Modelling sediment yield of a highly erodible catchment based on reservoir siltation volumes

G. Bussi [1], F. Francés [1], J. A. López-Tarazón [2], R. J. Batalla [2,3,4]

1 - Research Institute of Water and Environmental Engineering, Universitat Politècnica de València, Spain
2 Department of Environment and Soil Sciences, University of Lleida, Lleida, Spain
3 - Catalan Institute for Water Research, Girona, Spain
4 - Forest Science Centre of Catalonia, Solsona, Spain

EGU General assembly – Vienna – April 2013

Introduction

- *Problem*: sediment model application is limited by data availability:
  - **No or little availability** of gauged sediment series in almost all catchment;
  - **Proxy data** must be used.

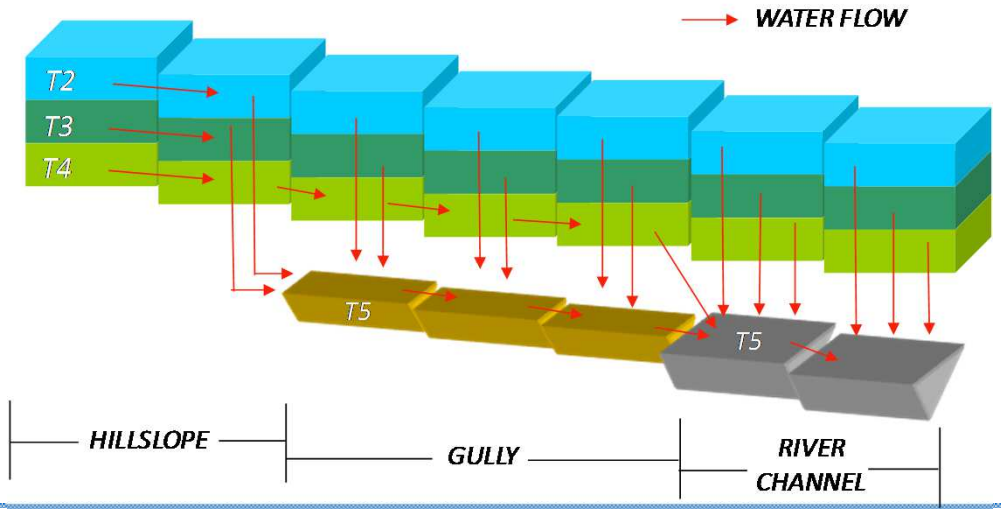
- *Aim of the work*: **calibration and validation** of a sediment model in a highly erodible catchment (Ésera catchment) using **reservoir sedimentation**.
  - 1 – sedimentation data: the Barasona reservoir (Spain);
  - 2 – gauged data (for model verification): suspended sediment series of the Isábena River (tributary of the Ésera River).

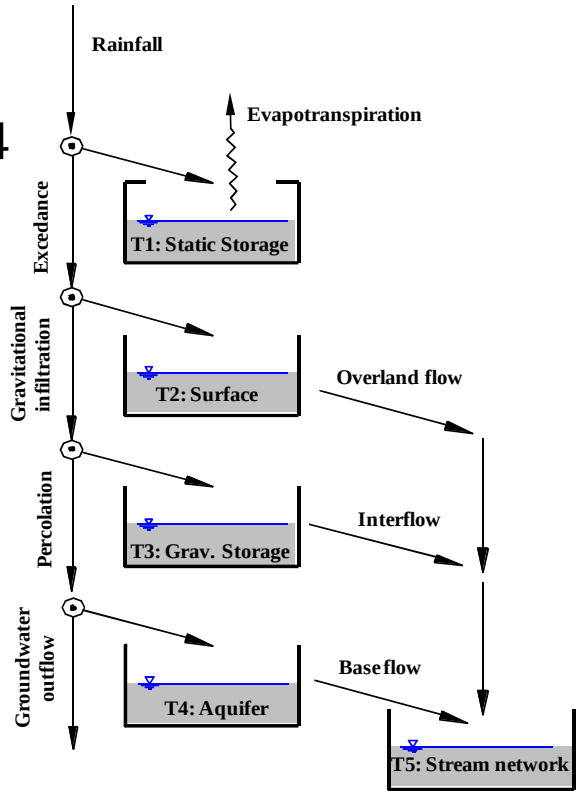
Introduction

- Methodology:
  - 1 – Calibration and validation of the hydrological sub-model;
    - Data: gauged water discharge.
  - 2 – Calibration and validation of the sediment sub-model;
    - Data: reservoir sedimentation volumes.
  - 3 – Reservoir depositional history reconstruction.
  - 4 – Verification of the sediment sub-model:
    - Data: gauged suspended sediment discharge.
  - 5 – Results analysis.

The model

- TETIS model: hydrological sub-model
  - Developed in the TU of Valencia since 1994
  - Distributed and conceptual (tank structure) model, with physically based parameters
  - Reproduction of hydrological cycle spatial variability
  - It uses all spatial information available



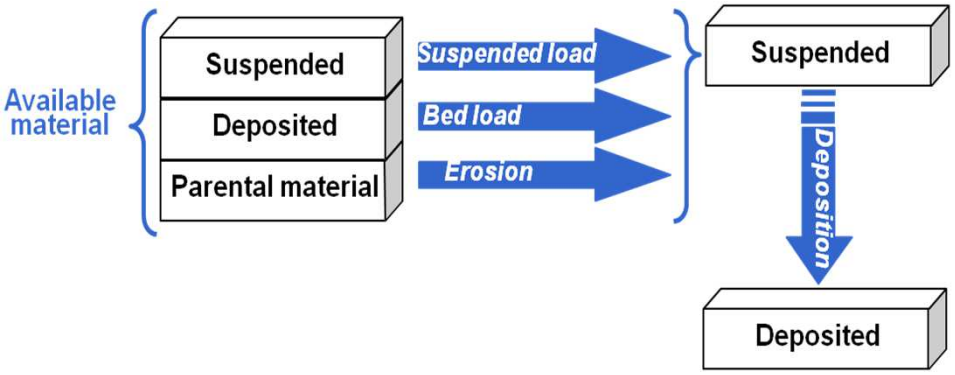


The model

- TETIS model: sediment sub-model
  - Integration of CASC2D-SED (Julien and Rojas, 2002) in TETIS
  - Balance between water transport capacity and sediment availability
  - Hillslope transport capacity: modified Kilinc – Richardson equation (Julien, 1995) (1)
  - Gully and channel transport: Engelund – Hansen equation (2)

(1) $$Q_h = \frac{1}{\gamma_s} W \alpha S_o^{1.66} \left(\frac{Q}{W}\right)^{2.035} \frac{K}{0.15} C P$$

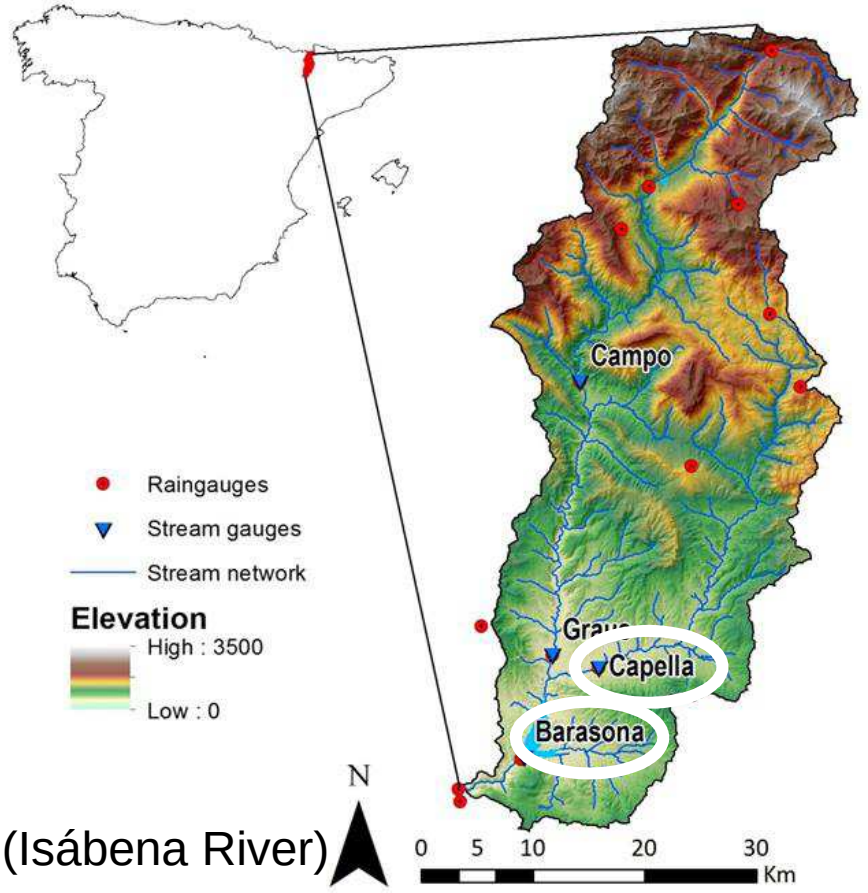
(2) $$C_{w,i} = \beta \left(\frac{G}{G-1}\right) \frac{V S_f}{\sqrt{(G-1) g d_i}} \sqrt{\frac{R_h S_f}{(G-1) d_i}}$$



Study area

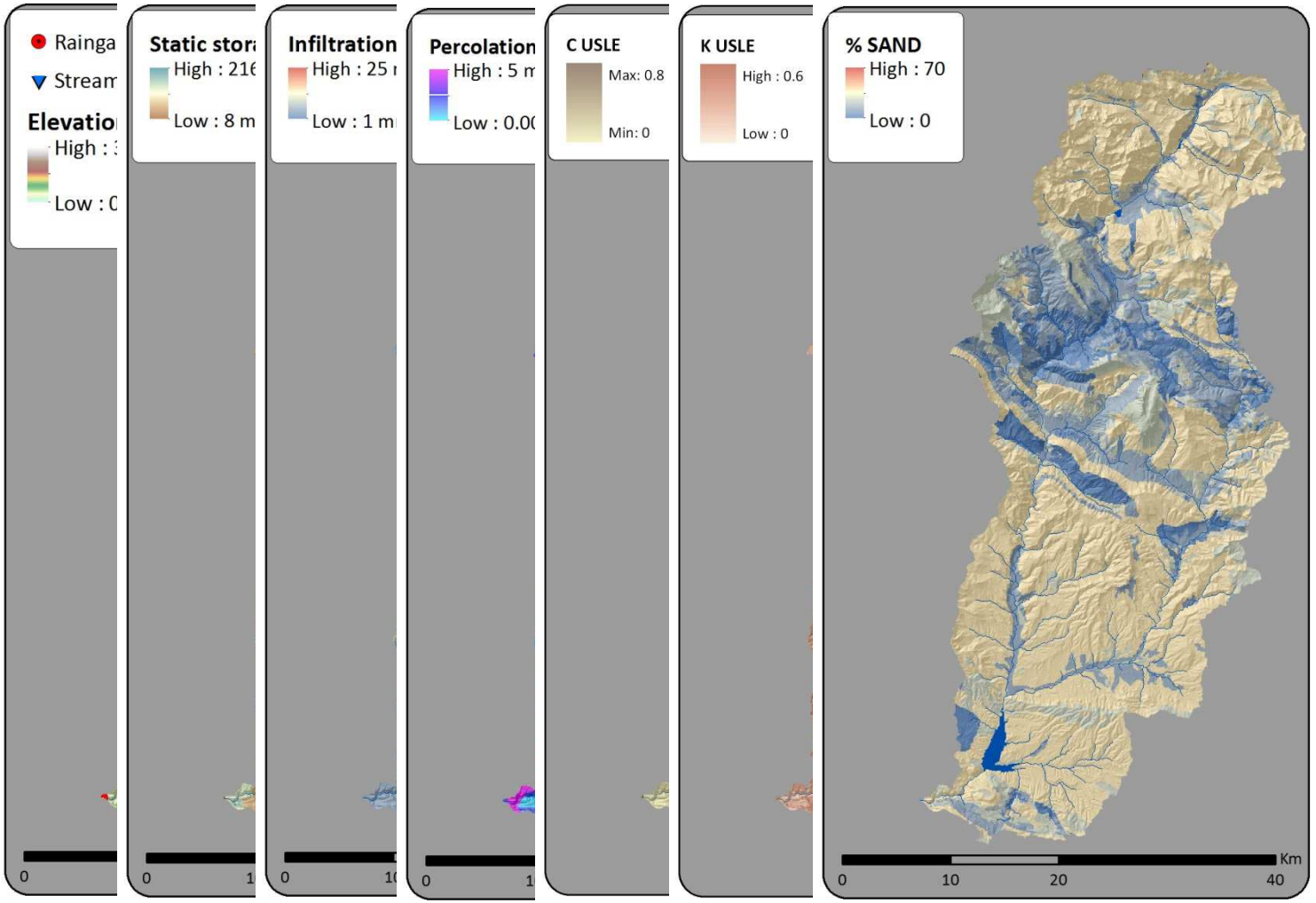
- Ésera River catchment (Southern Central Pyrenees, Spain)

  - 1500 km^2;
  - Mountain catchment;
  - Highly erodible (marls and badlands);
  - Drained by a large reservoir (Barasona reservoir, 92.2 Hm^3);
  - Sediment gauged data: suspended sed. at Capella station (Isábena River)



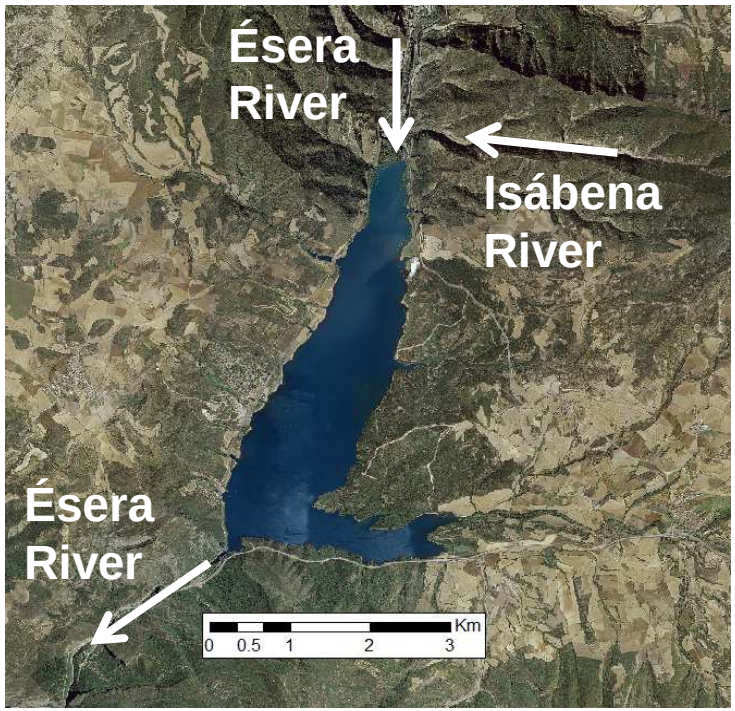
The model parameters

- Model parameters:



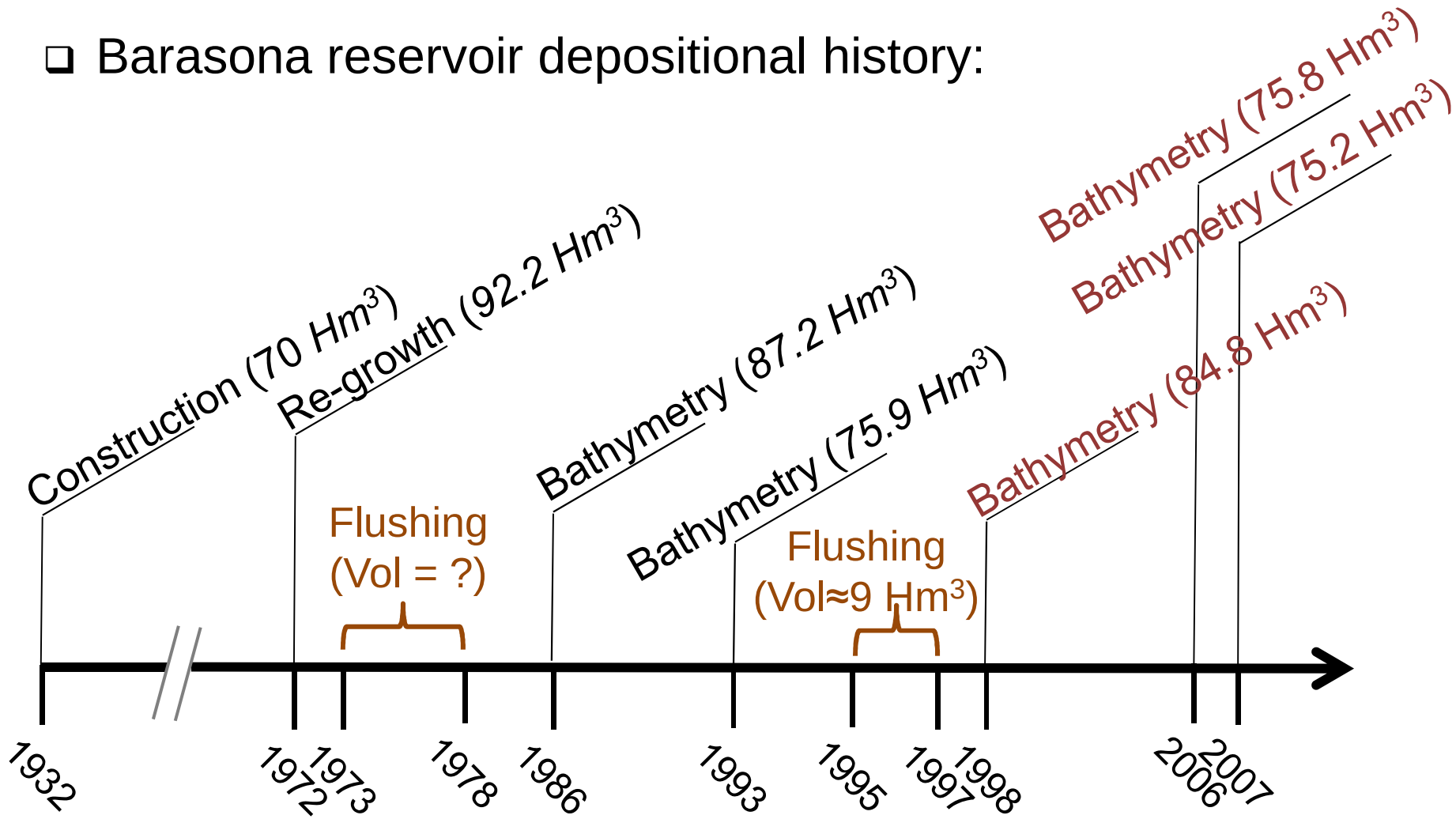
Sediment data

- Barasona reservoir:
  - Built in 1932 (70 Hm^3)
  - Regrown in 1972 (92.2 Hm^3)
  - High siltation rates
  - Various bathymetries available



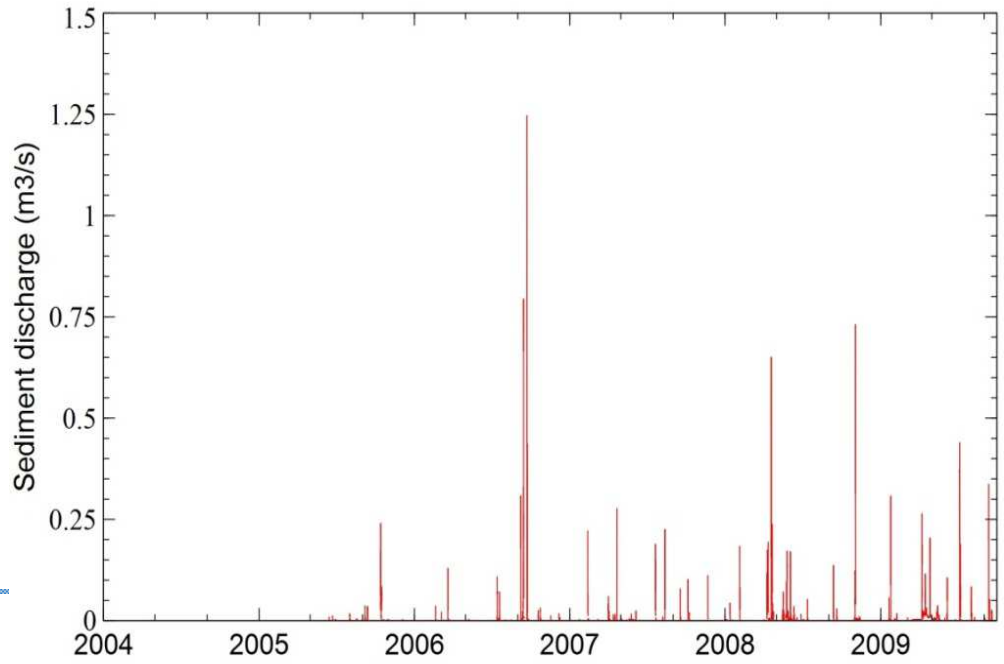
Sediment data

- Barasona reservoir depositional history:



Sediment data

- Measured suspended sediments:
  - Gauged by the University of Lleida (Spain) team – *López-Tarazón et al. 2009, Geomorphology*;
  - Only suspended sediment (the bed load fraction is almost negligible);
  - Very high concentrations: up to 300 g/l;
  - Techniques:
    - Manual sampling
    - Turbidimeter

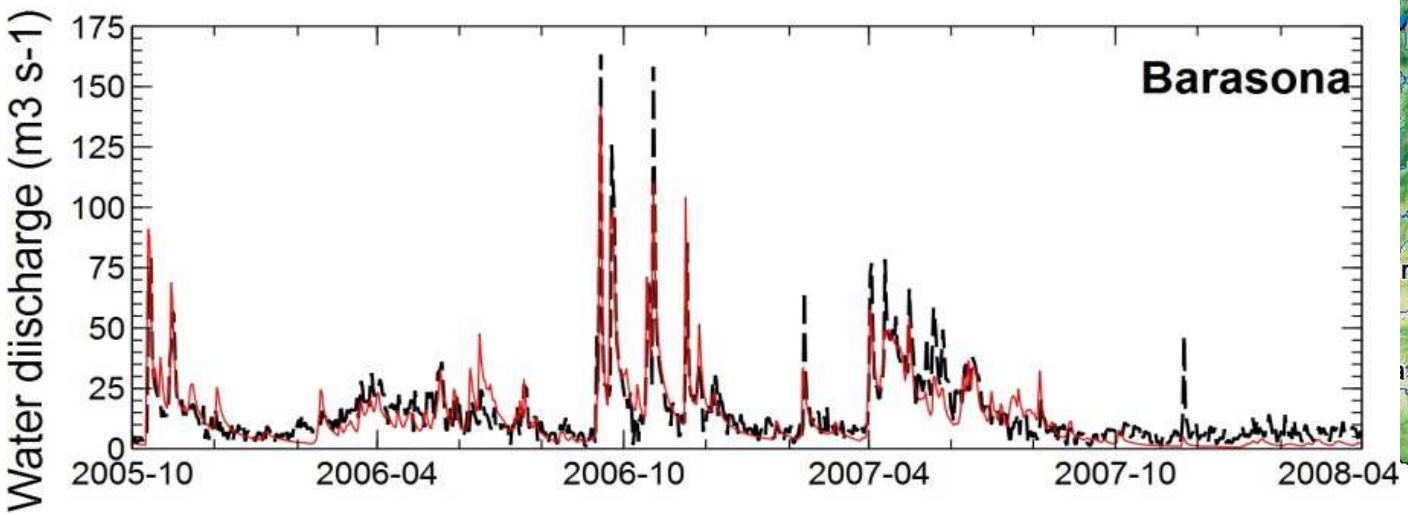


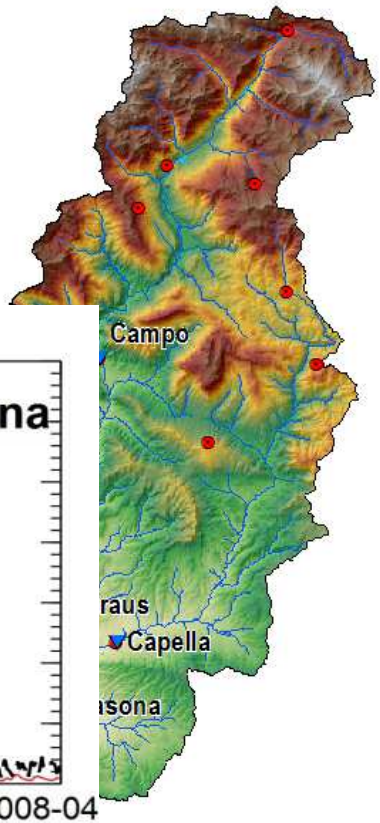
Instituto de Ingeniería del Agua y Medio Ambiente

Calibration and validation

- Hydrological sub-model:
  - Calibration at Capella station (2005-2008)
  - Validation at Graus, Campo, Barasona and Capella (1997-2005)

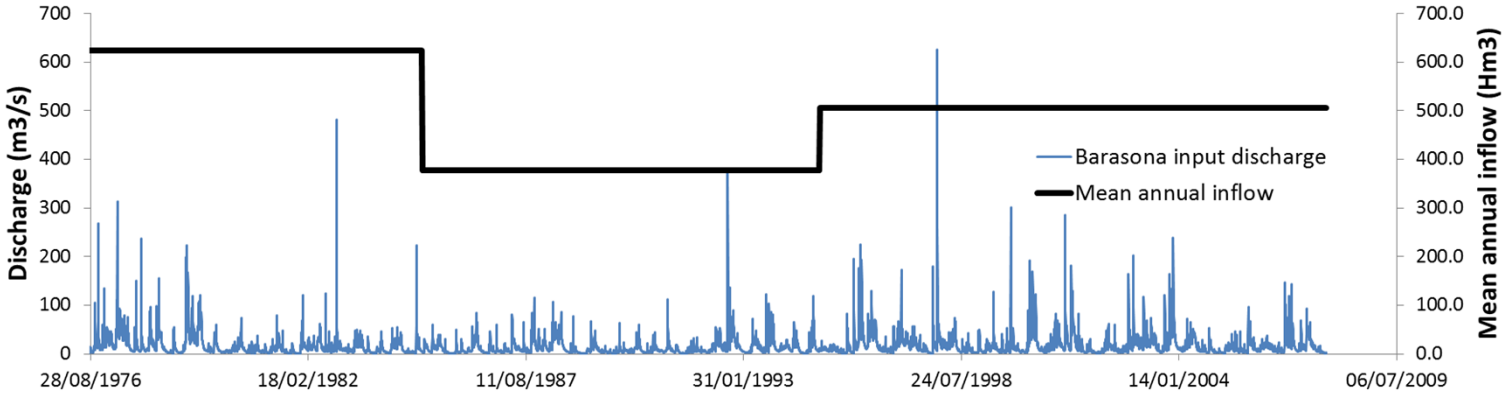
	Calibration period		Validation period	
Station	NSE	VE%	NSE	VE%
Capella	**0.720**	**-6%**	0.686	-39%
Graus	0.581	-28%	0.704	-61%
Campo	0.294	-44%	0.455	-35%
Barasona	0.708	-10%	0.529	-22%





Calibration and validation

- Sediment sub-model: implementation
  - Dry Bulk Density:
    - Miller formula (Lane and Koelzer coefficients);
    - Sediment texture: provided by the TETIS model;
    - Results validated against measured value (1.112 t m^{-3} in 1986).
  - Trap efficiency:
    - Brune curves, function of reservoir capacity and average inflow;
    - Average inflow previously calculated;
    - Reservoir capacity calculated by the model;
    - Avendaño Salas et al. (1995) → 86%.

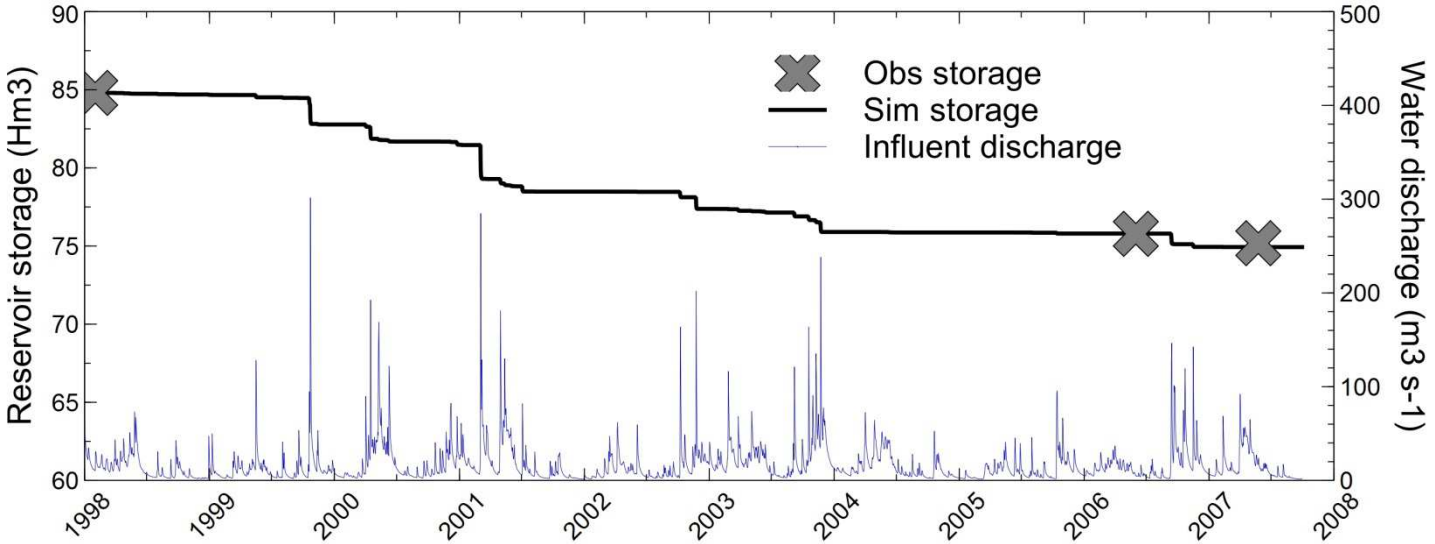


Calibration and validation

- Sediment sub-model: results
  - Calibration and validation vs Barasona storage volumes:

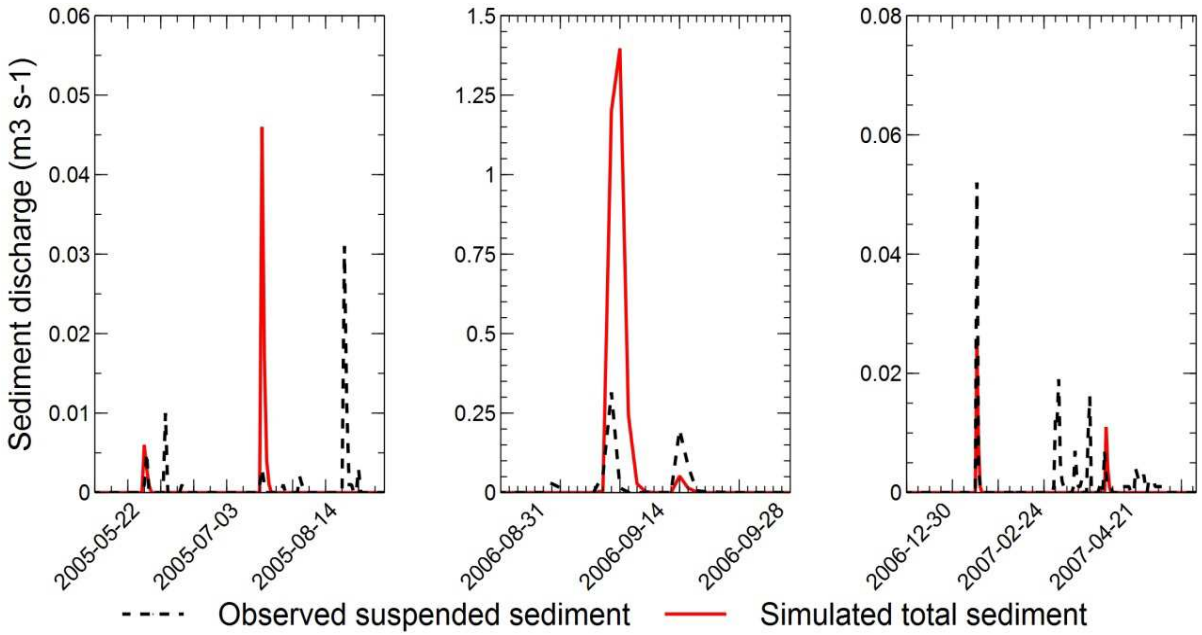
Period	Accumulated sediments Hm^3	Specific sediment yield $t\ km^{-2}\ year^{-1}$	Simulated volume Hm^3	VE %
1998-2006	9.02	820	9.02	0%
2006-2007	0.60	435	0.76	23%

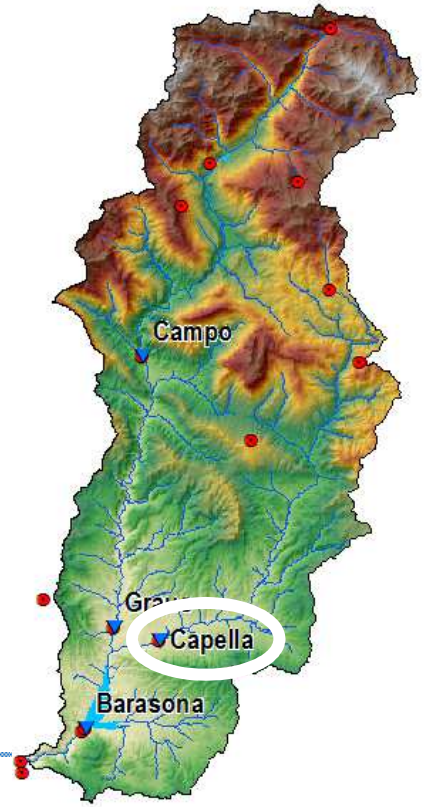
  - Reconstruction of the storage evolution



Verification

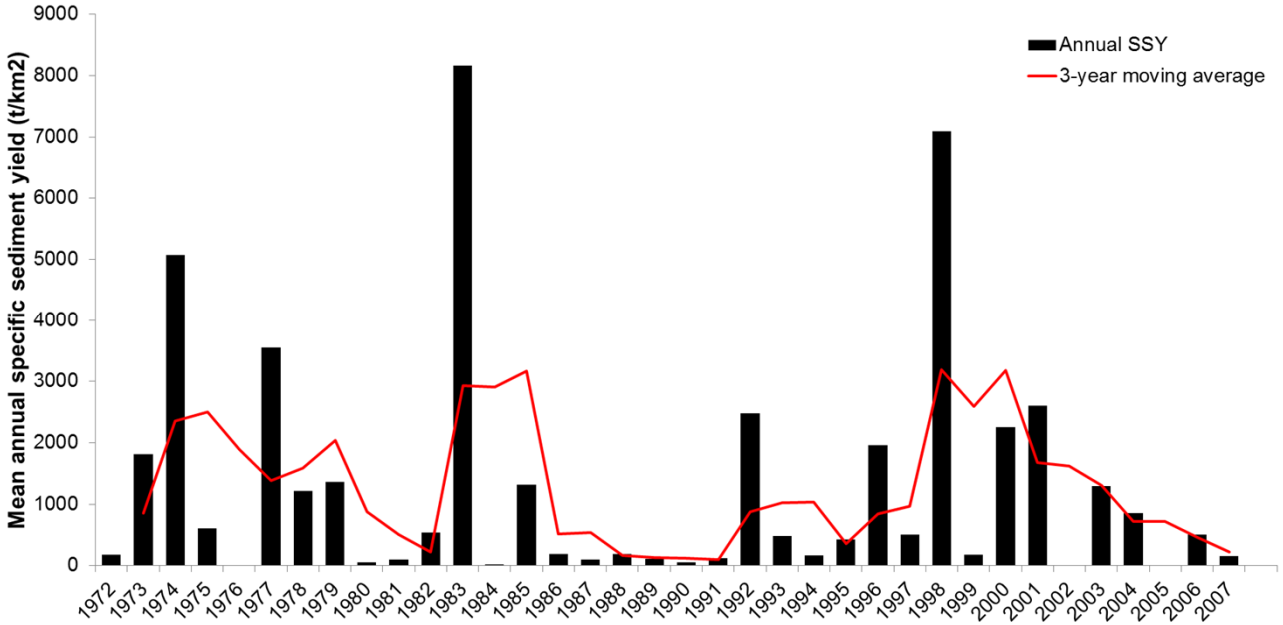
- Sediment sub-model: validation @ Capella
  - Model results (total load) VS gauged data (suspended load);
  - Measurement errors: turbidimeter measurements can be misleading with high concentrations (Regües & Nadal-Romero 2012, CATENA)

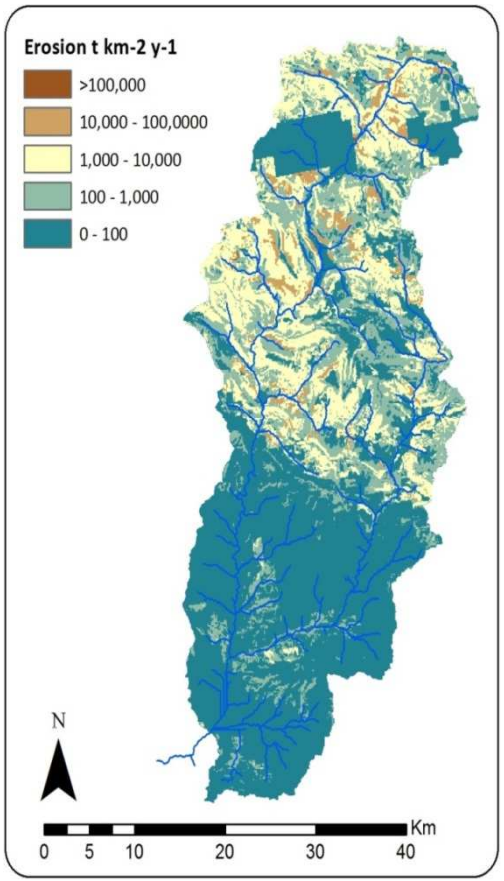




Analysis

- Sediment sub-model:
  - Erosion zones: central marl strip and headwater:
  - Average sediment yield:





Conclusions

- Due to lack of sediment data, reservoir sedimentation can be used as **proxy data** for **model calibration** and validation;
- The methodology can be **extended to** all catchments drained by a **large reservoir**;
- The TETIS water sub-model behaves very good, and the sediment sub-model result are satisfactory;
- The model gives a total specific sediment yield of **12.7 ton Ha^{-1} y^{-1}** (high specific sediment yield);
- The main sediment source is the **central marl area**.

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Instituto de Ingeniería del Agua y Medio Ambiente

Thanks for your attention!

Gianbattista Bussi (gbussi@upvnet.upv.es)

Research Group of Hydrological and Environmental Modelling
lluvia.dihma.upv.es

Acknowledgements:
SCARCE (CSD2009-00065) and ECOTETIS (CGL2011-28776-C02-01) Projects.
The work has been funded by the Spanish Ministry of Economy and Competitiveness.

EGU General assembly – Vienna – April 2013