

FLOOD HAZARD MAPPING USING TWO-DIMENSIONAL RIVER MODELLING FOR SUNGAI MUAR, JOHOR

LIEW YUK SAN

Research Officer, Research Center for River Management, National Hydraulic
Research Institute of Malaysia (NAHRIM)

Lot 5377, Jalan Putra Permai, 43300, Seri Kembangan, Selangor, Malaysia

ZALILAH SELAMAT

Director, Research Center for River Management, National Hydraulic Research
Institute of Malaysia (NAHRIM)

Lot 5377, Jalan Putra Permai, 43300, Seri Kembangan, Selangor, Malaysia

Abstract

Over the years, Muar River or Sungai Muar experienced numerous flooding as being recorded in 1971, 1982, 1987, 1988, 1992, 1995 and 2006 and 2007. The areas affected by flooding included Tangkak, Serom, Kundang, Kesang, Gersik, Bukit Kepong, Bukit Serampang, Lenga, Jorak, Air Hitam, Sri Menanti, Sg Balang and Segamat. Many studies have been conducted to overcome the intense problem of flooding in the study area. Besides that, it is also necessary to develop flood hazard maps to help the local authority and community in the event of floods and minimize losses. The objectives of the study are to develop a 2-Dimensional River Model covering the flood plain of Muar River from Kuala Pilah to the river mouth for a distance of 280 km and to generate flood risk map for various return period. The total catchment area is 6149 km². There are 25% of forest areas with the rest of agriculture, housing and other land uses within Muar river basin. InfoWorks River Simulation is used to model the Muar River while historical flood events were used to calibrate and verify the model. From the study, it is found that 2-Dimensional hydrodynamic model is useful in developing a better quality of flood maps based on available LiDAR informations. It is beneficial as a planning and design tools for the local authority and local community in preparing evacuation plan.

Keywords: Flood; Numerical modeling; InfoWorks RS; Flood Hazard Map

1.0 INTRODUCTION

Over the years, Muar river basin experienced numerous flooding as being recorded in 1971, 1982, 1987, 1988, 1992, 1995 and 2006 and 2007. The most serious flooding badly hit Muar river basin in end of 2006 and early 2007 which almost paralyze the whole state. The areas affected by flooding included Tangkak, Serom, Kundang, Kesang, Gersik, Bukit Kepong, Bukit Serampang, Lenga, Jorak, Air Hitam, Sri Menanti, Sg Balang and Segamat (Social Welfare Department of Malaysia, Muar District, 2007). Figure 1.1 shows the flooding area for December 2006 to January 2007 floods in Muar River Basin.

Many studies have been conducted to overcome the intense problem of flooding in the study area. Several flood mitigation masterplans were proposed in Flood Mitigation Plan for Muar River (Phase 1) which was based on an earlier study entitled "Masterplan Study on Flood Mitigation and River Improvement for Muar River Basin" to prepare a detail design and tender table document for the purpose of implementing the flood mitigation project for crucial flood prone areas especially within Muar River basin.

Besides the masterplan study, it is necessary to develop flood hazard maps to help the local authority and community in the event of floods and minimize losses. The objectives of the study are to develop a 2-Dimensional River Model covering the flood plain of Muar River from Kuala Pilah to the river mouth for a distance of 280 km and to generate flood risk map for a return period of 2-, 5-, 10-, 20-, 50- and 100-year.



Figure 1.1: Flooding area in Dec 2006 to Jan 2007 floods in Muar River Basin

2.0 STUDY SITE

The study site is Muar river basin with the catchment area of 6149 km². It is under the jurisdiction of Johor, Malacca and Negeri Sembilan. Sungai Muar or Muar River originates from Titiwangsa Mountains and flows through various districts like Kuala Pilah (Negeri Sembilan), Jempol, Segamat and Muar (Johor) before ending at Straits of Malacca. Figure 1.2 shows the location map of the study site. The total length of the stream is 288 kilometres. The main river tributaries which form the entire river systems are Ring River, Gemas River, Chodan River, Pagoh River, Segamat River and Palong River. Figure 1.3 shows the main river tributaries.

There are 25% of forest areas with the rest of agriculture, housing and other land uses within Muar river basin (Source: DOA, 2006). Table 1.1 shows the landuse categories within Muar river basin.

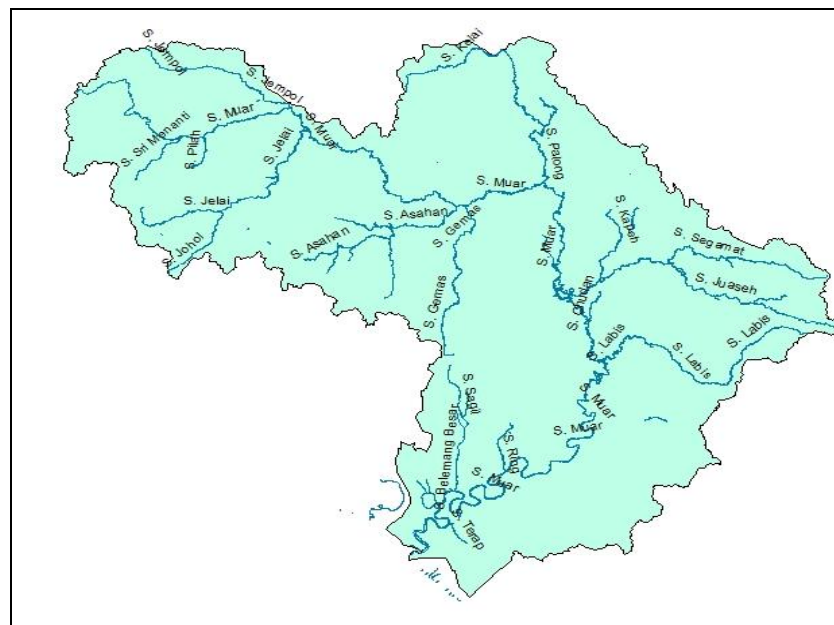
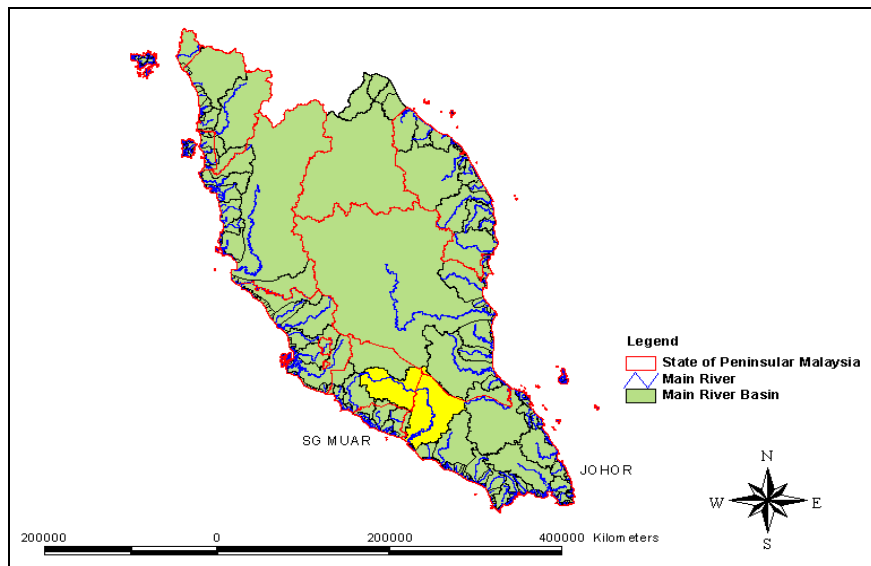


Table 1.1: Landuse category in percentage (DOA, 2006)

CATEGORY	PERCENTAGE (%)
Water body	0.29
Swamps, marshland and wetland forest	2.58
Forest land	24.38
Urban, settlements and associated non - agricultural area	2.43
Horticultural lands	3.51
Idle grassland	1.74
Animal husbandary areas	0.36
Others	0.40
Tree, palm and other permanent crops	63.66
Short-term crops	0.65
TOTAL	100.00

3.0 METHODOLOGY OF STUDY

The study involved data collection of river system, catchment characteristics and flood plains, model set-up for 1-Dimensional and 2-Dimensional river model, model calibration, verification and simulation. The verified model will then be used to produce flood map for different return periods. InfoWorks River Simulation (RS) version 10.5 is used to develop the River and Flood Plain Modelling for Muar River. Figure 1.4 shows the overall methodology of study.

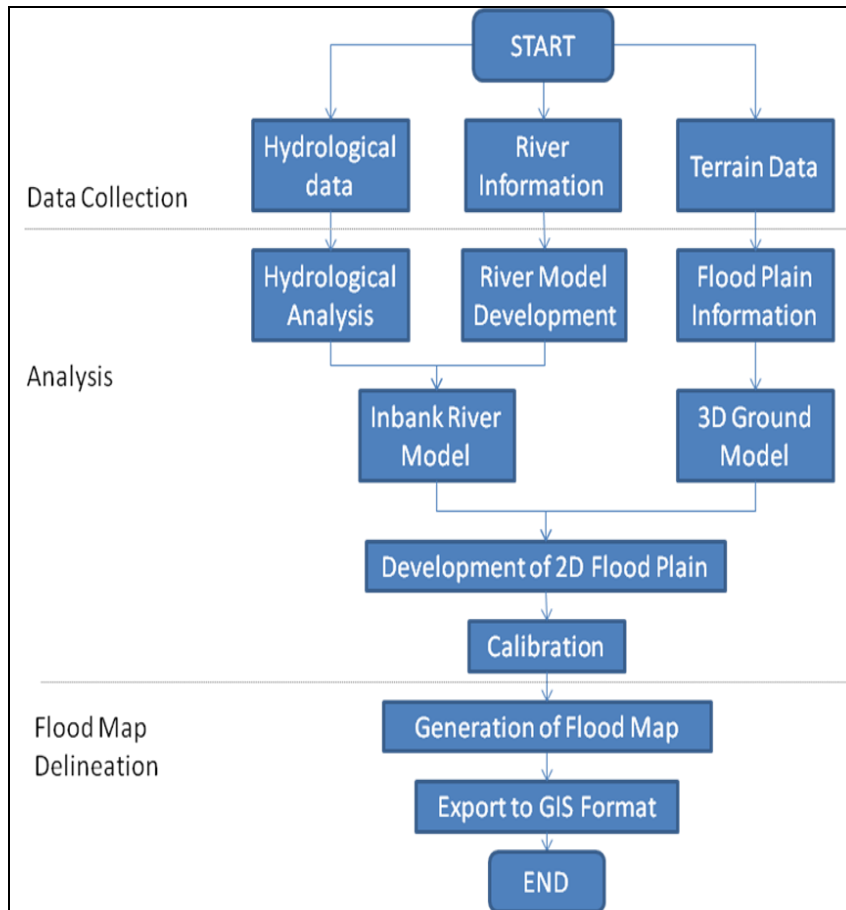


Figure 1.4: Methodology of Study

3.1 DATA COLLECTION AND ANALYSIS

The successful of the study are very dependent on the data availability and the quality of the data. The summary of the data source and characteristic is tabulated in Table 1.2.

Table 1.2: Information Source and its Characteristics

No	Information	Source	Format	Scale
1	Digital Topographical map	Department of Survey and Mapping (JUPEM)	ACAD	1:25,000
2	Satellite Image	Malaysia Centre for Remote Sensing (MACRES)	Image	2.5 m resolution
3	LIDAR	Department of Irrigation and Drainage (DID)	Text file	1 m resolution
4	Hydrology stations	Department of Irrigation and Drainage (DID)	Shape file	1:50000

No	Information	Source	Format	Scale
5	Historical Flood areas	Interview, site visits, reports	Hardcopy	
6	Future Landuse	Local Authorities / DOA	Hardcopy/ACAD	1:50,000
7	Survey alignment plan	Department of Irrigation and Drainage (DID)	ACAD	1:10,000
8	Tidal	National Hydrographic Centre, Royal Malaysian Navy	Hardcopy	

Hydrological data, river information and terrain data are the most pertinent information needed for numerical modelling. There are twenty-five (25) rainfall stations and three (3) water level stations around the study area. Frequency analyses are carried out to obtain Intensity-Duration-Frequency Curve. Tidal harmonic constants at Tanjung Keling, Malacca are obtained from Tide Table produced by National Hydrographic Centre, Royal Malaysian Navy to model the tidal effects to the entire system.

River survey drawings were provided by Department of Irrigation and Drainage Malaysia (DID) which served as the main input for the river hydrodynamic model. There were two river survey works carried out in the year of 1999 and 2009. Apart from the survey works, topographic map from the Department of Survey and Mapping (JUPEM) also used as the base map for the modelling. Digital topographical map was converted into GIS layers by extracting and changing them into the contour, river, road layer. Others layers in GIS such as catchment boundary, catchment size, road system and lake information about the Muar river basin were obtained from DID.

In addition to topographic map, satellite images within the study area was obtained from the DID. The image is to provide an indication of landuse activities besides verification during site investigation. Light Detection and Ranging (LiDAR) survey data is used to generate Digital Elevation Model (DEM) within the study area. LiDAR data is able to provide flood plain contour and complement to river survey information necessarily for a 2-Dimensional hydrodynamic modeling. LiDAR data also needed for defining catchment boundary from digital topographic map and satellite image. All topographic data obtained are processed using GIS method before applying into hydrodynamic software during analysis stage. Figure 1.5 shows example of LiDAR parcel along Muar river basin for 10 meter resolution.

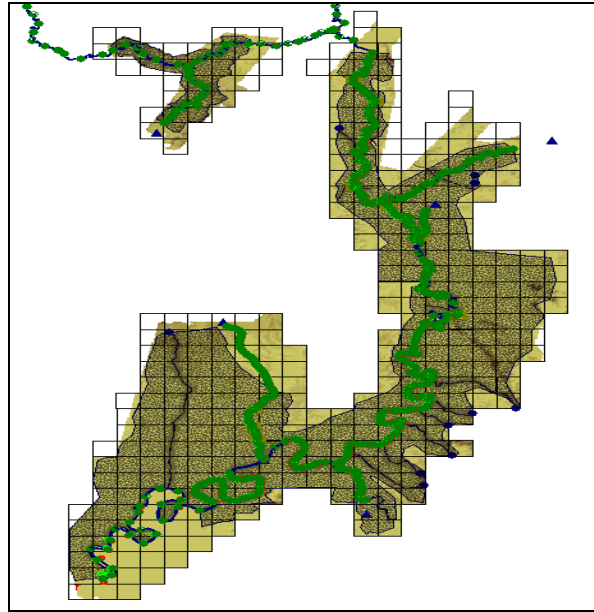


Figure 1.5 Example of LiDAR parcel along Muar River for 10 meter resolution

3.2 MODEL SET-UP

3.2.1 ONE-DIMENSIONAL (1-D) RIVER MODELLING

InfoWorks River Simulation (RS) software is used to build the 1-D hydrodynamic Muar river model which includes structures such as bridges, weirs and culverts. Figure 1.6 shows one-dimensional Muar River model using InfoWorks RS. InfoWorks RS is capable to simulate steady and non-steady flows by using Implicit Scheme. InfoWorks RS also integrates with GIS application where most of the data in AutoCAD drawings and GIS layes could be used as the base map to speed up the model development. For 1-D, the model enables to provide average velocity and water level at any particular node only (Hassan, 2009).

There are approximately 317 kilometers and 289 nodes representing cross sections with average of 1 kilometer interval of Muar River were built. Others main river tributaries such as Palong River, Chodan River, Gemas River, Ring River, Pagoh River and Segamat River contributing flows into Muar River are also built into the model. Besides that, bridges along the river systems are also modeled. There are a total of 10 bridges along Muar River, 6 for Ring River, 3 for Chodan River and 1 along Pagoh River.

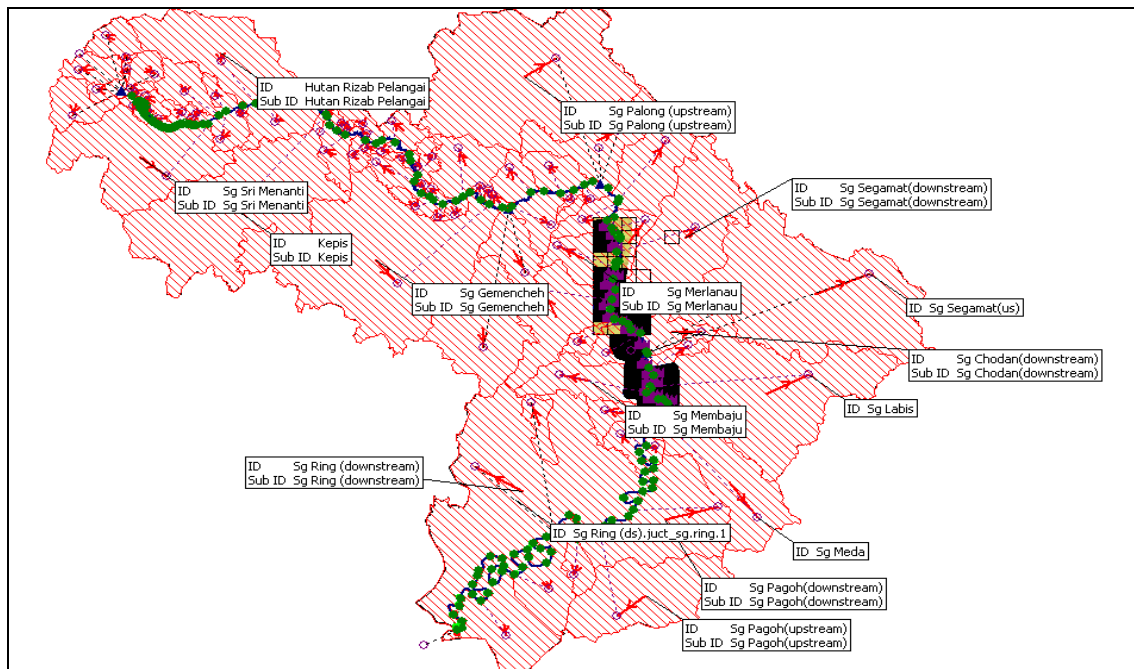


Figure 1.6: One-Dimensional Muar River model using InfoWorks RS

3.2.2 TWO-DIMENSIONAL (2-D) RIVER MODELLING

For 2-D Muar River modeling, InfoWorks RS 2-D is used to model the flood plain. InfoWorks RS 2-D model allows for the depth-averages solution of the St. Venant Equations, for depth and velocity in two dimensions (Clarke, 2009). The model may produce velocity and the direction of flows. These solutions use a finite volume method based on a semi-implicit, Gudonov Scheme and the so-called Riemanna Solvers.

In order to produce a quality flood map, various methods can be used to represent a flood plain. A conventional approach using 1-D is to represent the flood plain as reservoir and connected to the main river using spill unit. However, this approach does not produce the velocity and thus will lose the hydrodynamic effect. A better presentation of the flood plain is using 2-D approach to divide the flood plain into segments based on the ground information and triangulation of spot heights at specifies spacing. The area to be modeled is discretised into triangular mesh based on user defines parameters like maximum and minimum triangular areas. However, this 2-D approach required longer computation time.

4.0 MODEL CALIBRATION AND MODEL VERIFICATION

Calibration of model is carried out to make sure observed and simulated data are within the range. Twenty three (23) rainfall stations and three (3) water level stations are used for calibrating the models. A total of three (3) locations were checked on the flood extend produced from modeling against manually drawn and rough estimated flood map available from DID. Figure 1.7 to Figure 1.8 show some of the overlaying of observed and simulated flood extend where the observed flood extend is mark in red colour. From the overlaying process, it can be assume that the simulated flood extent have a similar trend with the observation.

For model verification, four (4) locations were checked based on some flood marks captured during site visit during December 2009. Example of the verification is at Kuala Pagoh (Pagoh 3.6) with maximum water level around 1.5 meter. Figure 1.9 shows the verification point at Kuala Pagoh.

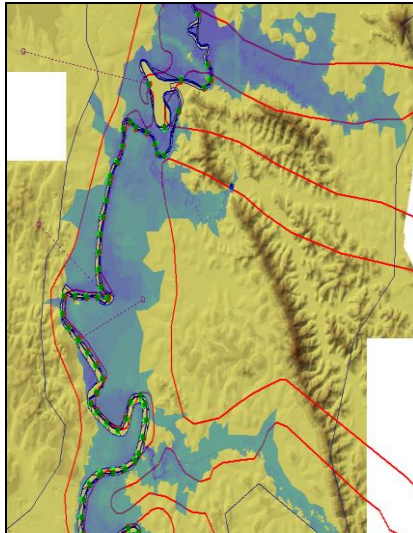


Figure 1.7: 2006 Simulated Flood Map from Ch170 – 180

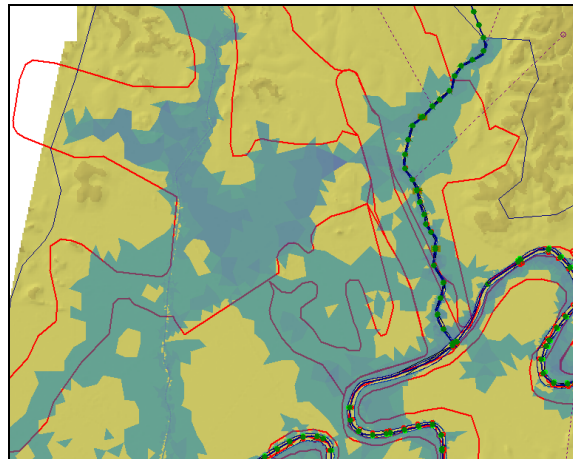


Figure 1.8: 2006 Simulated Flood Map from Ch KM180 – 200

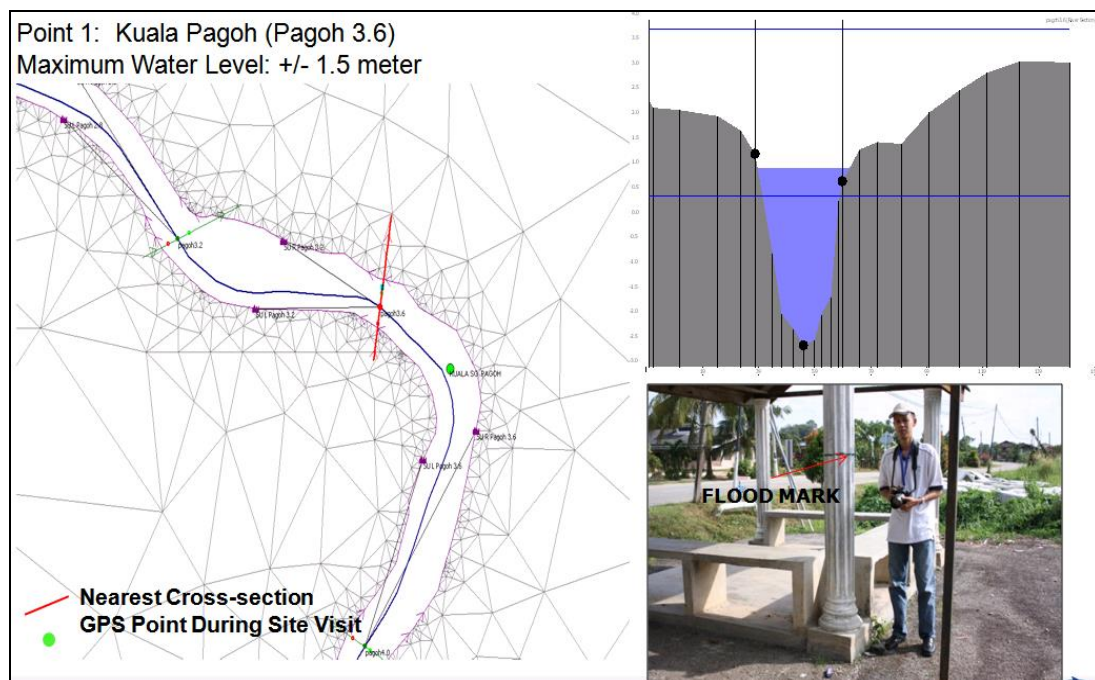


Figure 1.9: Verification point at Kuala Pagoh

5.0 RESULTS AND DISCUSSION

Various flood extent for different ARIs will be generated from the hydrodynamic analysis. The flood extent showing different depth will be exported to GIS format i.e ArcView format. Figure 1.10 and Figure 1.15 show flood maps produced for 2-, 5-, 10-, 20-, 50- and 100-year return period.

It is found that, 2-D model could provide more detail information on the flooding extent such as the flow direction and velocity. Example of flow direction is shown in Figure 1.16 and Figure 1.17. The quality of results highly depends on the available data such as LiDAR data and the model stability. For non-steady flow simulation, time step and duration of simulations are two main factors to be considered to ensure the model stability. Time step is set by using guidelines as follow as recommended by Hassan (2009):

- The time step has to be small to describe the shape of boundary condition
- The time step has to be small to detect a sudden change such as the movement of gate for gated structure
- If oscillations of the water level are observed, the value of time step needs to be reduced to ensure the stability of the simulation

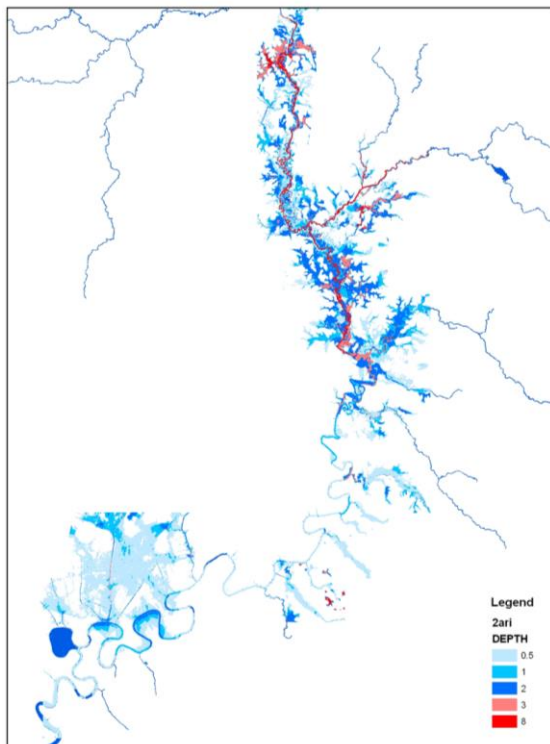


Figure 1.10: Flood Map for 2-year return period

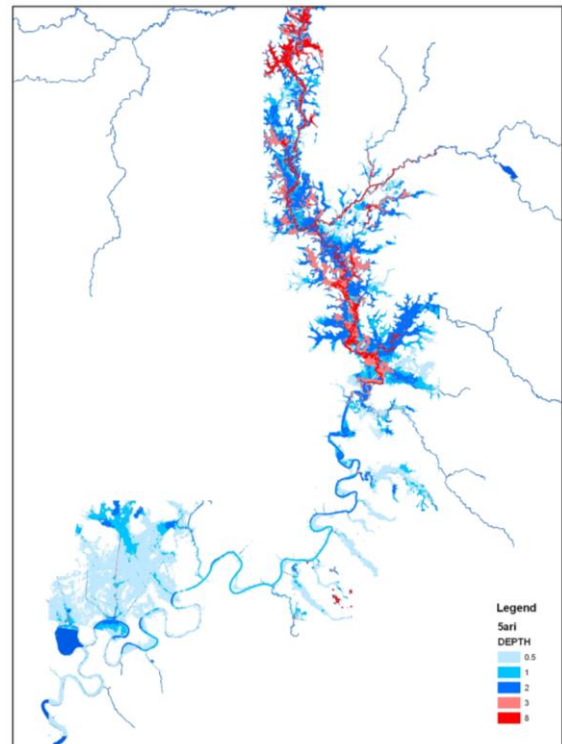


Figure 1.11: Flood Map for 5-year return period

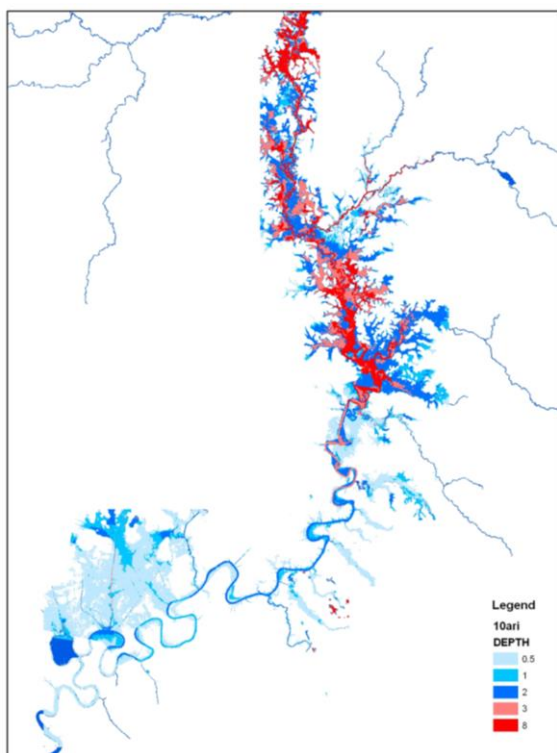


Figure 1.12: Flood Map for 10-year return period

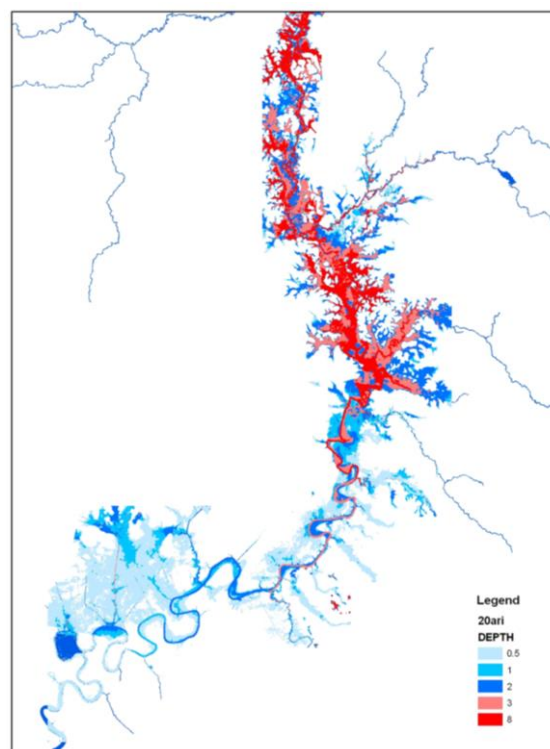


Figure 1.13: Flood Map for 20-year return period

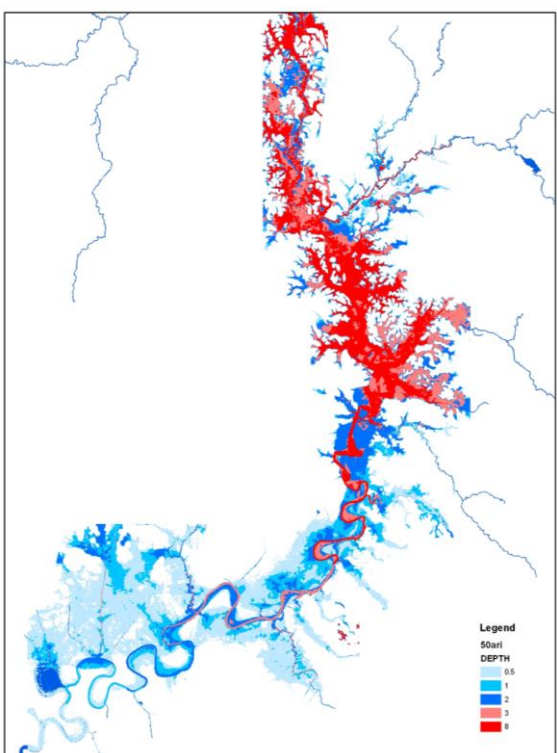


Figure 1.14: Flood Map for 50-year return period

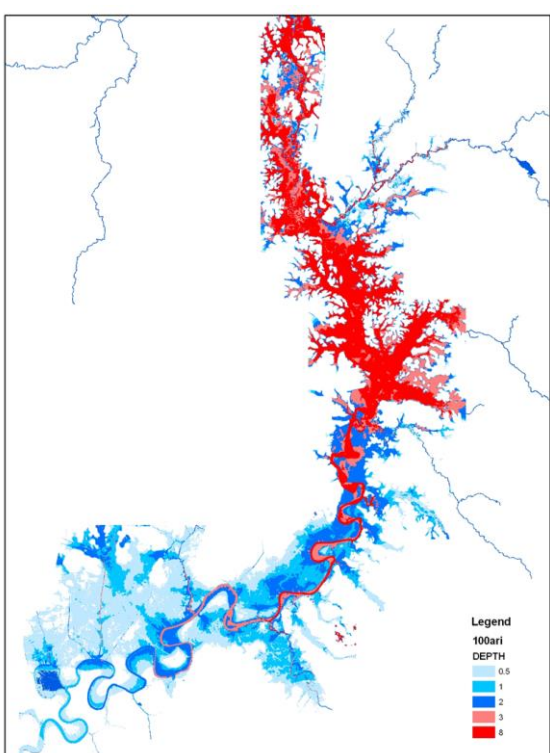


Figure 1.15: Flood Map for 100-year return period

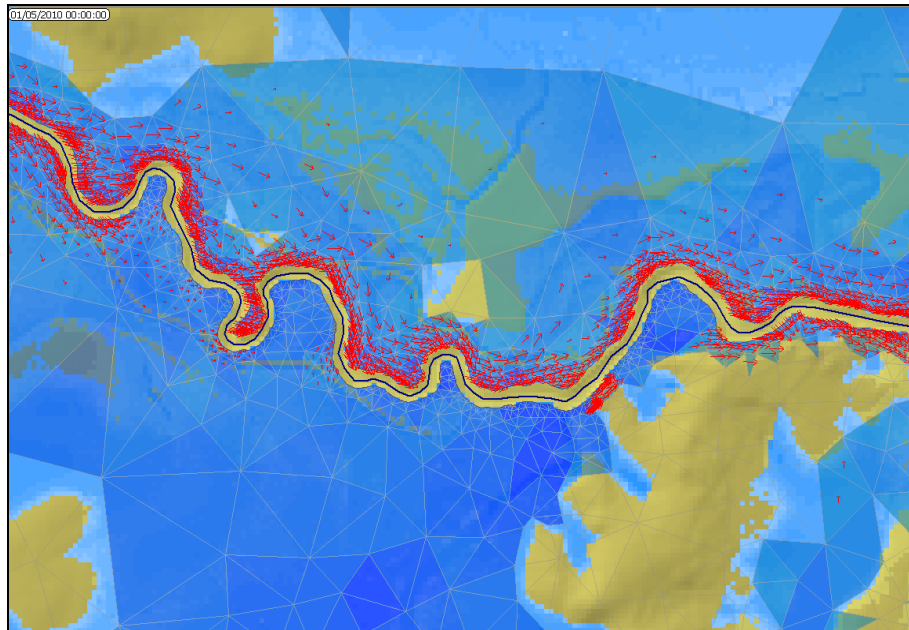


Figure 1.16: Flow direction at 150 hr (Sg Muar upstream)

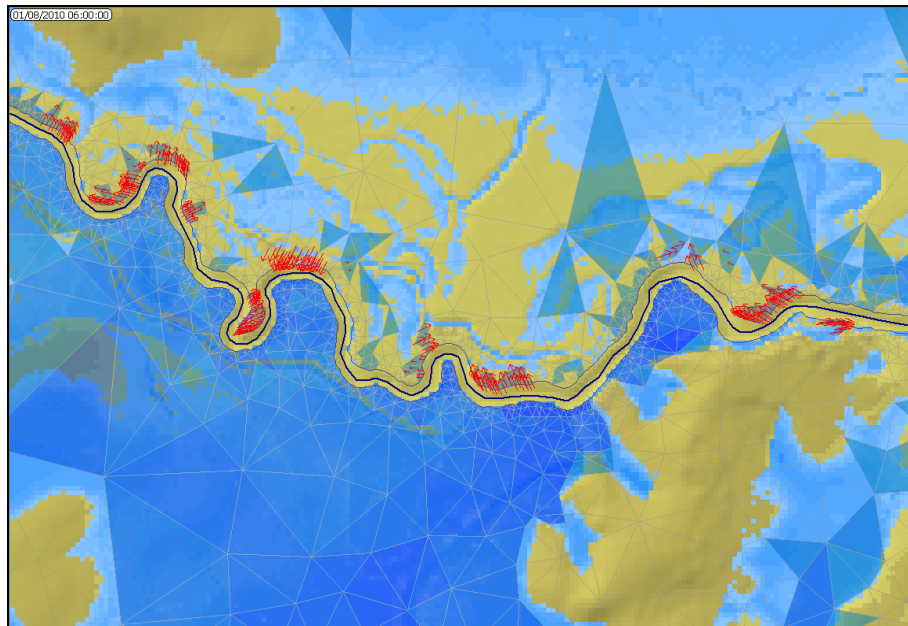


Figure 1.17: Flow direction at 200 hr (Sg Muar upstream)

6.0 CONCLUSION

2-Dimensional hydrodynamic model is useful in developing a better quality of flood maps based on available LiDAR informations. This technique can be used for future flood mapping delineation. A total of 300,000 meshes of simulation polygon were created for 2-D model which is a complex model and thus time consuming compared to 1-D Model.

2-Dimensional flood map which show flow direction and speed is beneficial as a planning and design tool for new developments and also assist engineers in designing flood mitigation measures. Further analyses of flood maps showing different flood depths scenarios may help engineers or planners to determine the platform level for various return periods and future landuse planning in a new

development project to minimize flooding risk. It is also useful for the local authority and local community to prioritise flood preparedness, mitigation and control activities.

ACKNOWLEDGEMENTS:

This study reported herein is a government funded project by the Malaysian Center For Geospatial Data Infrastructure (MaCGDI), Ministry of Natural Resources and Environment. The author would like to thank all involved in giving guidance and support throughout the study period.

REFERENCES:

Clarke, R. (2009). *2-D Modelling in IWRS*. Power Point Presentation Slides.

Hassan, A. J. (2009). *River and Floodplain Modelling*. pp. 29-34, 162-193

Social Welfare Department of Malaysia, Muar District (2007). *Maklumat Banjir*.