RELIABILITY OF USING CALIBRATED BASIN MODEL IN PRODUCING FLOOD INUNDATION MAP

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ABSTRACT: Flooding is one of the major natural disasters affecting population, livelihood and properties. It has become a common event every year and has not spared anybody from the loss. Key in preventing and reducing its effect is to provide flood models and flood hazard maps that would give reliable information on flood-prone areas and could serves as basis on Disaster Risk Reduction and Management (DRRM) operation. Though generation of reliable flood inundation map still remain a challenge.

Using the Cabulig River Basin in Misamis Oriental, Mindanao, Philippines, the study aims to elevate the use of calibrated flood model in producing flood inundation map of 100-year return period overlaid with Light Detection and Ranging- Digital Terrain Model (LiDAR-DTM) in ArcGIS. Cabulig River consists of 5.5 m^2 flood plain area with 6 barangays in the municipality of Jasaan. The river inundates when excessive rainfall occurs in the upper portion of the watershed. The methods also involved the utilization of standalone software: Hydrologic Modeling System (HMS) for the flood model and the River Analysis System (RAS) for the river inundation. The latter result showed that 24-hour rainfall of 239.7 mm, the calibrated model produces more define river inundation with 839.9 mm volume of the peak flow than un-calibrated model with 1884.08 mm.

Thus, the use of calibrated basin model is essential in generating reliable flood inundation providing specific area of interest to address the monitoring, preparation, rescue and relief operation in relation to flooding.

1. INTRODUCTION

Flood is a natural phenomenon that has existed and will continue to exist. However, its nature has been affected by human activities and human interventions thus exposition to risk and vulnerability to flood-prone area increases.

Cabulig River is one of the flood prone areas and is geographically located East of Cagayan de Oro, the regional capital of Northern Mindanao, Philippines. It runs from East in the Municipality of Claveria draining to West in the Municipality of Jasaan. The Cabulig river basin falls with the political jurisdiction of Balingasag and Claveria in the North, Gingoog and Claveria on the East, Claveria and Villanueva on the South and Jasaan on the West. Cabulig river basin has a flood plain area of 5.5 m^2 with 6 barangays in the municipality of Jasaan with approximate population of 20,000.

One way of helping flooded communities is the development of flood model that would serves as an early warning and will show the possible areas to be affected based on rainfall intensity. Developing a model needs reliable and updated data. Despite of unavailability of high resolution digital elevation model (DEM) and updated land cover and soil data, calibration is relevant in creating a flood model.

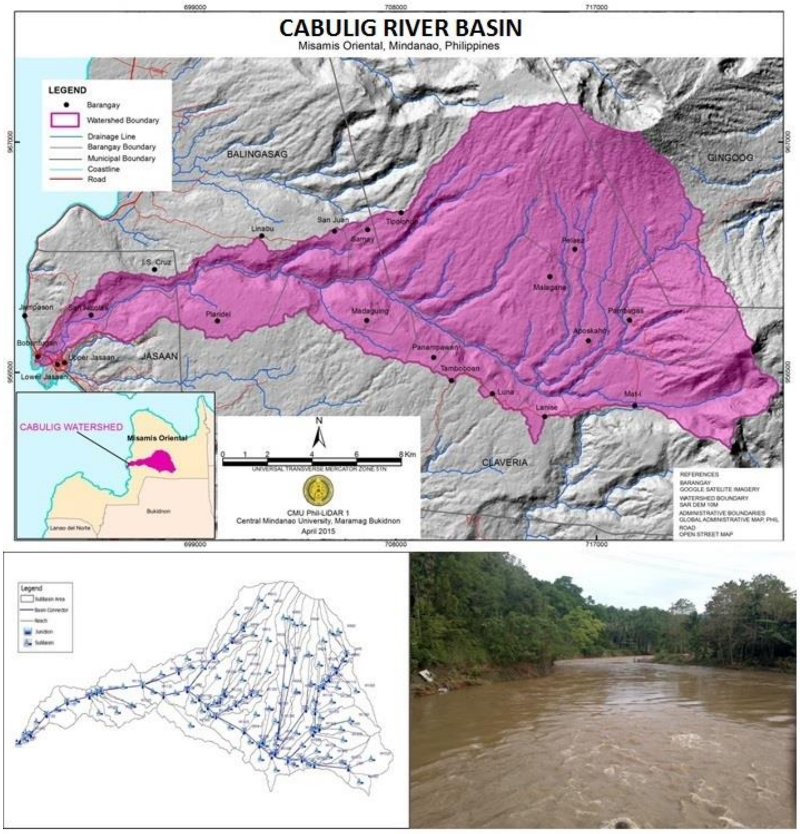

Figure 1. Cabulig river drainage system.

2. MATERIALS AND METHODS

2.1 Model Development

Basic to the development of the model is the delineation of the river channel using Google Earth burned with Synthetic Aperture Radar – Digital Elevation Model with 10 meters resolution (SAR-DEM 10m) through HEC-GeoHMS 10.1 extension tool in ArcGIS 10.1. HEC-GeoHMS allowed the filling of sinks on the DEM to create flow direction and accumulation as well as the required value for threshold as basis for stream segmentation and catchment delineation. In addition, the river and basin characteristics as length, slope, centroid, longest flow path, and elevation were also processed.

Different parameters are assigned and manipulated in the process of model development. The parameters includes infiltration loss, direct run-off (transform), base flow and channel routing as assigned as Soil Conservation Service (SCS), Clark, Recession and Muskingum-Cunge respectively. The Curve Number (CN) is also integrated to the model which is generated from the soil map of the Bureau of Soils and Water Management (BSWM 2004) and land cover map of the National Mapping and Resource Information Authority (NAMRIA 2004).

Other hydrologic parameters such as Initial Abstraction (IA), Storage Coefficient (SC) and Time of Concentration (TC) were calculated using HMS extension tool. Then the basin model is converted to HMS basin model file as the primary input of HMS stand-alone software necessary for further basin model calibration.

2.2 Model Calibration and Performance Ratings

The GeoHMS Basin Model output and other components such as meteorological model, control specification, and time series data were set-up in HEC-HMS stand-alone software for calibration. Cabulig Basin Model was manually calibrated using the hydrologic data (discharge and rainfall) gathered during the Inter-Tropical Convergence Zone (ITCZ) on September 29, 2015 in Misamis Oriental, Mindanao, Philippines specifically in Riverside, Brgy. Lower, Jasaan, Jasaan for discharge and in Brgy, Lanise, Claveria for rainfall. Calibration was done by changing parameters' values of Mannings' N, SC, TC, CN, IA, Initial Discharge (ID), Recession Constant (RC) and Ratio to Peak (RP) to establish model fitness to the observed outflow.

Accuracy tests are relevant in evaluating the model performance. Observed and simulated outflow derived from the model time series table were assessed together using the 5 accuracy tests based on Chai, et.al of 2014 and Moriasi, et.al of 2007, the Root Mean Square Error (RMSE), Pearson correlation coefficient (r^2), RMSE-observations standard deviation ratio (RSR), Nash–Sutcliffe efficiency index (NSE), and Percent bias (PBIAS).

The model calibration and validation is an iterative process aimed at making the simulated results closely fit the measured data. Table 1 shows the Model Performance Ratings used as basis. These will define how effective and accurate the model in the flood model application as well as in the generation of flood hazard map.

Table 1. Hydrological Model Performance Ratings

Performance Rating	**Statistics**		
	NSE	**PBIAS**	**RSR**
Very Good	0.75<E≤1.00	PBIAS≤±10	0.00<RSR≤0.50
Good	0.75<E≤1.00	±10≤PBIAS≤±10	0.50<RSR≤0.60
Satisfactory	0.5<E≤0.65	±15≤PBIAS≤±25	0.60<RSR≤0.70

2.3 Model Simulation using RIDF

The Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) has data on Rainfall Intensity Duration Frequency (RIDF) for the Lumbia Rain Gauge. It is the rain gauge station that covers the area of Cabulig river basin with 26-year record of RIDF values. Thus, the Lumbia RG station is chosen as basis for RIDF data for model simulation of 100-year return period with 24 hours duration and peaks after 12 hours. Two simulations were done at this period, the simulation of RIDF data of 100-year return period with a 24 hour rainfall of 239.7 mm using the calibrated and un-calibrated models.

2.4 Flood Inundation Mapping

Geometric data were created using the GeoRAS extension tool in ArcGIS overlaid with LiDAR-DTM (Light Detection and Ranging- Digital Terrain Model). Then it is used in HEC-RAS (Hydrologic Engineering Center – River Analysis System) with 100-year return period outflow results from both calibrated and un-calibrated models for flood mapping.

3. RESULTS AND DISCUSSIONS

3.1 Basin Model

The resulting Cabulig Basin Model has an area of 28163 hectares and is consists of 83 sub basins, 43 reaches, and 43 junctions. Observed outflow is in the junction labelled as riverside while the main outlet is in the estuary of Cabulig River at Lower Jasaan, Misamis Oriental draining to Macajalar Bay.

3.2 Calibrated Basin Model Performance Ratings

Figure 2 shows the hydrograph of the Cabulig HMS Basin Model and observed values. The calibrated model has RMSE value of 2 and r^2 of 0.8049 indicating our predictive model is good over the actual data and the regression line closely fits the observed data. The calibrated model also shows satisfactory performance ratings in relation to NSE, PBIAS and RSR with the values of 0.52, 19.32 and 0.70 respectively. These results serve as basis for the calibrated model acceptability and reliability in simulating rainfall events as well as the 100-year return period.

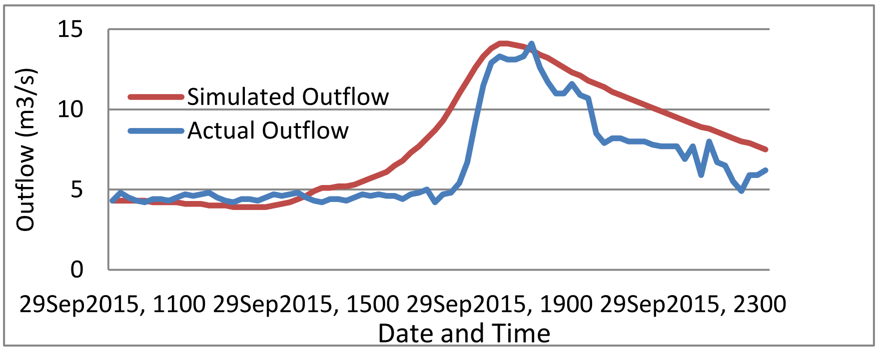

Figure 2. Cabulig river hydrograph.

3.3 Model Outflow using RIDF

In general, the calibrated model got satisfactory performance ratings using the accuracy tests. The simulation results of RIDF data of 100-year return period reveal 37% significant difference of outflow generated between the calibrated and un-calibrated models with a peak outflow of 839.9 m^3/s and 1884.08 m^3/s respectively.

3.4. 100-Year Return Period Flood Map

Figures below show the output of calibrated and un-calibrated models. Calibrated model delivers more define flood extent and depth than un-calibrated model with 151.25 ha or 54.8% of area flooded. Moreover, the un-calibrated model output exaggeratedly flooded the area with higher elevation and delivered depth range which is 10% higher than the calibrated model.

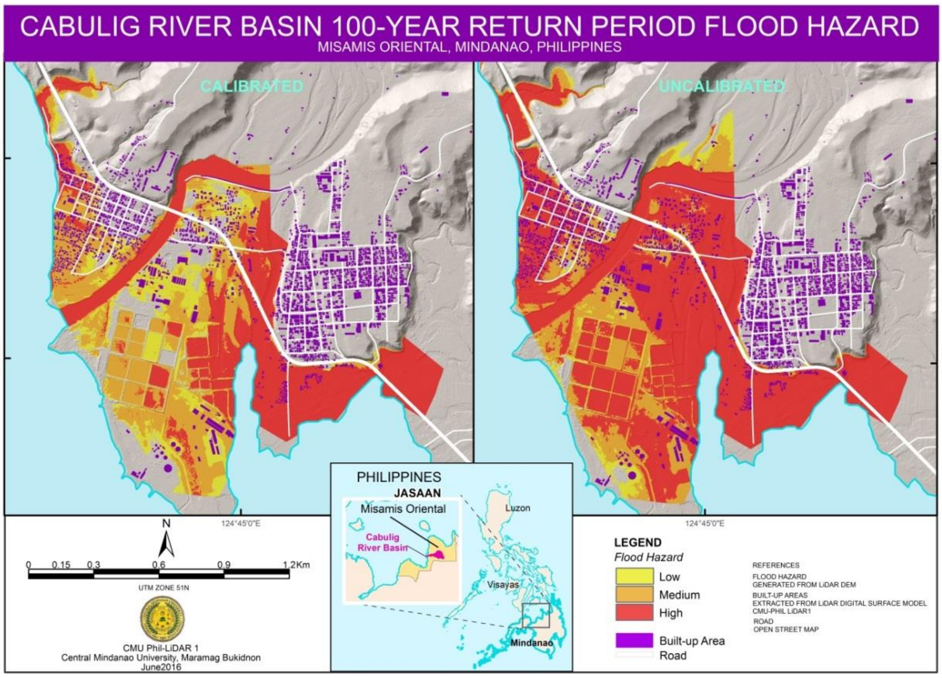

Figure 3. Flood hazard map output of calibrated and un-calibrated models.

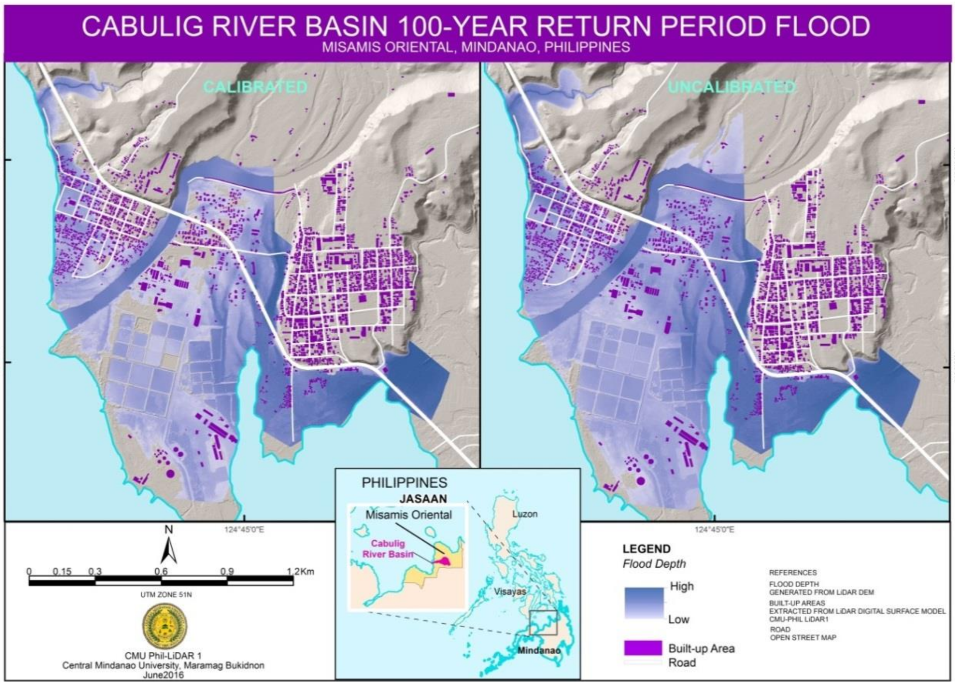

Figure 4. Flood depth map of 100-year return period.

The information generated can aid in the implementation process for DRRM as well as in selecting flood model that would help in providing reliable information for the vulnerable communities.

4. CONCLUSION AND RECOMMENDATION

Output revealed the reliability of using calibrated model in producing flood hazard and depth maps. This model can provide more define areas, especially the critical areas flooded. Details and accuracy provided by the model are important in DRRM.

Based on the results gathered in the study, a further ground validation is highly recommended to ascertain the affected barangays in relation to the actual flood extent and depth of such return period. Thus, ground verification and validation should be conducted to correct and complete the information.

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