

Deliverable 9: The TREHS manual

June 2015

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LIFE13 ENV/ES/000341

With support from the LIFE+ programme of the European Union



Duration: 06/2014 – 06/2018

Implementing the Water Framework Directive to temporary rivers: tools for the assessment of their ecological status
LIFE13 ENV/ES/000341

Project partners:



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Design by: © GLOBAL DESIGN DEVELOPMENT, S.L.

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Abstract

TREHS (Temporary Rivers Ecological and Hydrological Status) is a PC application developed for helping the River basin managers the implementation of the WFD to the temporary rivers. In order to understand the rationale behind TREHS, the main concepts are firstly introduced in this manual. Second, data needs and output results are explained. Finally, TREHS layout and user interface are presented and the different applications are described step by step using screenshots.

1. TREHS principles: Aquatic States, metrics and graphs

In Europe, the implementation of the Water Framework Directive (WFD) has been unable to provide a solution for the establishment of the Ecological Status of temporary rivers because even the river typology is still unclear for water managers and a matter of controversy for some researchers. TREHS (Temporary Rivers Ecological and Hydrological Status) is a PC application developed for helping the River basin managers the implementation of the WFD to the temporary rivers, based in the application of the EU FP7 MIRAGE project results (FP7-ENV-2007-1- 211732) and the derived publications (Gallart et al. 2012; Prat et al. 2014; De Girolamo et al (2015). Reading these works is recommended for a sound use of the TREHS tool.

The used approach is based on two main ideas: i) the macroinvertebrate aquatic life in a temporary stream is controlled by the temporal succession of Aquatic States (AS) or transient sets of mesohabitats occurring in a stream reach at a given moment, depending on the hydrological conditions. ii) using only the statistics of the periods with/without flow, two metrics may be defined that allow the characterisation of the regime: the flow permanence (Mf) and the seasonal 6-months predictability of the period without flow (Sd6).

1.1. The Aquatic States

The ASs summarize the transient sets of aquatic mesohabitats occurring on a given stream reach at a particular moment, depending on the hydrological conditions. The following ASs may be defined as relevant in the ecology of temporary stream reaches, in a sequence from wetter to drier. The terms were selected in a way similar to the widely accepted grades in aquatic ecology for nutrient availability (i.e. Eutrophic, Mesotrophic, Oligotrophic) or pollution (i.e. Oligosaprobic, Mesosaprobic) that grade from the highest (hyper-) to the lowest condition (A-, hypo-), using here the Greek suffix “-rheos” as indicating flowing water:

a. Hyperrheic: infrequently high water (flood) causes major movement of stream bed alluvium and the drift of most of the aquatic fauna in the reach. In permanent streams, this state corresponds to flow above bankfull discharge, but temporary streams may not show distinct channel banks. Observations of temporary streams suggest that floods cause a strong but short-lived disturbance in aquatic communities, whereas their occurrence is considered highly relevant to the health of river systems. In low gradient rivers of dry areas, overbank floods may be the periods of the highest biological productivity due to the release of nutrients from sediments and detritus in the alluvial plain.

b. Eurheic: water discharge is high enough to allow the occurrence of all the available aquatic habitats in the reach, including the abundant presence of riffles, and to allow optimum hydraulic connectivity between the diverse habitats. This is the habitual state in permanent streams and the one with the widest range of discharges in temporary streams; a succession of riffles and pools (macrohabitats) is the rule, with great variability in microhabitat conditions.

c. Oligorheic: water discharge is low but sufficient to connect most pools in the reach through water rivulets. Riffles are absent or limited to scarce rapid flow areas between main pools. When few riffles persist, the riffle macroinvertebrate community can be still effective for bio-monitoring, but it ends to resemble that of pools and edges, due to decreased flow and increased lentic habitats.

d. Arheic: surface discharge is null or close to zero, but a number of water pools remain in the stream bed. If this is alluvial, some sub-surface connectivity of water may occur, allowing the preservation of the physicochemical quality of the water in the pools for some time at least. If the stream bed is impervious, the pool waters are vulnerable to undergoing quality deterioration trends or cycles. When the disconnection lasts for many weeks, the pools tend to disappear (through evaporation) and water quality may deteriorate rapidly. In large dryland rivers, persistent pools (usually named waterholes in Australia) play a primary role in river ecology as refugia of many species during the long periods between flow events.

e. Hyporheic: most of the stream bed is devoid of surface water in the reach, although alluvium may remain wet enough to allow hyporheic life (alluvium water content is higher than the field capacity point). Only terrestrial fauna may be observed on the surface of the stream bed, but since the hyporheic zone may be a refuge for many animals when surface water is absent it should also be considered an aquatic mesohabitat.

f. Edaphic: the entire stream bed is devoid of surface water in the reach and alluvium is dry enough to impede active hyporheic life (alluvium water content is lower than field capacity and similar to the surrounding soils in terrestrial locations). The active life in the alluvium is similar to the edaphic life in the interfluvial soils, but some invertebrates may survive in desiccation-resistant stages in dry substrata for some time. Only terrestrial fauna exists on the surface and, if the state lasts for many weeks, the river bed may be invaded by terrestrial plants, creating a quite different ecosystem.

1.1.1. Getting statistics on the Aquatic States

Statistics of the temporal patterns of the ASs are necessary for three main purposes: i) to characterize and compare the stream regime, ii) to help selecting the more appropriate sampling calendar given the regime of the stream and ii) to help interpreting the results of the biological samples given the aquatic states occurring on the sampling date and the antecedent months. The basic temporal unit in TREHS is the month.

There are three possible sources of information for obtaining the statistics of the ASs addressed in TREHS: Stream discharge records, stream discharge simulations obtained with a rainfall-runoff model, and the results of interviews made to the neighbours and users of the fluvial system. The first and third sources correspond to actual regimes whereas the second corresponds to a virtual regime that may reflect just the climatic conditions or can also include the effect of human surface or ground water abstractions. In fact, temporary streams are typically undergauged ones, so the most current situation is to have only simulated flows and the results of interviews for most of the water bodies to be managed.

The conversion of flow records or simulations into aquatic states statistics needs the establishment of threshold flow discharges that separate the diverse aquatic states, so the flow duration curve can be easily translated into an aquatic states duration graph. An accurate definition of these flow thresholds would be a cumbersome task needing many field observations synchronous to flow discharge measurements, but in the practice approximate values will be sufficient, taking into account the qualitative nature of the aquatic states and the nature of the use of their statistics.

On the other hand, interviews designed for estimating the statistics of the aquatic states take advantage of their qualitative nature, as it is easier to get information from people on the frequency of occurrence of running water or stagnant pools than on quantitative discharges of flowing water. But both the number of aquatic states and the time resolution had to be simplified in order to obtain robust results from the interviews.

1.1.2. Aquatic States Frequency Graph

The main result of the analysis of the statistics of the ASs is the drawing of the Aquatic States Frequency Graph (ASFG). This figure summarizes the long-term ASs seasonal patterns in the form of monthly frequencies of occurrence of the diverse ASs during one water year.

Figure 1 shows a set of 8 ASFGs obtained from diverse streams in the Mediterranean. The relative importance of wet and dry states throughout the year and the degree of seasonality of the regime may be assessed at a glance from these graphs. The regimes are ordered with the wetter ones in the upper part and the drier in the lowest part. The left row correspond with the least seasonal regimes (low variability among the months) whereas the right row correspond to the more seasonal ones (clearer differences among the months).

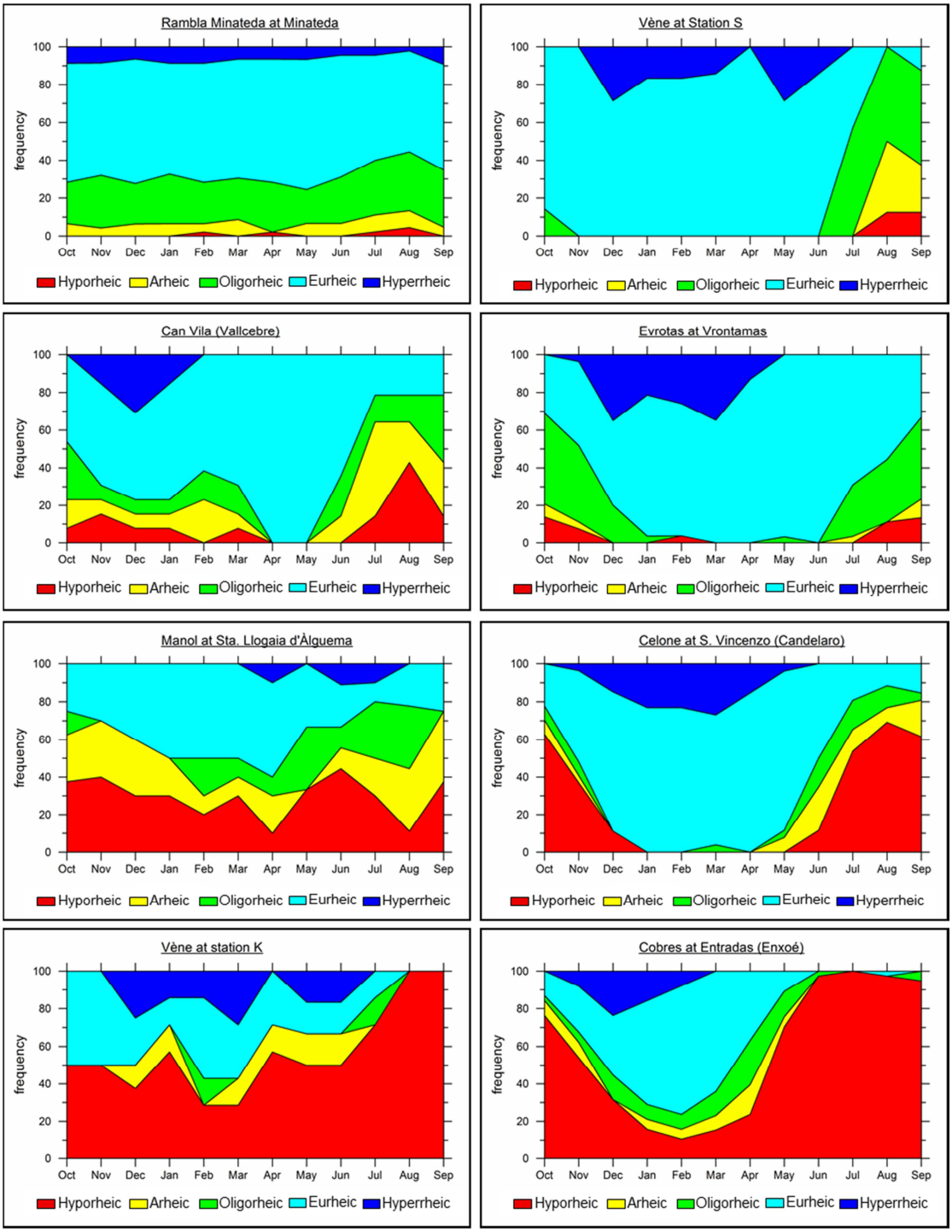


Figure 1: Aquatic states frequency graphs for a set of 8 Mediterranean streams. Reproduced from Gallart et al (2012).

These graphs were made for long-term analysis at the monthly scale. THRES allows also the representation of the aquatic states for a single water year, in order to allow the help analysing the regime control on sampling results.

1.2. Temporary Regime metrics

The ASFG method given above allows appraisal of the aquatic regime of the reach, as it describes the mean annual prevalence and timing of aquatic states for a stream reach by month. Nevertheless, the information shown is too complex to be synthesised in a few metrics and it depends on the somewhat subjective selection of flow thresholds. To circumvent these limitations, it may be hypothesized that the cessation of flow is the key feature defining the aquatic regime in a temporary stream and, therefore, the statistics of its metrics will summarize the main characteristics of the regimes of its aquatic states, as seen in its ASFG. Therefore, we selected the metrics that synthesize the two main hydrological parameters that are relevant to river ecology: the duration and predictability of periods with and without flow.

These metrics, as used in TREHS are the long-term mean annual relative number of months with flow, Mf (taking values between 0 and 1) and the the six-month seasonal predictability of dry periods (Sd6) defined in equation 1:

$$Sd_6 = 1 - \left(\sum_{1}^{6} Fd_i \Big/ \sum_{1}^{6} Fd_j \right) \qquad \text{(Eq. 1)}$$

where Fdi represents the multi-annual frequencies of 0-flow months for the contiguous 6 wetter months of the year and Fdj represents the multi-annual frequencies of 0-flow months for the remaining 6 drier months. Wet and dry 6-month periods mean here those with fewer and more zero-flow frequencies, respectively. This variable is dimensionless and takes the value of 0 when zero flows occur equally throughout the year in the long run and 1 when all the zero flows occur in the same 6-month period every year. When the regime is fully permanent, this metric cannot be computed, so the value of 1 is set to indicate full predictability.

1.2.1. Temporary Regime Plot and Types

The metrics obtained for diverse streams can be better compared if plot in the Temporary Regime Plot (TRP) as shown in Figure 2. In this figure, the metrics obtained for the same streams of the Figure 1 are shown. In this figure, four sectors representing the four temporary regime types were defined by Gallart et al (2012): Perennial (P), Intermittent-pools (I-P), Intermittent-dry (I-P) and Ephemeral (E).

This plot can be used to compare the regimes of diverse streams. In the example shown in the Figure 2, it can be observed that the wetter (upper) streams in the Figure 1 appear in the right part of the plot (high Mf metrics), whereas the more seasonal appear in the upper part here (high Sd6 metrics).

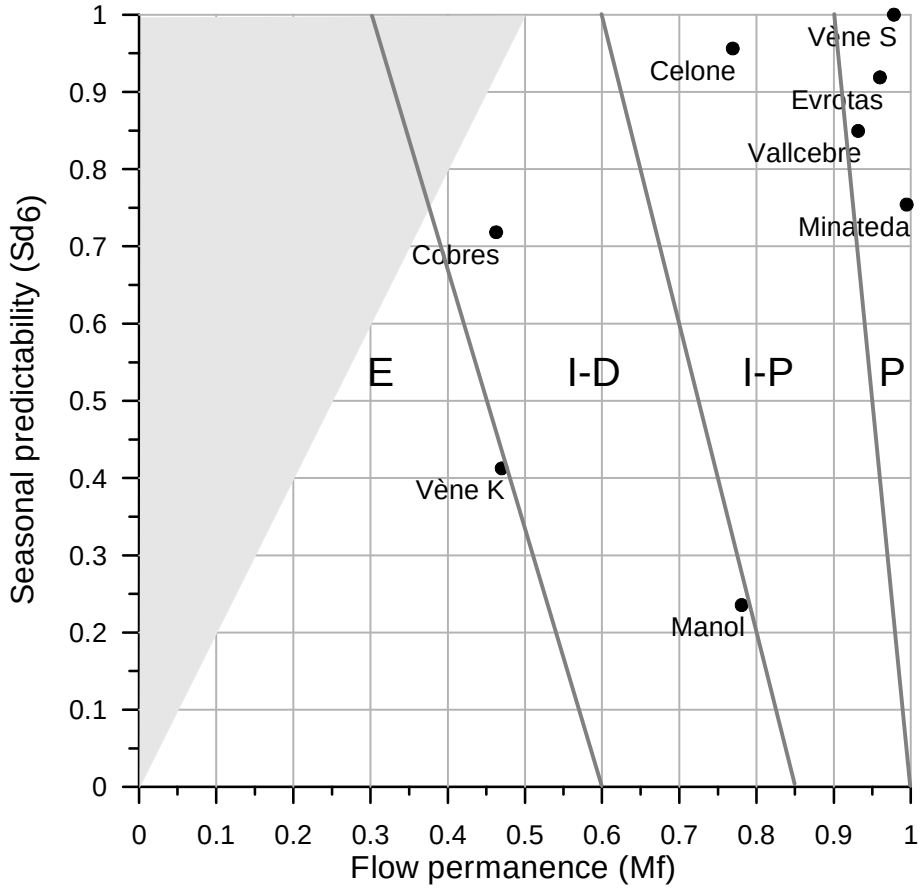


Figure 2: Plot of the temporary regime metrics Mf and Sd6 obtained for the same streams shown in the Figure 1. The four sectors represent the diverse types of temporary regime: P: Perennial; I-P: Intermittent-pools; I-D: Intermittent-dry; E: Ephemeral. Reproduced from Gallart et al (2012).

Another function of this plot is the comparison of the metrics obtained for the same stream when diverse sources of information are used. This means, for instance, the comparison of the potential regime obtained with a rainfall-runoff model with the regime obtained from flow records or neighbours interviews. In this case, it is possible to analyse the alteration of the regime resulting from human activity impacts such as water abstractions. Both the Euclidean distance between impacted and unimpacted regimes and the transitions between regime classes may be compared with the standard errors of the metrics in order to assess a measure of regime alterations. An example of this use of the TRP is shown in Figure 3.

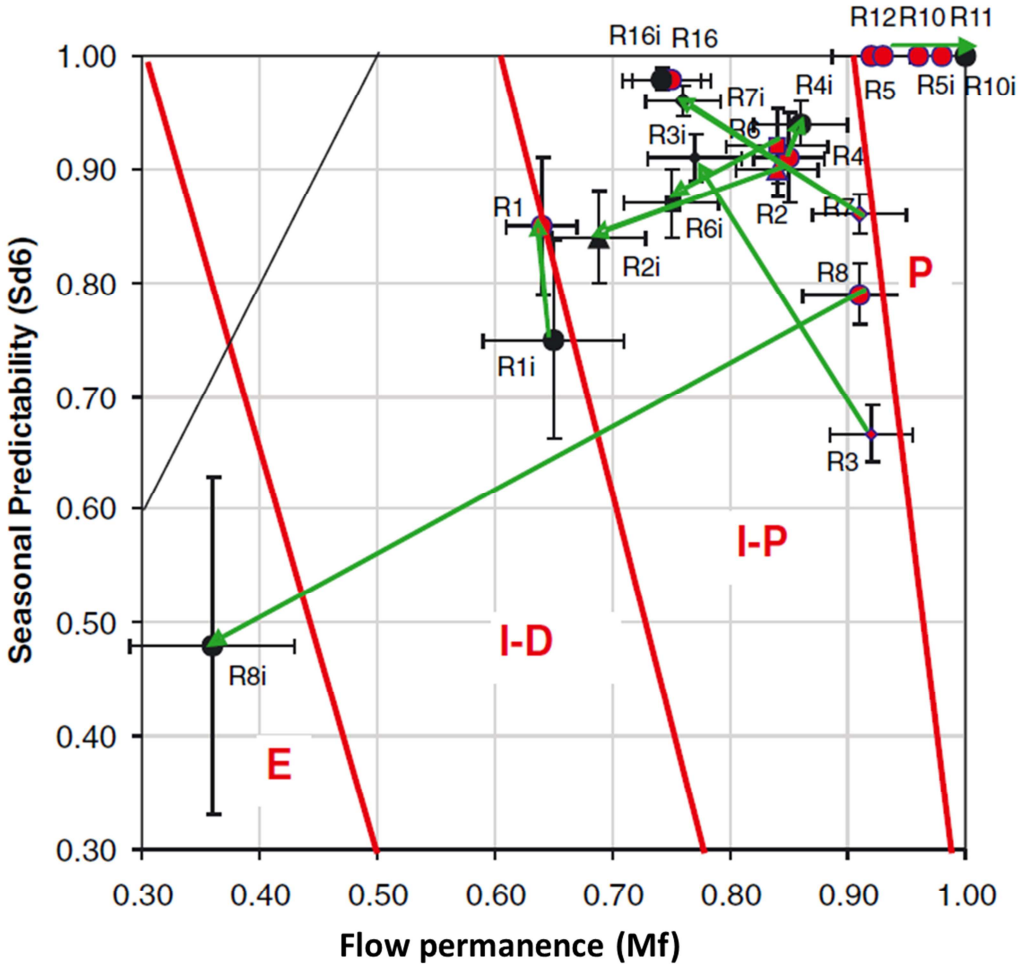


Figure 3: Plot of interannual Sd6 versus Mf metrics in actual (black points) and natural conditions (red points). Error bars show standard errors. Arrows linking two corresponding points represent the degree of hydrological alteration. Taken from De Girolamo et al. in press.

2. Data needs

The main unit of TREHS is the monitoring station within a water body, as defined by the WFD. This opens the possibility that the same water body have diverse stream regimes. The diverse kinds of information to be fed to TREHS are of three types: i) Identification and location ii) flow data iii) interview results.

2.1. Identification and location data (heading page)

- **Name** of the monitoring station, textual name as commonly used by the corresponding Water Authority
- **Synonyms and description:** Other names eventually used for the same station, site or stream reach. Textual description and any other information relevant to the site.
- **Code:** it is formed by a sequence of hierarchical codes:
  - Member State
  - River basin district
  - River basin
  - Water body
  - Monitoring station
- **Location:** ETRS89 longitude and latitude in geographic degrees and decimal fractions. Altitude in metres a.s.l.
- **Observations:** Any relevant information, such as the existence of known pressures on water quantity or quality by the monitoring station.
- **Group selection:** The current station can be assigned to a new or extant group of stations (by any criteria such as location, geology, land use…)

2.2 Hydrological information

TREHS uses essentially qualitative information (aquatic states and flow-no flow statistics) but, as the more usual hydrological information is in quantitative values of water flows, this kind of information can be input to the tool in order to appraise the statistics of aquatic states and flow-no flow metrics. Flow data units in TREHS are m3 s-1 (cubic metres per second or cumecs), usually averaged for a period of one month.

It is expected that flow simulations obtained with an operational rainfall-runoff model will be available for most water bodies. TREHS does not provide any original flow simulation, but uses any available simulations, typically under assumed natural conditions or eventually including some water quantity pressure. Occasionally, flow records from a gauging station may be available for the monitoring station or water body. Finally, TREHS includes a facility to incorporate estimates of flow regime obtained from interviews made to water users of stream neighbours.

The management of flow information obtained from model simulations or gauging data are analogous, whereas the information obtained from interviews is directly of qualitative nature and is being managed in a different way.

2.2.1. Flow data or simulations (Obs. Or Sim. pages, DATA banner)

The following information is needed:

- **Date** of the data entry
- **Author**'s name, or person entering the data
- **Observations** such as the name of the model or the gauging station
- **Model** data: modelling origin of the data, natural or altered simulated flows and periods of simulations if different
- **Threshold**: flow value threshold corresponding to actual 0 flows; this is needed for some flow simulations or records that do not properly identify the cessation of flow.
- Monthly flow data must be input using a grid format, with the columns corresponding to the months (13 columns, year number and monthly flows from October to September) and the lines corresponding to water years. TREHS is able to accept this format by copy-and-paste of nearly any table from a document, word processor or spreadsheet. The system asks for the flow units after the table has been accepted, and subsequently the data are transformed into monthly averaged $m^3 s^{-1}$.

2.2.2. Setting flow thresholds between Aquatic States (DISTRIBUTION OF DISCHARGES banner)

The conversion of flow statistics into aquatic states statistics needs the establishment of the flow thresholds between aquatic states. Although a precise determination of these thresholds is a cumbersome task, because there is not usually the adequate information, in the practice and approximate estimation is sufficient because the subsequent use of it is only of a qualitative nature. TREHS proposes an automated interim set of flow thresholds based on given fractions of the peak observed discharge; the values of these fractions can be set in the tool settings.

Once the DISTRIBUTION OF DISCHARGES banner has been selected, the AUTO knob will set the automated thresholds. If the distribution of the aquatic states (colours) is not satisfactory, the thresholds may be modified by dragging the round knobs in the upper part of the graph to the left or to the right sides in order to respectively decrease or increase the threshold flow value. The flow value (in m3 s-1) and exceedance frequency corresponding to the aquatic states are shown close to the round knobs.

2.2.3. Managing Interviews

Interviews made to the fluvial system users and neighbours are recommended for getting several kinds of information on the fluvial system, but here only the information that can be used for assessing the statistics of the aquatic states as well as and the value of the temporary regime metrics is analysed.

All the information is to be entered in the INTERVIEWS EDITOR:

A SECTION: heading of the interview

- **Date** of the interview
- **Ref.** user's reference for the interview
- **Interviewer**: name of the person who made the interview
- **Interviewed**: name of the person who answered the interview questions

- **Validated**: in the case of this interview is accepted, with regards to the consistence with the other information, it must be validated before being taken into account for subsequent analyses, graphs and metrics.

B SECTION: general questions on the temporary regime

- (1) Occurrence and overall frequency of stream drying
- (2) Occurrence and duration of the arheic state (pools)
- (3) Occurrence of the Hyporheic state (no surface waters but saturated alluvium)

C SECTION: Array of the seasonal frequencies of three summarized states

This array has four columns (seasons) and three rows (summarized states). The figure in every one of the cells represents the frequency in months (may be fractional) this state occurs in the long term. Every column must sum 3, which is the number of months of every season. This can be summarized as:

- Number of months when water flows during every season
- Number of months when stagnant pools occur in every season
- Number of months when surface water disappears in every season

This information, after validation of the interview, is used to calculate the Mf and Sd6 metrics and to draw a simplified ASFG.

3. Output results

TREHS manages the input information to calculate metrics and generate graphs; from this output, the regime of the station is classified, the best periods for biological sampling may be proposed, and a first assessment of the hydrological status (degree of conservation of the natural hydrological regime) is made. Nevertheless, before the final diagnostics on the hydrological status are attained, the actuation of an expert user is needed in order to take into account the information not automatically generated by the tool.

Graphic and metric results are separately obtained and shown in the diverse pages corresponding to the diverse sources of information managed: observed discharges (Obs), simulated discharges (Sim) and interviews. Standard deviations of the metrics are also shown, based on the annual values for observed and simulated flows, and on the results of the diverse interviews made in the corresponding case. These partial results are gathered together in the station heading page as well as in the report that can be ordered for the station.

The overall automated results consist of:

- The values of TREHS metrics obtained from the three types of information: flow simulations, flow records and interviews.
- TREHS stream regime classifications corresponding to the metrics obtained with the three diverse types of information
- Prescribed stream regime, based on the regulations issued by the Member State in the transposition of the WFD, if applicable.
- Normalized Metric Distances (NMD) in the TRP (Euclidean distance divided by the maximal standard deviation) when comparing simulated versus observed as well as simulated versus interviews metrics determinations.
- Interim determination of the hydrological status using the following criterion: NMD<1: good; 1<NMD<2: fair; 2<NMD<3: poor; 3<NMD: bad.

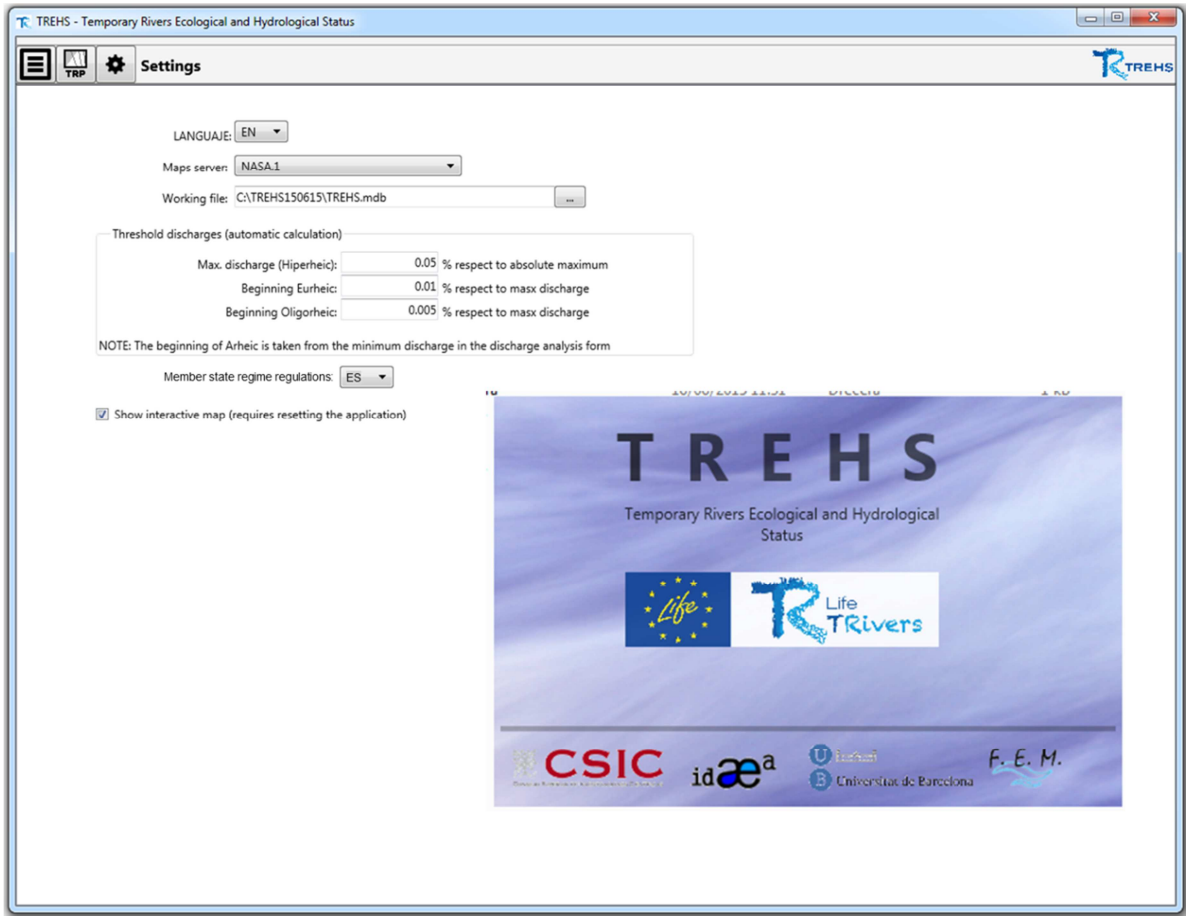
From these results and taking into account all the information behind, the expert user is then invited to insert the following outcomes:

- Determination of the hydrological status of the station
- Recommended biological sampling periods, with an assessment of the probability of finding a range of aquatic states during these periods.
- Recommendation of using alternative methods for assessing the ecological status when the stream regime makes common aquatic biological methods impracticable.

Finally, TREHS can be required to produce a detailed report with all the relevant information from a single station, or a listing of the main results obtained for all the stations included in a group, a River Basin, a River basin district, or a Member State.

4. TREHS layout and user interface

Subsequently, a set of TREHS screenshots are commented for the shake of clarity when using the application.

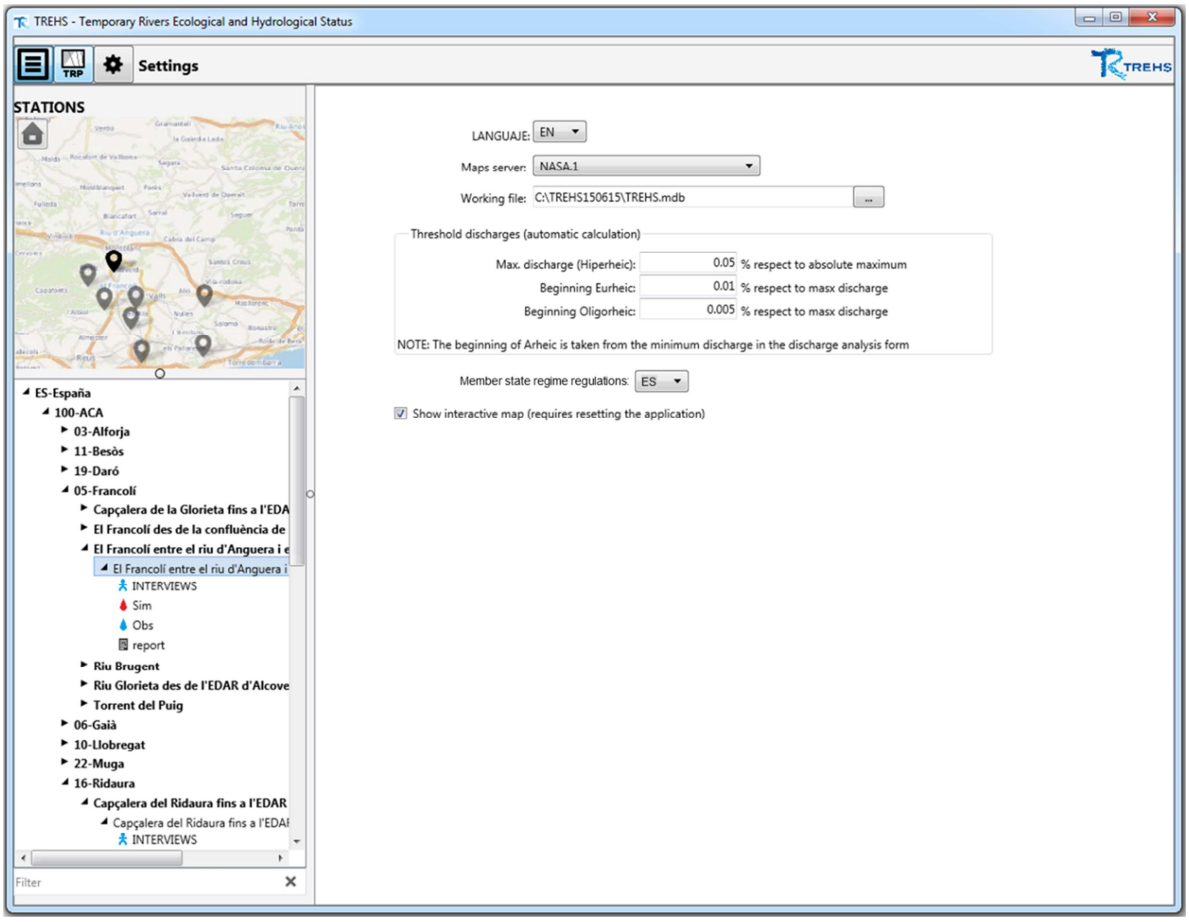


Screenshot 1: TREHS settings and starting pop-up.

The settings page of TREHS is shown in Screenshot 1. It is selected clicking on the gear icon (✿) in the heading banner. This page allows selecting the main adjustments of the application:

- Language used
- Online server for the maps
- Name of the data base used in the exercise (new or extant)
- Default threshold discharges between aquatic states
- Member state regulations for prescribed temporary regimes
- Toggle of the Interactive map display

When any page is shown, clicking on the view icon (▤), the side windows with the interactive map and the station tree is shown as in Screenshot 2.

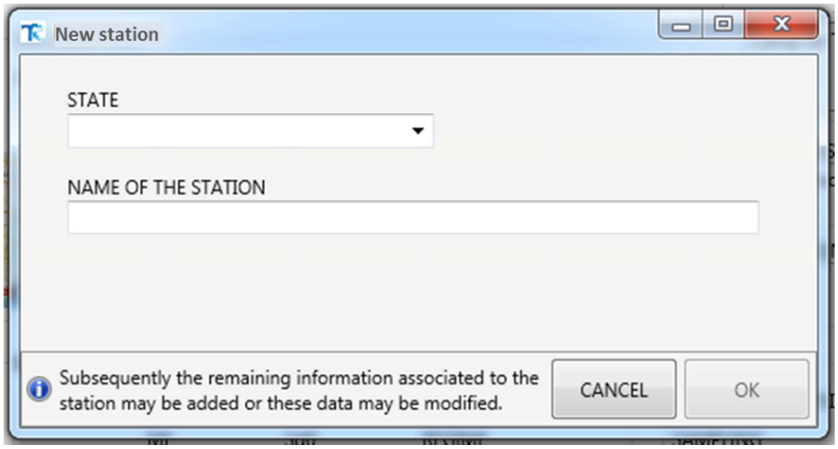


Screenshot 2: TREHS settings page showing the lateral windows with the interactive map and the stations tree.

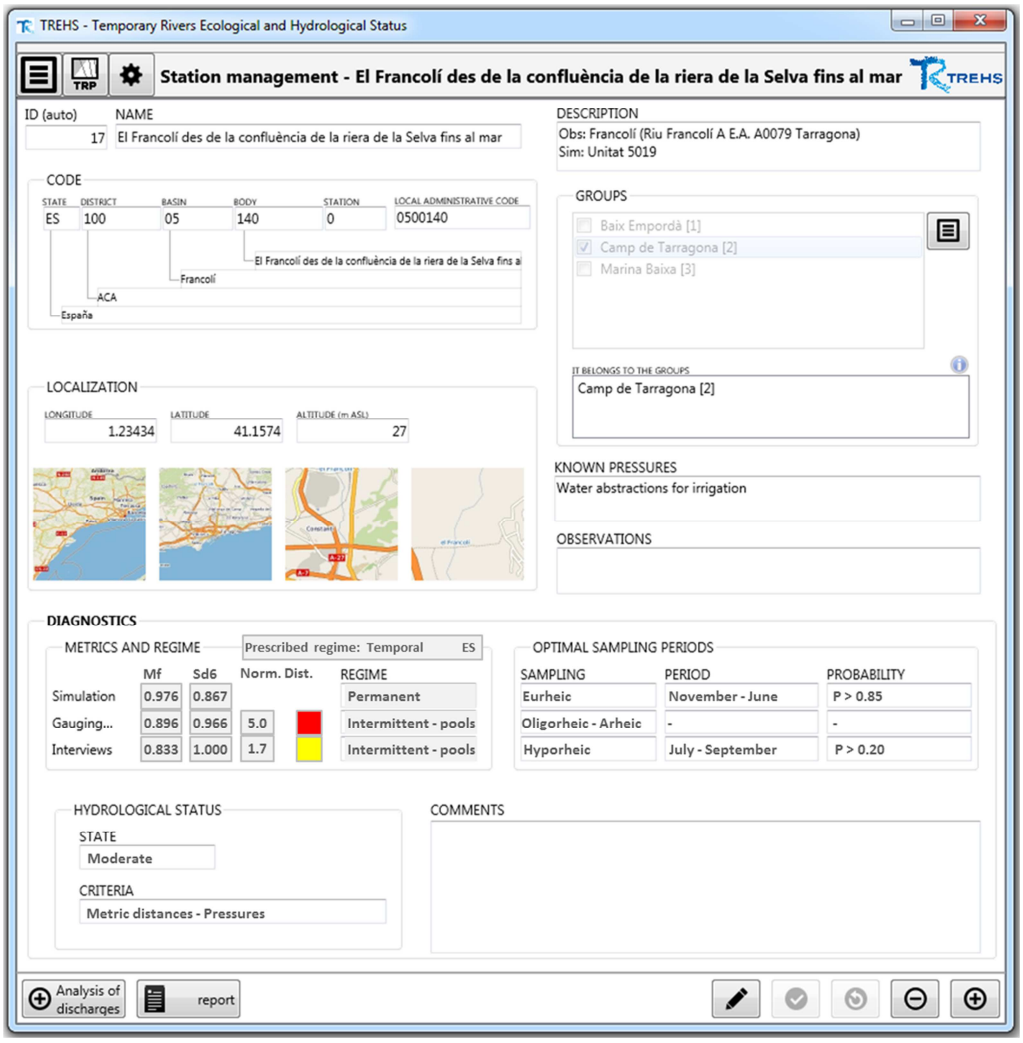
The interactive map can be zoomed rolling up and downwards the mouse wheel and the working stations may be selected by clicking on the respective icons in the map.

The stations tree shows the hierarchical arrangement of member states, River Basin Districts, River Basins, Water Bodies and Stations. The categories may be collapsed or extended by clicking on the triangles and arrows respectively, and the stations are selected when clicked.

When a new station is to be added, it is necessary to select the plus knob (⊕) in the right lower corner, and a window pops-up for introducing the Member State and the name of the station (Screenshot 3).



Screenshot 3: Pop-up for the addition of a new station.

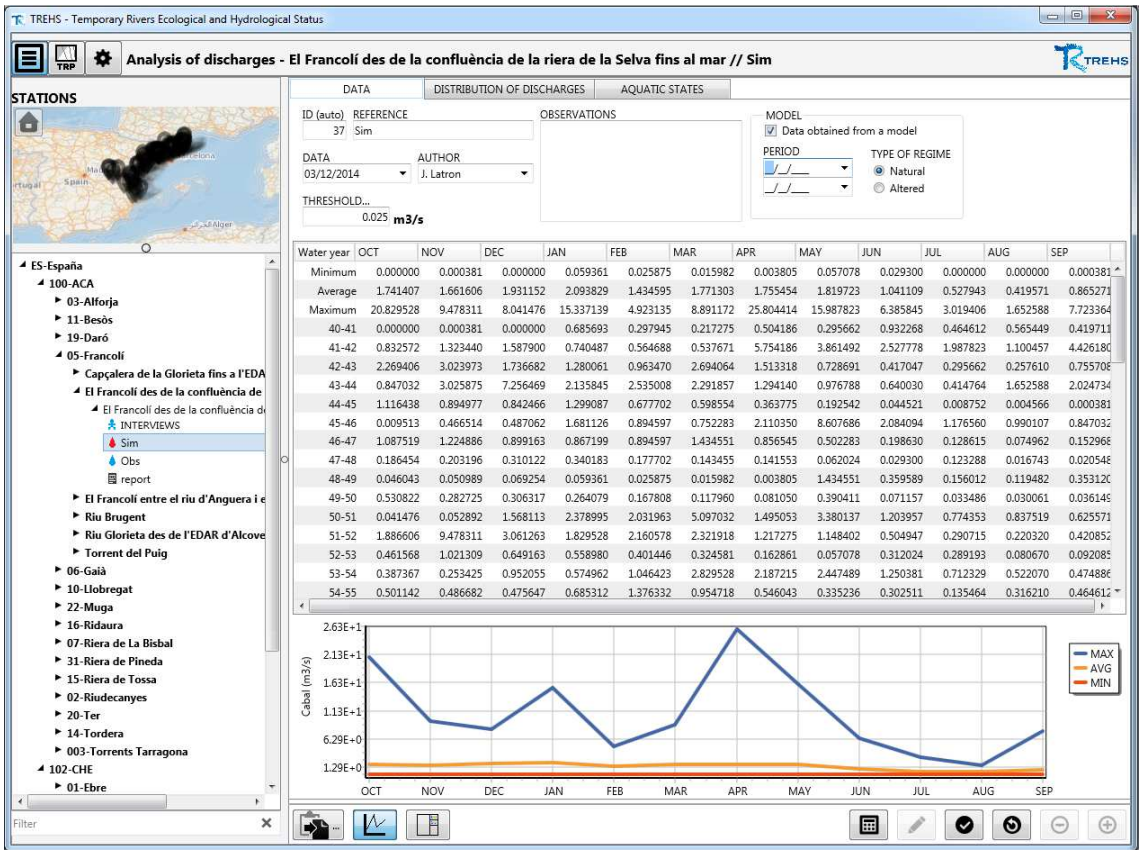


Screenshot 4: heading page of a station with the general information and the overall results.

The heading page of the station is shown when it is selected (Screenshot 4).

This page allows the input of the general information of the station in the upper part and displays the overall results and diagnosis in the lower part, when all the data have been provided. Before typing it is necessary to select the pencil knob in the lower tool bar, and the introduced information can afterwards be validated or cancelled by selecting respectively the OK of the recycle knobs in the lower tool bar.

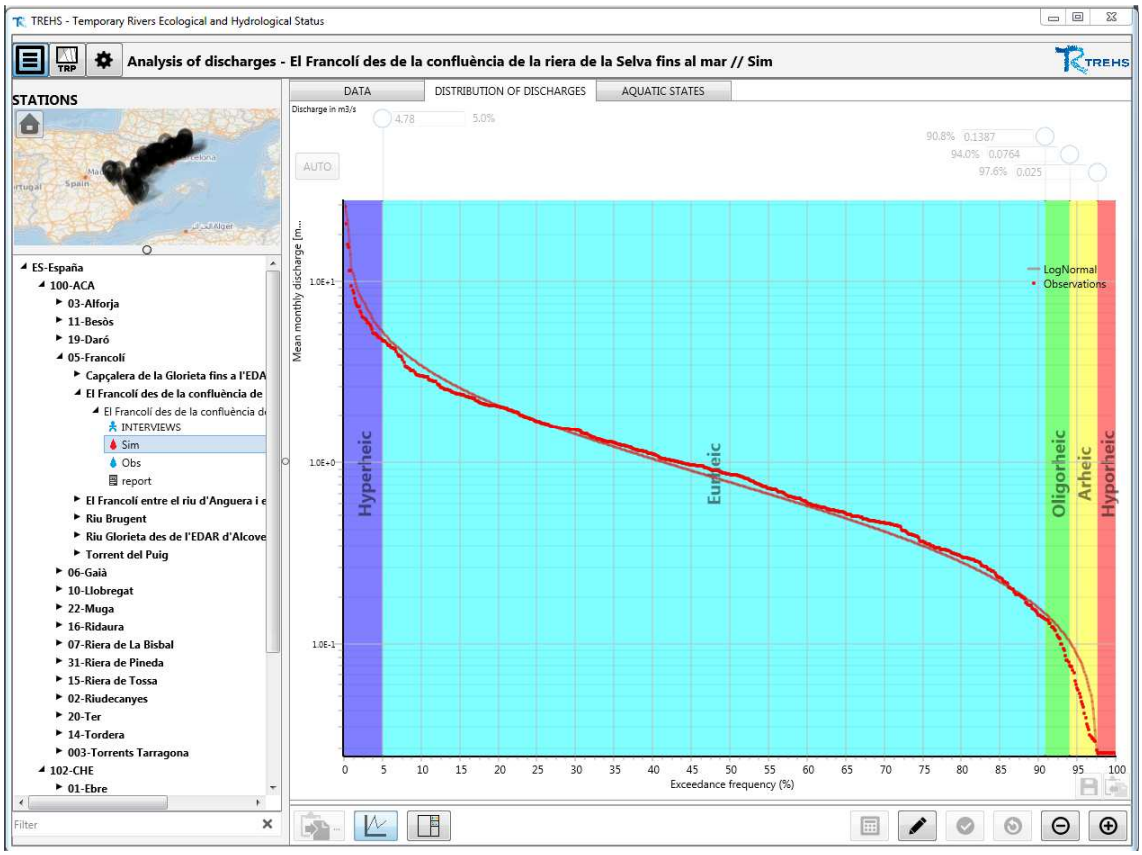
Once a new station has been introduced, it is necessary to select in the item ‘new discharge analysis’ in the tree of the left window to open the flow data. This can be simulated or observed flows.



Screenshot 5: Display of the simulated flows data page.

An example of the data page of simulated flows for a station is shown in Screenshot 5. The user has to state the heading information, to copy and paste the data grid, and to add the zero-threshold discharge, if this is necessary given the type of the model used.

Once the flow data grid is in the system, the next step is the selection of the 'DISTRIBUTION OF DISCHARGES' button in the heading bar. This opens a new window with the flow duration curve (distribution function of discharges), the fitted log-normal distribution (just to visualize eventual anomalies of the data) and the relative frequency of the aquatic states in colour bands (Screenshot 6).

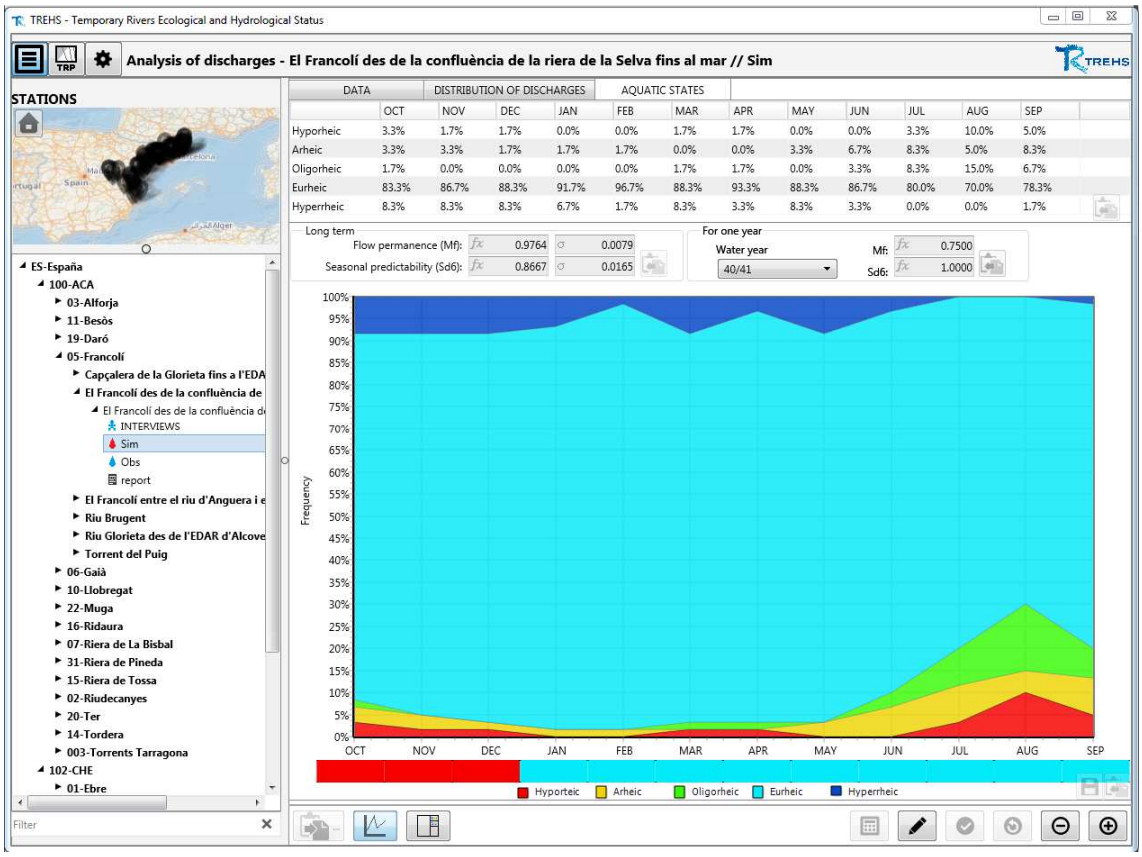


Screenshot 6: Distribution of discharges and aquatic states for the simulated flows in a station.

The flow thresholds separating the aquatic states in this window are initially those selected in the settings page. These thresholds may be modified if there is some additional information or the initial results are not appropriate, by selecting the pencil knob in the lower bar and moving left- or rightwards the circles above the colour bars.

Once the flow thresholds have been accepted, the next step is the display of the ASFG available by selecting the 'AQUATIC STATES' button in the header. This page shows the monthly frequencies of occurrence of the aquatic states in numerical form and in graphic form. It also shows the mean and standard deviations of the two temporary metrics.

Furthermore, it is also possible to show the occurrence of aquatic states and the values of the metrics for only one year. The corresponding aquatic states are shown in a coloured bar below the temporal axis of the graph (Screenshot 7).



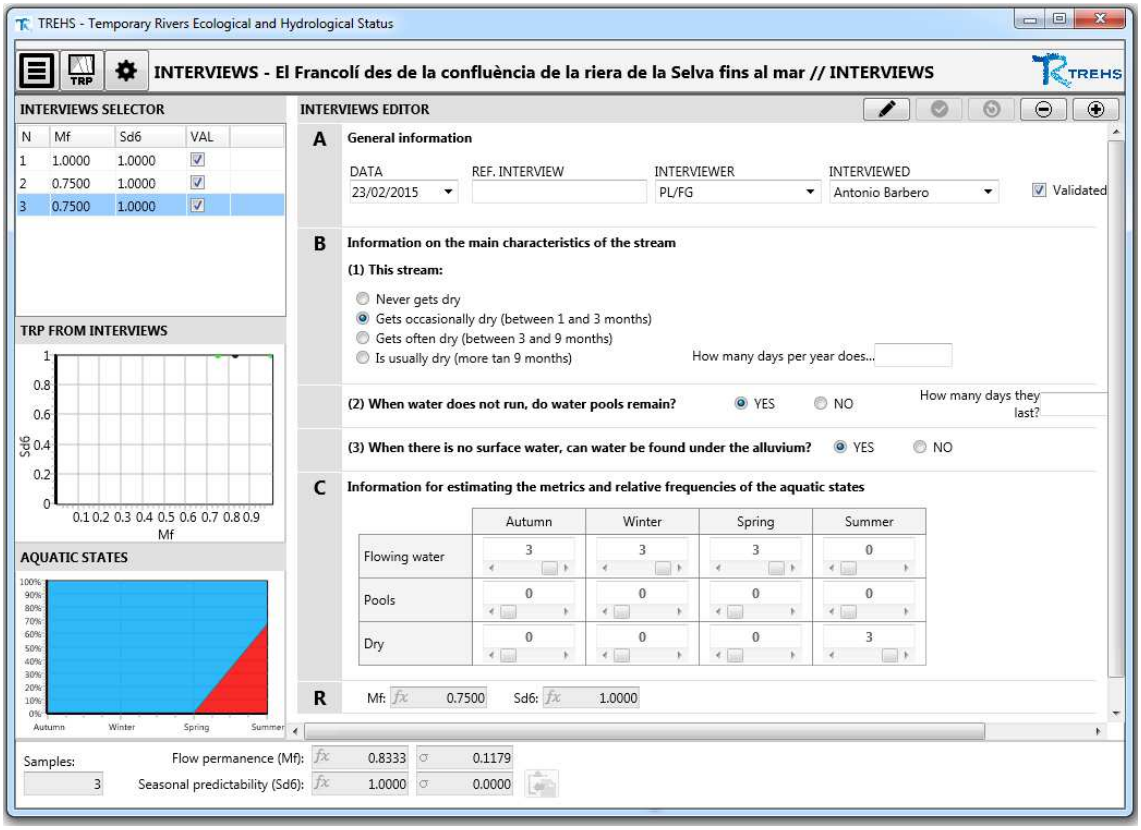
Screenshot 7: Aquatic States Frequency Graph window. The lower color bar shows the occurrence of aquatic states in the water year selected (1941-42)

The same steps are to be made if there are observed flow records for the selected station. As this is not common, the usual next step is the management of interviews in the corresponding window (Screenshot 8).

This page allows the creation of a new interview by selecting the plus knob in the heading bar, and entering all the responses to the questions. When the monthly frequencies of the simplified aquatic states are entered, the system warns if the sum of a column is not 3 months.

Once the new interview is entered, it is necessary to decide if it is to be taken into account for further analyses, by selecting the 'Validated' box. After several interviews have been included, they appear in the left upper window, along with the resulting values of the metrics. The lower left windows show the results of the set of interviews in a TRP as well as in an ASFG.

After all the available information has been entered into TREHS, the next step is the analysis of the diverse sources of information as well as the comparison with other available stations. This can be made by selecting the TRP knob in the upper banner.

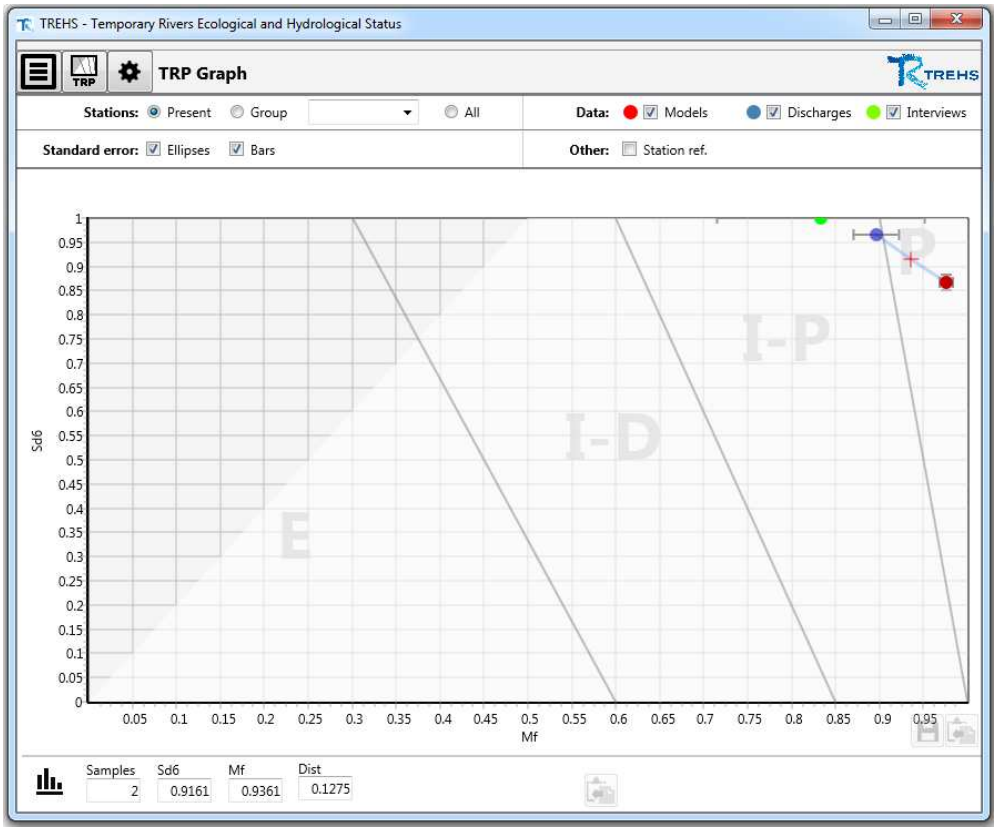


Screenshot 8: Interviews manager window in TREHS.

The analyses shown in this page may be selected from the options in the upper part. It is possible to show the current station, those belonging to a statin group or all the stations in the current data base. The data source can also be selected by choosing Models, Discharges or Interviews. Yet, the error of the determinations can be viewed by error bars or ellipses.

The average values of the metrics as well as the Euclidean distance between several points in the graph can be measured by selecting groups of points (Screenshot 9).

As stated before, this graph allows the comparison of the data obtained from diverse stations. As an example, Screenshot 10 shows the display of all the data in the current data base, note that most of the points are red, corresponding to simulated flows.



Screenshot 9: TRP shown for the current station. The average metrics and the distance between the simulation results (red dot) and the gauging station (blue dot) is shown in the lower window.



Screenshot 10: TRP shown for all the data available in the current data base.

5. References

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