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Numerical Modelling of Extreme Flooding for Flood Risk Assessment in Tra Bong River Basin

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ABSTRACT

Flooding and inundation are of the most concerns in Vietnam recently. Many extreme floods have been happening frequently in Vietnam, especially during the period of 1999 to 2009. Therefore, considering the impacts of flooding plays an important role in mitigating and adapting to flood risks. In this study, a rainfall-runoff model (MIKE NAM), two hydrodynamic models (MIKE 11HD, MIKE 21 FM) and a coupling model (MIKE Flood) were applied as effective tools to simulate flooding and inundation in the Tra Bong River Basin. The basin is located in the Binh Son District, in the North of Quang Ngai Province, Vietnam. The eastern part borders the East Sea with 54 km of length of the seashore. This basin spreads widely between latitudes of $15^0$11 – $15^0$25 N and longitudes of $108^0$34 – $108^0$56 E. The total river system basin area is over 700 km^2, of which more than 80% is mountainous or hilly. The river has a length of 59 km and its network density is about 0.43 km/km^2, the average altitude is 196 m and the average river slope is 10.9%.

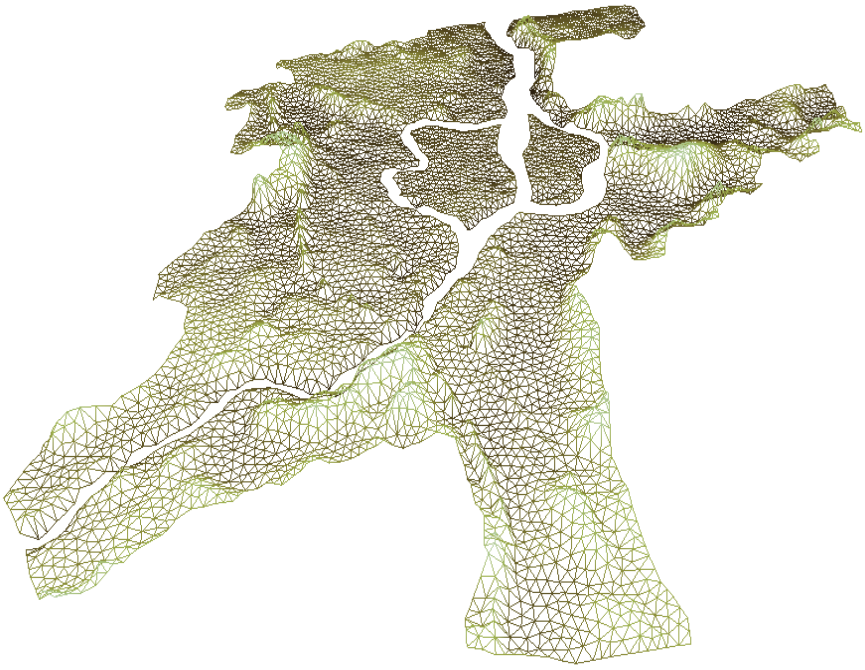

Fig. 1. The domain mesh in a 3D view

Hydro-meteorological data in this study was collected from many sources such as the National Centre for Hydro-Meteorological Forecast of Vietnam (NCHMF), the Institute of Hydrology, Environment and Climate change (IHECC) – Thuy Loi University and further experts. The data used, comprises daily and one hourly discharge, rainfall, water levels and temperature data. Geospatial data of the area and 50 cross sections of the main river bed are available. However, cross sections are unevenly distributed from the upstream to downstream area and do not cover the entire river. Particularly, the cross sections are scarcely distributed at the conjunction of the river, at its tributaries and in middle of the river. A Digital Elevation Model (DEM) with high resolution (10x10m) and a land use map in raster format (30x30m resolution) are also available. The land use map with a scale of 1:50,000, which was created in 2010, was obtained from the Urban Planning Office of Quang Ngai Province.

The MIKE models were applied in order to investigate flood behavior as well as to generate flooding maps in the basin. Accordingly, MIKE NAM model was applied to simulate runoff from rainfall as input for the 1D model. Then, MIKE 11 HD was used to simulate the discharge hydrograph from the upstream to the downstream of the river system. The Manning values are varying from 0.03 to 0.12 sm-1/3 for river banks and channel sections respectively. MIKE 21 FM was applied to simulate flow on the floodplain. According to Kalyanapu (2009), the Manning's roughness coefficient is commonly used to represent surface roughness in distributed models and for large watersheds. Therefore, a manning value is assigned to each element in the mesh domain based on the suggested values for the overland surface from McCuen (1998). Eventually, the overland flow or lateral flow from the river onto floodplain was simulated by using the MIKE Flood model. Besides that, in order to generate a mesh of the study domain, the DEM was used and subsequently combined with a topographical map. The mesh properties consist of specific information such as: the number of nodes (9,224), the number of elements (17,921), the minimum element area (896 m^2), the maximum area (16,073 m^2), and the smallest allowable angle (28 degrees) (Fig.1).

Due to a lack of sufficient hourly discharge data in the basin, the application of a direct calibration of rainfall-runoff model for the basin is impossible. Therefore, model parameters are able to identify by using parameter determined from a similar river basin. The An Chi River Basin, which is approximately 764 km^2 and nearby the study area, satisfies all the assumptions corresponding to the regionalization approach. To identify optimal input values for the parameters of MIKE NAM model for this basin, three gauging stations located within and around the basin were used. The hourly discharge time series and hourly rainfall time series in the year of 1999 and 2003 were used to calibrate and validate respectively due to synchronous data and typical extreme flood events in both years. The average rainfall was calculated by using the Thiessen polygon approach. In order to evaluate the model performance using observed data at specific control stations and results that are extracted from the model, a series of statistical analyses were applied. Nash-Sutcliffe coefficient of efficiency (NSCE) is one of the most important errors. The model performances showed a reasonable agreement between the simulated and the observed values. The peak values in the hydrographs were rather well calculated. The Nash Sutcliffe coefficient of efficiency and Correlation coefficient are above 0.89 and 0.96 respectively.

The flood events from 15th October 2003 to 20th October 2003 and from 27th September 2009 to 2nd October 2009 were used for the 1D and 2D model calibration and validation. As for the calibration period, the Nash-Sutcliffe efficiency is about 0.63, the peak error is 0.013, the volume error is 10%, and the correlation coefficient is 81%. As for the verification period, the model simulated high accuracy of water levels whereby the NSCE is 0.7 and the correlation coefficient is up to 92%. Due to a lack of data, the model results above indicate that those applied models are suitable and reliable for flooding simulation in the Tra Bong River Basin. In order to build a scenario for simulating extreme flooding, a flood event with a 100 year return period as a simulation scenario was selected. For this reason, the return interval or return period places magnitude of floods in terms of the frequency giving a probability of a particular flood event. The coupled model setup for the 100 year return period flood event is the same as the model for the validation process. During the design flood with a 100 year return period, the area of 54.6 km^2 would probably be affected by the flooding with a flood depth varying from 0.25 up to 6.2 meters. In this case, some of the areas in downstream of the river basin such as Binh Trung, Binh Chanh, Binh Duong and Chau O Town would be the most affected areas in the floodplain.