END OF REPORT

Program Title: Flood and flood disaster: Integrated assessment of extreme rainfall-runoff on flood hazard, water quality and microbial variability, and enhancement of standard operating procedures (SOP) for flood disaster awareness: Case study of Sungai Pahang River Basin

Project Title: Project 2 - Land-use and land-cover: Development of a two-dimensional numerical model for mudflow with application on flood routing with the incorporation of mud flow

A. Project Information

Start Date	: 1/04/2015
End Date	: 31/03/2016
Extension Date	: RMC Level: 30/04/2016
Project Status	: Completed
Project Leader	: Puay How Tion
I/C Number	: 781031-01-5921
University	: Universiti Sains Malaysia
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Project Members	: Lau Tze Liang
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B. Project Achievement

Project Progress	: 100%
Research Output	: Indexed Journal - 1 (1 - Under Review)
	Conference Proceedings – 2
Talent	: PhD student - (IC No:) ()
	RA - Marhanis Zailan (IC No: 900527-07-5572)

C. Expenditure

Budget Approved	: RM 150,000.00
Amount Spent	: RM 147,754.50
Balance	: RM 2,245.49
% of Amount Spent	: 98.50

SUMMARY OF RESEARCH FINDINGS

1.0 Introduction

The recent December 2014 unprecedented Malaysia East Coast flood has brought the attention to the lack of river basin management in our country. The effects of land-clearing and uncontrolled agricultural activities on steep slope have resulted failure of the river to accommodate the rapid increase of flow discharge and sediment load. Other events related to the exposure of soil at steep slope are the mudflow and debris flow which are often triggered during high intensity and long duration storm or monsoon rain. This study aims to develop an in-house numerical code to simulate the phenomena of mudflow and to use the model to simulate flood routing with the incorporation of mudflow. Based on several proposed constitutive relations for mudflow and debris flow, a two-dimensional code will be developed. The investigation of suitable constitutive relation for local mudflow will be carried out and incorporated into the numerical model. The model will be later used to investigate the potential damage of a typical mudflow. The effectiveness of mudflow and debris barrier will also be investigated using the model. The study starts with the collection of soil samples followed by the development and application of numerical model and finally potential damage assessment and hazard map development. The ability of numerical model to simulate mudflow provides an efficient way for engineers, planners, policy makers, investor and even inventors to make quick yet wise decisions when managing land use. Numerical model comes in handy when physical experiment is time-consuming and expensive in providing reliable information for better land-use management.

2.0 Methodology

The study begins with the validation of the numerical model by simulating the "dam-break flow" benchmark problem using several candidates for mudflow constitutive relations. This is carried out using a one-dimensional depth averaged model and a two-dimensional depth averaged model. The results are compared with theoretical and experimental data from literature studies. By using the two-dimensional depth averaged model, the numerical model is then used to assess the damage potential of mudflow. The flood routing simulation which incorporate mudflow will be carried out using the numerical model, with several flood mitigation scenarios.

3.0 Results and Discussion

The results of the studies can be divided into three parts, based on the type of numerical model used to study the mudflow :

i) Two-dimensional model

The two-dimensional continuity and momentum equations are solved in this model based on the finite volume method with VSIAM3 technique (VSIAM3=Volume Surface Integrated Averaged Multi-moment Method). The VOF method is used for surface tracking where the F function is solved using the THINC method (THINC=Tangent of Hyperbola for Interface Capturing) which is a conservative, oscillationless and smearing-less scheme. Two constitutive models are used for the mudflow: a modified Herschel-Buckley model and Papanastasiou model. It was found out that the modified Herschel-Buckley model performed better than the Papanastasiou model. However, the disadvantage of adopting the modified Herschel-Buckley model is in achieving convergence in the initial stage when viscosity is high.

The findings in this part was submitted in the following paper :

Puay, H. T., Abdullah, M. Z., Zakaria, N. A., Chan, N. W., Ahamad, M. S. S. and Lau, T. L., Evaluation of rheological model for numerical simulation of mudflow on steep slope triggerd by heavy rainfall., Jurnal Teknologi, 2015.

ii) One-dimensional depth averaged model

The St. Venent equation was solved in this model by finite difference method. Harten's TVD scheme (TVD=Total Variation Diminishing) scheme was adopted in the numerical model to improve shock wave capturing and suppress oscillations. The numerical model was initially validated against Ritter's solution for a simple dam-break problem. For the simulation of mudflow, it was assumed that the mudflow is made up of hyper-concentrated fine suspension, and the constitutive relation is based on Herschel-Buckley model and expressed in the form of bedshear stress, which was obtained empirically. The model was then used to simulate the release of mudflow from a reservoir onto an inclined channel. The performance of the model was validated with experimental data from literature for the time variations of flow depth at three locations along the channel. It was found that the empirical model based on Herschel-Buckley model is suitable for the simulation of mudflow if it comprised of hyper-concentrated fine suspension.

The findings in this part was submitted and accepted for following conference paper :

Puay, H. T., Zakaria, N. A. and Hosoda, T., Numerical simulation of mudflow on steep slope triggered by heavy rainfall., 20th Congress of the Asia Pacific Division of the

International Association for Hydro Environment Engineering & Research, IAHR APD Sri Lanka, 2016.

iii) Two-dimensional depth averaged model

A two-dimensional depth averaged model was solved by discretizing the governing equaitons using finite volume method. A high accuracy in space was achieved by adopting van Leer's MUSCL scheme (MUSCL= Monotone Upstream-Centered Scheme for Conservation Law) with midmod slope limiter to ensure TVD property. Meanwhile, a second order accuracy in time was achived by using the second order Adams-Bashforth method. The verification of the model was carried out by simulating the partial dam-break problem and validated with numerical data from literature studies. The model was then used to simulate the release of mud suspension from reservoir onto an inclined plane. The flow profile, peak discharge and run-out distance were compared with experimental data from literature studies. Finally, the model is used to simulate mudflow event with obstacles representing buildings at the downstream.

The findings in this part was submitted for the following conference paper :

Puay, H. T., Zakaria, N. A., Numerical simulation of mudflow event with a two-dimensional depth-averaged flow model, Persidangan Kajian Bencana Banjir 2014, 2016.

4.0 Conclusion

Important findings of the study are summarized as follows.

i. Selection of suitable constitutive model for the numerical simulation of mudflow is critical. If the mudflow is mostly comprised of fine suspension, the Herschel Buckley model is suitable.

ii. For simulation of mudflow event, a two-dimensional depth-averaged model with empirical formula based on Herchel Buckley model is suitable. However, this is only applicable for mudflow which is mostly comprised of hyper-concentrated fine suspension.

iii. For more accurate simulation, the mudflow sample has to be obtained from site immediately or during the mudflow event. However obtaining such sample is very dangerous and access to the site is usually cut-off during such events.

References

Puay, H. T., Zakaria, N. A., Numerical simulation of mudflow event with a two-dimensional depth-averaged flow model, Persidangan Kajian Bencana Banjir 2014, 2016.

Puay, H. T., Zakaria, N. A. and Hosoda, T., Numerical simulation of mudflow on steep slope triggered by heavy rainfall., 20th Congress of the Asia Pacific Division of the International Association for Hydro Environment Engineering & Research, IAHR APD Sri Lanka, 2016.

Puay, H. T., Abdullah, M. Z., Zakaria, N. A., Chan, N. W., Ahamad, M. S. S. and Lau, T. L., Evaluation of rheological model for numerical simulation of mudflow on steep slope triggerd by heavy rainfall., Jurnal Teknologi, 2015.