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INTERNATIONAL CONFERENCE ON LAND AND WATER DEGRADATION

PROCESSES AND MANAGEMENT

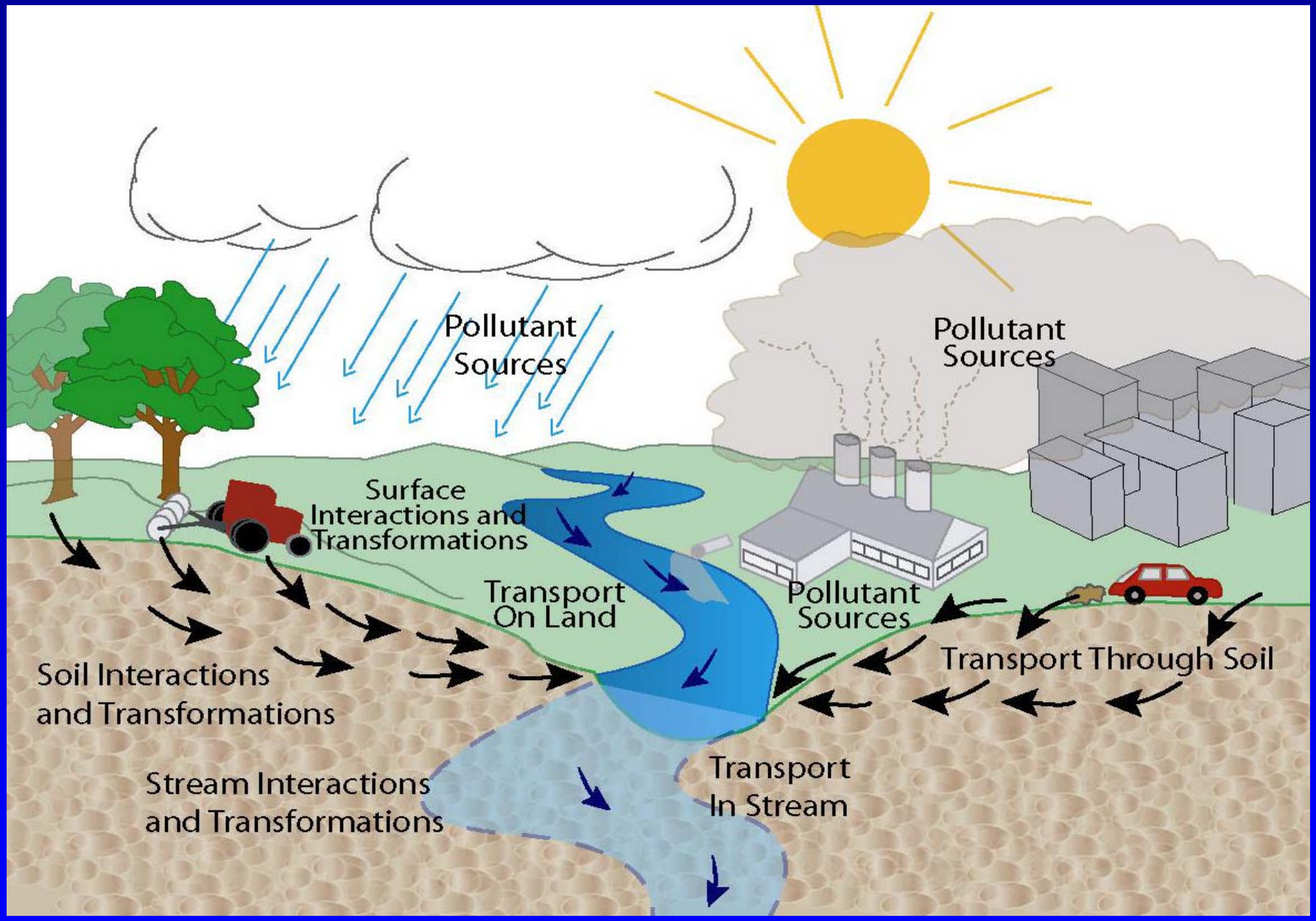
6th–9thSeptember 2009

"An operational model for nutrient dynamics during flood events under anthropogenic impacts in a small mountainous catchment"

Hong Quan Nguyen,Günter Meon

The work is partly a PhD study financially supported by the German Ministry of Education and Research (BMBF) within the IPSWAT program

CONTENTS



(Sources: BASINS lecture notes)

BACKGROUND

Wastewater discharge

Water quality pollution

BACKGROUND

- Water degradation (both quantity and quality) is increasing in the recent decades
- Difficult in controlling wastewater discharge in developing countries (point sources; illegal disposal)
- Non-point sources induced by e.g. extreme rainfall are ignored
- It is required an urgent need of powerful tools, integrated approaches for improving water quality management

BACKGROUND

Countries rely on mathematical models for water resources management

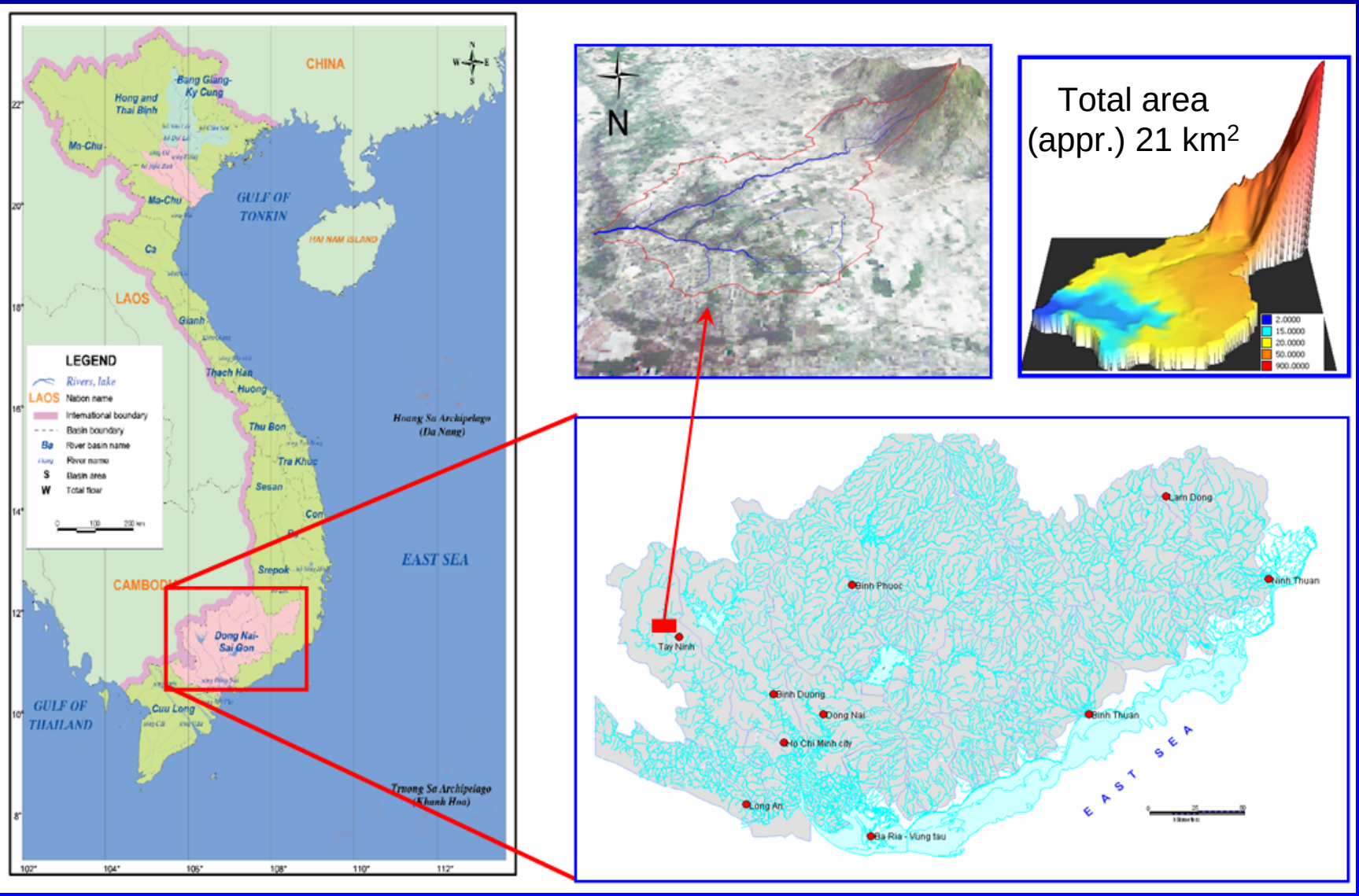
- **EUROPE => Water Framework Directive "models are powerful tools for efficient water management and planning " (**B.Arheimer, J. Olsson , 2005; Barlebo, et al., 2007 **)**
- **The US: Total Maximum Daily Load (TMDL) => "Models are the means of making predictions"; "Model results are the backbone of a TDML" (**K. H. Reckhow et al, 2001; Lung, 2001**)**

OBJECTIVES

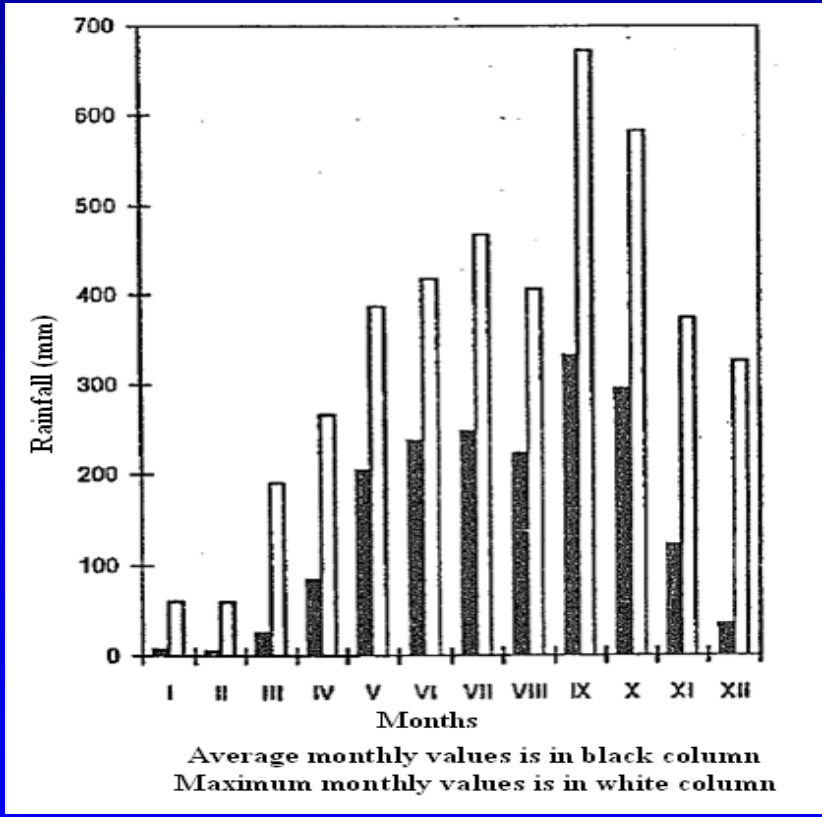
To develop a robust model for watershed water quality management accounting for :

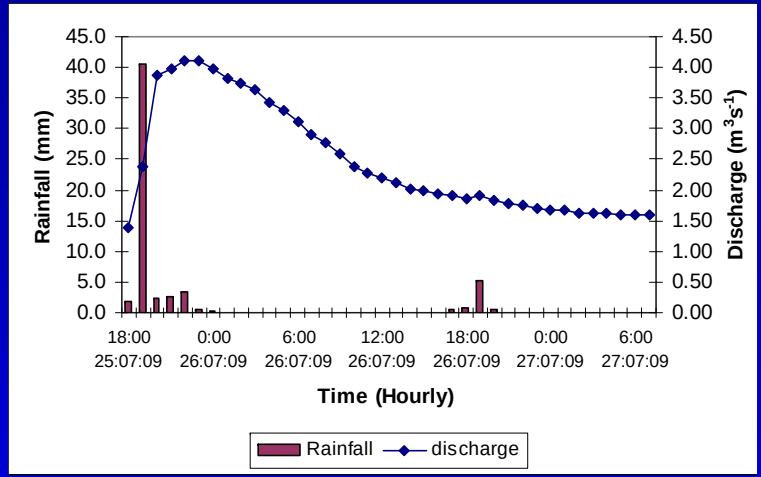
- ***Both point and non-point sources***
- ***Limited data areas (ungauged catchment)***
- ***Uncertainty analysis***

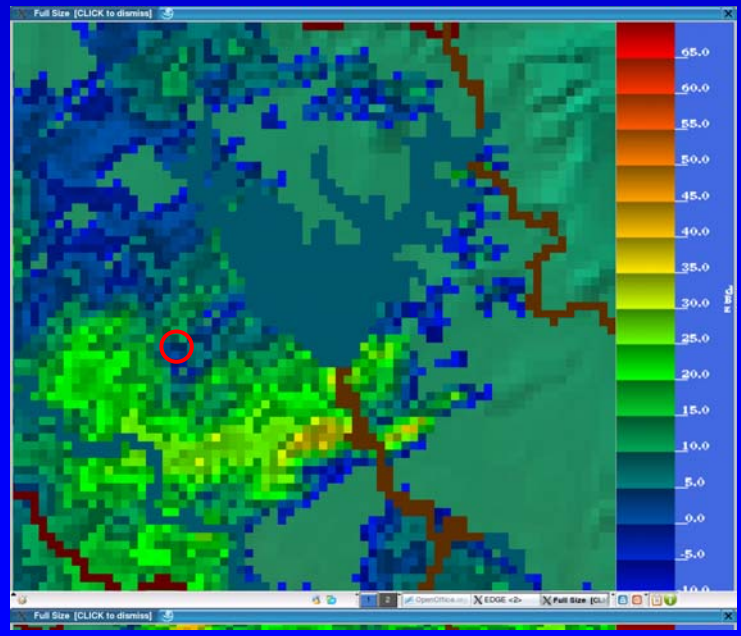
STUDY AREAS


CHINA
Bang Giang-Ky Cung
Hong and Thai Binh
Ma-Chu
Ma-Chu
Ca
GULF OF TONKIN
HAI NAM ISLAND
LAOS
Gianh
Thach Han
Huong
Thu Bon
Tra Khuc
Sesan
Srepok
EAST SEA
Hoang Sa Archipelago (Da Nang)
Dong Nai-Sai Gon
Cuu Long
GULF OF THAILAND
Truong Sa Archipelago (Khanh Hoa)
LEGEND
Rivers, lake
LAOS Nation name
International boundary
Basin boundary
Ba River basin name
River name
S Basin area
W Total flow
N
Total area (appr.) 21 km2
2.0000
15.0000
20.0000
50.0000
900.0000
Lam Dong
Binh Phuoc
Ninh Thuan
Tay Ninh
Binh Duong
Dong Nai
Binh Thuan
Ho Chi Minh city
Long An
Ba Ria - Vung tau
EAST SEA

STUDY AREAS





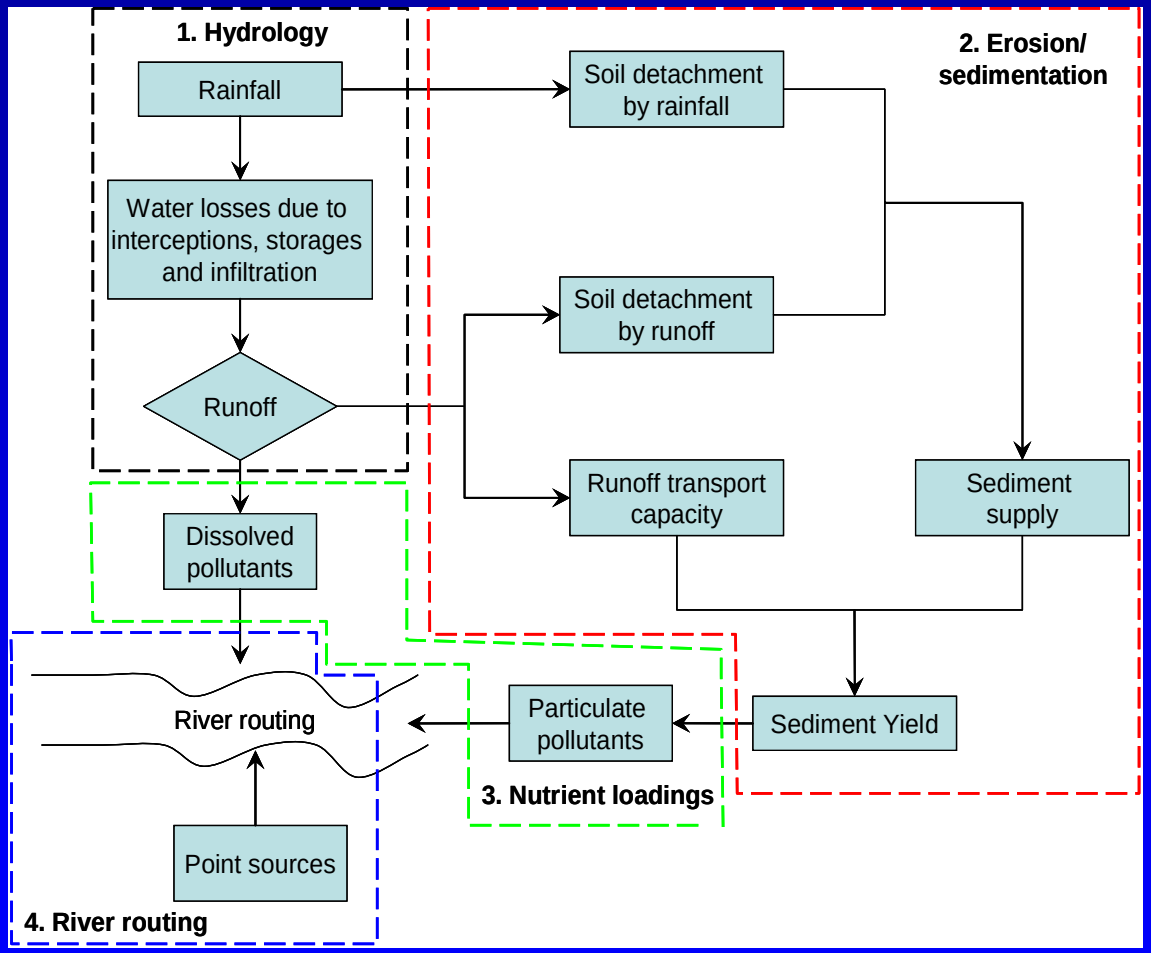


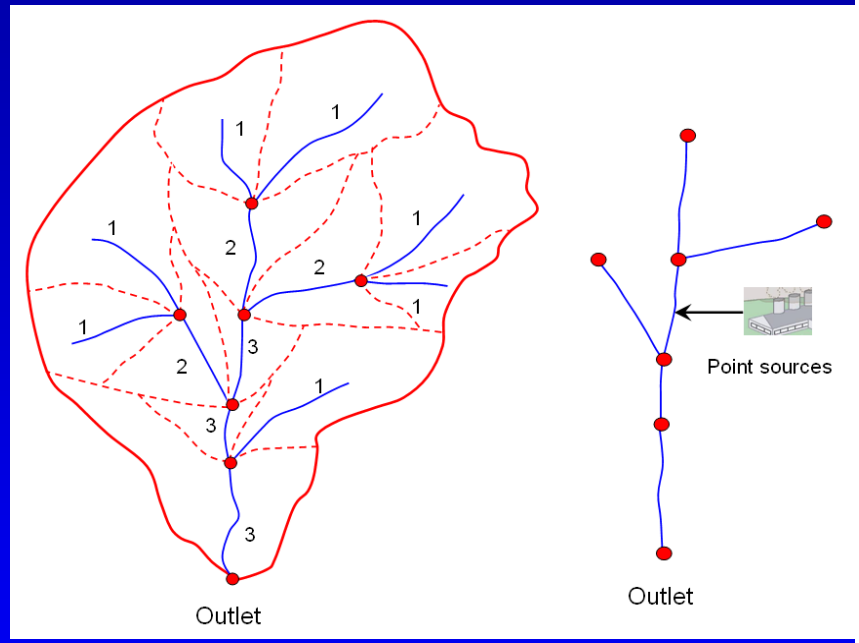
Rainfall distribution

MODEL DEVELOPMENT

- Modelling objectives
- Scale issues (spatial and temporal)
- Model complexity (processes, model coupling)
- Limited data areas (ungauged catchment)
- Uncertainty analysis

MODEL DEVELOPMENT

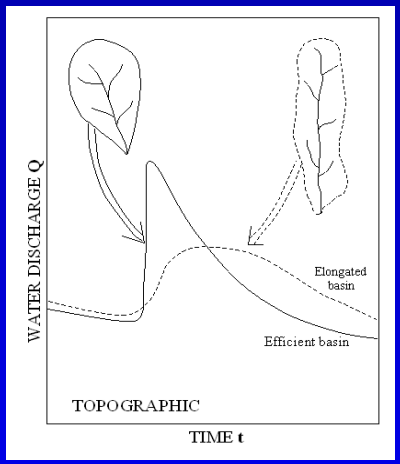




MODEL FRAMEWORK

Hydrology: The Geomorphologic Instantaneous Unit Hydrograph

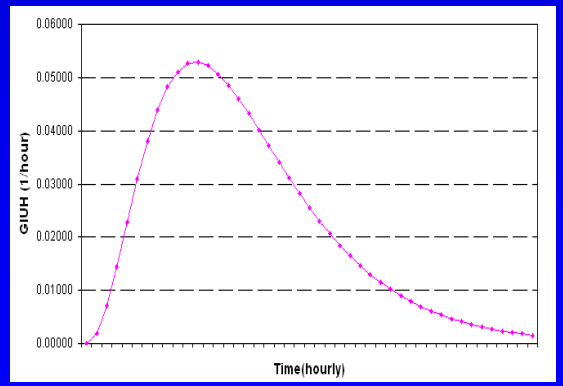
(Rodríguez-Iturbe et al 1979; Bras and Rodriguez-Iturbe , 1989; Nguyen et al, 2009)



- Coupling quantitative geomorphology and hydrologic modeling
- Lumped, empirical model
- Unit hydrograph is calculated by Geomorphologic parameters such as: bifurcation ratio, length ratio, area ratio based on DEM processing, and estimated flow velocity

$$Q(t) = \int_0^t i(\tau)u(t-\tau)$$

$$u(t) = \frac{\partial}{\partial t}\left(\sum_{Si} \Pr ob(T_{Si} \le t) \Pr ob(S_i)\right)$$



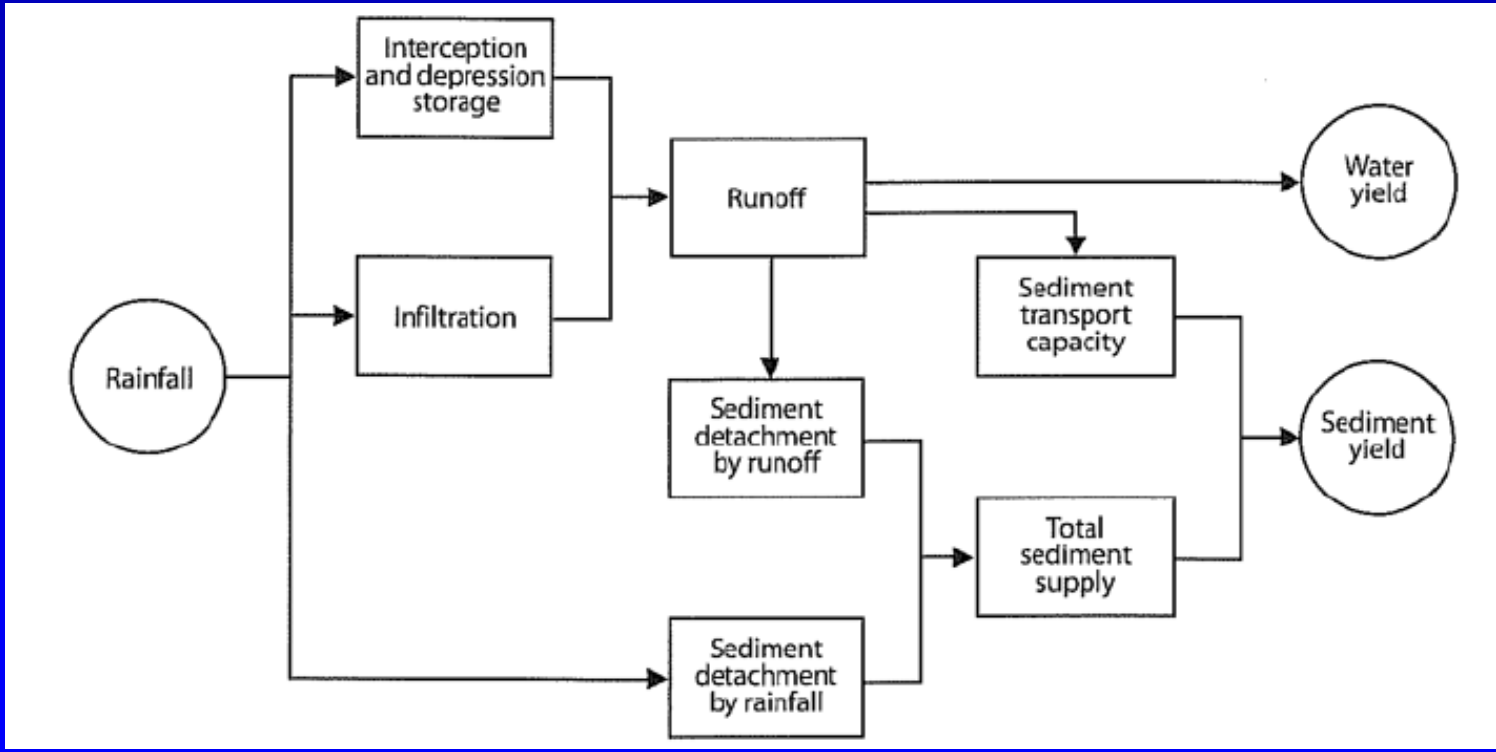
$\Pr ob(S_i)$ **is the probability of a drop which will travel all possible paths *Si* to the outlet.**

$\Pr ob(T_{Si_i})$ **is the probability density function of the total path travel time T_s**

MODEL FRAMEWORK

Erosion, sediment: the simplified process model for sediment yield

(Hartley, 1987a, 1987b; León, et al., 2001)



MODEL DEVELOPMENT

Nutrient loadings: Loading functions

(Haith and Tubbs, 1981; Haith, et al., 1984)

$$LD_{kt} = 0.1 Cd_{kt} Q_{kt} TD_k$$

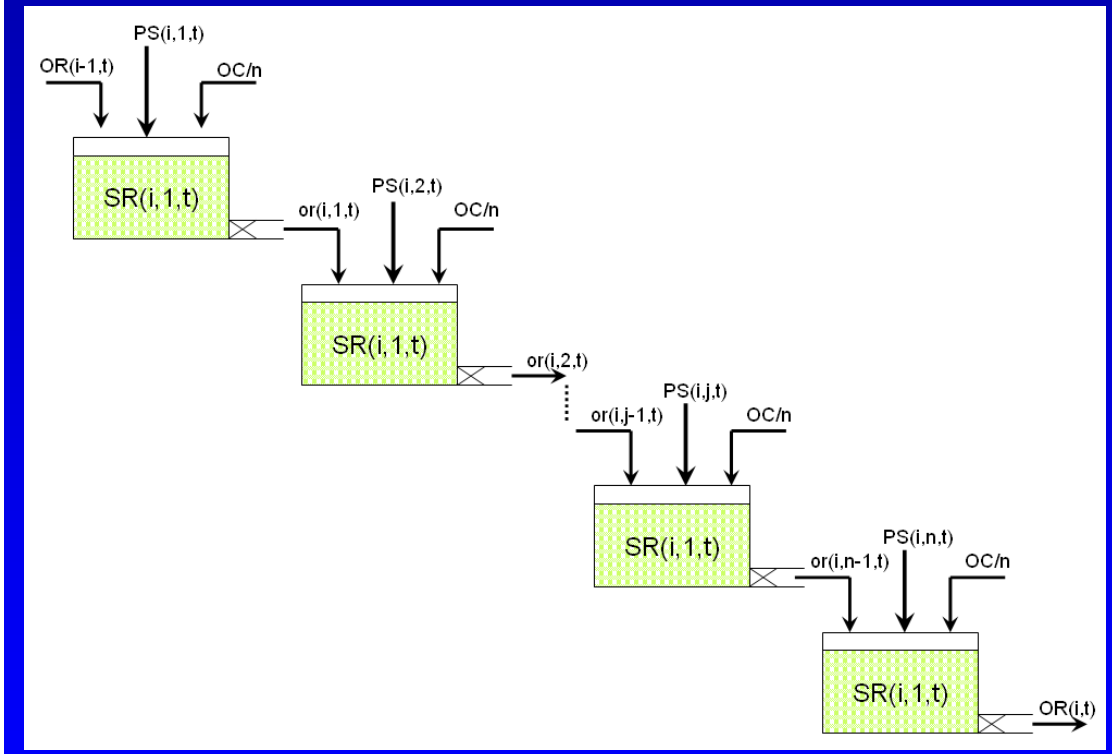
$$LS_{kt} = 0.001\ Cs_{kt} X_{kt} TS_k$$

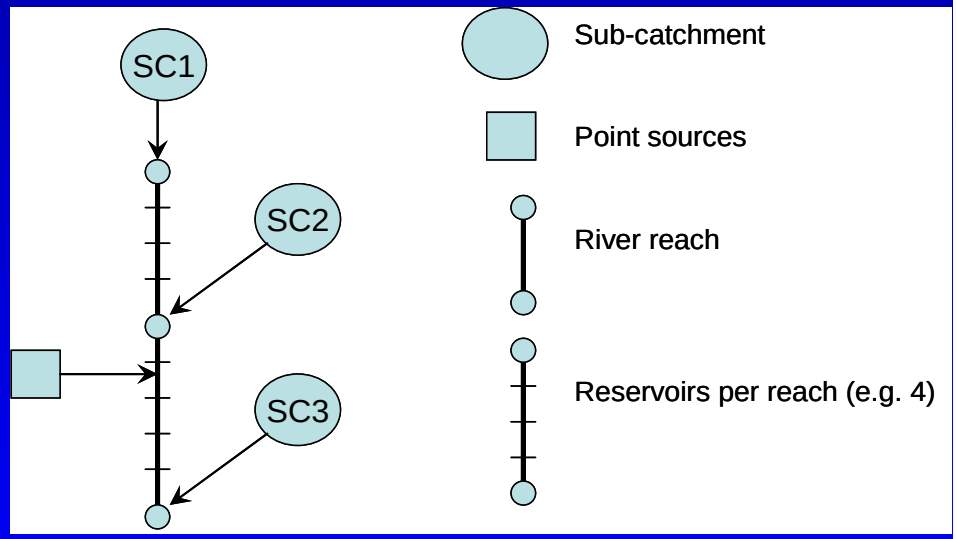
$$C = C_1 \exp\left[\frac{-(F - ABST)}{(K_d)(\frac{1 - POR}{2.65}) + POR}\right]$$

(Knisel, et al., 1993)

MODEL DEVELOPMENT

Flow routing
(Chu, et al., 2008)





$$\frac{dSR(i,j,t)}{dt} = PS(i,j,t) + \frac{OC(ci,t)}{n(i)} + or(i,j-1,t) - or(i,j,t)$$

Assumption:

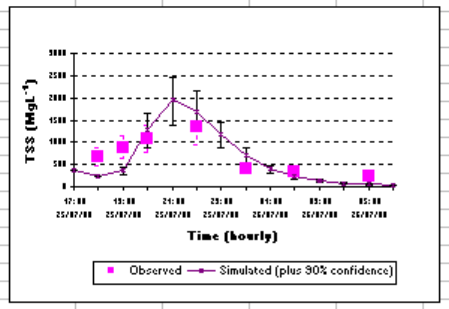
Pollutant loads/concentration are conservative along the river reaches during storm events

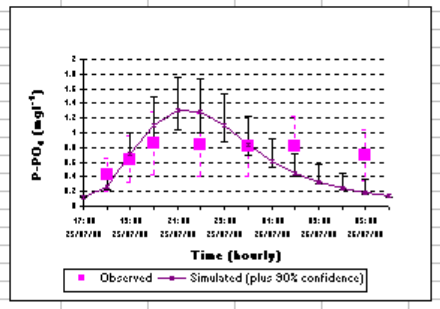
MODEL DEVELOPMENT

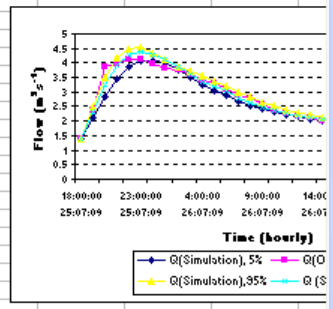
Microsoft Excel - sub_catchment_25July08_V4_MC.xls

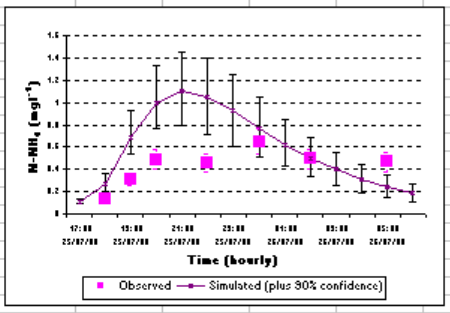
	A	B	C	D	E	F	G
1	acronyms	Description	pdf		original		Ranges
2	CN	Curve Number	uniform	54	54	**55**	(52;56)
3	Rain	Rainfall (mm)	uniform	41	40.5	**42**	(38;42)
4	Vo	Overlandflow velocity (GIUH mo	uniform	0.04	0.04	**0.04**	(0.03;0.05)
5	Vs	Average stream velocity (GIUH	uniform	0.77	0.75	**0.77**	(0.65;0.8)
6	D (K)	Soil erodibility factor	uniform	0.14	0.14	**0.14**	(0.1;0.18)
7	D50	Median size of soil particle	uniform	0.13	0.11	**0.13**	(0.05;0.15)
8	POR	Poprosity of surface soil layer	uniform	0.58	0.6	**0.58**	(0.5;0.7)
9	Cdkt (NO3)	N-NO3 concentrations in dissol	uniform	0.21	0.08	**0.21**	(0.02;0.3)
10	Cskt (P-PO4)	P-PO4 concentrations in solid-p	uniform	3.42	1	**3.42**	(1;5)
11	Cskt (N-NH4)	N-NH4 concentrations in solid-p	uniform	0.27	0.2	**0.27**	(0.04;1)
12	V	River reach velocity (Flow routin	uniform	0.80	0.8	**0.78**	(0.75;0.85)
13	Point sources						
14	TSS	TSS point sources (hourly)	uniform	84.27	50	**84.27**	(10;150)
15	P-PO4	P-PO4 point sources (hourly)	uniform	0.56	0.8	**0.56**	(0.5;1)
16	N-NH4	N-NH4 point sources (hourly)	uniform	0.77	0.6	**0.77**	(0.4;1)
17	N-NO3	N-NO3 point sources (hourly)	uniform	0.89	1.2	**0.89**	(0.6;1.5)

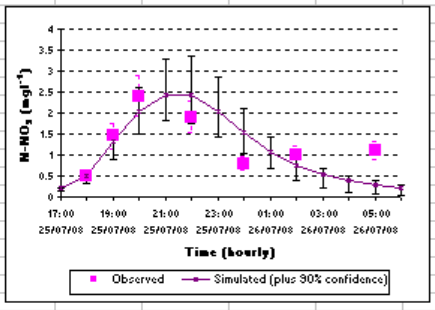
18	Computed	Observed	y_a	(y-y_c)^	(y-y_a)^2	NSE	RSR
19	1.39	1.39	3.10	3E-06	2.9411	0.94	0.16423279
20	2.31	2.39		0.005	0.5137	0.92	
21	3.23	3.86		0.403	0.5786	0.81	
22	3.91	3.98		0.005	0.7752	0.95	
23	4.29	4.10		0.034	1.0005		
24	4.39	4.10		0.083	1.0005		
25	4.30	3.98		0.101	0.7752		
26	4.10	3.82		0.076	0.5195		
27	3.85	3.74		0.011	0.4107		
28	3.60	3.62		7E-04	0.2715		
29	3.37	3.42		0.003	0.1033		
30	3.17	3.30		0.018	0.0407		
31	3.02	3.11		0.008	4E-06		
32	2.80	2.91		0.01	0.0391		
33	2.63	2.79		0.025	0.1008		
34	2.48	2.59		0.011	0.2674		
35	2.36	2.39		6E-04	0.5137		
36	2.26	2.27		2E-05	0.6998		
37	2.18	2.19		5E-05	0.8398		
38	2.11	2.11		6E-06	0.9925		
39	2.05	2.03		5E-04	1.158		
40	2.00	1.99		1E-04	1.2455		
41	1.95	1.95		1E-05	1.3362		
42	1.91	1.91		2E-06	1.4302		
43	1.87	1.87		7E-06	1.5273		
44	1.83	1.91		0.005	1.4302		
45	1.80	1.83		8E-04	1.6275		

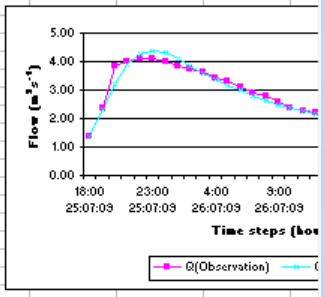






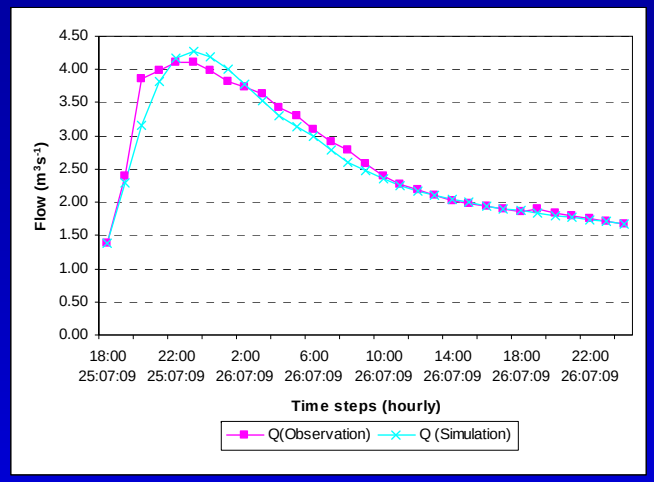




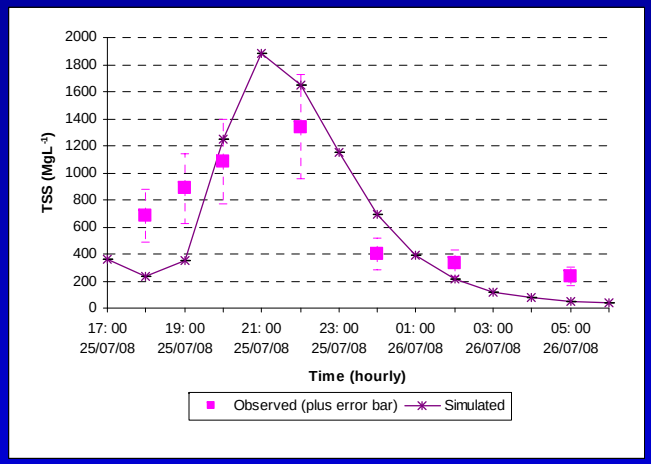


Landus_par / Unchanged_par / Time_series_data / Erosion / Diffuse_pollution / pointsources / reaches_TSS / reaches_PO4 / reaches_NH4 / reaches_NO3 / MC_Graphs / Horton_numb

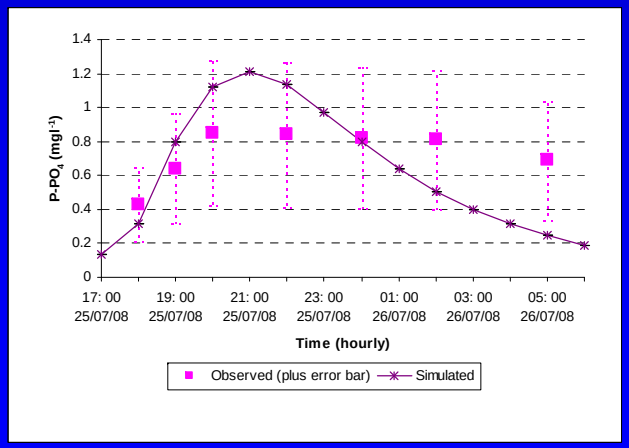
RESULTS



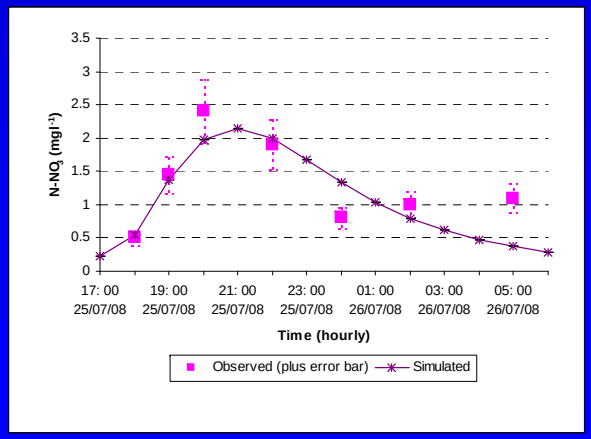
Flow discharge



Suspended solid



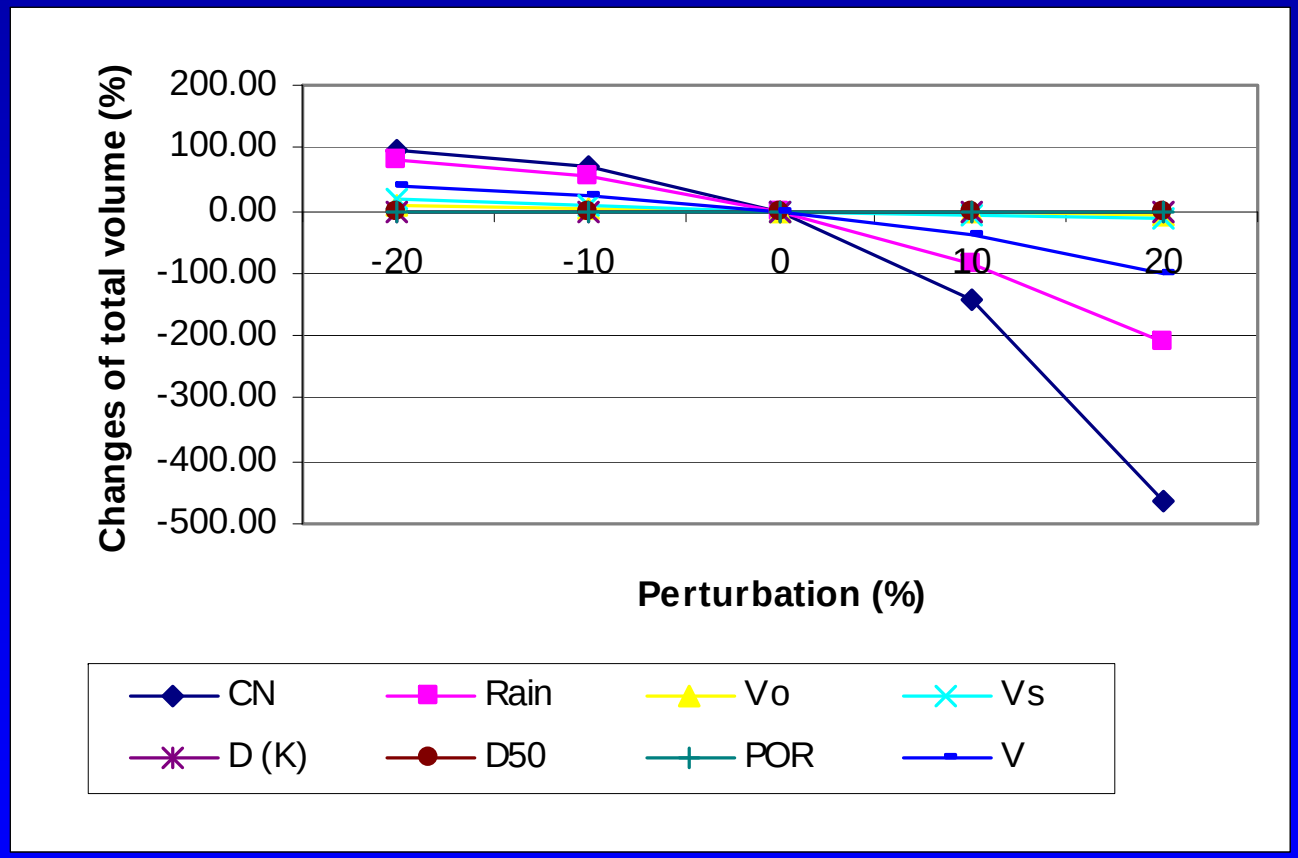
P-PO4



N-NO3

MODEL UNCERTAINTY

Sensitivity analysis

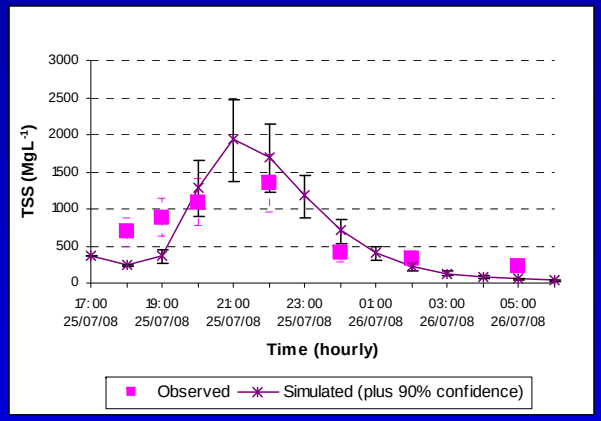


MODEL UNCERTAINTY

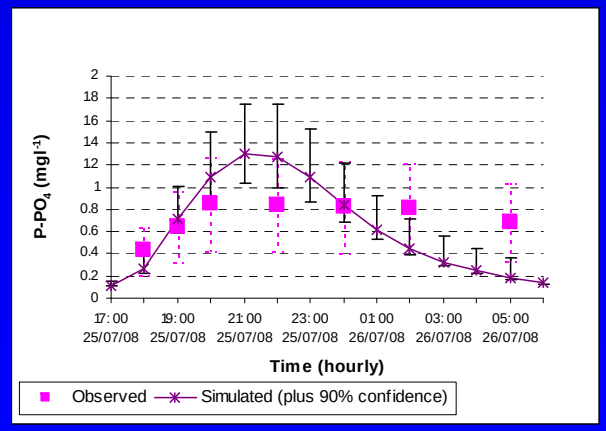
Monte-Carlo simulation

Acronyms	Description	pdf	Calibrated values	(min;max)
CN	Curve Number	uniform	54	(52;56)
Rain	Rainfall (mm)	uniform	40.5	(38;42)
Vo	Overlandflow velocity (GIUH module)	uniform	0.04	(0.03;0.05)
Vs	Average stream velocity (GIUH module)	uniform	0.75	(0.65;0.8)
D (K)	Soil erodibility factor	uniform	0.14	(0.1;0.18)
D50	Median size of soil particle	uniform	0.11	(0.05;0.15)
POR	Poprosity of surface soil layer	uniform	0.6	(0.5;0.7)
Cdkt (NO_3)	N-NO_3 concentrations in dissolved forms	uniform	0.08(*)	(0.02;0.3)
Cskt (P-PO_4)	P-PO_4 concentrations in solid-phase forms	uniform	1 (*)	(1;5)
Cskt (N-NH_4)	N-NH_4 concentrations in solid-phase forms	uniform	0.2 (*)	(0.04;1)
V	River reach velocity (Flow routing module)	uniform	0.8	(0.75;0.85)
TSS	TSS point sources (hourly)	uniform	50	(30;100)
P-PO_4	P-PO_4 point sources (hourly)	uniform	0.8	(0.5;1)
N-NH_4	N-NH_4 point sources (hourly)	uniform	0.6	(0.4;1)
N-NO_3	N-NO_3 point sources (hourly)	uniform	1.2	(0.6;1.5)

(*): multiply factor for each land use



Suspended solid



P-PO4

CONCLUSIONS

- Non-point sources are significant pollution contributions to surface water in Vietnam
- A robust modelling framework has been developed and tested
- Uncertainty sources

OUTLOOKS

- Integrating model algorithms in GIS environments
- Improving monitoring data to reduce uncertainty
- Model-based water quality management at catchment scale
- Adaptive water quality management


Thank you for your attention