

## Water physical accounts: from occasional estimates to regular production

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# 1. Introduction

From a hydrologist's point of view, the physical "water accounts" concept, especially dealing with water quality assessment, seems a queer idea. The concept, first defined by national accountants (Weber, 1986), had to wait quiescently until it could be positively realized.

Two major problems jeopardized the production of physical water accounts:

1. water quality accounts were poorly understood and accepted by classical quality hydrologists, hence the length of river falling into a certain quality grade was not a regular outcome of monitoring data;
2. water resource accounts, which concept is quite classical among hydrologists could hardly be produced since data participating to it are weakly comparable and seldom available.

The methodological and practical efforts devoted by Ifen to physical accounts, with the substantial support from Eurostat focused on:

- demonstrating first the usefulness and practicability of the "water quality accounts concept", aiming in parallel to define and sample produce indexes and indicators derived from water accounting techniques fuelled by the water accounts results proper;
- building data layers required by quality accounts in common with resource accounts;
- developing the possibility to make linear quality data from monitored data in order to regularly produce accounts and deliver outcomes both at the catchment (assessment indexes) and administrative (to match with economic accounts);
- constructing the resource water accounts around existing (or "recycled") information, (noticeably emissions and Namea data) from different sources in a flexible way.

This paper recalls the past steps and the current state-of-the-art at the very moment when systematic production can be envisaged and reported, the pilot and prototype phases having been successfully achieved.

The paper has been drafted quite comprehensively, to yield accurate information regarding the complexity of the development and the relative simplicity of use. However, it is underlined that water quality accounts and water resource accounts are addressed in very different ways. They share a common data layer, -the river discharge data-, required by the objective of producing results both at catchment and by NUTS levels of aggregation.

## 2. Water quality accounts

### 2.1. Scope of water quality accounts

The reporting needs with respect to rivers and river water quality fall into one of the following categories:

- The requirements specified in the Water Framework Directive<sup>1</sup> or necessary to meet the demands resulting from its enforcement. The general objective of this directive is to achieve **good ecological and chemical quality status in all water bodies** (groundwater, surface and coastal) of the Member States of the European Union **within the next two decades**.
- The information needs of the EEA to fulfil its mission as specified by Council Regulation n° 933/1999<sup>2</sup>, in particular with respect to assessing policy efficiency and policy effectiveness in the field of water.

Two of the major goals of the Water Framework Directive are the protection and improvement of the aquatic environment and the promotion of sustainable water uses. Hence, provision of tools for assessing the environmental status becomes all the more important.

Considering continental waters, the current development of the EuroWaternet process contributes to providing a part of the needed information, namely *water status* and *effectiveness of sectoral policies*. Water quality accounts (WQA) are understood as a complementary method, within the EuroWaternet framework, capable of providing complementary information, namely *river status* and *efficiency of basin measure programmes*. This method is based on the WQA methodology, the principles of which are recalled in the next section.

This survey of the water quality accounts takes stock of the presentation that was made at the "Bridging the gaps" workshop held in Paris, Ministry of the Environment, 7 February 2001. At this moment, experience and findings from test application in the United Kingdom (England and Wales), Ireland and Slovenia as well as pilot application in France were available.

These pilot applications are summarized in an EEA report (EEA, 2001a). They showed also that the concepts were applicable and welcome but that production should be made directly from monitoring data instead of from quality maps.

In 2002-2003, Ifen, supported by Eurostat grant<sup>3</sup>, completed the methodology and installed in the NOPOLU *Système 2*, with the assistance of Beture-Cerec consulting firm, a new module that calculates the quality accounts from hydrologic and quality data. This new module adds as well a new dimension in the capabilities of the application, since it makes it possible to aggregate the accounts at administrative scale. In turn, it becomes now possible to match economic data to physical accounting data. This is not yet achieved, but it becomes possible.

### 2.2. Recalls of fundamentals in quality issues

Typical questions related to water quality assessment include for example: *"does agriculture contribute more to the nitrate concentration in rivers than urban wastewater discharge?"*, or *"Does the implementation of the urban waste water directive result in significant changes in phosphorus concentration in rivers of catchment X?"*.

These questions can be responded using the statistical stratification suggested by EuroWaternet (Nixon, 1997; EEA, 2001b), however, it can hardly provide quality status. [

By contrast, questions potentially answered by the WQA methods are, for example: *"does nitrate load impair the quality of a river more than phosphate?"*, or *"are quality issues in catchment X determined by local discharges or by diffuse*

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<sup>1</sup> OJEC L327/1 22/12/2000.

<sup>2</sup> OJEC L117 5/5/1999. The modification to the initial regulation of the EEA explicitly mentions that the tasks of the Agency are 'to provide the Community and the Member States with the objective information necessary for framing and implementing sound and effective environmental policies; to that end in particular to provide the Commission with the information that it needs to be able to carry out successfully its tasks of identifying, preparing and evaluating measures and legislation in the field of the environment'.

<sup>3</sup> grant agreement 200141200031.

*sources?*", or *"are small rivers in country A in a better status than main tributaries?"*. The response to these questions requires the use of criteria allowing the assessment of the relative impact of nitrate and phosphate. It requires as well a method that allows aggregating all rivers (first and second questions) or processing separately groups of water bodies (third question).

To assess the status of any river, a method for weighting quality data by the size of the different water bodies composing the river was developed (Crouzet, Germain *et coll.*, 1999) using linear quality maps obtained from the river survey services. Weighting method is directly derived from the findings by Norway statisticians (Heldal et Østdahl, 1984) and developed as indicative method by Jean Margat (in Weber, 1986). Weighting deals with all the components of the river system with their correct share to represent accurately their individual contribution to the overall quality of the system. The resulting indicators are **quality status classes or quality indices by river size class**.

The methods used to address both types of questions are summarized in the next table, focusing on the different indicators produced and data needs.

**Table 1: Comparative presentation of approaches currently available for Eurowaternet**

Issue	Eurowaternet stratified network <i>Entry by Driving Force</i>	Water Quality Accounts derived methodology <i>Entry by river</i>
Produced indicators	<ul style="list-style-type: none"> <li>• Representative <b>determinant statistics</b> per stratum.</li> <li>• Relative impact of <b>sectors</b> (same determinant).</li> <li>• <b>Efficiency of sectoral policies</b> ( <i>i.e.</i>, dealing with one economic sector: nitrate directive, UWW directive, etc.)</li> <li>• Trends in concentration (changes in mg/l/year; year at which a certain threshold shall be met)</li> </ul>	<ul style="list-style-type: none"> <li>• Representative <b>quality</b> per river size class.</li> <li>• Ranking of <b>determinants</b> (within or across catchments).</li> <li>• <b>Efficiency of planned measures</b> (<i>mixing sectoral policies as well as local and other measures</i>).</li> <li>• Change in quality status (as aggregated RQGI <sup>(4)</sup> index changes per river size class for example)</li> </ul>
Calculation method	<ul style="list-style-type: none"> <li>• Compute statistics on monitored data (mean, variance of the mean) per stratum. Data must lie within a narrow range; otherwise, the mean values are not meaningful.</li> <li>• Representativity of strata is given by apportioning the number of selected stations to the relative size of sectors.</li> </ul>	<ul style="list-style-type: none"> <li>• Aggregates quality status per river size class, otherwise biases or inconsistencies would result.</li> <li>• Representativity of aggregation is given by weighting the quality of rivers according to the relative size of rivers.</li> </ul>
External data required	<ul style="list-style-type: none"> <li>• Stratum definition requires homogeneous land use and sector data, at geographical level.</li> <li>• Selection procedure requires limited river arborescence GIS.</li> </ul>	<ul style="list-style-type: none"> <li>• River size weight calculation requires consistent river arborescence and complementary data (areas drained, river size and discharge data).</li> </ul>
Quality data	<ul style="list-style-type: none"> <li>• Sampling frequency must be consistent with the averaging period. Biological measurements (1/year) cannot be processed.</li> <li>• WFD "surveillance monitoring" data unlikely to be processed.</li> </ul>	<ul style="list-style-type: none"> <li>• Quality is determined by extreme events. Most data can be used.</li> <li>• Mixed networks (including comprehensive monitoring and random monitoring) can be processed</li> </ul>
General comment	<ul style="list-style-type: none"> <li>• Principally fitted to assessing <i>Pressure</i> vs. <i>State</i> and <i>Pressure</i> vs. <i>Response</i> relationships ⇒ (D and P/S ; D and P/R)</li> </ul>	<ul style="list-style-type: none"> <li>• Principally fitted to assessing <i>State</i> vs. <i>Impact</i> and <i>State / Impact</i> vs. <i>Response</i> relationships. ⇒ (S/I ; S / R ; I/R)</li> </ul>

Source : (EEA, 2001a)

An important difference between the two approaches is that the units in which the results are expressed govern the type of assessment that can be done. The stratified network provides determinant statistics values.

<sup>4</sup> RQGI stands for River Quality General Index, see definition in section 0, page 7.

Hence, sectoral policies can be assessed. For example, the trends in nitrate concentration in the stratum impacted by agriculture can compare with the Nitrate directive dispositions, especially the forecasted date at which requirements must be met.

By contrast, the Water Quality Accounts provide the quality classes weighted by the "quantity of rivers<sup>5</sup>" that falls into each class. The changes in weighted quality class can compare with the measures taken within certain catchments, for example, purification capacity installed, amount of expenses etc. The integrated index aggregating these results provides information comparable to a quality class and highlights the effects of practical measures applied per catchment.

## 2.3. Recall of Water accounts methodology

### 2.3.1. *Reasons for improving the Water Quality Accounts methodology*

As indicated above, WQA calculation requires computing an indicative quantity of river resource, expressed in SRU<sup>6</sup>. SRU stands for "Standard river Unit", English translation of the French UMEC suggested by Margat (Margat, 1996), from the French '*Unité de Mesure des Eaux Courantes*' (Measurement Unit for Running Waters). The quantity of SRU is further apportioned according to the assessed water quality of river stretches.

The main advantage of the SRU is that the sum of the SRU for a river system is a finite value, independent of the length of the individual stretches. The SRU approximates the inertial momentum of the river, and consequently shares the properties of energy (conservation, additivity). The river size weight is independent of the survey system and is comparable across Europe, provided a minimum of precautions. Hence it constitutes a powerful stratification variable representing the river systems.

The stretch is the basis of the method, although not requiring precise definition. A stretch is a suitable item when all its physical (e.g., discharge) and sorting (e.g., drained area, eco-region, altitude, etc.) characteristics, required for further processing can reasonably be considered as constant. Since there is no critical value related to calculations, it seems wise to define the main drainage system with the stretches in the range 1 to 20 km, according to the monitoring network and to define separately lumped stretches, grouping the brooks belonging to medium size (e.g., 200- 1000 km<sup>2</sup>) catchments. It has been shown, in the French pilot study that lumped stretched allowed nevertheless to carry out accounts.

These calculations apply to a large number of rivers. There are more than 7 000 rivers with a sea outlet (that is "drainage basins" as defined by the Water Framework Directive<sup>7</sup>), of an overall length of about 2 million kilometres<sup>8</sup>. Between 820 and 910 of these drainage basins have a size of at least 2 500 km<sup>2</sup> (therefore obligatorily monitored at least once per "*river basin management plan*" according to WFD, Annex V, 1.3.1). The Annex II to the WFD (art 1.2.1) regards as being of "average size" the watercourses draining between 100 and 1 000 km<sup>2</sup> of catchment area. Their number is not known, but the number of watercourses draining more than 250 km<sup>2</sup> is estimated at between 4 000 and 8 000. This size class is of great ecological importance; all these rivers, - not just those most polluted -, should be followed-up to make sure they meet the objectives of the Water Framework Directive.

Obviously, if assessment using the WQA outcomes becomes a WFD tool (as suggested in the European Guidelines: *Guidance for the analysis of Pressures and Impacts In accordance with the Water Framework Directive*), care must be taken to produce these WQA in an efficient way.

However, the different indicators derived from the WQA are not subject to change.

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<sup>5</sup> Precise definition is in next section.

<sup>6</sup> One SRU is worth *one km.m<sup>3</sup>.s<sup>-1</sup>*. The SRU is a conversion unit that allows aggregating rivers of different length and different discharge, giving the "river size weight" for further calculations. One SRU can be thought of as a stretch of a river that is one kilometre long and with a reference flow of 1 m<sup>3</sup>/s (or a stretch of 0.5 km with a flow of 2 m<sup>3</sup>/s, etc.). Such conversion units are common, for example the population equivalent (PE), the oil equivalent tonne (TOE) used by the International Energy Agency or the livestock unit (LU)..

<sup>7</sup> Art 2, (13)

<sup>8</sup> At 1/50 000 scale, according to the sources available reported in the report mentioned in footnote N°. This value seems low. For example, there are in France approximately 80 000 kilometres of water-courses on the scale of the 1/1 400 000 and 523 000 kilometres at the 1/50 000.

The ingredients to produce WQA results are threefold and their source depend upon the different processes according to the degree of industrialization of the production process:

1. River stretch maps, yielding length of stretches, river size data and catchment location;
2. River stretch liquid discharge for reference values ;
3. River stretch quality index or class.

**Table 2: Comparison of ingredients required to produce WQA according to the level of production method**

Ingredient	Occasional estimate	Regular production
<b>River stretch maps</b>	Published river maps, preferably on electronic format.  Set of rivers is map editor's depending.  Proxy River length (map depending)  Proxy river size class, depends on attached information.	GIS based river system (eg., Carthage (F), Gisco, etc.)  Stable set of rivers, defined at GIS design.  River length from GIS  River size from codification (eg., Strahler, Pfafstetter).
<b>River stretch liquid discharge for reference values</b>	Not included in map, hence approximated from eg., catchment productivity (effective rainfall or sample gauging stations data). Results hardly re-usable.  Applies to all rivers within a catchment.  Demands special processing when considering rivers crossing catchments.	Discharge computed per stretch, for different reference hypothesis. Results directly re-usable for a) aggregation per NUTS and b) water resource accounts.  Applies to individual rivers, including water abstractions.  Backs on data collected for other applications (general hydrologic data for example)  Several hypotheses can be stored, hence permitting sensitivity analysis.
<b>River stretch quality index or class</b>	Mapped data is only quality class, hence limiting possible calculations range.  Only mapped quality can be computed.  No quality check is possible, especially if quality reporting has been "smoothed".  Trend assessment only if maps are regularly produced.	Source data is monitored stations. Any quality assessment method can be applied. Classes are replaced by indexes.  Any assessable quality can be processed.  Quality checking possible, since basic data is used.  Trend assessment not depending on map production.  Linear maps are side outcomes that give added value.

The details reported in Table 2 are developed in further sections. Summarizing, occasional estimate is carried out using the simplified methodology, described in previous reports (Crouzet, 1999; Crouzet, Germain *et coll.*, 1999). This simplified approach was satisfactorily applied to test countries (Ireland, United Kingdom ). This approach is not suitable for large and regular assessments.

The regular production process and tools was developed to tackle the different problems met during the pilot application to test countries. A major problem is the loss of information resulting from the use of quality classes to derive quality accounts.

### ***2.3.2. The indicators resulting of the Water Quality Accounts methodology***

#### *Definition and calculation of the River Quality Generalised Index(RQGI)*

The River Quality Generalised Index (RQGI) is the weighted average quality grade of the system considered. It applies to a river size class within a catchment as well as to all rivers size classes of a whole country. The weight used is the quantity of SRU having a certain quality grade or class, that represent the river size.

The calculation system was developed in such a way that the calculation of the RQGI could be carried out even in the case where several quality grades are provided for given stretch. This situation may happen since the physical stretches and the monitoring points are defined independently, e.g., in Ireland. In this case, the SRU value attached to the stretch is broken down according to the proportion of the stretch described by the monitoring points.

To present the RQGI in a neutral unit, different of all the quality scaling used by different countries, a scale 0-10 was chosen, where "0" is the worst possible quality grade and "10" the best quality. Conversion into the five quality classes of the Water Framework Directive is then immediate. It is therefore an assessment of the general quality; when expressed as quality classes is it is called GQA (Generalised Quality Assessment) to distinguish clearly reporting as grades (RQGI) or as classes (GQA)

**Equation 1: RQGI calculation**

$$RQGI = \frac{10}{n} \times \frac{\sum_{j=1}^C \sum_{i=1}^n U_j \times li/L_j}{\sum_{j=1}^C U_j}$$

where  $U_j$  is the quantity of UMEC of stretch  $j$ ,  $l_i$  the length on stretch  $j$  with quality grade  $i$ ,  $n$  is the range of quality grades of the assessment system,  $L_j$  is the total length of stretch  $j$ . This equation allows processing any initial quality grade scaling.

For example, if using the French SEQ, any value or series of values ranging between 0 and 100 could be processed in a stretch. The scaling factor  $10/n$  is then  $10/(1000)$  just making it possible to output RQGI in the range 0-10. In Ireland, where the range is 0-16 (Figure 1, below), the scaling would be  $10/(16-0)$ . This scaling is not a conversion factor.

The way the original quality classes are converted into grades is discussed in section below. Obviously, the RQGI does not apply to a single monitoring point. If quality assessment on a unique point is to be reported with a 0-10 range, it should be called "grade" and not "index".

The WQA module initially developed in the NOPOLU *Système 2* has allowed since the pilot applications converting back the processed data into the original classification scaling used by any country. The RQGI thus provides a first stage of harmonisation of quality reporting across the European countries.

"Quality patterns" identification and mapping

Within a catchment, the majority of water bodies are expected to have a good quality status; the proportion of water bodies showing bad quality should be as close as possible to zero. However, it is possible that in a catchment good and bad quality river stretches co-exist. This "diversity" is not adequately captured by the average index alone. The relative proportion of "good quality" and "bad quality" can be shown as a **quality pattern**.

A tentative table crossing three categories of "good quality" and "bad quality" is presented below. The adjectives defining the proportions of "good" and "bad" are different to emphasise that the respective threshold values must be different.

**Table 3: Tentative combination table for quality patterns definition and assessment.**

Proportion of bad quality	Proportion of good quality		
	High	Medium	Low
Negligible	Good status (A)	Acceptable, with good quality rivers (B)	Mediocre everywhere (C)
Significant	Some black spots, surrounded by good quality waters (B)	Transition, risks of degradation (C)	Mediocre, with localised polluted points. (D)
Excessive	Important black spots, high risk of degradation (D)	Catchment highly polluted (D)	Overall pollution, unacceptable. (E)

*Legend: the cells are shaded according to combination of columns and rows entries. The lighter the shade, the better the overall status of the catchment. The 9 combinations were clustered into 5 lumped patterns indicated by letters "A" to "E". This classification is provisional.*

The results can be reported as maps or as statistics, by counting the number of catchments and applies as well to all river systems or to any size group of rivers.

The calculation of the pattern requires defining two sets of values:



1. The threshold values of the RQGI that fall into the "good" and "bad" categories. For example, RQGI greater or equal to 6.0 was assumed "good", whereas the RQGI less or equal to 4.0 was assumed "bad". This is equivalent to the assessment made in the French pilot study where SEQ-classes 1 and 2 on the one hand, 4 and 5 ("HC") on the other were respectively considered as "good" and "bad".
2. The proportion of SRU falling into the three quality categories defined above that are considered as respectively high / negligible, medium / significant and low / excessive. For example, more than 60% of the sum of SRU having a RQGI greater or equal to 6.0 is a "high proportion of good quality", whereas 10% or more of the sum of SRU having a RQGI less than 4.0 are considered as "excessive proportion of bad quality".

These values are still tentative and need sensitivity assessment before being used in comparative reporting. The tentative values utilised during the test application are in Table 4 below.

**Table 4: Tentative threshold values for calculating categories of Table 3**

Good quality definition	Any stretch with RQGI $\geq 6.0$ , is "G"		
Bad quality definition	Any stretch with RQGI $\leq 4.0$ id "B"		
Good quality distribution	High: $\geq 60\%$ of total SRU "G"	Medium: otherwise	Low : $\leq 30\%$ of total SRU "G"
Bad quality distribution	Negligible: $\leq 5\%$ of total SRU "B"	Significant : otherwise	Excessive $\geq 10\%$ UMEC "B"

*Remark: the values are those used for the test applications, they must be considered provisional. "G" and "B" are for 'good' and 'bad', as previously defined.*

Using these provisional values, patterns maps can be made to represent any river size class.

#### Relative impact of determinands

Comparing two periods is always possible, since the basic assessment of quality grades is made using identical ranking method. This comparison may be extended to different determinands<sup>9</sup> (or groups of determinands: the "*altérations*" [perturbations] of the French SEQ-eau) if the ranking method meets the same objectives.

In some quality ranking methods, as recommended in the Water Framework Directive, each quality class expresses a certain degree of quality (very good, average, etc.), which is the same whichever the determinands used for the assessment. This is automatically reflected in the quality grades calculated previously to SEQ classes assignment.

Hence, a given degree of quality is irrespective of the cause: the "mediocre" degree relating to quality assessed using nitrate values expresses the same concern as the one indicated by the "mediocre" degree due to eutrophication. The French SEQ system explicitly considers the different causes that determine water quality. This goal is shared by many other water quality assessment systems, even if they do not explicitly refer to a unique ranking of degrees of quality.

If the different degrees of quality assessment are comparable, it becomes possible to analyse the relative impact of different sources of water perturbation. This approach defines the relative importance of different groups of determinants. This analysis is the complement of the calculation of pollution patterns. It can be stated, for example: "*nitrate is the major issue in the medium class size of rivers of catchments X, Y, Z etc., whereas eutrophication is the major concern for the large rivers of the same catchments.*"

Practically, the calculations are carried out by comparing the respective RQGI previously computed per determinand, at the relevant aggregation level.

### **2.3.3. River and river water Quality assessment**

Water quality class and water quality grade differ in the capability to produce further calculations. In this document, "index" has specific acceptance.

- **Water quality class** is a range of assessment designated by an adjective, for example: good, acceptable, bad, etc. A class is generally represented by a colour code and it encompasses a certain range of water composition. According to the different systems in use in Europe, the number of classes ranges from 4 to 9. The width of these classes can be identical (even classes) or different (uneven classes). The class is analogous to the mark or distinction (e.g., excellent, good, etc.) obtained at an exam in school.

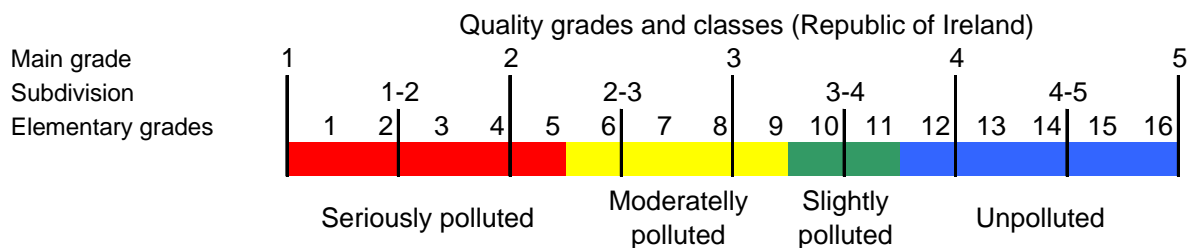
<sup>9</sup> The new word "determinand" is used and justified by the ETC/Water

- **Water quality grade** is a numeric or alphanumeric <sup>(10)</sup> value that designates water quality. Grades are used in some quality assessment methods, e.g. in the French SEQ (*Système d'évaluation de la qualité* (Oudin et Maupas, 1999)) or in the Irish biological quality assessment system (see Figure 2). Grades are continuous categorisations of the elementary observations of water quality determinants. Water quality classes usually comprise several grades. The grade is analogous to the number of points (e.g., 12/20) obtained at an exam.
- **Water quality index** is used in this document to designate the *composite grades* resulting from the aggregation. The *River Quality Generalised Index* (RQGI) is the weighted quality grade calculated for a river system. It ranges, by construction, from 0 to 10. The index is the analogous to the compound note obtained at an exam.

The French *SEQ-eau* system first calculates, for a given point, a quality grade ranging between 0 and 100 (from worst to best) according to different threshold values. In a second step, five evenly distributed quality classes are derived from the quality grades. The classes are evenly distributed because the choice of the threshold values was purposely made to allow this even distribution.

The relationship between classes and grades is illustrated by the Irish example, where *uneven* quality classes are constructed from *even* quality grades.

**Figure 1: Schematic indication of water quality grades (numbers) and classes (colours, text) used in the Republic of Ireland**



*Redrawn from (McGarrigle, 2001)*

The best accuracy in calculating the Water Quality Accounts is expected when the quality values attached to each stretch are expressed in continuous quality grades. Grades can be aggregated. If only classes are available, they must first be converted into grades. In that case, each class value is given an estimated average grade equal to the median grade of the class. In the example of Figure 2, the "red" class would be given grade 3, the "yellow" class would be given the grade 7.5 and so on. The use of such average quality grades derived from quality classes is less accurate than using the original grades, in the same way as calculating a sum from rounded values is less accurate than rounding the final sum.

When using quality classes in an occasional WQA calculation, these classes must be first replaced by a median grade, otherwise the WQA value would be biased by 1/2 quality class.

### 2.3.4. Transforming quality classes into grade values

When the provided quality values are all expressed in domestic quality classes <sup>(11)</sup>, a double problem must be solved:

1. To compute the final RQGI as a true average quality grade equivalent, and not as the average quality class number.
2. To convert accurately the original quality classes (that have each their own number of classes) into a grade value, in order to compute the RQGI using the standard 0-10 range, instead of the domestic classification systems.

Since a quality class is reported within its own ranking system, there is no possibility to convert a single assessment class data into another ranking based on grades. However, the objective is not to convert individual assessments, but to express the overall assessment among a series of stretches using another grading system.

<sup>10</sup> "Alphanumeric" is a computer-science term designating the codes composed with alphabetic (a, A to z, Z), numeric (0-9) and special characters (i.e., -, \*, #, etc.).

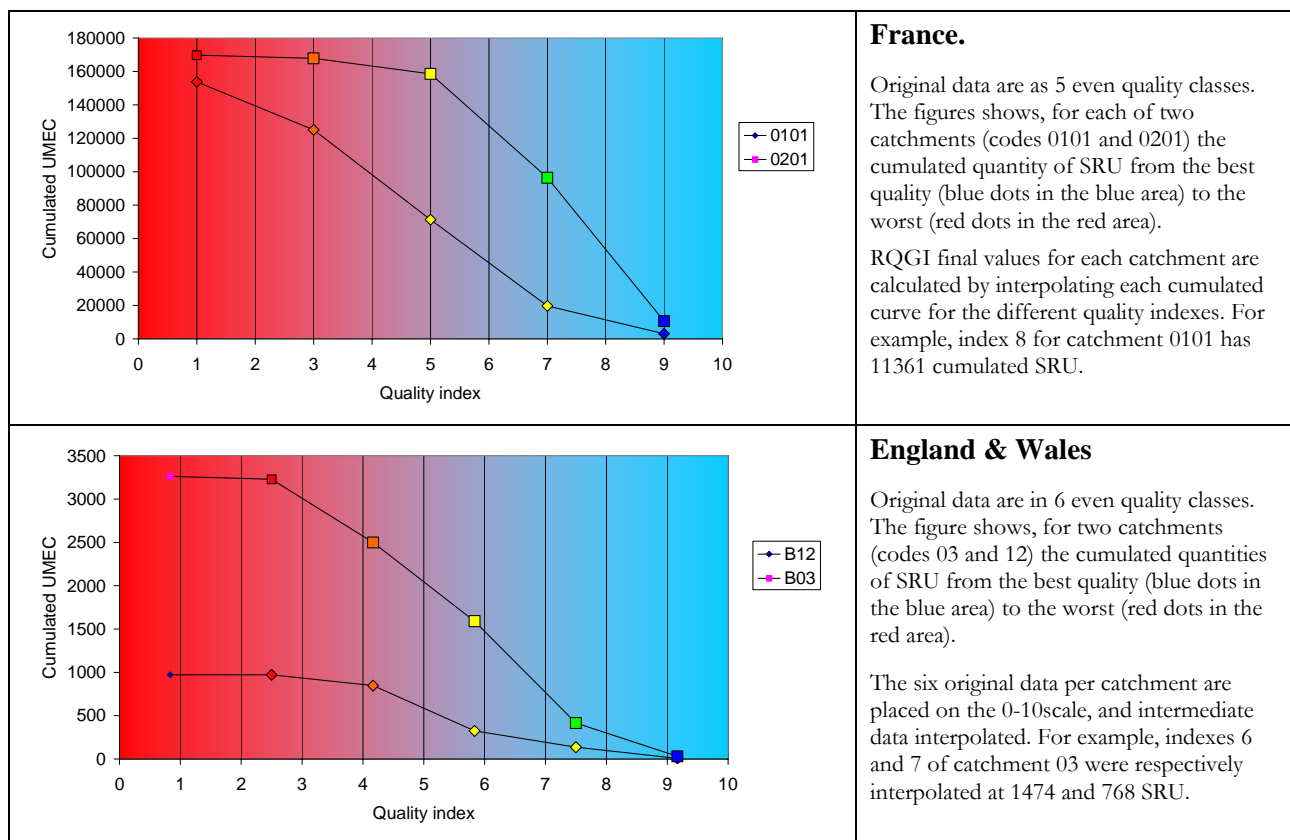
<sup>11</sup> The difference between grades and classes is discussed in section 2.3.2 page 7.

The available information is the extremes grades and the even or uneven distance between the original boundaries of the classes. The calculation methods, using intervals, does not allow a full equivalence, especially considering the ends of the grades range. In other words, the grades better than the grade in the middle of the best class as well as the grades worse than the grade in the middle of the worst class cannot be reconstructed.

For example, a five-class system covers only the range 1-9 of RQGI, whilst a six-class system encompasses values between 0.8 and 9.2, instead of the full 0-10 RQGI range. This classical interpolation problem needs a supplementary hypothesis. The most likely is that the cumulative number of SRU, from best to worst quality is kept if the quality scale is subdivided. This hypothesis expresses that the quality grades recorded on a catchment are continuously distributed over all the range of observed grades within this catchment. This is shown in the next figures.

The next two schemes represent conversions from the French and England & Wales systems, exemplified for two catchments in each case. River size class is of no importance in the examples, but is taken into account in the actual calculations.

**Figure 2: Examples of the RQGI first stage of calculation: interpolation of original data on the RQGI scale.**



The same method applies to any class scale. Obviously, the larger the number of original grades, the better the final assessment. In the case of Slovenia, where the classes are not evenly distributed, the same method applies; however, the original point are placed according to their true co-ordinates and not evenly placed.

By contrast, in the case of Ireland, the provided values are the 16 elementary grades, and had not to be extrapolated. Hence, they could be directly calculated as RQGI or either reported as domestic quality classes.

The final calculation consists in subtracting the successive values to compute the true quantity of SRU for a certain RQGI.

For further developments, it would be preferable to use raw data (the only data that is relevant for quality assessment) and compute first a continuous RQGI-like grade, weight averaged in a second stage, as defined by Equation 1. The interpolation steps described above are made necessary by the current type of data provided. They are not intrinsic to the Water Quality Accounts methodology.

## 2.4. Method for regular production

### 2.4.1. Requirements

The method was first developed, and later applied using the NOPOLU *Système 2* <sup>(12)</sup> This application, following the requirements imposed by Ifen, allows any aggregation, provided the stretches are earmarked with the size classification value and information allowing to attach the stretch to any nested catchment system.

Following feasibility study carried out in France, EEA supported a pilot application in England and Wales, Republic of Ireland and Slovenia. These applications showed the difficulties to obtain suitable data. Therefore, a project was prepared and submitted to Eurostat that gave a grant participation to the development of regular production module.

The requirements to the development of this module were:

- WQA must be produced using all monitored data that can reasonably be collected (for example, data collected through the EuroWaternet process), but not limited to this collection.
- The product should calculate a linear map of river quality by interpolating quality grades between monitoring points, backing on scenarios (especially dealing with position of sharp changes in water quality). To avoid bias, the quality assessed at monitoring points should be verified in results.
- The hydrologic layer must be a shared layer with the resource accounts and should be produced either from daily discharge data or from hydrologic statistics,
- The outputs should be all the indicators and SRU values apportioned by quality.

These requirements are very demanding with respect to the quality of data that is used. Main problems met during the development of the module and prototype application to the Rhin-Meuse district and other large catchments in France resulted from major gaps in the river and catchment GIS (the BD-Carthage) currently used in France.

To tackle this problem, a special software development was done to clean and fix the errors in the BD-Carthage. Hence, regular production will become possible in metropolitan France in 2004.

### 2.4.2. Production process implemented

The new facilities designed, developed and tested comprise six steps that are normally addressed in the given order when first calculating a new catchment:

1. Implementing facilities to break down and process the rivers into calculation reaches. A reach is the elementary unit of river characterization in which both discharge and quality have a unique value for a certain calculation. Hence, a reach is the “pixel” of any water body, in the acceptance of the Water Framework Directive. Any elementary catchment main drain comprises several reaches.
2. Calculating the discharge reference values for any statistical indicator (e.g., annual module, low flow reference, etc.) all along the reaches of all rivers to be considered. Discharge reference data are stored in a library for reuse.
3. Managing the quality indexes library (computed thanks to the SEQ approach, extended), the basis for these calculations being the existing quality monitoring network used, for instance for the EuroWaternet reporting.
4. Interpolating the quality indexes along the rivers, by reach, using any available discharge reference values or, if lacking, the change in catchment area as proxy.
5. Managing the discharge and linear quality libraries so that linear quality can be broken down and re-aggregated either by catchment or by administrative units, before computing the SRU values, The SRU data is the basis for any further use of the WQA.
6. all previously developed steps, from SRU raw management to RQGI indexes and mapping are fully compatible with the former approach, based on the importation of existing quality maps.

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<sup>12</sup> Commercial name, for further details see NOPOLU *Système 2 / 2.5*, for Windows 98 / 2000/ NT4, 2000, édité par “BETURE CEREC / JAAKKO PÖYRY INFRA”, St Quentin en Yvelines, (*développé par Le Gall G.*), contact: glgfromys@magic.fr.

### ***2.4.3. River arborescence and hydrology***

Computing linear attribute on a river system requires disposing all information related to river arborescence. The actual calculation of values must be done from upstream to downstream, to respect the causality (for example, river quality depend on upstream quality) whereas branching must be computed from the mouth to the spring.

The main problems to solve were:

- Flagging gaps in stretches (eg., an element of river is not correctly populated in the GIS file);
- Processing or flagging shortcuts (river divides into branches around an island, the process enters but cannot get out, because error in flow direction);
- Lack of main river channel, because inaccurate GIS attributes;
- Gauging or quality monitoring station not placed on the good reach.

The different types of errors were documented during the realisation of the module and some corrections installed in this module.

The calculation modules were tested on three large catchments (the Vilaine, the Mayenne and the Allier "RNDE" catchments<sup>13</sup>) all together covering c.a. 30,000 km<sup>2</sup>. To make the checking of the calculation modules comprehensive, contacts have been taken with the Rhin-Meuse district directorate (DIREN RM). The Rhin-Meuse district encompasses the French catchment of the Rhine river and the upstream catchments of the Meuse river (including for instance the Moselle).

These catchments (constituting two "RNDE" catchments) are extremely well covered by quality surveillance stations and the Rhin-Meuse basin agency has computed many important discharge data (module, low flow, etc., indicators for a large number of real and virtual gauging stations. Moreover, by contrast with other parts of France, the BD-Carthage has a quite good quality that makes it possible to envisage correcting the errors through manual procedures.

Therefore, the sample results deal with these different catchments.

#### Hydrological network construction

The considered hydrological network consists in the main drains of each elementary catchment. If some drains are not defined in the GIS beneath the application, it is possible to add "main drains" provided the segments are present. A functionality forcing reaches as main drains is available.

However, the presence of a monitoring station on a segment does not force the reach hosting this station to be considered. This possibility is kept inasmuch it allows keeping homogeneity of the main drains arborescence (e.g., if a monitoring point was placed on a very small creek for surveillance purposes).

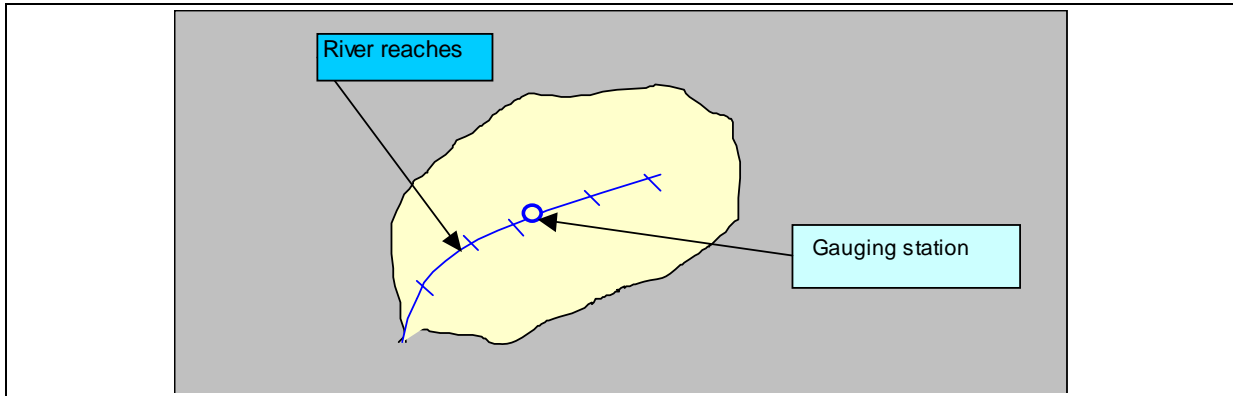
#### Discharge calculation

Discharge calculation is carried out in different ways according to the relative position and the number of gauging stations and catchment arborescence.

- Catchment having a single gauging station

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<sup>13</sup> The "RNDE" catchment is an aggregate of elementary catchments encompassing significant rivers in the metropolitan France. Fifty-five such catchments apportion the French territory and constitute as many aggregation areas for different reporting purposes. The average size is 10,000 km<sup>2</sup> (range 6,000 – 14,000 km<sup>2</sup>).



**Figure 3 : Unique gauging station on the main drain of an elementary catchment**

As a principle, the discharge is understood to increase with the increase of the catchment area. However, the calculation method allows producing interpolated discharge values in the case the discharge decreases, just considering the local productivity between two gauging stations. If no downstream gauging station is present, the discharge is understood to increase with the catchment.

The simplifying hypothesis is that the discharge allocated to each reach is proportional to the drained area, the productivity being derived from the gauging station data that drains  $S\_DRAI^{14}$ ; the area drained at the gauging station being SURF. In the general case, where the considered catchment has upstream catchments, the area of these upstream catchments is noted SURFC.

Discharge of every reach is proxied as a unique value understood to represent the actual discharge at mid reach, close to the average discharge of the reach. To this end, the  $Q_{S1}$  discharge is computed at the outlet of the elementary catchment, as a function of the sum of areas drained and ad hoc value of discharge at reported gauging stations.

**Equation 2: General case of discharge calculation**

$$Q_{S1} = Q_{S2} * \frac{SURF\_tr1}{s\_drai}$$

The hydrological yield (productivity), used in many cases in noted P.

**Equation 3: Hydrological yield**

$$P = \frac{Q_{S2}}{s\_drai}$$

Since discharges at both ending reaches Tr1 and Tr2 are known, intermediate reached can be computed as well to this end, the distance between the ends of reaches is used as a proxy of the change in area drained. By definition, the only area available is given for the elementary catchment, whereas reaches are inside the elementary catchment.

**Equation 4: Distance between reaches' ends**

$$d = \frac{lg\_tr1 + lg\_trn}{2} + \sum_{i=2}^{i=n-1} lg\_tri$$

- Catchment having two gauging stations

<sup>14</sup> Notation of variables of table fields as in the NOPOLU *Système 2* implementation

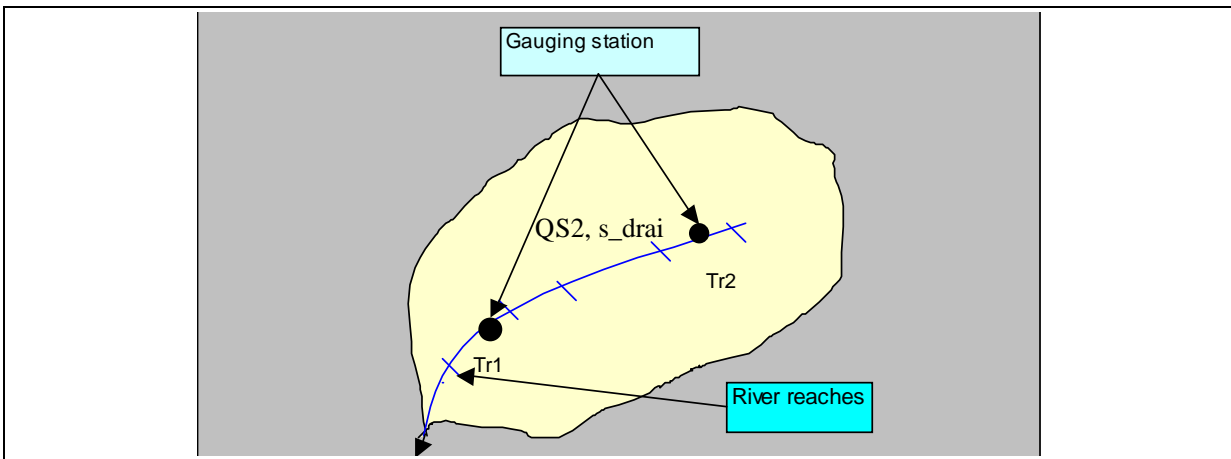


Figure 4 : Catchment having two gauging stations

In this case, discharge is interpolated between Tr1 and Tr2, as a distance starting at Tr1.

Equation 5: discharge calculation between two gauging stations

$$Q_{-trx} = Q_{s1} + \frac{Q_{s2} - Q_{s1}}{d} * lg x$$

- Case where the upstream gauging station is located in the next upstream catchment

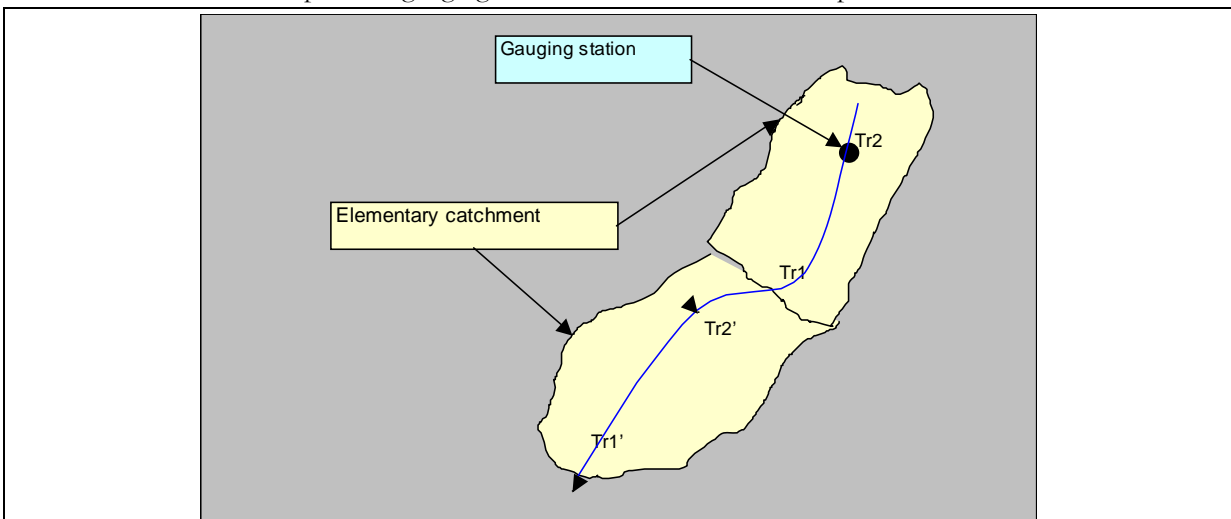


Figure 5 : Change of elementary catchment

Discharge at reach Tr1 is noted QS1, hence:

Equation 6: Local productivity

$$Q_{s1} = P * SURF_{-tr1}$$

In the absence of otherwise data, discharge at Tr2' is the same as at Tr1, here QS1.

Equation 7: equality of discharge at catchment boundary

$$Q_{s2'} = Q_{s1}$$

Next equation expresses that discharge at Tr1' is a function of productivity and area drained bay reach Tr1'.

Equation 8: local discharge at reach end

$$Q_{s1}' = P * SURF_{-tr1}'$$

This calculation is repeated if several catchments are processed.

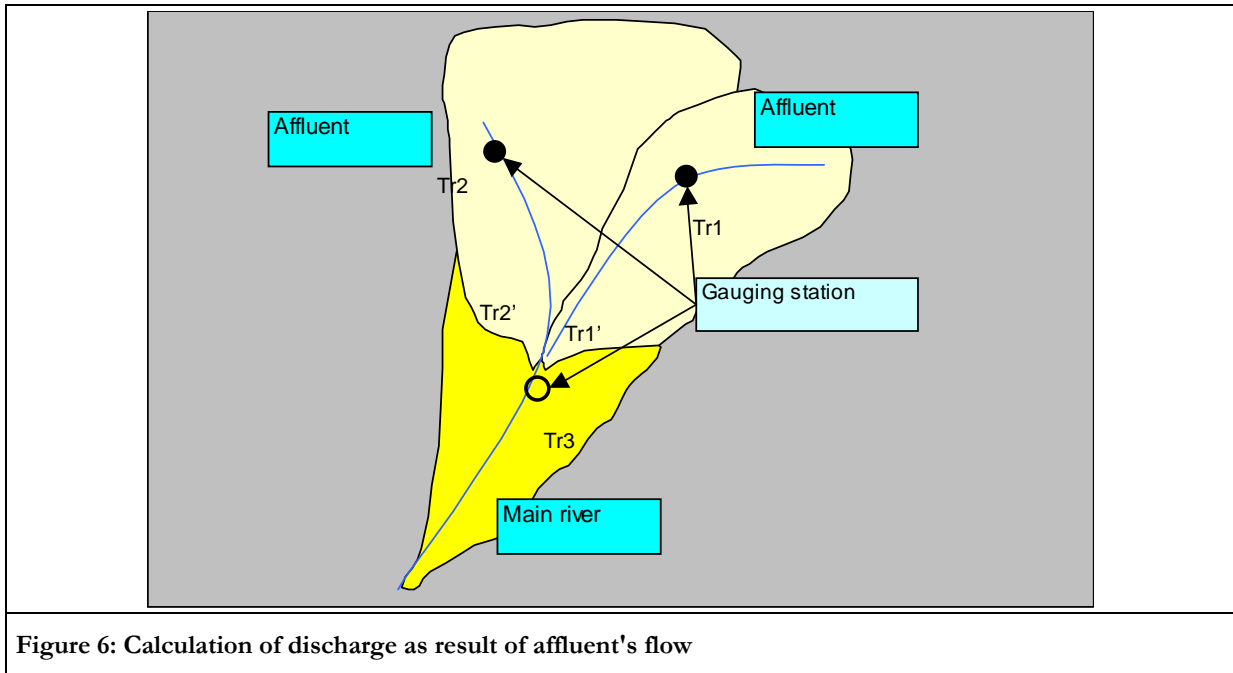
- Case where river results of gauged affluent

In this case, the discharge is first calculated for the upstream components (affluent) of the main river. Hence, the partial discharges  $Q_{S1'}$  and  $Q_{S2'}$  are known. The discharge after confluence is the sum of upstream partial discharges.

**Equation 9: Discharge downstream confluence**

$$Q_{S3} = Q_{S1'} + Q_{S2'}$$

Discharge is then computed for each reach until Tr3 using the above mentioned methods.



**Figure 6: Calculation of discharge as result of affluent's flow**

It may happen that only one of both affluents is monitored (Tr1 for example). In this case, the discharge at yields productivity of Tr1', applying Equation 6.

Then, discharge at Tr2' is proxied considering that its catchment has the same productivity as Tr1.

**Equation 10: Proxying discharge in the absence of gauging**

$$Q_2' = P(Tr1) * SURF_{Tr2'}$$

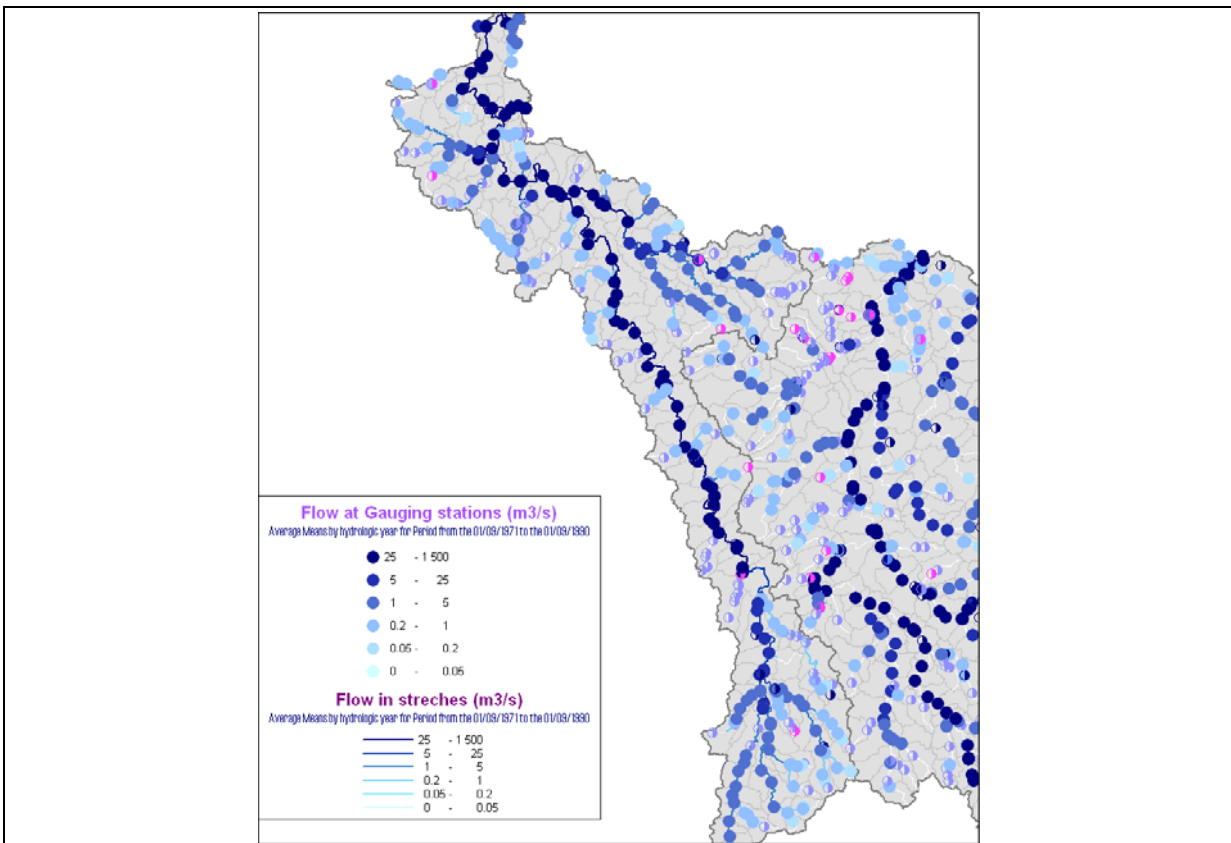
after this, calculation is identical to the ones detailed above.

These general principles are locally adapted in the software to tackle specific problems and relative position of gauging stations and reaches, for example when the gauging station is exactly at the reach end, thus making its distance to the reach equal to zero, etc.

- Example of results

The next figure displays the set of stations (reported as blue circles) and the modelled linear discharge values calculated by NOPOLU *Système 2*. In this figure, only the Meuse catchment (left hand side of the figure) has been computed.

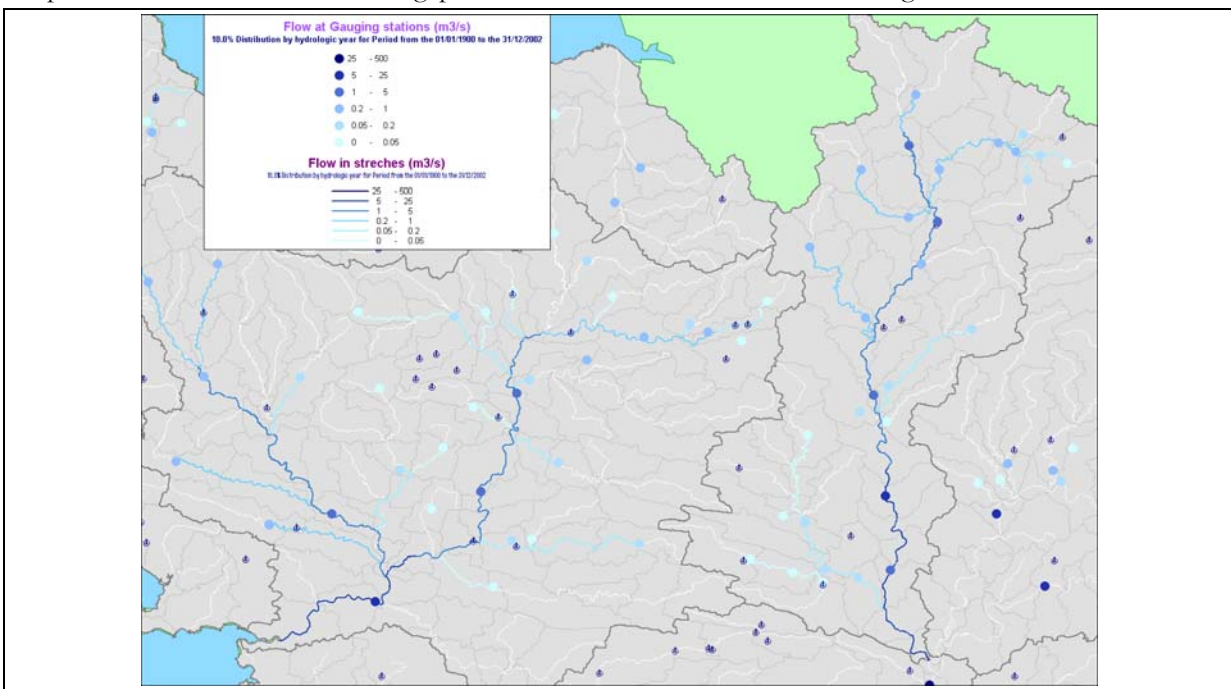




**Figure 7 : modules observed and modelled, Meuse catchment of the Rhin-Meuse district**

The next figure shows calculation of the low flow values on both the Mayenne and Vilaine catchments (Brittany, West of France) where the density of gauging station is very low. In reality, the actual number is greater, but a limited set was used for testing purposes.

The lesser number of tributaries modelled (many points without lines in between) results of gaps in the BD-Carthage layer. In these cases, the river reaches are not correctly connected, preventing the programme to find its path in the arborescence. These gaps are under correction for the time being.



**Figure 8: Low flow calculations on the Mayenne and Vilaine catchments**

#### 2.4.4. Quality interpolation

All calculations carried out in this module use the continuous SEQ indexes previously calculated using the SEQ facility of NOPOLU *Système 2*, or imported from calculations provided by other means. NOPOLU *Système 2* provides the possibility to define and code new "alterations" following the SEQ methodology, thus coping with any problem or new question or new way to assess water quality.

The change of quality index between two monitoring points does not generally follow a simple or linear rule. The objective of the calculation is to lower the final error in estimating the SRU values, not (in a first stage) to outcome with accurate maps. From upstream to downstream, index interpolation can be done using three different rules that apply for an "alteration":

1. linear interpolation , both monitoring points have the same weight (notwithstanding the change in discharge or inputs from affluent, etc.);
2. logarithmic, where the downstream station has a greater weight that the upstream one and;
3. parabolic, where weights are reversed with respect to the previous interpolation.

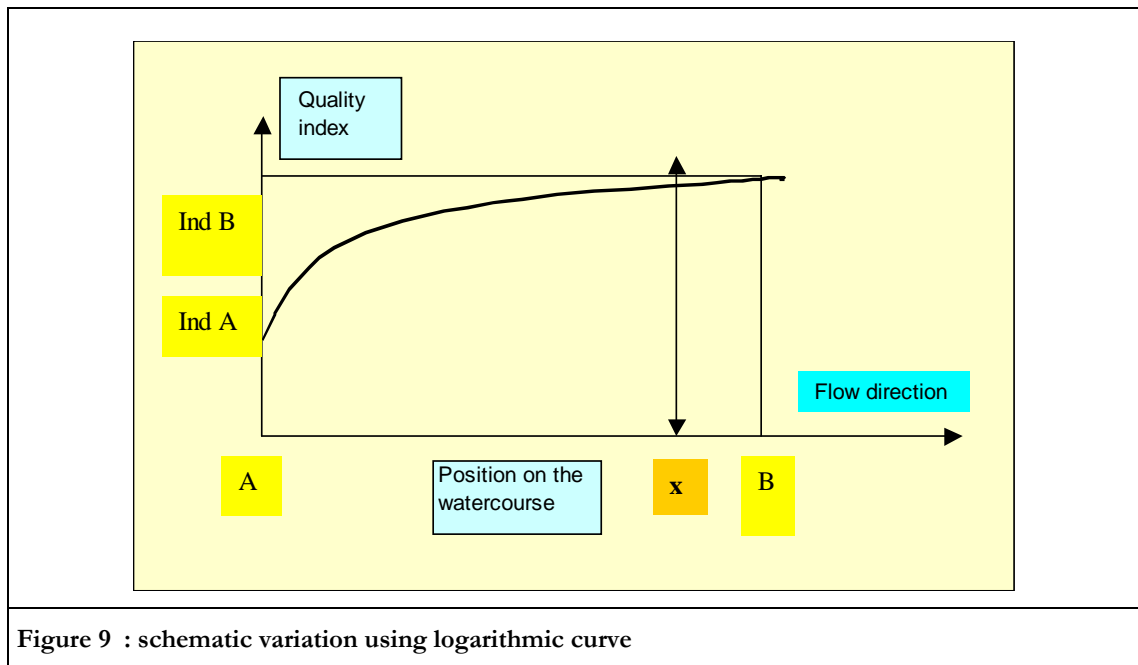


Figure 9 : schematic variation using logarithmic curve

1. If Ind A and Ind B represent respectively quality indexes in points A and B, the index at point x is computed according to logarithmic variation, which is defined according next equations. The expected value of the index at any x point on the watercourse is:

**Equation 11: general calculation of the index (logarithmic interpolation)**

$$g(x) = \lambda f(x) \text{ in practice } \text{Ind}(x) = \text{coeff} \log(X + X_0) + \text{ord}$$

However, the index of a reach is unique, hence the average index has to be computed as the integral of the indexes along the segment of watercourse::

**Equation 12: averaging index (logarithmic interpolation)**

$$\langle f(x) \rangle = \frac{1}{B - A} \int_A^B f(x) dx$$

2. In practice, this method is quite demanding in calculation resources, hence linear approximation is used instead in the current release. This has virtually no incidence, considering the short length of the computed reaches in the general case.

**Equation 13: approximation of Erreur ! Source du renvoi introuvable.**

$$\langle f(x) \rangle \approx \frac{f(B) + f(A)}{2}$$

Monitoring stations in use

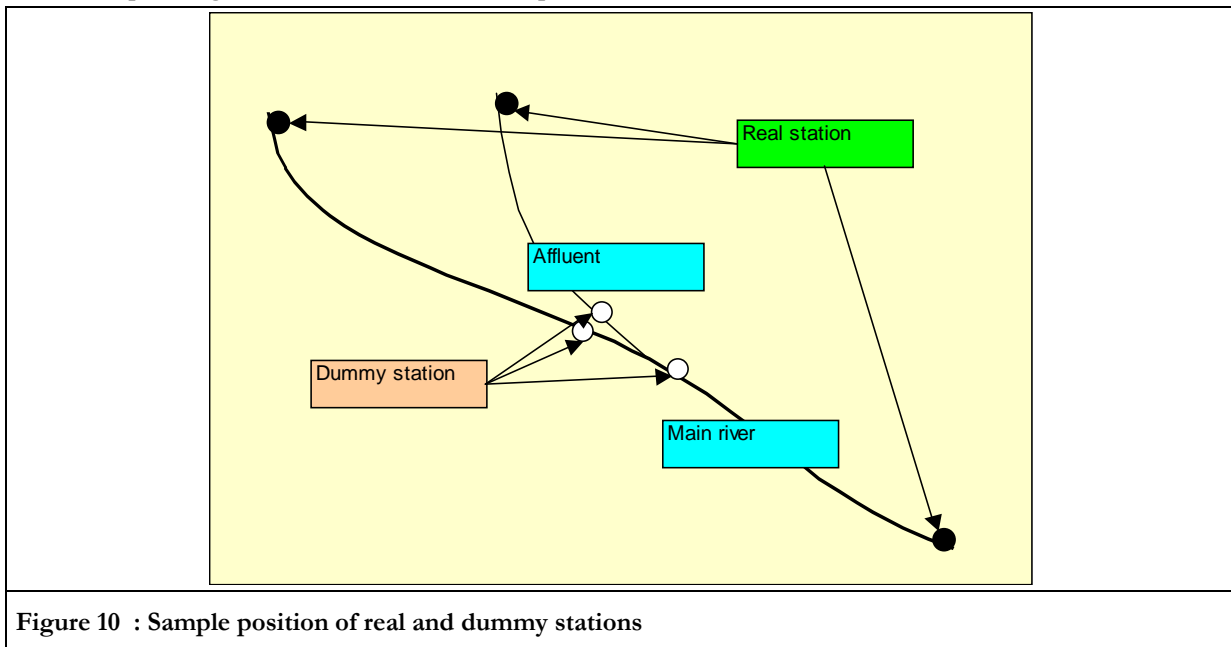
All monitoring stations recorded in the C\_QUAL table can be used, provided they are related to a reach. This integration must be done on purpose since the existence of a station in the C\_QUAL table does not make it available for the linearization process (whereas this station is systematically available for the SEQ calculation process).

- Thanks to MapInfo® installed facilities, any quality station may be added to the reach-station tables and make it becoming available for further calculations.

Dummy stations can be added to simplify the linearization process if a value must be forced in the absence of monitoring station. In the present release, this facility has been made **not straightforward** to avoid abuse in use. Besides, this methods avoids as well to provide a station code that would pollute the C\_QUAL table.

- Another configuration could result in placing dummy station next to a significant polluting discharge.

Dummy stations have no impact on the physical structure of the river system. The values are directly input to the corresponding reach, and used in the interpolation afterwards.



**Figure 10 : Sample position of real and dummy stations**

Index calculation along the watercourse

- General case

The index is calculated using the preferred model (linear, logarithmic, etc.) imposed.

- Sharp change in quality

They may result either of affluent or sewage inputs. In these cases, the changes take into account the relative discharges values or, if this information is lacking, the changes in areas that are considered instead.

Let  $I_1$ , be the quality index of the first affluent and  $I_2$  the quality index of the second one (the main river at the confluence is considered as an affluent) and  $I_A$  the quality index just downstream the confluence. Besides,  $S_1$  is the area of elementary catchments upstream the firsts affluent and  $S_2$  the same information referring to the second affluent. The resulting quality index downstream the confluence is simply calculated as a weighted proportion of the corresponding areas. If discharge is available, just replace  $S$  by  $Q$  in the equations.

**Equation 14: calculation of quality indexes downstream a confluence**

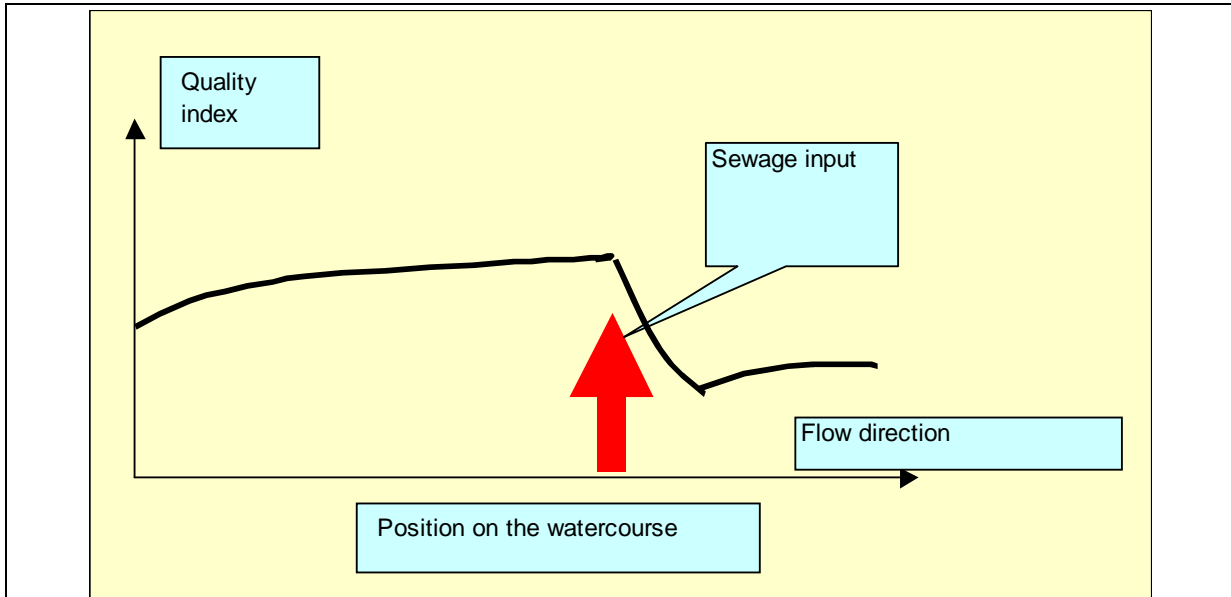
$$Ind_A = \frac{I_1 S_1 + I_2 S_2}{S_1 + S_2}$$

Note if discharge is available, replace S by Q in Equation 14

### Sewage discharge

A sewage discharge is considered as an affluent with no flow. It is (current release) processed as a sharp change (decrease) in quality index. The chosen index function is applied before and after the input.

This method is provisional and is installed until accurate and well-placed sewage inputs data is available. At this moment a new method shall be made available.



**Equation 1 : schematic behaviour of the calculated index in case of sewage input**

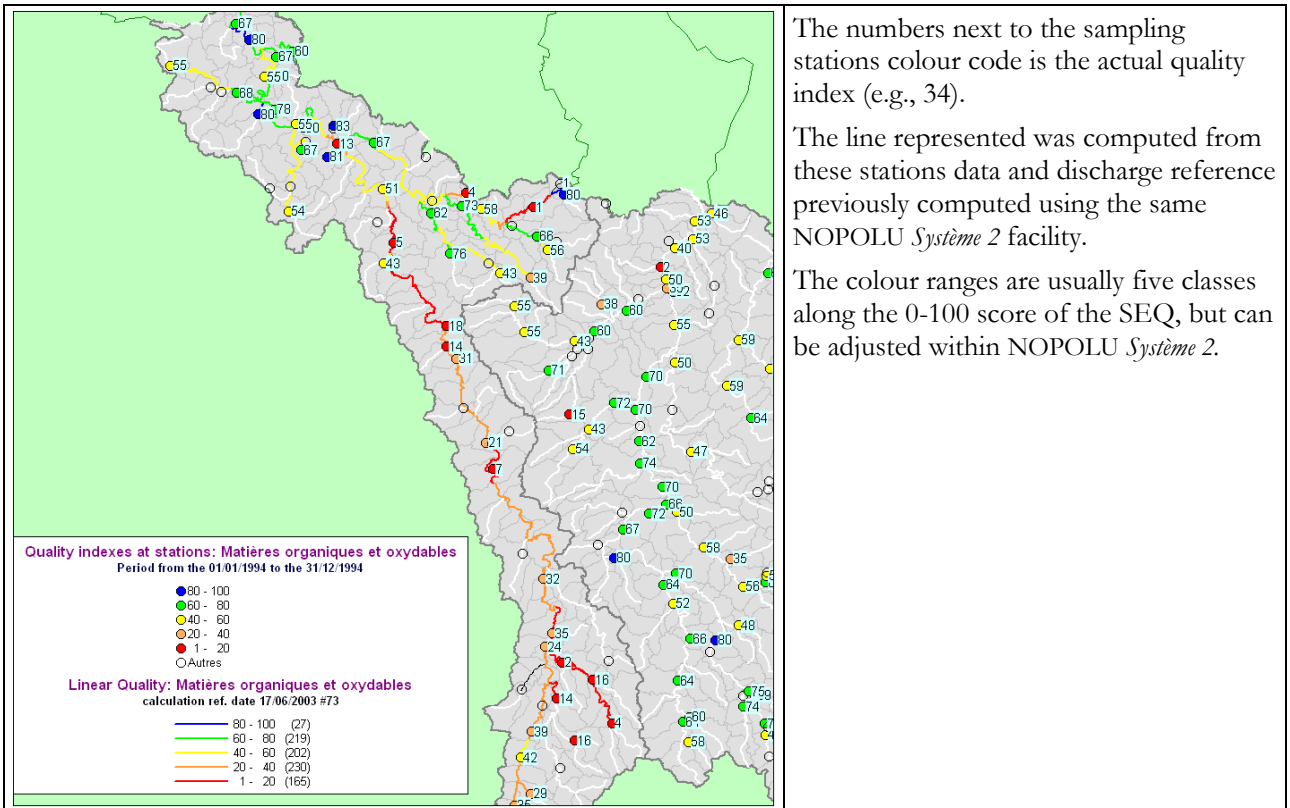
### SRU calculation

The SRU calculation is now possible at any relevant scale, catchment or administrative. This facility comes from the different libraries used:

- Library of the SEQ indexes, computed for all stations,
- Library of hydrological simulation, allowing to compute different SRU references,
- Library of linearization of quality indexes.

And from the GIS based linearization that makes it possible to reallocate river reach to any cluster. Allocating from catchment to administrative unit is possible for any unit, however, it is unwise to use too small units, since the crossing between river reaches and administrative boundaries introduce an error.

Sample results

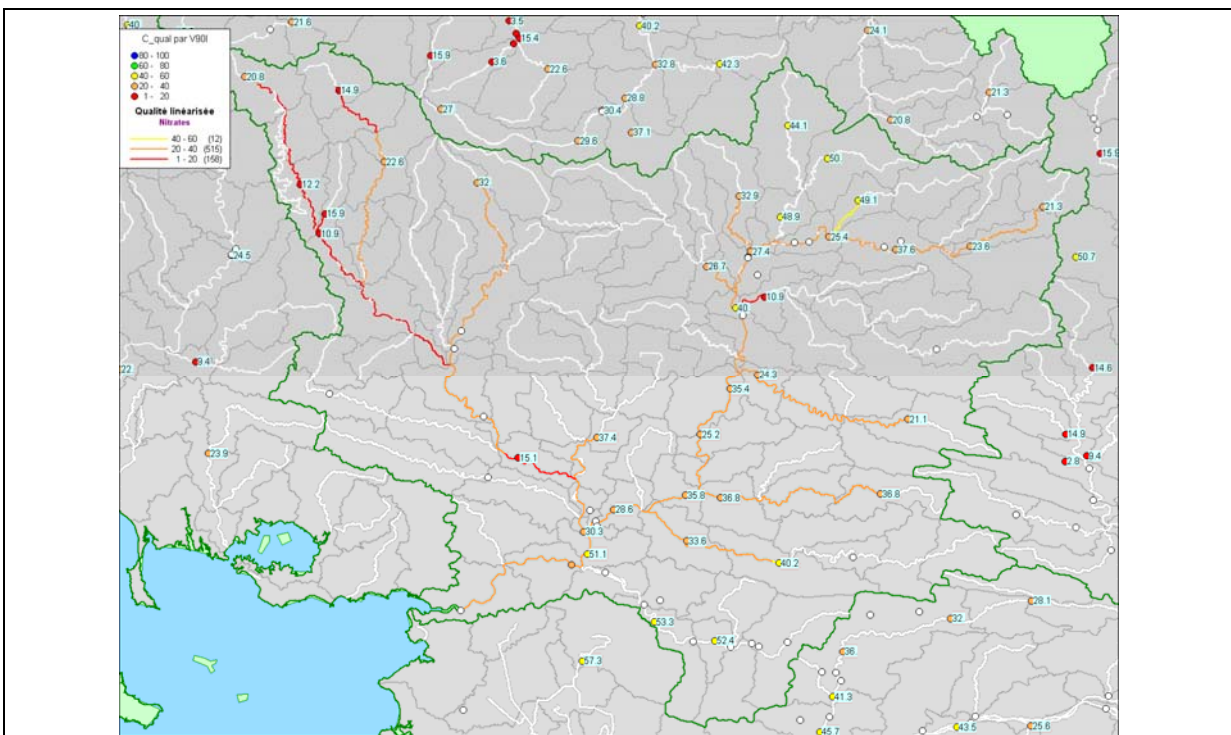


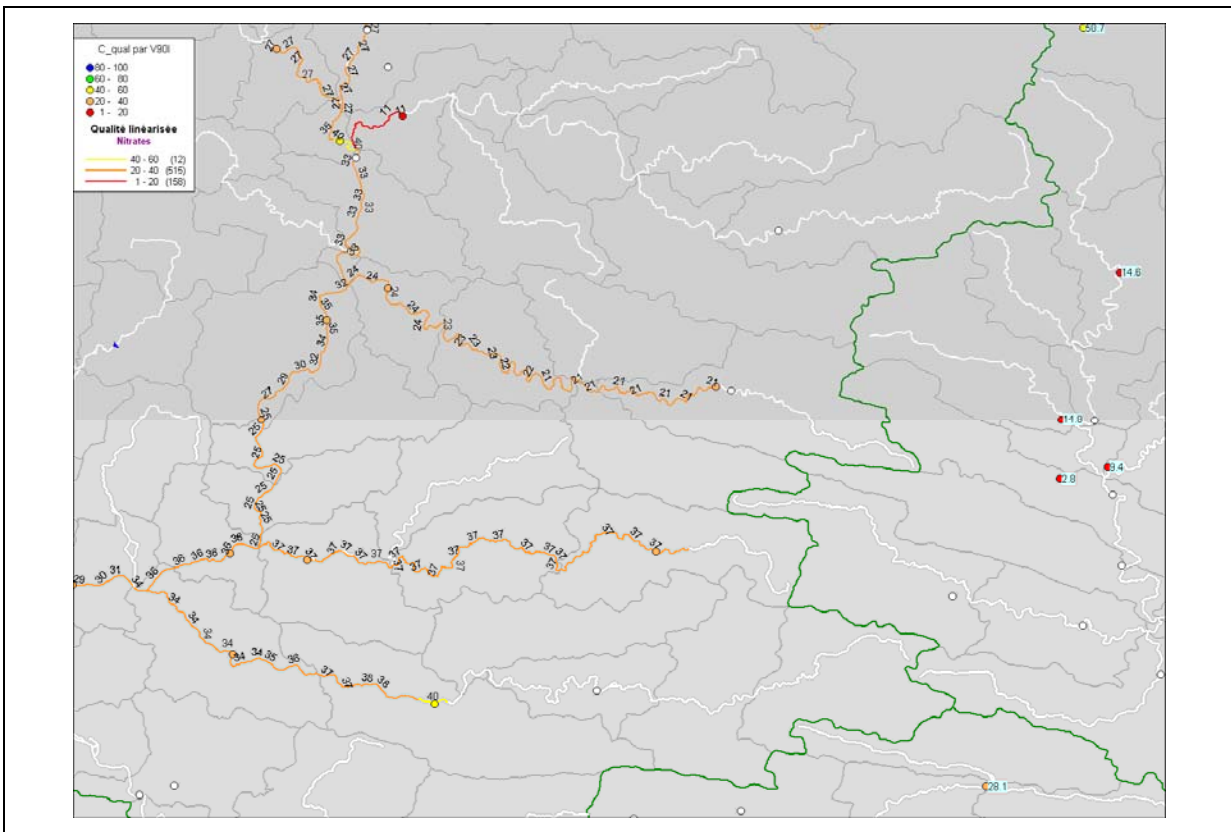
The numbers next to the sampling stations colour code is the actual quality index (e.g., 34).

The line represented was computed from these stations data and discharge reference previously computed using the same NOPOLU *Système 2* facility.

The colour ranges are usually five classes along the 0-100 score of the SEQ, but can be adjusted within NOPOLU *Système 2*.

Figure 11: Organic matters alteration calculation on the Meuse basin





**Figure 12: Nitrate alteration calculation on the Vilaine catchment and zoom**

The two figures above indicate the use of zooming provided to scrutinize precisely the values attached to every reach. The figures are the calculated quality index.

White lines indicate the rivers declared as “main drains” but that could not be computed either because lack of upstream data or gap in the arborescence.

## 3. Water resource accounts

### 3.1. Scope and rationales of WRA module

By contrast with the WQA the "Water resource accounts" (WRA) were delayed in France, for some reasons:

- Resource is a lesser issue than quality,
- Methodology was understood to be available,
- Data collection was understood to be difficult.

Some applications and training sessions suggested that none of these assumptions was true. The improvement of the "water resource accounts" methodology developed by Ifen for domestic purposes was then decided. It takes stock of test application to France, Moldova (Inland Water Accounts of the Republic of Moldova, 2000) and Turkey that permitted along with the training tables prepared in the context of MedStat1 (Plan Bleu pour la Méditerranée) to stabilize the expected outputs of the system.

Besides, the finalisation of the "water quality accounts methodology" is likely to provide some essential data on rivers, with the possibility to break-down this data into administrative and catchment aggregates.

The specificity of the development lays into its "data collector" aspect. As a matter of fact, the water resources accounts are basically a huge aggregation of data, generally not needing a hard calculation process. Hence, a module, intended to be used with NOPOLU *Système 2* acts like a cataloger of data sources which won't be all described individually in this paper – because of their number, and the complexity to reach them through the multiple and various tables of NOPOLU databases. The present description would rather light up the user-oriented conception and the handling of the module.

This module allows the user to calculate water resources accounts at different scales (administrative – NUTS1 to NUTS3 - or hydrologic – subsectors to basins -) and for different years.

Once the computation is over, the results can be viewed in four tables - derived from the SEEA formatted Tables - including:

- 1) **Water supply and use:** describing where and how industrial, domestic, or agricultural activities abstract and use water.
- 2) **Matrix of flows within the economy:** explicating the transfers of the resource between the different kinds of activities.
- 3) **Overall balance of water:** describing the abstraction and the supply of water concerning every type of sources.
- 4) **Transfers between water resources:** indicating volumes transferred between sources.

The results can also be exported under EXCEL Spreadsheets for a specified entity or for all entities included in the computation scale, thus permitting the user to reconcile the different data.

### 3.2. Recalls of data sources in WRA production

#### 3.2.1. Water uses

The overall view of the project shows two main difficulties linked with each other: the diversity of data required and the program standardization. These problems are exemplified in the matrix of flows within the economy.



Table 5: Table 8.4 of the SEEA WRA matrix

	Agriculture	Fisheries	Energy	Mining	Manufacturing & Construction	Distribution/ irrigation water	Distribution/ municipal water	Sewerage	Government	Household	Rest of the World	S2 Total water supplied
Agriculture	*											
Fisheries												
Energy								*				
Mining				*								
Manufacturing		*										
Distribution/ irrigation water												
Distribution/ municipal water												
Sewerage								*				
Government												
Household												
Rest of the World												
<b>U2 Total water received (use)</b>												

Government activities include college, schools, mayor's offices, and more but the corresponding data are not clearly classified. The flow between two same activities can have different meaning: for mining (\*) it means reuse of water whereas it would mean losses in transport for sewerage (\*). The source of data is also quite different considering agriculture, fisheries, energy, ... which would be classified as industrial activities and household which reports to domestic activities. Furthermore, some data are non-existent, for example flow between manufacturing and fisheries (\*), ...

### 3.2.2. Resource data

According to the importance of natural resources in the country in which the WRA is implemented, the natural resource data may come from different systems. From calculation point's of view, the main problem to solve is: can the information be disaggregated / aggregated on different geographic boundaries?

For instance, rainfall and effective rainfall are areal information, that are simply allocated thanks to surface ratio. By contrast, river flow requires much more detailed data.

## 3.3. Method chosen for regular production

### 3.3.1. Technical choice

This diversity of data sources implies to have a flexible algorithm to collect all data, and to be able to modify it easily. Considering that an unique data table containing all results is unrealizable, the choice has been made to define separately every source in relation with a cell in the accounts matrix– via the Structured Query Language – and to group all this definitions in an unique table.

Internal coding of elementary piece of data was done as a compromise between understandability by person and machine efficiency. Every cell has its own code, respecting the format XY\_LLCC, where XY, LL and CC



represent respectively the table, the line and the column number. For example, the flow between agriculture (\*) would be coded by 84\_0000 and the flow between Energy and sewerage (\*) would get the 84\_0207 code (the first line/column is always coded with 00). Results display and export are then easily possible.

In other words, the system developed is a library of queries that manages data from as many individual sets as installed in customer's database. This library of queries then places and structures the obtained values of data in matrixes that mirror the final accounts tables and export them.

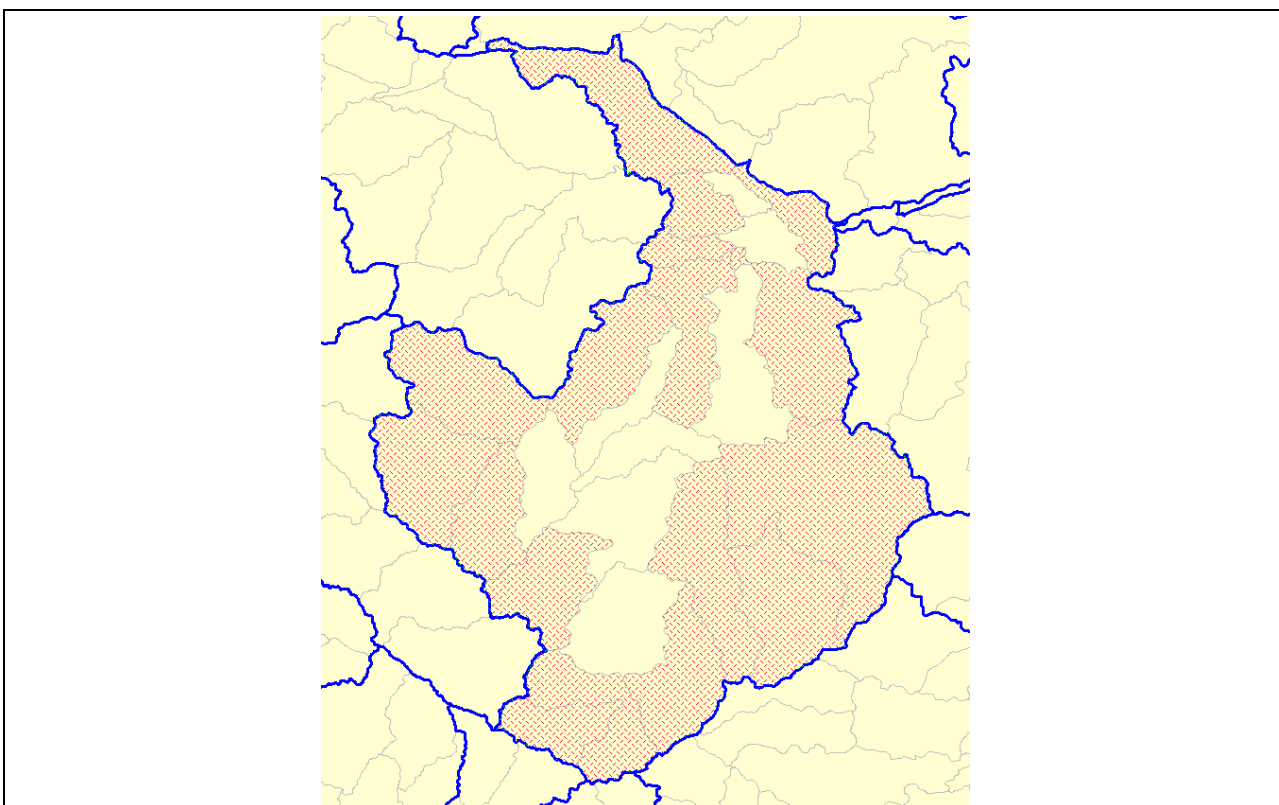
A new query can be stored just by first building it and then placing it in the target library.

### 3.3.2. Results Scale management

The two types of scales implemented in the module are treated differently. All data are provided at hydrological zone scale: a selected hydrologic scale isn't therefore a problem because a simple addition of values per hydrological zones contained in the current entity is adequate to get the results.

The case of administrative scale is quite harder : hydrologic borders rarely matches with administrative borders. In order to ease the calculation, an approximation has been made: considering the small area of an hydrological zone, the administrative entities can be represented nevertheless as an aggregation of hydrologic zones. The idea is to group as many hydrological zones as it needs to fill completely the administrative territory, the extra parts (hydrological zones crossing the borders) are then submitted to a ratio calculation *Surface in the administrative area on Total Surface of the hydrological zone*.

The resulted percentage is applied to all possible data such as rain (if given in volume unit), but does not mean anything regarding inflows and outflows volumes. In this case, the flow direction has to be examined : it is necessary to determine what gets in and what gets out. The outflow of an hydrological zone can be directed to the sea, then it is also an outflow for the current entity, or it can be the inlet of another hydrological zone, then it has not to be considered if this one belongs to the same entity.



**Figure 13 : Definition of bordering zones for a sub sector scale (flow from inner zones is automatically transmitted to selected zones)**

The calculation of inflows and outflows for an hydrological scale consists in determining all bordering zones in the current entity. The corresponding inflow or outflow value is given by the linearization module results; the inlet or outlet flow from main stretch of the zone can be calculated. Once the flow direction is known, a sum

of the inputs and of the outputs determines respectively the inflow and outflow of the considered entity. The case of an administrative scale is still submitted to a study because the ratio calculation isn't always a pertinent method.

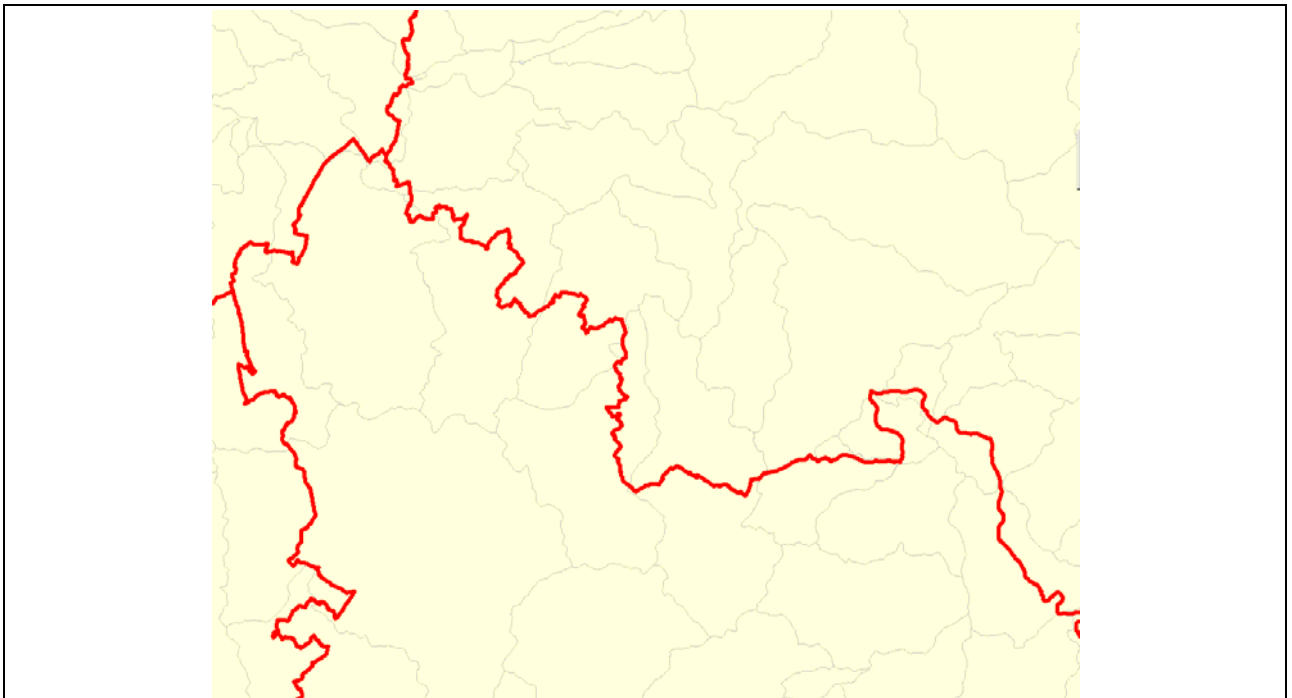


Figure 14 : Disparities between administrative and hydrological borders

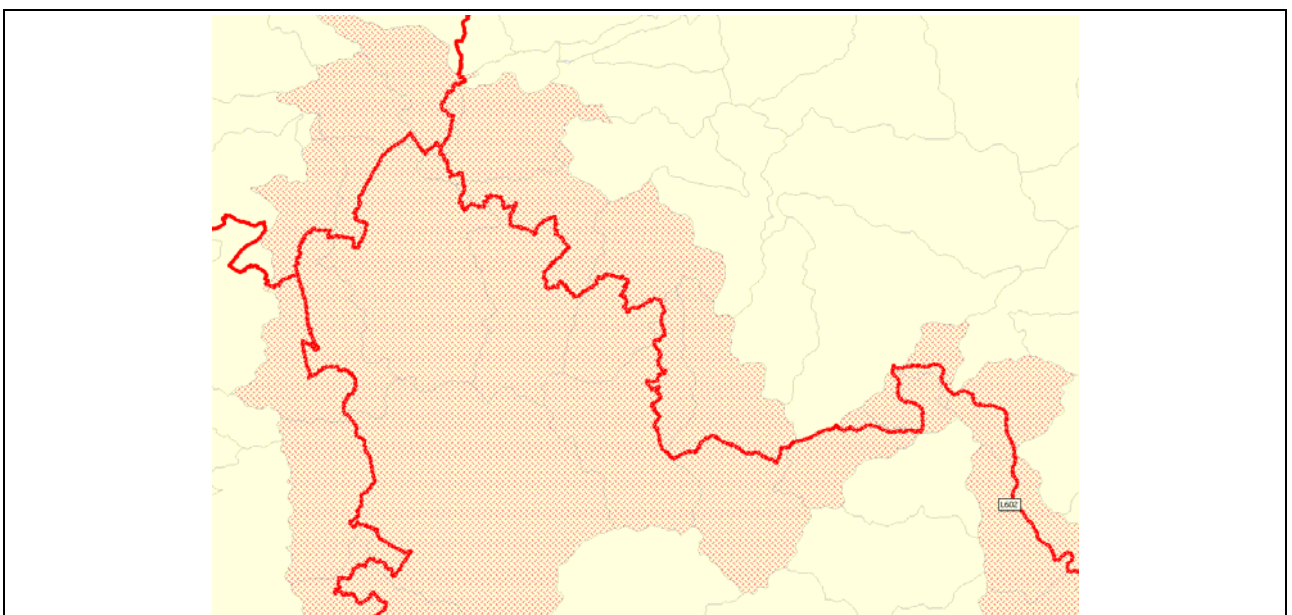


Figure 15 : problems in defining inflows and outflows of bordering zones for administrative scale

### 3.3.3. Application tables management

The three main features of the module are: calculation at a defined scale, results display, and results export. Several tables have been created to ease all of these processes and to light data treatment, they are shown in the next figure.

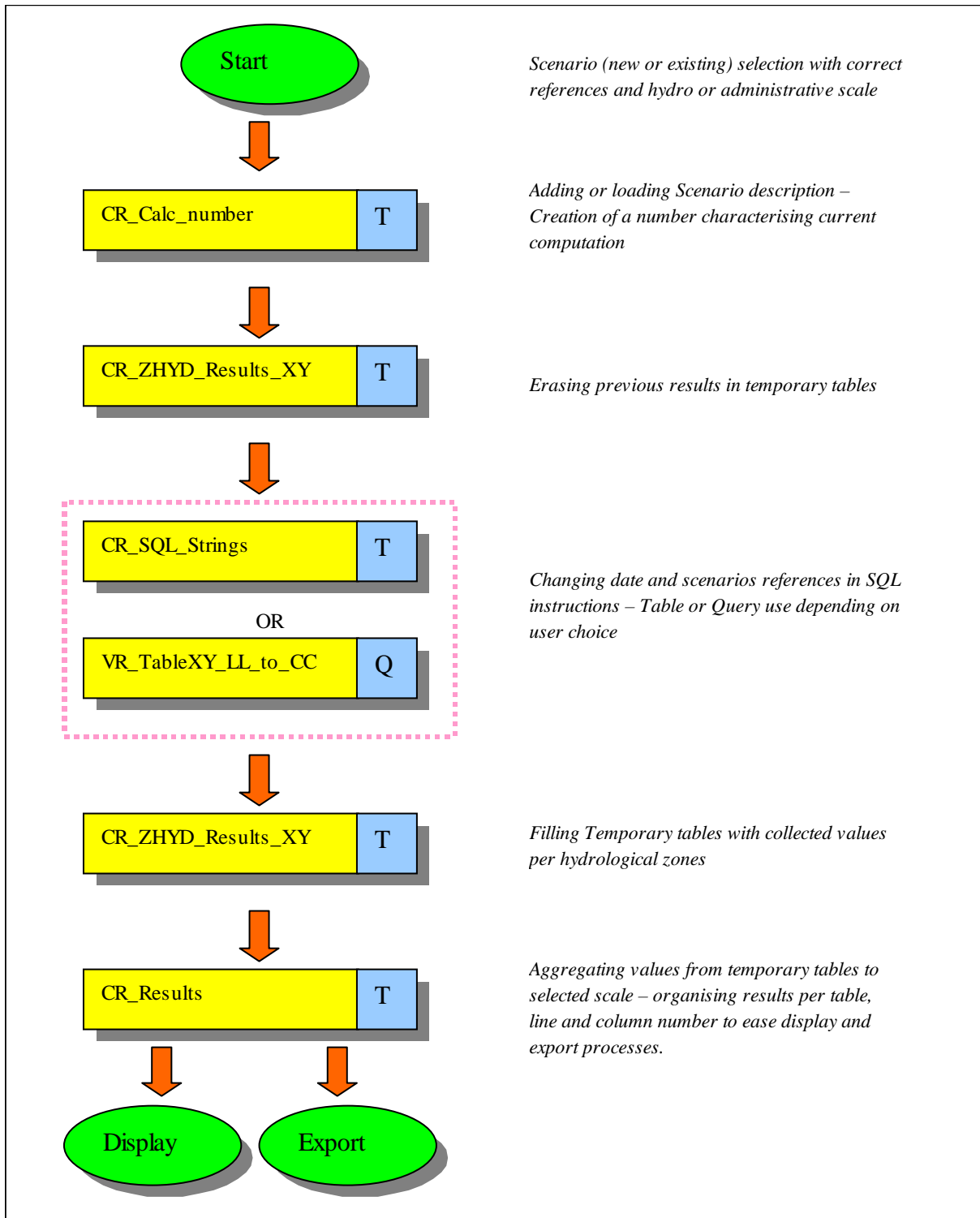


Figure 16: Table use organization chart

### 3.4. Detailed relationships between WRA components

The current database used for module implementation is the Loire Bretagne Water Agency base, the present section refers to data tables used in this base but could apply to other organizations for all that data tables would have the same structure.

In this section, table names refer to the actual names in the application database. These names are provided to exemplify which organization is required to carry out regular WRA production.

#### 3.4.1. Table 8.3/8.5

- **U1 section** (water abstraction) can be entirely determined with an unique table  $V\_IO$  describing intakes/outlet measures per activity; it also indicates the kind of water source by a specific code. The results display of this table does not follow the same protocol than the others but it won't be explained in this report.
- **U2 section** (water received) is entirely determined with data taken from the matrix of transfers within the economy (table 8.4).
- **S2 section** is also present in table 8.4.
- **S3 section** is more diversified: lost water from irrigation concerns only the agricultural activities and comes from a percent of infiltration on total water supplied ( $C\_IO$  table). **Treated waste water** concerning industrial activities (including distribution) is the output flow sent to an internal WWTP if the industry ever has one ( $V\_Pol\_indus$  table used), concerning sewerage it corresponds to the output flow effectively treated by WWTP ( $V\_STEP$  table). The same method can be applied to **untreated waste water** : for industries it would match with the volume not transiting via an external or internal WWTP ( $V\_Pol\_indus$ ), for sewerage it would be the untreated WWTP volumes (when plant capacity is overflowed –  $V\_STEP$  Table) associated with the volumes corresponding to non connected networks and the network leaks (both  $V\_STEP$ ). Finally, the ad hoc household value represents all outflows from domestic activities where there are no connections with a water network. **Cooling water** can be considered as untreated water but only for energy activities ( $V\_STEP$  table). **Water used for hydroelectricity** is taken from  $V\_BAR$  table. Water lost in transport is determined by application of a loss coefficient, multiplied by an extra coefficient (irrigation loss or municipal loss) for water distribution activities only ( $V\_DISTRIB$  table).
- **S4 section**, dealing with resource consumption corresponds to the value of evaporation and evapotranspiration added with the volume of the discharge to the sea.

#### 3.4.2. Table 8.4

The Main data source is the  $V\_act\_indus$  table, which includes flow sampling measures for all indexed industrial activities and also the  $V\_act\_domes$  table, dealing with the household measures. All implemented cells concern the flow between activities and sewerage or Rest of the world. The part attributed to sewerage is known if the activity is connected to a water network, in the contrary case the flow is considered to be thrown away in the nature, the value is then attributed to Rest of the world. Then, **Section U2** and **S2** corresponding to total water used and supplied can be determined by a simple addition – the result is provided to tables 8.3 and 8.5.

#### 3.4.3. Table 8.7

- **Opening stocks** : Total Stock considered for every source type at calculation year start. These values are definable with the opening stocks scenario.
- **Abstraction** : Total abstraction is taken from  $V\_act\_indus$  and  $V\_act\_domes$  tables, any outlet is characterized by an environment description : the sum is done by outlet water type for any domestic and agricultural activities.
- **Residuals & returns** : All fields are calculated with the same method used for Residual & returns by activity type (table 8.3) but the regrouping is done per output water environment (this is given for all activity code in  $V\_act\_indus$  and  $V\_act\_domes$  tables).
- **Precipitation** : The monthly value of rain height is given for several years per entity in  $V\_ZHYD\_RAIN$  table, the product of the annual average of this value by the current surface of dams, lakes and rivers ( $C\_Bar$ ,  $C\_TR$ ). The value for land and soils corresponds to the difference between the total area of the entity and the three previous volumes calculated.
- **Inflows** : These values calculation have been explained in the part II.4, they correspond to the total of (surface) water entering in the considered entity. Nets areas do not match with basins and furthermore no significant pieces of information concerning subterranean water are available yet, inflows values will be, by default, attributed to the rivers.

- **Net natural transfers** : This value is the repartition of the transfers between sources. This value is taken from the corresponding value calculated in table 8.8.
- **Spontaneous real evapo-transpiration** : This value corresponds to the part of precipitation volumes returned to the atmosphere. A ratio defined by the user in the transfers scenario enables to calculate this value.
- **Outflows** : Like inflows, the calculation of these values is explained in part II.4. The destination (sea or other basin) is also easily determinable.
- **Other volume changes** : No data is available for Loire Bretagne territory, but could be existing for another region, for example the discovery of a water source would be an important piece of data for a desert land – this special case illustrates the need of maintainability of data sources.
- **Net accumulation** : This corresponds to the deficit or the excess generated by all input and output previous pieces of data (opening stocks excluded).
- **Closing stocks** : This value is the sum of Opening stocks and net accumulation.

#### 3.4.4. Table 8.8

Transfers between sources are particularly hard to determine especially because there aren't any existing pieces of data on a whole region like Loire Bretagne: transfers quantification depends on geology, topography, etc, so as it is possible to get values on small areas with a soil research but a quantification over a large territory remains tedious and is moreover not available yet.

The globalizing aspect of the module has therefore oriented the conception to set up a transfer rating editable by the user, which can't consider all transfer phenomenon exactly but aims to be as realistic as possible in spite of a consequent pieces of data lack.

The transfers coming from Land and soils can be illustrated by the simple figure below. The precipitations (1) represent the main input of the system (irrigation waters will also be considered but does not depend on any rate defined in this section). A first rate concerns the part of evaporated water over the total of precipitation: it will determine the quantity transferred from the land and soil, to groundwater by infiltration (3), to rivers, lakes and reservoirs by Run off (4,5,6) . The sum of the three rates concerned has to be 100%.

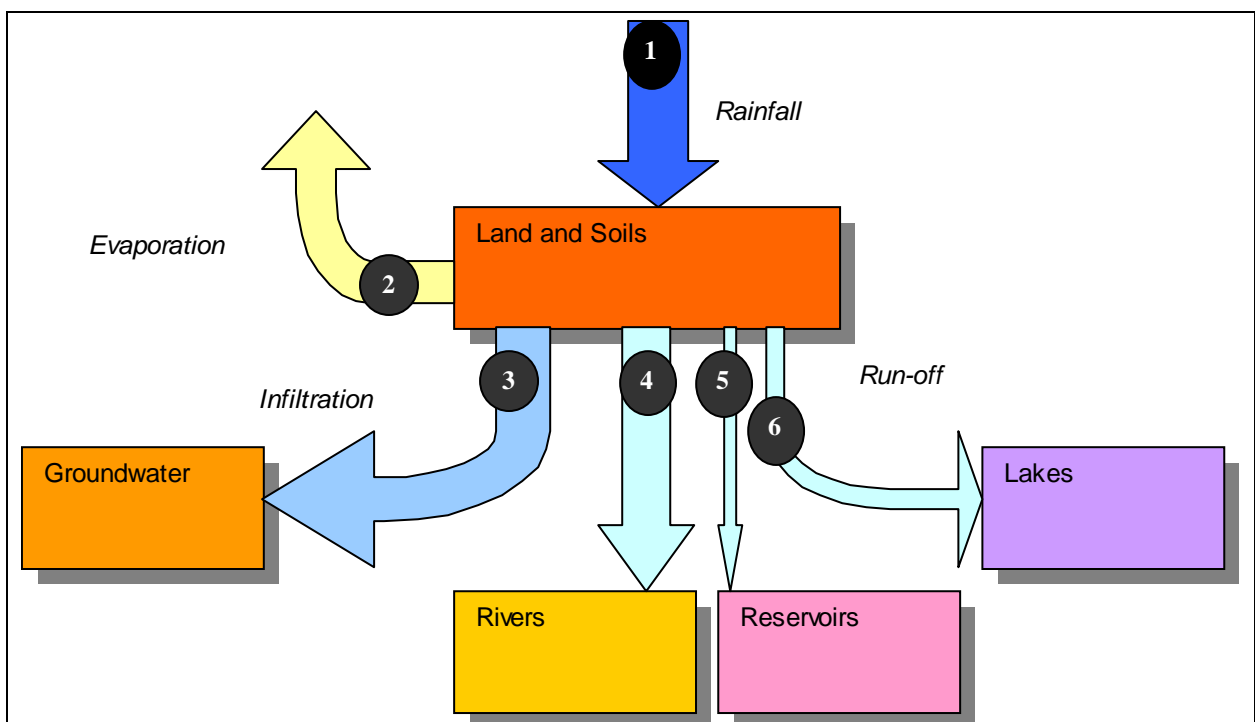


Figure 17 : *Transfers from Land and soil*

Regarding groundwater: Considering the simple scheme below, the ground water possesses four inputs 1,2,4,6 which are unknown values except 1 – Infiltration; this value will therefore be the only source used to determine the outputs (3,5,7), the other inputs are neglected compared to the infiltration so that it is considered to fill almost all variable net capacity. It is nevertheless possible to affect more or less than a sum of 100% to the outputs.

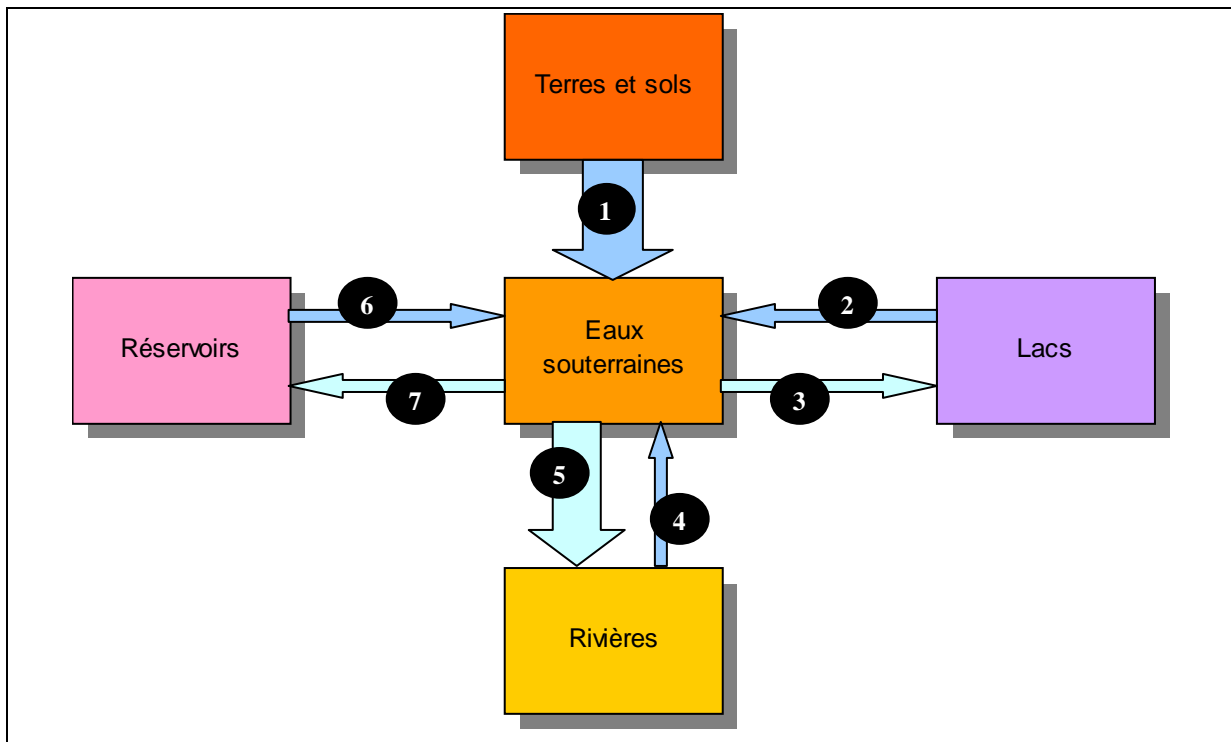


Figure 18 : *Transfers to/from groundwater*

The figure below describes transfers concerning Lakes or Reservoirs. The transfers to and from the rivers (4 & 5) correspond to the input and output flow of the lake or the reservoir, considering that these ones are always linked to a river. Run off (1) and inflow from the groundwater (2) are henceforth known values, it is then possible, with human intakes and outtakes volumes on lakes or reservoirs, to determine an approximate value for transfer to groundwater (3). Therefore, no rates have to be entered for those sources.

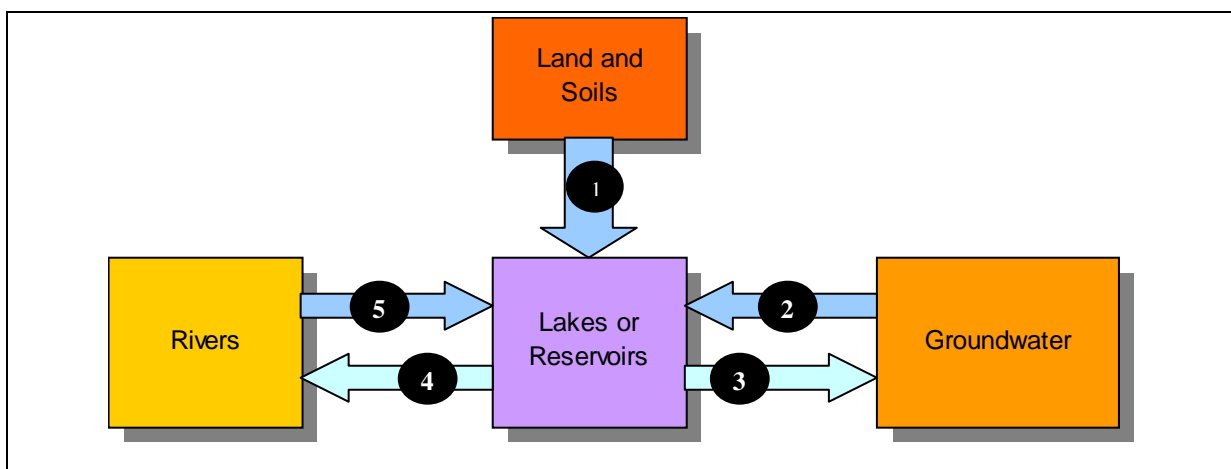
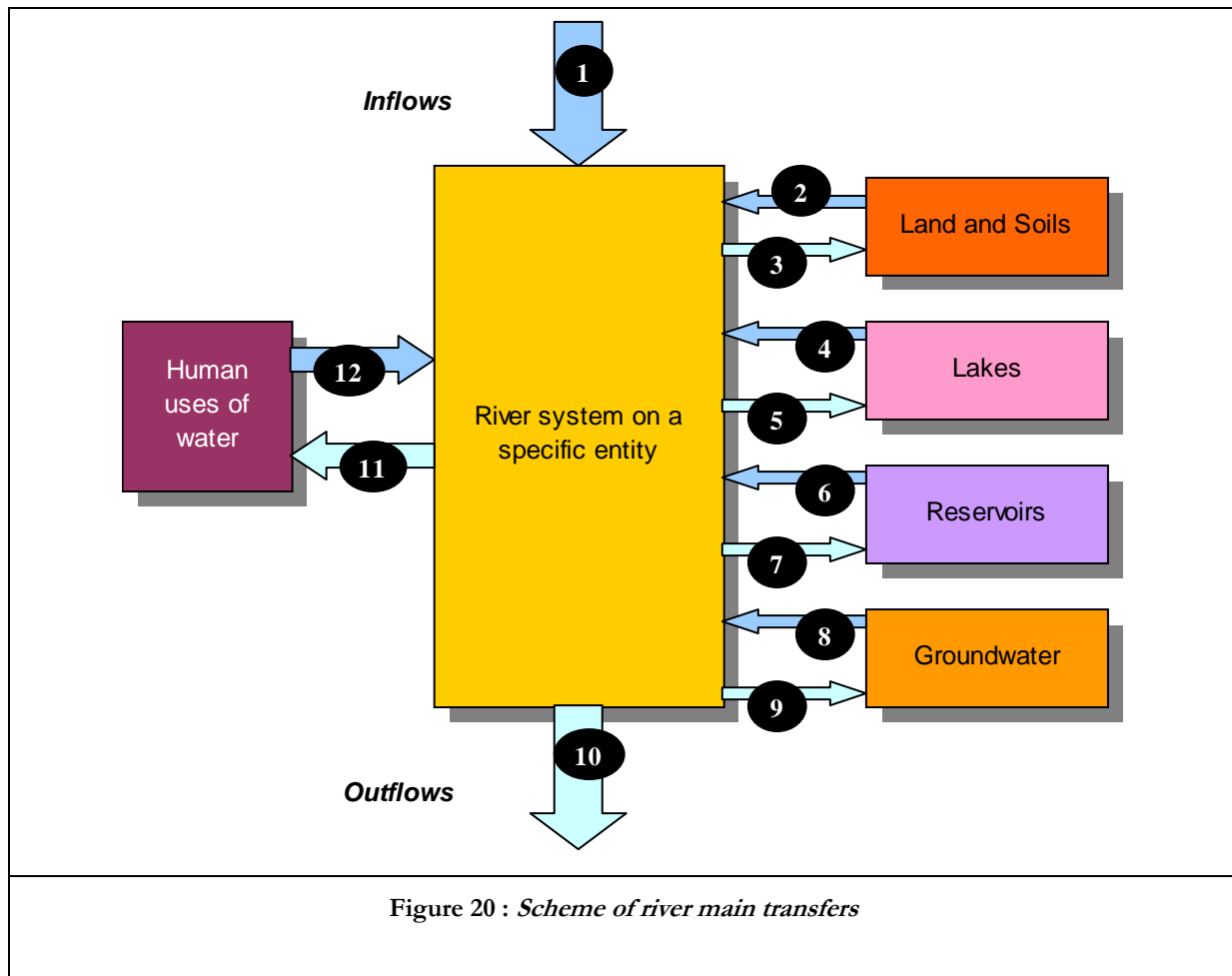


Figure 19 : *Transfers concerning Lakes and Reservoirs*

The last source to be considered is the river system, which a simplified scheme is given below. Relations 2 to 8 represent all resource transfers with river system; all inputs 2, 4, 6, 8 are now known values, outputs to lakes (5), reservoirs (7) are also known. Two transfers remain undetermined : flooding (3) and transfers to groundwater (9). Considering a specific entity, values of totalized transfers can be calculated by  $\Delta = \text{Outflow (10)} - \text{Inflow (1)} - \text{Human intervention (11 - 12)}$ , pieces of data which can be found in table 8.7. Two rates have to be defined to distribute the difference  $\Delta$  - known transfers between flooding and transfer to groundwater.



This rating system generates approximate values, but if pieces of data concerning transfers and especially transfers to/from groundwater become available, the data sources can be easily updated with the procedure describes in chapter 4.3 Data collecting.

### 3.5. Example of use

#### 3.5.1. Scenario Management

The computation is based on scenarios. Every new computation requires the choice of the following parameters:

- A scenario name has to be entered
- The scale of result has to be chosen: it includes hydrologic entities such as basins, sub basins, and sub sectors, or administrative entities from NUTS1 to NUTS3.
- Several references are also required: a precipitation year, a wasteload measure date, a IO measure date, a linearization scenario, an opening stocks scenario and a transfers rates scenario.
- The description can also be filled but it remains optional.

You can define different parameters related to your computation : Select or modify an existing scenario, or create a new one. You have to define the name of the new scenario, the scale of results, and the references used in the calcul, such as the precipitation year, the date of wasteloads

**Scenario Properties**

Scenario Name :  Description :

Scenario Number :  Compute date :

Spatial Scale :

**Loading/Deletion of an existing scenario**

Select existing scenario :

**Computation parameters**

Wasteloads Scenario Date :

Precipitation reference year :

Between :  And

Outlet flow measurement year :

Flows references values for stretches:

Opening stocks values Scenario :

Resources Transfers rates scenario :

Figure 21 : Creation/Loading of a new scenario

The wasteload scenario date corresponds to a date of industrial or domestic outflow measures. The I/O measure date matches with the date of measures of intake/outlet. The linearization scenario is used for inflow and outflow calculation at hydrological scale: it uses the previously computed stretches results – Quality accounts NOPOLU module – as reference data for hydrological zone inlet/outlet flow value.

It is also possible to define yearly resource quantities via a scenario building. The process is the following one : The values first considered are default values, then, if a particular value is defined at a given scale, this one will overwrite the default value. Furthermore, the most precise scale – which contains defined values – is always preponderant over the upper ones.

The user can choose an existing scenario to modify it or to use as initial values for a new stocks scenario, the “edit default scenario” button allows the user to create or modify a set of values defined at a specific scale, which will affect the same values for all entities of the definition scale. The definition of values for a scale leads to a ventilation of values on smaller scales, inversely proportional to the number of sub-entities : for example a river stock of 150 entered for a basin containing 5 sub-basins will be set to  $150/5 = 30$  for each one of the sub-basins unless a particular value is already existing. On the other hand, the value is not ventilated to upper scales.



Once the values are entered, a click on “cancel” will erase all changes made whereas a click on “save” will validate changes (stocks scenario overwrite or creation depending on which button was chosen in main menu). If there isn’t any stocks scenario chosen, all values are set to 0.

Scenario name:  Description :

Scale :  Date :

**You first have to select a scale, then you can define initial water quantity (in millions m3). A value set at a given scale is automatically ventilated over the smaller ones (The ratio coefficient is the number of sub-entities). On the other hand, values are not diffused over upper scales. For default scenarios, you can just define values for one scale.**

Entity Code	Entity name	Dams Reservoirs	Lakes	Rivers	Groundwater	Land and soil	Rest of the world
J0	COTIERS DU COUESNON (ir	150	140	310	25000	0	0
J1	COTIERS DE LA RANCE (exc	150	140	310	25000	0	0
J2	COTIERS DU TRIEX (exclu	150	140	310	25000	0	0
J3	COTIERS DE LA POINTE DE	150	140	310	25000	0	0
J4	COTIERS DE LA POINTE DU	150	140	310	25000	0	0
J5	LE BLAVET DE SA SOURCE	150	140	310	25000	0	0
J6	COTIERS DU BLAVET (exclu	150	140	310	25000	0	0
J7	LA VILAINE DE SA SOURCE	150	140	310	25000	0	0
J8	LOUST & SES AFFLUENTS	150	140	310	25000	0	0
J9	LA VILAINE DU CANAL DE N.	150	140	310	25000	0	0
K0	LA LOIRE DE SA SOURCE A	150	140	310	25000	0	0
K1	LA LOIRE DU RHINS (exclue	150	140	310	25000	0	0
K2	LALLIER DE SA SOURCE A L	150	140	310	25000	0	0
K3	LALLIER DE LA DORE (exclu	150	140	310	25000	0	0
K4	LA LOIRE DE LALLIER (exclu	150	140	310	25000	0	0
K5	LE CHER DE SA SOURCE A L	150	140	310	25000	0	0
K6	LE CHER DE LARNON (inclus	150	140	310	25000	0	0
K7	LINDRE DE SA SOURCE A L	150	140	310	25000	0	0
L0	LA VIENNE DE SA SOURCE	150	140	310	25000	0	0
L1	LA VIENNE DE LA GOIRE (ex	150	140	310	25000	0	0
L2	LE CLAIN & SES AFFLUENTS	150	140	310	25000	0	0
L3	LA VIENNE DU CLAIN (exclu	150	140	310	25000	0	0
L4	LA CREUSE DE SA SOURCE	150	140	310	25000	0	0
L5	LA GARTEMPE & SES AFFLU	150	140	310	25000	0	0

Save Cancel

Enr :  sur 48  
Opening Stock (unit: million cubic meters)

**Figure 22 : Definition of opening stocks with a scenario**

As explained in chapter 4.6, no pieces of data are available to fill entirely table 8.8, it has been decided to get those part of information with a scenario process. It is then possible to define part of evaporated water over total precipitations on soil, once this value defined the distribution of the corresponding volume on reservoirs, lakes, rivers and groundwater. The distribution of groundwater transfers can also be done, with the infiltrated volume as reference, which is different from groundwater volume (unknown value), so that total of rates can be different from 100%. The last ratios to define are rivers distribution on groundwater and land and soil. The reader should refer to part 4.6 to see what approximations have been made to obtain resources transfers quantities.

The same recurrent entity managing principle is applied to the transfers scenario : Values can be defined at different scales but the most precise scale is always preponderant in comparison with upper scales. A click on “save” modifies or creates the current scenario.

If no transfer scenario is selected, a default scenario is automatically selected, excepted if the data sources have been implemented by the user.

**You first have to select a scale, then you can define percentage of transfers form origin sources to destination sources**

Name :  Description :

Scale :

Entity :  COTIERS DE LA RANCE (exclue) AU TRIEUX (incluse)

		DESTINATION					
		Reservoirs Dams	Lakes	Rivers	Ground-water	Land and soil	
O R I G I N	Rivers				95,00%	5,00%	of non-determined volume (= 100%)
	Groundwater	2,00%	3,00%	80,00%		0,00%	of infiltrated water (< or > 100 %)
	Land and soil	5,00%	5,00%	10,00%	80,00%		of non-evaporated rain (=100%)

Define part of evaporated water over total precipitation on soil :

Enr :  sur 48

**Figure 23 : Definition of a transfer scenario**

Existing computation scenarios can be loaded by the corresponding list box; a click on “Load Results” displays all results in all tables.

It is moreover possible to delete an existing scenario via the same list box; a warning message asks for a confirmation. During the scenario deletion, all related results and settings are deleted too.

**Scenario Properties**

Scenario Name :  Description :

Scenario Number :  Compute date :

Spatial Scale :

Do you really want to delete this scenario ?

Select existing scenario :

**Figure 24 : Deletion of an existing scenario**

### 3.6. Results consultation

Once the computation is over, the results can be viewed directly in the accounts tables. Four Tables are available : Table 8.3/8.5 describing use and supply volumes by all kind of activities, Table 8.4 showing flows between these activities, Table 8.7 considering volume changes from all kind of water sources and table 8.8 indicating volumes transferred from a water sources to the others.

The process to access one of those tables is quite simple : click on the desired table button and select the entity, the results shall appear on the screen. All results are already calculated and stocked in “CR\_Results” table, the consultation is therefore instantaneous.

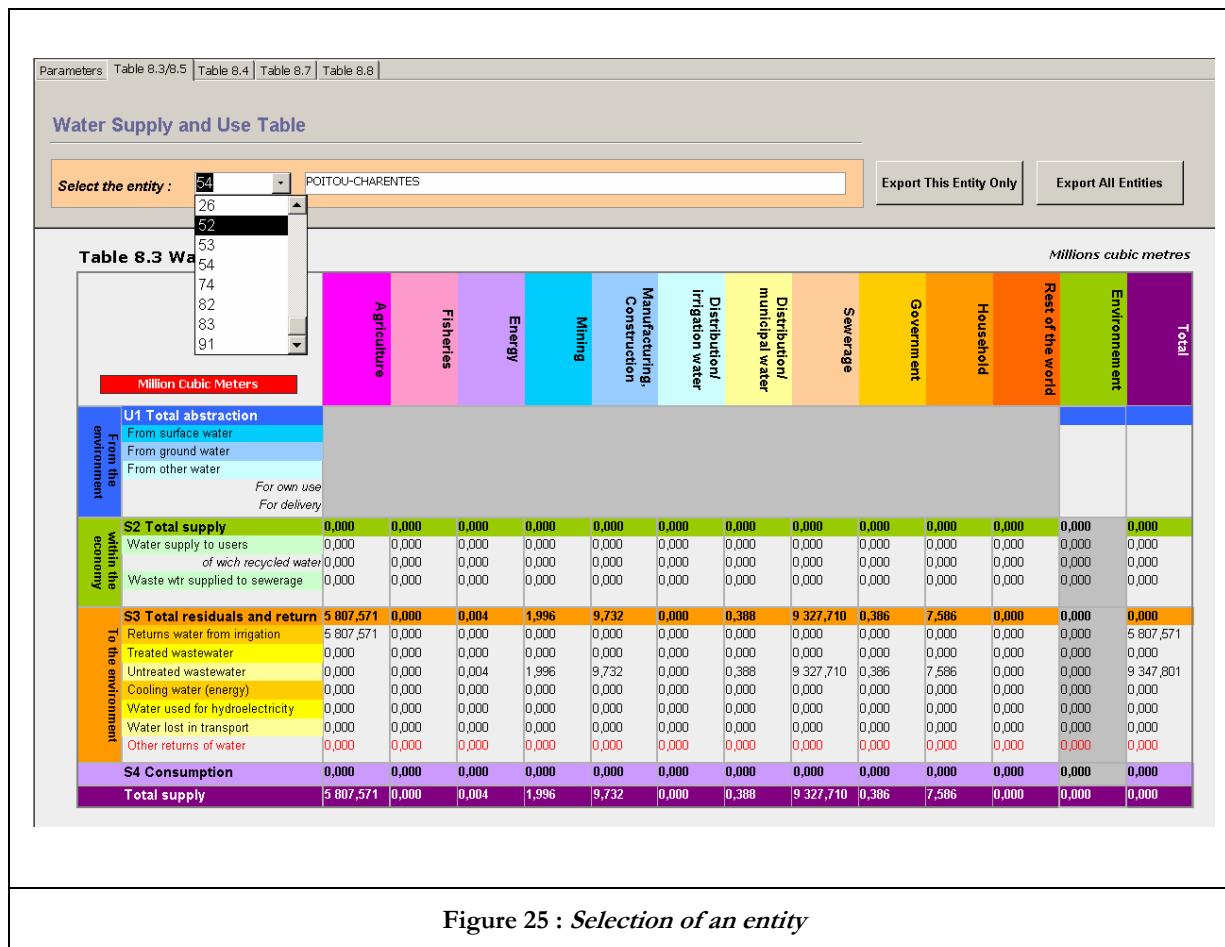


Figure 25 : Selection of an entity

### 3.6.1. Results Export

The interest of the calculation is not only to watch results but especially to be able to handle it. The export command allows the user to save the results under MS EXCEL format. The file created is based on a spreadsheet model named “blank\_tables” which contains the skeleton of the four tables implemented: a click on the **export this entity only** button saves all results for the selected entity in a spreadsheet named with the entity code. A click on **export all entities** creates a file with as many sheets as entities included in the results scale.

The created EXCEL file is similar to the model : all tables are systematically filled. The path and name of the output file can be modified in “SitParam” table.

	K1	K2	NUM	TEXTE	Description
	CR_Blank_exp	Path	0	D:\Sommeilly\Ressources\blank_tables.xls	complete path with model file extension
	CR_result_exp	NomFichier	0	Water_Ressources_Account	Name without EXTENSION of the output file
	CR_result_exp	Path	0	D:\Sommeilly\Ressources\	Path (including / at the end) of the output file
			0		

Figure 26 : Export file and model file Path and name

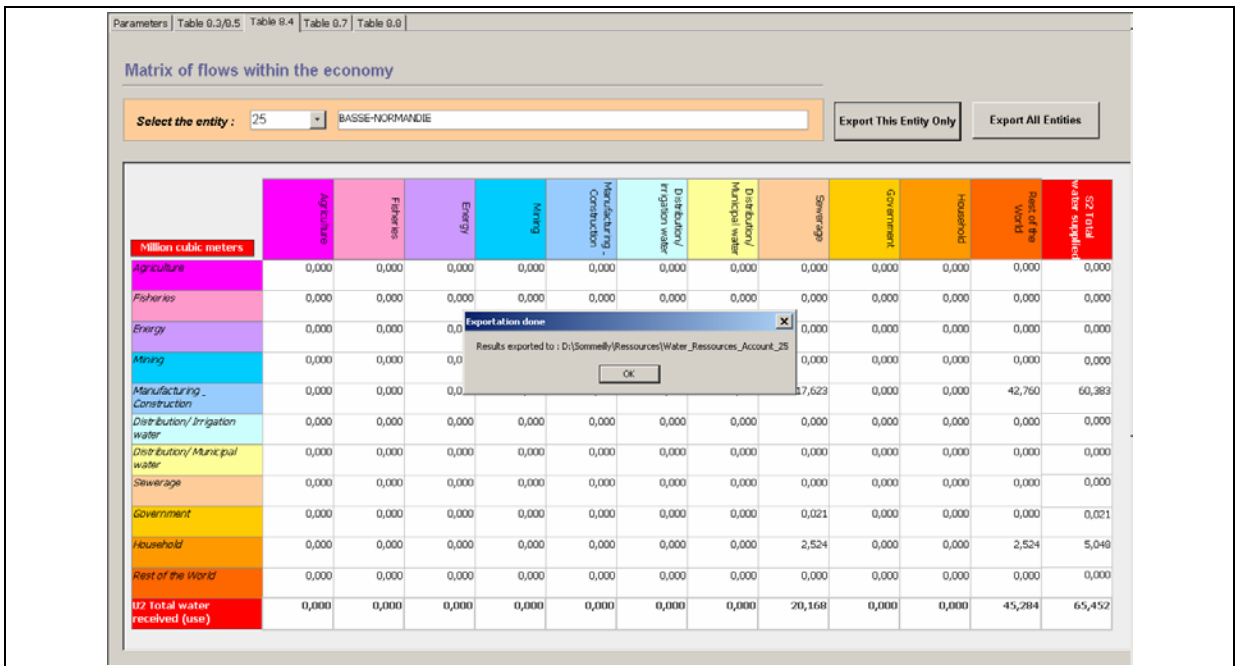


Figure 27 : Results export

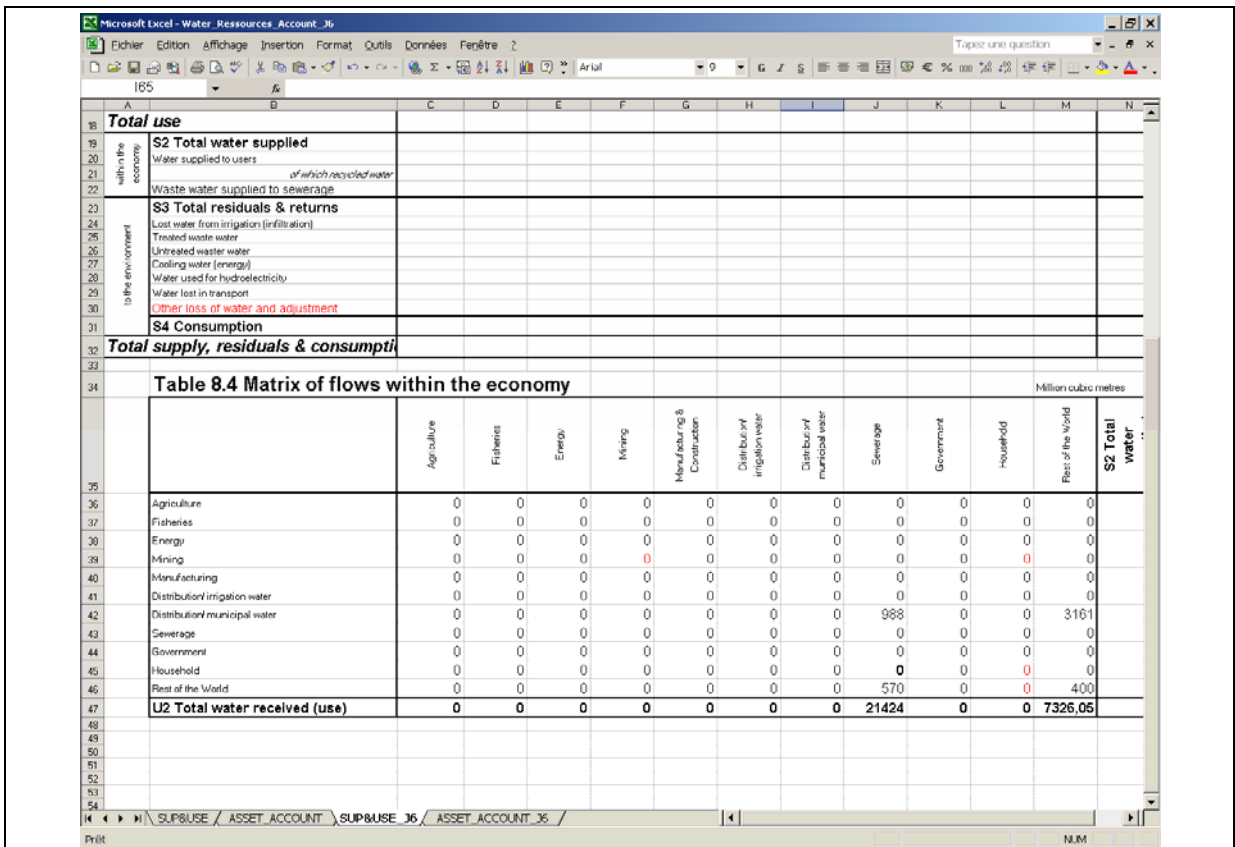


Figure 28 : Creation of the export EXCEL file

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