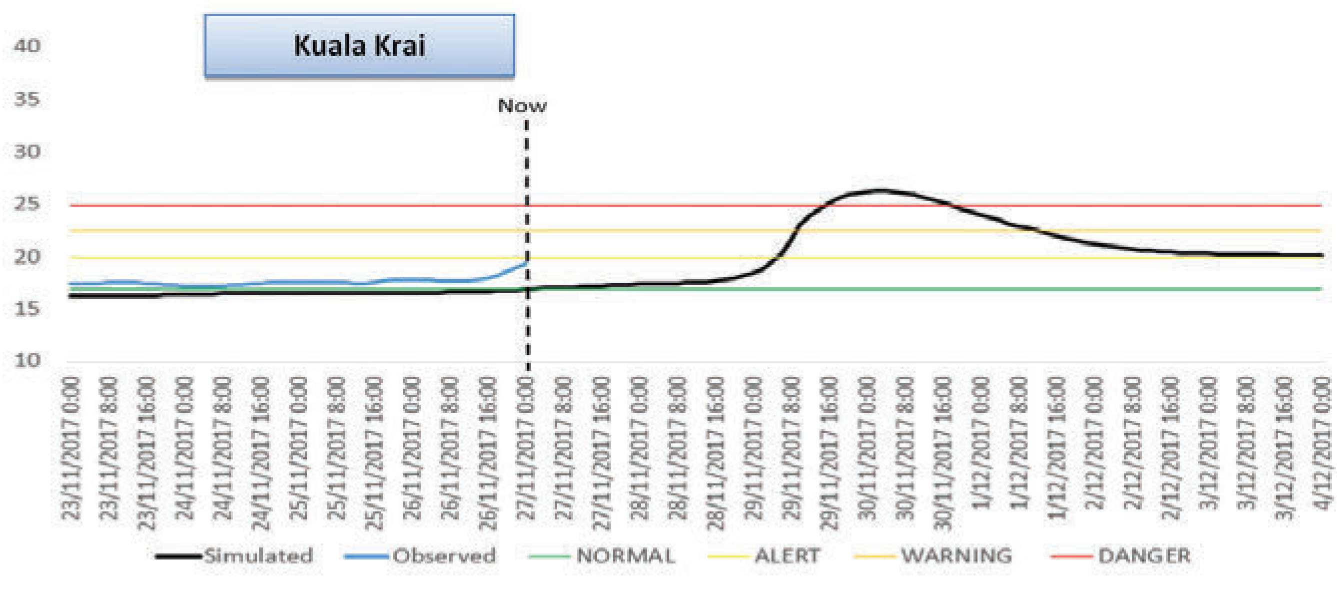

Figure 3: Example of 7-day river level forecast simulation result

TRANSFORMATION AND ADVANCED TECHNOLOGY

The PRAB programme has targeted to adopt and transform the flood forecast and warning system to be more advanced and to provide significant impact to the public. There are four elements in the transformation plan:

1. Early flood forecast duration. The system will improve the advance flood forecast from 1 day to 7 days. The use of Numerical Weather Prediction (NWP) data from Weather Research & Forecasting (WRF) Model data will provide a 7-day rainfall forecast as input parameters to the flood model.
2. Early flood warning duration. The system will improve the advance flood warning from 6 hours to 2 days. The WRF model data will provide a 2-day rainfall forecast and the flood model will simulate 2 days in advance the flooding area. The accuracy of forecast simulation will be improved through continuous checking with observed rainfall and water level data.
3. Enhanced flood warning database system. The database system is a key component of PRAB as all components will integrate with the Forecast Data Centre Servers System as the central database system. The FDC will operate 24/7 to house data from more than 2,000 hydrological stations, data from multiple agencies, NWP and radar data, flood modelling output, real-time CCTV and dissemination modules such as intelligent siren and public portals.
4. Wider coverage for flood warning dissemination. Problems with communication coverage will limit the dissemination of warning to people in remote areas. The existing system, which can only forecast results at dedicated water level stations, will be improved to simulate the forecast level along the river and flood-prone areas using the 2D analysis method.

ISSUES AND CHALLENGES

PRAB began in an ad-hoc manner, in reaction to the severe flooding in 2014. The implementation of an advanced modelling system is crucial and requires a high commitment from the client, consultant, contractor and all related agencies. There are some issues and challenges.

1. One of the challenges is to have locally-made products using local material and innovation by local experts. Almost 50% of hydrological instrumentation, such as hydrological sensors, are imported. The difficulty in promoting and marketing the product to the restricted number of local customers, limits the efforts of local manufacturers.
2. PRAB has been using a flood forecast model developed in the United Kingdom. Allocating a certain amount of financial resources for licensing and technical supports will incur significant accumulated losses in the long run. However, it is also very challenging to develop our own flood model as, according to the existing model developer, this requires a lot of expertise and a very long period of development (20-40 years).
3. Flash floods occur almost every month and happen over very short periods of time (1-6 hours). The impacted areas are also relatively small. However, the situation can be detrimental when it occurs in urban areas such as Penang and Kuala Lumpur. Therefore, an early warning system for flash floods is required and for this, the state of the art technology using radar and satellite can be explored.
4. There is a need to monitor how flood alert messages are disseminated to the targeted people as well as the public's ability to understand, react and share such alerts. The current delivery system needs to be improved to represent a proper stakeholder engagement which will help to better understand the situation and to deliver a more dedicated type of information.

THE WAY FORWARD

The implementation of PRAB is in line with the United Nation's Vision 2030 for the world, under Agenda 2030 of the Sustainable Development Goals No. 3 and No. 11, which is to promote good health and well-being for the peoples and sustainable cities and communities.

PRAB will continue to be developed under the 12th Malaysia Plan, focusing on 38 river basins. It will be an important tool to reduce vulnerabilities and flooding. It will contribute to national sustainable development and is an important ingredient for the future development strategy where Malaysians need to embrace the concept of "Living With Flood".

Preparedness and the response action of the National Disaster Management authorities are highly dependent on the availability of accurate and timely flood forecasting and timely dissemination to authorities responsible for civil protection and the general public.

Towards the new National Vision 2030: Shared Prosperity, four new fields will be explored and strategised: Re-Engineering, Big Data Analytics & Machine Learning, Impact Based Forecast and Flash Flood Forecast for rivers and urban areas.

In order to pursue these, service partnership and close cooperation with universities, research agencies and international bodies will be widened and strengthened. Innovative and creative solutions, with practical strategies, are important to bring Malaysia to the status of a developed country. ■

Authors' Biodata

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