Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River

Authors: ShahiriParsa, Ahmad, Noori, Mohammad, Heydari, Mohammad, and Rashidi, Mahmood

Source: Air, Soil and Water Research, 9(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/ASWR.S36089

Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River

Ahmad ShahiriParsa[1], Mohammad Noori[2], Mohammad Heydari[3] and Mahmood Rashidi[4]

[1]Graduated Student, Department of Civil Engineering, Universiti Tenaga Nasional (UNITEN), Kuala Lumpur, Malaysia. [2]Assistant Professor, Department of Water Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan, Iran. [3]PhD Candidate, Department of Civil Engineering, University of Malaya, Kuala Lumpur, Malaysia. [4]PhD Student, Department of Civil Engineering, Faculty of Civil Engineering, University of Tabriz, Tabriz, Iran.

ABSTRACT: River flooding causes several human and financial casualties. It is necessary to perform research studies and implement subsequent actions consistent with the nature of the river. In order to reduce flood damage, floodplain zoning maps and river cross-sectional boundaries are important to nonstructural measures in planning and optimizing utilization of the areas around the river. Due to the complex behavior of the rivers during floods, computer modeling is the most efficient tool with the least possible cost to study and simulate the behavior of the rivers. In this study, one-dimensional model Hydrologic Engineering Centers—River Analysis System and two-dimensional model CCHE2D were used to simulate the flood zoning in the Sungai Maka district in Kelantan state, Malaysia. The results of these two models in most sections approximately match. Most differences in the results were in the shape of the river.

KEYWORDS: flood management, flood mitigation, flood mapping, 2D modeling

CITATION: ShahiriParsa et al. Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River. *Air, Soil and Water Research* 2016:9 55–62 doi:10.4137/ASWR.S36089.

TYPE: Original Research

RECEIVED: October 8, 2015. **RESUBMITTED:** February 9, 2016. **ACCEPTED FOR PUBLICATION:** February 14, 2016.

ACADEMIC EDITOR: Carlos Alberto Martinez-Huitle, Editor in Chief

PEER REVIEW: Four peer reviewers contributed to the peer review report. Reviewers' reports totaled 839 words, excluding any confidential comments to the academic editor.

FUNDING: Authors disclose no external funding sources.

COMPETING INTERESTS: Authors disclose no potential conflicts of interest.

CORRESPONDENCE: shahiriparsa@gmail.com

Paper subject to independent expert single-blind peer review. All editorial decisions made by independent academic editor. Upon submission manuscript was subject to anti-plagiarism scanning. Prior to publication all authors have given signed confirmation of agreement to article publication and compliance with all applicable ethical and legal requirements, including the accuracy of author and contributor information, disclosure of competing interests and funding sources, compliance with ethical requirements relating to human and animal study participants, and compliance with any copyright requirements of third parties. This journal is a member of the Committee on Publication Ethics (COPE).

Published by Libertas Academica. Learn more about this journal.

Introduction

Necessity of flood zoning maps. Flood has always been considered as one of the natural catastrophes that accompanies with huge losses and damages, which affect the lives of human beings. However, different methods of flood mitigation have been applied. Floodplain management and the use of science and knowledge can reduce flood damages. Management measures to reduce flood damage can be done in two parts: structural and nonstructural measures. Structural flood management application involves damming, trenches, the diversion of river flooding, and other physical flood mitigation structure constructions. The nonstructural flood management approach includes eliminating the destructive effects of flood without constructing physical structures. To optimize the surrounding lands, the most essential tool is to prevent the risks of flood in rivers and determine their boundaries. The river zoning maps are certainly one of the most basic and important information needed in civil engineering projects and should be taken into consideration before any investment or operational development in the projects. As the river zoning maps give valuable information, such as the depth and area of flood prevention in flood zones, it is crucial to provide the maps in the first place. Numerical models are based on mathematics and have to deal with many physical parameters.[1] One has to understand all these parameters and make sure that all are in the correct range.

Literature review.

Hydrologic Engineering Centers—River Analysis System as a one-dimensional model. Hydrologic Engineering Centers—River Analysis System (HEC-RAS) is an integrated package of hydraulic analysis programs, in which the user interacts with the system through the use of a graphical user interface (GUI). The system is capable of performing steady flow water surface profile calculations and includes unsteady flow, sediment transport, and several hydraulic design calculations. The results of the model can be applied to floodplain management and flood insurance studies.[2]

More information about HEC-RAS model, floodplain zoning simulation models through dimensional approach, the governing rules of models, and data requirements is provided in many manuals[3–5] and studies.[6,7] In many studies, HEC-RAS, a one-dimensional (1D) software, is used to simulate floodplain,[8–10] sediment[11,12] and sediment transport,[13] water quality,[14] dam break,[15–17] blocking bridges,[18] scour phenomenon,[19] and ice-covered river.[20]

To resolve the weaknesses of the 1D model, such as HEC-RAS model, or to compare the results with the two-dimensional (2D) model, many studies have been done in combination. For example, Tate and Maidment[9] and Kraus[8] used a combination of HEC-RAS and ArcView GIS for flood mapping. Some researchers used the combination of HEC-RAS and HEC-HMS in order to precisely understand the watershed modeling and riverine sediment processes,[11] dam break modeling,[16] hydrologic risk management,[21] and regional-scale flood modeling.[22] Bennett et al[23] by using HEC-RAS and MIKE 11 compared the unsteady flow results in the Tillamook Valley. Gee and Brunner[15] and Zhou et al[17] used the combination of HEC-RAS and Flood Wave Dynamic Models (NWS FLDWAV/FLDWAV) for dam break analysis. In addition, Moreda et al[24] explained the major differences in their results between HEC-RAS and FLDWAV in Tar River and Columbia River. Fan et al[14] used the combination of QUAL2K and HEC-RAS models to assess the impact of tidal effect on river water quality simulation. Rodriguez et al[25] used HEC-RAS with MODFLOW in a combined form to simulate stream–aquifer interactions in a drainage basin.

CCHE2D as a 2D model. MIKE 21, InfoWorks 2D, JFLOW, and CCHE2D are the examples of 2D models of river flows and open channels.[26] The benefits of these models are their ability to show the direction and magnitude of flow, riverbed, and floodplains. Similar simulations, such as floodplain,[27,28] sediment[29] and sediment transport,[30–34] flow simulation,[35–38] water quality,[39,40] dam break,[41] and scour phenomenon,[29] were also carried out for 1D models using CCHE2D.

Purpose of this study. The purpose of this study is to focus on the analysis of HEC-RAS and CCHE2D in order to assess and predict the flood depth and spatial extent of flood in the Sungai Maka floodplain. This will help the decision-makers, especially the involved government's department, and developers make a proper plan for future development.

Material and Methods

Study area. The town of Tanah Merah in the Kelantan state, Malaysia (Fig. 1), is particularly distressed with annual flooding due to Sungai Kelantan (Kelantan River) bank overflowing. This is an effect of a northeast monsoon climate experienced in the country that occurs between November and February and brings about heavy rainfall, as much as 600 mm during intensive precipitation.[42] Sungai Maka River is one of the six catchments in Tanah Merah with the most affected areas by flooding due to its proximity to the river Sungai Kelantan. This catchment occupies an area of 940 hectares and covers the entire town center. The boundaries of the area are shown in Figure 2.

The Department of Irrigation and Drainage (DID) of Kelantan state reported the flooding occurrences in Tanah Merah in the years 2003, 2004, and 2005, which were all caused by backflow of flood water from Sungai Kelantan to the town areas. The highest number of flood damage recorded was in 2004, where it reached as many as 2,599 individuals. On the other hand, flooding condition in the catchment is documented in 2007, as shown in Figure 3.

Data collection. In this study, data are important and consist of two categories: spatial data and attribute data. Spatial data illustrate the river location with geographical characteristics, whereas attribute data describe and represent spatial data as numbers or phrases. The plan data, geometric data, flow data, and hydraulic design data are used for modeling with HEC-RAS model. The basic input data requirements to run the CCHE2D model include gridded raster terrain data, river location coordinates, initial water surface elevation, and Manning's roughness coefficient.

Figure 1. Kelantan state in northern Malaysia.

Methods.

Hydrologic Engineering Centers—River Analysis System. HEC-RAS program is one of the 1D dynamic models developed by U.S. Army Corps Hydrology Centre in 1995.[43] This model is capable of carrying out a steady flow modeling and dynamic routing of flood hydrograph, and it is completely compatible with Windows operating system.[44] In this model, various river features, such as storages, diversions, bridges, and any hydraulic structures in the river, could be defined. Simulating steady flow is one of the previous capabilities of the model, in which Manning's roughness coefficient could be defined and

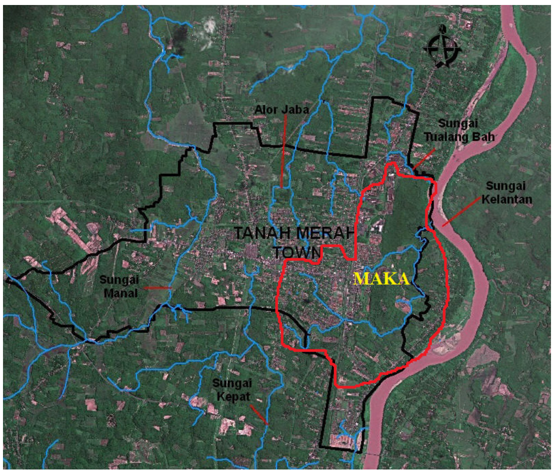

Figure 2. Boundaries of Sungai Maka Catchment in Tanah Merah, Kelantan (DID, 2013).

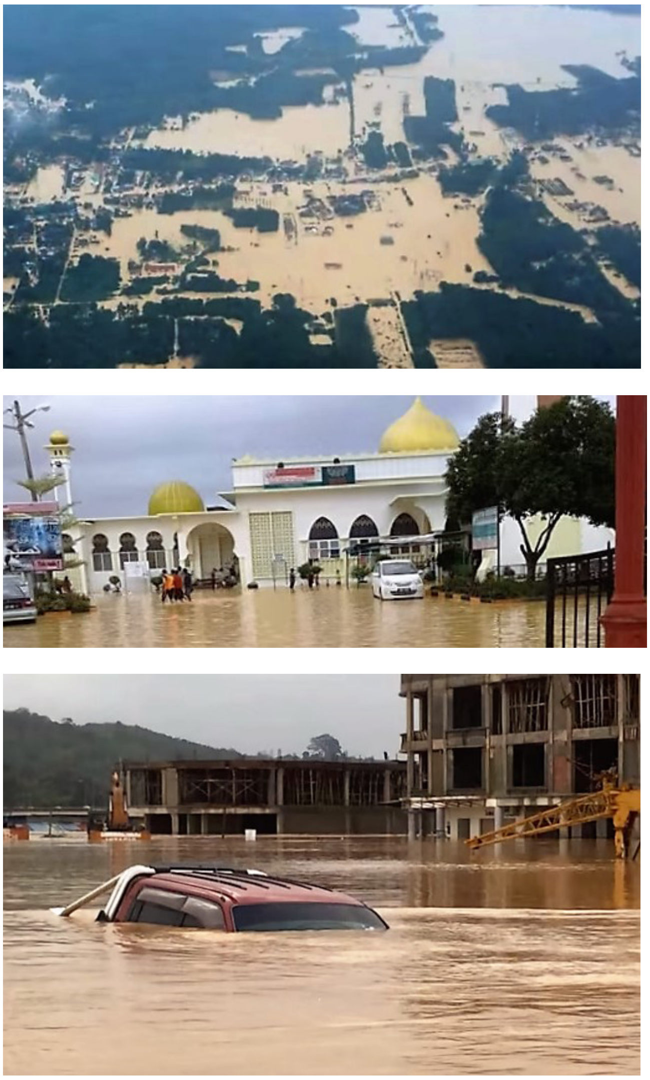

Figure 3. Flooding in Sungai Maka catchment in 2007.

calibrated in various ways. HEC-RAS software could be used in the 1D hydraulic analysis of both the steady and unsteady flows in natural rivers or canals. Water surface profiles using a standard method to solve the energy equation are derived:

$$y_2 + z_2 + \frac{\alpha_2 v_2^2}{2g} = y_1 + z_1 + \frac{\alpha_1 v_1^2}{2g} + h_e \quad (1)$$

In this equation, y_1 and y_2 are water depth in two cross sections, z_1 and z_2 are the floor heights of the main channel, v_1 and v_2 are average velocities of discharge, α_1 and α_2 are coefficients of mass momentum speed, g is acceleration due to gravity, and h_e is the head loss of energy level. Figure 4 shows a geometric data and cross-sectional shape in a sample station of Sungai Maka as an input data.

CCHE2D. CCHE2D is an aggregated software package created in 2005 by Wang et al in the National Centre of Calculation and Hydraulic Engineering under the supervision of the University of Mississippi, USA. This model is a 2D hydraulic model that is created for analyzing the simulation of flow, hydraulics, sediment transport, and morphology processes in open flows. The model uses the average equations of Reynolds for solving flow area in depth. This model is applicable for both steady and unsteady flows. The view of CCHE2D model is shown in Figure 5.

CCHE2D has two important categories: CCHE2D mesh generator and CCHE2D GUI. The mesh generator allows the user to introduce the geometric condition and structures of environment to the model and then proceeds to create the structure's network. Then, using the GUI model, user can observe hydraulic parameters of flow, sediment, boundary condition, parameters needed for simulation, and the output results.[45] In this model, 2D equations are integrated with the depth parameter to be solved simultaneously.

Continuity equation:

$$\frac{\partial Z}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \quad (2)$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -g\frac{\partial Z}{\partial x} + \frac{1}{h}\left[\frac{\partial (h\tau_{xx})}{\partial x} + \frac{\partial (h\tau_{xy})}{\partial y}\right] - \frac{\tau_{bx}}{\rho h} + f_{cor} v \quad (3)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -g\frac{\partial Z}{\partial y} + \frac{1}{h}\left[\frac{\partial (h\tau_{yx})}{\partial x} + \frac{\partial (h\tau_{yy})}{\partial y}\right] - \frac{\tau_{by}}{\rho h} + f_{cor} u \quad (4)$$

where u and v are the depth-integrated velocity components in the x and y directions, respectively; g is the gravitational acceleration; Z is the water surface elevation; ρ is water density; h is the local water depth; f_{cor} is the Coriolis parameter; τ_{yx}, τ_{xy}, τ_{xx}, and τ_{yy} are the depth-integrated Reynolds stresses; and τ_{bx} and τ_{by} are shear stresses on the bed surface.

Model input data requirements. The basic input data requirements to run the CCHE2D model include gridded raster terrain data, river location coordinates, initial water surface elevation, and Manning's roughness coefficient.

Model output. The basic output of the model consists of grids representing flow depth and flow velocity at whatever time increment is desired by the user.

Result and Discussion

HEC-RAS. Figures 6–8 show the results of water elevation, perspective view, velocity, and rating curves in a sample cross section of Sungai Maka River by HEC-RAS. According to the survey conducted in this research, topographic maps, metropolitan area, and flood zoning maps

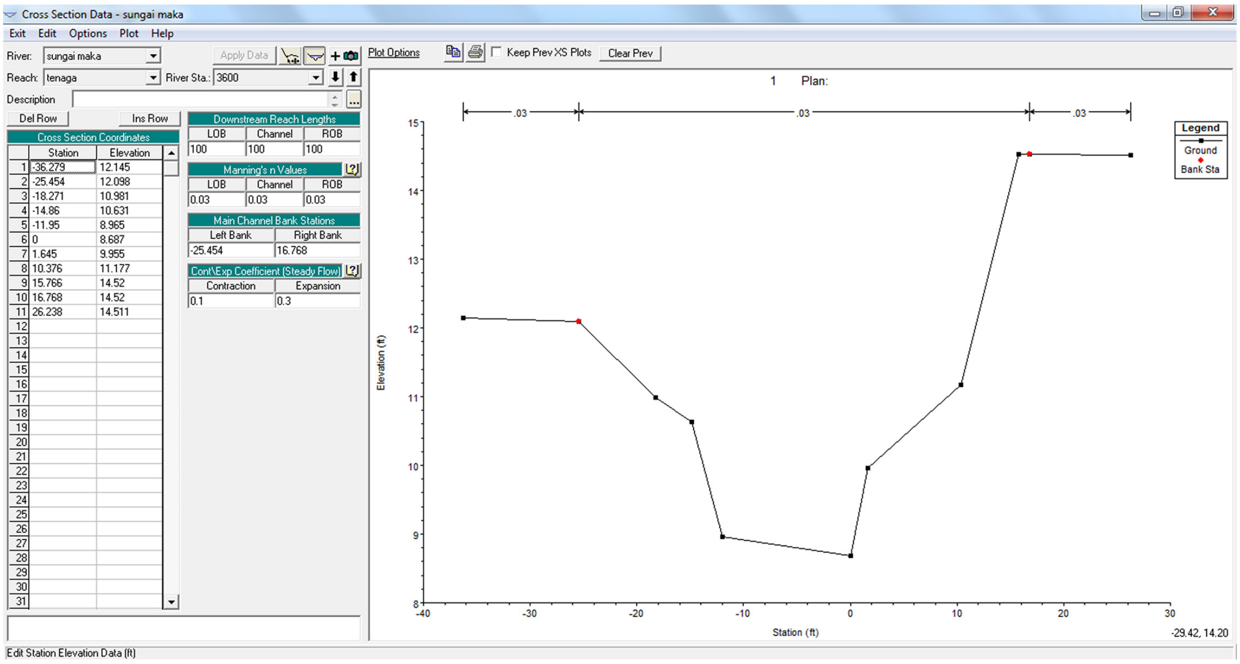

Figure 4. A view of a cross section (in station 3600).

for a return period of 10 years were obtained. Changes in the depth, velocity, and flow area, and Froude number were also calculated for different return periods (Table 1).

The result shows that the difference in expanding flood retention zone is primarily stemmed from the route topographical features. Every width of the stream bed is increased, width of the floodplain is also increased, and water is spread over a larger surface. The steep topography along the sidelines of the main river is the reason for the little difference on the level of flood retention on many parts.

CCHE2D. CCHE2D supplies a visualization tool to select and plot flow changes. Due to velocity distribution, the plotter and modeler can make a best decision to solve the problems, eg, the location and the length of bank protection structure.[46]

Figure 9 shows the physical data input for a 2D model. The ground topology in the 2D model is more accurate than that in the 1D model. However, this can be reached by making the required mesh. Making a mesh by obtaining a correct representation of bed topology is the most critical, difficult, and time-consuming part of 2D hydrodynamic modeling.[47]

Sungai Maka River with XY plot view simulated by using CCHE2D is shown in Figure 10.

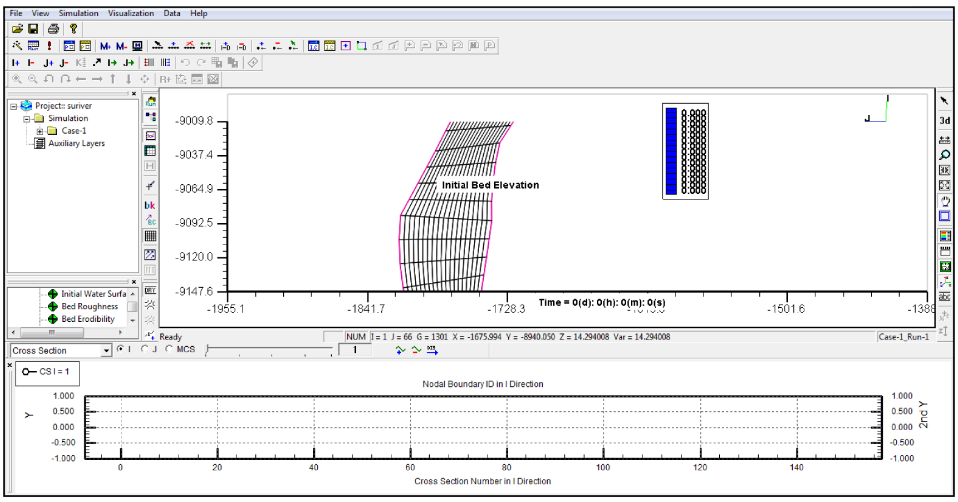

Figure 5. A view of CCHE2D model.

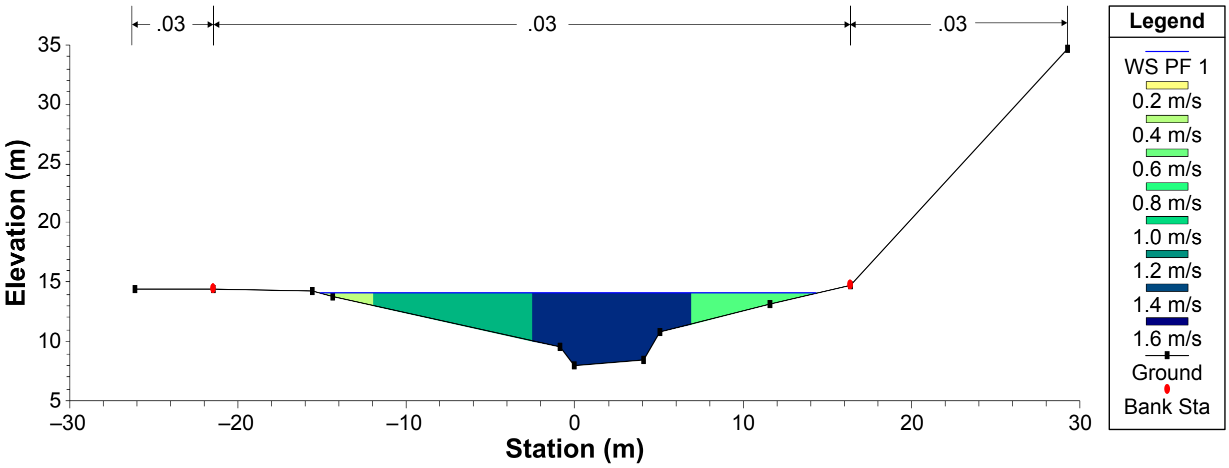

Figure 6. A view of a cross section (in station 1900).

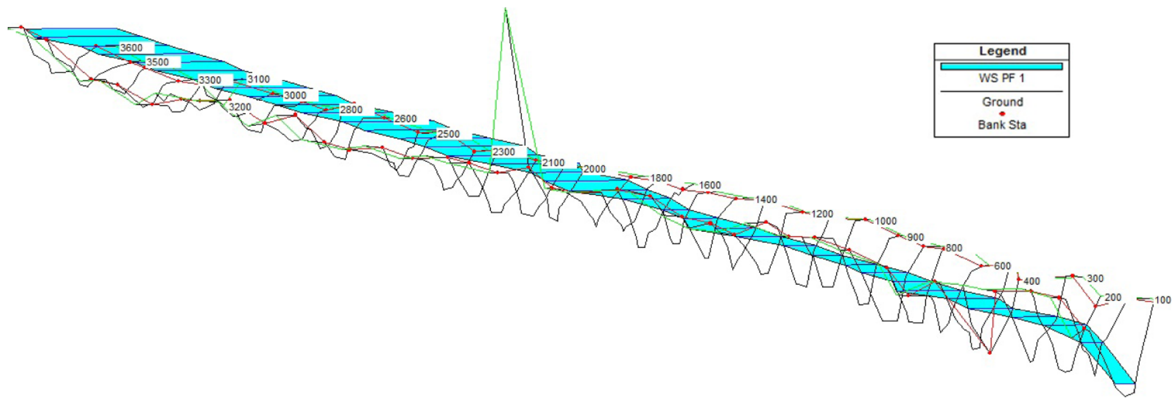

Figure 7. Perspective view by HEC-RAS model.

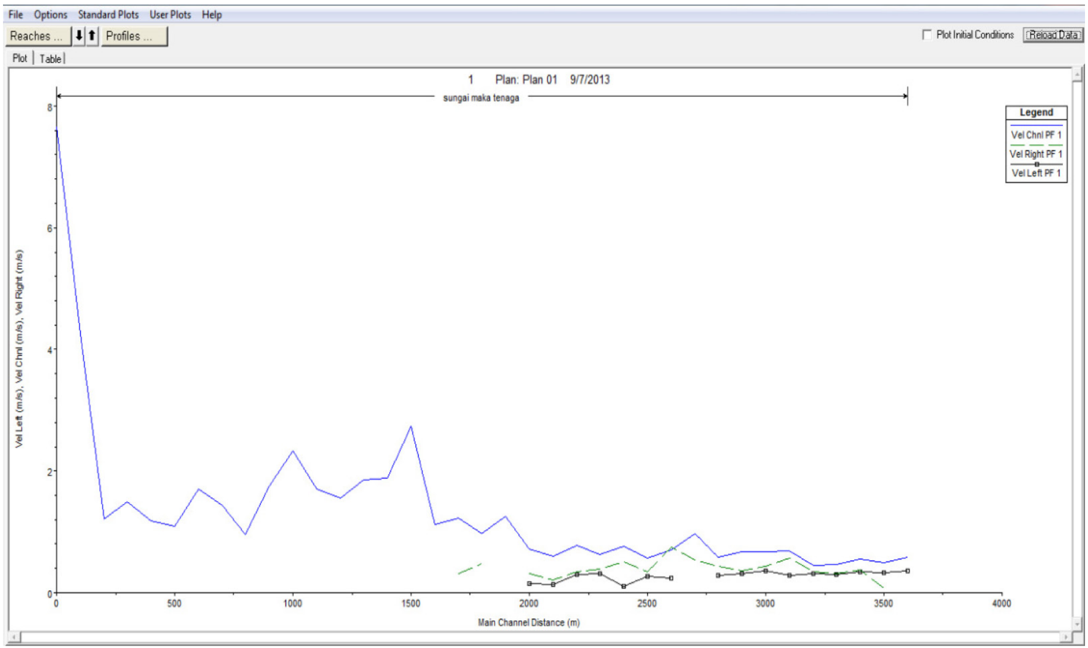

Figure 8. A view of general profile plot—velocities.

Table 1. Sungai Maka river modeling by HEC-RAS model.

		ELEMENT	LEFT OB	CHANNEL	RIGHT OB
E.G. Elev (m)	14.3	Wt. n-Val.	0.03	0.03	
Vel Head (m)	0.02	Reach Len. (m)	100	100	100
W.S. Elev (m)	14.28	Flow Area (m^2)	23.41	158.25	
Crit W.S. (m)	10.64	Area (m^2)	23.41	158.25	
E.G. Slope (m/m)	0.000053	Flow (m^3/s)	8.4	91.6	
Q Total (m^3/s)	100	Top Width (m)	10.83	40.84	
Top Width (m)	51.66	Avg. Vel. (m/s)	0.36	0.58	
Vel Total (m/s)	0.55	Hydr. Depth (m)	2.16	3.87	
Max Chl Dpth (m)	5.6	Conv. (m^3/s)	1156.8	12614.6	
Conv. Total (m^3/s)	13771.4	Wetted Per. (m)	12.96	42.79	
Length Wtd. (m)	100	Shear (N/m^2)	0.93	1.91	
Min Ch El (m)	8.69	Stream Power (N/m s)	1256.22	0	0
Alpha	1.05	Cum Volume (1000 m^3)	22.02	353.56	42.27
Frctn Loss (m)	0	Cum SA (1000 m^2)	11.14	105.07	18.15
C & E Loss (m)	0				

Conclusion and Recommendations

Conclusion. The results show that the maximum difference between the 1D and 2D models is 6% in the meander's part of the river. The main differences between the 1D and 2D flood zoning models are shown in Table 2.

Recommendations. The following pointed factors would considerably improve the accuracy of results:

1. One of the most important hydraulic parameters for calibration of the model is the roughness coefficient. The roughness coefficient depends on the length, density, distribution, vegetable species, and also the riverbed's material and sizes. The engineering experience and the use of riverbed's material tables give a clear criterion to choose the best roughness coefficient.
2. To estimate the flow characteristics of a particular interval on a river, the adaptation of boundary condition is required. Boundary conditions are used to determine the input and output streams in the given upstream intervals. Obviously, the exact specifications bring up better results. The number of intervals also increases the accuracy.
3. Geometry of rivers is also important, as they are used for hydraulic calculations and studies on riverbeds. Topographic maps are used to show natural and man-made features of rivers in detail and accurate graphical repre-

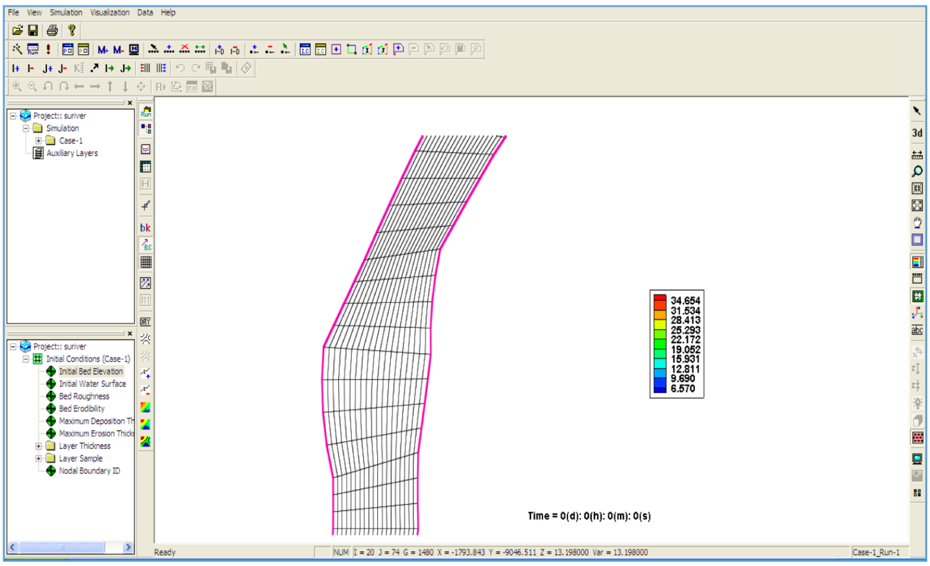

Figure 9. Sungai Maka river in 2D view.

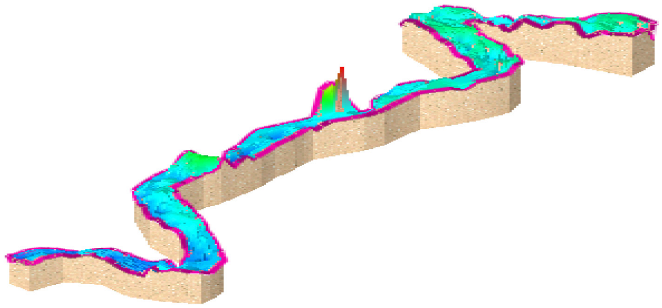

Figure 10. Sungai Maka River with XY plot view.

sentation. Hence, the sampling should be done for the main parts and also flood plains surrounding the sides of the river. This consideration would be usually between 100 and 400 m.

4. Basic and professional studies, frequent visits to the field, paying adequate attention to the necessary interactions in the river, software simulations, and ultimately the engineering experiences are significantly effective for the best water flow limitation results in a particular river interval.
5. Another factor in floodplain zoning maps is to choose a suitable return period to match the proposed design and area. The most significant factors that can affect any area of flood return periods are volume and surface runoff to the upstream of the river or flood conditions and its physical characteristics (such as surface morphology).

Acknowledgments

The authors would like to acknowledge the Universiti Tenaga Nasional (UNITEN) and Department of Irrigation and Drainage Malaysia for their support. We are most grateful and would like to thank the reviewers for their valuable suggestions that have led to substantial improvements to this article.

Author Contributions

Conceived and designed the experiments: ASP. Analyzed the data: MN and ASP. Wrote the first draft of the manuscript: MR and MH. Contributed to the writing of the manuscript: MN, MR, and MH. Agreed with the manuscript results and conclusions: ASP and MN. Jointly developed the structure and arguments for the paper: ASP and MN. Made critical revisions and approved the final version: MR and MH. All the authors reviewed and approved the final manuscript.

Table 2. Main differences between 1D and 2D models.

ONE-DIMENSIONAL	TWO-DIMENSIONAL
Flow velocity perpendicular to the cross section considers	Speed in different directions are considered
Ability to model the flow is permanent and non-permanent	Ability to model the flow is turbulent
Only the channel cross sections are defined	Model in computational mesh is divided into small pieces
Average speed in cross-section considers	Flow rate can vary

REFERENCES

1. Heydari M, Othman F, Qaderi K. Developing optimal reservoir operation for multiple and multipurpose reservoirs using mathematical programming. *Math Probl Eng*. 2014;2015:11.
2. Othman F, Heydari M, Sadeghian MS, Rashidi M, Shahiri Parsa M. The necessity of systematic and integrated approach in water resources problems and evaluation methods, a review. *Adv Environ Biol*. 2014;8(19):307–315.
3. Brunner GW. *HEC-RAS River Analysis System. Hydraulic Reference Manual. Version 4.1*. Davis, CA: US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center; 2010.
4. Ackerman CT. *HEC-GeoRAS: GIS Tools for Support of HEC-RAS Using ArcGIS. Users Manual Version 4*. US Army Corps of Engineers; 2005. Available at: http://www.hec.usace.army.mil/software/hec-ras/documents/HEC-GeoRAS4_UsersManual.pdf
5. Brunner GW. *HEC-RAS River Analysis System: User's Manual*. US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center, Davis, CA; 2001.
6. Els Z. Data Availability and Requirements for Flood Hazard Mapping. PositionIT. Master of Natural Sciences at Stellenbosch University, 2013.
7. Gilles D, Moore M. Review of Hydraulic Flood Modeling Software Used in Belgium, The Netherlands, and The United Kingdom. International Perspectives in Water Resources Management, Iowa City, IA; 2010.
8. Kraus R. Floodplain Determination Using ArcView GIS and HEC-RAS. Hydrologic and Hydraulic Modeling Support with Geographic Information Systems. New York, NY: ESRI Press; 2000.
9. Tate EC, Maidment DR. *Floodplain Mapping Using HEC-RAS and ArcView GIS*. Austin: University of Texas; 1999.
10. Parsa AS, Heydari M, Sadeghian MS, Moharrampour M. Flood zoning simulation by HEC-RAS model (Case Study: Johor River-Kota Tinggi Region). *J River Eng*. 2013:1–6.
11. Gibson S, Pak J, Fleming M. Modeling watershed and riverine sediment processes with HEC-HMS and HEC-RAS. Paper presented at: Watershed Management Conference, Davis, CA; 2010.
12. Gibson SA, Little Jr C. Implementation of the sediment impact assessment model (SIAM) in HEC-RAS. Paper presented at: 8th Federal Interagency Sedimentation Conference, Reno, NV; 2006.
13. Gibson S, Brunner G, Piper S, Jensen M. Sediment Transport Computations in HEC-RAS. Paper presented at: Eighth Federal Interagency Sedimentation Conference, Reno, NV, USA; 2006.
14. Fan C, Ko C-H, Wang W-S. An innovative modeling approach using Qual2K and HEC-RAS integration to assess the impact of tidal effect on River Water quality simulation. *J Environ Manage*. 2009;90(5):1824–1832.
15. Gee MD, Brunner GW. Dam Break Flood Routing Using HEC-RAS and NWS-FLDWAV. ASCE/EWRI. American Society of Civil Engineering (ASCE), St., Davis, CA; 2005.
16. Goodell CR. Dam break modeling for tandem reservoirs—a case study using HEC-RAS and HEC-HMS. Paper presented at: Impacts of Global Climate Change, Salem, OR; 2005.
17. Zhou RD, Eng P, Donnelly CR. Comparison of HEC-RAS with FLDWAV and DAMBRK models for dam break analysis. Paper presented at: CDA 2005 Annual Conference, Polish Academy of Sciences (PAN) in Warsaw; 2005.
18. Lee KT, Ho Y-H, Chyan Y-J. Bridge blockage and overbank flow simulations using HEC–RAS in the Keelung River during the 2001 Nari typhoon. *J Hydraul Eng*. 2006;132(3):319–323.
19. Canfield HE, Wilson CJ, Lane LJ, Crowell KJ, Thomas WA. Modeling scour and deposition in ephemeral channels after wildfire. *Catena*. 2005;61(2):273–291.
20. Daly SF, Brunner G, Piper S, Jensen M, Tuthill A. Modeling ice-covered rivers using HEC-RAS. Paper presented at: Cold Regions Impact on Civil Works, Duluth, Minn; 1998.
21. Pistocchi A, Mazzoli P. Use of HEC-RAS and HEC-HMS models with ArcView for hydrologic risk management. Paper presented at: Proc. Conference IEMSS, Lugano, Switzerland; 2002.
22. Knebl M, Yang Z-L, Hutchison K, Maidment D. Regional scale flood modeling using NEXRAD rainfall, GIS, and HEC-HMS/RAS: a case study for the San Antonio River Basin Summer 2002 storm event. *J Environ Manage*. 2005;75(4):325–336.
23. Bennett TH, Walton R, Dickerson PD, Howard JW. Comparison of HEC-RAS and MIKE11 unsteady flow modeling for the Tillamook Valley. *Bridges*. 2004;10(40737):182.

24. Moreda F, Gutierrez A, Reed S, Aschwanden C. Transitioning NWS operational hydraulics models from FLDWAV to HEC-RAS. Paper presented at: World Environmental and Water Resources Congress 2009. Great Rivers, Kansas City, Missouri; 2009.
25. Rodriguez LB, Cello PA, Vionnet CA, Goodrich D. Fully conservative coupling of HEC-RAS with MODFLOW to simulate stream–aquifer interactions in a drainage basin. *J Hydrol*. 2008;353(1):129–142.
26. ShahiriParsa A, Qalo N, Heydari M, bt Mohd Amin NF. Introduction to floodplain zoning simulation models through dimensional approach. *Int J Adv Civil Struct Environ Eng*. 2013;1(1):20–23.
27. Altinakar M, Kiedrzynska E, Magnuszewski A. Modelling of inundation patterns on the Pilica River flood plain, Poland. *IAHS Publ*. 2006;308:579.
28. Magnuszewski A, Kiedrzyńska E, Wagner-Łotkowska I, Zalewski M. *Numerical Modelling of Material Fluxes on the Floodplain Wetland of the Pilica River, Poland*. Wetlands: Monitoring, Modelling and Management; 2007:205–210.
29. Wu W, Wang S. Prediction of local scour of non-cohesive sediment around bridge piers using FVM-based CCHE2D Model. Paper presented at: First International Conference on Scour of Foundations, TEXAS, USA; 2002.
30. Jia Y, Wang SS. CCHE2D: Two-dimensional hydrodynamic and sediment transport model for unsteady open channel flows over loose bed. National Center for Computational Hydroscience and Engineering. Technical Report No. NCCHE-TR-2001–1, February 2001.
31. Wu W. CCHE2D sediment transport model (version 2.1). Technical Rep. of National Center for Computational Hydroscience and Engineering NCCHE-TR-2001–03, Univ. of Mississippi; 2001.
32. Scott SH, Jia Y. Simulation of sediment transport and channel morphology change in large river systems. US-China Workshop on Advanced Computational Modelling in Hydroscience & Engineering, Mississippi, USA; 2005.
33. Panigrahy S, Upadhyay G, Ray SS, Parihar JS. Mapping of cropping system for the Indo-Gangetic plain using multi-date SPOT NDVI-VGT data. *J Indian Soc Remote Sens*. 2010;38(4):627–632.
34. Johnson DH, Schwartz J. The Application of a Two-Dimensional Sediment Transport Model in a Cumberland Plateau Mountainous Stream Reach with Complex Morphology and Coarse Substrate. Knoxville: University of Tennessee; 2008.
35. Hasan ZA, Lee KH, Azamathulla HM, Ghani AA. Flow simulation for lake Harapan using CCHE2D—a case study. *Int J Modell Simul*. 2011;31(1):85.
36. Jia Y, Wang SS. Capability assessment of CCHE2D in channel flow simulations. *Proc Adv Hydro Sci Eng*. 1998;3.
37. Nassar M. Multi-parametric sensitivity analysis of CCHE2D for channel flow simulations in Nile River. *J Hydro Environ Res*. 2011;5(3):187–195.
38. Khan AA, Barkdoll B. Two-dimensional depth-averaged models for flow simulation in river bends. *Int J Comput Eng Sci*. 2001;2(03):453–467.
39. Zhu T, Jia Y, Altinakar MS, et al. Study of potential impacts of radioactive contamination on drinking water quality in two collinear reservoirs using CCHE2D model. Paper presented at: ICHE 2012 Conference, Orlando, FL; 2012.
40. Zhu T, Jia Y, Shields F. *Water Quality Modeling of Lake Using CCHE2D [CD-ROM]*. Philadelphia, PA: ASCE; 2003.
41. Ying X, Wang SS. Two-dimensional numerical simulations of Malpasset dam break wave propagation. Paper presented at: Proceeding of 6th International Conference on Hydroscience and Engineering (CD ROM), Brisbane, Australia; 2004.
42. DID. Dataset. Department of Irrigation and Drainage Malaysia, Kuala Lumpur; 2013.
43. Brunner G. *HEC-RAS Hydraulic Reference Manual*. Davis: US Army Corps of Engineers, Hydrologic Engineering Center; 2001.
44. ShahiriParsa A, Vuatalevu NQ, Heydari M, Noor Farahain BMA. Introduction to Floodplain Zoning Simulation Models Through Dimensional Approach. Proc. of the Intl. Conf. on Advances in Structural,Civil and Environmental Engineering—SCEE, Kuala Lumpur; 2013.
45. NCCHE. National Center for Computational Hydroscience and Engineering; 2013.
46. Hasan ZA, Ghani AA, Zakaria N. Application of 2-D Modelling for Muda River Using CCHE2D. Paper presented at: International Conference on Managing Rivers in the 21st Century: Solution Towards Sustainable River Basins, Riverside Kuching, Sarawak, Malaysia; 2007.
47. Hasan ZA, Hamidon N, Zakaria N, Ghani AA, Siang LC. Incoperating GIS in Water Resources Modelling: Application of SWAT 2005 Model in Sungai Kurau, Perak and CCHE2D Model in Tasik Harapan USM. A River Engineering and Urban Drainage Research Center (REDAC), Penang; 2009.