INVESTIGATION OF HYDROLOGICAL RESPONSE OF FLOOD CONTROL SCHENARIOS AND ASSESSMENT OF THE EFFECTIVENESS IN COMORO RIVER BASIN DILI, TIMOR-LESTE

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ABSTRACT

Comoro River is the main and largest river, experiences serious floods with damage to infrastructure and houses in Dili capital City, Timor-Leste. This study, therefore, investigated the impact of floods and proposed countermeasures in the basin by using Rainfall-Runoff-Inundation (RRI) model. In this research, I reviewed the previous pilot studies on the "Design Flood Mitigation measures", conducted by two international consultants in 2012 by Sinclair Knight Merz (SKM) and in 2016 by Japan International Cooperation Agency (JICA). RRI model was calibrated for 2013 flood and validated for 2012 flood, to represent Comoro rivers actual condition. The result for design rainfall at downstream area showed very low in the calibration period and the peak discharge was 80.04 m^3/s in case of design rainfall (50-year return period) due to high infiltration rate. On the other hand, without infiltration and evaporation, the result showed the overestimated peak discharge about 361.19 m^3/s. This significantly corresponded with the SKM study with total peak discharge of 288.9 m^3/s. According to the hydrologic analysis, Comoro River is wide enough to flow the peak discharges despites overestimated discharge under a 50-year return period. In order to mitigate the impacts of the flood risk, flood control should be implemented to strengthen existing countermeasures e.g., rehabilitation of the levees in downstream.

Keywords: Comoro River Basin, Observed Data, Previous Studies, RRI Model

INTRODUCTION

The Republic of Democratic of Timor-Leste (RDTL) located in the Southeast Asia, in the East of the Indonesian archipelago and to the North-West of Australia. The country itself consists of thirteen municipalities (Figure 1.a). According to the 2013 report of the Division of Research and Special Services, the average of the total annual rainfall as measured in the thirteen municipalities centers, is 1,583 mm. Geographically, the country is exposed to several kinds of natural disasters, which includes strong tropical windstorms, heavy rain, drought, and landslides. Flood is one of the most common disaster, resulting from a combination of heavy monsoon rain, steep topography, and widespread deforestation. Dili is the capital city of the country, it has a population of 252,884 (2015 Population Census), total area is 48.27 km^2. Comoro River is the main and largest river in Dili, supplying water for both industrial and domestic use to the local residence, taken from Bemos (Upstream of Comoro River) and conveyed through the subject raw water main to the Dili central water treatment plant. The River flows between the main international airport and inner city. The hydrological boundaries of Comoro river basin cover four municipalities namely Dili, Liquica, Ermera, and Aileu. The total catchment area was approximately 213 km^2 (Figure 1.b). The catchment system is mainly sandy soil with relatively higher infiltration capacity, high rate of groundwater recharge at the mountain sides can be expected.

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In addition, this study was also researched by Lindsay in 2011, groundwater study in Dili shows that 60 % of the river flows in the upper reach of Comoro River is diverted to an underground river system that eventually recharges the groundwater body in Caicoli, Dili. Due to heavy rainfall, according to the national disaster loss database in Dili, the great flood of 2010 and 2013, were reported in 2010 total affected 2,467 people and 2013 are 667 people. Realizing the negative impacts that are brought by the floods and also considering the prominence of the city, which is the center of economic growth of Timor-Leste, it is essential to undertake an assessment of the risks and propose effective countermeasures to reduce the impacts, allowing sustainable economic growth and development of the city, and at the same time building resilience to floods. In 2011, government of Timor-Leste allocated to flood control budget about USD 1.75 million (Source: SKM final of DSDMP report, 2012). These budget already implemented by the government was used to rehabilitation and maintenance of channel in Dili. Rehabilitation and construction managed by National Directorate of Roads, Bridges and Flood Control (NDRBFC), maintenance managed by National Directorate for Basic Sanitation (NDSSB) and Dili municipality administration. Besides these measures already implemented, under a cooperation between the government of Timor-Leste and the government of Victoria was developed between 2010 and 2012 one master plan drainage in Dili, to investigate the magnitude of problems related to existing drainage infrastructure, formulation of proposal for medium to long term strategic plans for flood mitigation in Dili. In the area of Comoro, river basin was proposed constructing a flood control reservoir at the upstream area to reduce the peak flow at the river mouth with 50-year return period designed plan. In 2016 JICA project Comoro Bridge three, was proposed design river for 50-year return period to increase embankment and river widening. This study aimed to investigate the hydrological response of flood control scenarios and assessment of the effectiveness in Comoro river basin to minimizing the flood occurrences affected in the area. Furthermore, to minimize the impact of floods, this study was previously conducted by SKM in 2012 and by JICA in 2016.

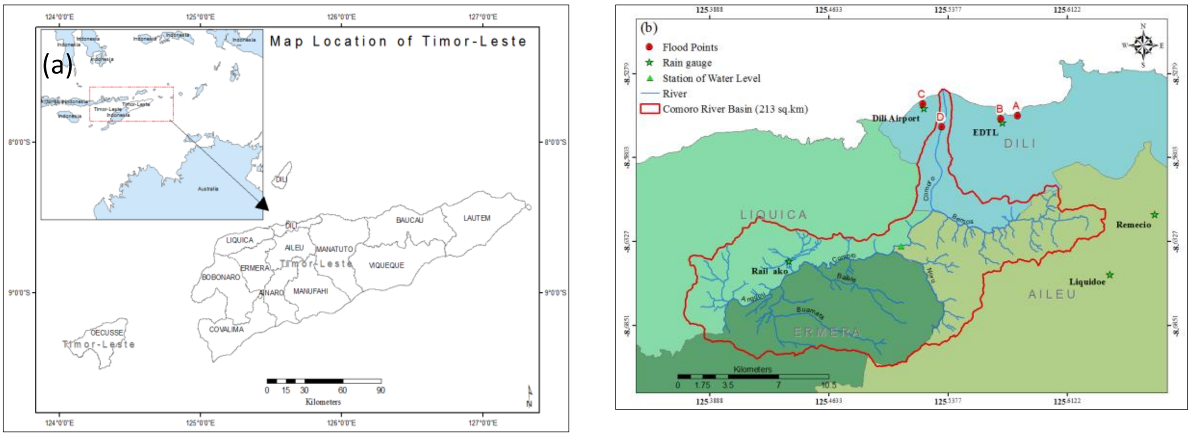

Figure 1. Location study area (a) Timor-Leste, (b) Comoro River Basin

METHODOLOGY

The Methodology of this study was divided to two parts: observation and scenarios based analysis's (Figure 2). The Rainfall-Runoff-Inundation (RRI) model, was used to calibrate the 2013 flood event and validate the 2012 flood event. These flood events were chosen as they are the worst in the Comoro River basin which caused more damage to infrastructure, including people's houses. The observed water level data was convert to discharge. This was achieved by computation using manning equation and river bed slope based on the assumption from DEM 30 meter. The observed discharge was compared to the RRI simulated discharge using average rainfall data from four stations (Dili Airport, Railaco, Remexio and EDTL). The calibration and validation of the RRI model showed better results, meaning that the model represented well the conditions of the basin. The frequency analysis was conducted by using 34 years maximum annual daily rainfall data recorded at Dili Airport station. Considering that rainfall distribution follows probability density function, the study used GEV and Gumbel distribution. Rainfall pattern of 2013 flood event was used for the 50-year return period design rainfall under Gumbel distribution function. The ratio factor for Dili Airport obtained from the Gumbel distribution, was multiplied by daily rainfall data for other three rain gauges. The rainfall data was run by the RRI model and the obtained discharges were used to prepare the flood hazard maps as well as compared with the simulated discharges which were obtained by international consultants.

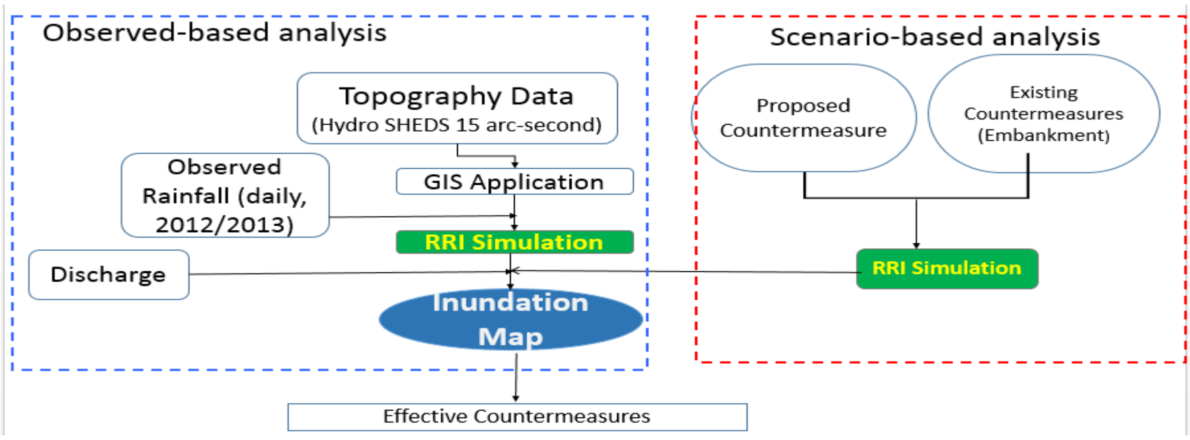

Figure 2. Flow Chart for Flood Risk Assessment

DATA

Daily rainfall (2003-2016) and maximum annual daily rainfall (1978-1999) data were obtained from the National Directorate of Meteorology and Geophysics at (☆) Dili Airport station respectively. Additional daily rainfall data (2010-2015) from rain gauge stations namely (☆) EDTL, Remexio and Railaco and (▲) Water level data (both manual and automated) for 2012 and 2013 were obtained from National Directorate for Water Quality and Control. Topographical data, 15 Arc seconds, which include; Shuttle Radar Topography Mission, Digital Elevation Model (Figure 3.a), flow direction (Figure 3.b), and flow accumulation (Figure 3.c) were downloaded from hydro SHEDS, United States Geological Survey (USGS) website.

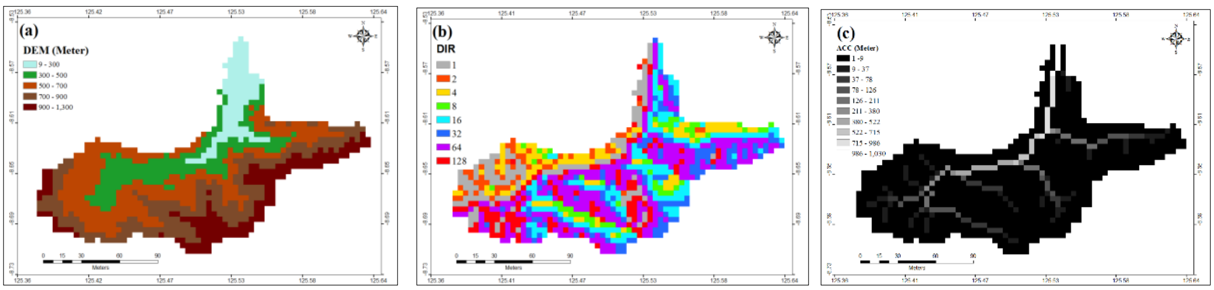

Figure 3 Topography Input Data; (a) DEM, (b) DIR, (c) ACC for RRI Simulation

RESULT

Calibrated RRI Model

RRI model was calibrated to the flood event in 2013. The parameters are related to soil characteristics of the catchment and gives the possible values (Table 1). Comparing the observed water level records from daily manual measurements to water level from simulated result of 2013 rainfall event (Figure 4), it showed that observed water level remain uniform or constant, before and after high rainfall event, which did not indicated the high water level during flooding. Therefore, records for manual measurement could not be used. Observed data from automatic measurement water level was used. The comparison result between simulation and observed river discharge were conducted by RRI model for the flood event from January 1 to July 4 on 2013 (Figure 5). Approximation value of peak river discharge and similarity in hydrograph pattern between simulation and observed result prove that RRI model was well calibrated and to represent to actual conditions of the slope and river.

Table 1 RRI Model Parameter

Parameters	Notation	Default	Calibrated Value
n(River) ($m^{-1/3}$ s)	ns_river	3.000d-2	1.500d-1
n(Land) ($m^{-1/3}$s)	ns_slope	3.000d-1	5.000d-1
Ka(m/s)	ka	0.000d0	1.000d-2
Soil depth (m)	soil depth	1.000d0	4.000d0
River width (meter)	River width	-	8

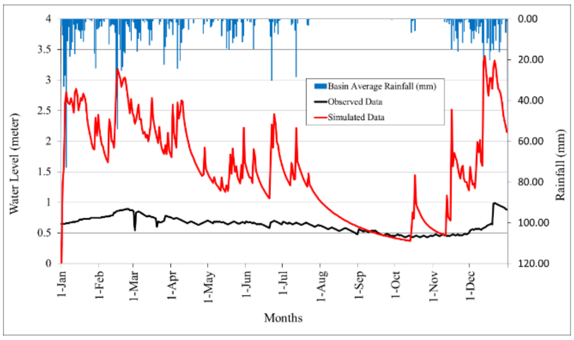

Figure 4 Comparison of Hydrograph of 2013 Floods

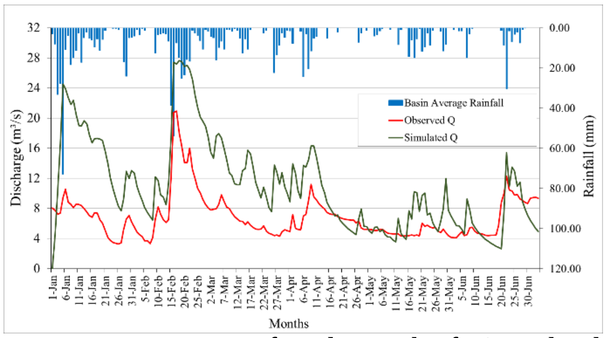

Figure 5 Comparison of Hydrograph of 2013 Floods

Estimation of Water Budget in the Comoro River Basin

In this study, water budget was estimated from different scenarios using observed river discharge and simulation discharge based on calibration RRI data. The simulated discharge is higher than observed discharge scenarios, because the value of soil depth is less than the actual condition and affects to the soil capacity of infiltration. Water budget estimated (Table 2).

Table 2 Estimated Water Budget from Discharge Observed & Simulated Discharge

Automatic Measurement (January 1-July 4, 2013)	Discharge (m^3/day)	Vol. Rainfall (m^3/day)	Budget (m^3/day)
Observed Data	110,024,930.02	221,592,775.00	111,567,844.98
Simulated Data	177,138,144.00		44,454,631.00

Validation RRI Model

RRI model was validated by using 2012 flood event. The comparison result between simulation discharge and observed river discharge for the 2012 flood event (Figure 6).

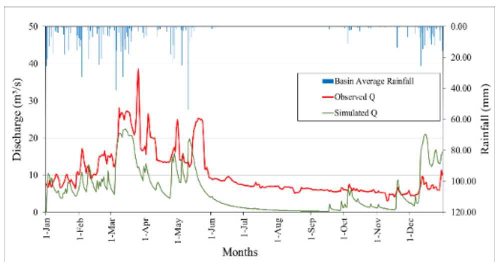

Figure 6 Comparison of Hydrograph in 2012 Flood

Frequency Analysis Result

Rainfall process and the setting of design rainfall is necessary to predict the scenario extreme flood and to prepare the flood hazard maps. The design rainfall for 50-years return period for four rain gauges station (Figure 7).

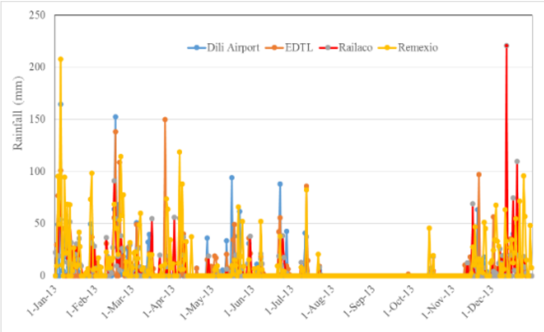

Figure 7 the 50-Years Return Period Rainfall from Four Rain Gauge Station

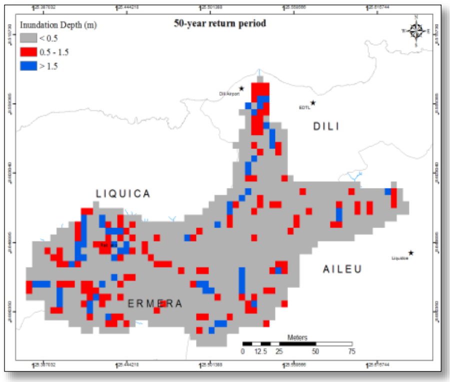

Figure 8 Flood Inundation Map of 50-

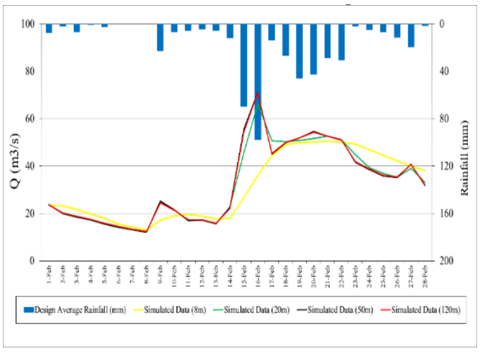

Figure 9 Comparison of Hydrograph from Different River Width

Flood Inundation Analysis without Countermeasure

The inundation area in different inundation depth without considering the control existing countermeasures of 50-years return period (Figure 8).

Flood Inundation Analysis with Countermeasure

The results (Table 3), showing different river width with maximum peak discharge and water level, indicates how much river width influences the peak discharge. When the width, was changed from 8 meters to 20 meters, there was an increase in peak discharge at the peak rainfall period. As the width was further increased to 50 meters, a slight increase was observed. However no change in peak discharged was observed, when the width was increased from 50 meters to 120 meters (Figure 9). Comparing with the previous studies, the result found using simulated river discharge for the design rainfall of 50-years return period (Table 4).

Table 3 Simulated Discharge from Different River Width

River width (meter)	River High (meter)	Q (m³/s)
8	3.351	50.46
20	2.394	66.47
50	1.58	78.53
120	0.978	80.04

Table 4 Comparison of peak discharge 50-year return period between RRI model and DSDMP report SKM 2012, Construction up river Comoro bridge report JICA 2016

Comoro River basin Total Area 213 km^2	Proposed Scenarios		Preparatory Survey Report on Construction of Upriver Comoro Bridge, JICA 2016	SKM final DSDMP report, October 2012
	Without Infiltration, Evaporation	With Calibrated Value		
Peak Discharge (m³/s)	361.19	80.04	2500	288.9

CONCLUSION

The Rainfall-Runoff-Inundation (RRI) model, was calibrated for the 2013 floods and validated for the 2012 flood, to represent the Comoro rivers actual conditions. Frequency analysis was applied to determine rainfall for 50-year return period. The simulated results from RRI model was put into comparison with two existing studies on hydrological modeling which were conducted by Japan International Cooperation Agency (JICA) in 2016 and Sinclair Knight Merz (SKM) in 2012. The result for the design rainfall at downstream area, showed very low in the calibration period of 80.04 m^3/s compared with the previous studies. However, in the case of simulation without infiltration and evaporation, the result showed the peak discharge of 361.19 m^3/s. This significantly corresponded with the SKM study with total peak discharge of 288.9 m^3/s. However, the JICA study estimated discharges of 2500 m^3/s for peak flood. This result from JICA is overestimated considering the size of the Comoro river basin. According to the hydrologic analysis, Comoro River is wide enough to flow despites the simulated discharge under a 50-year return period. In order to mitigate the impacts of the flood risk, flood control should be implemented to strengthen existing countermeasures e.g., rehabilitation of the levees in downstream and construction of check dam for sediment control in upstream.

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