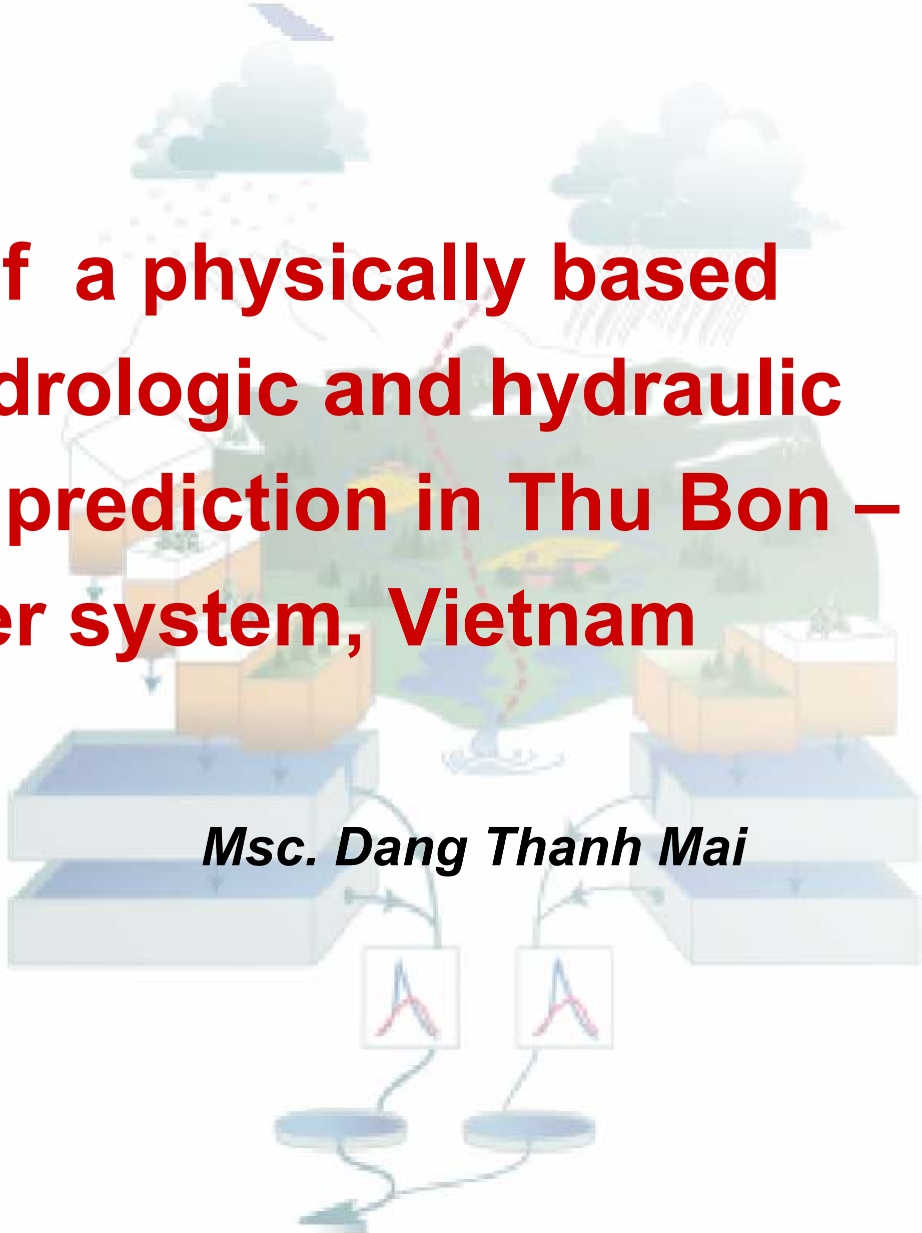
Integration of a physically based distributed hydrologic and hydraulic model for flood prediction in Thu Bon – Vu Gia river system, Vietnam



Msc. Dang Thanh Mai

Introduction

The Thu Bon – Vu Gia river system located in Central Vietnam is often affected by large floods and inundations causing considerable damages to people and infrastructure.

The floods are a serious and major issue for the development of Thu Bon – Vu Gia Basin

The flood protection and mitigation in the region has led to heighten interest in real-time flood forecasting systems in which the crucial component is the flood forecasting modelling.

Introduction

The main objective : to develop a tool for flood forecasting using integration of a physically based distributed hydrological and hydraulic models.

Models used:

GIS based distributed hydrological model : WETSPA

One-dimensional hydraulic model: HECRAS

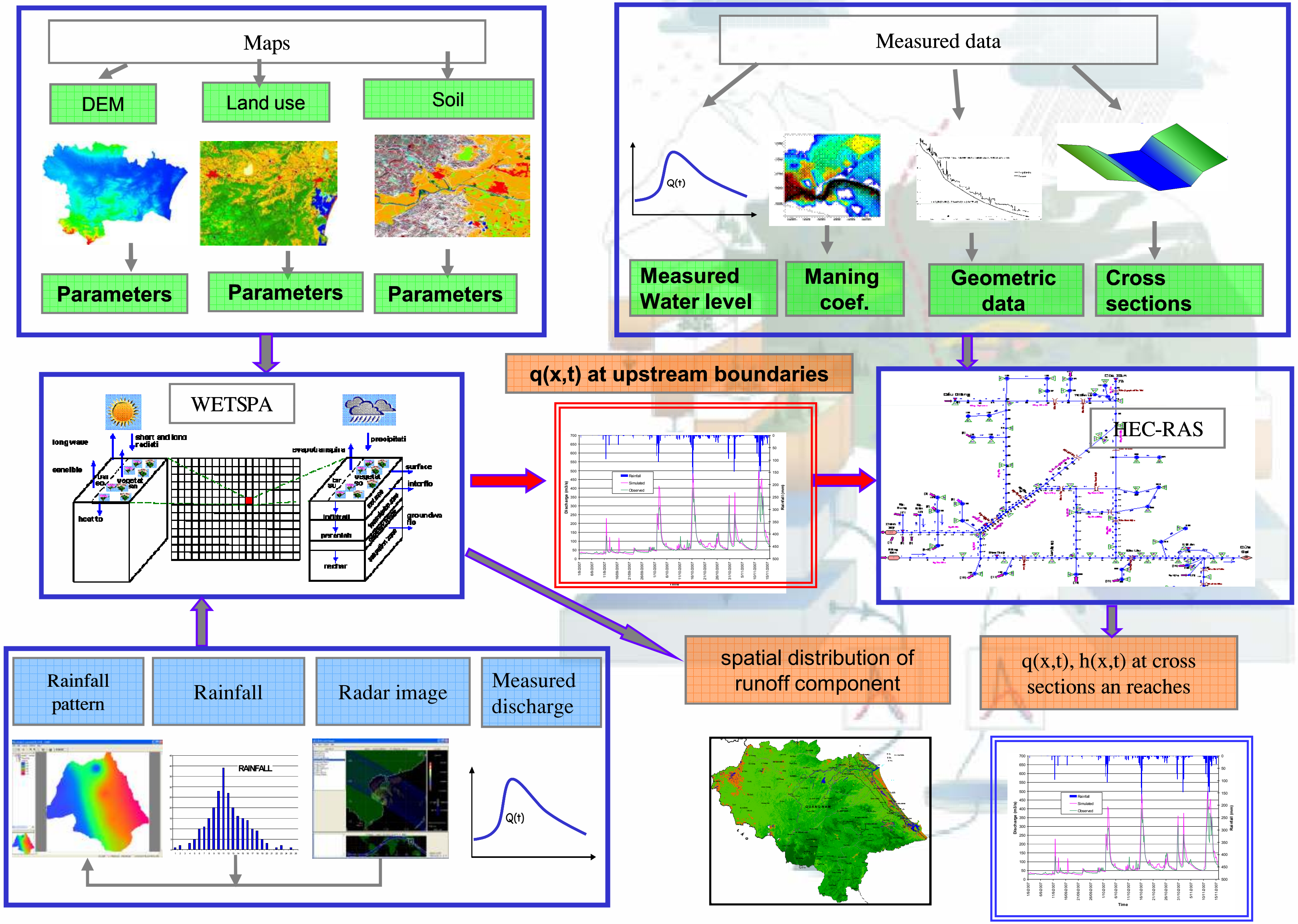
3 steps are implemented

- Calibration and verification of WETSPA model
- Calibration and verification of HECRAS model
- Development of software to integrate two models and can be used in real-time flood forecast in the study area

Introduction

- Wetspa model is a grid based, fully spatially distributed model for water and energy transfer between soil, plants and atmosphere a grid based.
- Due to the complexity of Thu Bon – Vu Gia river system and effects of tide to flow in the downstream area. The one-dimensional unsteady state flow model HECRAS (USACE, 2001) is chosen for coupling with the Wetspa model to simulate peak discharge, flow and water level hydrographs in this area.
- The integration of two models is becoming more capable for flood prediction, and decision making in the river.
- The WetSpa model calculates discharges from rainfall and potential evaporation inputs.
- The simulated flows from the Wetspa model are used as the input for the HECRAS model for flow routing at an upstream discharge point.

Structure of the WetSpa and HECRAS models and their coupling



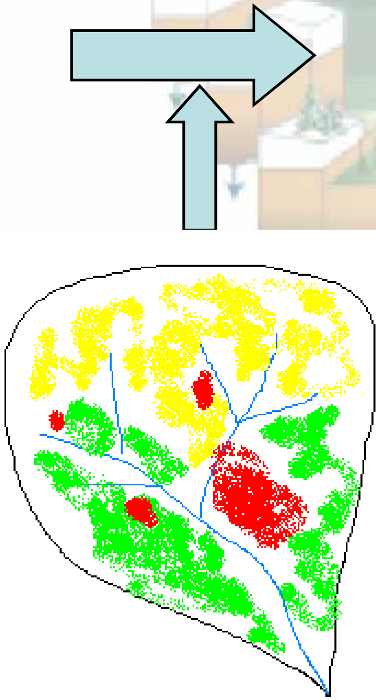
WetSpa?

Water and **E**nergy **T**ransport between **S**oil, **P**lants and **A**tmosphere

Hydrological model:

Rainfall

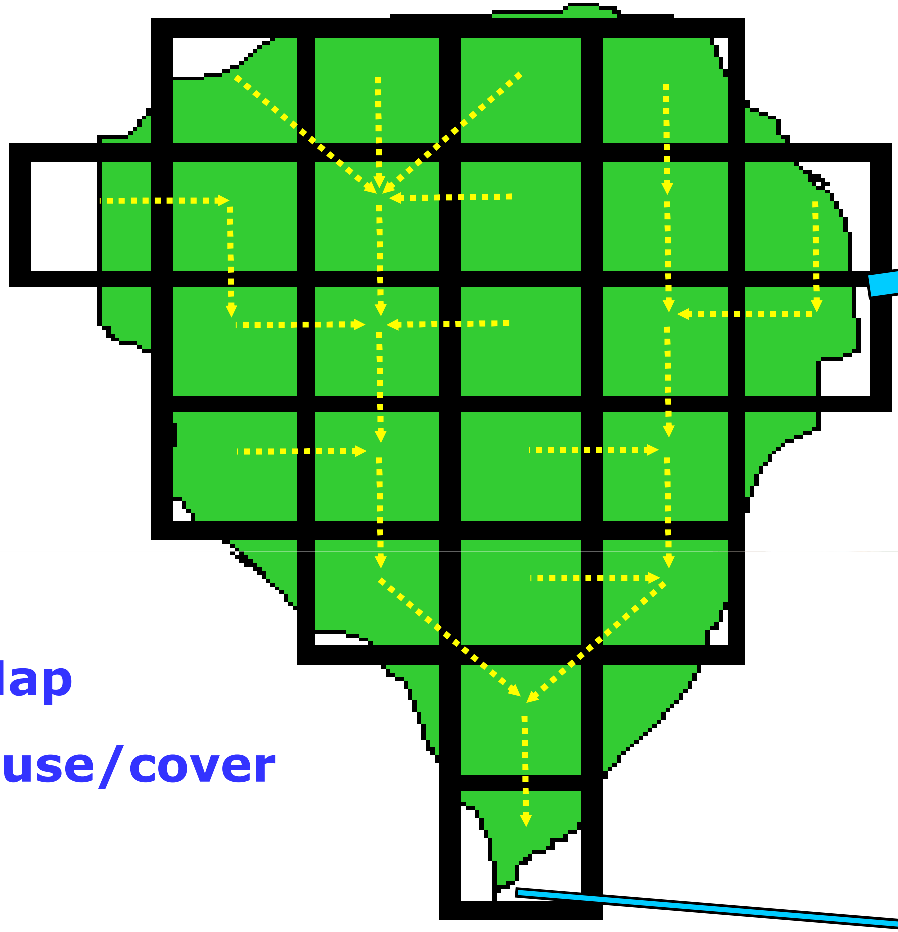
(measure)



Runoff

(simulate/predict)

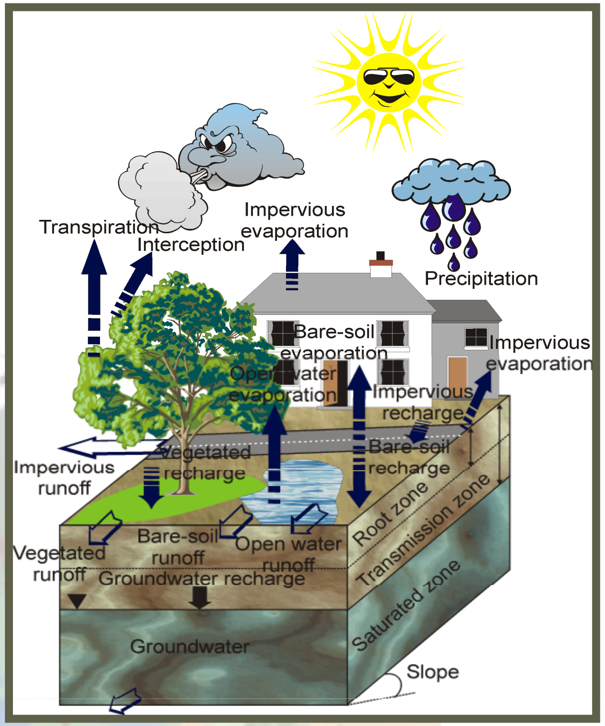
WETSPA MODEL



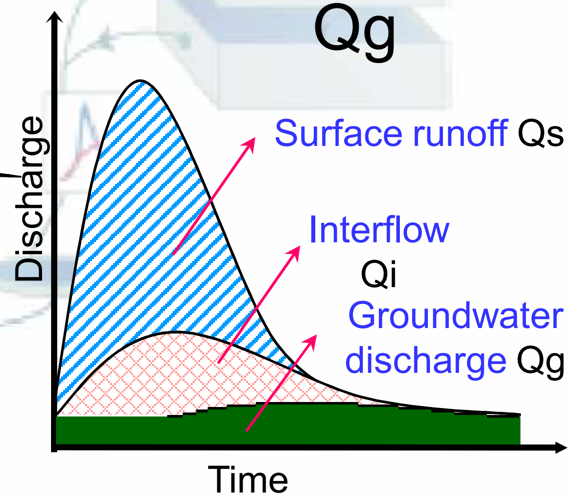
DEM

Soil Map

Land-use/cover

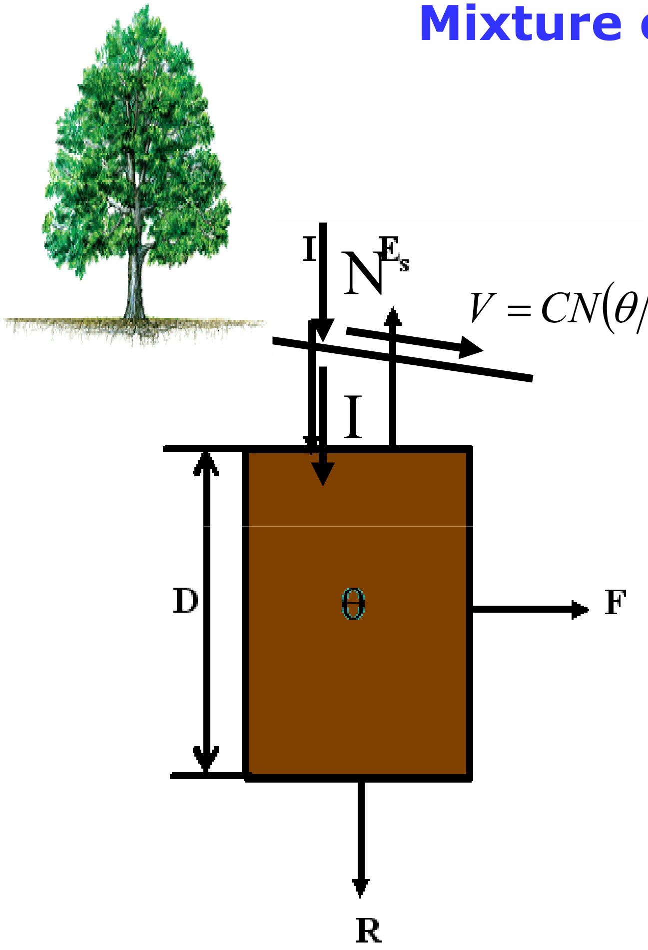


$$Q = Qs + Qi + Qg$$



For each grid cell, four layers are divided as vegetation zone, root zone, transmission zone and saturated zone. Several hydrological processes such as precipitation, evapotranspiration, interflow, etc. are taken into account to calculate a water balance and excess rainfall for each cell.

Simulating hydrological processes



$$V = CN\left(\theta/\theta_s\right)^{\alpha}$$

Mixture of empirical and physically based equations:

- **Evapotranspiration (E)**

$$E = c_e E_p \left(\frac{\theta - \theta_w}{\theta_f - \theta_w}\right) \quad for\ \theta_w < \theta < \theta_f$$

$$E = c_e E_p \quad for\ \theta \geq \theta_f$$

- **Runoff Production (V)**

Potential Runoff Coefficient (C)

C = f(slope, soil type, land use)

- **Percolation (R)** $R = K(\theta) = K_s \left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^{(2+3B)/B}$

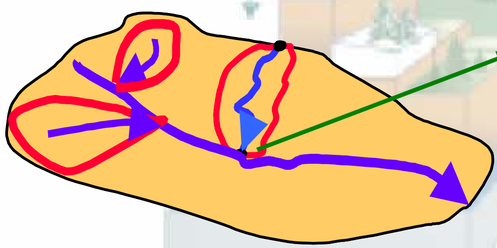
- **Interflow (F)** $F = c_i D S_0 K(\theta)/W$

- **Soil Water Balance**

$$D\frac{\Delta\theta}{\Delta t} = I - E_s - F - R$$

- **Groundwater Balance**

$$\frac{\Delta S_g}{\Delta t} = R - \frac{Q_g}{A} - E_g$$



$$Q_g = c_g S_g A$$

$$E_g = \left(E_p - E_i - E_d - E_s\right)\frac{S_g}{S_{\max}}$$

- **Total Evapotranspiration**

$$E = E_i + E_d + E_s + E_g$$

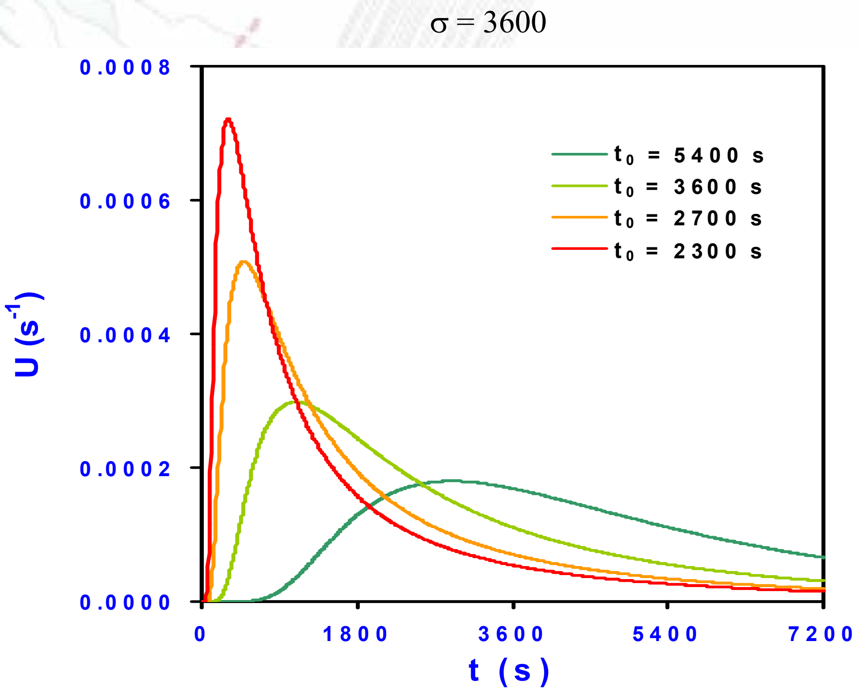
Flow routing

- **Diffusive Wave Approximation:**

$$\frac{\partial Q}{\partial t} = D(x)\frac{\partial^2 Q}{\partial x^2} - c(x)\frac{\partial Q}{\partial x}$$

- **Flow Response Function:**

$$U(t) = \frac{1}{\sigma\sqrt{2\pi t^3/t_0^{\;3}}}\mathrm{Exp}\left[-\frac{(t-t_0)^2}{2\sigma^2 t/t_0}\right]$$

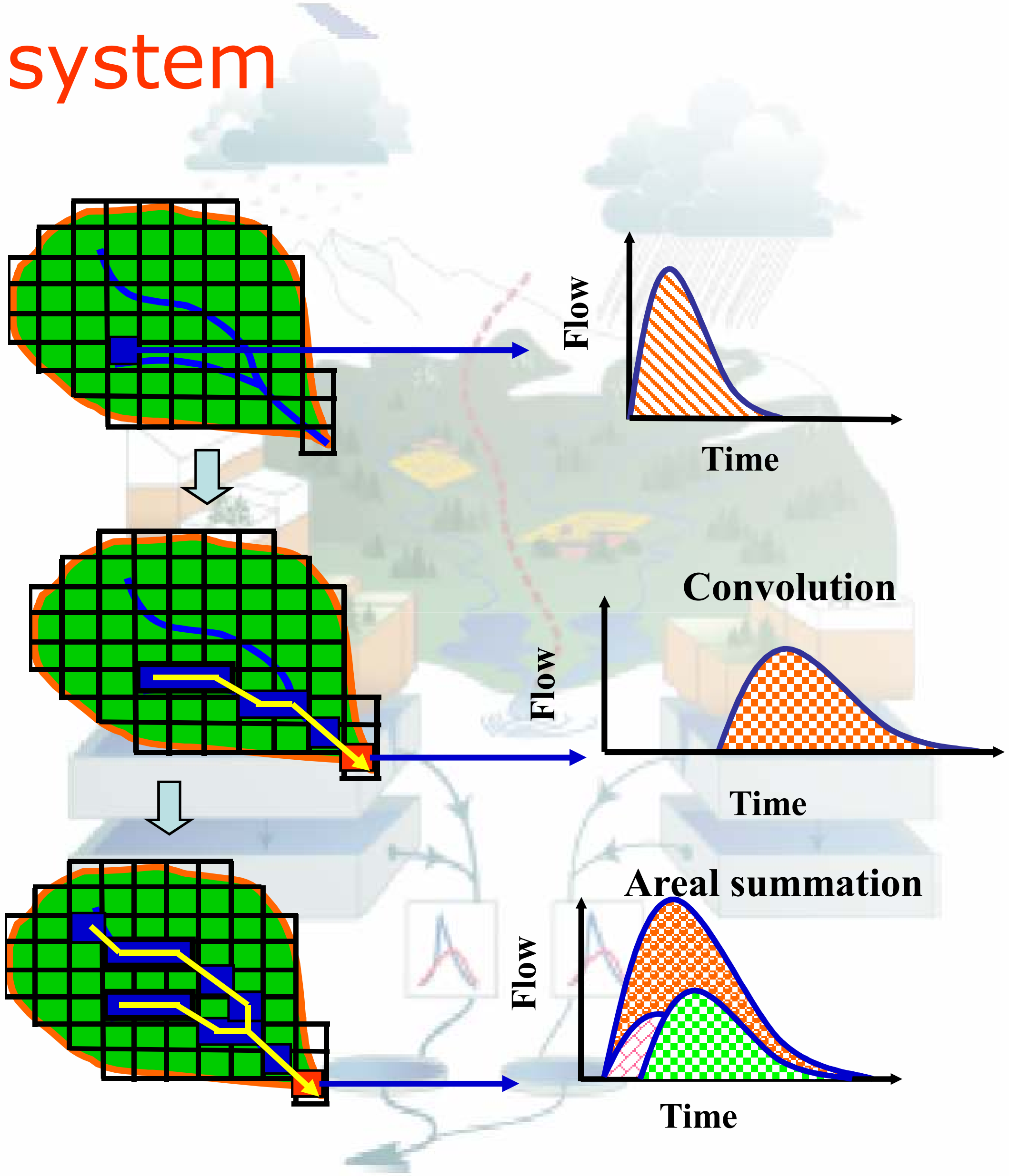


- **Outflow Hydrograph**

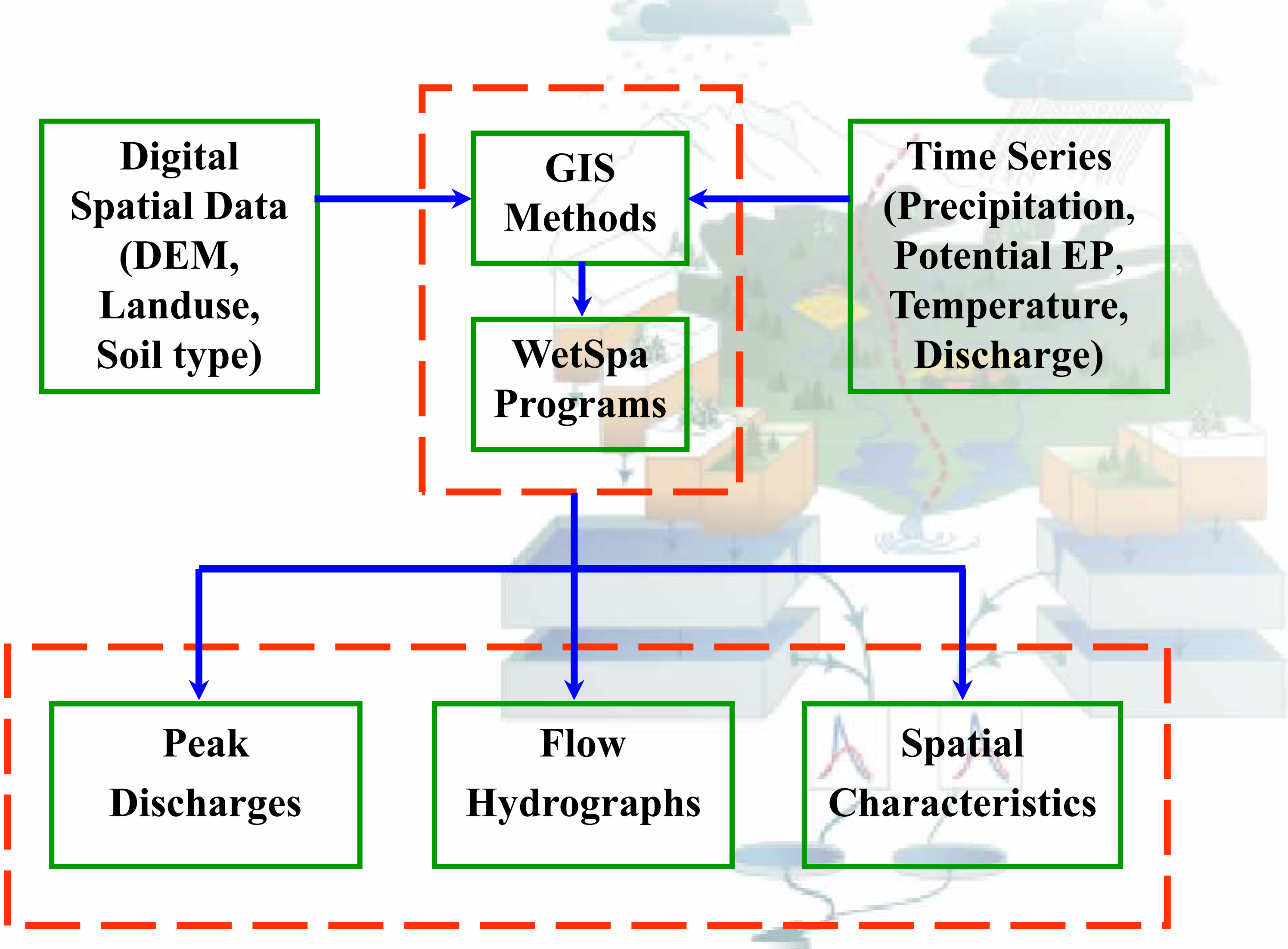
$$Q(t) = \int_A \int_0^t Q_0(\tau)U(t-\tau)\,d\tau\,dA$$

Linear routing system

- **Cell Level**
- **Flow Path Level**
- **Watershed Level**



Model input and output



Model Evaluation

Code	Criteria	Description
C1	$\dfrac{\sum_i Qc_i}{\sum_i Qo_i} - 1$	Model bias, ability to reproduce water balance with best value of 0
C2	$\dfrac{\sum_i \left(Qc_i - \overline{Qo_i}\right)^2}{\sum_i \left(Qo_i - \overline{Qo_i}\right)^2}$	Model confidential coefficient with best value of 1
C3	$1 - \dfrac{\sum_i \left(Qc_i - Qo_i\right)^2}{\sum_i \left(Qo_i - \overline{Qo}\right)^2}$	Nash-Sutcliffe efficiency, ability to reproduce time evolution of discharges with best value of 1
C4	$1 - \dfrac{\sum_i \left(\ln(Qc_i) - \ln(Qo_i)\right)^2}{\sum_i \left(\ln(Qo_i) - \ln(\overline{Qo})\right)^2}$	Logarithmic Nash-Sutcliffe efficiency, ability to reproduce time evolution of low flow discharges with best value of 1
C5	$1 - \dfrac{\sum_i \left(Qo_i + \overline{Qo}\right)\left(Qc_i - Qo_i\right)^2}{\sum_i \left(Qo_i + \overline{Qo}\right)\left(\overline{Qo} - Qo_i\right)^2}$	Adapted Nash-Sutcliffe efficiency, ability to reproduce time evolution of high flow discharges with best value of 1

HECRAS

HECRAS is a hydraulic model package of the US Army Corps of Engineers - Hydrologic Engineering Center (HEC).

The package contains three one-dimensional hydraulic analysis components for:

(1) steady flow water surface profile computations;

(2) unsteady flow simulation;

(3) movable boundary sediment transport computations.

The Unsteady flow is simulated based on two equations (USACE, 2001)

The Continuity Equation

The Momentum equation

The Continuity Equation

$$\frac{\partial \omega}{\partial t} + \frac{\partial S}{\partial t} + \frac{\partial Q}{\partial x} - q_l = 0$$

Where: ω – Cross-sectional area;
t – time; Q – flow ;
S – storage from non conveying portions of cross section;
X – distance along the channel;
ql – Lateral inflow per unit distance

The above equation can be written for the channel and floodplain:

$$\frac{\partial \omega_f}{\partial t} + \frac{\partial S}{\partial t} + \frac{\partial Q_f}{\partial x_f} = q_l + q_c \qquad \frac{\partial Q_c}{\partial x_c} + \frac{\partial A_c}{\partial t} = q_l$$

Where the subscripts c and f refer to the channel and floodplain, respectively,

ql is the lateral inflow per unit length of floodplain, and

qc and qf are the exchanges of water between the channel and the floodplain.

The Momentum equation:

$$\frac{\partial Q}{\partial t} + \frac{\partial (VQ)}{\partial x} + g\omega\left(\frac{\partial z}{\partial x} + S_f\right) = 0$$

The above equation can be written for the channel

$$\frac{\partial Q_c}{\partial t} + \frac{\partial (V_c Q_c)}{\partial x_c} + g\omega_c\left(\frac{\partial z}{\partial x_c} + S_{f_c}\right) = M_f$$

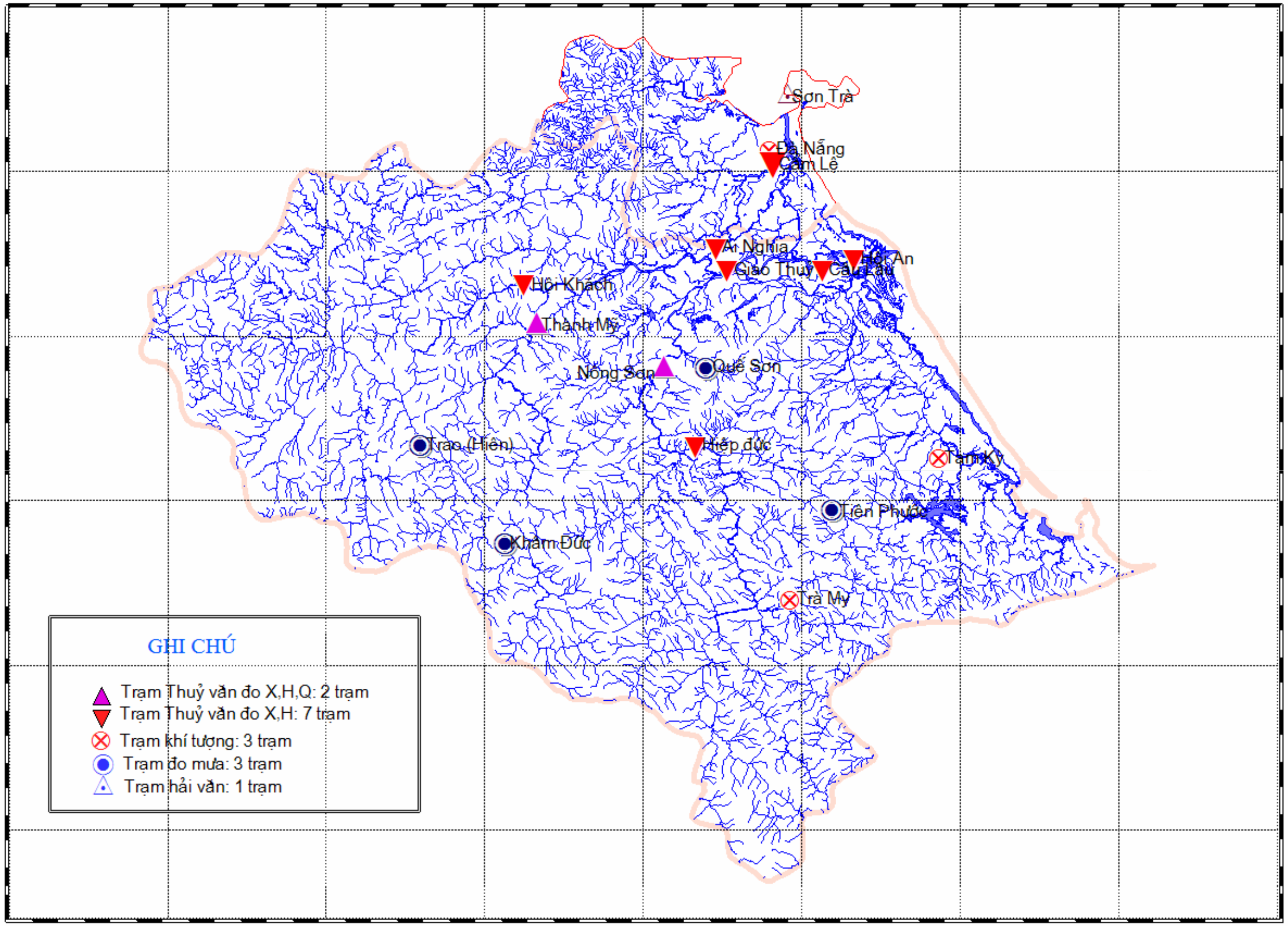
And for the floodplain

$$\frac{\partial Q_f}{\partial t} + \frac{\partial (V_f Q_f)}{\partial x_f} + g\omega_f\left(\frac{\partial z}{\partial x_f} + S_{ff}\right) = M_c$$

Where
Q – Discharge;
t – time;
V – velocity;
x – distance along the channel
g – acceleration of gravity;
ω- Cross-sectional area;
Sf – friction slope
Mf and Mc are the momentum fluxes per unit distance exchange between the floodplain and the channel.

The study area

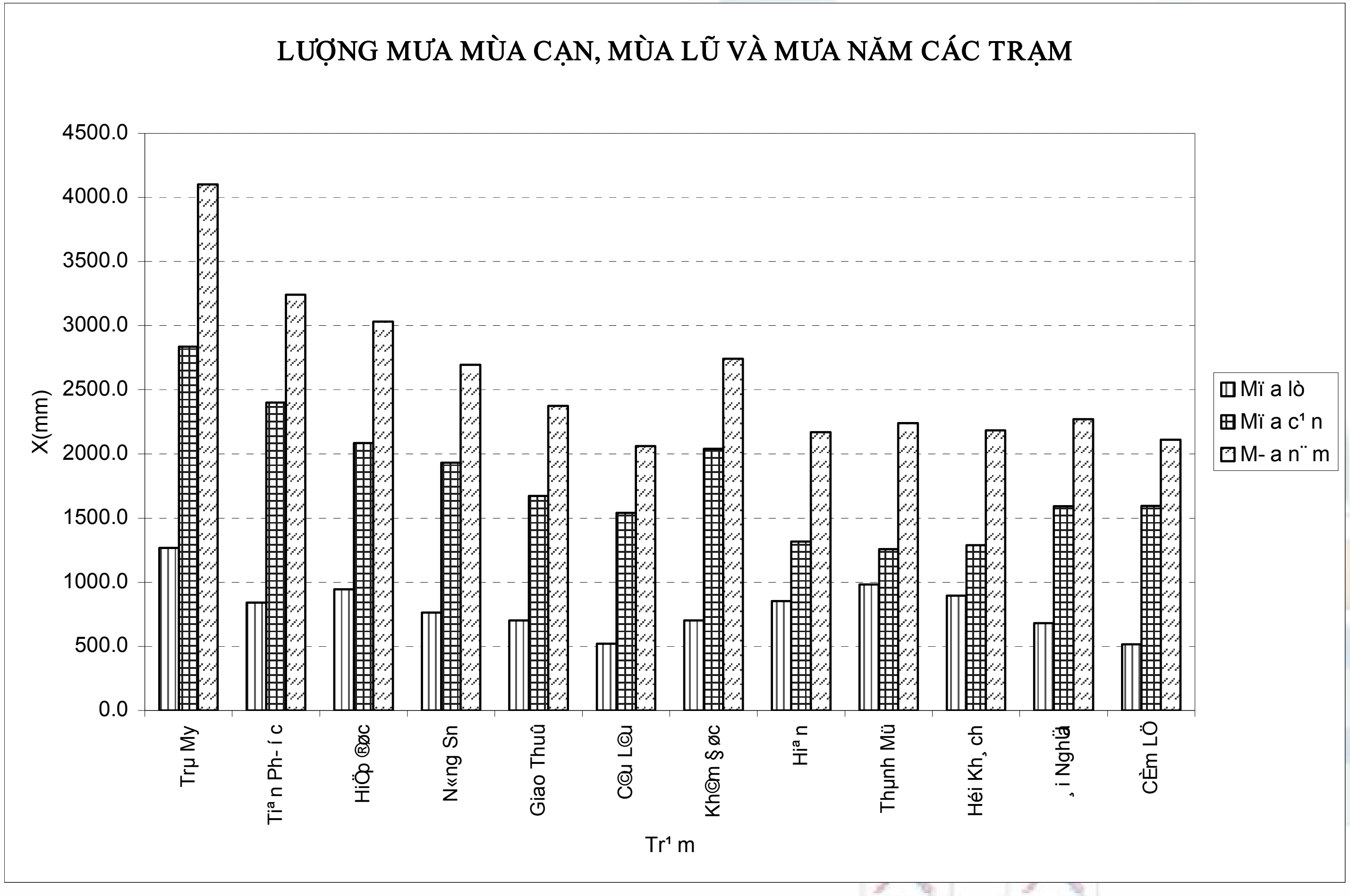
BẢN ĐỒ MẠNG LƯỚI SÔNG VÀ TRẠM ĐO KTTV LƯU VỰC SÔNG THU BỒN - VU GIA



Thu Bon – Vu Gia river system and location of hydro-meteorological stations.

Some characteristics of the study area

- Annual average temperature ranges from 21^{O}C to 26 ^{O}C
- Annual average relative humidity of 85%.
- Mean annual precipitation from 1960 to 4000 mm.
- Rainy season prolongs from September to December accounting from 60-80 % of yearly rainfall.
- The high floods of Thu Bon – Vu Gia occur usually from October to November.
- The effect of the upstream tidal influence is clearly visible during periods of low water
- Flood and inundation usually follows heavy rains, typhoon, and tropical depression. Large floods only occur under the affect of synoptic combination of typhoon, tropical depression with cold air surge.



Graph of dry season, rainy season and yearly precipitation in Thu Bon – Vu Gia river basin

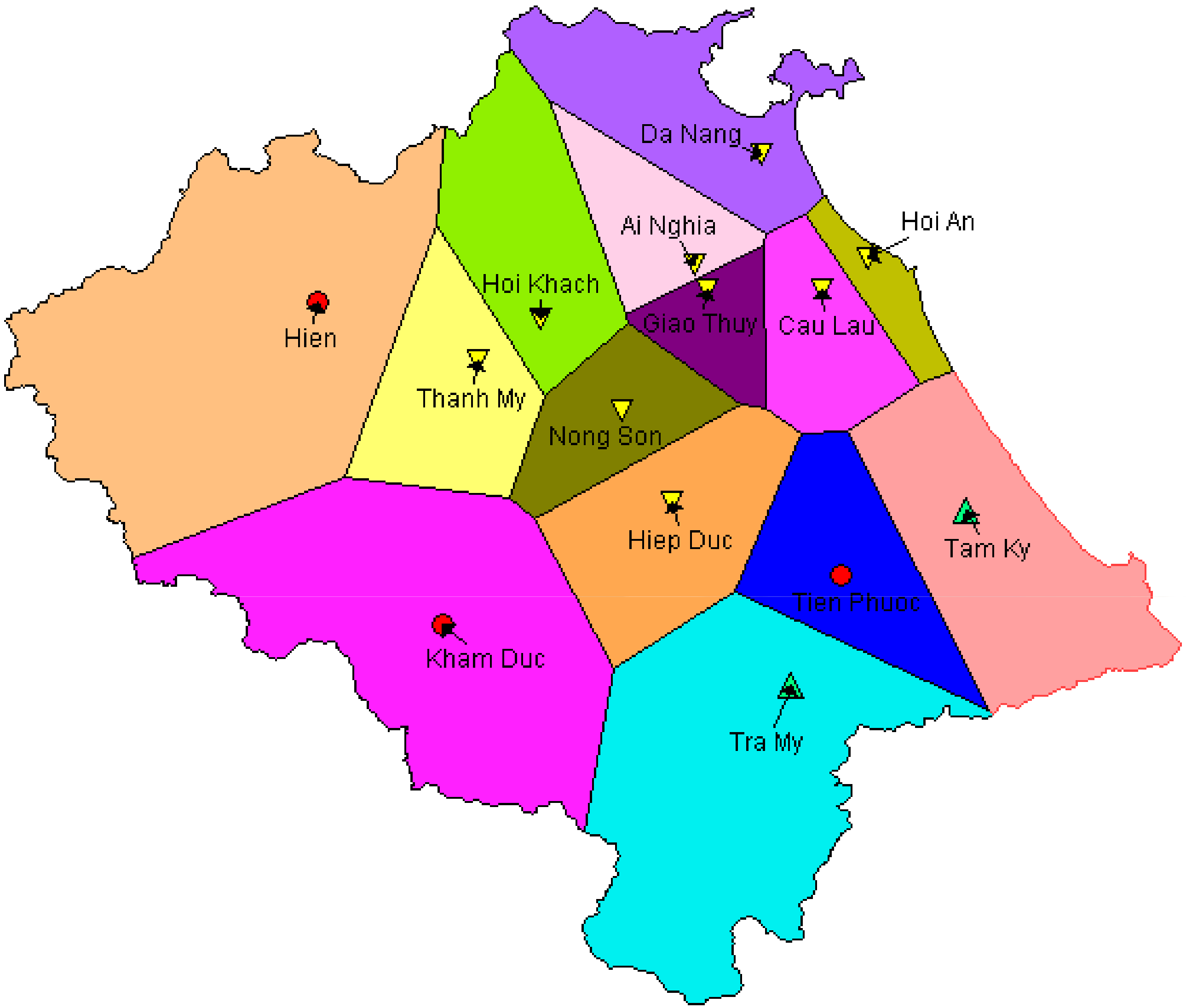
Input data for models

GIS data:

- DEM(50x50 m) map: derived from 1:50.000 resolution elevation contour maps.
- Land use map: consists of 25 land use types. A reclassification is made using nine land use types.
- Soil type map: The map is reclassified to 12 USDA soil texture classes

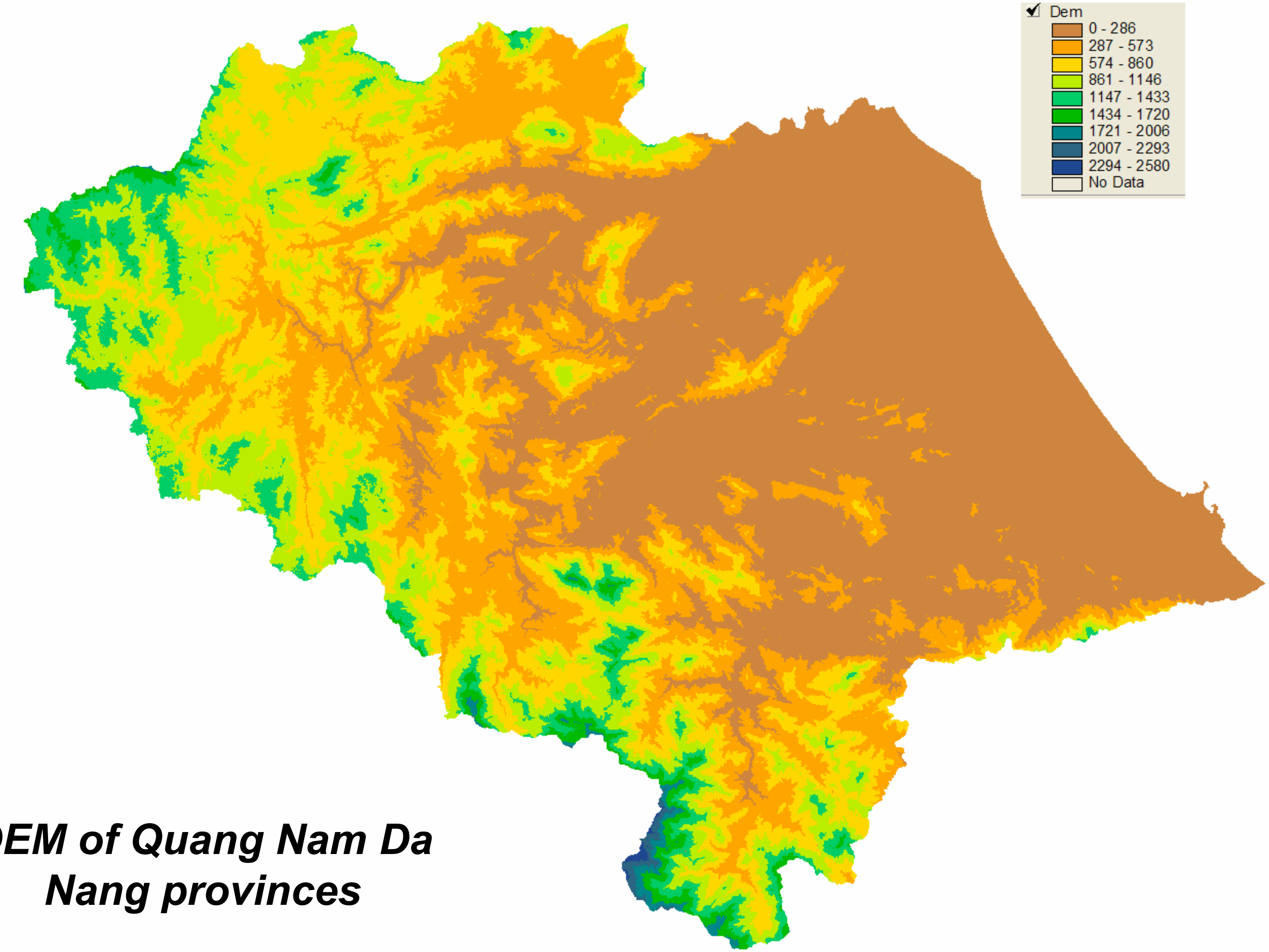
Hydrological data:

- 14 rain gauges and stream gauges data : Daily and 6-hourly time step.
- Tidal data available at Da Nang for a long period of time
- River geometry and cross section data: 320 cross sections

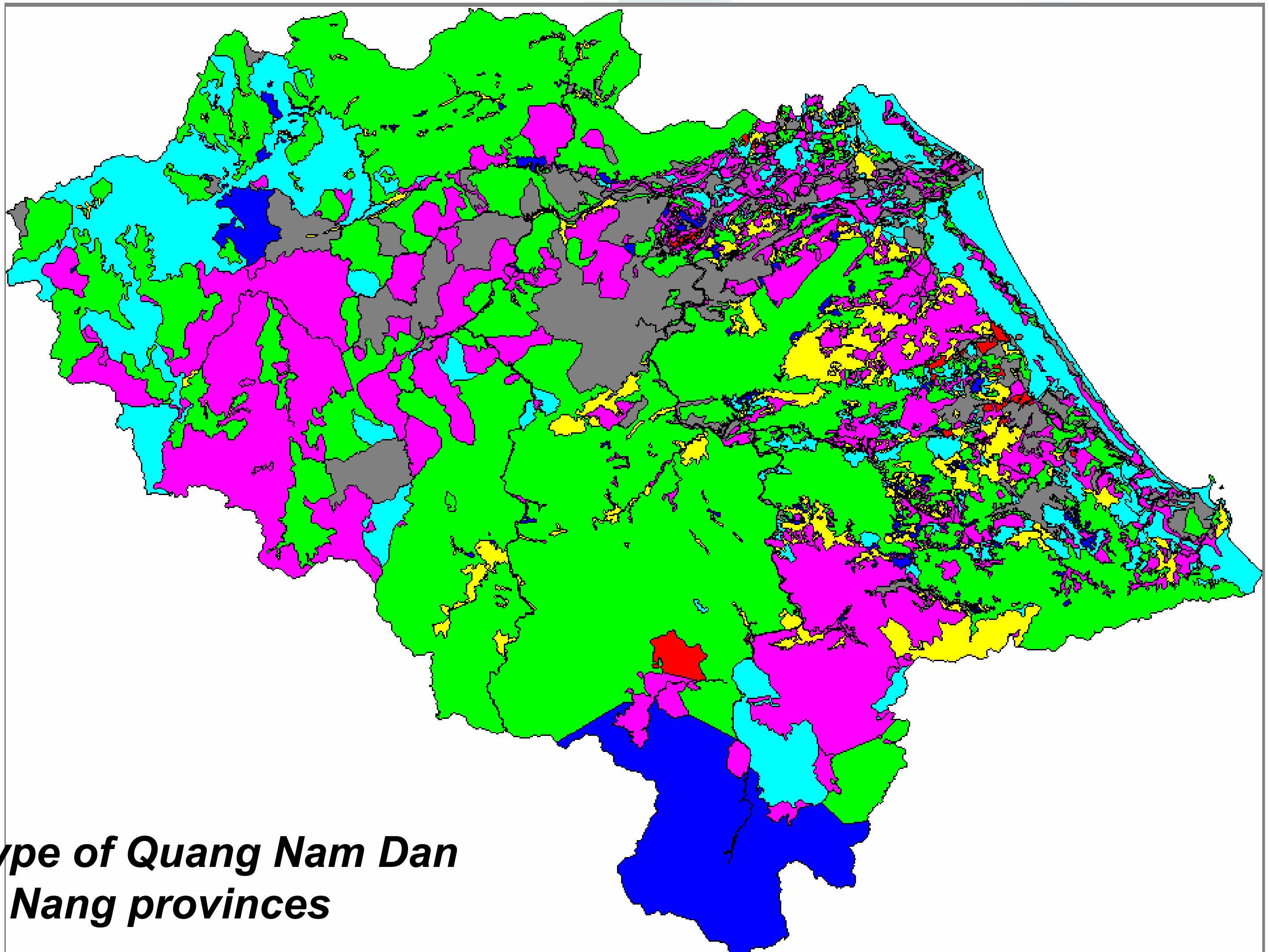


Rainfall calculation

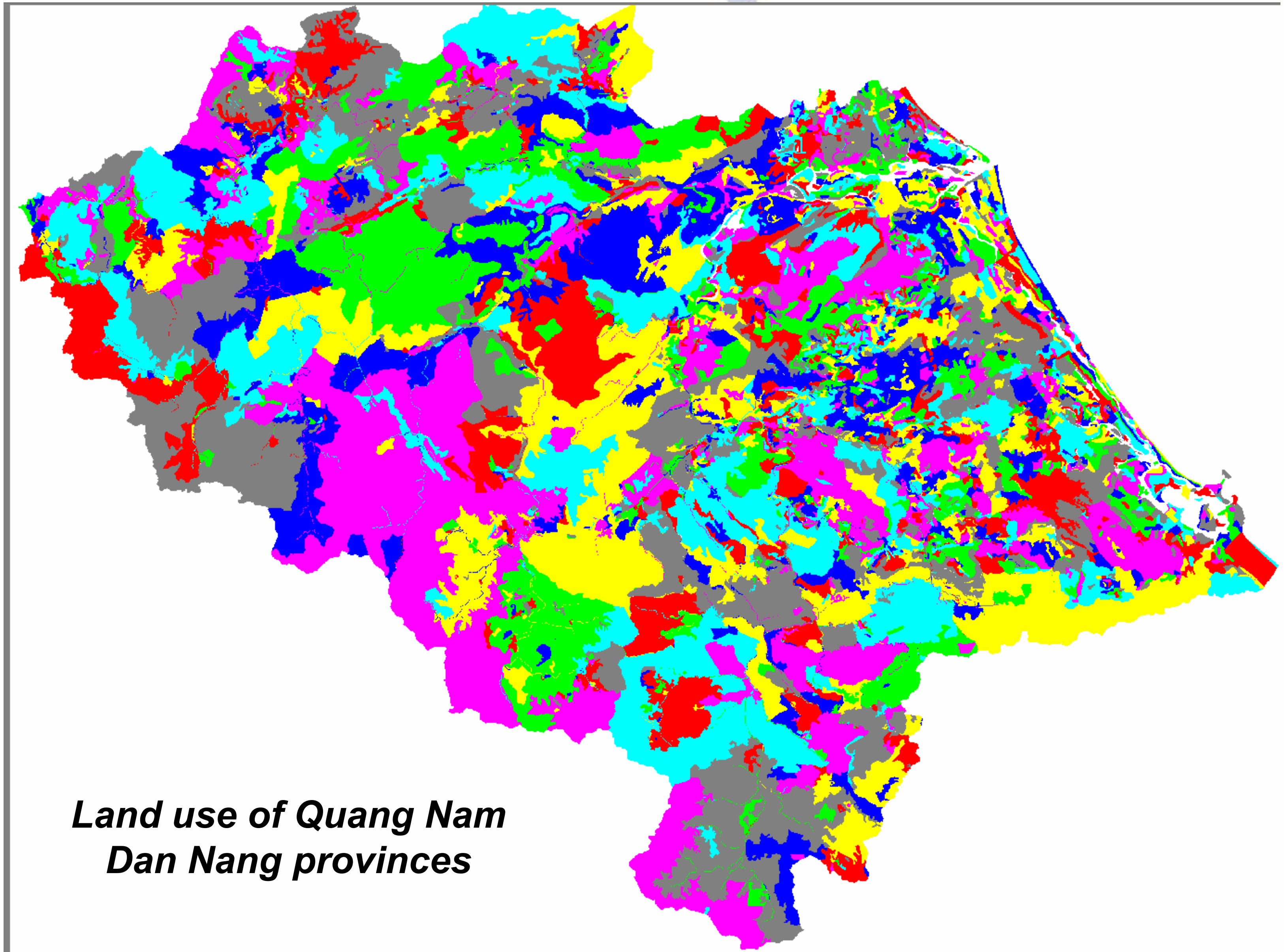
The grid of precipitation was created using Thiessen polygon method



DEM of Quang Nam Da Nang provinces

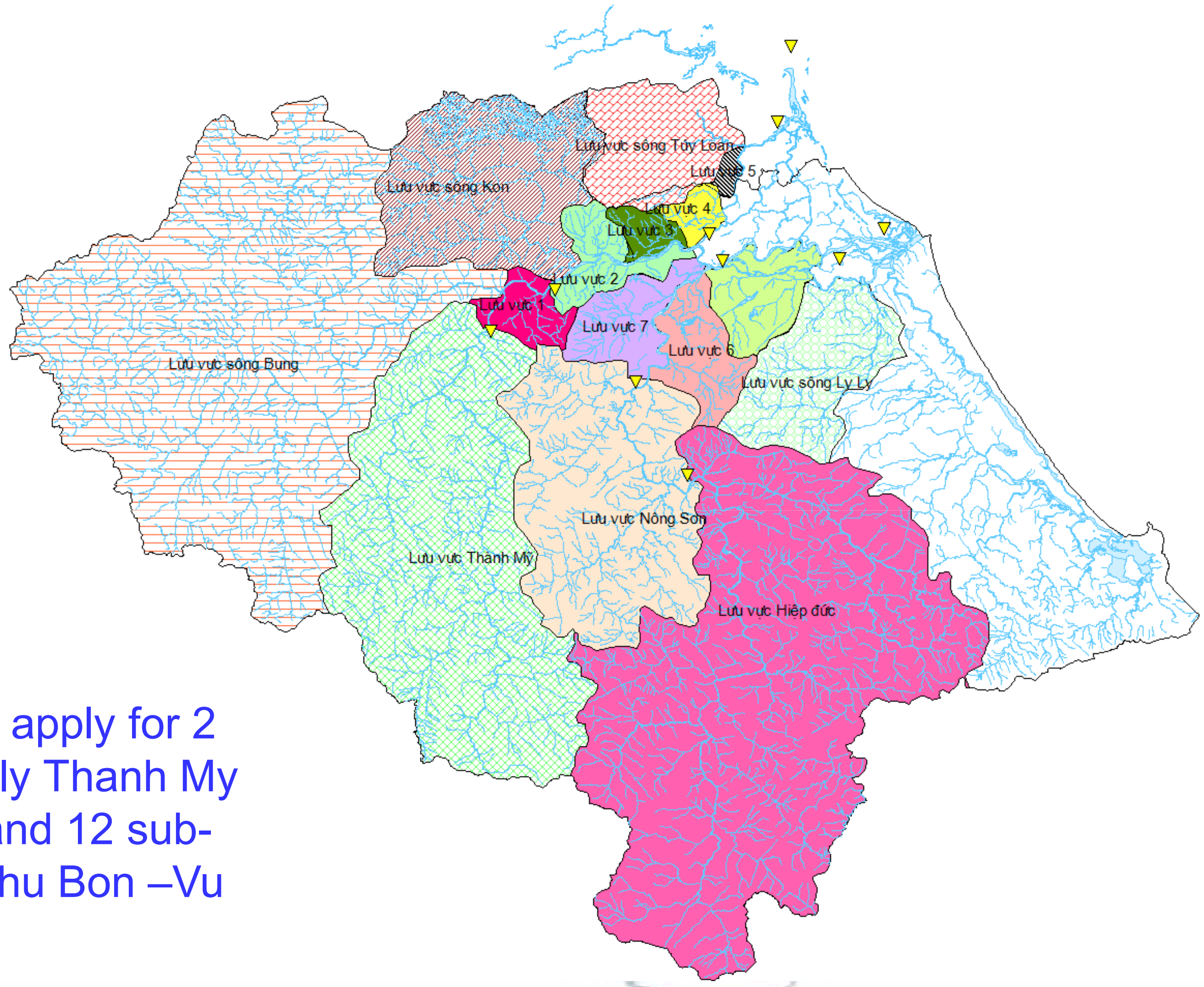


Soil type of Quang Nam Dan Nang provinces



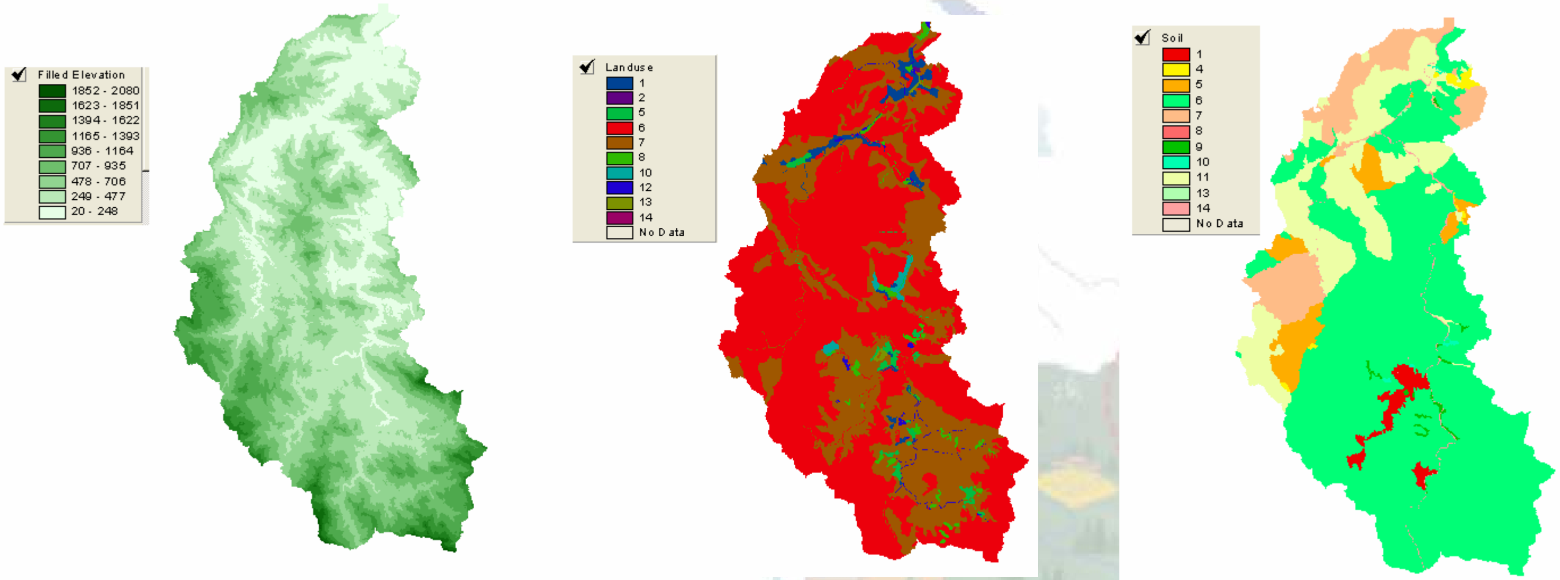
Land use of Quang Nam
Dan Nang provinces

Calibration and verification of WETSPA model

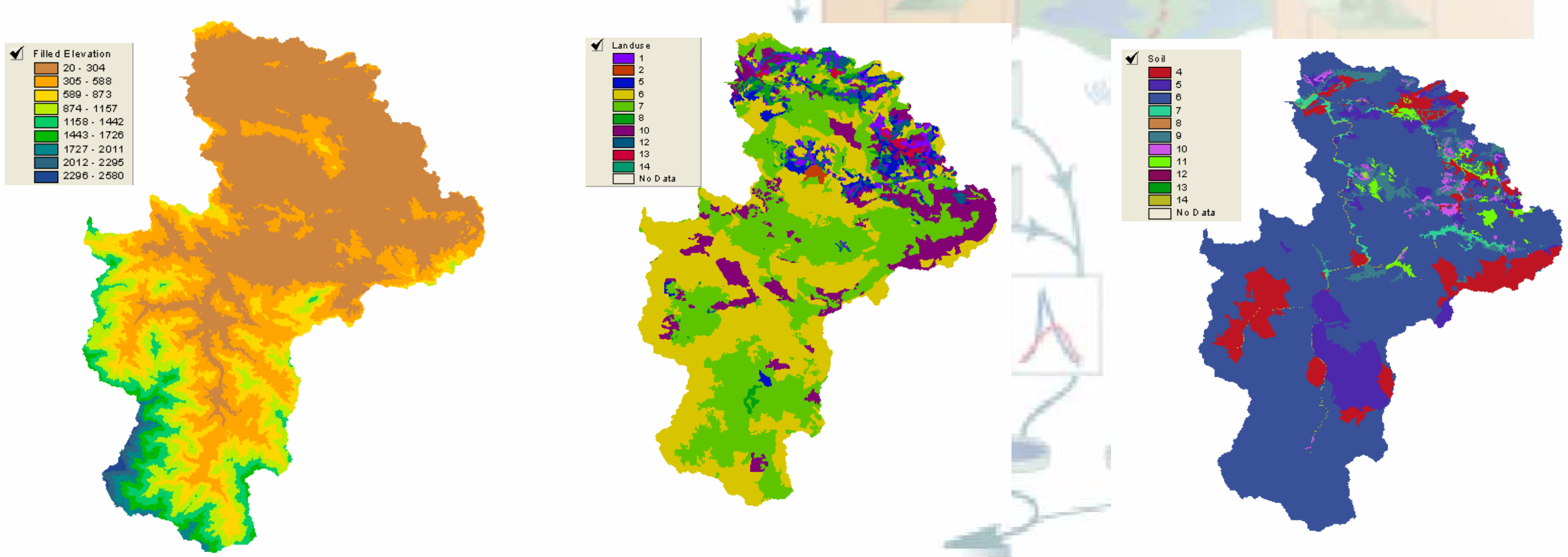


Wetspa model is apply for 2 catchment namely Thanh My and Nong Son and 12 sub-catchments in Thu Bon –Vu Gia river basin

Location of Sub-Catchments

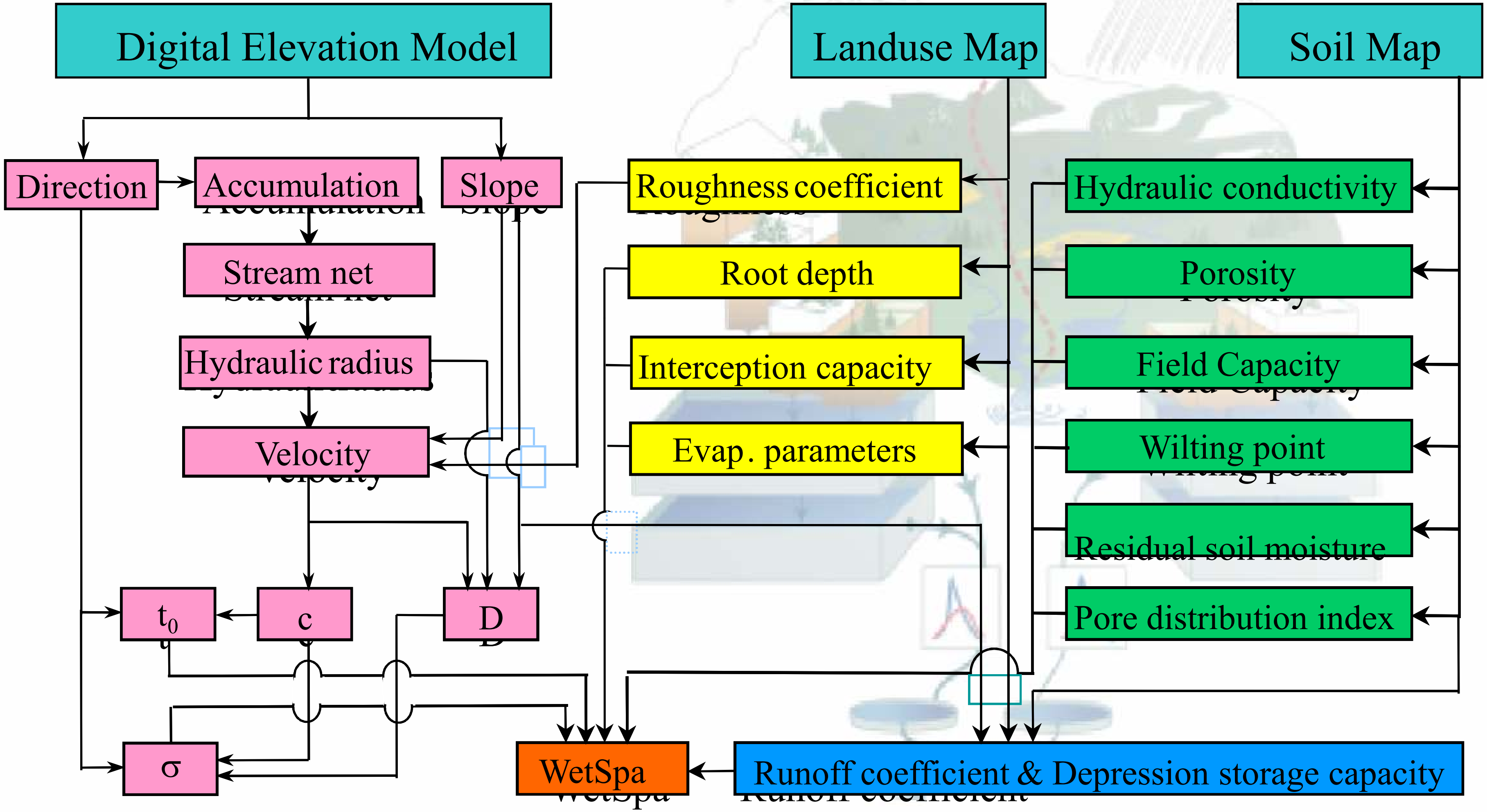


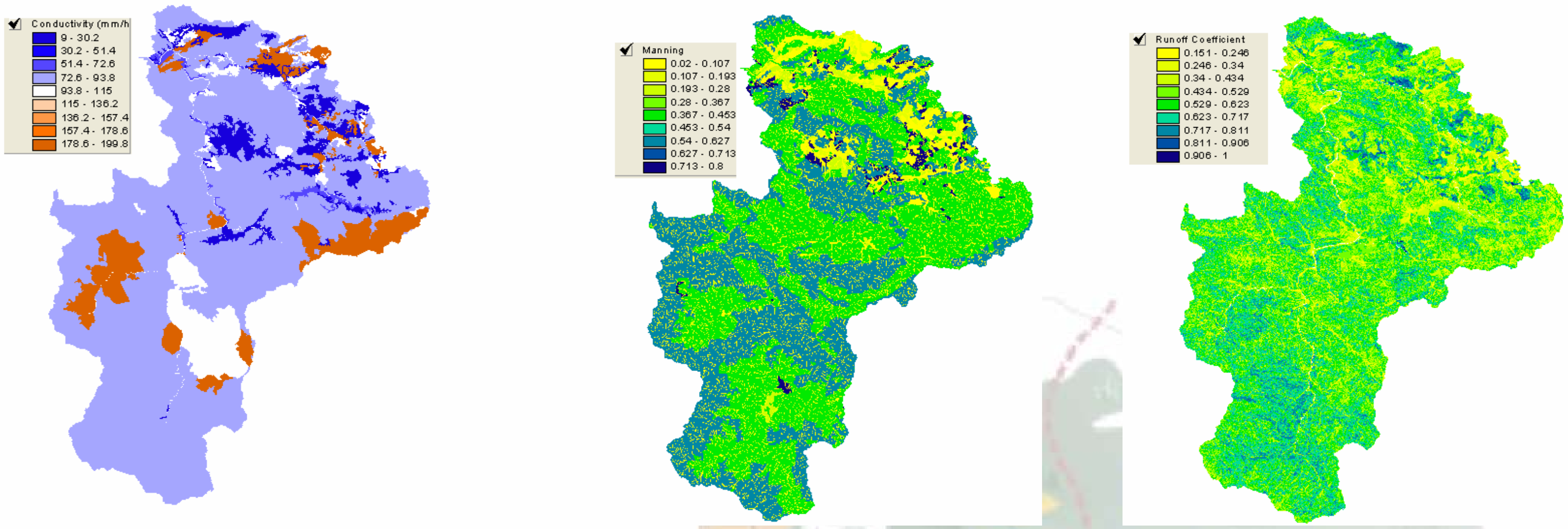
DEM, Soil type and Land use of Nong Son sub-catchment.



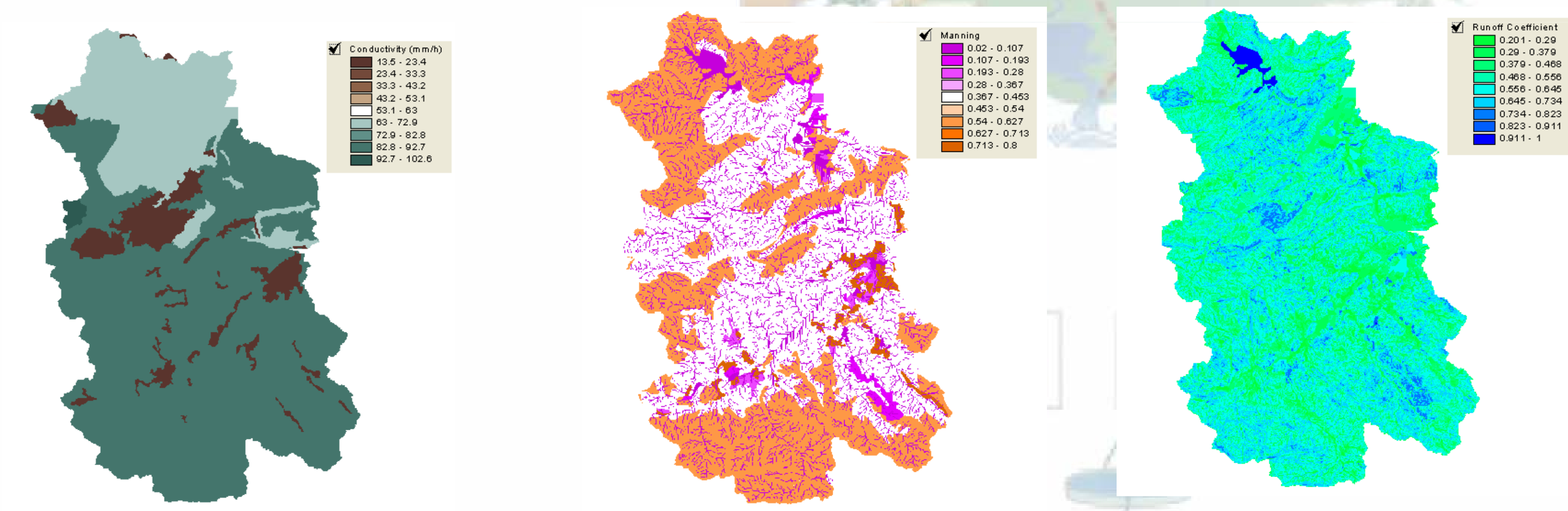
DEM, Soil type and Land use Hiep Duc sub-catchment.

Model Parameter Derivation





Some parameter maps of Hiep Duc sub-catchment.



Some parameter maps of Nong Son sub-catchment.

Calibration and verification of WETSPA model

Model Parameters:
- ✓ Distributed parameters: Maps
- ✓ Global parameters : 8 parameters

Model Calibration
- ✓ Manual calibration

Data: *6 hourly data: flood season 2002-2005*

Model verification *6 hourly data: flood season 2006-2007*

Model Evaluation
- ✓ Graphical comparisons
- ✓ Statistical comparisons

Global parameter of Thanh My and Nong Son sub-catchment.

	ki	Kg	K_ss	K_ep	g0	g_max	k_run	P_max
Thành Mỹ	1.24	0.01	0.8	1.0	200	500	7.53	44.83
Nông Sơn	0.8	0.07	0.65	0.9	400	600	4.5	30

Parameter Results

Calibration process was performed mainly for the global parameters:

• The interflow scaling factor was calibrated by matching the computed discharge with the observed discharge for the recession part of the flood hydrograph.

• Groundwater flow recession coefficient was obtained by the analysis of recession curves at discharge gauging stations.

• Refinement of this base flow recession coefficient was necessary to get a better fit for the low flows.

• The initial soil moisture and initial groundwater storage were adjusted based on the comparison between the calculated and observed hydrographs for the initial period.

• And the runoff exponent and the rainfall intensity threshold were adjusted based on the agreement between calculated and observed flows for the small storms with lower rainfall intensity.

Evaluated result

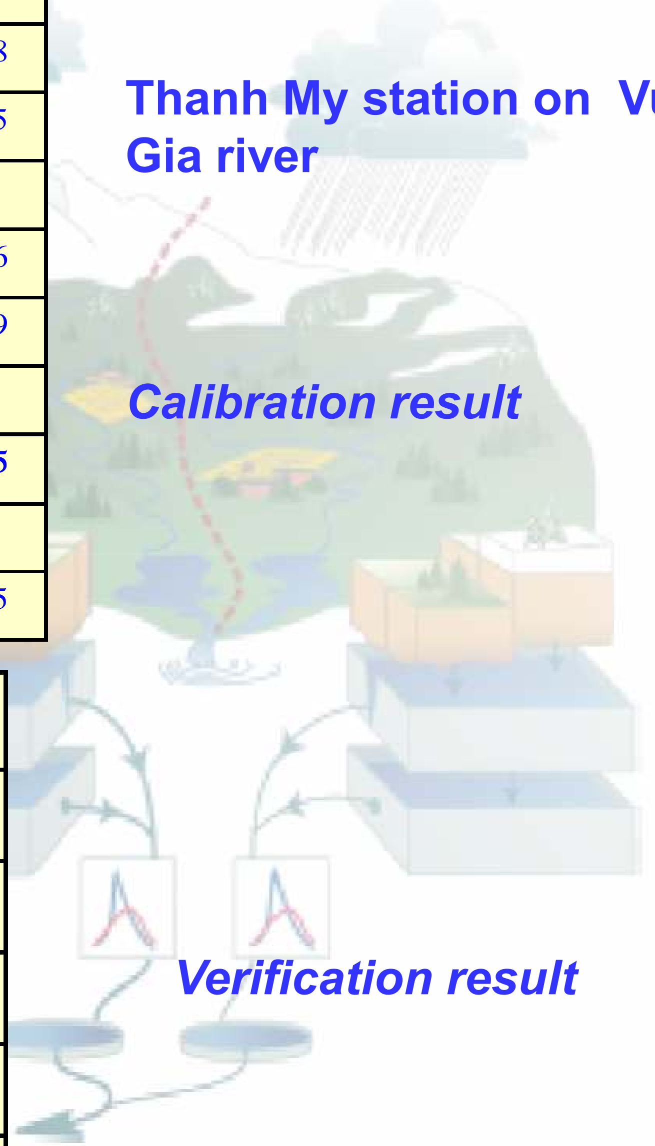
Thanh My station on Vu Gia river

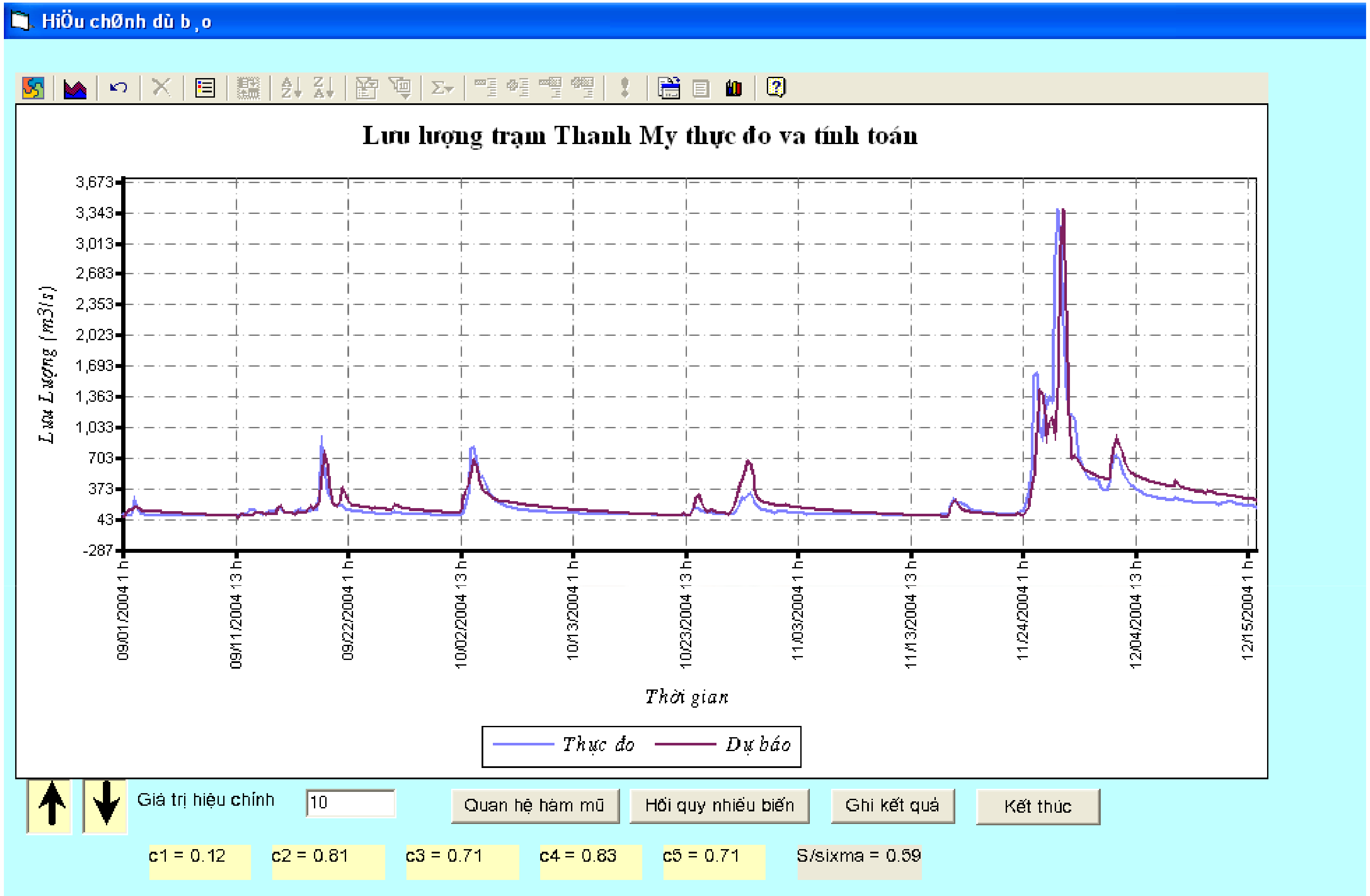
Calibration result

year	C1	C2	C3	C4	C5	S/σ
1998	0.15	0.7	0.71	0.8	0.68	0.6
1999	0.2	0.72	0.7	0.82	0.66	0.58
2001	0.1	0.83	0.83	0.91	0.84	0.45
2002	0.12	0.8	0.8	0.87	0.79	0.5
2003	0	0.76	0.76	0.92	0.74	0.56
2004	0.12	0.81	0.71	0.83	0.71	0.59
2005	0.3	0.73	0.73	0.87	0.68	0.6
Mean	**0.15**	**0.76**	**0.75**	**0.86**	**0.73**	**0.55**
Max	0.3	0.83	0.83	0.92	0.84	0.6
Min	0.05	0.7	0.7	0.8	0.66	0.45

Verification result

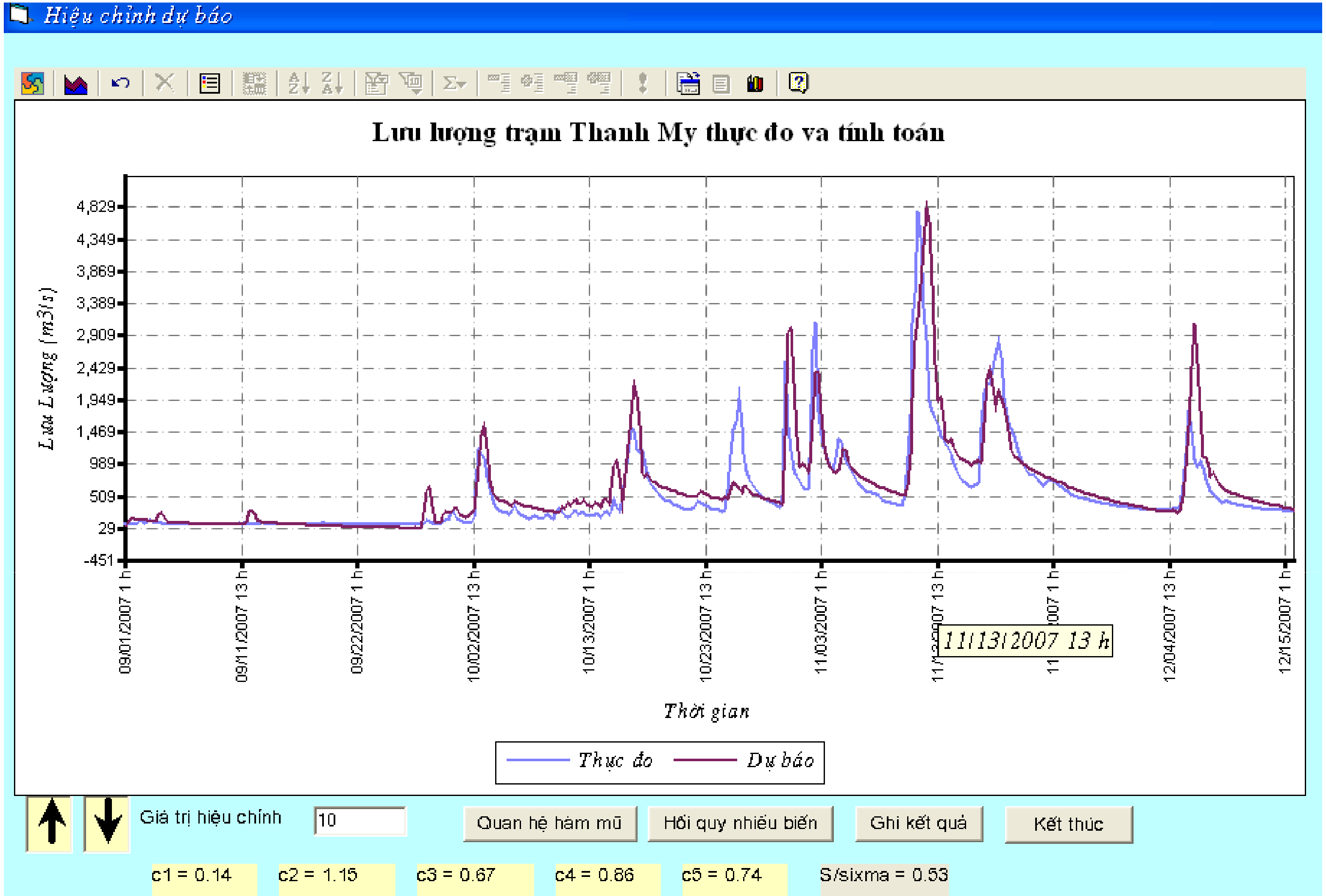
Year	C1	C2	C3	C4	C5	S/σ
2006	0.05	0.78	0.78	0.85	0.78	0.54
2007	0.14	1.15	0.67	0.86	0.74	0.53
Mean	0.1	0.97	0.73	0.86	0.76	0.54
Max	0.14	1.15	0.78	0.86	0.78	0.54
Min	0.05	0.78	0.67	0.85	0.74	0.53





Calibration result :

Observed and calculated 6-hourly water level in flood season 2004 at Thanh My station on Vu Gia river



Verification result :

Observed and calculated 6-hourly water level in flood season 2007 at Thanh My station on Vu Gia river

Evaluated result

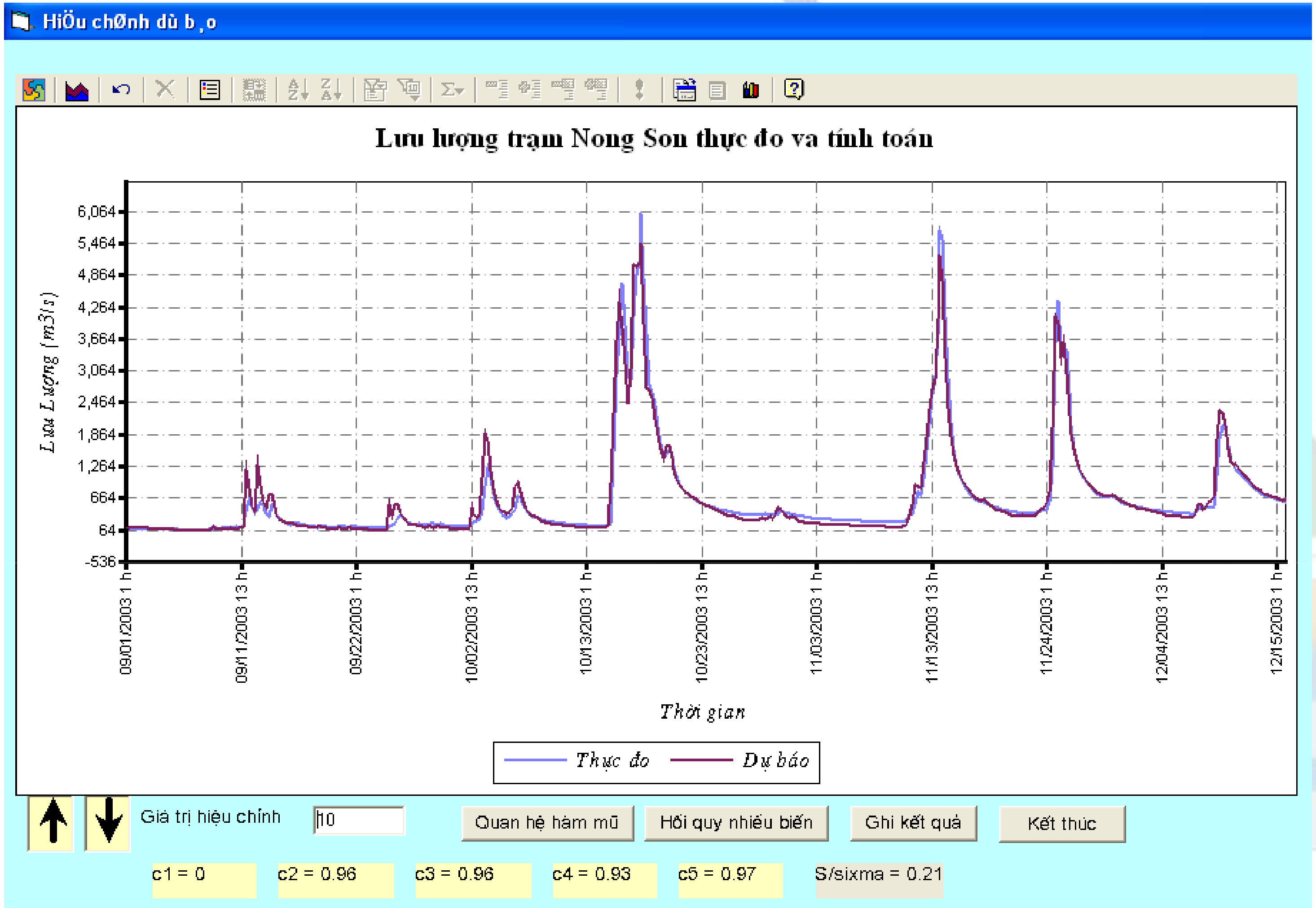
Nong Son station on Thu Bon river

Calibration result

Year	C1	C2	C3	C4	C5	S/σ
1998	0.1	0.92	0.8	0.90	0.87	0.3
1999	0.2	0.85	0.8	0.85	0.86	0.35
2001	0	0.96	0.96	0.96	0.97	0.21
2002	0	0.95	0.95	0.95	0.96	0.24
2003	0.05	0.96	0.96	0.93	0.97	0.21
2004	0.05	0.96	0.96	0.95	0.97	0.21
2005	0	0.95	0.95	0.91	0.96	0.23
TB	0.06	0.94	0.91	0.92	0.94	0.25
Max	0.2	0.96	0.96	0.96	0.97	0.35
Min	0	0.85	0.8	0.85	0.86	0.21

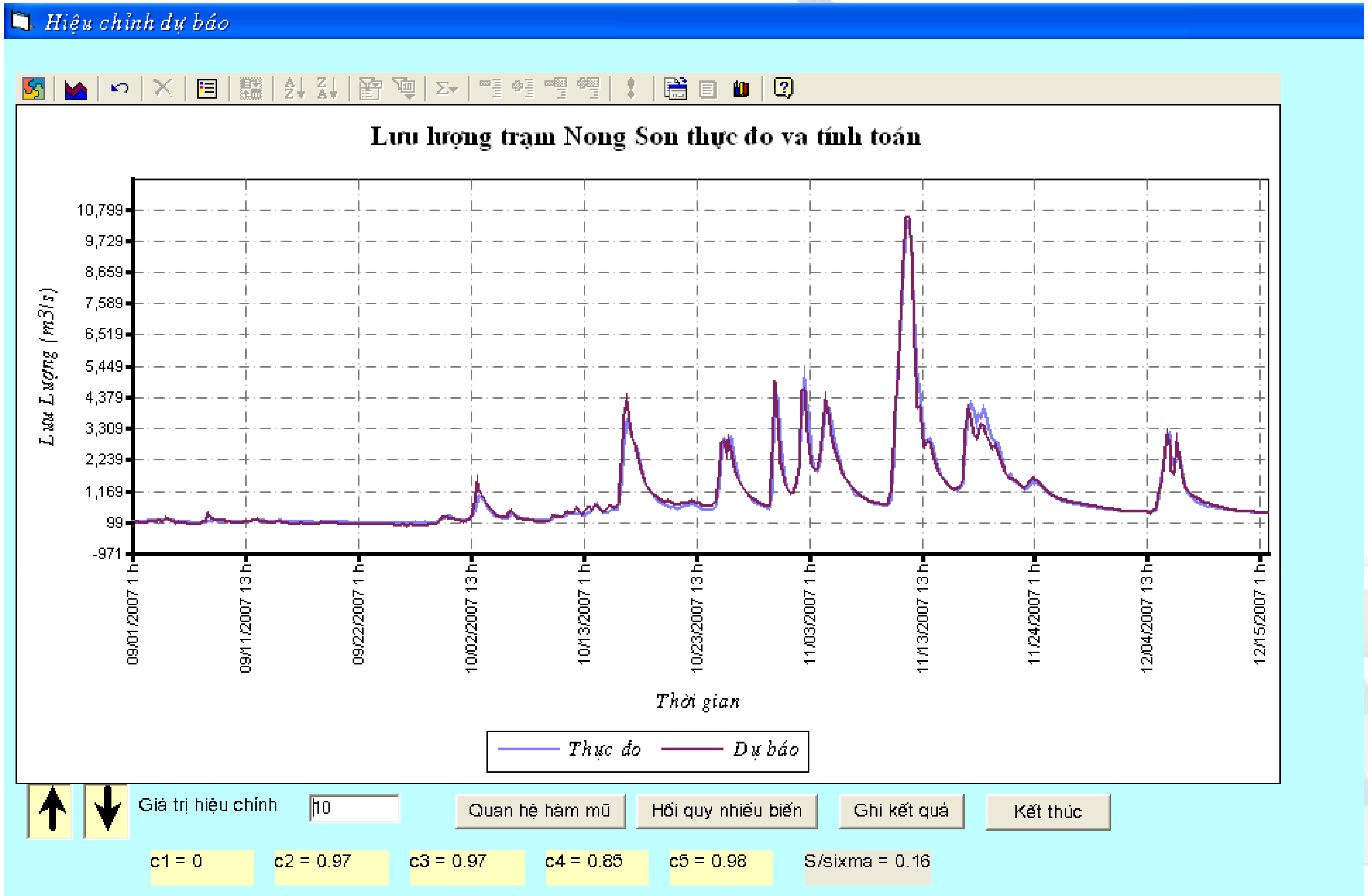
Verification result

Năm	**C1**	**C2**	**C3**	**C4**	**C5**	**S/σ**
2006	0.02	0.96	0.96	0.97	0.97	0.21
2007	0.012	0.97	0.97	0.85	0.98	0.16
TB	**0.016**	**0.97**	**0.97**	**0.91**	**0.98**	**0.19**
Max	**0.02**	**0.97**	**0.97**	**0.97**	**0.98**	**0.21**
Min	**0.012**	**0.96**	**0.96**	**0.85**	**0.97**	**0.16**



Calibration result :

Observed and calculated 6-hourly water level in flood season 2003 at Nong Son station on Thu Bon river



Verification result :

Observed and calculated 6-hourly water level in flood season 2007 at Nong son station on Thu Bon river

Result

• The model performance is satisfactory for both calibration and validation periods

• Flow peak discharges are quite well reproduced: the Nash-Sutcliffe coefficients were between 0,64 to 0,82; model bias within the range of -0.09 to 0.15; model determination coefficient within the range of 0.82 to 1.05; the flow efficiency coefficient within the range of 0.54 to 0.9, while the efficiency coefficient ranges from 0.60 to 0.9 for low-flow, and 0.56 to 0.92 for high-flow.

• The model calculation results have a good agreement with observed hydrographs.

• The model can well reproduce high flows, but low flows are a little under estimated

• Evaluation criteria for both calibration and verification show that model is reliable performance and give a reperesentation of both low flow and high flow

Calibration and verification of HECRAS model

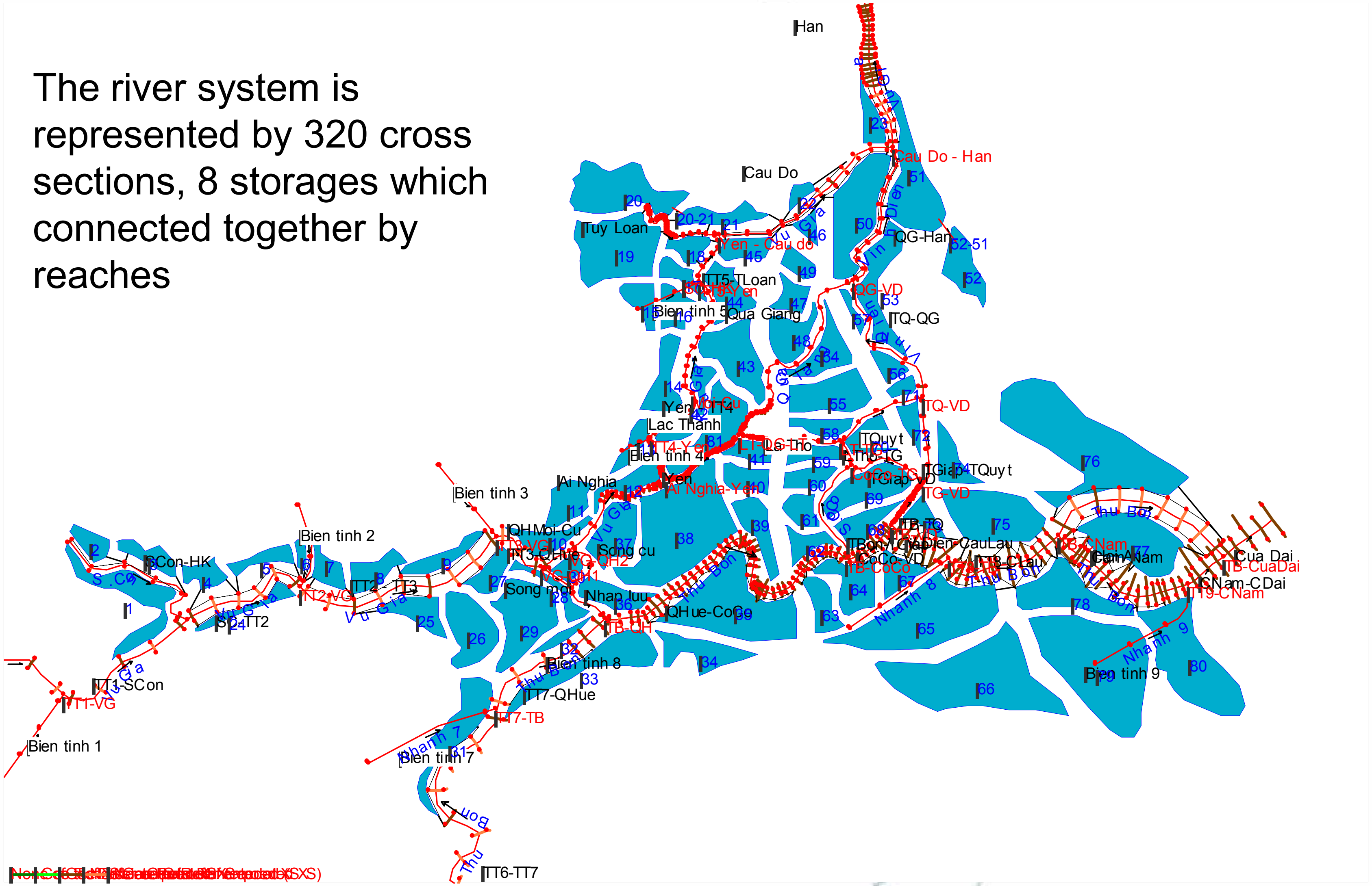
Three steps to flood simulation using the HECRASS model are performed including

1 - Processing the geometry data in HECRAS;

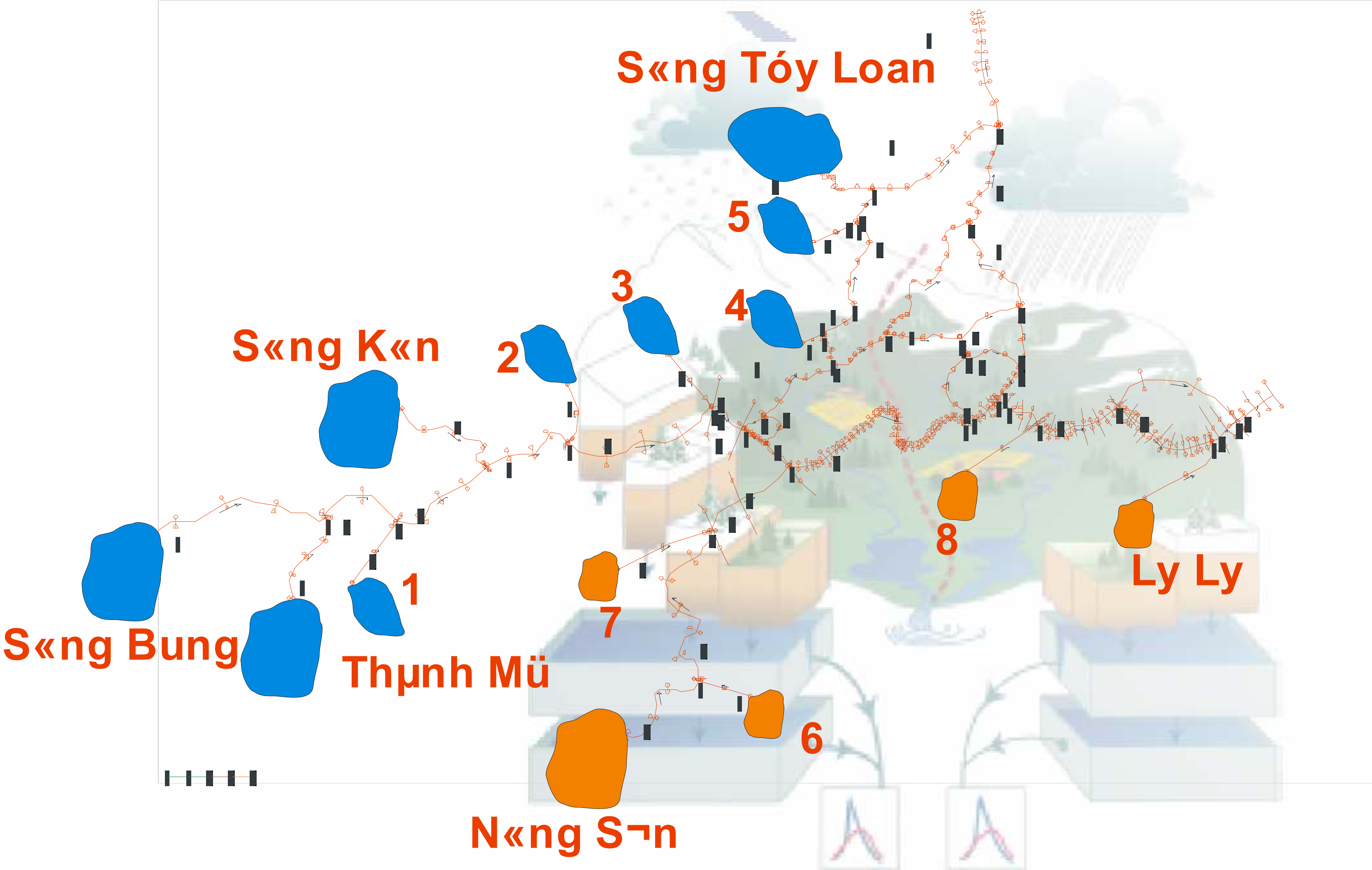
2 - Integration of hydrologic data as initial conditions and boundary conditions in the HECRAS unsteady flow data file;

3 - Calibration and simulation flood using HECRAS model

The river system is represented by 320 cross sections, 8 storages which connected together by reaches



Geometric data for downstream area of Thu bon - River basin



The flows of the upstream catchments which were results of Wetspa model were linked with the river network in the downstream area as upstream boundary condition

Calibration and verification of HECRAS model

- Hydrographs of the flood season from 2002 to 2007, obtained from the Wetspa model for upstream sub-catchments of Vu Gia and Thu Bon branches are used as upstream boundary conditions.
- Tidal hydrographs recorded at Da Nang are used as a downstream boundary condition for the river network
- The initial flow conditions are the base flow conditions for Vu Gia and Thu Bon branches

Calibration and verification of HECRAS model

• Data for calibration is 6-hourly water level hydrograph at Ai Nghia, Giao Thuy and Cau Lau station from 2002 to 2005.

• For model verification, the calibrated parameters are used to simulate the 6-hourly stream flow for flood seasons from 2006 and 2007

• The calibration adjustments to HECRAS parameters were made in Manning's *n*.

• Model calibration was discrete into two schemes: Rough scale, Delicate scale:

Rough scale: The calibration process divides the Manning’s values into 0.005 interval from the values of 0.02 to 0.05 by applying statistical method to finally evaluate the best interval value as an input for next step.

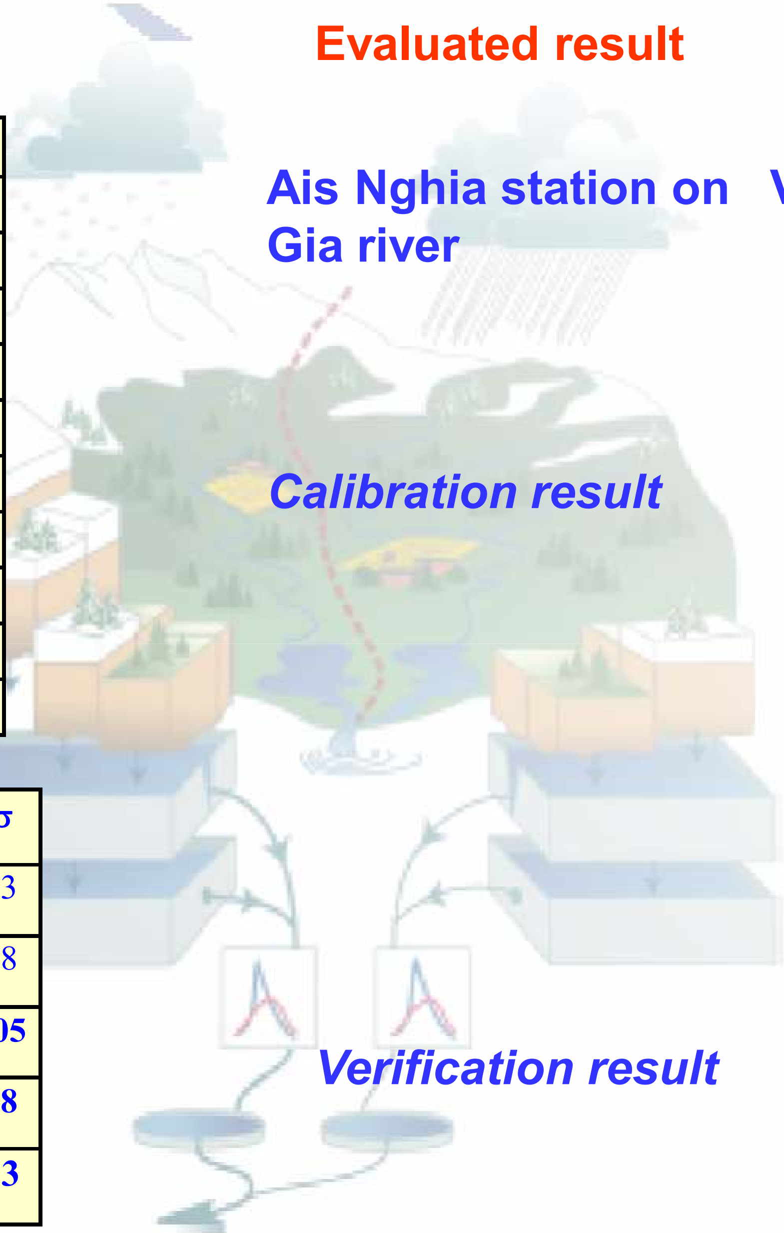
Delicate scale: The calibration process divides the Manning’s values into 0.001 interval from the selected rough scale values and applying statistical method to evaluate the best n Manning’s values for this study

1	River	Reach	n coef.
1	Thu Bồn	Nông Sơn -Quảng Huế	0.010 - 0.031
2		Quảng Huế - Vĩnh Điện	0.015 - 0.061
3		Vĩnh Điện - Cửa Đại	0.025 -0.055
4	Vu Gia	Thành Mỹ - Quảng Huế mới	0.025 - 0.035
5		Quảng Huế mới - Quảng Huế cũ	0.020 - 0.040
6		Quảng Huế cũ - Ái Nghĩa	0.010 - 0.040
7		Ái Nghĩa - Yên	0.010 - 0.045
8		Yên - Hàn	0.025 - 0.060
9	Vĩnh Điện	Thu Bồn - Thanh Quýt	0.025 - 0.030
10		Thanh Quýt - Quá Giáng	0.025 - 0.030
11		Quá Giáng - Hàn	0.025 - 0.030
12	Quảng Huế	Sông Mới	0.035 - 0.050
13		Sông Cũ	0.025 - 0.035
14		Nhập lưu	0.025 - 0.035
15	Lạc Thành	Lạc Thành	0.025 - 0.030
16	Quá Giáng	Quá Giáng	0.025 - 0.030
17	La Thọ-Thanh Quýt	La Thọ-Thanh Quýt	0.025 - 0.030

Results of Parameter calibration

Evaluated result

Ais Nghia station on Vu Gia river

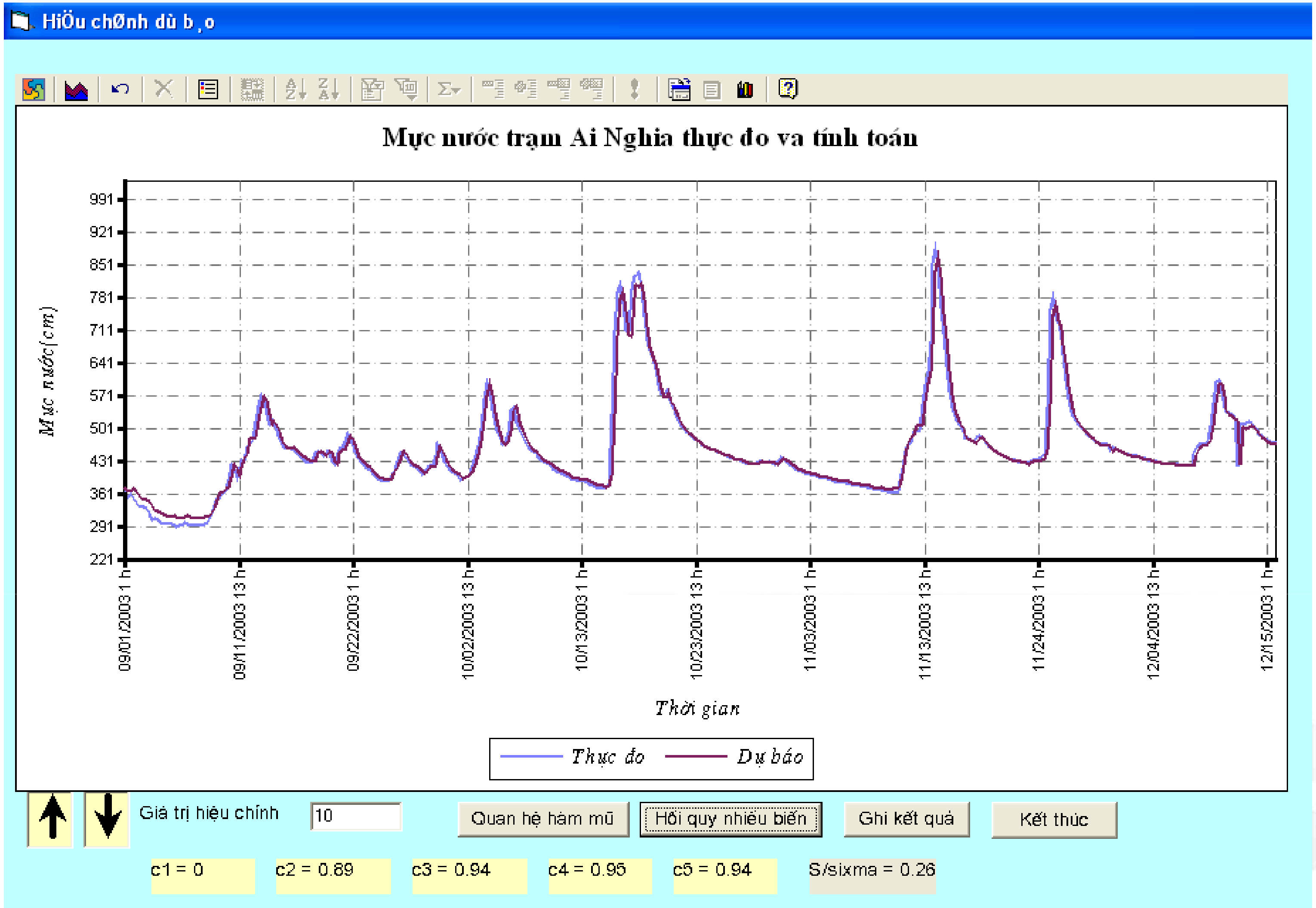


Calibration result

Năm	C1	C2	C3	C4	C5	S/σ
1998	0.05	0.8	0.78	0.83	0.84	0.35
1999	-0.04	0.84	0.8	0.82	0.85	0.4
2001	-0.014	0.81	0.83	0.87	0.8	0.3
2002	-0.1	0.93	0.93	0.93	0.93	0.27
2003	0.15	0.89	0.94	0.95	0.94	0.26
2004	-0.1	0.8	0.85	0.88	0.88	0.36
2005	0.02	0.74	0.74	0.71	0.76	0.59
TB	**-0.005**	**0.83**	**0.839**	**0.856**	**0.857**	**0.361**
Max	**0.15**	**0.93**	**0.94**	**0.95**	**0.94**	**0.59**
Min	**-0.1**	**0.74**	**0.74**	**0.71**	**0.76**	**0.26**

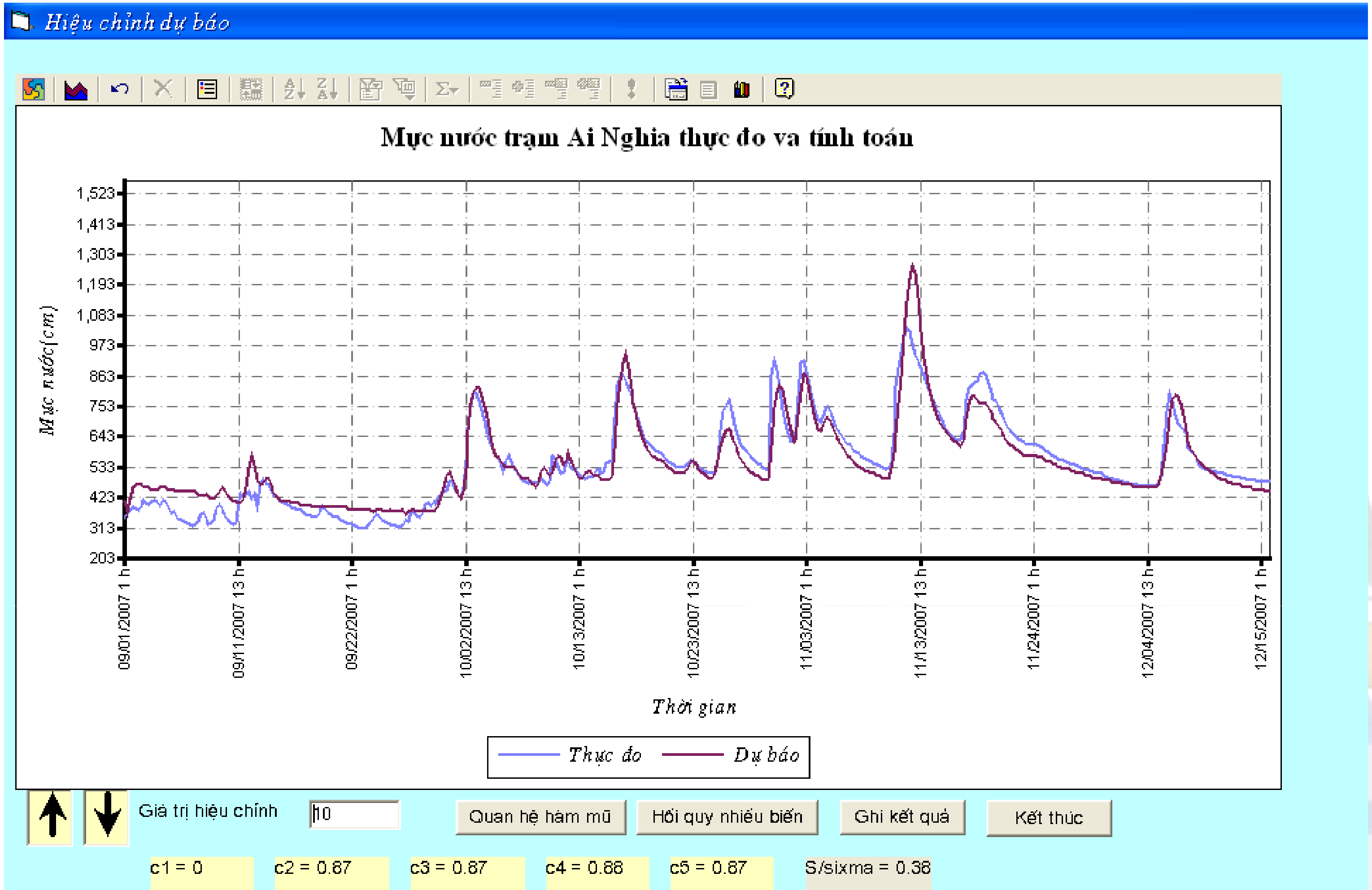
Verification result

Năm	C1	C2	C3	C4	C5	S/σ
2006	0.015	0.95	0.95	0.95	0.95	0.23
2007	0.12	0.87	0.87	0.88	0.87	0.38
TB	**0.0675**	**0.91**	**0.91**	**0.915**	**0.91**	**0.305**
Max	**0.12**	**0.95**	**0.95**	**0.95**	**0.95**	**0.38**
Min	**0.015**	**0.87**	**0.87**	**0.88**	**0.87**	**0.23**



Calibration result :

Observed and calculated 6-hourly water level in flood season 2003 at Ai Nghia station on Thu Bon river



Verification result :

Observed and calculated 6-hourly water level in flood season 2007 at Ai Nghia station on Thu Bon river

Evaluated result

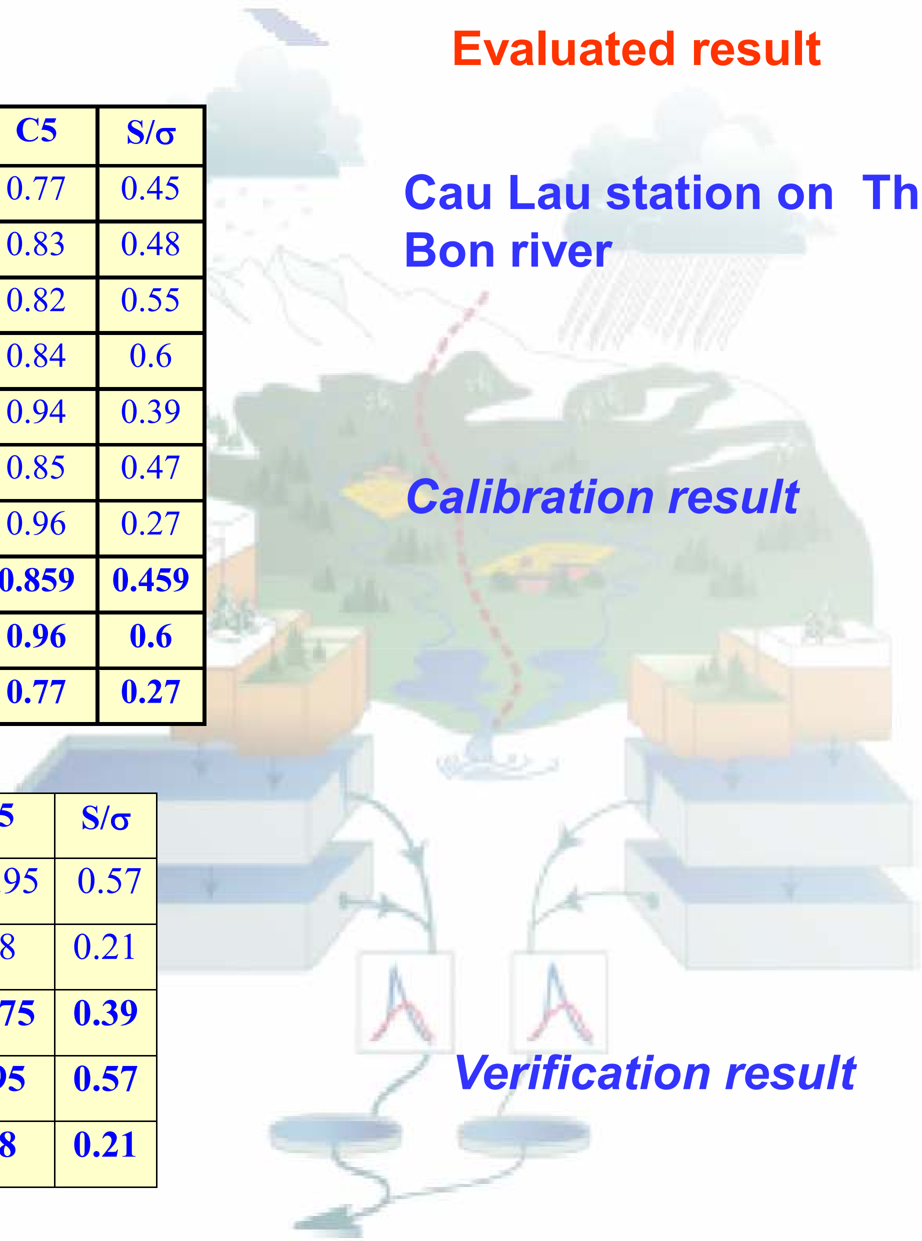
Cau Lau station on Thu Bon river

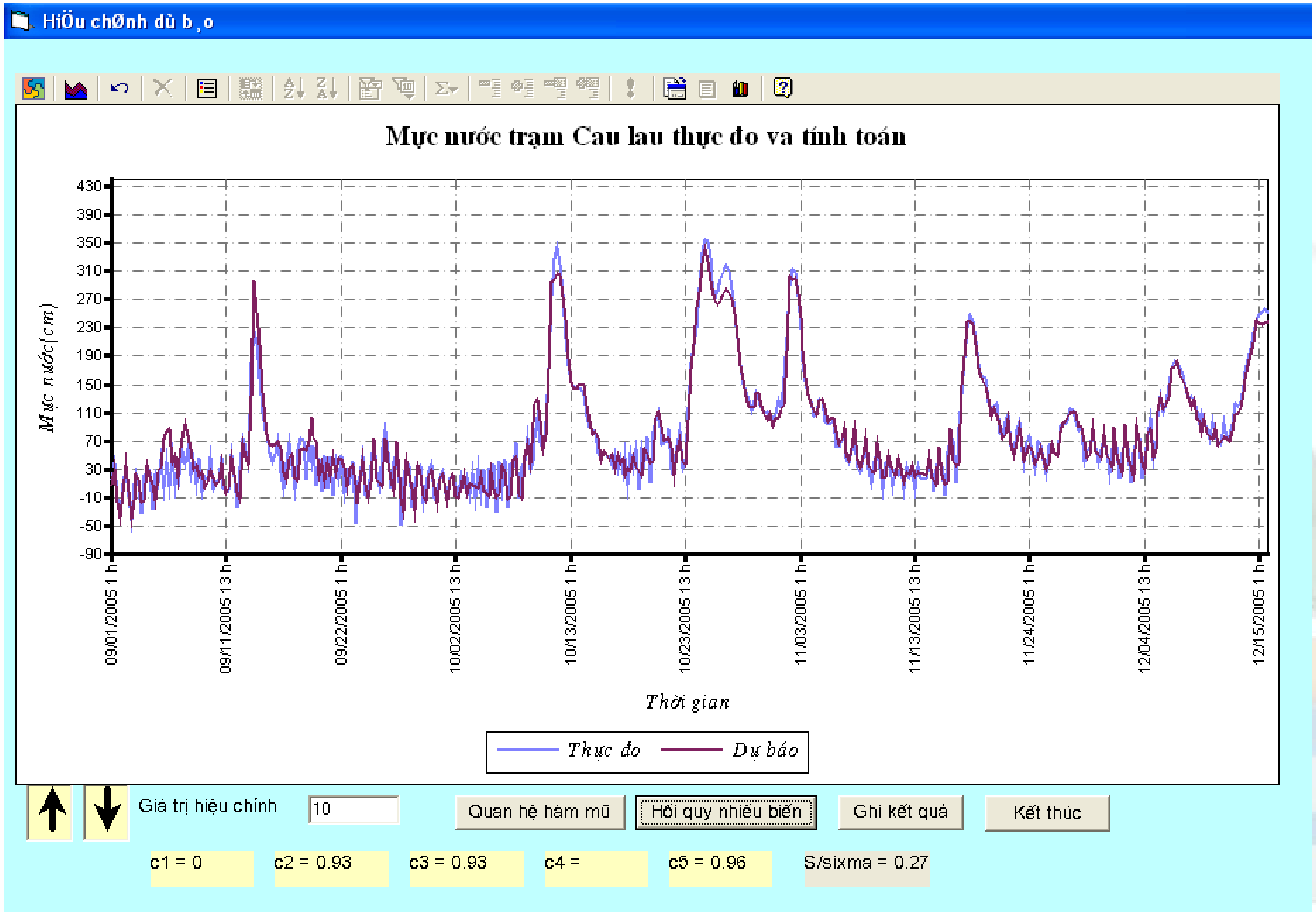
Calibration result

Năm	C1	C2	C3	C4	C5	S/σ
1998	0.12	0.76	0.8		0.77	0.45
1999	0.15	0.8	0.82		0.83	0.48
2001	-0.16	0.68	0.79		0.82	0.55
2002	0.1	0.62	0.78		0.84	0.6
2003	0.06	0.85	0.87		0.94	0.39
2004	-0.12	0.78	0.76		0.85	0.47
2005	0.05	0.93	0.93		0.96	0.27
TB	**0.029**	**0.774**	**0.821**		**0.859**	**0.459**
Max	**0.15**	**0.93**	**0.93**		**0.96**	**0.6**
Min	**-0.16**	**0.62**	**0.76**		**0.77**	**0.27**

Verification result

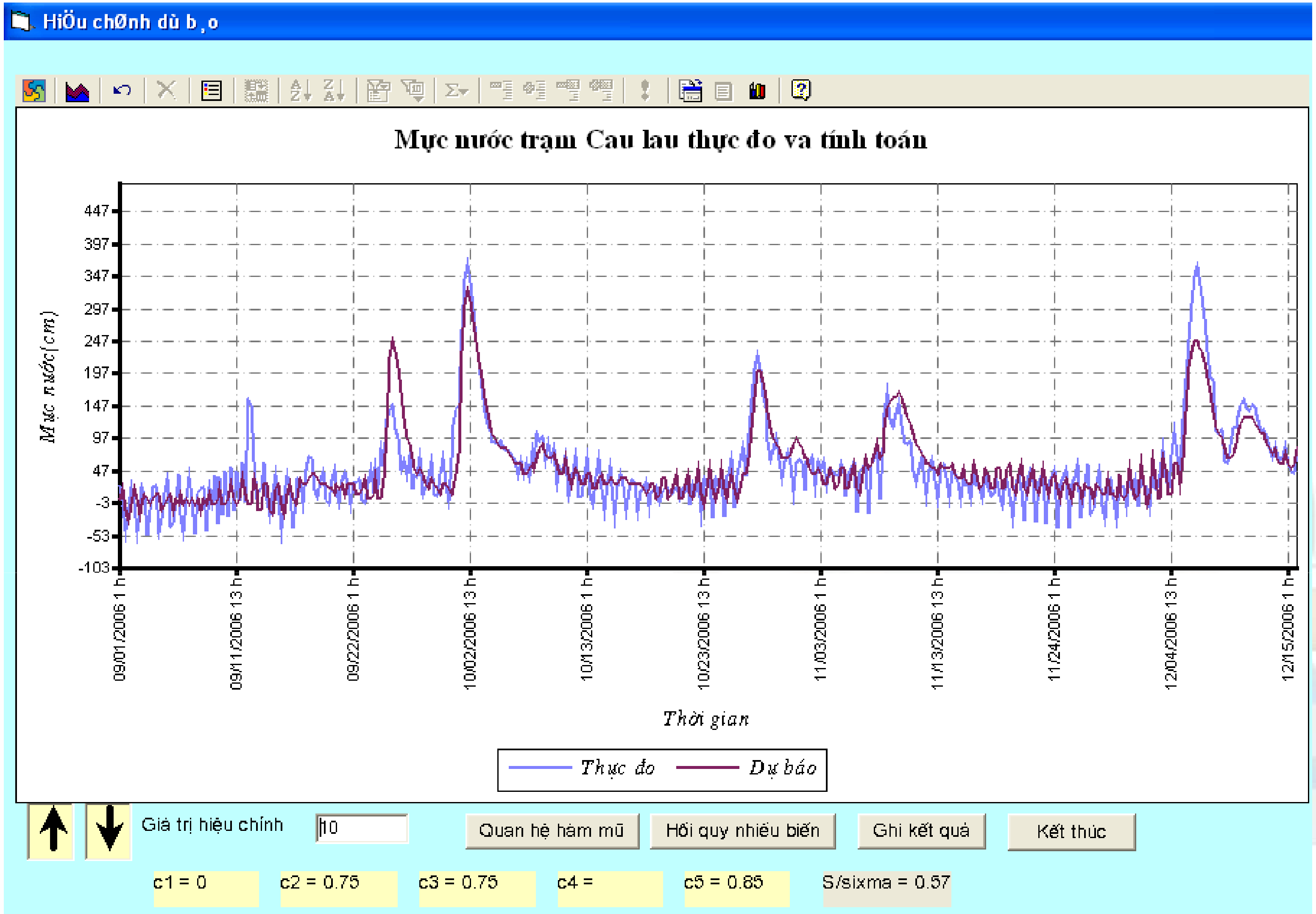
Năm	C1	C2	C3	C4	C5	S/σ
2006	0.2	0.75	0.75		0.95	0.57
2007	-0.1	0.96	0.96		0.8	0.21
TB	**0.05**	**0.855**	**0.855**		**0.875**	**0.39**
Max	**0.2**	**0.96**	**0.96**		**0.95**	**0.57**
Min	**-0.1**	**0.75**	**0.75**		**0.8**	**0.21**





Calibration result :

Observed and calculated 6-hourly water level in flood season 2005 at Cau Lau station on Thu Bon river



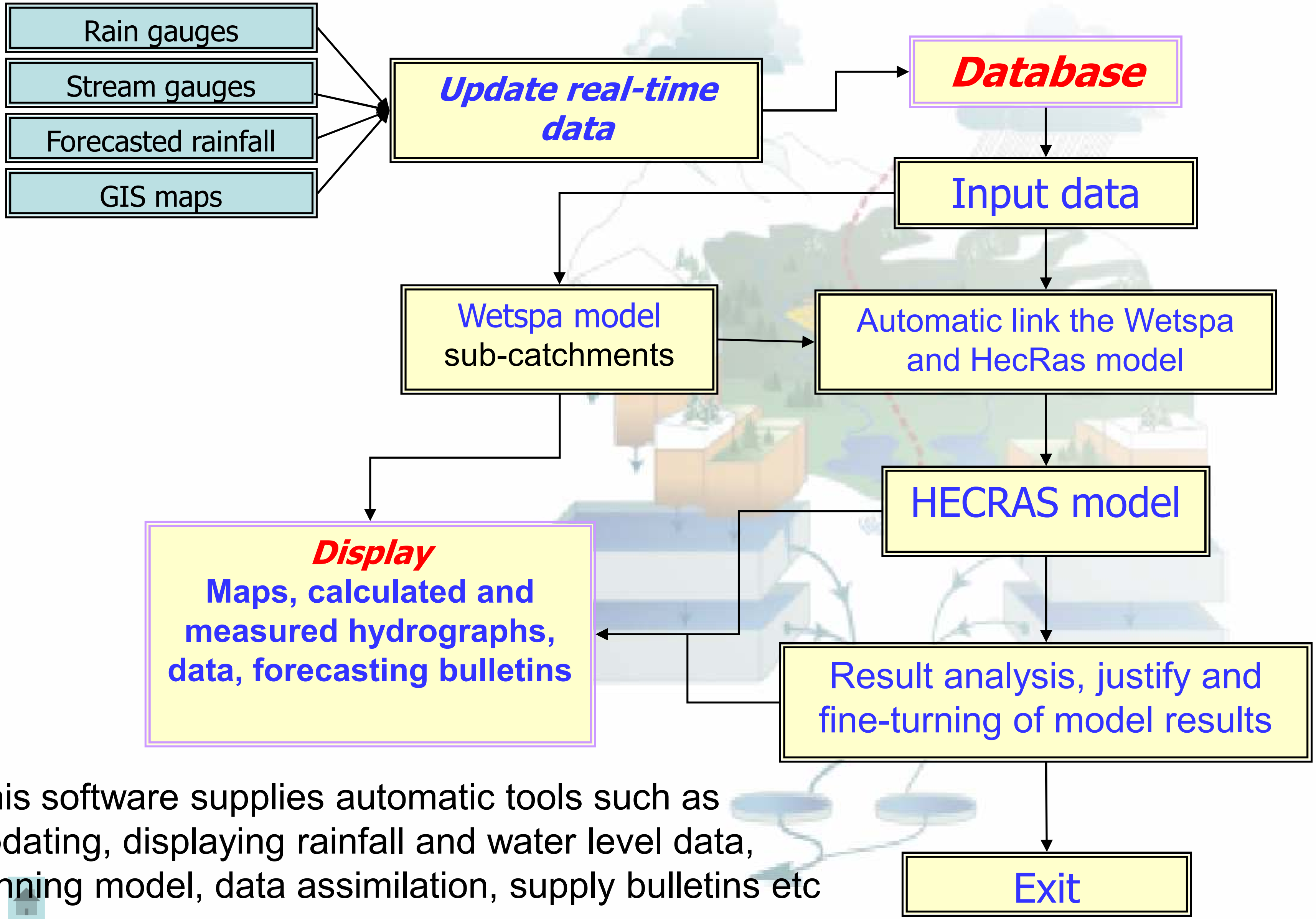
Verification result :

Observed and calculated 6-hourly water level in flood season 2007 at Cau Lau station on Thu Bon river

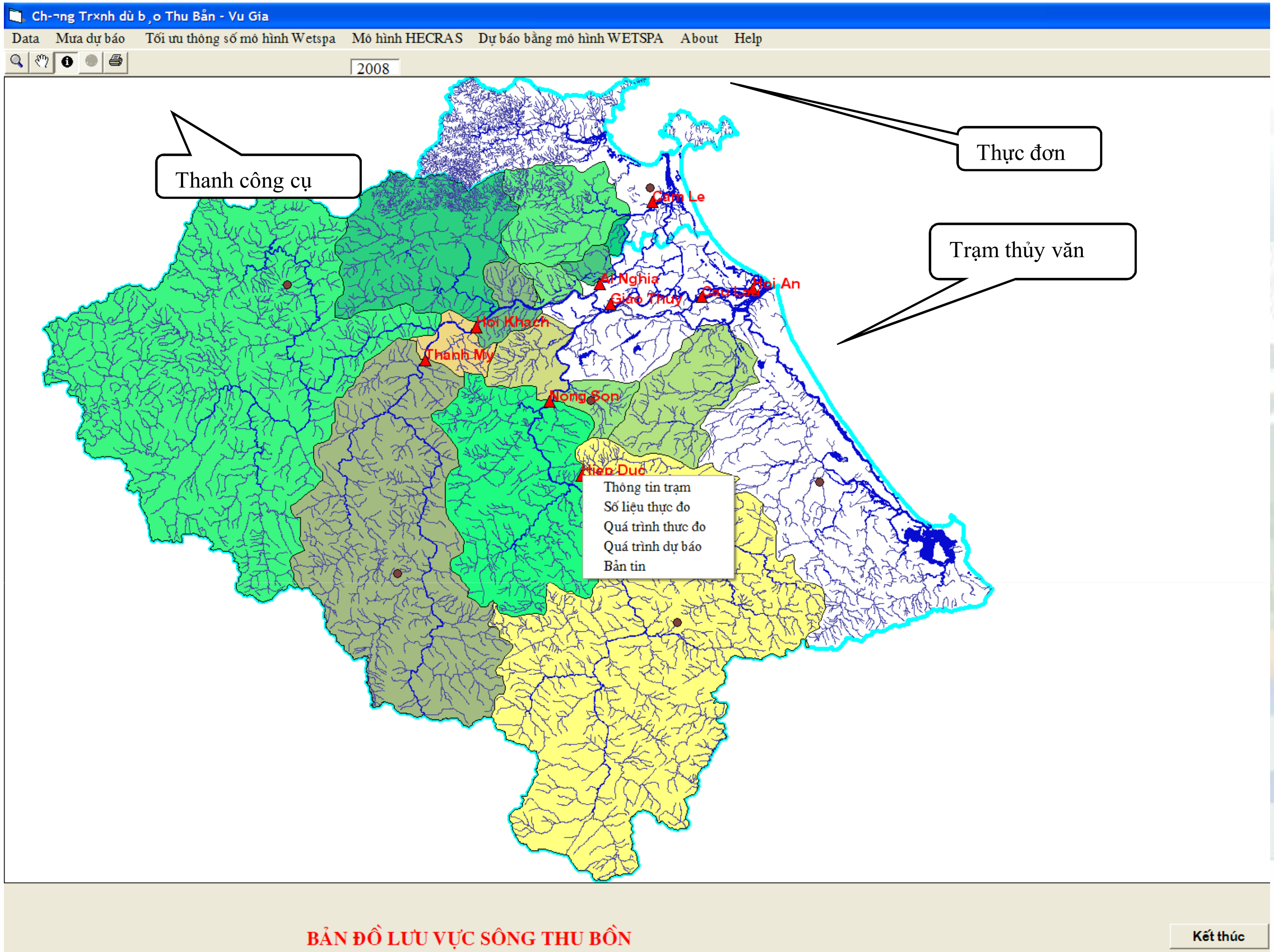
Result

- The model performance is satisfactory for both calibration and validation periods
- The calculated hydrograph is generally in a good agreement compared with the observed hydrograph.
- The peak flood at Ai Nghia and Cau Lau is good simulated with the maximum error of 1,05 m.
- Peak discharges, concentration time, and flow volumes are quite well predicted.
- These results for calibration and verification indicate that the model can represent both low-flow and high-flow runoff.

Flood forecasting software

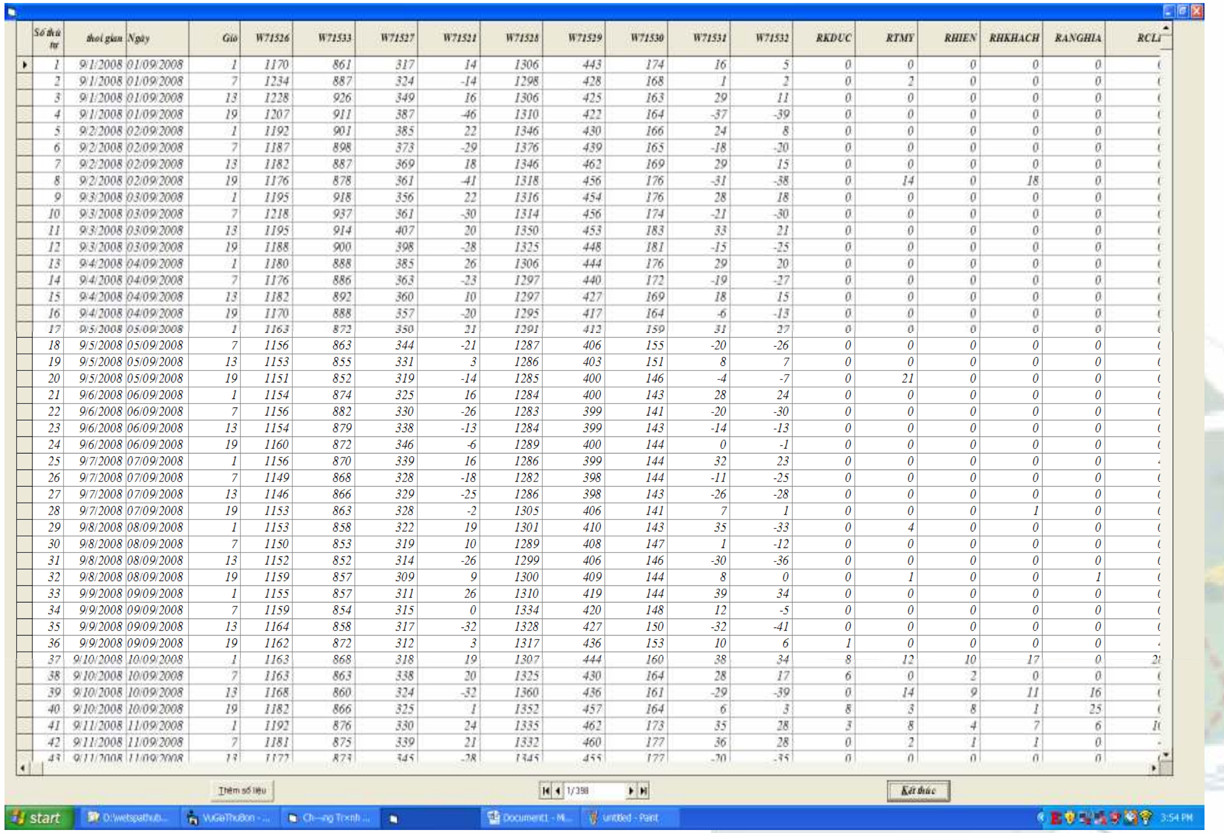


This software supplies automatic tools such as updating, displaying rainfall and water level data, running model, data assimilation, supply bulletins etc

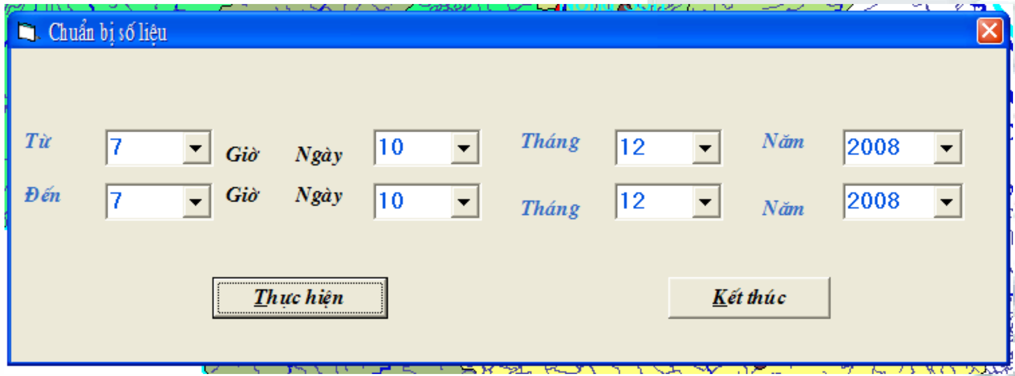


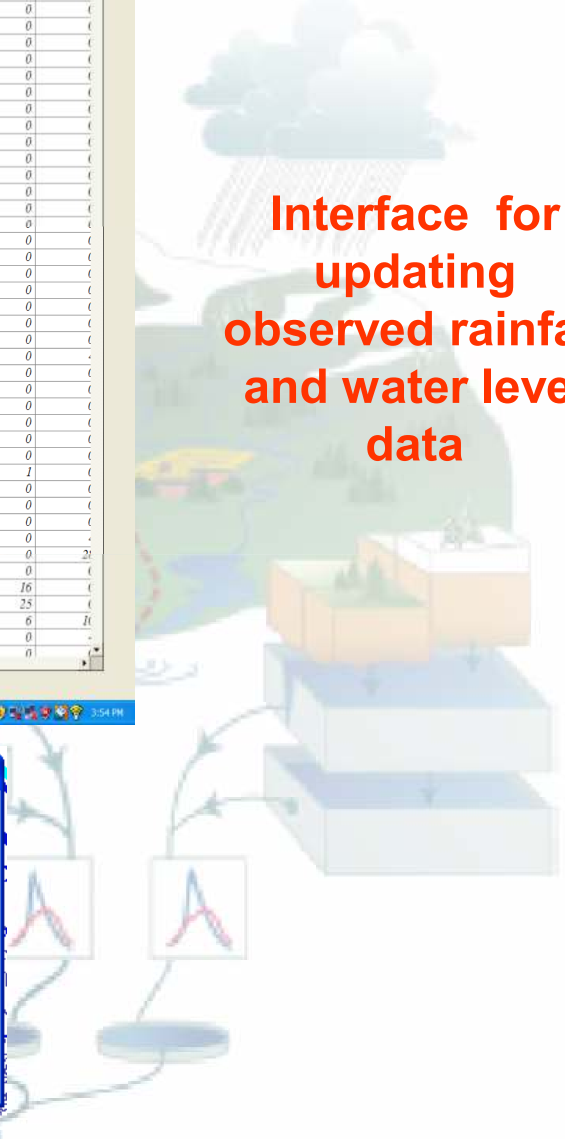
Main interface of Flood forecasting software

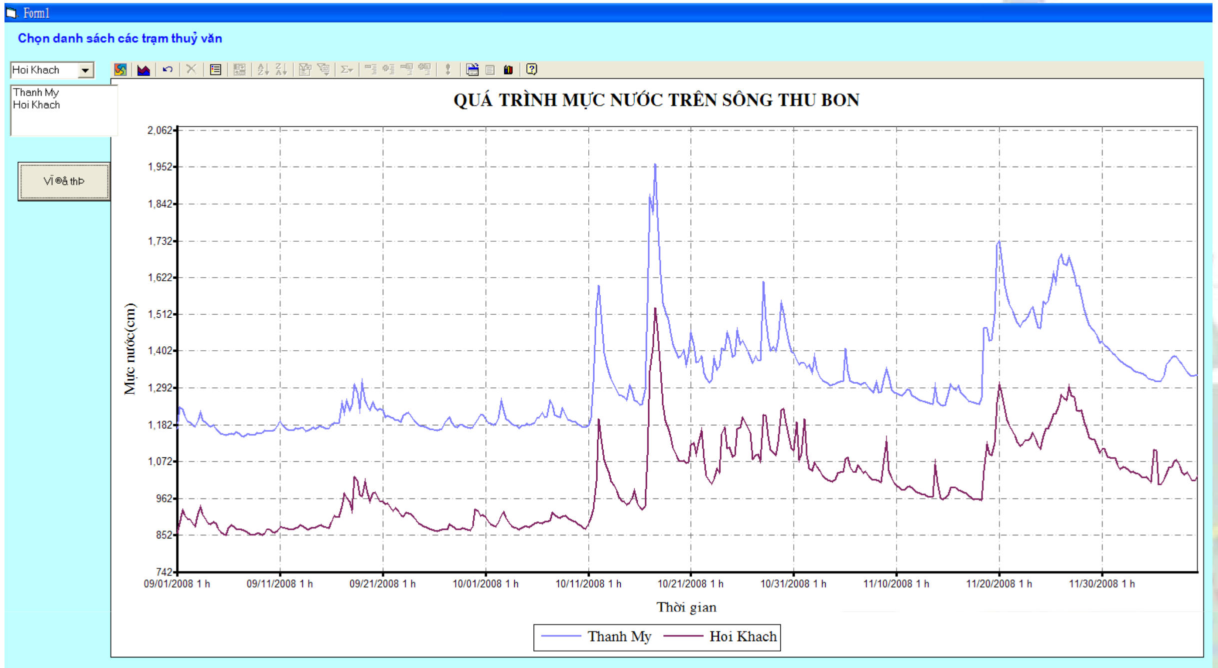
Interface for updating observed rainfall and water level data

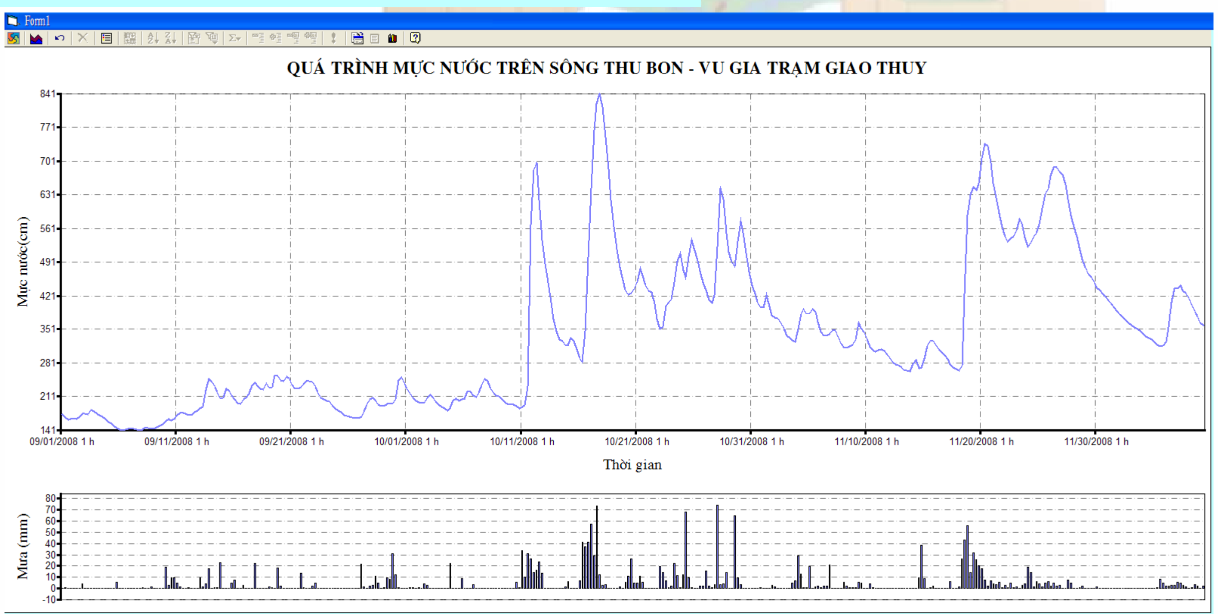


Số thứ tự	thời gian	Ngày	Giờ	W71526	W71533	W71527	W71521	W71528	W71529	W71530	W71531	W71532	RKDUC	RTMY	RHIEN	RHKHACH	RANGHIA	RCLI
1	9/1/2008	01/09/2008	1	1170	861	317	14	1306	443	174	16	5	0	0	0	0	0	
2	9/1/2008	01/09/2008	7	1234	887	324	-14	1298	428	168	1	2	0	2	0	0	0	
3	9/1/2008	01/09/2008	13	1228	926	349	16	1306	425	163	29	11	0	0	0	0	0	
4	9/1/2008	01/09/2008	19	1207	911	387	-46	1310	422	164	-37	-39	0	0	0	0	0	
5	9/2/2008	02/09/2008	1	1192	901	385	22	1346	430	166	24	8	0	0	0	0	0	
6	9/2/2008	02/09/2008	7	1187	898	373	-29	1376	439	165	-18	-20	0	0	0	0	0	
7	9/2/2008	02/09/2008	13	1182	887	369	18	1346	462	169	29	15	0	0	0	0	0	
8	9/2/2008	02/09/2008	19	1176	878	361	-41	1318	456	176	-31	-38	0	14	0	18	0	
9	9/3/2008	03/09/2008	1	1195	918	356	22	1316	454	176	28	18	0	0	0	0	0	
10	9/3/2008	03/09/2008	7	1218	937	361	-30	1314	456	174	-21	-30	0	0	0	0	0	
11	9/3/2008	03/09/2008	13	1195	914	407	20	1350	453	183	33	21	0	0	0	0	0	
12	9/3/2008	03/09/2008	19	1188	900	398	-28	1325	448	181	-15	-25	0	0	0	0	0	
13	9/4/2008	04/09/2008	1	1180	888	385	26	1306	444	176	29	20	0	0	0	0	0	
14	9/4/2008	04/09/2008	7	1176	886	363	-23	1297	440	172	-19	-27	0	0	0	0	0	
15	9/4/2008	04/09/2008	13	1182	892	360	10	1297	427	169	18	15	0	0	0	0	0	
16	9/4/2008	04/09/2008	19	1170	888	357	-20	1295	417	164	-6	-13	0	0	0	0	0	
17	9/5/2008	05/09/2008	1	1163	872	350	21	1291	412	159	31	27	0	0	0	0	0	
18	9/5/2008	05/09/2008	7	1156	863	344	-21	1287	406	155	-20	-26	0	0	0	0	0	
19	9/5/2008	05/09/2008	13	1153	855	331	3	1286	403	151	8	7	0	0	0	0	0	
20	9/5/2008	05/09/2008	19	1151	852	319	-14	1285	400	146	-4	-7	0	21	0	0	0	
21	9/6/2008	06/09/2008	1	1154	874	325	16	1284	400	143	28	24	0	0	0	0	0	
22	9/6/2008	06/09/2008	7	1156	882	330	-26	1283	399	141	-20	-30	0	0	0	0	0	
23	9/6/2008	06/09/2008	13	1154	879	338	-13	1284	399	143	-14	-13	0	0	0	0	0	
24	9/6/2008	06/09/2008	19	1160	872	346	-6	1289	400	144	0	-1	0	0	0	0	0	
25	9/7/2008	07/09/2008	1	1156	870	339	16	1286	399	144	32	23	0	0	0	0	0	
26	9/7/2008	07/09/2008	7	1149	868	328	-18	1282	398	144	-11	-25	0	0	0	0	0	
27	9/7/2008	07/09/2008	13	1146	866	329	-25	1286	398	143	-26	-28	0	0	0	0	0	
28	9/7/2008	07/09/2008	19	1153	863	328	-2	1305	406	141	7	1	0	0	0	1	0	
29	9/8/2008	08/09/2008	1	1153	858	322	19	1301	410	143	35	-33	0	4	0	0	0	
30	9/8/2008	08/09/2008	7	1150	853	319	10	1289	408	147	1	-12	0	0	0	0	0	
31	9/8/2008	08/09/2008	13	1152	852	314	-26	1299	406	146	-30	-36	0	0	0	0	0	
32	9/8/2008	08/09/2008	19	1159	857	309	9	1300	409	144	8	0	0	1	0	0	1	
33	9/9/2008	09/09/2008	1	1155	857	311	26	1310	419	144	39	34	0	0	0	0	0	
34	9/9/2008	09/09/2008	7	1159	854	315	0	1334	420	148	12	-5	0	0	0	0	0	
35	9/9/2008	09/09/2008	13	1164	858	317	-32	1328	427	150	-32	-41	0	0	0	0	0	
36	9/9/2008	09/09/2008	19	1162	872	312	3	1317	436	153	10	6	1	0	0	0	0	
37	9/10/2008	10/09/2008	1	1163	868	318	19	1307	444	160	38	34	8	12	10	17	0	
38	9/10/2008	10/09/2008	7	1163	863	338	20	1325	430	164	28	17	6	0	2	0	0	
39	9/10/2008	10/09/2008	13	1168	860	324	-32	1360	436	161	-29	-39	0	14	9	11	16	
40	9/10/2008	10/09/2008	19	1182	866	325	1	1352	457	164	6	3	8	3	8	1	25	
41	9/11/2008	11/09/2008	1	1192	876	330	24	1335	462	173	35	28	3	8	4	7	6	
42	9/11/2008	11/09/2008	7	1181	875	339	21	1332	460	177	36	28	0	2	1	1	0	
43	9/11/2008	11/09/2008	13	1177	873	345	-28	1345	455	177	-20	-35	0	0	0	0	0	





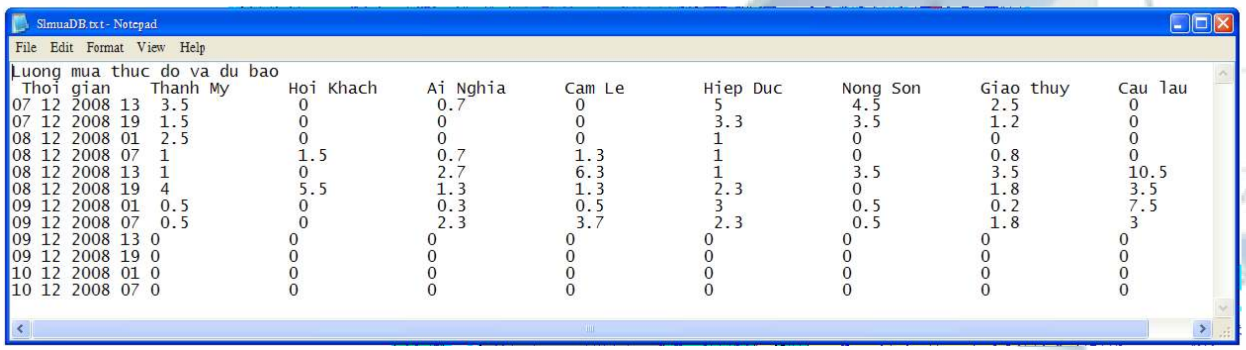




Interface for displaying observed data

Display hydrograph of water level and rainfall of all stations

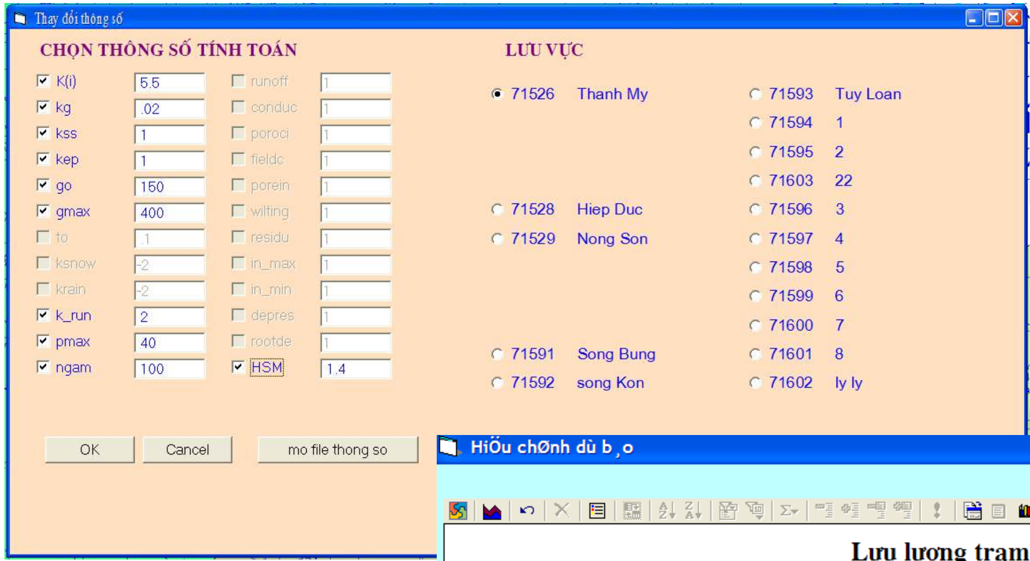
Interface for input forecasted rainfall data



SImuaDB.txt - Notepad

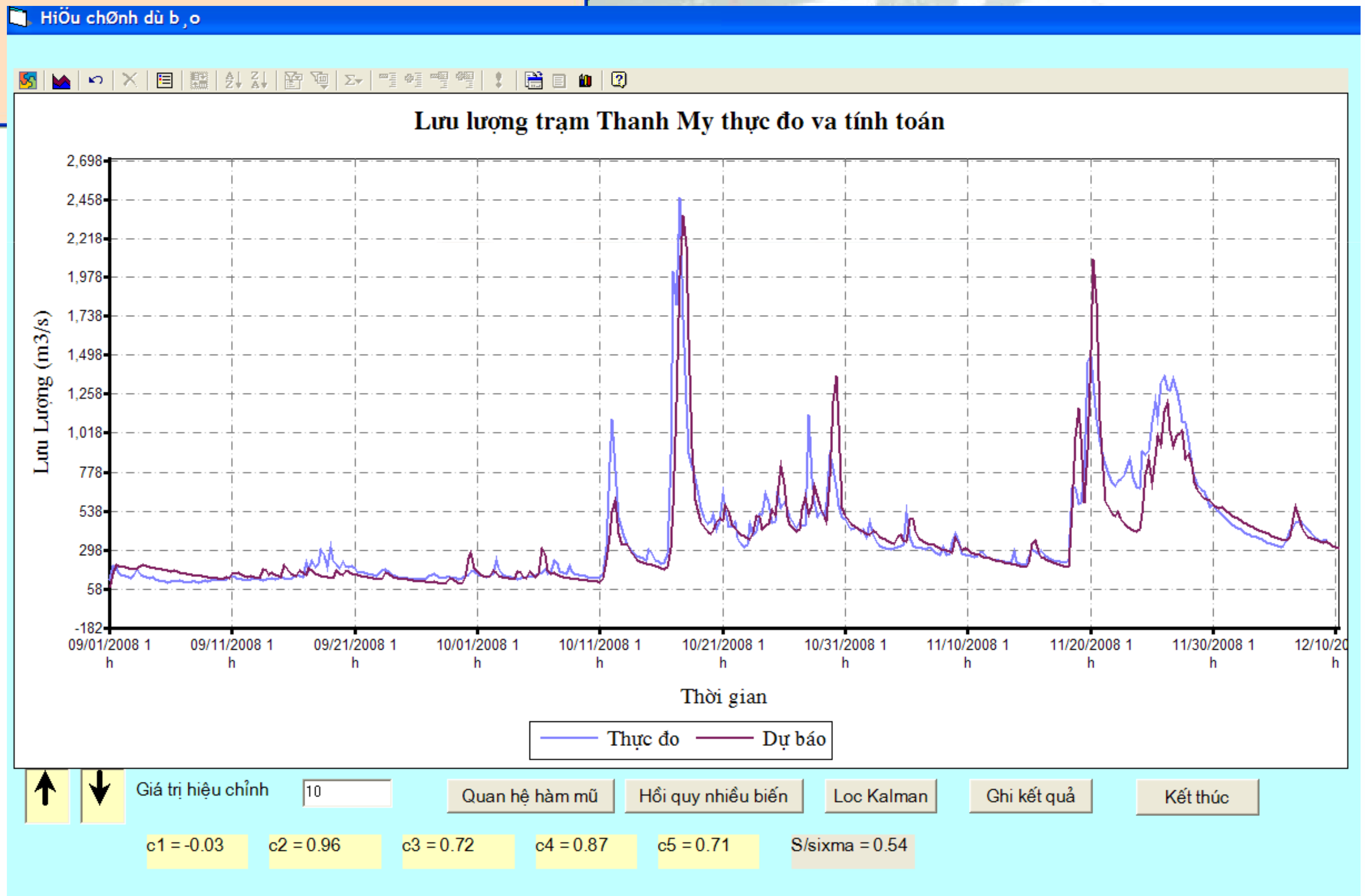
Luong mua thuc do va du bao

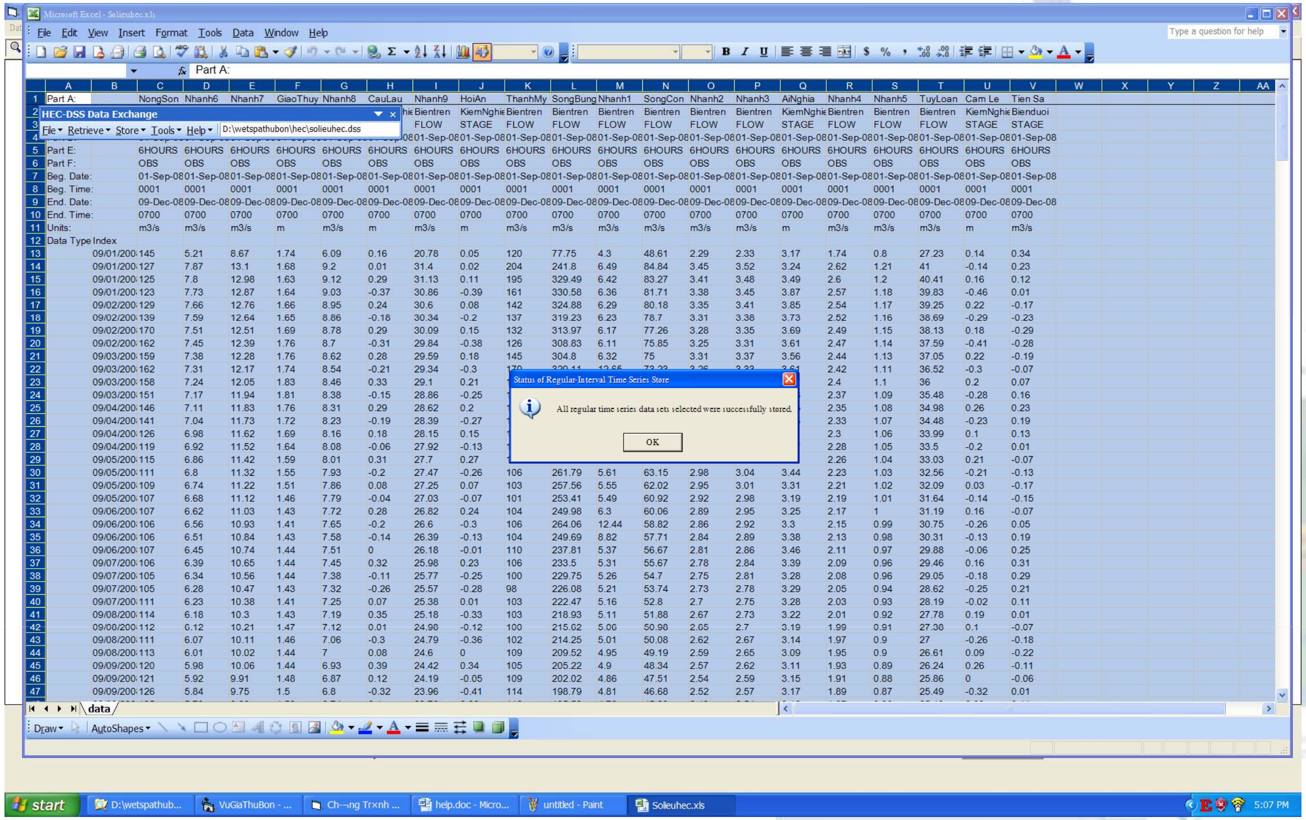
Thoi gian	Thanh My	Hoi Khach	Ai Nghia	Cam Le	Hiep Duc	Nong Son	Giao thuy	Cau lau
07 12 2008 13	3.5	0	0.7	0	5	4.5	2.5	0
07 12 2008 19	1.5	0	0	0	3.3	3.5	1.2	0
08 12 2008 01	2.5	0	0	0	1	0	0	0
08 12 2008 07	1	1.5	0.7	1.3	1	0	0.8	0
08 12 2008 13	1	0	2.7	6.3	1	3.5	3.5	10.5
08 12 2008 19	4	5.5	1.3	1.3	2.3	0	1.8	3.5
09 12 2008 01	0.5	0	0.3	0.5	3	0.5	0.2	7.5
09 12 2008 07	0.5	0	2.3	3.7	2.3	0.5	1.8	3
09 12 2008 13	0	0	0	0	0	0	0	0
09 12 2008 19	0	0	0	0	0	0	0	0
10 12 2008 01	0	0	0	0	0	0	0	0
10 12 2008 07	0	0	0	0	0	0	0	0



Interface for parameter calibration

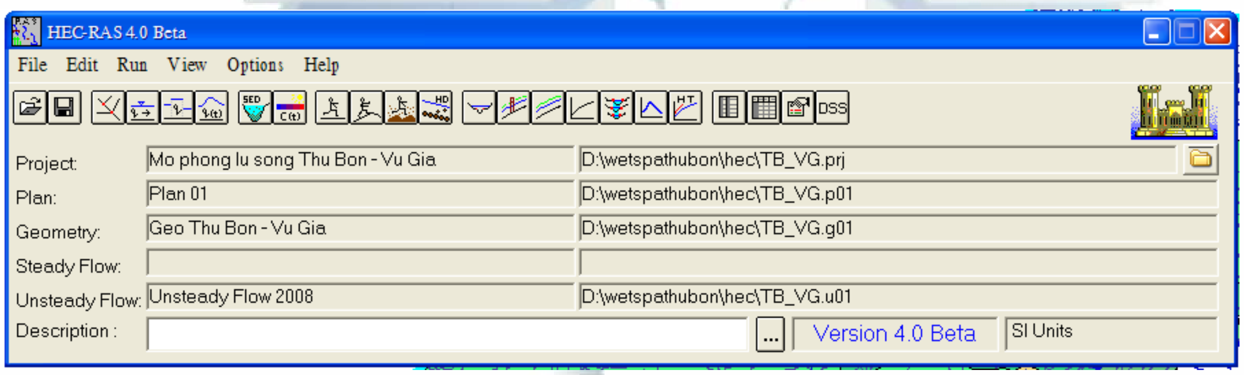
WETSPA implementation





Interface for automatic updating boundary condition for HECRAS model

HECRAS implementation



TRUNG TÂM KTTV QUỐC GIA
Trung tâm Dự báo KTTV TW
Số: HN/05

CỘNG HOÀ XÃ HỘI CHỦ NGHĨA VIỆT NAM
Độc lập - Tự do - Hạnh phúc

BẢN TIN DỰ BÁO KHÍ TƯỢNG THUỶ VĂN HẠN NGẮN
(Lưu vực sông Vu Gia – Thu Bồn)

I- Dự báo mưa lưu vực sông *sông Vu Gia – Thu Bồn* trong 24 giờ tới

II - Dự báo thủy văn
Nhận xét

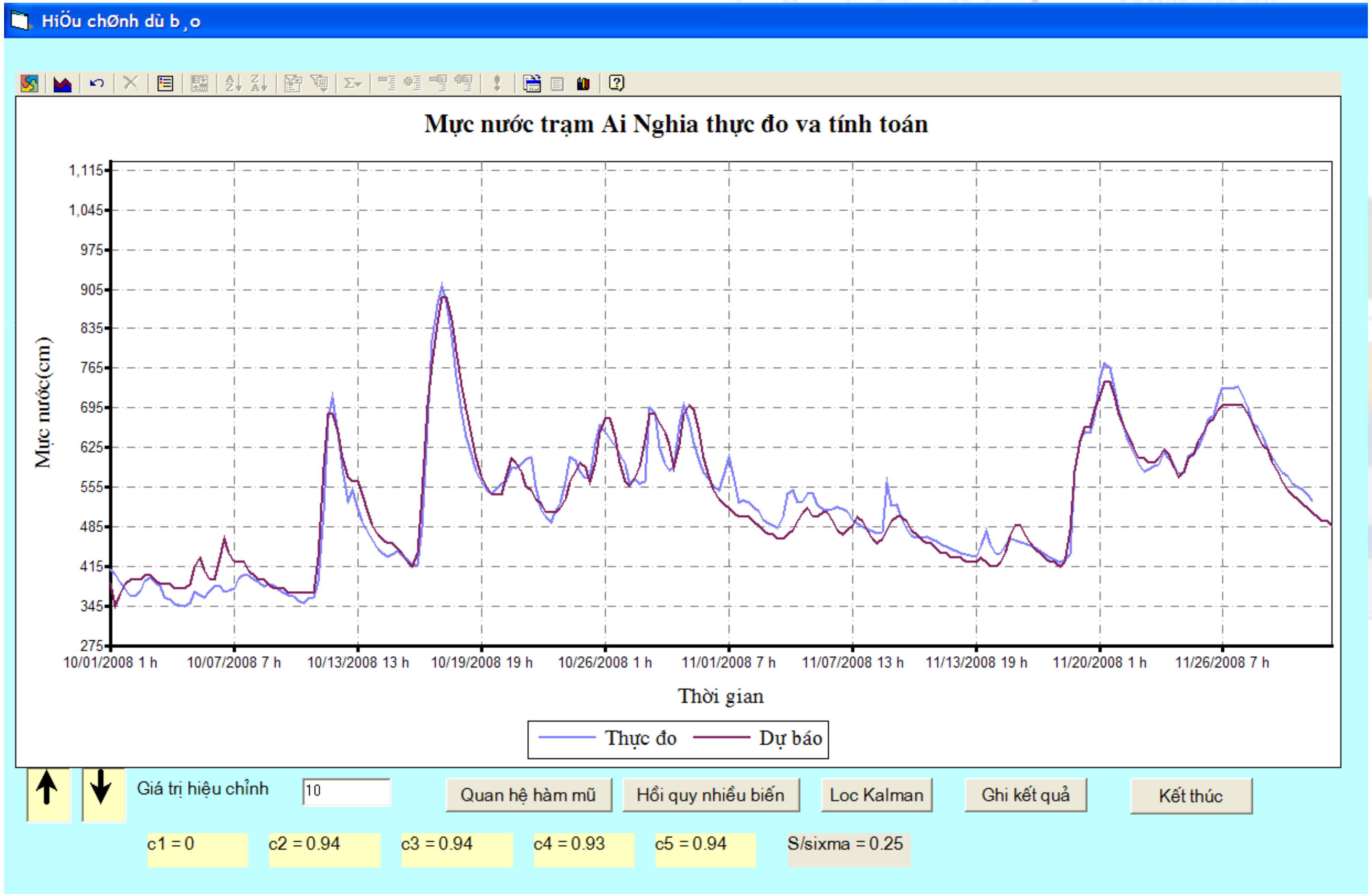
Dự báo

Trạm	**Thực đo**				**Dự báo**			
	Ngày 08/12 - 09/12				***Ngày 09/12 - 09/12***			
	13 h	19 h	1 h	7 h	13 h	19 h	1 h	7 h
Aí nghĩa H, cm	485	481	476	469	412.5	412	398	390
Q, m^3/s	236	230	223	213	133	133	118	111
Cẩm lệ H, cm	37	74	14	29	22.5	25.4	28.3	28.3
Q, m^3/s	314	528	203	269	237	249	265	265
Giao Thủy H, cm	389	378	365	360	352	352	343	334
Q, m^3/s	1550	1490	1430	1400	1360	1360	1320	1270
Thu Bồn H, cm	81	105	66	60	60.7	60.7	60.7	54.7
Q, m^3/s	1010	1250	860	800	808	808	808	748
Hội An H, cm	46	81	25	35	29.9	34.8	34.8	39.8
Q, m^3/s	1140	1660	860	985	919	983	983	1050

Hà Nội, 10h, ngày 9 tháng 12 năm 2008
Người dự báo : **Vũ Đức Long**
Người duyệt bản tin: **Bùi Đức Long**

Flood Forecasting bulletin

This software was experimented on flood forecasting for Thu Bon – Vu Gia river system in flood season 2008 and gave quite good results .



Conclusion

The WETSPA model was calibrated and validated on upstream watersheds in Thu Bon - Vu Gia river basin for which topography, land-use and soil data are available in GIS form

HECRAS model was developed for the hydraulic simulations in this area using the upstream boundary data calculated by the Wetspa model and downstream boundary tidal data.

These results for calibration and verification indicate that the model is suitable for both peak flow prediction and hydrograph simulation.

Flood forecasting software based on two models was developed. This software was experimented on flood forecasting for Thu Bon – Vu Gia river system in flood season 2008 and gave quite good results .

Improvement

Precipitation data: as mentioned above, in this application the grid of precipitation is estimated using Thiessen method. In the future, grid precipitation estimated from radar, satellite image will be developed to improve the quality of model.

Thank you very much for your attention !