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Application of hydro-mathematical models for flood forecast and inundation warning of Tra Khuc-Ve River basins

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Abstract. The papers present the results of study on application of rainfall-runoff, channel routing models for improvement and extending forecast lead time and Diffusion Hydrodynamic Model (DHM) for inundation warning of Tra Khuc and Ve river basins.

Keywords: Time of concentration T_c, update of forecast errors, flood forecast, inundation warning.

1. Introduction

For river basins in the central coastal provinces, the rivers has steep terrain, plains adjacent to the sea are relatively flat, so every year, floods and flash floods caused heavy damage to persons and property of people in the areas.

The floods on the central river basins are characterized by short concentration time, fast flood rising up, widespread flooding, and often cause difficulties for the implementation of response measures for flood situation. Therefore, for the region, information on flood forecasting and inundation warning is very important to take the prevention measures and activities for reduction damages, caused by flooding.

To serve the flood forecasting and warning for the central region, several measures have been proposed and applied at the Central Hydro-meteorological Prediction Center, Research Center for Hydrology and Water Resources, and Regional Hydro-meteorological Services to extend the lead time for flood forecasting, inundation warning, such as:

- Classification of the combination of weather statures caused heavy rainfall to Central provinces for early identifying the rainfall-flood situations;

- Refer to the numerical predicted rainfall results, interpretation of cloud satellite image and radar image for warning the flood peaks;

- Application of mathematical hydrologic models for flood forecasting, inundation warning.

However, the achieved results of flood investigation have been somewhat limited due to the hydro-meteorological monitoring network is not thick enough and the limitation of the rainfall data measured in short time needing for short-term forecasting. These

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papers will present a option for application of hydro-mathematical models to improve efficiency and extend the lead time for flood forecasting and inundation warning, applicable to Tra Khuc and Ve river basins.

2. Study on improvement of accuracy and extending the lead time for flood forecasting, inundation warning of Tra Khuc – Ve river basins

2.1. Study on extending the lead time of flood forecast

Theoretical principle of hydrological prediction methods is based on the relationship between the required forecast lead time T with the hydrologic response time of the catchment or time of concentration T_c and the travel time through the channel/river system, T_r as follows [1]:

- If $T>T_c + T_r$, then meteorological forecasting of the precipitation is required.

- If $T<T_c+T_r$ and $T_c<<T_r$, then stream flow forecasts can be based on observed flows at upstream gauge locations.

- If $T <T_c + T_r$ and $T_r <<T_c$, then stream flow forecasts should be based on observed rainfall from a network of rain gauges whose data are transmitted to the forecast center. The flood forecasting method can be made based on the rainfall-runoff models.

- If $T<T_c+T_r$ and $T_r » T_c$, then forecasting methods are based on rainfall-runoff models combined with the river channel routing models.

There are different methods to determine time of concentration T_c on the river basin: the method using empirical formula and method using rainfall-runoff model. One of the empirical formula to determine T_c is the Kirpich [2]:

$$T_c = k * L^{0.77} * S^{-0.385}$$

Where: k: unit coefficient; L: length of the river; S: slope of the river bed.

Method using rainfall-runoff model to calculate the time of concentration T_c can be done by using rainfall data series with time delay compared to the flow sequence. The time delay t_1 that give best results of the relationship: $Q(t) = f(X(t-t_1))$ will approximate the time of concentration of river basin T_c.

Application of *NLRRM* model for Tra Khuc River basin, using rainfall data series at Tra Mi and Ba To meteorological stations and flood flow data in 1999 at the Son Giang hydrological stations, as well as rainfall data series at Ba To rain gauge and flood flow data in 1998 at An Chi hydrological station, gives the calculation results, shown in the Table 1.

Table 1. The effective of NLRRM model (%) for different lag- time between rainfall and runoff on the Tra Khuc – Ve river basins.

Time delay (lag-time)	t_1**=0 h**	t_1**=3 h**	t_1**=6 h**	t_1**=9 h**	t_1**=12h**
Effective model for station Son Giang, Tra Khuc River	84.1	88.5	89.2	68.3	47.6
Effective model for station An Chi, Ve River	89.4	92.1	89.8	70.9	50.9

The results of the numerical calculation show the capacity for application of the rainfall-runoff models for flood forecasting, using observed rainfall from a network of rain gauges whose data can be transmitted to the forecast center, for the Tra Khuc River basin, the flood forecast can be made with an average lead time of 6 hour at Son Giang hydrological station and with lead time of 3 hour at An Chi hydrological station for Ve River Basin.

The travel time through the river network is usually estimated by the method of characteristics of flow discharge or water levels between upstream and downstream stations respectively. Under this method, Hydro-meteorological Center of Quang Ngai province has plans for river flood forecasting for Tra Khuc river and Ve river as follows [3]:

- For the Tra Khuc hydrological station:

$H_{tk}(t)=f[H_{sg}(t-t_2)]$ where $T_r=t_2=6h$;

With the allowed error of 45cm and ensure forecast level of 94%.

- For the Song Ve hydrological station:

$H_{sv}(t)=f[H_{ac}(t-t_2)]$ where $T_r=t_2=3h$;

With the allowed error of 64cm and ensure forecast level of 100%.

Where: - H_{tk}, H_{sg}, H_{ac}, H_{sv} - water level at the stations of Tra Khuc, Son Giang, An Chi and Song Ve ; τ_2 – forecast lead time.

- Another way to apply hydrological models for forecasting flood routing is Muskingum model taking into account the travel time of flood from upstream station as follows:

$$Q_D(t+t_2)=C_1Q_T(t)+C_2Q_T(t-t_2)+C_3Q_D(t)$$

Where: Q_D: Water flow at the downstream station; Q_T: Water flow at the upstream station.

If we the combined rainfall-runoff models and flood flow routing model in river channel, the prediction lead time at these stations will be extended to $t = t_1 + t_2$.

2.2. Improve the efficiency of the forecasting results:

To improve the efficiency of the model or the established predicted relationship, the method for updating the error is applied based on analyzing the errors were encountered in the previous forecast, using the relationship:

$$\Delta Q_t = a_1\Delta Q_{t-1} + a_2\Delta Q_{t-2} + ...$$

Where: $\Delta Q_{t-1}, \Delta Q_{t-2}$,...: errors of previous forecasting; a_1, a_2,...: coefficients.

2.3. Application of hydrodynamic models for inundation simulation:

Hydrodynamic model DHM (Diffusion Hydrodynamic Model) [4], after being improved by adding an inertial component in the one-dimensional diffusion wave equation has been applied to simulate flooding of downstream areas of Tra Khuc – Ve rivers. Diagram for application of DHM model is shown in Figure 1.

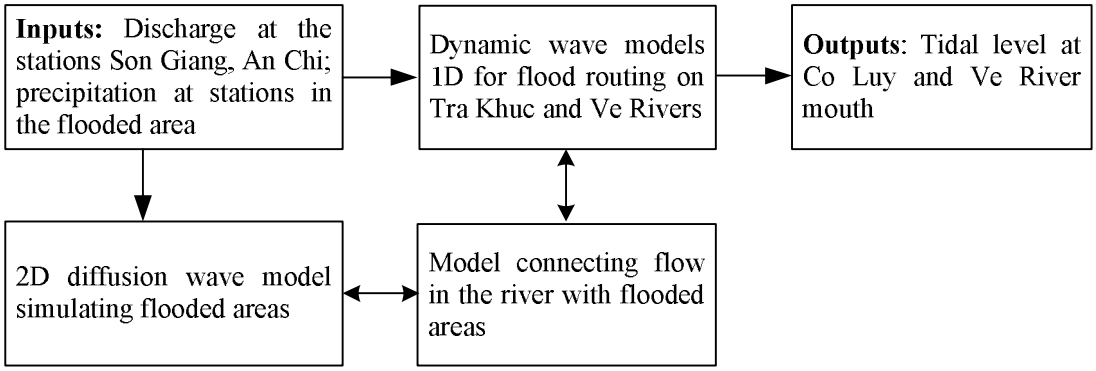

Figure 1. Scheme for inundation computation of downstream areas of Tra Khuc – Ve rivers.

2.4. Combining flood forecasting and inundation warning for Tra Khuc and Ve river basins

Scheme for connection of flood forecasting and inundation warning is shown in Figure 2.

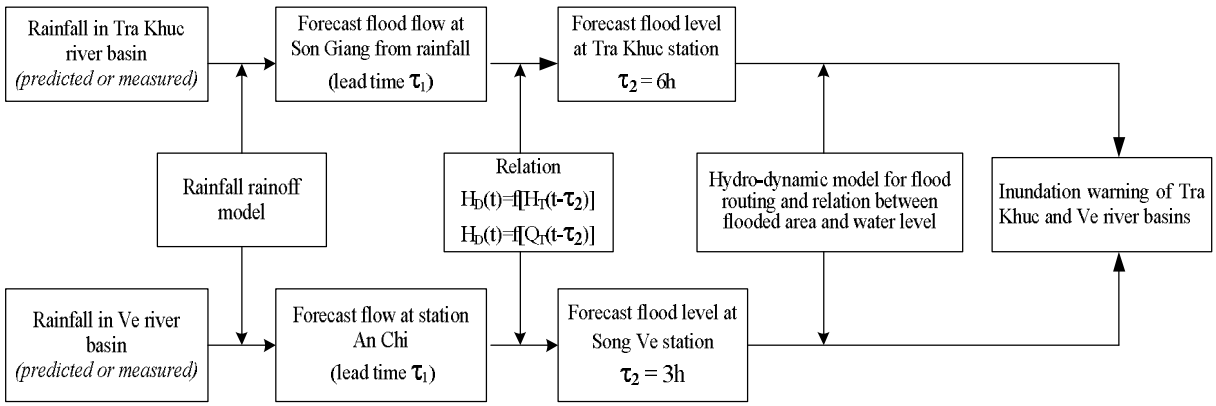

Figure 2. Scheme for flood forecasting and inundation warning of Tra Khuc – Ve river basin.

3. Some research results of inundation warning for downstream areas of Tra Khuc – Ve river basins

The results of design flood calculation, application of *NLRRM* model, *HEC-HMS* model, multivariable correlation model to improve efficiency and extend the lead time for flood forecasting of Tra Khuc and Ve river basins is presented in details in studies [5]. After the prediction of water levels at hydrological stations in the flood plain, the connection between the core water level of flood plain and inundation magnitude is built based on the simulation of floods with different magnitude. For flood plain areas of Tra Khuc and Ve river basins, when the water level at Tra Khuc hydrological station is rising up flood warning level II, interaction between flood of the Tra Khuc and Ve Rivers has been appeared. When water level at Tra Khuc hydrological station is rising up flood warning level III (6.5m), the flood of two rivers has been closely interacted with each other. Therefore, we can

use the simulation results of occurred large floods to build the flood maps with different water levels at Tra Khuc hydrological station and thus, if the water level of flood in downstream area is predicted, inundation warning can be made for the flood plain of the Tra Khuc – Ve river basins.

Inundation simulation of Tra Khuc and Ve Rivers has been done for the largest flood, occurring in the series of observed data from 1977, which occurred in XII/1999 with flood peak water level at Tra Khuc hydrological stations of 8.36 m. Calculated and observed flood processes is shown in Figure 3. Verification of the model is done for the flood occured in XI/1998, with flood peak water level at the Tra Khuc Bridge of 7.72 m, higher than the current alert level III 1.22 m (Figure 4).

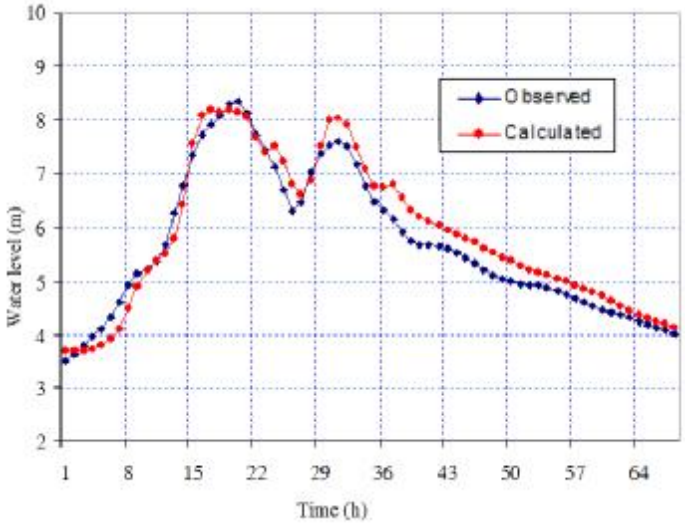

Figure 3. Calibration of DHM model for XII/1999 flood at Tra Khuc hydrological station.

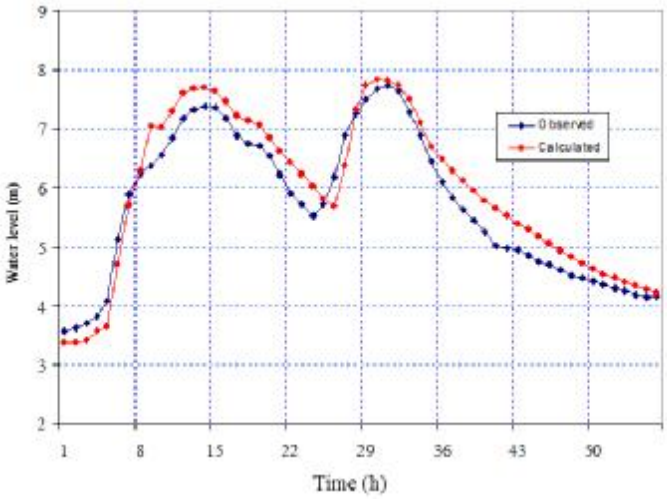

Figure 4. Verification of DHM model for XI/1998 flood at Tra Khuc hydrological station.

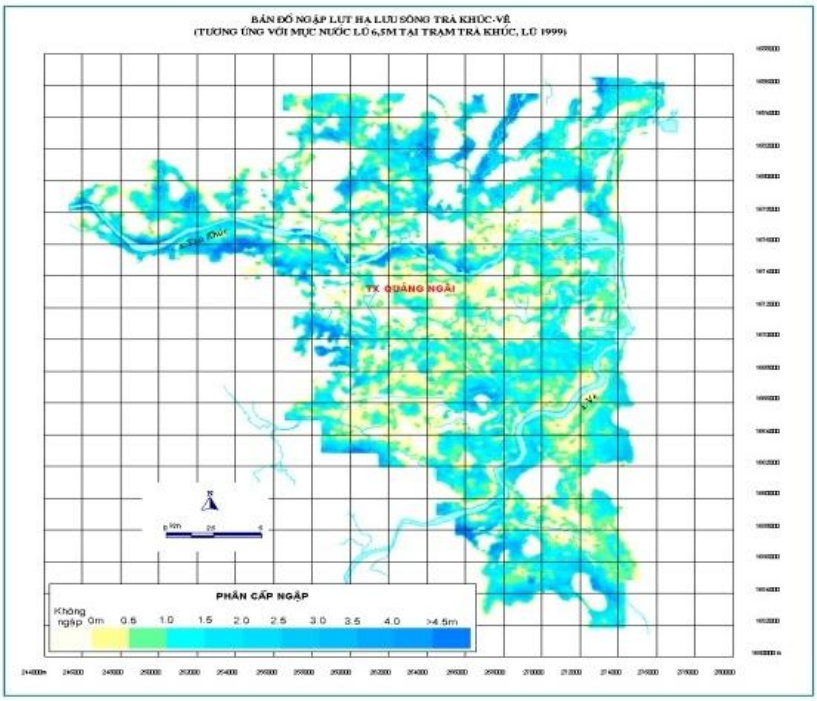

Figure 5. Inundation map for Tra Khuc -Ve rivers, with the flood warning level- III.

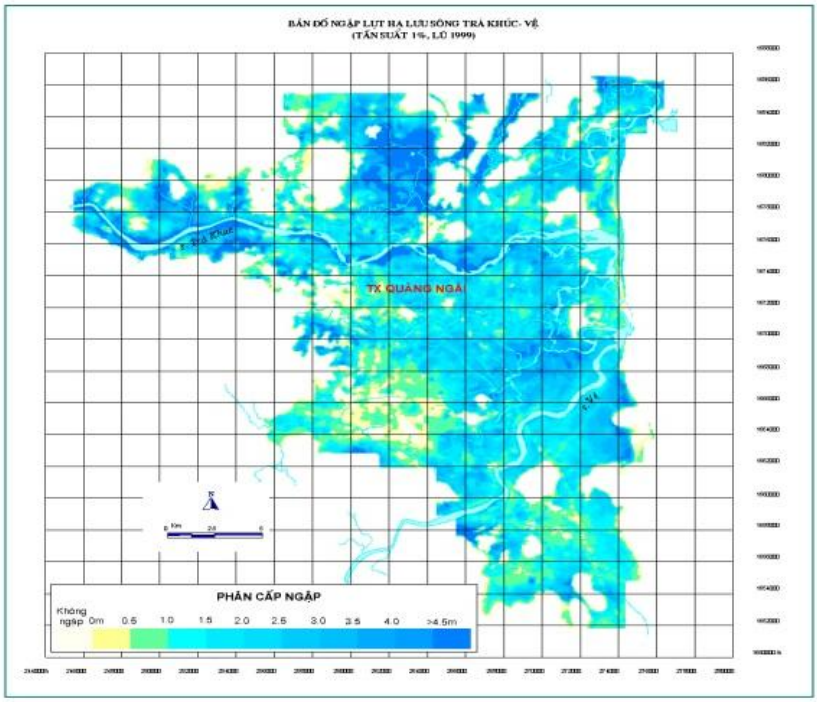

Figure 6. Inundation map for Tra Khuc-Ve rivers, with flood of 1% frequency.

After DHM model has been adjusted and verified to ensure stability and reliability, the model is applied to calculate for construction of various flood maps, corresponding to the flood water level at Tra Khuc hydrological gauge. Inundation map of Tra Khuc - Ve Rivers, corresponding to warning water level III (6.5 m) at Tra Khuc water level station is shown in Figure 5 and inundation maps of Tra Khuc – Ve rivers, equivalent to rainfall-flood of 1% frequency is shown in Figure 6. The flood maps have been established in conjunction with the flooding beacons done by Regional Central Hydrometeorological Services in flood plains of Tra Khuc – Ve rivers has important contribution in service executive agency's for flood prevention and help local people actively to prevent flooding.

4. Conclusions and recommendations

For river basins of central coast, the damage caused by floods is most serious in the country, the application of science and technology to improve efficiency and extend the forecast lead time is essential to minimize damage caused by flooding. With the above objectives, the report has presented a feasible option for application of rainfall-runoff models, hydrological model and coupled one and two dimensional hydrodynamic model for flood forecasting and inundation warning of Tra Khuc – Ve rivers. However, together with the continued application of research methods, new technologies, the model with high reliability, the enhancement of the density of hydrometeorological measurements in space and time, topographic surveying and updating of the river cross section data is very necessary to effectively improve flood forecasting, inundation warning and contribute to reducing damage caused by floods, flash floods in central provinces in general and for the Tra Khuc – Ve rivers in particular.

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