Deliverable 25: Report on the alteration of temporary stream regimes, methods and implications for management

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Contact:
F.E.M. Research Group,
Departament d'Ecologia, Facultat de Biologia, UB
Diagonal, 643 - 08028 Barcelona +34 93 403 11 88

lifetrivers@ub.edu
www.lifetrivers.eu

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Implementing the Water Framework Directive to temporary rivers: tools for the assessment of their ecological status
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D25

Authors: Francesc Gallart (IDAEA- CSIC), Jérôme Latron (IDAEA- CSIC), Pilar Llorens (IDAEA- CSIC), Núria Cid (UB-FEM), Núria Bonada (UB-FEM), Narcís Prat (UB-FEM), Antoni Munné (ACA), Carolina Solà (ACA, Mònica Bardina (ACA), Teodoro Estrela (CHJ), Arancha Fidalgo (CHJ) Sara-Maria Jiménez-Argudo (CHJ), Rosa-María Vega (CHJ), Justin Jeuffroy (ENGEES), Antoni Hernández-Casahuga

Contributors: Andreu Manzano (ACA).

Deliverable 25: Report/paper on the alteration of temporary stream regimes, methods and implications for management
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CONTENT

Abstract

The purpose of this deliverable is to provide two examples of the application of TREHS to two actual temporary fluvial systems for assessing the degree of alteration of their regimes.

It demonstrates the practicality of TREHS for getting data in the real world and the way different sources of data may be compared with it, along with the limitations of these data. A particular emphasis is put on the issue of finding reference (unimpacted) river regime, as a necessary step for assessing the degree of hydrologic alteration.

The first case is the Sénia River, in the Jucar River Basin District, a river with an original temporary river that has been clearly impaired due to water abstractions for irrigation

The second case is the headwaters of the Daró River, in the Catalan River basin District. This river was perennial in the past but became temporary due to the increased evapotransiration subsequent to the encroachment of dense forest cover in the last decennials due to land abandonment.

Case 1: the Sénia River

Example of TREHS application to the water body 01.04 corresponding to the Sénia River between La Sénia village and the Foies irrigation channel.

The studied water body is placed in the Júcar River Basin District, between the Castelló and Tarragona provinces. In the studied segment, the river Sénia is characterized by a temporary hydrological regime, not being possible its ecological status assessment according to the biological, physico-chemical and chemical parameters required by the Water Framework Directive (WFD). Furthermore, this water body is subjected to a high water abstraction pressure mainly for irrigation waters; the hydrological regime is therefore a priori suspect of alteration.

Given that this is a temporary river, there are no recent flow gauging records that would allow to characterise the current hydrological regime. Furthermore, water quality data are not available because during sampling campaigns planned by the competent Authority the river is usually dry.

Application of TREHS to the study water body, on the one hand allows us to improve characterization of the current hydrological regime by using quantitative data from gauging records (if any), together with the use of qualitative data from interviews and in situ or photographic observations. On the other hand, the characterization of the current hydrological regime allows the design of an optimal sampling schedule for conducting ecological status assessments adapted to the seasons of the year in which there is a high probability that the river conveys water. Finally, if data or simulations describing the natural river regime are available, it allows analysing the degree of current hydrologic alteration by comparison of the metrics representing the natural regime with those representing the current regime.

To this end, the Sénia river water body 01.04 was subjected to a compilation of all existing hydrologic data, complemented with interviews and observations through orthophotographs.

1.1 Input data:

The input data for this water body were the following:

a) Flow simulation records obtained with the PATRICAL hydrological model (Pérez, M.A., 2005; Pérez-Martín et al., 2013) as for a natural regime (Figs.1.1 and 1.2).

It is worth to note that the PATRICAL model operates at monthly temporal scale and therefore it does not allow a sufficiently adequate interpretation of the hydrological regime in many temporary rivers. In this case the simulations resulted in a fully permanent regime (Fig. 1.1). As this was not consistent with the traditional perception of the regime, it was decided not to use these simulations in the further analysis in TREHS.

b) Historical Flow gauging records. These data are available for this water body (series corresponding to the period 1912-1930). Given that irrigation pressures in the area were produced in later periods, it can be assumed that this series adequately represents the natural regime of the river in the studied reaches (water body 01.04).

After these historical flow gauging data, this river segment behaves as temporary (Fig. 1.3), being dry during mainly from July to January (Fig. 1.4).

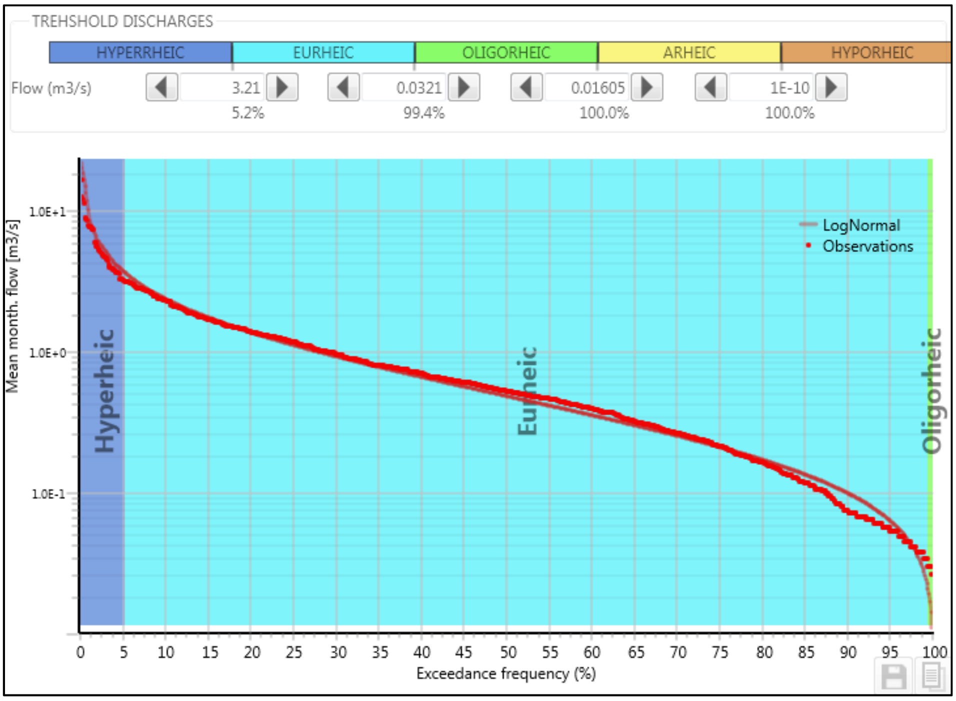


Fig.1.1: Flow duration curve for the flow series simulated with the PATRICAL model

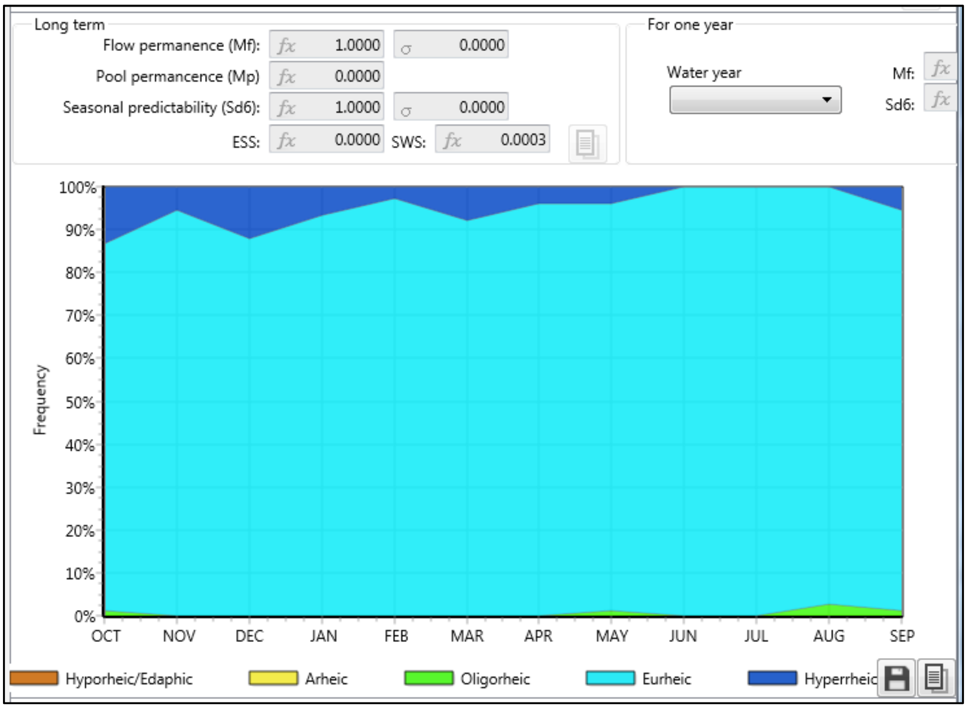


Fig. 1.2: TREHS metrics and Aquatic States Frequency Graph derived from flow simulations of Fig. 1.1.

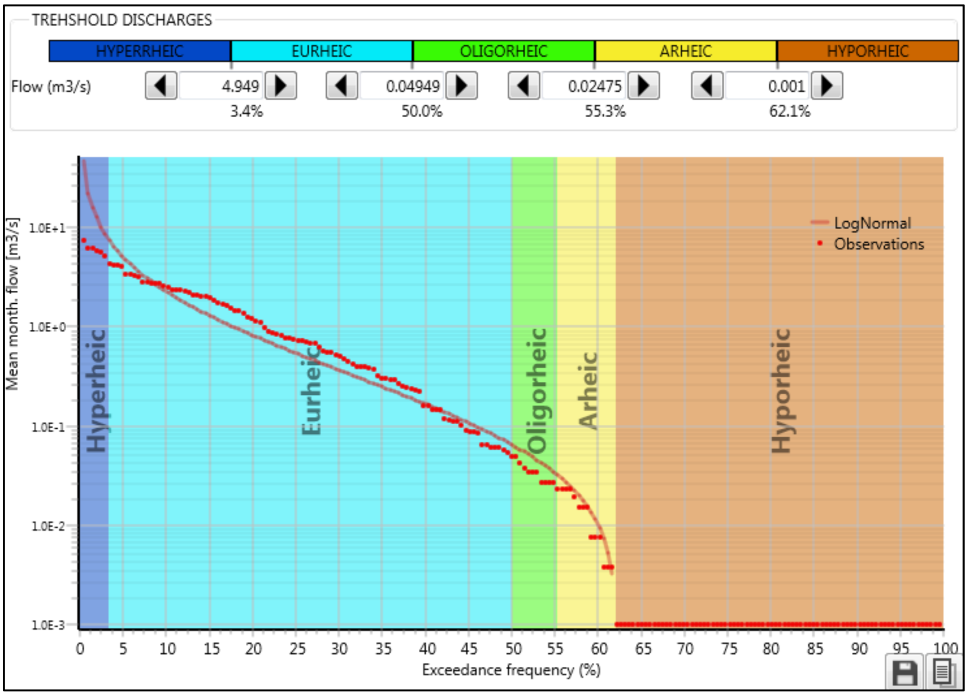


Fig.1.3: Flow duration curve and interim thresholds between aquatic states for the historical flow series 1912-1930

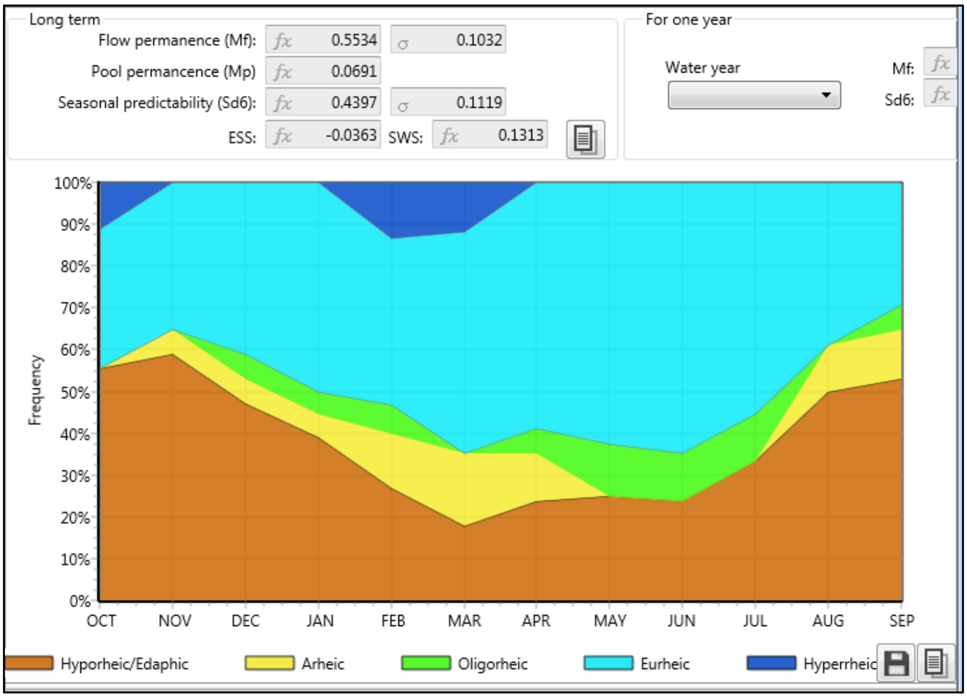


Fig. 1.4: TREHS metrics and Aquatic States Frequency Graph derived from flow records of Fig. 1.3.

c) Interviews. These were made with the staff of the river domain of the Confederación Hidrográfica del Júcar, who is the competent River Authority. This hydrologic information responds to the most recent hydrological regime. According to this data, the river became ephemeral during the last years and water flows only during rainy episodes. Flow permanence was estimated as Mf = 0.011 (four flowing days per year), without any clear seasonal pattern (Fig. 1.5).

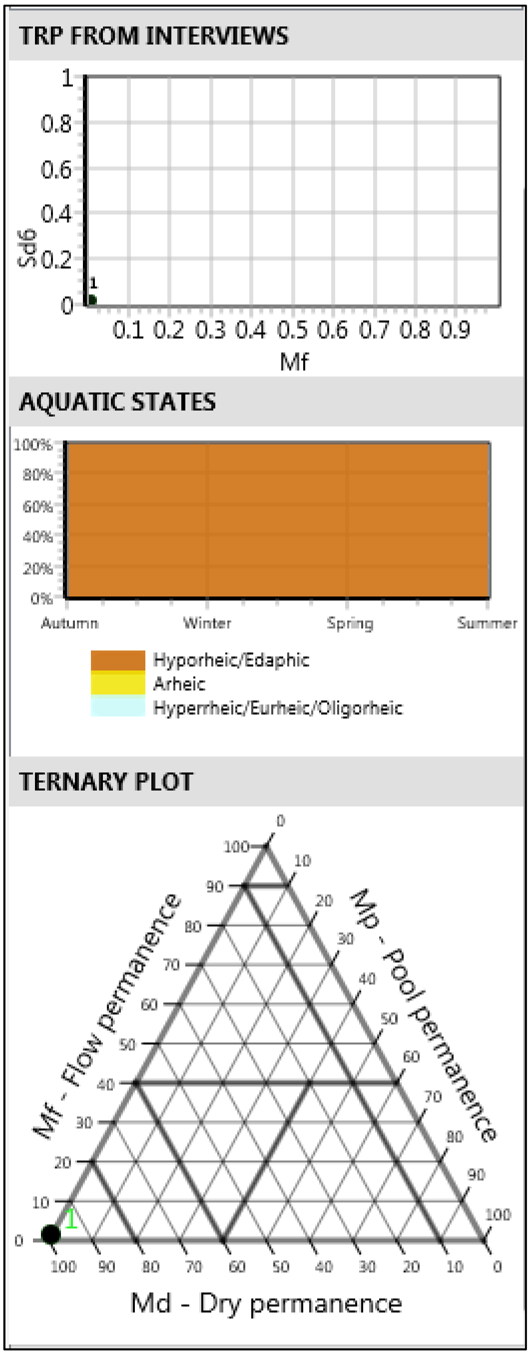


Fig. 1.5: TREHS results obtained with the information from interviews. Top: Temporary Regime Plot, showing both Mf and Sd_6 metrics close to 0. Middle: simplified Aquatic States Frequency Graph showing that only Hyporheic/Edaphic states could be estimated. Bottom: Flow-Pool-Dry plot where the river reach appears as Episodic (Ep), close to the permanently dry situation.

d) In situ and photographic observations. A detailed analysis of the water body using available ortophotographs between 2004 and 2017 was made. This allowed the complementation of the hydrological information respect to the current situation.

Observations collected data since 2004, allowing representing the reality of this River segment during a broader time period than interviews.According to the observations analysed, the river is dry for long periods of time, and may even remain dry during several consecutive years. However it is not as harsh as shown in the interviews since there are years in which the river carries water in certain seasons. In this case, there are sufficient observations not only to allow the calculation of permanence metrics, but also to obtain those describing the temporal patterns of aquatic phases.Flow duration was estimated as $Mf = 0.32$, with a clear seasonal pattern (Fig. 1.6).

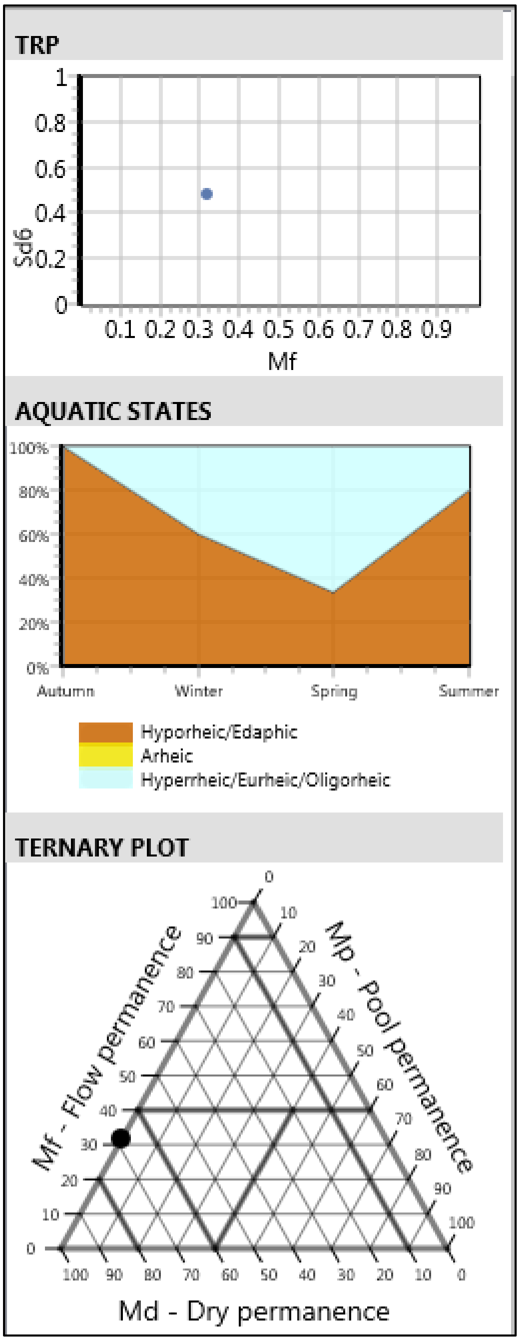


Fig. 1.6: TREHS results obtained with the information from observations (ortophotographs). Top: Temporary Regime Plot, showing both Mf and Sd_6 metrics in the area of predictable ephemeral rivers. Middle: simplified Aquatic States Frequency Graph showing an annual pattern similar to the one obtained with historical flows but significantly drier. Bottom: Flow-Pool-Dry plot where the river reach appears in the Occasional (Oc) regime without pool phases.

1.2 Results

Based in the data inputs provided, TREHS showed the following results:

a) Optimal sampling period. For this River section, from the hydrological point of view, the more recommendable sampling period is spring, because this is the season with the highest probability to find flowing water (33% in Eurheic / Oligorheic aquatic states). Furthermore, this season is the optimal season to perform standard sampling after the WFD. Nevertheless, the Competent Authority can adapt the sampling campaign in this River segment during a period that ensures the presence of flowing water. This recommendation is made after the current river regime, whereas the degree of alteration of the natural regime is analysed below in subsection 3.

b) River regime. The natural river regime may be characterized as intermitente following the Spanish regulations (WFD transposition) and Alternate-Fluent after the TREHS classification. The actual regime is characterized as Occasional (Oc) from observations and Episodic (Ep) from interviews, both following the TREHS classification (Figs. 1.7 and 1.9)

c) Hydrologic status. As can be deduced from the preceding paragraph, it can be considered that the hydrological state is highly altered, due to a severe decrease of the permanence of flow and surface water (Figs 1.7, 1.8 and 1.9).

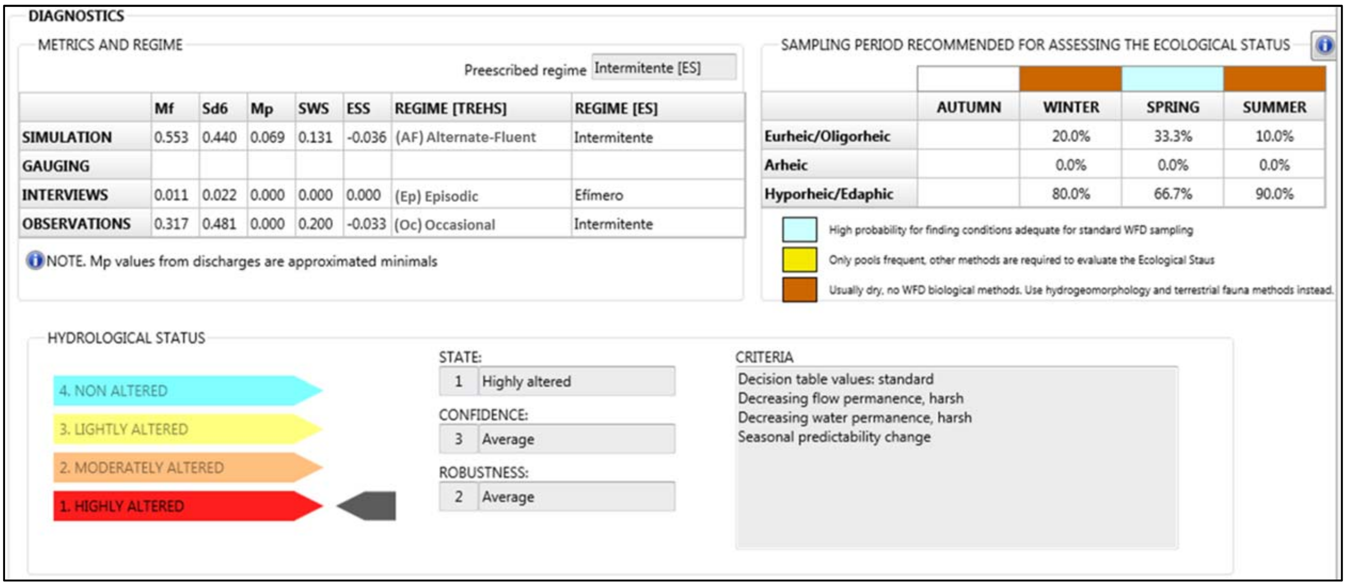


Fig. 1.7: TREHS diagnostics block. It shows: metrics obtained from the diverse sources of information; corresponding regimes using the TREHS classification as well as the Spanish regulations [ES]; recommended sampling period; hydrologic alteration along with the criteria used and the valuation of the confidence and robustness of the assessment. Note that in this case 'Simulation' refers to historical flow gauging.

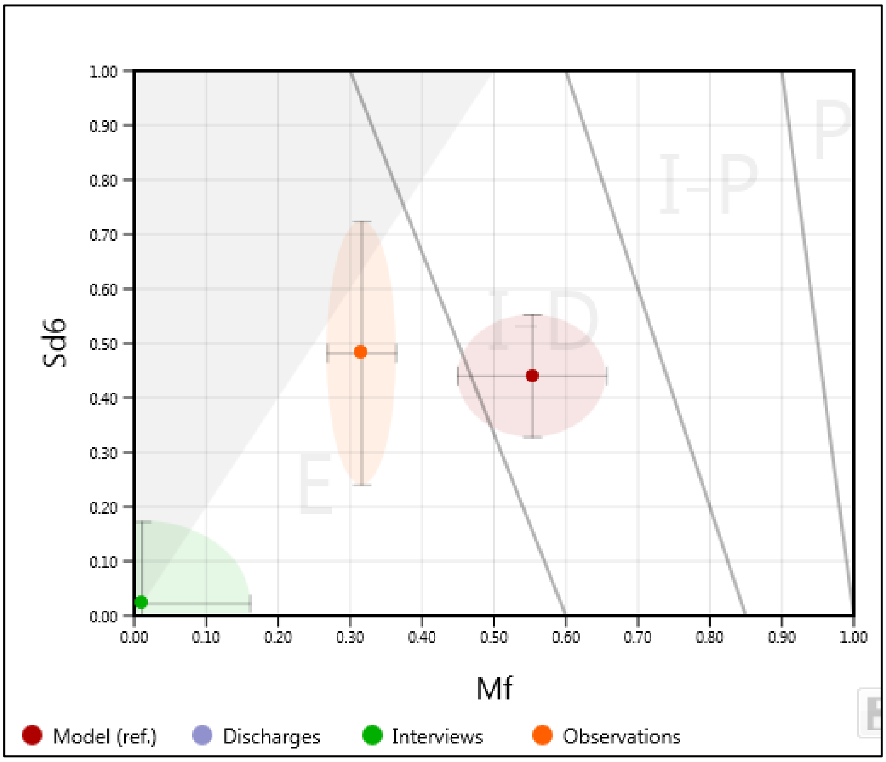


Fig. 1.8: Temporary regime plot for the diverse sources of data used. Ellipsoids show the uncertainty of the metrics. In this case Model (ref.) refers to the historical flow records.

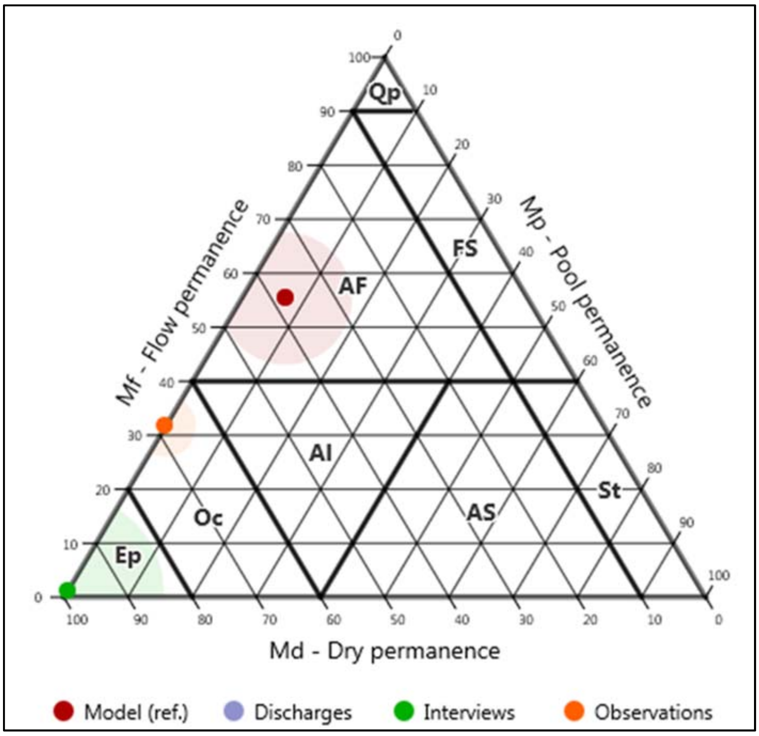


Fig. 1.9: Flow-Pools-Dry (FPD) plot for the diverse sources of data used. Circles show the uncertainty (resolution) of the metrics. In this case Model (ref.) refers to the historical flow records.

1.3 References

Pérez Martín, M.A., 2005. Modelo distribuido de simulación del ciclo hidrológico y de la calidad del agua, integrado en sistemas de información geográfica, para las grandes cuencas. Aportación al análisis de presiones e impactos de la Directiva Marco del Agua. Tesis Doctoral. Dpto. de Ingeniería Hidráulica y Medio Ambiente. UPV.

Pérez-Martín, M.A., Estrela, T., Andreu, J. and Ferrer, J., 2014. Modeling water resources and river-aquifer interaction in the Júcar River Basin, Spain. *Water resources management*, *28*(12), pp.4337-4358. DOI 10.1007/s11269-014-0755-3

Case 2: the Daró River

Example of TREHS application to the water body 1900010 corresponding to the Daró River from the headwaters to the confluence with the Marqueta stream (Catalan river basin district, Spain).

The studied water body is placed in the Catalan River Basin District, in the province of Girona. The Daró is a temporary river that has its source in the Gavarres massif, a densely forested semi-natural low mountain area, and flows into the Ter River. The studied river segment is a natural fluvial reserve that belongs to the network of reference sites in Catalonia. Among other aquatic species of interest, several populations of the three-spined stickleback (*Gasterosteus aculeatus*) are present.

There are no flow records adequate to characterise the current hydrological regime of this water body because the closest gauging station in the Daró River is at La Bisbal de l'Empordà, in the subsequent water body located several kilometres downstream, which is affected by several pressures on water resources for irrigation and urban consumption. The application of TREHS to the studied water body seeks to characterize the current hydrological regime mainly for conservation and management purposes within a land use and global change setting.

2.1 Input data

The input data for the Daró River water body 1900010 to TREHS were the following:

a) Flow simulation series obtained with the SACRAMENTO hydrological model (1940-2000) as for a natural regime, implemented through a regional calibration approach (ACA, 2004): Figs. 2.1 and 2.2.

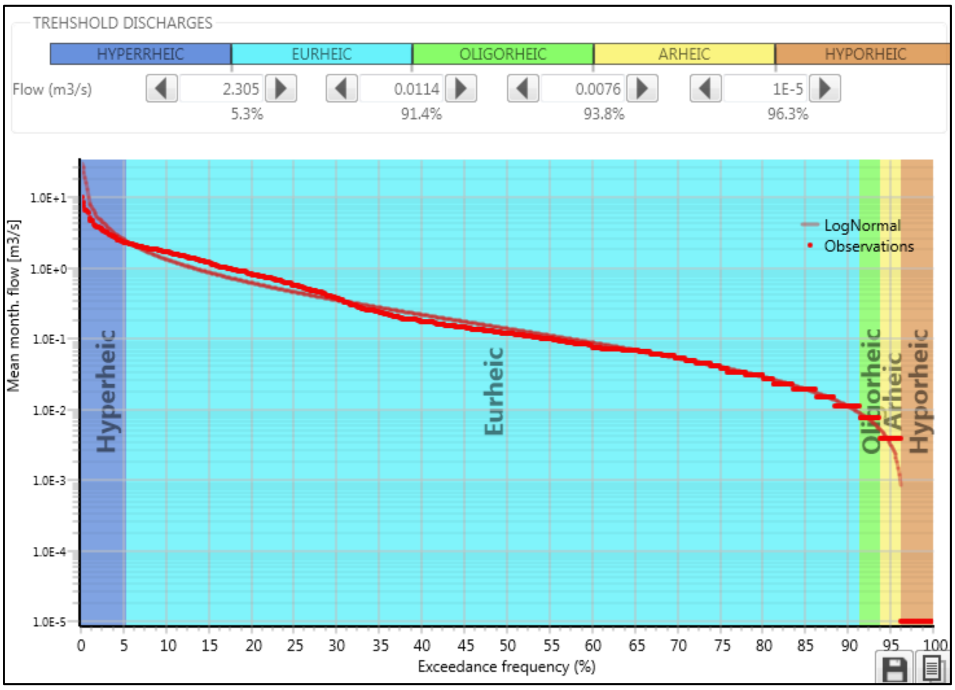


Fig.2.1: Flow duration curve for the flow series simulated with the SACRAMENTO model

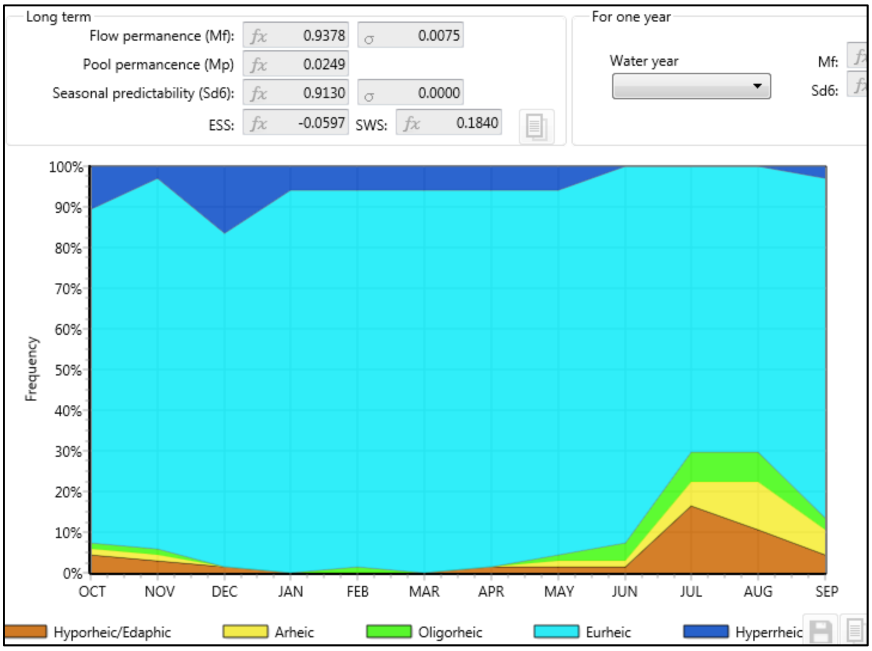


Fig. 2.2: TREHS metrics and Aquatic States Frequency Graph derived from flow simulations of Fig. 2.1.

b) Flow simulation series obtained with the Thornthwaite-Mather (TM) water balance model (Steenhuis & Van der Molen, 1986) for the same period, as for a natural regime under densely forested cover (Figs, 2.3 and 2.4). This simulation was attempted because it is well known that most headwater basins in the Catalan River Basin District suffered a significant decrease of flows during the last decades due to the encroachment of forest cover subsequent to land abandonment (e.g. Gallart et al., 2011). Note that the threshold between *Oligorheic* and *Arheic* states was fixed by 5 $l \cdot s^{-1}$ (assuming that this flow was mainly through the alluvium) and between Arheic and Hyporheic by 0.01 $l \cdot s^{-1}$.

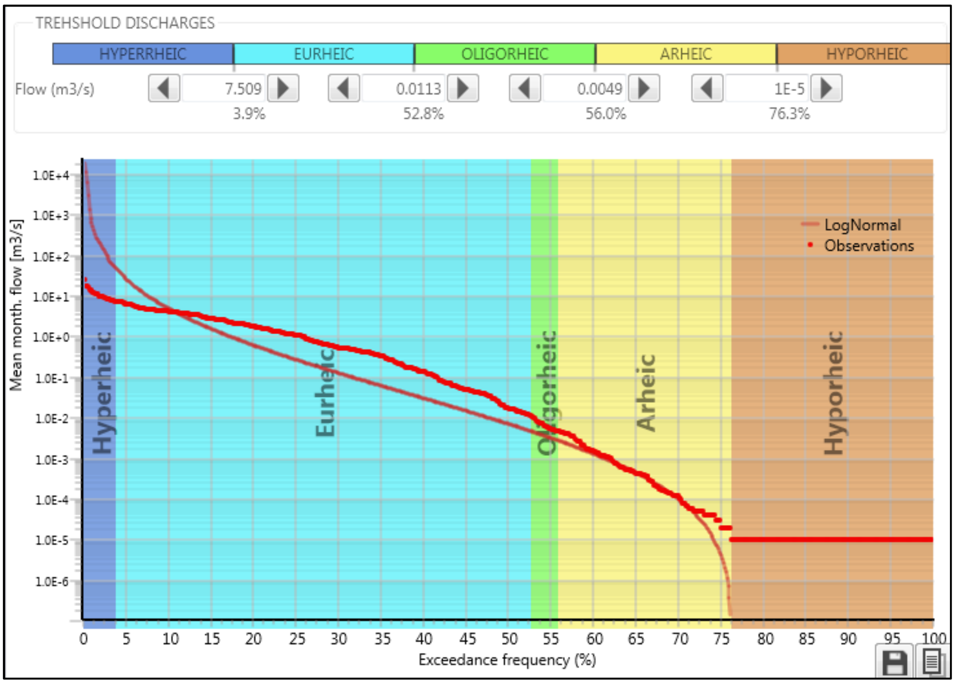


Fig.2.3: Flow duration curve for the flow series simulated with the Thornthwaite-Mather model

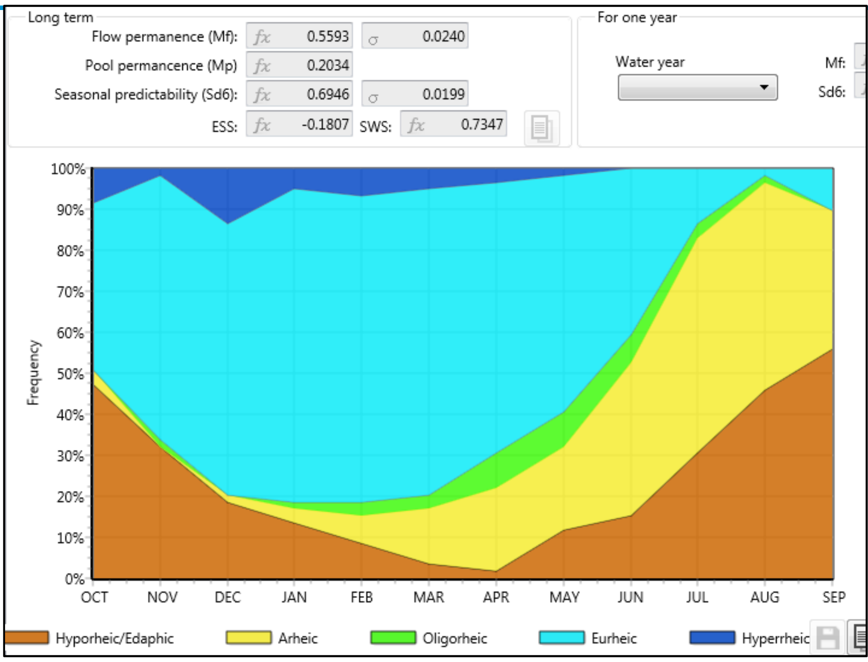


Fig. 2.4: TREHS metrics and Aquatic States Frequency Graph derived from flow records of Fig. 2.3.

b) Interviews. Given the low density population in the area, only one interview was made with the Major of the village of Cruïlles, which is located in the lower part of the water body, where the Daró River leaves the Gavarres massif and flows into the Baix Empordà lowland (Fig. 2.5).

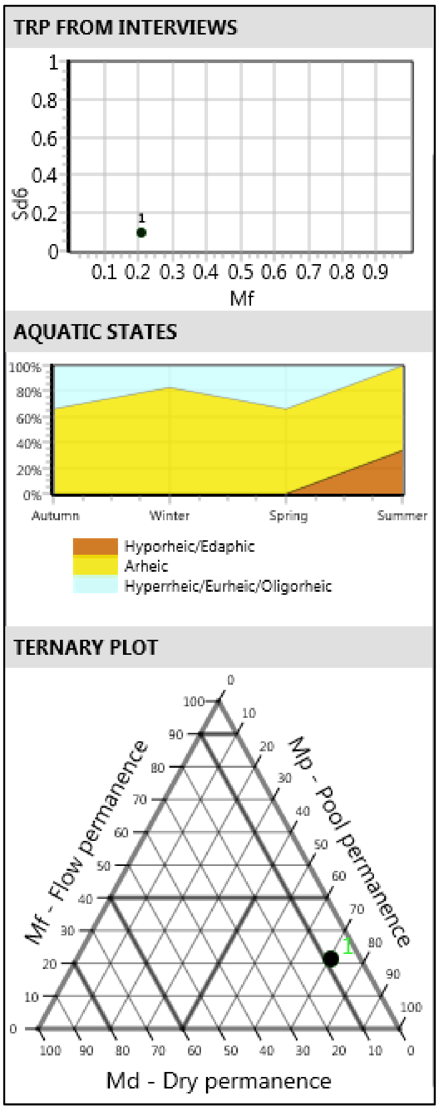


Fig. 2.5: TREHS results obtained with the information from interviews. Top: Temporary Regime Plot, showing both Mf and Sd_6 metrics corresponding to ephemeral rivers. Middle: simplified Aquatic States Frequency Graph showing the high frequency of the Arheic state (pools phase) throughout the year, whereas the stream is only dry during summer. Bottom: Flow-Pool-Dry plot where the river reach is located in the Stagnant (St) regime area.

c) *In situ* and photographic observations. A river reach in this water body was repeatedly visited during 2015 in order to take biological samples and to record the concurrent aquatic states. Furthermore, several ortophotographs and ground-level Street View photographs were interpreted for determining the corresponding aquatic phases. Although a total of 20 observations were made, the temporal patterns of aquatic phases could not be determined because an insufficient number of observations was unambiguously obtained for autumn and winter (two observations in every one of these seasons). Consequently, only the metrics corresponding to the permanence of aquatic phases were obtained, showing an Alternate-Fluent (FS) river regime, with *Mf*=0.50 and *Mp*=0.40 (Fig. 2.6).

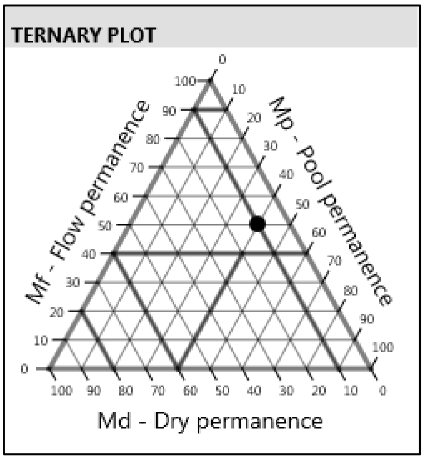


Fig. 2.6: TREHS results obtained with the information from direct and photographic observations. The river appears in the Alternate-Fluent (AF) regime in the Flow-Pool-Dry plot

2.2 Results

Once the data were introduced into TREHS, the following results were obtained:

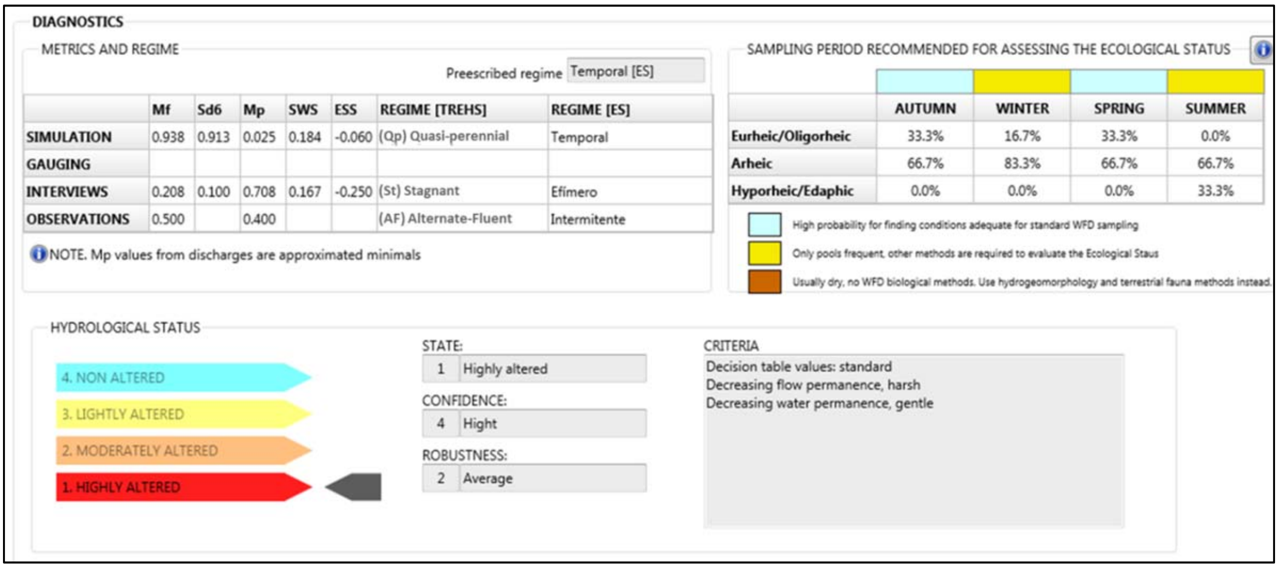
a) Optimal sampling period. This water body presents surface water during most of the year, whereas flow phase seems more frequent in spring and probably in winter or autumn. If only the sampling visits are taken into account, from five visits, none was made during a dry phase, three in Arheic state (pools phase; two in summer and one in spring), one in Oligorheic state (flow phase, autumn) and another one in Eurheic state (flow phase, spring).

b) River regime. The natural river regime may be characterized as temporal following the Spanish regulations (WFD transpositions) and Quasi-perennial (Qp) following the TREHS classification, if the SACRAMENTO simulations are used. Nevertheless, under the TM model simulations, the river regimes turned into intermitente and Alternate-Fluent (AF) using the respective classifications. The actual regime is characterized as Alternate-Fluent (AF) from observations and Stagnant (St) from interviews, both following the TREHS classification (Fig. 2.9).

c) Hydrologic status. Although there are no relevant known pressures on water resources in the studied water body, TREHS showed some hydrologic alteration that shifted from negligible to high depending on the flow simulations and the type of data used for assessing the current regime. Indeed, contrasting the SACRAMENTO simulations versus interviews yielded a high alteration, whereas contrasting the TM simulations versus observations yielded negligible alteration (Fig. 2.7 below). It is clear that both observations and interviews claim that the frequency of the dry river bed phase (Md metric) is low, but this is due to high permanence of either flow phase (Mf metric) or pools phase (Mp metric).

Given the current characteristics of the land cover in the headwaters, the flow simulations made with the TM model are deemed as more appropriate for depicting the present-day natural regime of the water body. On the other hand, the in situ and photographic observations may be assumed as more representative of the current regime of the water body than the interview, given both the lack of replication and the biased location of the interview.

For environmental protection purposes, the results obtained with TREHS show that this water body is characterized by a high permanence of surface water and a low permanence of the dry phase, whereas the permanence of the flow phase might have been subject to some decrease in the last decades due land abandonment in the Gavarres massif. It is recommended to protect the quantity and quality of the water during the pools phase, because this phase waters are very fragile to abstractions and pollution. On the other hand, land cover management strategies to restraint forest encroachment after land abandonment for preventing wildfires may be also useful to restore more frequent flow phases.


DIAGNOSTICS

METRICS AND REGIME

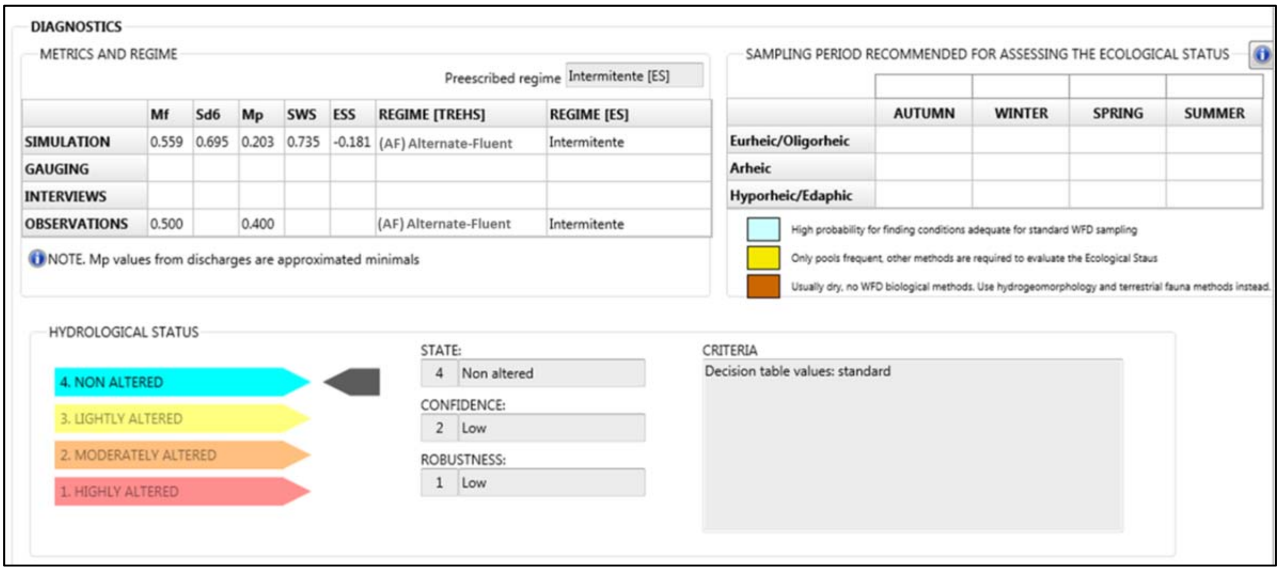
Preescribed regime: Temporal [ES]

	Mf	Sd6	Mp	SWS	ESS	REGIME [TREHS]	REGIME [ES]
SIMULATION	0.938	0.913	0.025	0.184	-0.060	(Qp) Quasi-perennial	Temporal
GAUGING							
INTERVIEWS	0.208	0.100	0.708	0.167	-0.250	(St) Stagnant	Efimero
OBSERVATIONS	0.500		0.400			(AF) Alternate-Fluent	Intermitente

NOTE. Mp values from discharges are approximated minimals

SAMPLING PERIOD RECOMMENDED FOR ASSESSING THE ECOLOGICAL STATUS

	AUTUMN	WINTER	SPRING	SUMMER
Eurheic/Oligorheic	33.3%	16.7%	33.3%	0.0%
Arheic	66.7%	83.3%	66.7%	66.7%
Hyporheic/Edaphic	0.0%	0.0%	0.0%	33.3%


DIAGNOSTICS

METRICS AND REGIME

Preescribed regime: Intermitente [ES]

	Mf	Sd6	Mp	SWS	ESS	REGIME [TREHS]	REGIME [ES]
SIMULATION	0.559	0.695	0.203	0.735	-0.181	(AF) Alternate-Fluent	Intermitente
GAUGING							
INTERVIEWS							
OBSERVATIONS	0.500		0.400			(AF) Alternate-Fluent	Intermitente

NOTE. Mp values from discharges are approximated minimals

SAMPLING PERIOD RECOMMENDED FOR ASSESSING THE ECOLOGICAL STATUS

	AUTUMN	WINTER	SPRING	SUMMER
Eurheic/Oligorheic				
Arheic				
Hyporheic/Edaphic				

Fig. 2.7: TREHS diagnostics blocks when the SACRAMENTO (upper) and TM (lower) model flow simulations are used to infer the natural regime. It shows: metrics obtained from the diverse sources of information; corresponding regimes using the TREHS classification as well as the Spanish regulations [ES]; recommended sampling period; hydrologic alteration along with the criteria used and the valuation of the confidence and robustness of the assessment.

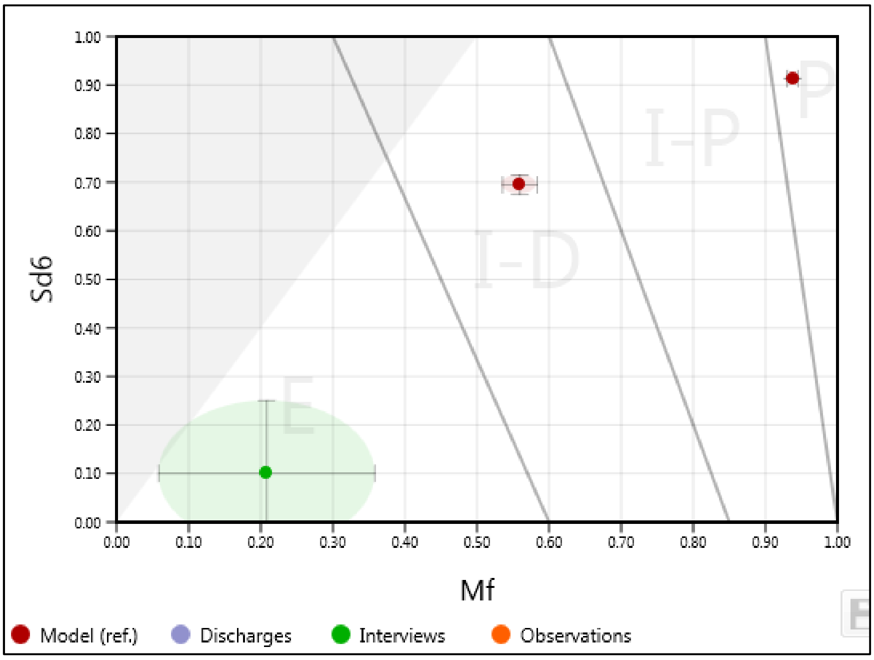


Fig. 2.8: Temporary regime plot for the diverse sources of data used. Ellipsoids show the uncertainty of the metrics. In this case two Model (ref.) are shown; the upper point refers to the SACRAMENTO simulations and the lower to the TM simulations for a densely forested land cover.

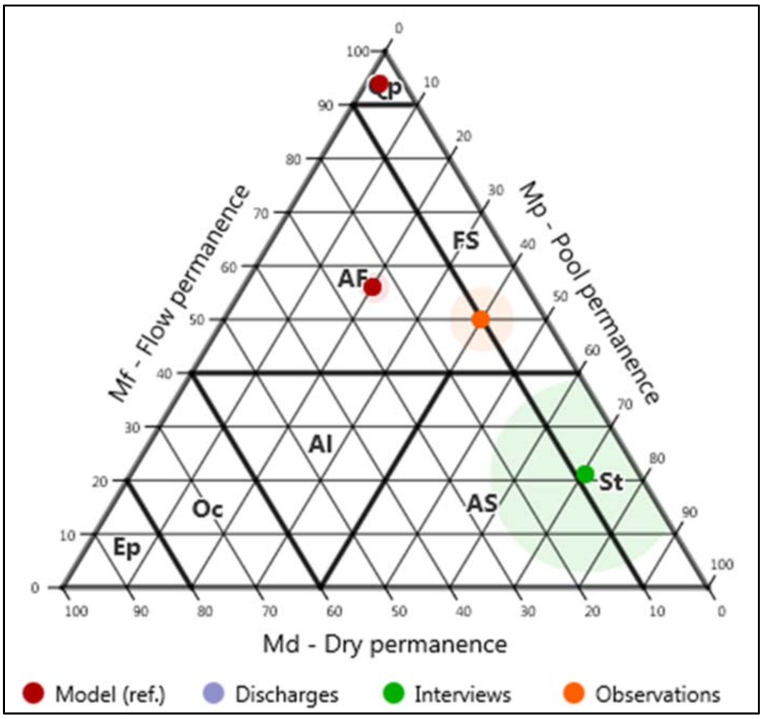


Fig. 2.9: Flow-Pools-Dry (FPD) plot for the diverse sources of data used. Circles show the uncertainty (resolution) of the metrics. In this case two Model (ref.) are shown; the upper point refers to the SACRAMENTO simulations and the lower to the TM simulations for a densely forested land cover.

2.3 References

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Steenhuis, T.S. & Van der Molen, W.H., 1986. The Thornthwaite-Mather procedure as a simple engineering method to predict recharge. J. Hydrol. 84, 221-229.