Application of 2-D Modelling for Muda River Using CCHE2D

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ABSTRACT
Although 1-Dimensional hydraulic modelling packages (for example HEC-RAS) has been extensively used and proven to be very useful for flood management but the capability is basically limited to water profiles and some hydraulics variables. For specific analyses such as determining the locations susceptible to longer inundation, erosions and deposition in floodplain, dan velocities distribution requires a more sophisticated 2-D model and modelling techniques.

Keywords: 1-D modelling, 2-D modelling, flood management.

1 Introduction

In March 2006, the Government of Malaysia through the Department of Irrigation and Drainage appointed River Engineering and Urban Drainage Research Centre (REDAC) of Universiti Sains Malaysia to carry out a study titled DESIGN OPTION OF THE FLOOD MITIGATION PLAN OF SG. MUDA, SUNGAI MUDA, KEDAH. The study completed in September 2006. In short, the main objectives of the study were

a) To ensure that the design cross-sections and alignment of the main river channel are economic, effective and environmentally sound;
b) To propose alternative designs for identified locations to meet the above requirements; and
c) To examine the long-term river behaviour through model studies, to minimise expensive repair works in future resulting from the new alignment.

To accommodate all the above objectives, all necessary analyses and modelling tools were used during the study. Mathematical model HEC-HMS was used for hydrologic modelling, and HEC-RAS 3.1.3 for hydraulic analyses. The study shows that HEC-RAS 3.1.3 is excellent for analysing flood profiles and extent of flooding but not for river stability analysis. Fluvial-12 was used to analyse the long term behaviour of the channel. Both models, being 1D are not capable of analysing the flood behaviour in the channel and on the floodplains.

Flooding is a natural phenomenon and cannot be easily prevented. However, the impact of flooding can be reduced by improving forecasting systems. Forecasting system not only limited to hydrology and water profile but also how floods propagate in the channel and within the floodplains. By knowing how flood propagates within the floodplains may assist authorities to address some of the effect of flooding. For example, locations where sedimentation or erosion might occurs in floodplains, and areas where the duration of inundation might be prolonged due to its low elevation compare to neighbouring areas are difficult to visualised using conventional 1D mathematical models. These problems can be examined using 2D mathematical model.

2 Comparing 1-D and 2-D Modeling

In natural rivers, the banks and bed usually have different roughness. Besides that, accurate representation of physical features such as platform and cross-sections of river system play important role in simulating the extent and severity of flooding. 1-D models require simple geometry and hence needs very little computation time as compared to 2-D model. For same river length and boundary conditions, 2-D modelling requires more computer memory and consumed more than 1000 times computing time.

For geometry input, 1-D model requires only the x and y coordinate, but for 2-D model requires x, y, and z coordinate. In most cases, geometry representation of 2-D model requires supporting software to generate the mesh before obtaining the bed topology. This is the most critical, difficult, and time consuming part of the 2-D hydrodynamic modelling work [Hsu (2002)] and consumed 80% of total hours of computational fluid dynamic (CFD) project (Zhang and Jia, 2005). However, integration with the Geographic Information System (GIS) softwares, geometric input for both 1-D and 2-D models are interchangeable. Steffler and Blackburn (2002) also noted that with the advancement of personal computer capability and software technology, two-dimensional (2D), and depth averaged models are beginning to join one-dimensional models in channel and river engineering.

There are a number of commercial and public domain 2D models available. This study utilises 2-dimensional mathematical model CCHE2D (beta version) developed by

National Centre for Computational Hydroscience and Engineering, School of Engineering, University of Mississippi.

3 CCHE2D Mathematical Model

CCHE2D model is an integrated package for two-dimensional simulation and analysis of free surface flows, sediment transport and morphological processes. The package comprises of the numerical models, a mesh generator (CCHE2D Mesh Generator) and a Graphical User Interface (CCHE2D-GUI) as illustrated in Figure 1.

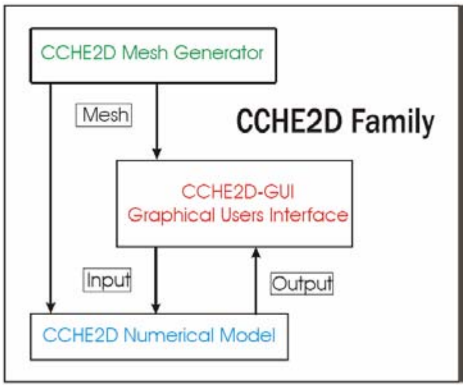


Figure 1 CCHE2D Package

3.1 CCHE2D Mesh Generator

CCHE2D Mesh Generator helps in creation of complex structured mesh system for CCHE2D model system. It is a comprehensive and user-friendly mesh generator for generating structured quadrilateral mesh on the background of bed topography and the bed elevation data. A Graphic User Interface (GUI) is also available with detailed manual and documentation. The processes involves in generating the mesh is as below

a. defining block boundaries (single or multi-block),
b. generate algebraic mesh
c. generate numerical mesh (to improve and smoothing the mesh)
d. interpolate bed elevation
e. save mesh into geo file, to be used for simulation using CCHE2D

3.2 CCHE2D Model

CCHE2D-GUI is a graphical users environment for the CCHE2D model with four main functions: preparation of initial conditions and boundary conditions, preparation of model parameters, run numerical solutions, and visualization of modelling result. The CCHE-2D is a depth-averaged two-dimensional numerical model for simulating unsteady, turbulent, free-surface flow in open channels with loose bed. It has been developed for simulating the sediment transport, soil erosion and morphological changes of a variety of shallow water bodies with special emphasis on natural streams and rivers (Jia and Wang, 1998). This study only utilise the hydraulics capability of CCHE2D.

4 Application of CCHE2D in Sg Muda Study

Muda River Flood Mitigation project can be sub-divided into two reaches. First reach is from Merdeka Bridge upstream and the second one from Merdeka Bridge to the river mouth (Figure 2). Simulation using CCHE2D was carried out only for the downstream reach. This is a preliminary study to examine the applicability of 2-D modelling for floodplain management. List of data provided for the modelling are AutoCAD project drawing, tidal record, and historical flood hydrograph. General procedure of modelling using CCHE2D listed as follows:-

a) mesh generation
b) specified boundary conditions
c) setting parameters
d) simulation
e) viewing and interpretation results

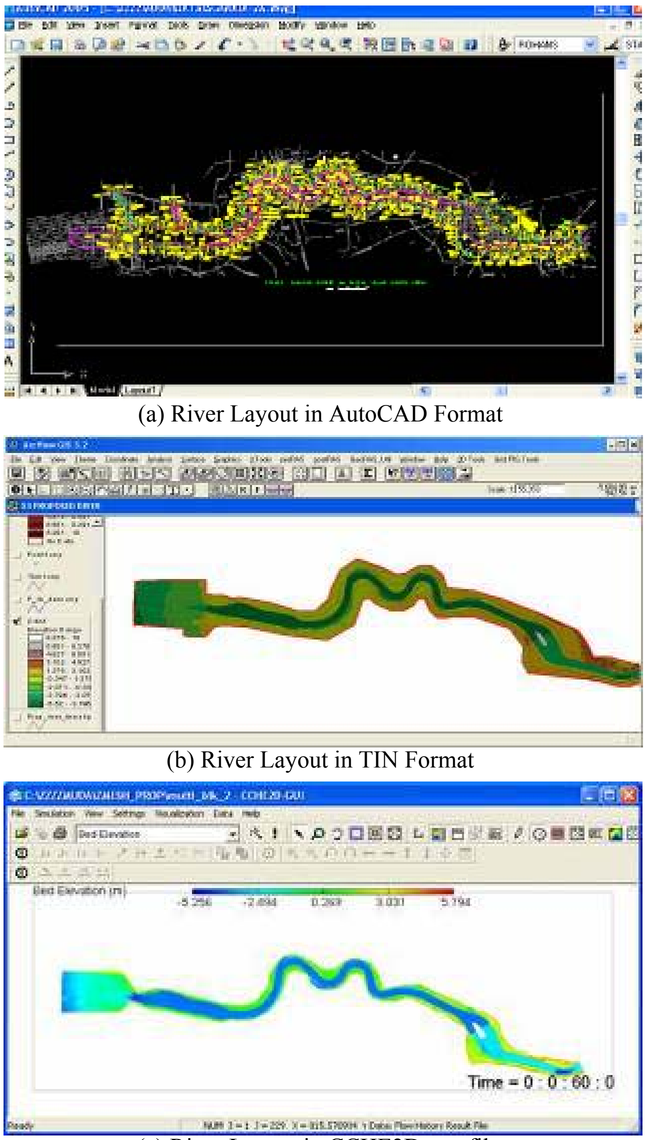
Figure 2 Project Area

4.1 Mesh and Bed Topology Generation

This is the most important step in the whole modelling process. An arduous effort was made to convert AutoCAD project drawing to TIN. The process involved was very lengthy because the AutoCAD drawing was not in GIS ready format. ArcView 3.2 and MS Excel were used in the process as summarised in Table 1 and Figure 4. Once the DEM was ready, the mesh was prepared as explained in section 3.1.

Table 1 Processes of converting AutoCAD Project Drawing to TIN and DEM

Step	ArcView 3.2	MS Excel
1	Converting 3D points to 2D	
2	Assign coordinate to each point	
3	Export the points to MS Excel	
4		Removing duplicates and joining points and assign elevations to the edited points
5	Construct river shape	
6	Generate TIN and DEM	



(a) River Layout in AutoCAD Format

(b) River Layout in TIN Format

(a) River Layout in CCHE2D geo file

Figure 4 Processing AutoCAD to CCHE2D geo file

4.2 Boundary Condition

4.2.1 Upstream Boundary Condition

Hydrograph at Ladang Victoria from 16th Jun to 29th December 2003 (Figure 5) was used. The 2003 flood occurred from 3rd to 13th October 2003. The peak flood took place on the 6th October 2003 at 4 p.m. with a value of 1340 m^3/s.

4.2.2 Downstream Boundary Condition

The tidal record (Figure 6) at the river mouth is used to define time variation of stage (water surface elevation) at a downstream cross section.

4.2.3 Hydraulic Parameter

Calibrated manning number of 0.030 was used for channel and 0.050 for the floodplain.

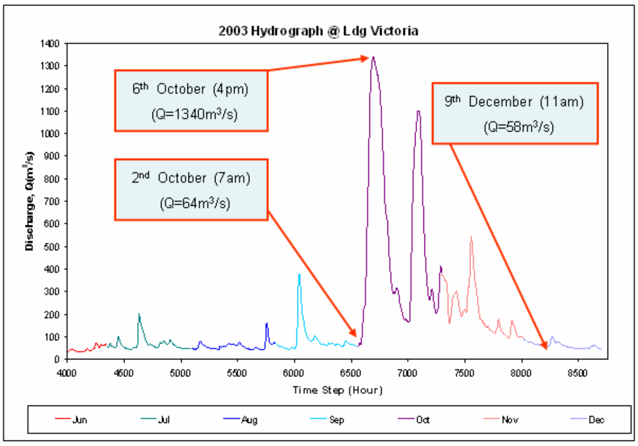


Figure 5 Input Hydrograph @ Ladang Victoria for Flood 2003

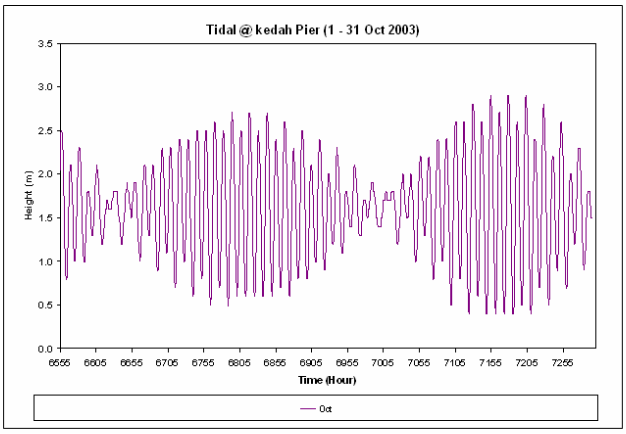


Figure 6 Tidal Record for the Month of October 2003

5 Results and Discussion

The results of the simulation can be visualised not only after but also during the execution of the model. CCHE2D provides a visualization tool to select and plot flow variables as shown in Figure 7. Tide influence on the study reach can be observed using the visualization tool. Some snapshots illustrating tidal influence are shown in Figure 8. Figure 9 shows velocity contour in the channel and floodplain. Based on the velocity distribution, the planner and designer will be able to decide on the best option to solving arising problems, e.g. location and the length of bank protection structure.

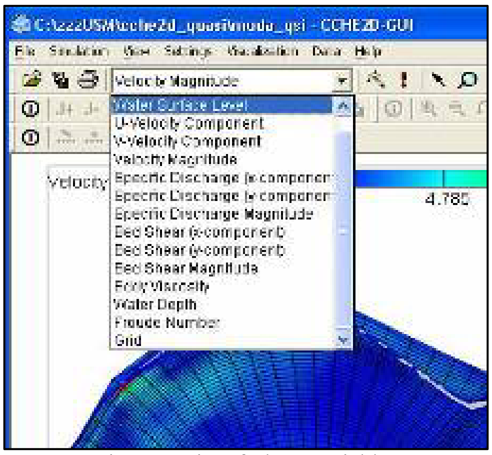
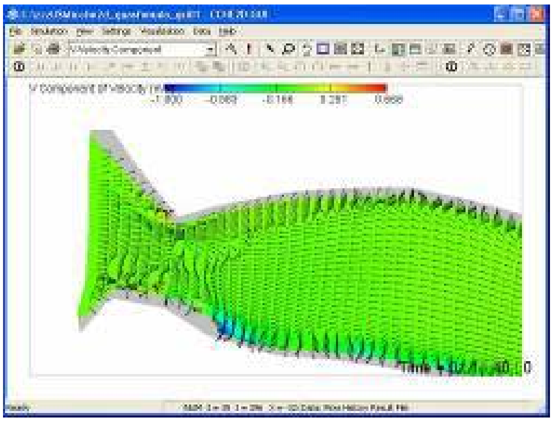
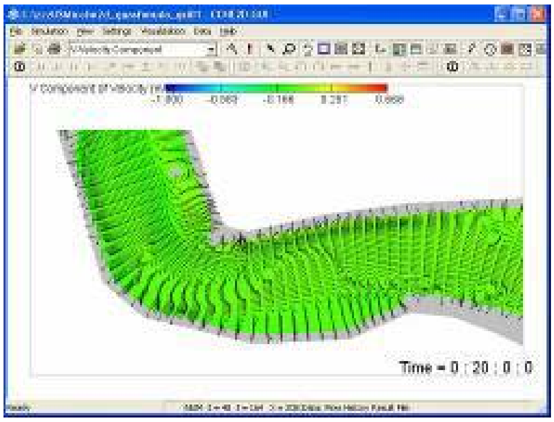


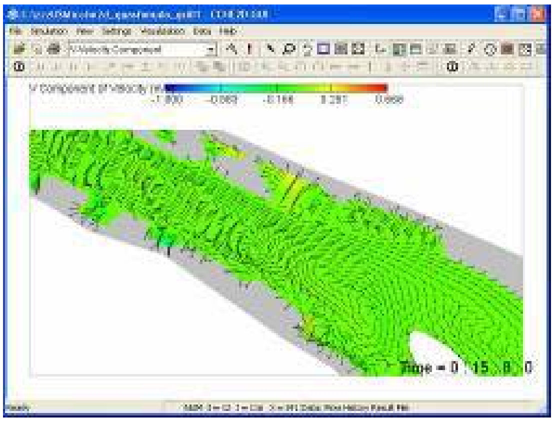
Figure 7 List of Flow Variables



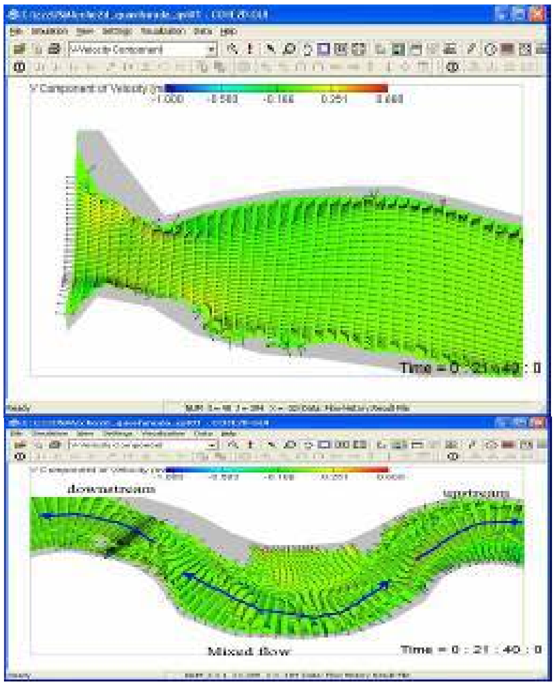
(a) At simulation time 6000 s (1 hr: 40min)
Inflow discharge = 58 m3/s, tide = 2.03m
Water starts to move into the river



(c) At simulation time 72000 s (20 hr: 0min)
Inflow discharge = 72 m3/s, tide = 1.40m
Backwater is retreating



(b) At simulation time 54000 s (15 hr: 0min)
Inflow discharge = 70 m3/s, tide = 2.00m
Backwater effect reached up to the Barrage, about
9.5 km upstream of river mouth



(d) At simulation time 78000 s (21 hr: 40min)
Inflow discharge = 71.33 m3/s, tide = 1.03m Most of the water is moving towards the sea with some water still moving upstream

Figure 8 Snapshots showing tidal influence

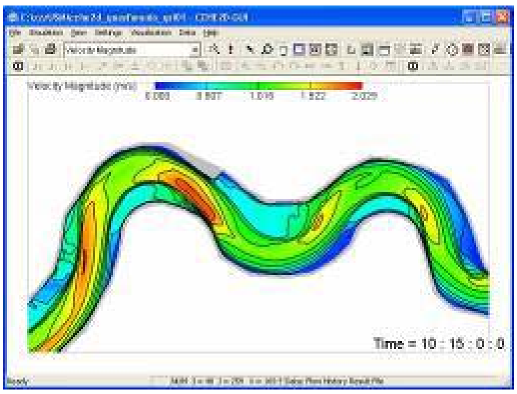


Figure 9 Velocity Contour

5 Conclusion

Due to the advancement to personal computer capability and software technologies, the use of 2-D modelling is expected to become a normal engineering practice for river and flood management in near future. These models are useful in studies where local details of velocity and depth distributions are important (Peter Steffler and Julia Blackburn, 2002). The study shows that it is possible to use CCHE2D package to analyse flow behaviour both in river channel and floodplains by using only the hydraulic component. Utilising the sediment transport component, CCHE2D will be used to analyse the behaviour of River Muda after undergoing training works and it stability due to sand mining activities.

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