Rainfall and Flood Forecast Models for Better Flood Relief Plan of the Mae Sot Municipality

S. Chuenchooklin, S. Taweepong, U. Pangnakorn

***Abstract*—**This research was conducted in the Mae Sot Watershed where located in the Moei River Basin at the Upper Salween River Basin in Tak Province, Thailand. The Mae Sot Municipality is the largest urban area in Tak Province and situated in the midstream of the Mae Sot Watershed. It usually faces flash flood problem after heavy rain due to poor flood management has been reported since economic rapidly bloom up in recent years. Its catchment can be classified as ungauged basin with lack of rainfall data and no any stream gaging station was reported. It was attached by most severely flood events in 2013 as the worst studied case for all those communities in this municipality. Moreover, other problems are also faced in this watershed, such shortage water supply for domestic consumption and agriculture utilizations including a deterioration of water quality and landslide as well. The research aimed to increase capability building and strengthening the participation of those local community leaders and related agencies to conduct better water management in urban area was started by mean of the data collection and illustration of the appropriated application of some short period rainfall forecasting model as they aim for better flood relief plan and management through the hydrologic model system and river analysis system programs. The authors intended to apply the global rainfall data via the integrated data viewer (IDV) program from the Unidata with the aim for rainfall forecasting in a short period of 7-10 days in advance during rainy season instead of real time record. The IDV product can be present in an advance period of rainfall with time step of 3-6 hours was introduced to the communities. The result can be used as input data to the hydrologic modeling system model (HEC-HMS) for synthesizing flood hydrographs and use for flood forecasting as well. The authors applied the river analysis system model (HEC-RAS) to present flood flow behaviors in the reach of the Mae Sot stream via the downtown of the Mae Sot City as flood extents as the water surface level at every cross-sectional profiles of the stream. Both models of HMS and RAS were tested in 2013 with observed rainfall and inflow-outflow data from the Mae Sot Dam. The result of HMS showed fit to the observed data at the dam and applied at upstream boundary discharge to RAS in order to simulate flood extents and tested in the field, and the result found satisfying. The product of rainfall from IDV was fair while compared with observed data. However, it is an appropriate tool to use in the ungauged catchment to use with flood hydrograph and river analysis models for future efficient flood relief plan and management.

***Keywords*—**Global rainfall, flood forecasting, hydrologic modeling system, river analysis system.

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I. Introduction

THE Mae Sot Municipality is located in the Huai Mae Sot Watershed one tributary of the Moei Sub-basin in the Salween River Basin in Thailand or Thanlyin in Myanmar (Fig. 1). The total catchment area of the Salween Basin in Thailand is 19103 square kilometers (km^2). Its mean annual rainfall is 1305 millimeters (mm) and produces annual stream flow with $9400 x 10^6$ m^3 (MCM) which can feed overall agricultural land of 19.2% of the watershed. The Huai Mae Sot is a mainstream of the Mae Sot Catchment and flows from east to west direction through the Mae Sot Municipality to the Moei River across from Myaewady, Karen State, Burma [1]. It is the main gateway between Thailand and Myanmar. It comprises of 20 local communities as for city administration management. The stream stretches from latitude 16.6994 N to 16.7912 N and from longitude 98.5146 E to 98.7233 E, with a catchment area of 199 km^2 (Fig. 2). It includes 9 tributary streams in the Mae Sot which are namely Huai Mae Sot, Huai Laeng, Huai Luek, Huai Seio, Huai Mae Ku, Huai Haeng, Huai Pong, Hui Tu Pa and Huai Mae Pa, respectively. The monsoon season runs from May to October [2] and results to the mean annual rainfall of 1468.3 mm with 145 rainy days [3]. The Mae Sot City is a small town with only 27.2 km^2 in Mae Sot district in Tak province and about 500 km northwestern of Bangkok the capital city of Thailand. Nowadays, many migrant workers from Myanmar have been employed to work in Mae Sot's industrial areas and they use natural resources and environment, including electricity, water supply, and others from Mae Sot as well. Lack of water sources particular for water supply will be happening in future, if there is poor water management plan [4]. Recently, flash flood from continuous heavy rainfall in the upper watershed occurred in the city area such the most severely flood in 2013 was reported. As well as inadequate drainage shallow and more obstruction structures across the streams, i.e. poor city planning and transportation systems were reported by HAII [5]. There are only 2 reservoirs with the location in the upstream of the overall watershed. However, only 1 dam with the storage capacity of 5 MCM name Mae Sot Dam can serve in irrigation area with 1600 ha upstream of the Mae Sot City. Another dam, Huai Luek, operates for adjacent watershed, which flows to the downstream of the stream and not effect in the city. Therefore, the city's community leaders need to be gained knowledge of efficiently flood management by themselves prior help from government. Recently, many flood forecast models are presented. But most of them need precisely rainfall data as for input to the flood package models such Tropical Rainfall Measuring Mission

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(TRMM). The events of the flood include overflow from the streams and poor flood drainage systems in the agricultural lands and lowland urban area after heavy rain occurs.

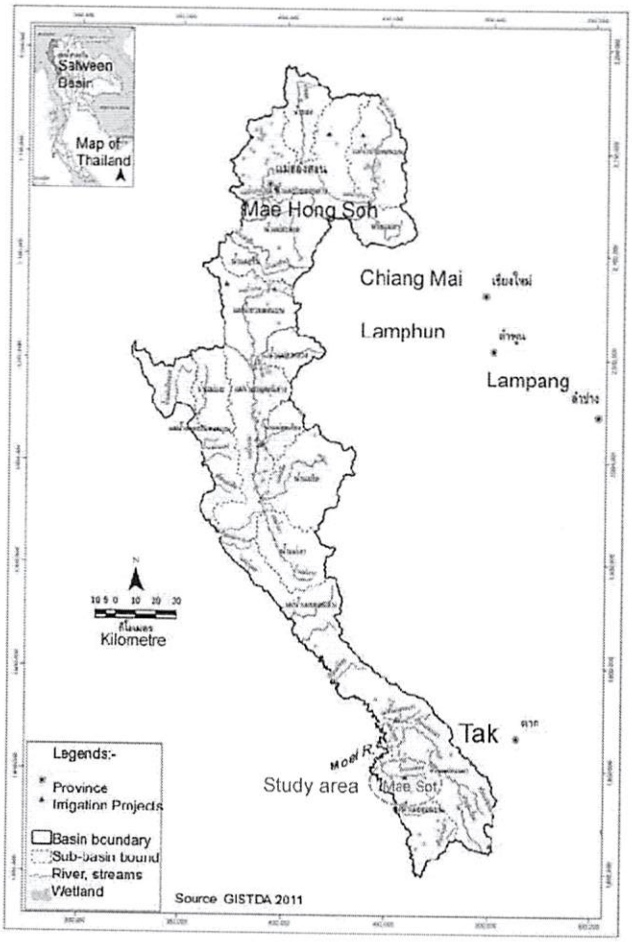

Fig. 1 Map of Salween Basin and study area in Tak province [5]

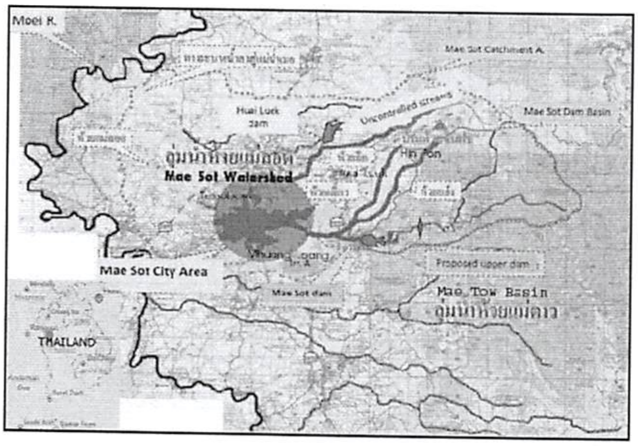

Fig. 2 Location of Mae Sot City and water sources in the watershed

Therefore, the research with the aims to increase capability building and more strengthening on the participation of those local leaders and related agencies in order to participate and conduct to build simply rainfall collectors and stream gaging stations. Since, most of flood forecasting models need real-time rainfall data to synthesize hydrography of the basin and stream discharge, i.e. HEC-HMS, and HEC-RAS [6]-[8]. Moreover, the numerical weather prediction model has introduced for predicting short range in coming rainfall, which can be every 3-6 hours for a period of 7-10 days i.e. the Integrated Data Viewer (IDV) from the Unidata [9]. This paper explained the participatory from the people whom concerned in flood management. The introduction of the global rainfall via IDV to be incorporated with the hydrologic system models in the Mae Sot City was also presented.

II. Materials and Methods

All relevant data, including drainage system layouts, cross-section profiles of the Huai Mae Sot stream from this survey using existing digital elevation model (DEM) from the Google Earth, neighboring rainfall recorded from TMD, and released dam outflow data from RID were collected and analyzed. These data were used to apply in flood hydrographs and flood behaviors in the river system. The HEC-HMS model was applied as for initial study as lateral inflow hydrograph from main and tributary streams in the basin. The transposing unit hygrograph's parameters for the Mae Sot watershed with (1) were initially applied in HEC-HMS based on the Snyder's and SCS transformed model formulation [6]. Therefore, the basin parameters involved in the model such as peak coefficients (C_p), peak lags (t_p), and loss rates shown in (2) were optimized using trial mode from the basin hydrographs. Finally, the hydrological parameter results from the optimized model were presented and fitted with observed data with gauged catchments. The curve number (CN) values in SCS transform were estimated from soil classes and land uses [6].

$$t_p = C_t[LL_c/S^{0.5}]^b \quad (1)$$

$$t_p = 0.75C_t(LL_c)^{0.3}, \text{ and } Q_P = 2.78C_pA/t_{IR} \quad (2)$$

where L, L_c are channel length, midstream lengths in km, S is the channel slope, A is the catchment area in km^2, t_p, t_{IR} are basin lag, adjust the duration in hours, Q_p is a peak discharge in m^3/s, C_t and b are basin coefficient and exponent values [10], and C_p is peak coefficient, respectively.

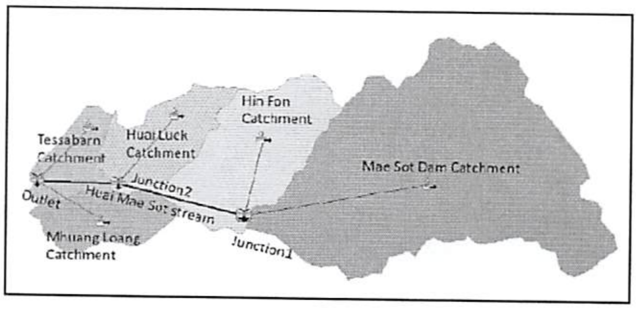

Fig. 3 Schematic model: sub-basins and stream layouts used in HMS

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The first part was the application of prediction of flood hydrograph in the Mae Sot City using available rainfall data and basin characteristic through HEC-HMS [6] with daily as time step mention above, whereas the Mae Sot Municipality locates between junctions 1 to outlet at 2 as shown in Fig. 3.

The river analysis system model using HEC-RAS [7] was applied in this study. It was a mathematical to simulate 1-dimensional unsteady flow profiles along the Huai Mae Sot main stream using St.Venant equations, both continuity and momentum shown in (3) and (4), respectively.

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}-q_l=0 \tag{3}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial QV}{\partial x}+gA\left(\frac{\partial z}{\partial x}+S_f\right)=0 \tag{4}$$

where A is the flow area in each section, Q is total discharge, q_l is lateral inflow per length of the channel, t is considered time, x is the distance along the channel, V is flow velocity, z is water surface elevation, and S_f is friction slope, respectively.

Some of real cross sectional profiles surveying with approx. 9.7 km of stream length from upstream to downstream of the city area were measured by the authors and the community leaders. Those were used to apply as a geometric model with automatically interpolated more stream cross sections with smaller step length (Δx) of 500 m. The upstream of a stream reach was started from the junction 1 (Fig. 3) downstream of the Mae Sot Dam at river station (RS) 9714 m in the model. The downstream end of this stream was located at the end border of the city boundary at RS 0 at the outlet (Fig. 3) and flow direction in the model shown in Fig. 4.

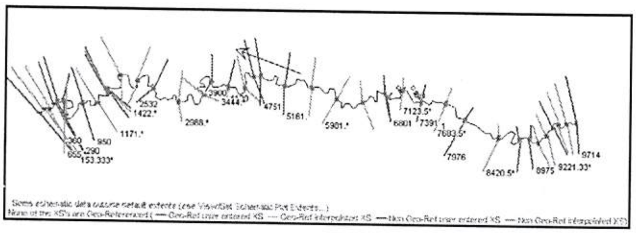

Fig. 4 Geometric data of plan, layout and location of cross-sectional profiles of the Huai Mae Sot reach for each RS in HEC-RAS model

All of the original cross-sectional data from field surveyed, including ground surface elevation versus distance from the left to the right banks were used in the model. Moreover, each cross section in the model contained with Manning's roughness coefficient (n-value) at both floodplain on the riverbanks and in the main channel as well. The optional data, such as levee data at both riverbanks including bridges and inline structures, i.e. weirs in a river reach were also considered. The simulation of water profiles preferable in this study was unsteady flow based on a daily basis as time increment (Δt). The upstream boundary condition in the model at RS 9714 applied river flow hydrograph that released from the dam through an outlet structure of the Mae Sot dam which observed and reported by RID. The downstream boundary condition at RS 0 applied normal depth based on the average friction slope of water surface levels over a river reach. The 4-uniformed lateral inflow to the river reach at RS 9344, 5161, 2532, and 230 with the Hin Fon, Huai Luek, Mhuang Loang, and Tessabarn streams respectively, were initially estimated using HEC-HMS model [6] from Fig. 3.

The recorded data from daily released flow from the dam was used for the calibration and verification of both HEC-HMS and HEC-RAS models at the upstream of junction 1. The digital elevation models (DEM) based on existing satellite image retrieved from the Geo-Informatics and Space Technology Development Agency (GISTDA) [11] as well as aerial photo maps from the Land Development Department (LDD) [12] including Google Earth were used to specify grounds surface elevations at both sides of stream banks with the location of each RS while some stream 10-cross sections were simple measured at each cross-way road. The upstream (u/s) discharge hydrographs as inflow to the dam result of observation was used as model calibration. All basin parameters of HMS were automatically produced by the model and observed data at the dam. Moreover, all lateral inflows produced from HMS applied as u/s boundary conditions of a reach in RAS including released flow from the dam. Unfortunately, there is no any stage record in this stream. Therefore, the major parameter in RAS with n-value of 0.035 was applied for all cross sections in a river reach based on Chow [13]. It was initially applied in RAS and computed water surface levels (WS) in the river reach at each RS.

Better future for the flood relief plans by mean of using appropriate technology for flood prediction, the manager should apply with good result of rainfall forecasting model as input precipitation into flood hydrograph and flood routing models explained above. The integrated data viewer (IDV) [9] as for rainfall forecast model was introduced and showed its effect production of the model [14], [15] which can be further applied to flood forecast models such as HEC-HMS and HEC-RAS including flood risk mapping. Unfortunately, it was introduced to this area during the late wet season in 2014. The IDV is a Java-based software framework for analyzing 2-3 dimensional visualizing Geoscience data, including Geo-referenced, satellite, radar, surface and upper air, and social data in geographic information system (GIS). It is further capable applied for flash flood forecasting via public domain system model using numerical weather prediction (NWP) model with every 3-6 hours for a period of 7-10 days [9].

III. Results and Discussion

The optimization of gauged hydrological parameters: t_p, C_p, and CN-values were applied as a calibration model with observed rainfall data in 2013 and summarized in Table I. The model output of flood hydrograph in HMS was calibrated using relevance observed daily data from the Mae Sot Dam, i.e. inflow, outflow, and change in water level during the wet season particularly in the flood period in 2013. The input precipitation with rainfall recorded data over the watershed during the wet season in 2013 was shown in Fig. 5. The results of both simulation and observation of inflow hydrographs to

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the dam fitted relationship as shown in Fig. 5. Therefore, those parameters in HMS for upstream catchment of existing dam were used to apply all other catchments as for tributary flow to the Mae Sot stream in RAS and result during a severe flood in 2013 was shown in Fig. 6.

TABLE I
HYDROLOGICAL PARAMETERS FOR ALL SUB-BASINS USED IN HEC-HMS

Sub-basin	Area, km^2	L, km	L_c, km	S	t_p, hr	C_p	Infiltration, or CN-value
Mae Sot Dam*	53.3	15.7	7.9	0.0281	16	0.66	0.3 mm/hr
Hin Fon	17.2	7.7	3.9	0.0064	4	0.60	CN=50
Huai Luek	8.5	6.1	3.0	0.0105	4	0.60	CN=60
Mhuang Loang	7.0	6.0	3.0	0.0044	4	0.60	CN=60
Tessabarn	5.3	3.0	1.5	0.0023	3	0.60	CN=70

Note *RID's gauging station at the dam.

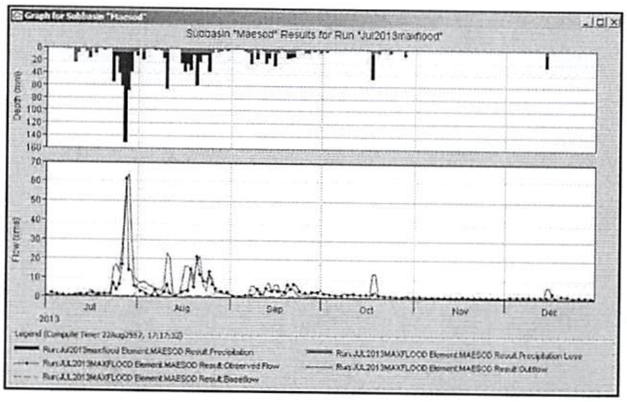

Fig. 5 Comparison HEC-HMS's hydrograph and observed inflow hydrograph at dam as for model calibration during wet season 2013

The water surface levels (WS) at each RS of RAS were based on upstream boundary conditions with daily unsteady flow hydrograph from the outlet of the dam and 4-side flows from uncontrolled catchments run from HMS. The calibration of RAS was done by using flood map and surveyed depth from the interview in 2013. The simulated results of WS at each RS during flood in 2013 for each cross section profile with 0.d day as Δt and presented flood extents and WS profiles along the river reach were shown on Figs. 6 and 7, respectively. The observed flood mapping showed in Fig. 8.

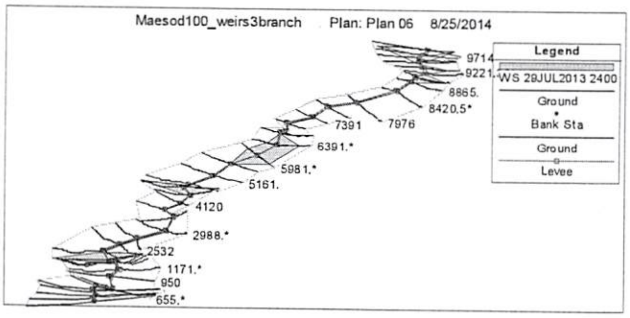

Fig. 6 Simulated flood extent using HEC-RAS on 29-31/07/2013

The existing parameters from HMS and RAS modeled calibration in 2013 were used for flood flow hydrograph in 2014 with observed rainfall data. The results of inflow hydrograph to a dam from HMS showed in Fig. 9 and total outflow produced from the overall watershed shown in Fig. 10. Since the total amount of rainfall in wet season 2014 was below mean value. Therefore, it was no flood happen in 2014.

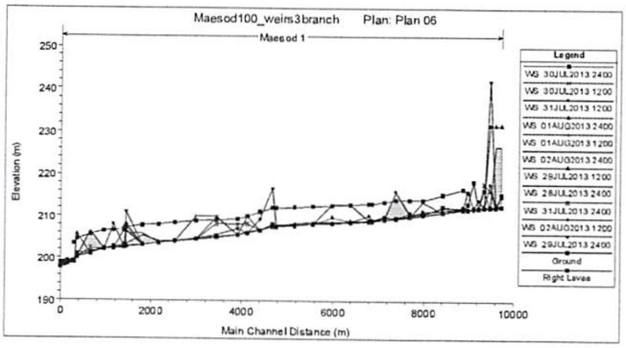

Fig. 7 Simulated daily water surface levels on 29-31/07/2013

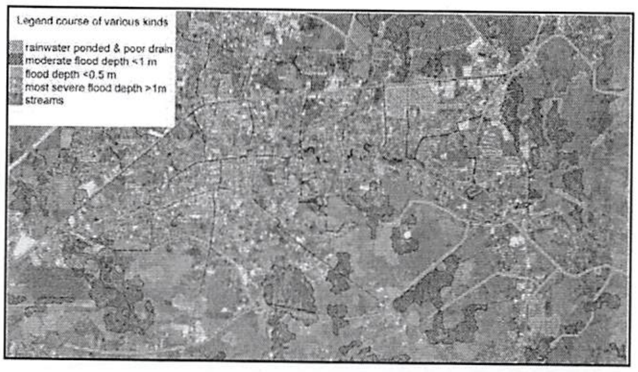

Fig. 8 Flood mapping from observation in the city area in 2013

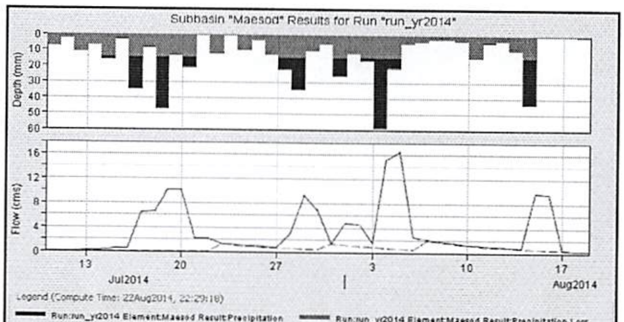

Fig. 9 Simulated dam's inflow hydrograph from HMS Jul-Aug 2014

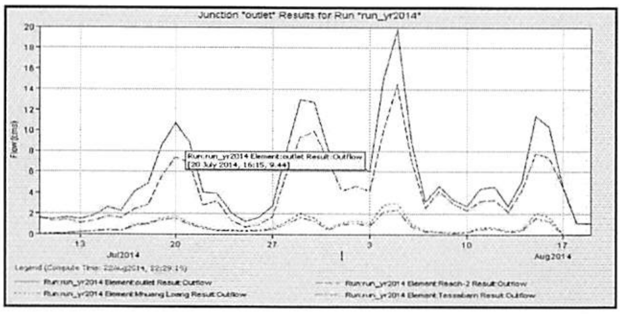

Fig. 10 Simulated flood hydrographs at each sta. from HMS in 2014

The authors introduced to apply the Unidata's IDV program with the aim of further applying with HEC-HMS and RAS as some example to produce the forecasting 3-hour rainfall in 2 days from 24-25/09/2014 shown in Fig. 11.

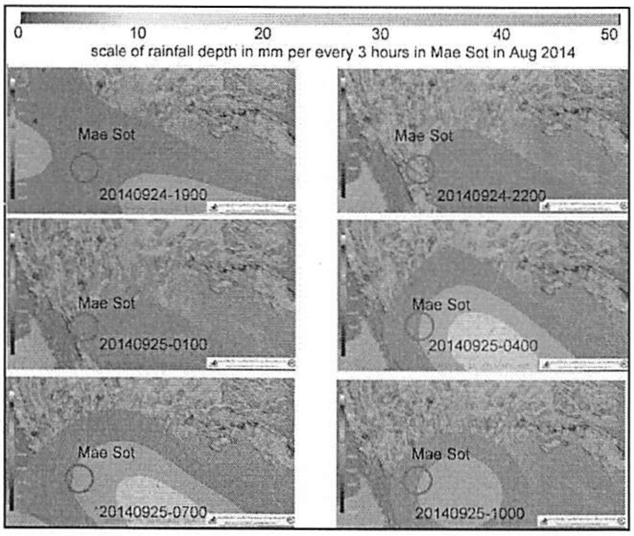

Fig. 11 Simulated IDV's rainfalls map every 3 hours over the Mae Sot district during 24/09/2014:19.00 to 25/09/2014:10.00

The production of rainfall amount of IDV found fare while compared to observe data during 3-14 Aug 2014 (Fig. 12). However, rainfall timing was closed in observation.

IV. Conclusion

The results showed well participated among stakeholders to work with flood relief plans for better flood forecasting and mappings. This will increase efficiency of urban flood water management of the Mae Sot Municipality in the near future using an appropriated technology to predict short periods of rainfall such IDV. Its production could be used as input data to HMS. Both models of flood hydrograph with HMS and flood extent with RAS could be further applied to analyzing the hydraulic behaviors in the stream systems if input correct data of prediction rainfall. Therefore, the IDV should be applied soon. However, its accuracy should be further researched.

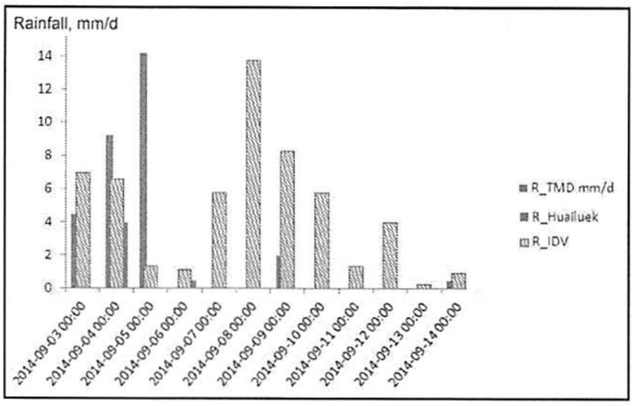

Fig. 12 Compare IDV rainfall & observed data during 3-14 Aug 2014 where R=rainfall in mm at each observed stations in Mae Sot at TMD station, Huai Luek dam, and IDV in mm/day, respectively.

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