MODELLING STREAMFLOW TO SET AN ENVIRONMENTAL FLOW

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Introduction

•Streamflow is a **critical determinant** of ecological status. However, how flow regime and its alteration affect ecological conditions remains an open scientific challenge in temporary rivers.

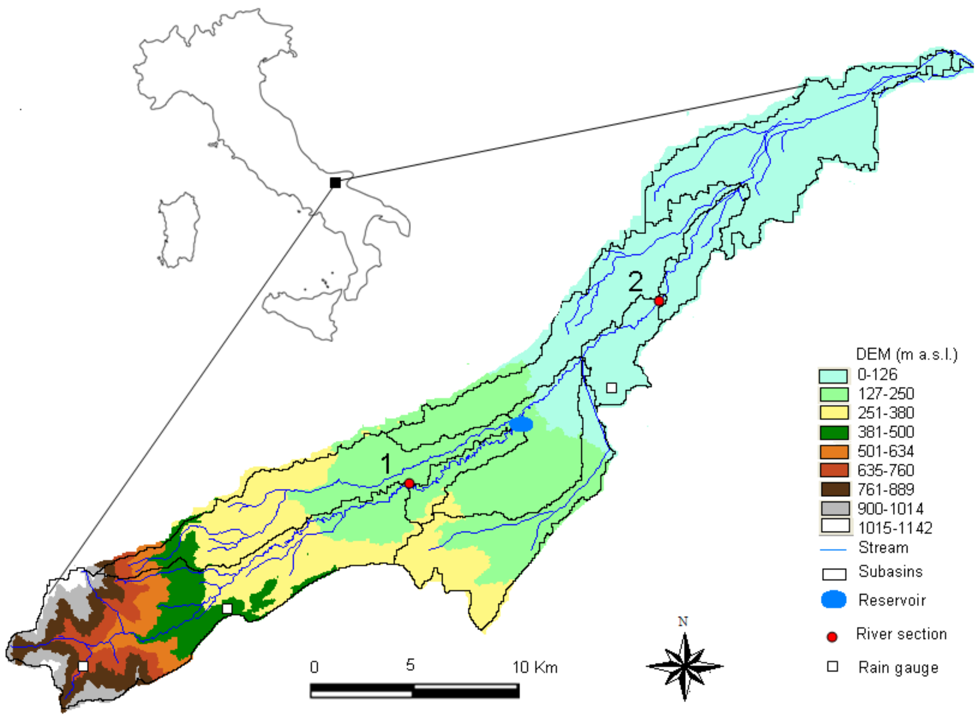
•**Streamflow regime characterization** is needed for eco-hydrological studies (i.e. EF, Hydrological Status).

•**Hydrological models** can be used to simulate streamflow regime and its alteration.

Objectives

- **Predict streamflow** in a river basin with a temporary river oriented at supporting eco-hydrological studies.
- **Evaluate hydrological alterations** by using hydrological indicators.
- **Test a hydrological method** (RVA) for setting an **Environmental Flow** in a temporary river

Study area: Celone River Basin



Agricultural watershed

Drainage Area: $317 km^2$

Mean rainfall: 625mm

Intermittent character

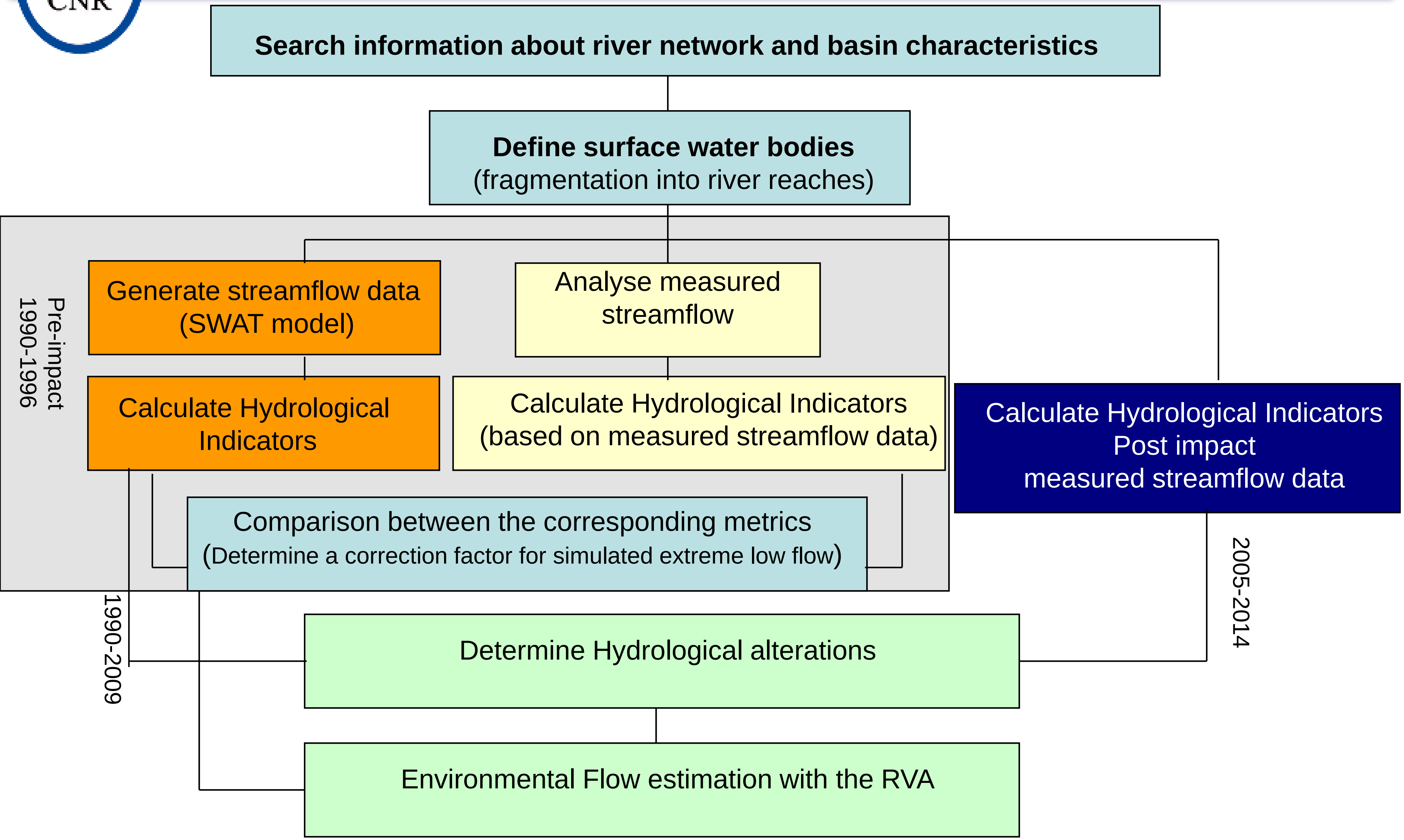
Reservoir: $25 Mm^3$

Q_m (1) = $0.48 m^3 s^{-1}$

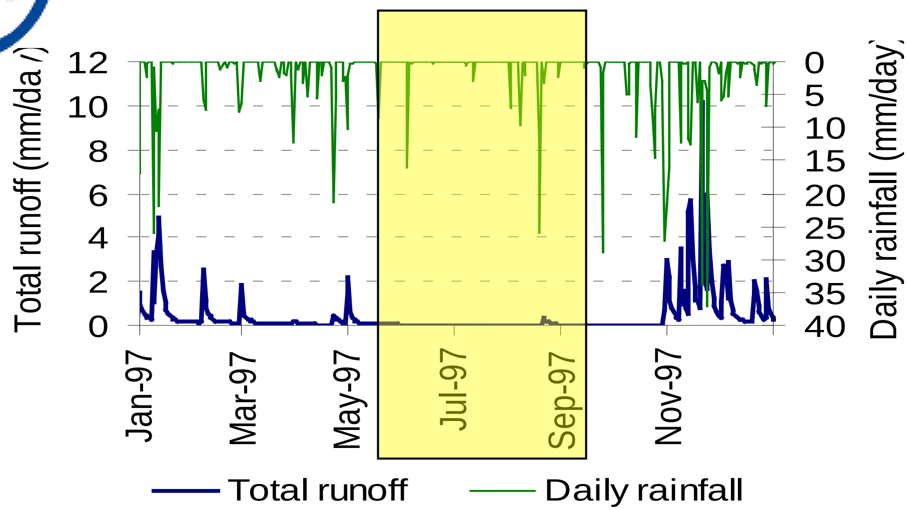
Q_m (2) = $0.77 m^3 s^{-1}$

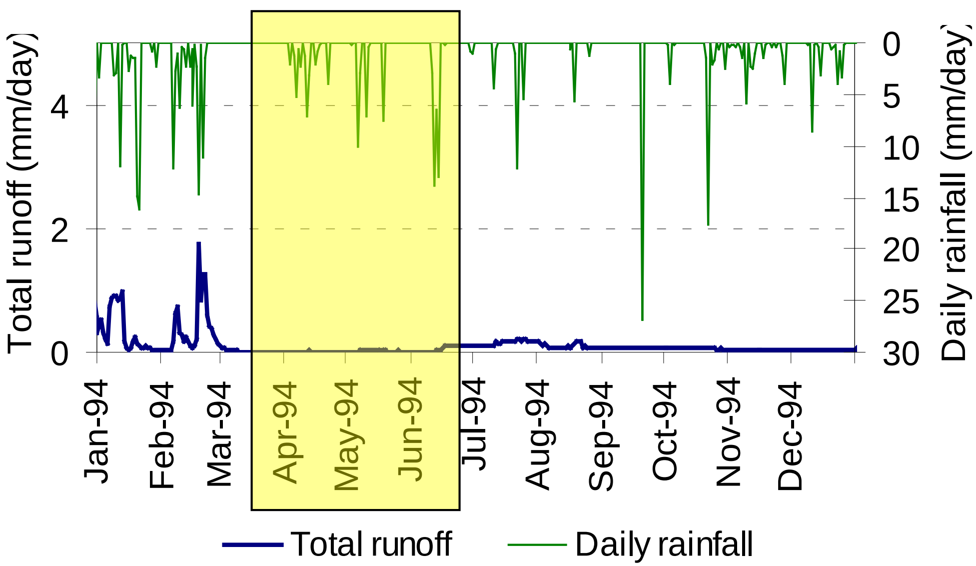
(pre-impact)

Methodology



Simulating streamflow

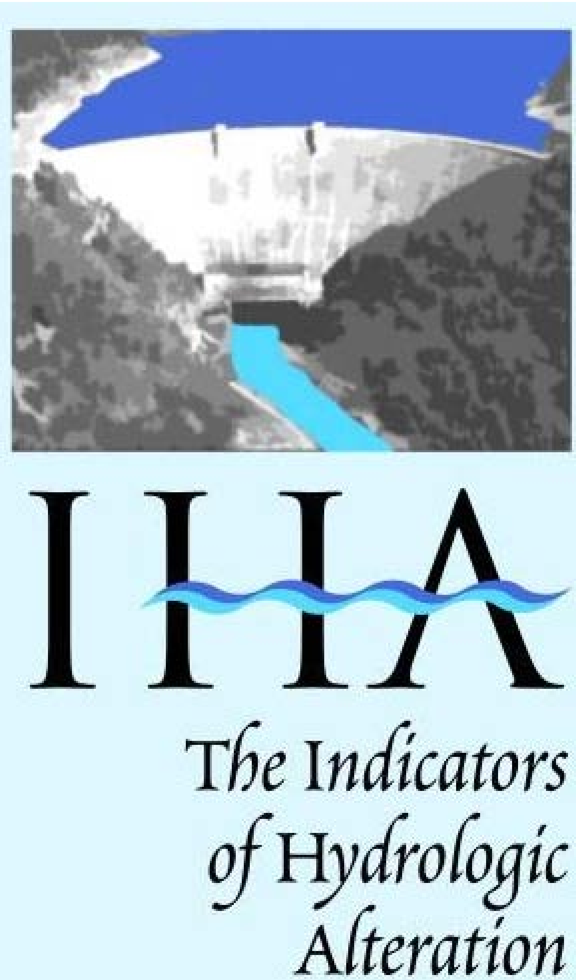




- ✓ **Few climatic gauging stations**
- ✓ **Several gaps in the datasets**
- ✓ **Soil hydraulic properties are not available**
- ✓ **Water abstraction quantifications are not available**
- ✓ **Measured rainfall data do not match measured streamflow**

Hydrological Indicators

32 Hydrological indicators

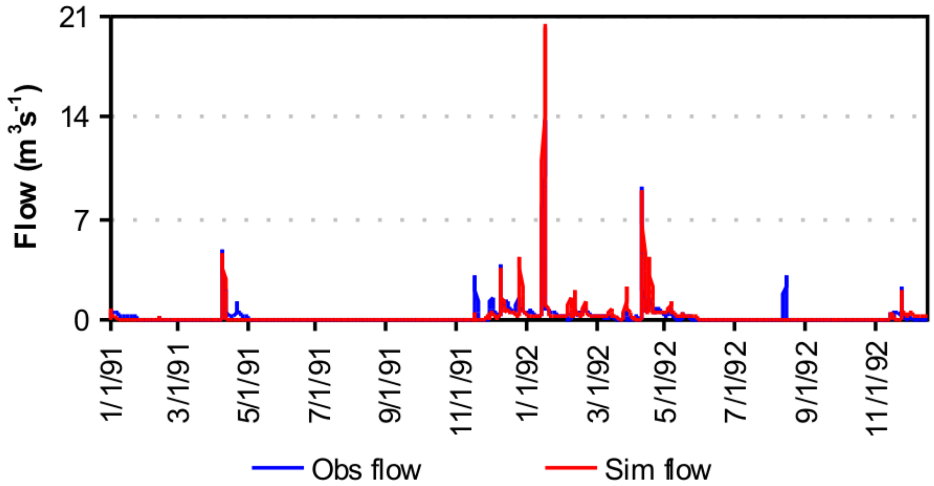


The Nature Conservancy, 2009

Richter et al., 1996, 1997

- The **magnitude of discharge** at any given time interval is the amount of water moving past a fixed location per time unit (measure of availability or suitability of habitat).
- The **frequency of occurrence** refers to how often a flow above a given magnitude recurs over some specified time intervals (can influence populations dynamics).
- The **duration** is the period of time associated with a specific flow condition (may determine if a life-cycle phase can be completed).
- The **timing of occurrence** of flows of defined magnitude refers to the regularity with which they occur (can influence the degree of stress).
- The **rate of change**, or flashiness, refers to how quickly flow changes from one magnitude to another.

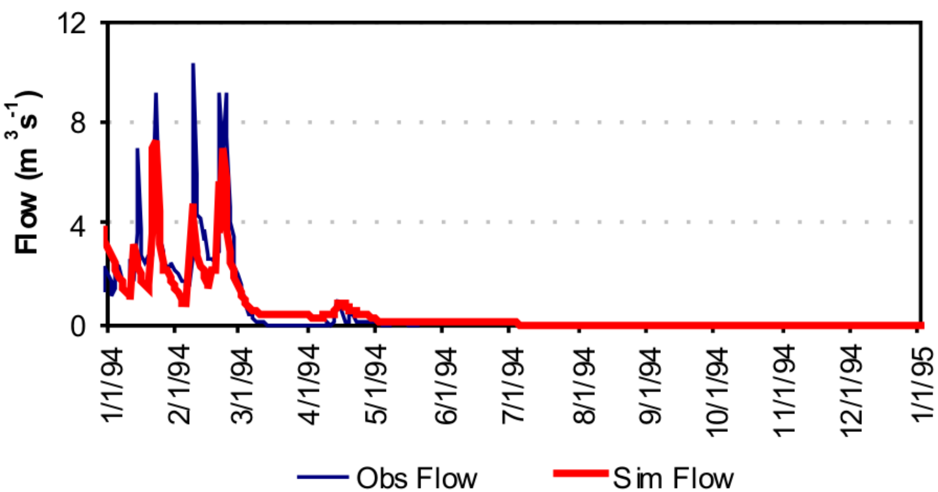
Model calibration and validation



Gauging station 1

✓ ***Calibration*** (1991-92)
NSE=0.74; R2=0.89;
PBIAS=-0.25

➢ ***Validation*** (1995-96)
NSE=0.47; R2=0.77;
PBIAS=0.26

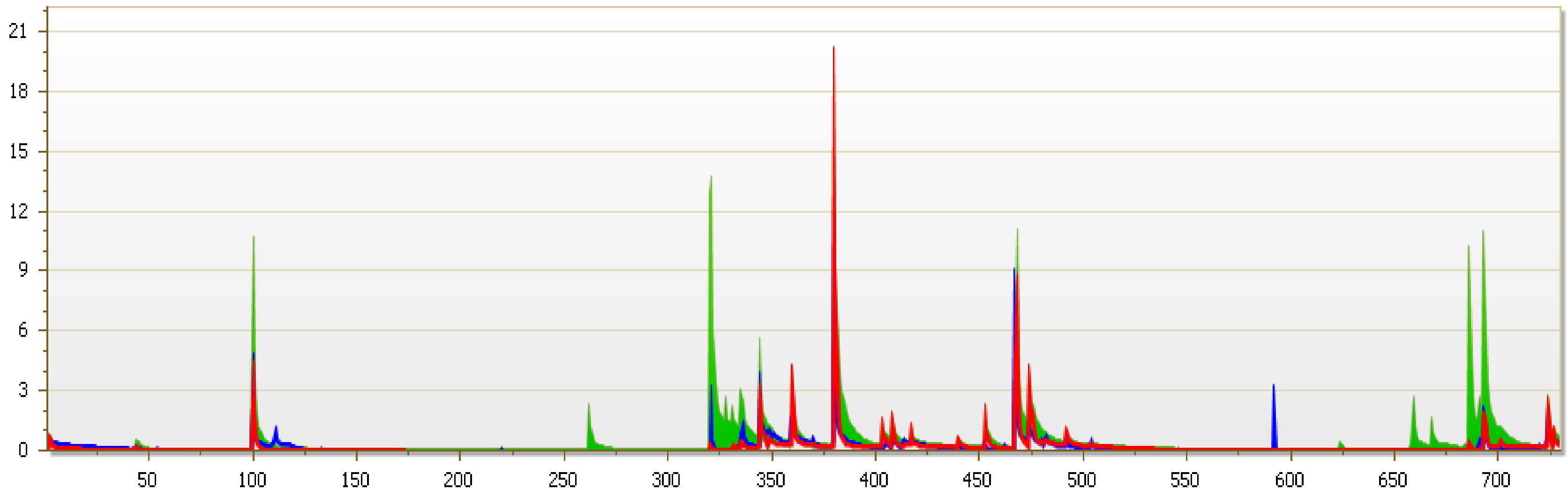


Gauging station 2

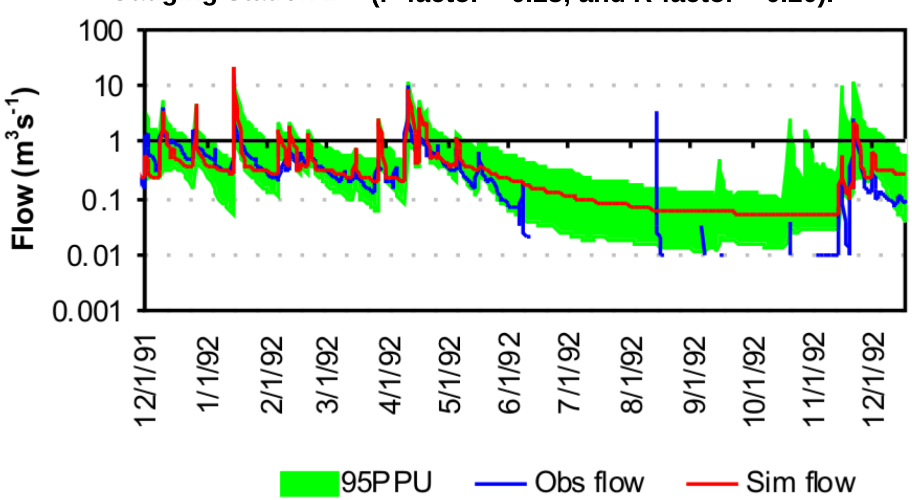
✓ ***Calibration*** (1991-92)
NSE=0.51; R2=0.83;
PBIAS=0.24

➢ ***Validation*** (1994)
NSE=0.83; R2=0.93;
PBIAS=0.10

Model uncertainty



Gauging Station 1. **(P-factor = 0.28; and R-factor = 0.20).**



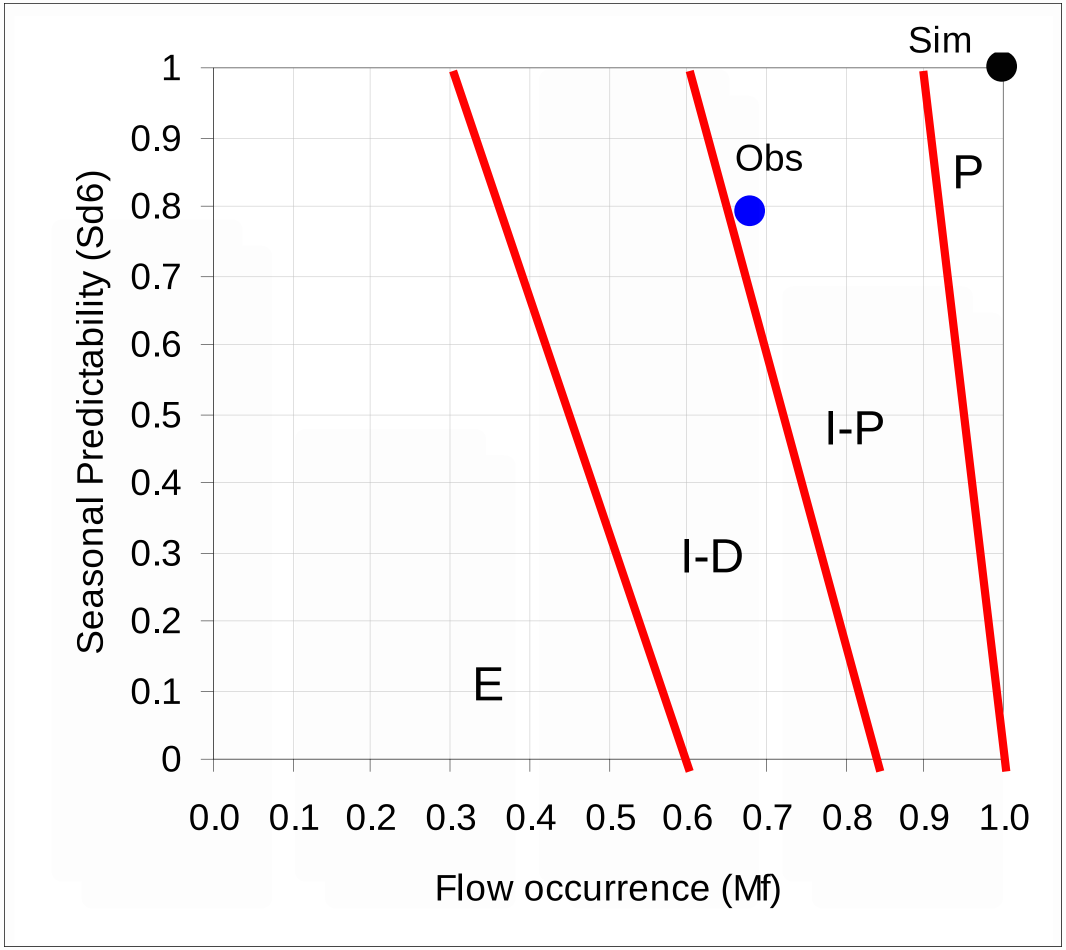
Gauging Station 2. **(P-factor = 0.41; and R-factor = 0.20).**

We applied the **Sequential Uncertainty Fitting** (SUFI 2) procedure to undertake the uncertainty analysis.

Results:

Uncertainty interval is quite large during the **dry period.**

Implications for eco-hydrological studies



- **Wrong River Classification**
- **Errors in Hydrological Alteration assessment**
- **Difficulties** for making **Environmental Flow** recommendations

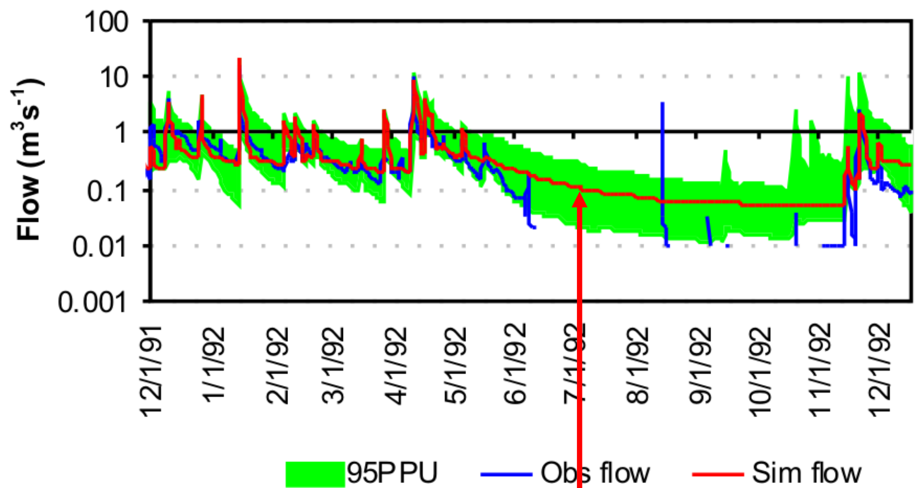
Comparing IHAs: simulated/observed

Simulated streamflow and measured streamflow are used to estimate Hydrological Indicators over the common period 1990-96

Parameter Group 1	Parameter Group 2	Parameter Group 3	Parameter Group 4	Parameter Group 5
Qm January	1-day minimum	**Date of minimum**	Low pulse count	Rise rate
February	3-day minimum	Date of maximum	Low pulse duration	Fall rate
March	7-day minimum		High pulse count	Number of reversals
April	**30-day minimum**		High pulse duration	
May	**90-day minimum**		Low Pulse Threshold	
June	1-day maximum		High Pulse Threshold	
July	3-day maximum			
August	7-day maximum			
September	30-day maximum			
October	90-day maximum			
November	**Number of zero days**			
December	**Base flow index**			

Statistical tests demonstrate the effectiveness of the model in predicting IHAs representing the magnitude of the wet months and high flow but it fails in predicting IHAs related to the period of dryness (De Girolamo et al., 2017).

Solution: introducing a Zero Flow threshold



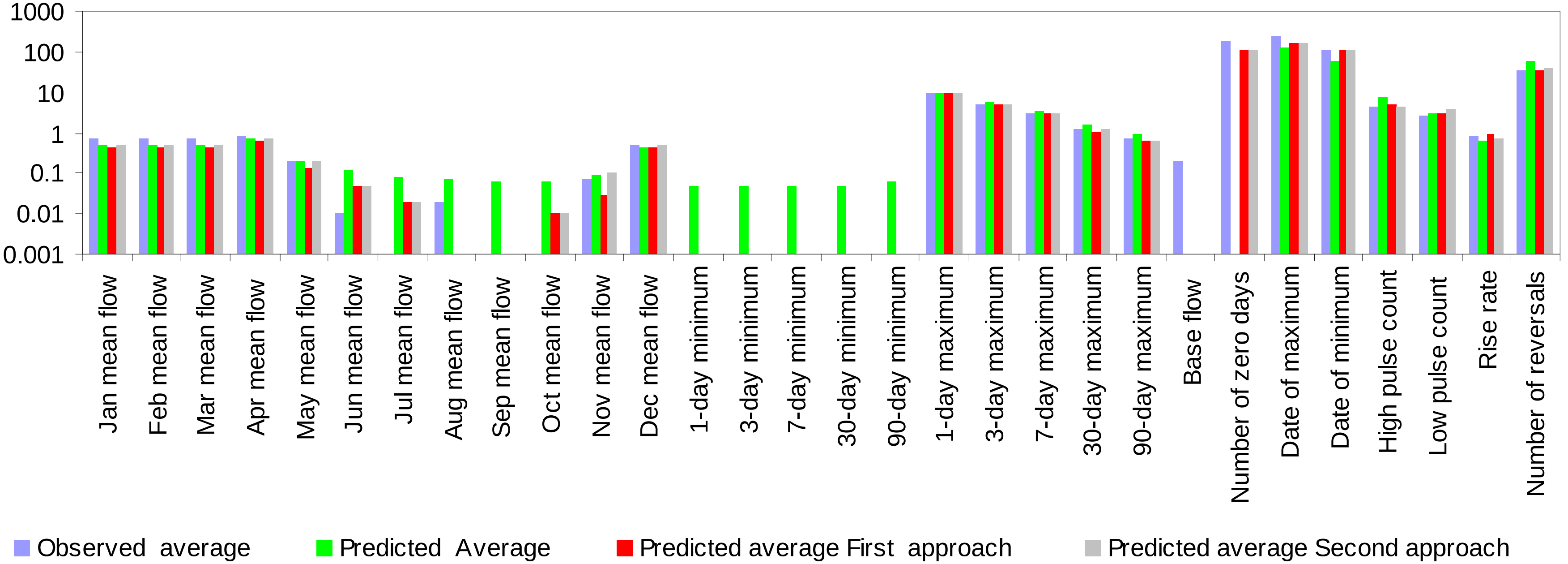
Correction of the simulated flow series with the "Zero Flow" threshold

(simulated streamflow value corresponding to actual dry condition)

i) threshold subtracted for all daily values

ii) threshold subtracted from June to October

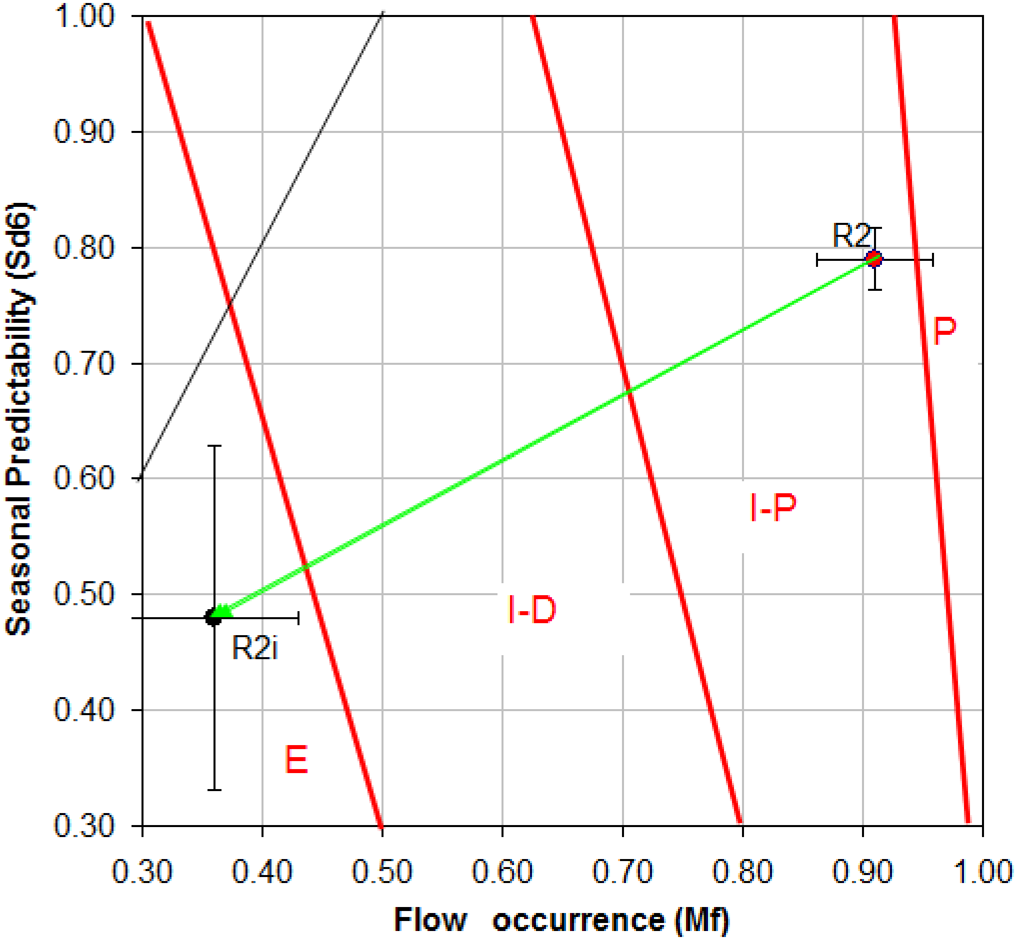
Comparing IHAs: simulated/observed



•Statistical performance of all hydrological indicators was improved after correction

•Model prediction does not need a correction for months with high and moderate flow regimes, while it appears to be needed for dry months (De Girolamo et al., 2017).

Comparing flow regime before and after dam impact



(De Girolamo et al., 2015)

Pre-impact: the river segment is classified as Intermittent-pools

Post-impact: the river is classified as ephemeral

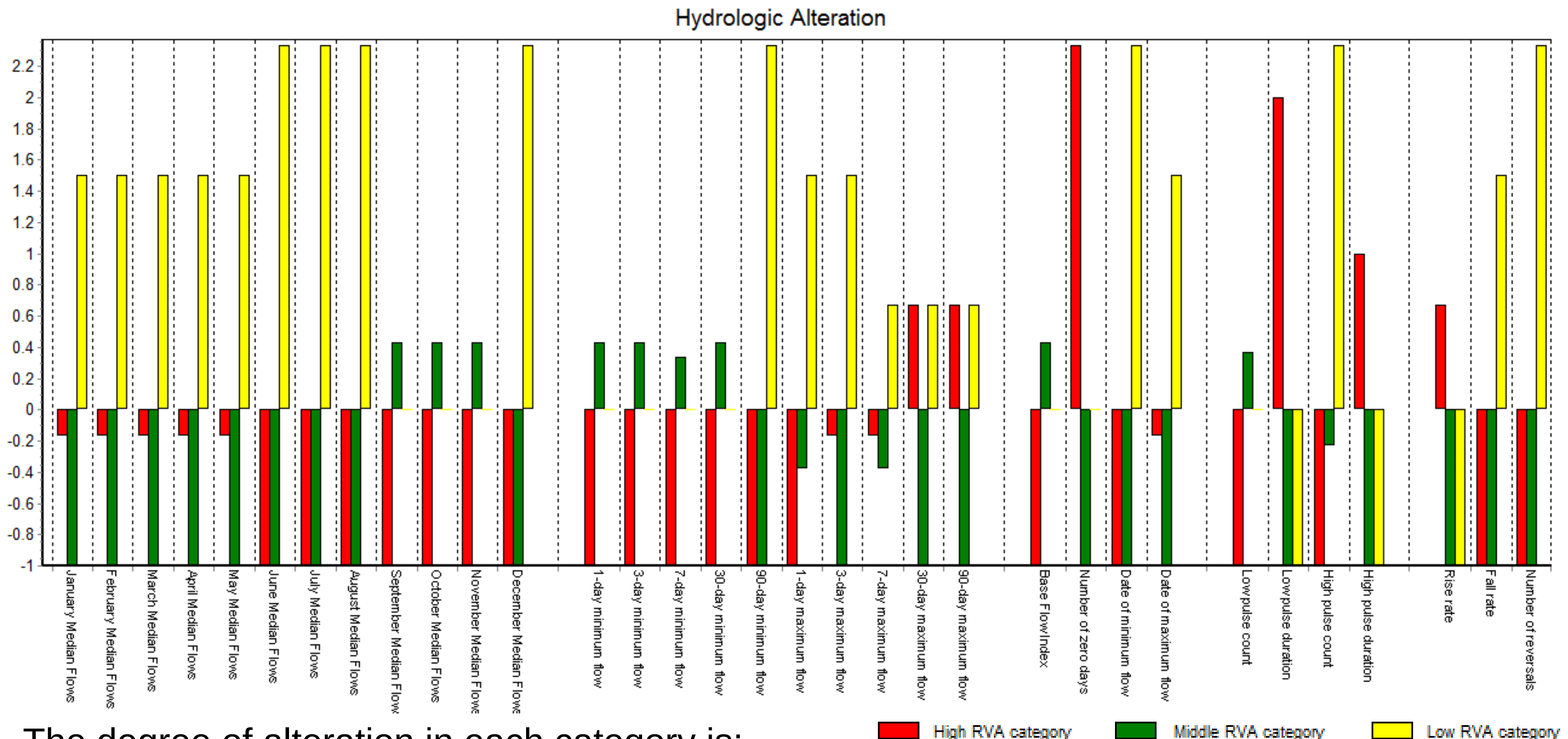
$$Sd6 = 1 - \left(\sum_{1}^{6} Fd_i / \sum_{1}^{6} Fd_j \right)$$

Where: Fdi is the multiannual frequency of no-flow months for the six contiguous wetter months per year and Fdj is the multiannual frequency of no-flow months for the six drier months).

$$M_f = \frac{N}{12}$$

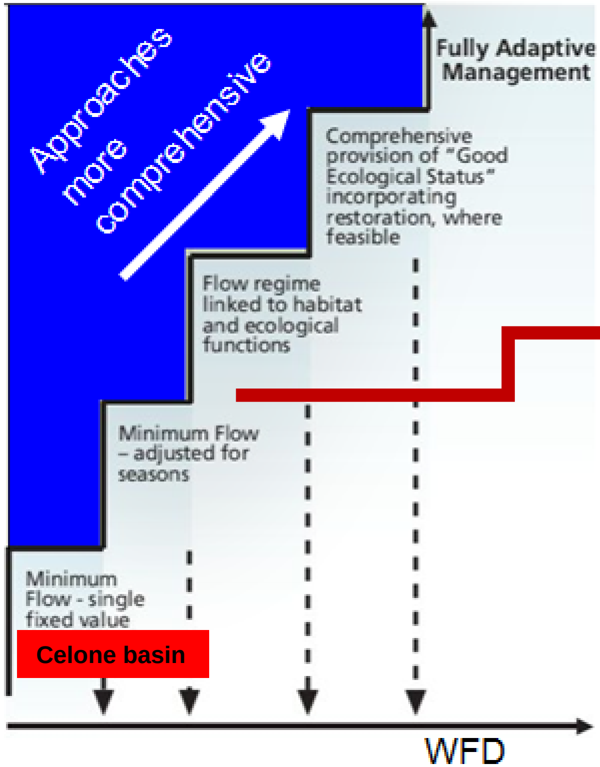
Number of months with flow

Comparing observed and simulated IHAs



The degree of alteration in each category is:
(post-impact frequency – pre-impact frequency) / pre-impact frequency.
A positive IHA factor means that the frequency of values in the category has increased from the pre-impact to the post-impact period, while a negative value means that the frequency of values has decreased.

Setting an EF in a temporary river



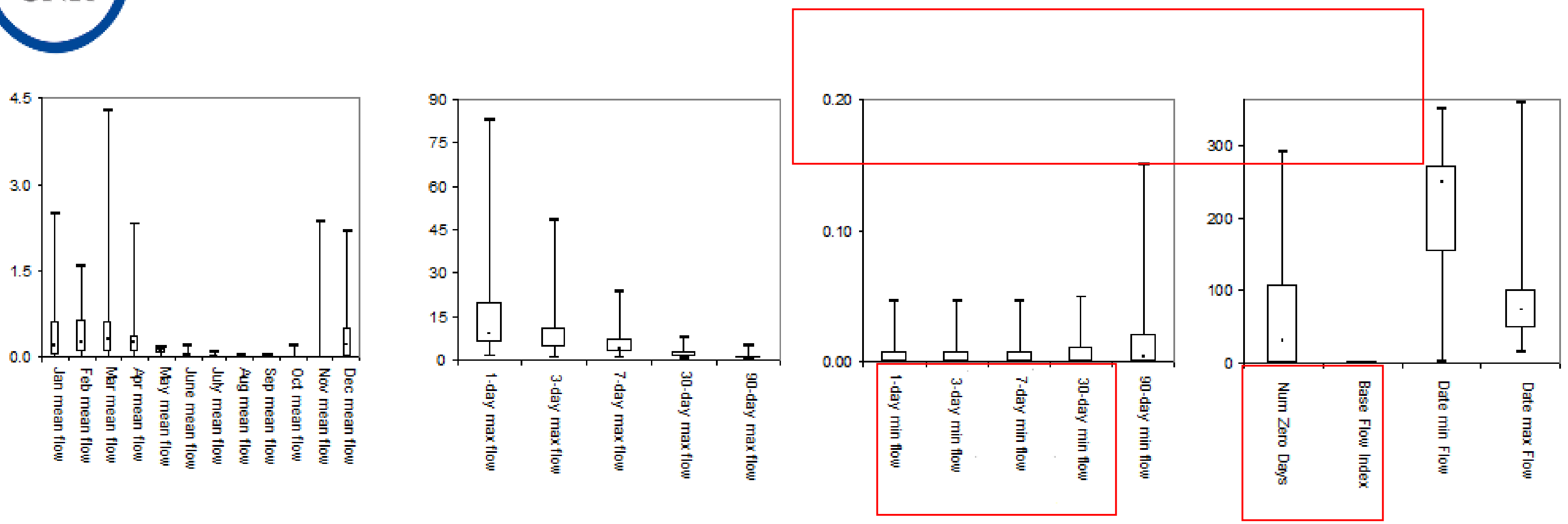
Setting an environmental flows should be an **adaptive process**, in which flows may be successively modified in the light of increased knowledge, changing priorities, and changes in infrastructure over time.

RVA

(Flow management targets are set as a range of variation for each HI)

A fundamental principle of the EF is to maintain **integrity**, **natural seasonality** and **variability of flows**, including **floods and low flows**.

Setting an EF in a temporary river



The thresholds should be fixed with input from experts and ecological data

In a modified regime, which is ecologically acceptable, each indicator should be maintained within the limits of its natural variability

When ecological data are not available an acceptable range of variation of the indices can be ±1 standard deviation (SD) from the mean or, in case of non-parametric analysis, between the 25th and 75th percentiles

Conclusions

•**Hydrology** frequently works under conditions of data scarcity. The **SWAT** model is able to provide streamflow data for ecological/EF studies.

•The replicability of the IHAs ranges from good to limited. The results show **a good performance for the annual flow, wet monthly and peak flows** and **limited** performance **for low flows, number of zero flow days**.

•These **discrepancies** do not necessarily indicate a shortcoming in this hydrological model for general hydrologic simulations, but **point to limitations** in how such models can be effectively applied in eco-hydrological studies.

•Introducing the **"zero flow" threshold** statistical performance for low-flow indicators is improved.

•Comparing the IHAs post- and pre-impact (simulated) a measure of hydrological alteration is obtained: downstream the reservoir the **hydrological regime is highly altered**.

•By using natural simulated streamflow we developed the RVA in order to set an EF

•Further analysis based on **ecological data are needed** in order to define the thresholds of accettability in IHA variability

Thank you

for your attention!

De Girolamo A.M., Barca E., Pappagallo E., Lo Porto A., 2017. Simulating hydrological relevant indicators. The Celone river a case study. Agricultural Water Management 180, 194-204

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