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Simulation of Flood Extent Mapping by InfoWorks RS-Case Study for Tropical Catchment

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ABSTRACT

Flooding is a natural part of a river's life cycle but it is a major disaster affecting many regions around the world, year after year. Malaysia is among the countries that faces potential flooding problems due to rapid development and, improper river systems. The Skudai river basin covers an area of 293.7 km^2 in the south-western part of Johor in Malaysia. The Skudai River has come under the spotlight due to the impacts of future development projects. Land clearing for urbanization and, infrastructure construction may increase the magnitude of flood. Flood risk map is one of the best ways to study and understand the flood behavior. To produce flood level at various locations along the river and flood plain, hydraulic modeling is required to carry out the flood simulation. However, analysis a river system requires tremendous amount of data such as rainfall distribution, river properties and, most important, the flood plain topography. This study presents flood mapping results in Skudai River basin in Johor, Malaysia using InfoWorks software 1D modeling. The tasks involved hydrological modeling, hydrodynamic modeling. Ground model and generation of flood risk map. The results show that eighteen locations are affected by flood of 100 years ARI.

Key words: Flood mapping, InfoWorks RS, flood plain, hydrodynamic modeling

INTRODUCTION

Flooding is a natural part of a river's cycles, affecting many regions around the world. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems which not only damages natural resources and environment but also causes losses of lives, economy and health. Human activity, however, has aggregated the natural flood occurrences by walling off rivers and straightening their courses. Removal of bogs, swamps and other wetlands in order to produce farmland has reduced the absorption zones for excess water and made floods into sudden disasters rather than gradual increases in water flow. Nowadays, floods are disasters, causing temendous property loss each year. Accurate information on the extent of water bodies is important for flood prediction, monitoring and relief (Mountz and Crowley, 2009; Baumann, 1999).

Malaysia has an equatorial climate with constant high temperature and high relative humidity throughout the year. The climate is influenced by the northeast and southwest monsoons. The northeast monsoon prevailing between November and February brings heavy rainfall which could persist for several days. In addition, there are two transitional periods between the monsoons

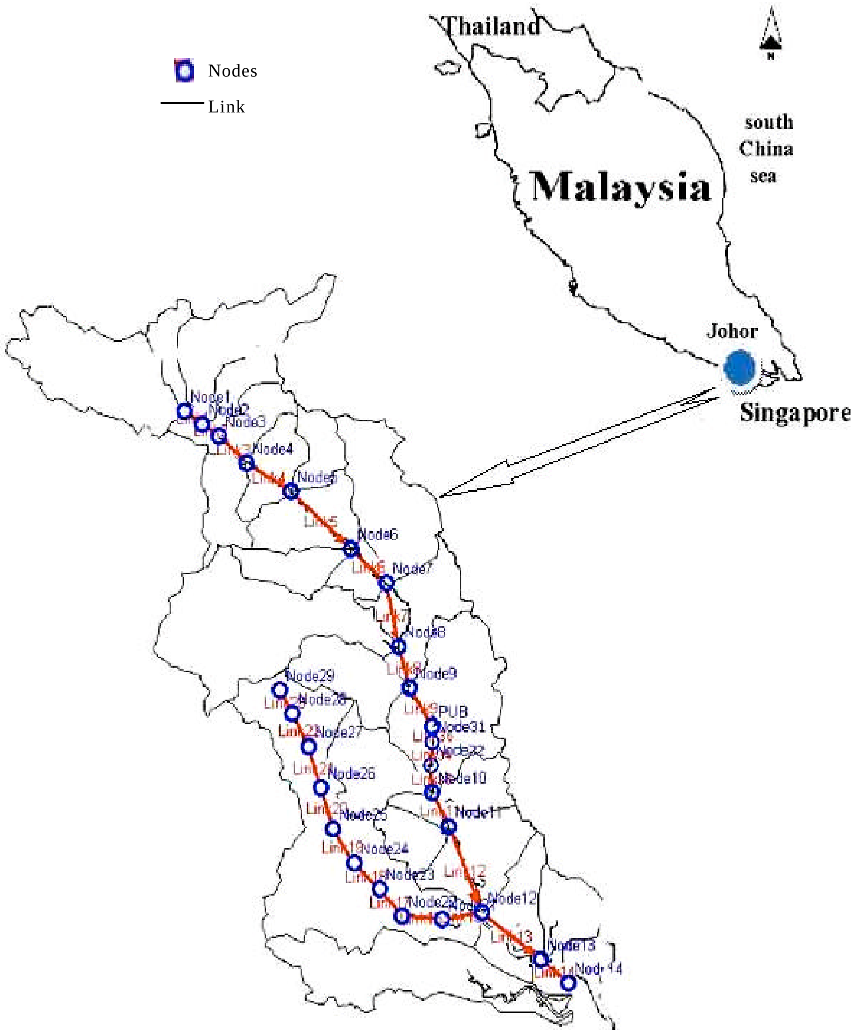

Fig. 1: Location of the case study site within the Skudai catchment

(inter monsoon) when convectional thunderstorms are common. There are about 200 river systems in Malaysia: 150 rivers systems in the Peninsular and 50 in Sabah and Sarawak. Major floods in Malaysia were recorded in 1926, 1931, 1947, 1957, 1967, 1971, 1973, 1979, 1983, 1995, 1998, 2003 and 2005 (Abdullah *et al*., 2007) and most recently in December 2006, January 2007 and January 2011 which occurred in Johor.

The January 1971 flood that hit Kuala Lumpur and many other states resulted in a loss of more than RM 200 million and 61 death. In fact, during the recent Johor 2006-2007 flood due to a couple of "abnormally" heavy rainfall events which caused massive floods, the estimated total loss was RM 1.5 billion and damages to infrastructure were estimated at RM 237.1 million which is the most costly flood events in Malaysian history.

The study area is located in the southwestern part of the WPI (Wilayah Pem bangunan Iskandar) region as shown in Fig. 1 and falls under the jurisdiction of two local authorities, namely Majlis Bandaraya Johor Bahru and Majlis Perbandaran Johor Bahru Tengah. The Skudai River catchment covers an area of 294 km^2 within the southernmost part of Johor and the total river length is 46.5 km. Skudai River starts from Sedenak east in the upstream to Danga Bay at the estuary. From Sengkan unit the river divides into two upstream parts. In the modeling of this study, we just consider the main part, Sengkan to Danga bay.

INFOWORKS RS

Information Technologies (IT) is useful to manage local and minor flooding problems. This involves applying computer-based models of the drainage/sewer system, such as MOUSE (Huber and Dickinson, 1988), Info Works (Bouteligier *et al.*, 2001), SWMM (EPA SWMM, MIKE SWMM and XP SWMM) (Lindberg *et al.*, 1989). Hydrological modeling is used to recognize the frequently multifaceted interactions between rainfall and flooding and to anticipate flood evolution due to land-use change. Once the existing conditions have been analyzed and understood, mitigation schemes can be evaluated and the optimal scheme implemented.

Most hydrological models include input and output procedures and possibly including graphics and statistical capabilities. The computing power of present computer gives major advantages over manual techniques. This is likely to result in more accurate designs, with cost saving s by avoiding over or under-sizing. A very important factor is that almost all computer models can fully account for storage in all stages of the hydrology/hydraulic routing (Bouteligier *et al.*, 2001).

InfoWorks RS as a hydrodynamic modeling software includes full solution modeling of open channels, floodplains, embankments and hydraulic structures. Using both event based and conceptual hydrological methods, the rainfall-runoff simulation is also available using geographical plan views, sectional view, long sections, spreadsheet and time varying graphical data in full interactive views of data. The underlying data can be accessed from any graphical or geographical view. In addition to presentation of results in geographical plan, cross section views, tables and long section and model also provide animation showing how a flood event progress. Full flood-mapping capability is provided based on a sophisticated flood-interpolation model overlaid onto an imported ground model. In 2002, the development of InfoWorks v4.5, saw the inclusion of water quality, sediment transport and Probability Distributed Moisture conceptual soil moisture runoff model.

The ground modeling functionality was enhanced to support both grid based and TIN (Triangular Irregular Networks) based ground models. Most recently, the release of v9.0 has provided a step change to functionality of InfoWorks RS with the inclusion of the InfoWorks 2D module and the HR Breach methods. For flood damage assessment and analyzing risk, the flows in 2D provides more detail and better accuracy and it is useful from flood inundation to particularly for local water levels and velocities. The HR Breach methods allow for simulation of the failure of embankments and dams providing completely integrated 1D, 2D and breach simulation functionality in a single product, single model networks, single data storage, single simulation and single results analysis and post-processing (Smith, 1997).

FLOOD MITIGATION STRATEGIES

Structural and non structural measures are two common approaches to solve flood problem. Firstly, structural measures like river widening, deepening and straightening are targeting to decrease flood extent but at the same time might transfer the flood problem to the downstream and Structural measures include building, channel improvement, flood bypass, pumping, flood storage dams and flood detention basins. Secondly, for non structural measures, some tools can be used to quantify the effects of human interference to the river system such as computer model, flood forecasting and warning, flood zoning and flood risk mapping and resettlement of affected population (Mohsen Salarpour, 2010). Such tools already available in advanced country but the application is still new in developing countries, including Malaysia. It is important to understand and analyze the flood behavior before construction or installation of any structural measure. Therefore, before any development activity river engineers must first evaluate potential impacts of flood extent and advice the implementing agencies, to carry out further prevention measure to avoid the anticipated adverse (EXCIMAP, 2007).

Methodology: The cross section profiles of Skudai River sub-basin were obtained from the Department of Irrigation and Drainage (DID), Skudai based on a survey done in May 2000. There are 110 river cross section profiles, The Chainages interval used in this study was five hundred meters but in some locations that are more prone to flood and more developed, smaller intervals down to 50 were used to calculate the water level and flood extent map more accurately (Fig. 2). The cross sections are available in AutoCAD format which is later processed using ESRI ArcView that enables the Shapefiles (SHP) data to be converted directly into InfoWorks RS model database.

Hydrological data that include cross section and water level data was imported into InfoWorks RS. From these data, a model is created and later simulated for the calibration and verification. The results can be either obtained from InfoWorks RS or directly displayed through ArcView.

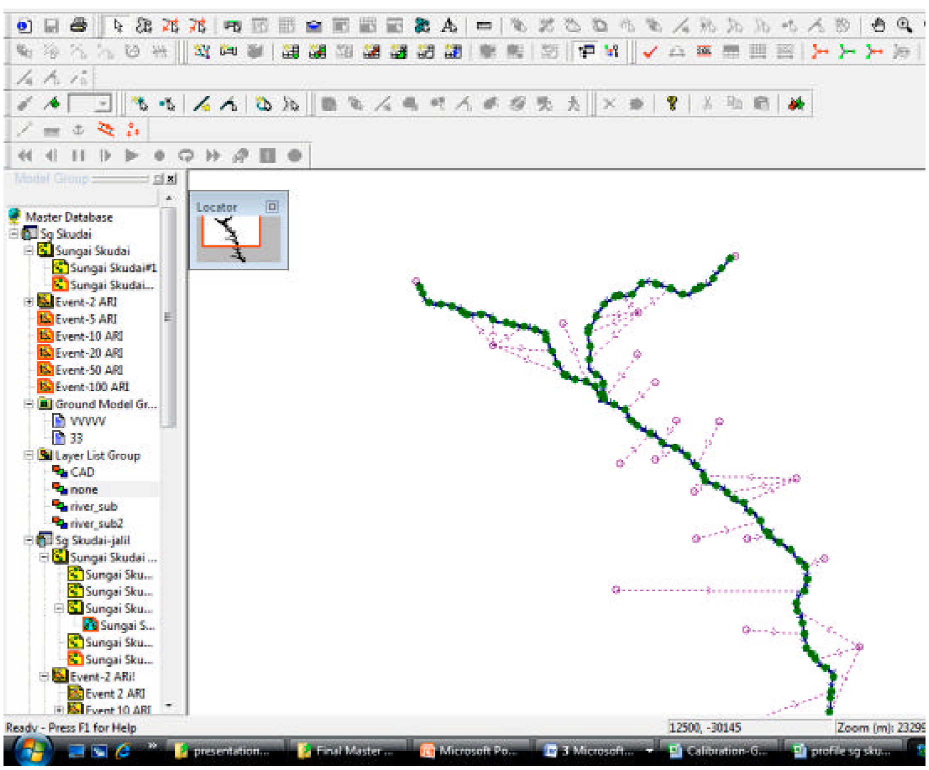

Fig. 2: Location of one hundred and ten cross-sections along Skudai River

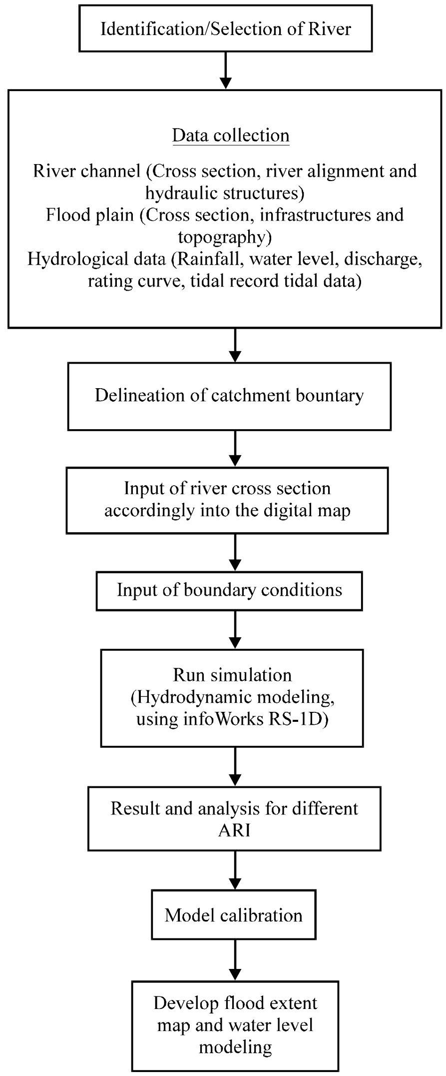

Fig. 3: Summary of Steps in River Modeling

The multiple steps involved in modeling the river by using InfoWorks RS are summarized in Fig. 3.

In any hydrodynamic river simulation, the most important input would be the shape of the river which is represented by the cross section, hydraulic structure, river flow and water level. Boundary conditions are the input data that are applied either at the upstream or downstream end points, to represent the river flow on each end or junction of the network. Flow-Time boundary was applied on Kpg. Git station as the upstream inflow hydrographs. The Flow-Time Boundary specifies a set of pairs of data consisting of flows and times. Stage Time Boundary was used on Sedenak plantation area as the upstream end of the network. A Stage Time Boundary also specifies a set of pairs of data comprises water levels above datum and time.

Simulation is the last process in river modeling: This procedure was carried out to view the behavior of the river network under particular conditions and the effects of the input or given boundary conditions to the modeled river over a period of time. Simulations are grouped into runs, with each run applied to a single network but utilizing one or more event data sets. The time span for simulations is depending on the model. For this study, the time span used for simulations is 24 h.

The data required for calibrating Info Works RS was the Manning's roughness coefficient, n for river and floodplains. Manning's n roughness coefficient depends on channel material, surface irregularities, variation in shape and size of cross section, vegetation and flow condition, channel obstruction and degree of meandering (Mah, 2006). The calibration session involved a trial and error method where different sets of model options and parameters were used until an acceptable match between the observed and modeled water level is achieved.

Two 24 h events were taken, where two for calibration of the model. Calibration events were carried out using data on- 1st and 9th April 2007. The correlations between the observed and simulated data were between 83-87%. The analysis indicates that for Skudai River sub-basin, a Manning's n of 0.03 and 0.05 are appropriate for its waterway and floodplain, respectively. A time step of 60 sec is appropriate for the conversion of model.

RESULTS AND DISCUSSION

The highest and lowest water levels (blue lines) for 100 ARI at station Taman Indahpura, Kulai are shown in Fig. 4. The green color represents the nearest cross section at the upstream and the red color is next cross section at the downstream. Therefore, checking the behavior of flood in 1 km in the downstream and upstream in this type of modeling is possible. This is one of the graphical ability of InfoWorks which is able to compare three cross sections in one figure together. The flood will happen in the units that the maximum water level is higher than the left and right banks of the river. Another modeling result for Skudai River is high water level modeling in longitudinal section from Sedenak plantation area (upstream) to Danga bay (downstream) in 46.5 km for 100 ARI.

The water level modeling result for the whole of river is illustrated in Fig. 5. In this Fig. 5, the red line represents the right bank and green line represents left bank of Skudai River. The upstream is Sedenak Plantation and the downstream is Danga Bay. This figure gives the overview of the water level for the complete section of the river. The upper layer (in blue) is the simulated

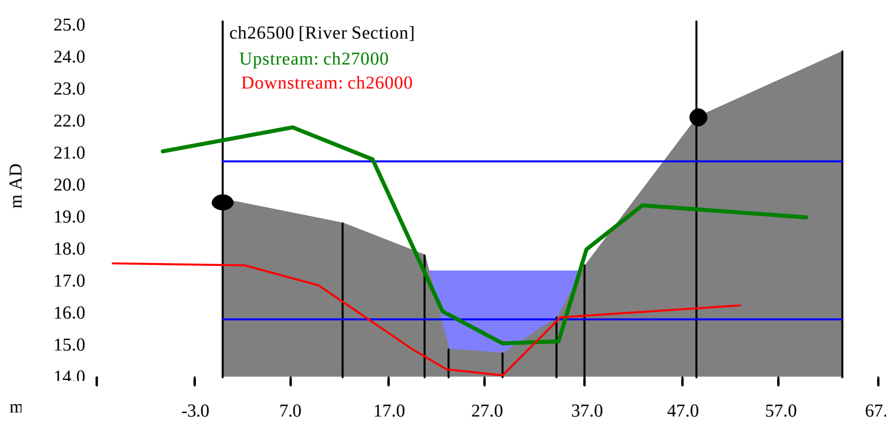

Fig. 4: Water level in Taman Indahpura, Kulai for 100 ARI

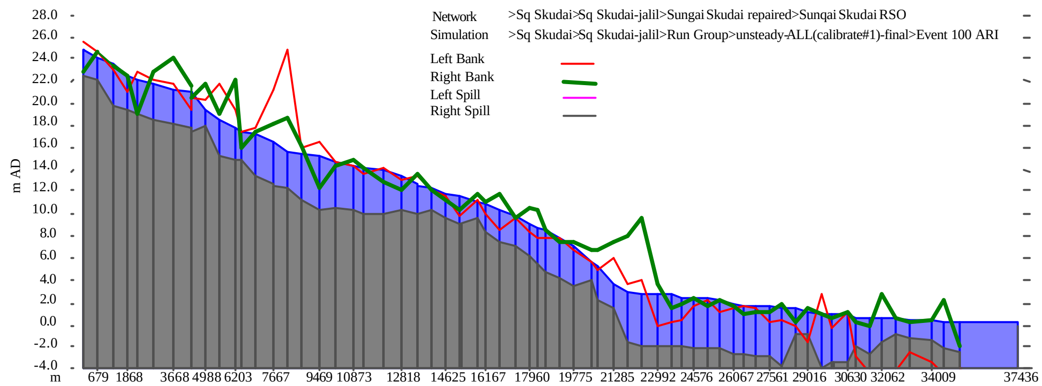

Fig. 5: Water level modeling with InfoWorks in Skudai River from Sedenak Plantation area (upstream) to Danga Bay (downstream)-100 ARI

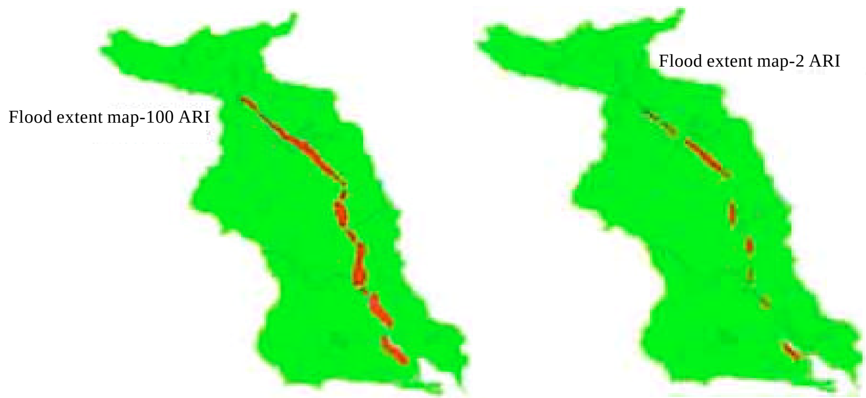

Fig. 6: Flood extent map simulated with InfoWorks for 2 ARI

water mass and the lower layer is the river bed. At any section that the water level is higher than red or green color, flood will occur.

Another important result in this modeling is the complete graphical output from simulation compare with other softwares that the water level figures in the whole simulation of the river and also in every cross section is available to monitoring for every time that we investigate during one year. Means in every considered time, the water level can be compared with the left and right bank of the river to find out the flood area.

Because of the importance region of Skudai River, the government should consider of the dangerous unites to make construction in this area. The flood risk area, has shown in red color and the flood map for 2 ARI and 100 ARI have been simulated by InfoWorks RS, because of comparing with the flood prone area that mentioned in Fig. 7 provided by DID. Flood extent map simulated with InfoWorks for 2 ARI is presented in Fig. 6.

According to the flood extent map which was modeled by InfoWorks 12% of the Skudai catchment would be affected by 100 years flood and 8% by the 2 years flood. Also the flood map modeled by InfoWorks is compared with the flood prone area provided by DID for 2 years ARI. Approximately 95% of the affected area is the same.

Fig. 7: Distribution of Various Flood Prone and Flood Areas in IM, 2007, Skudai River (provided by DID)

CONCLUSION

The study has shown that the processes, including the development of hydraulic, hydrological and ground model flood map delineation, can be produced for big river system in short time with the support of GIS tools. For the case of Skudai River which covers a distance of 46.5 km and total catchment area of 294 km^2, 18 locations would be affected by 100 years flood. These areas are Kg Sengkaang, Tmn Mewah, Tmn Mas, Kulai, Kg Separa, Kaw. Perindustrian, Senai, Jln Lapangan Terbang, Tmn Bahajia, Tmn Sepakat, L/raya U-S, Kg Laut, Tmn Impian Emas, Tmn Sri Putri, Tmn Sutera Utama, Perling, Kg Teluk, Kg Psir and Dnga Bay. With this development, flood risk map can provide a quick decision support system tool for assessing the impact in the catchment.

The modeling results using InfoWorks RS 1D show 95% similarity with the flood map earlier produced by DID.

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