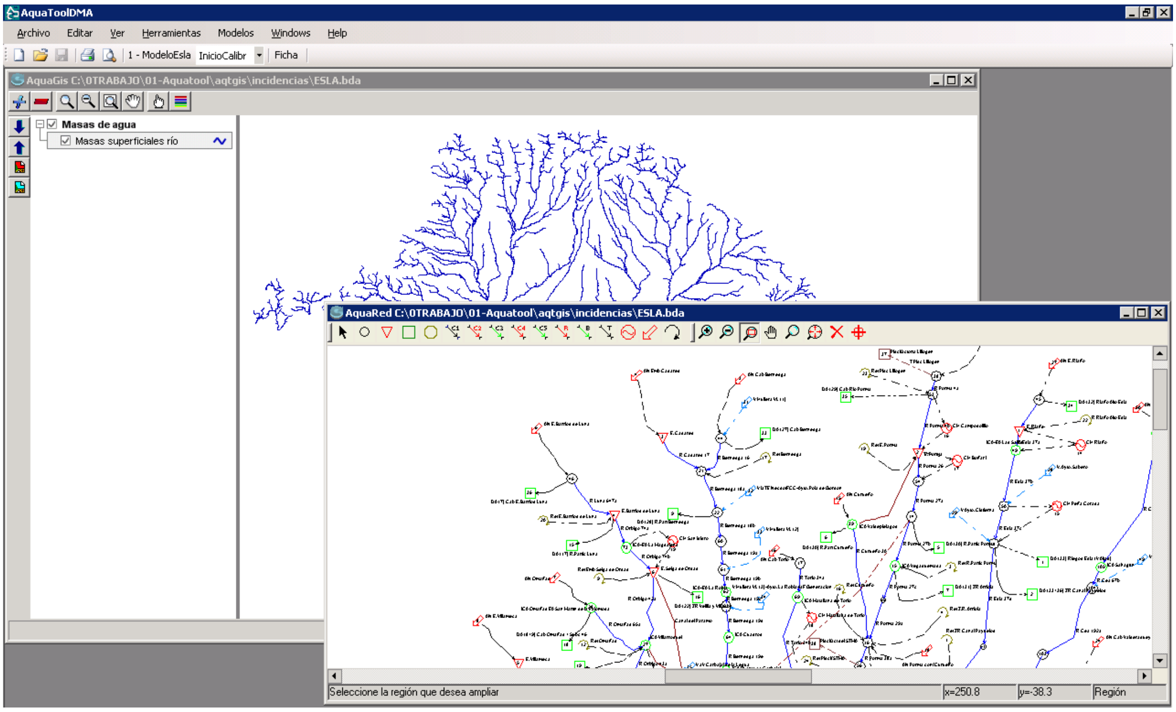
AQUATOOLDMA

Environment for the development of decision support systems for the planning and management of hydrological basins including conjunctive use and water quality criteria.

USER MANUAL

Version 1.003



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Contents:

1 INTRODUCTION.

This manual was designed to be of assistance in the use of the AQUATOOLDMA interface. No attempt is made here to explain the data, as this has already been done in the individual model manuals.

AQUATOOLDMA is an interface or working environment for the development and analysis of decision support systems for watershed planning and management. The program consists of a series of interactive files that provide a means of editing the data necessary for the analysis of different water resource management alternatives in hydrographic basins. As a working environment it provides direct access to other programs with specific functions related to basin management analysis. All these programs are integrated and coordinated into the interface in such a way that the user can make use of them all without realising that he is changing from one program to another. The principal programs that can be controlled from AQUATOOLDMA are the following:

- SIMGES Model (Andreu et alt. 2007) for basin simulation and management including conjunctive use.
- OPTIGES Module for optimising basin management.
- GESCAL Module for the simulation of water quality in complete basins (Paredes et al., 2007).
- SIMRISK Module
- GRAFDMA Module for viewing:
- Schemes
- Shapefiles

AQUATOOLDMA is a user interface for editing basin management simulation models with the SIMGES program and management-associated water-quality simulation models with the GESCAL program (Paredes et alt. 2007).

AQUATOOLDMA replaces the previous SIMWIN data interface (Andreu et al. 1996) for editing simulation schemes with SIMGES.

1.1 NEW FEATURES WITH RESPECT TO PREVIOUS VERSIONS.

Like SIMWIN[1], AQUATOOLDMA was designed as a tool to aid in developing basin management simulation models and includes the following improvements:

- Simulation data are stored in a file with a **data base** format, permitting manual edition of corrections and massive changes to data.
- The DB can differentiate data from different element by a unique element code and a scenario code. This means when simulating **different basin management alternatives**, all the alternatives can be stored in a single file to facilitate later data editing.

[1] An automatic update program has been created for immediate transition from SIMWIN to AQUATOOLDMA (see Annex 1).

- Data editing sheets include both SIMGES and **GESCAL** data clearly identified.
- Regarding the **water mass** classification criteria required by the European Water Framework Directive (WFD) (EU,2000), a GIS image viewer is included (with SHP files) with the necessary tools to link the model results with elements in GIS layers.

1.2 GENERAL DESCRIPTION OF AQUATOOLDMA.

In general terms, AQUATOOLDMA is an interface for editing, simulating, correcting and analysing basin management simulation models, including simulation of water quality.

The AQUATOOLDMA environment for the development of decision support systems for hydrographic basin planning and management includes the following programs:

- Aquatooldma.exe General interface for data editing and controlling the other programs. This manual focuses on the use of this program.
- simges.exe Program for the simulation of basin management, including conjunctive use (Andreu et al., 2007).
- gescal.exe Water quality simulation program for entire basins (Paredes et al., 2007).
- grafdma.exe Program for the treatment of graphic results of SIMGES and GESCAL simulations. Also used to calculate results for water masses or GIS elements (see Section 5).
- ges2dma.exe Program used to update projects developed with SIMWIN to projects for AQUATOOLDMA (see Annex 1).

1.3 CONTENTS OF THE MANUAL.

The aim of this manual is to help AQUATOOL users to plan new projects, edit data and analyse the results of calculation models. Model functioning principles are not described here but can be consulted in the individual model manuals.

Section contents are as follows:

2. ***Development of hydrological simulation models:*** Contains a description of the data for a simulation model with SIMGES.
3. ***Development of water quality simulation models:*** Contains a description of the data for a simulation model with GESCAL.
4. ***Treatment of results:*** Instructions for viewing and treating simulation results.
5. ***Linking results with GIS:*** Describes the relations between GIS and model elements and how to use the GIS data interface.

6. ***Managing scenarios in a single project:*** Describes the criteria to be considered for keeping various copies of the same basin model correctly synchronised in a single data base.

Annex 1: Importing projects from SIMWIN: Instructions for updating projects developed with SIMWIN to AQUATOOLDMA format.

Annex 2: Summary of the working of models: Description of files and functions for exchanging data between AQUATOOLDMA programs and those that could be useful for advanced program handling.

Annex 3: Installing the program.

2 DEVELOPING A NEW PROJECT.

On start-up, the AQUATOOLDMA working window is empty except for the different options of the upper Windows menu. To embark on a new project, the `[File]→ [New]` option is used (Figure 1). Before starting on the project, a work directory and a file name for the project data base must be selected.[2] This is done in the usual window for creating new files.

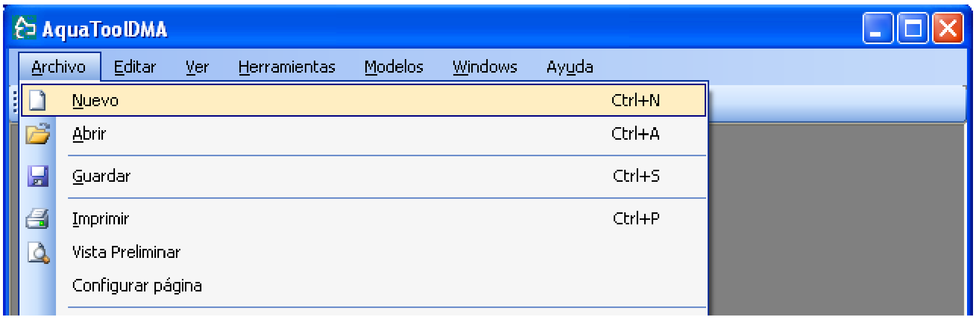


Figure 1: AQUATOOLDMA [File] menu.

After selecting a work directory and database file, the basic data for the first simulation project is entered as shown in Figure 2:

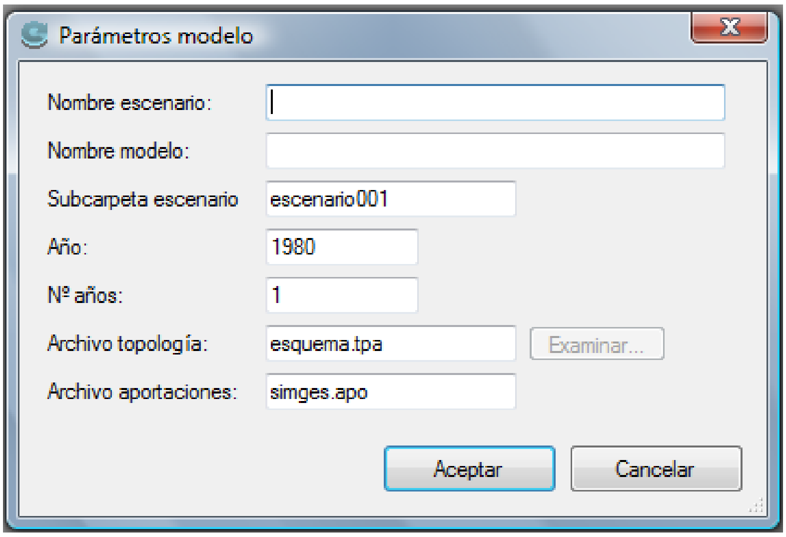


Figure 2: Initial parameters for simulation project.

- "`Name of scenario`" and "`name of model`": These are two headings that will be used in later processes to describe the working scenario (these can be changed later, if desired).
- "`Scenario subfile`": This file is created below the work file

[2] It is important to create a directory file exclusively for every AQUATOOLDMA project. If this is not done, the large number of files created during simulation could be confused with files from other projects.

described above. Here will be written all files specific to the current scenario.[3].

- “`Year`” and “`nº of years`”: are the initial year and the duration of the simulation (these can be changed later).
- “`Topology file`”: is the name of the file in which the program will write the data for the scheme graph.
- “`Inflows file`”: will contain the simulation model intermediate inflow data (this can be left blank and filled in when data are available). Natural inflow data must be prepared outside the AQUATOOLDMA program and included in the text file (for information on how to create this file, see the SIMGES User Manual (Andreu et al. 2007)) or it can be entered in the corresponding program windows.

2.1 ADDING AN ELEMENT TO THE MODEL.

When the data window has been accepted, the screen will show a drawing board on which to draw a scheme of the simulation model. A toolbar will also appear from which to select elements for inclusion in the model. The elements that figure in this toolbar (Figure 3) are those available in the SIMGES module for model design (see SIMGES Manual (Andreu et al., 2007)). If the user first opts for the optimisation model, some of these elements will not be available.

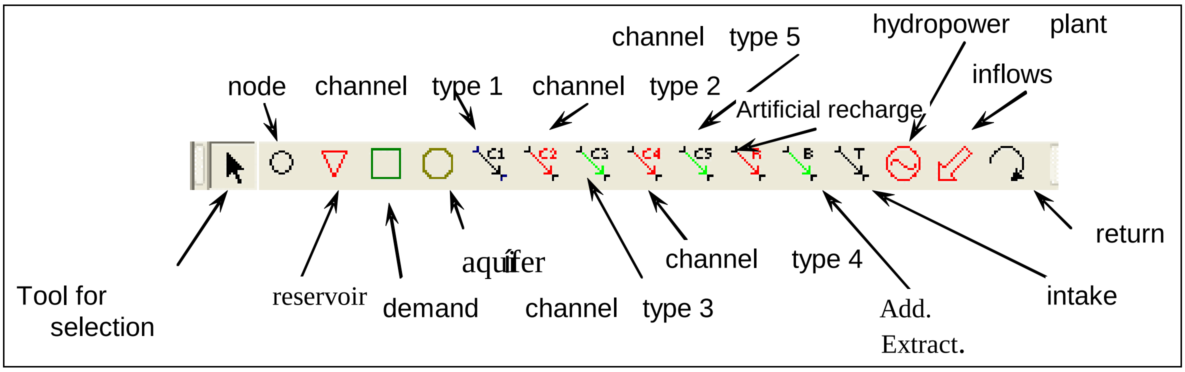
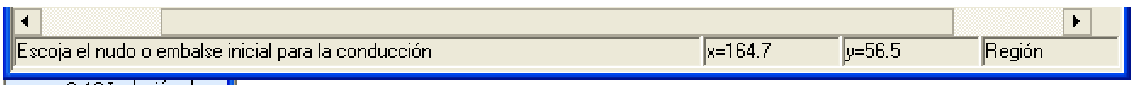


Figure 3: Toolbar for drawing plan of scheme.

To enter a new element in the scheme, the corresponding icon is selected from the toolbar and placed in the desired position by clicking on the mouse. Linear elements must start and finish in appropriate locations. A status bar at the bottom of the window (Figure 4) gives instructions for entering the active element and the screen coordinates of the mouse at all times.



[3] An AQUATOOLDMA project can handle various scenarios. Each scenario keeps its data files and results in a different subfile within the main project file (see Section 7).

Figure 4: Status bar of the drawing window.

After drawing an element, a dialogue window is opened to edit the relevant data. After accepting this window, the data are filed. If cancelled, the element is eliminated from the scheme. To edit the element's data sheet, double click on the element itself.

2.2 USE OF A TEMPLATE FOR MODEL SCHEMES.

For developing models of complex systems, a template can be used to locate elements accurately in relation to with their geographical locations. For this purpose, AQUATOOLDMA offers the use of an image file for display below the model elements.

On clicking the right-hand mouse button on the drawing screen a menu appears (Figure 5). The `[General viewer menu]`→ `[Add background image]` option is selected and the image is drawn below the scheme.[4]

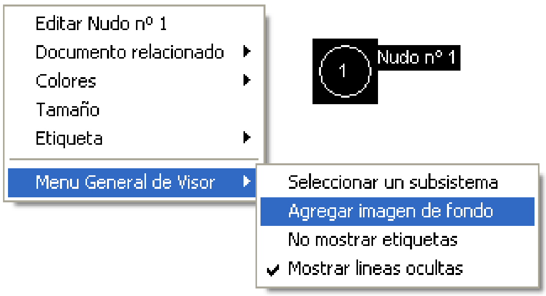


Figure 5: Context menu activated with the right-hand mouse button.

The image is initially drawn with the pixels of the original image. A menu also appears to configure image dimensions (Figure 6). Configuring the scheme and data editing cannot be continued until the accept button is clicked. The data contained in this window are as follows:

[4] The image selected is copied from the scenario directory. From now on the program works on its copy.

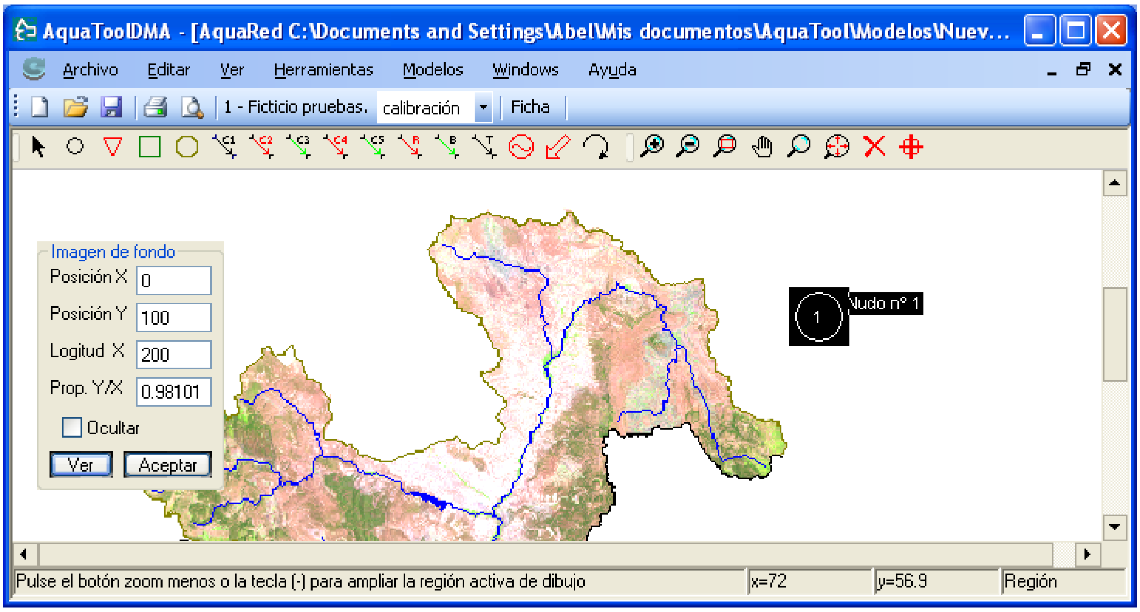


Figure 6: Configuration of background image.

- "`Position X`" and "`Position Y`": Coordinates of the upper left hand corner of the screen are indicated.
- "`Length X`": indicates the length of the horizontal side of the image in image measurement units (the coordinates in the image can be seen in the status bar below).
- "`Prop. Y/X`": ratio between image height and width. By default, the original file ratio is entered.
- "Hide" option: if activated, the image disappears.
- "See" button: press this button to see a preliminary view of the scheme of the model.
- "`Accept`" button: closes the configuration window and continues with the configuration of the scheme.

2.3 NODE ELEMENTS.

Nodes define significant points in the scheme, such as:

- river or channel inflows or outflows
- flow inputs: inflow, return or additional pumping
- flow outputs: for artificial recharge or demand intake
- changes in river or channel characteristics

A node does not require data but only an identifying name (Figure 7). Names must not be repeated, as this may cause confusion later in distinguishing between elements with the same name.

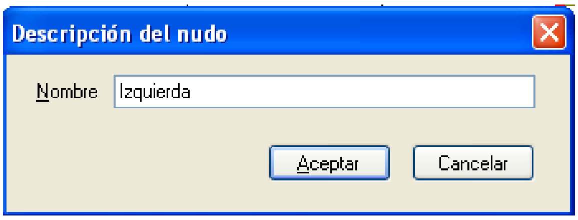


Figure7. –Data sheet for node-type elements.

The user can choose his own method of numbering nodes. The only exception to this is that a node must be defined to accept all system outflows and which will be assigned the number 0. This is done by selecting the node and then the menu option: `[Edit]`→ `[Final node]`→ `[Assign final node]`. The assigned final node can be de-assigned by the option: `[Unassign final node]`.

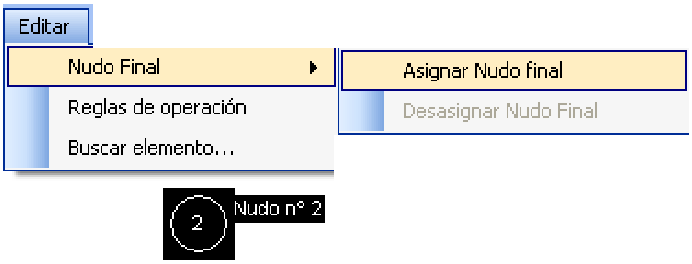


Figure 8.- Data sheet for node type elements.

2.4 RESERVOIR ELEMENTS.

Reservoirs are nodes with storage capacity.

The reservoir data sheet (Figure 8) contains a series of data classified according to type, as follows:

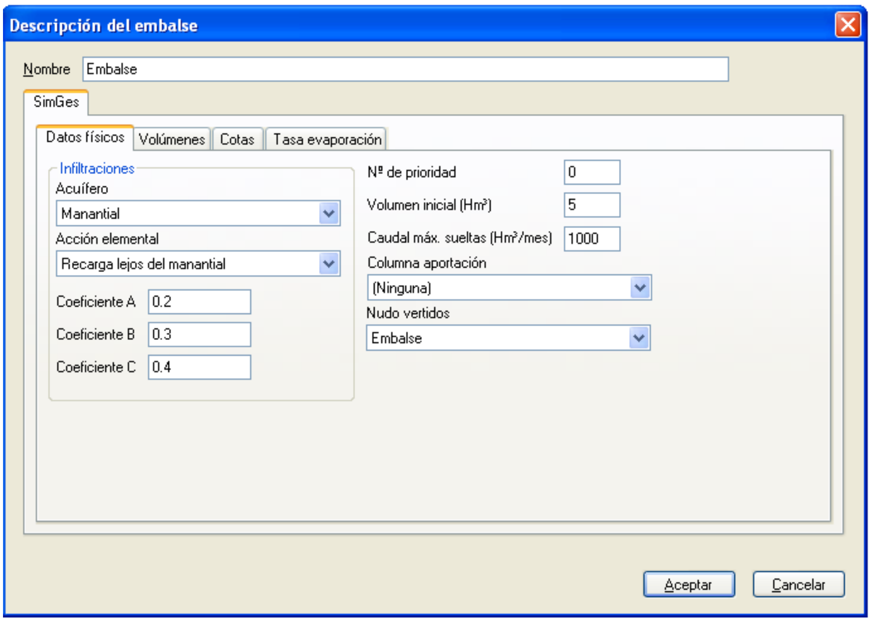


Figure 9.- Reservoir element data sheet.

"**Infiltration**". "Coef. A", "Coef. B" and "Coef. C" are the monthly infiltration loss formula. The aquifer that receives the infiltrated water is selected in "Aquifer", and in "Basic stress" the form of infiltration recharge. In "Aquifer" the "(to be determined)" option can be chosen provisionally if the aquifer still has nor been included in the scheme. However, if this field is not modified before the model execution, the program will show a design error. The "none" option is also available, which means that the infiltrated water is lost to the system.

"**Controlled discharge point**". A node must be indicated to which excess water volume, defined for each month, is sent when the reservoir level exceeds Vmax, and the excess cannot pass through controllable outlets (bottom drains, etc.). The capacity of these outlets is included as "Max.flow Uncontrolled discharges". The discharge node will almost always be the reservoir itself, and in this case the discharge outlets will be through a reservoir outlet channel selected on the grounds of costs and priorities. Another node will be selected as discharge node if this water is sent to another point away from the base of the dam. Maximum volume is assumed to vary from month to month in order to be able to define flood freeboard levels. If discharges cannot be used or leave the system, the final node may be assigned as the discharge node. Here again, the "`(to be determined)`" option can be selected provisionally.

“**Priority number**“. Basin reservoirs are managed in such a way as to keep all of them as far as possible within the same capacity zone. This is done by characterising reservoir levels, establishing different (capacity) zones and assigning reservoir priority numbers.

Capacity zones are defined on the basis of target volume (Vobj), minimum volume (Vmin) and maximum volume (Vmáx) for each month:

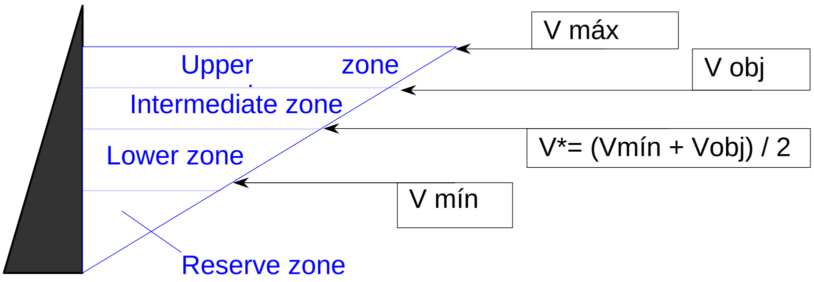


Figure 10.- Reservoir management scheme.

The model will not use water from the intermediate zone of a reservoir until all the water from the upper zones of all reservoirs has been exhausted (Figure 9). When two reservoirs are at the same capacity level, water will first be taken from the one with the highest priority number. If a reservoir is at the reserve level for successive months, no water can be taken from it (for exceptions see the Simges manual). .

“Initial volume” allows the stored water volume at the start of simulation to be entered.

“Max. discharge flow (Hm³/month)“. Here is defined the permitted monthly maximum discharge volume by regulating mechanisms (excluding uncontrolled discharges over spillways).

“Inflows column” is a drop-down menu that shows the names of the columns of the inflows data sheet. This must be previously defined in `[Models]`→ `[Simges]`→ `[Simges model parameters]`). If the sheets still have not been defined, the only possible option is "`None`".

The **[Volumes]** tab allows reservoir maximum, target and minimum volumes to be entered for each month (Figure 10). The "Maximum volume" ≥ "Target volume" ≥ "Minimum volume" ≥ 0 ratio must be complied with .

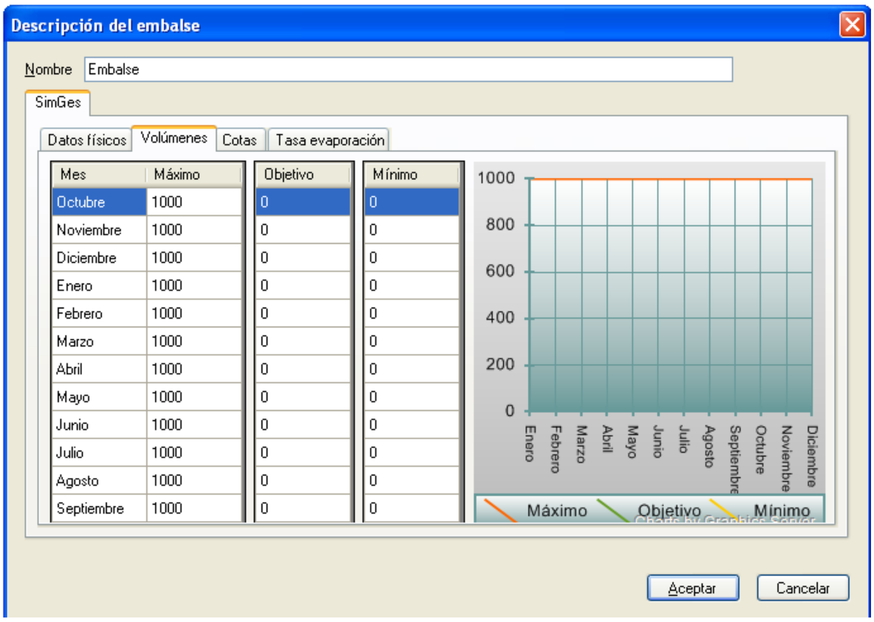


Figure 11.- Sheet for entering Volume data

The **[Elevations]** tab allows the elevation-surface-volume curve data and constant evaporation coefficient values to be entered for each month (Figure 11). Values in the fields of elevations, surface and volume must always be increasing.

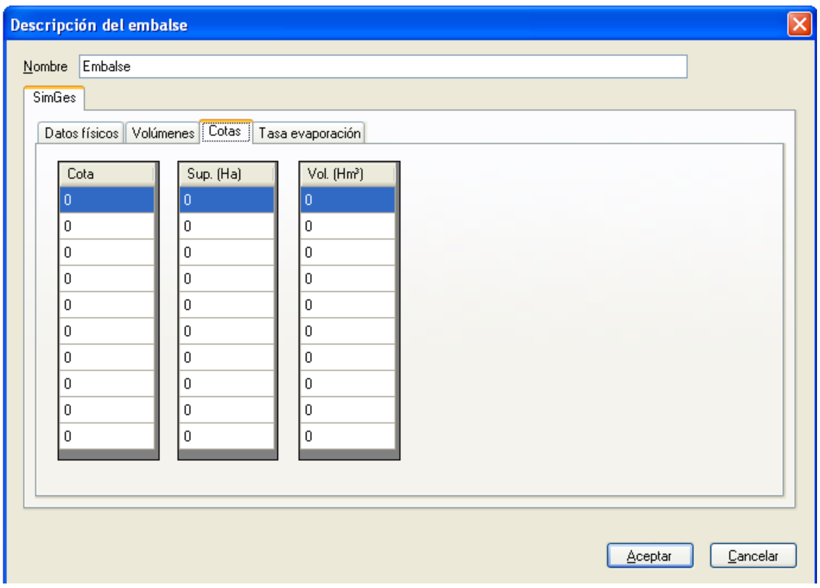


Figure 12.- Elevations-surface-volume ratio data sheet.

The **[Evaporation rate]** tab is used to enter data on monthly evaporation rate. In general, the data consist of 12 mean monthly values. However, if required and if the data are available, a monthly series of historical data can be used. This is done by selecting the series from the “`Evaporation column`”, which is another dropdown menu with the names of the columns in the evaporation data sheet. This sheet can be defined in the database but a menu option is not available to define it. Its design is similar to the inflows file and is described in the SIMGES user manual (Andreu et al. 2007).

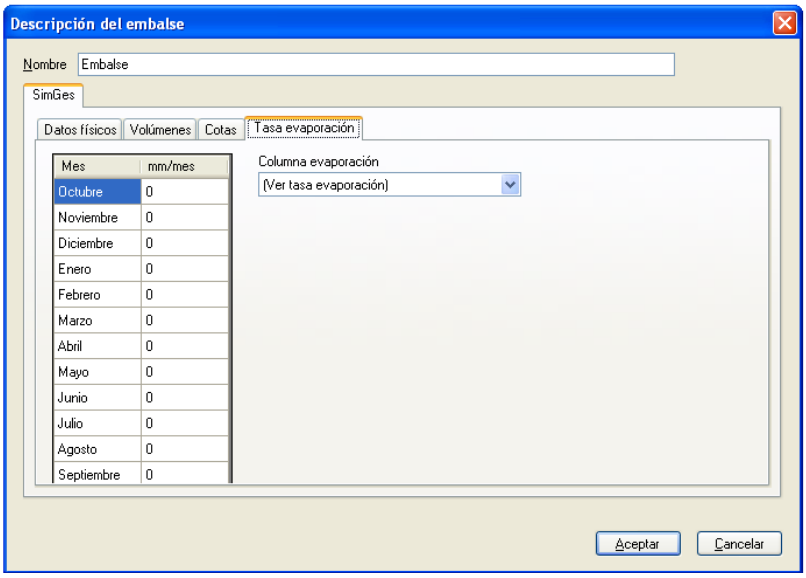


Figure 10.- Evaporation data sheet

2.5 INTERMEDIATE INFLOW ELEMENTS.

Intermediate inflows are understood to be the water entering the system at irregular intervals at a node or reservoir. The node or reservoir at which the water enters must therefore be in existence before including the inflow.

The inflow is entered in the model from an external data file or directly on the screen. To indicate whether the data are to be entered on the screen or from a file, go to the menu `[Models]`→ `[Project options]` to access the screen on which the basic model parameters are defined (Figure 14).

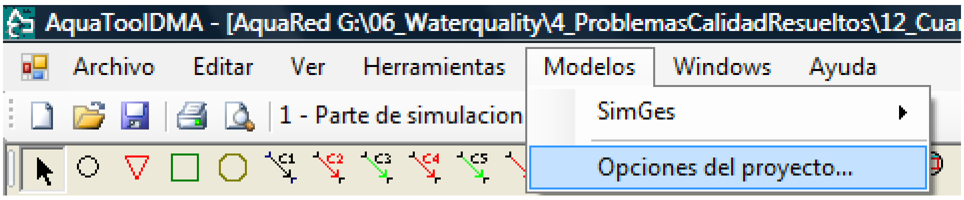


Figure 13: Menu for editing general simulation data.

This screen provides the option of choosing to enter inflow data from files or to enter it directly on the screen.

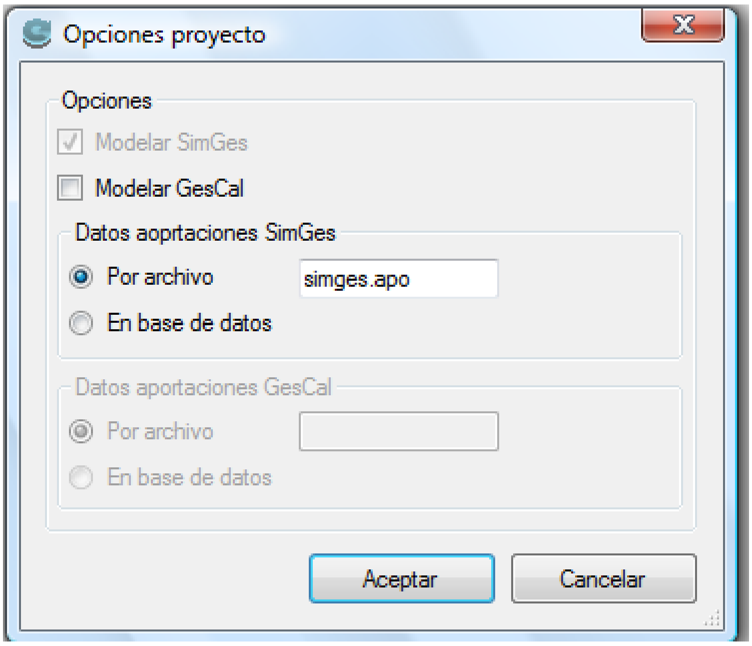


Figure 14. Project Options screen.

If inflow data is taken from files, the name of the file must be entered and the column of the file containing the inflow data is selected from the dropdown menu (Figure 15).

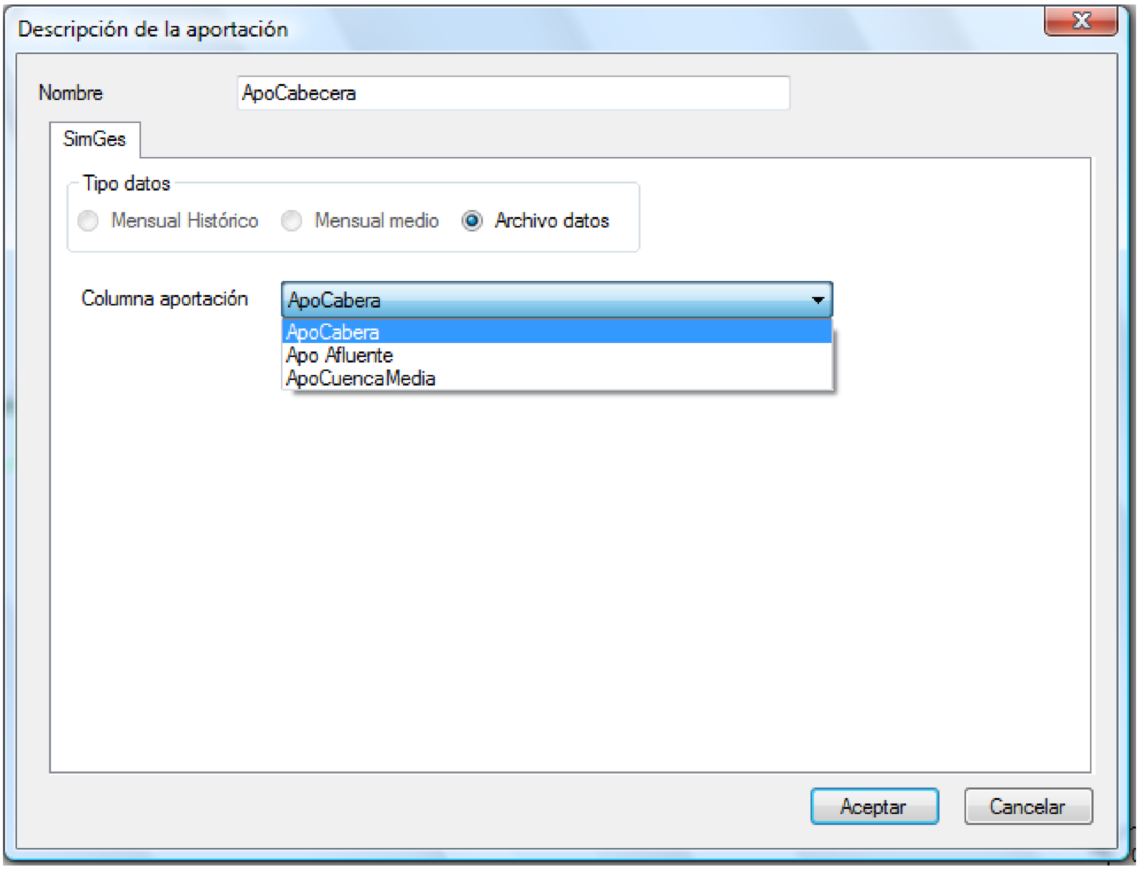


Figure 15. Defining inflow data from a file.

If the user prefers to enter data directly onto the screen, when editing the inflow the name of the inflow must be given and the window shown in Figure 16 will appear.

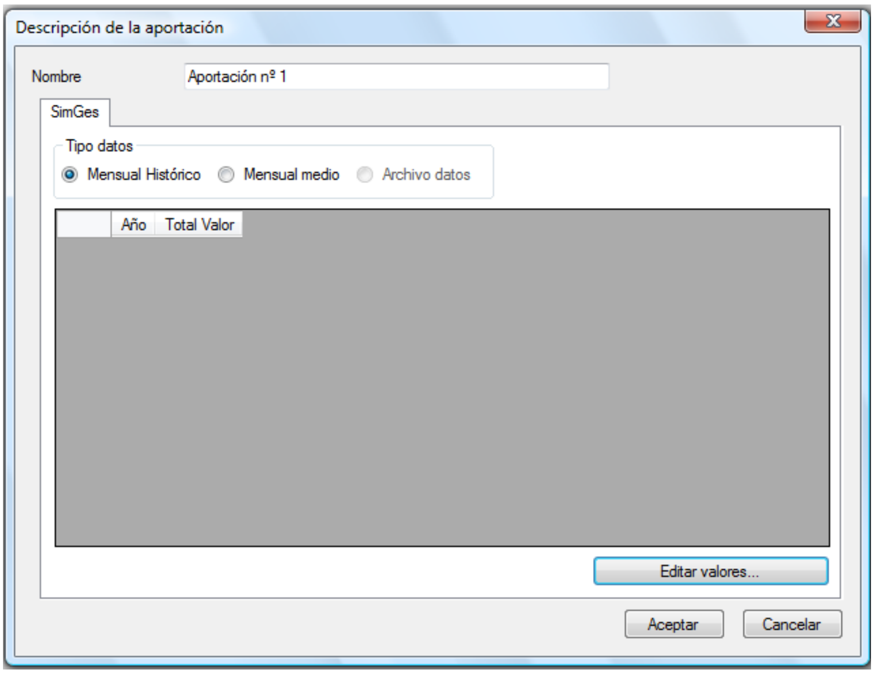


Figure 16. Entering inflow data on the screen.

To enter data, press the “Edit Values” key and the appropriate window will appear. Data can then be entered manually or copied from an Excel file (Figure 17).

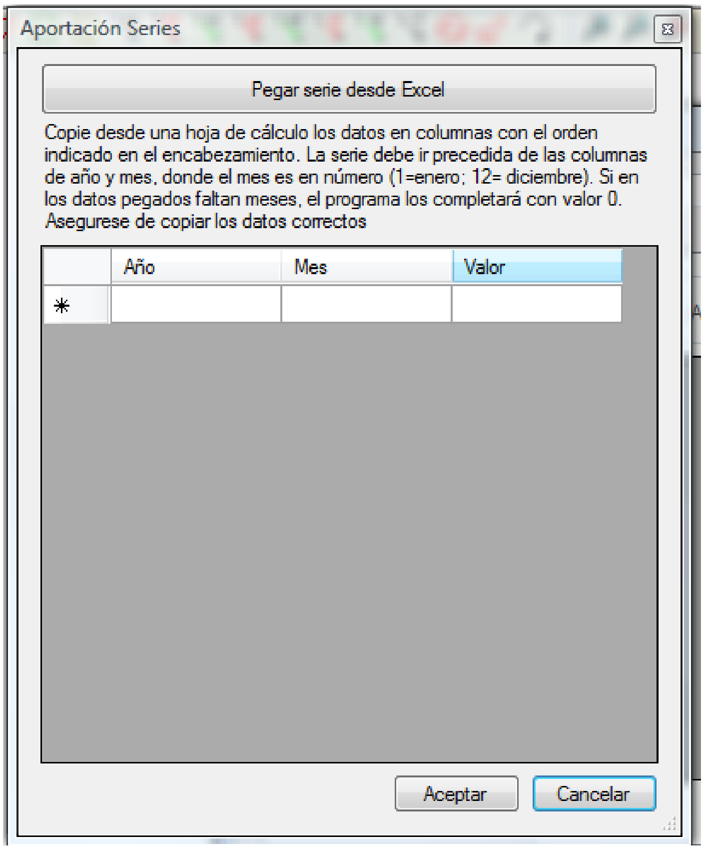


Figure 17. Window for entering data manually or from an Excel file.

2.6 DEMAND TYPE ELEMENTS.

Demands are elements that consume water, though part of the supply may later return to the system. They are normally for agricultural, urban or industrial uses.

The complete definition of a demand requires at least one “Intake” type element and an optional “Surface return” element, as described below.

The following is a description of the data included in a demand element (Figure 18).

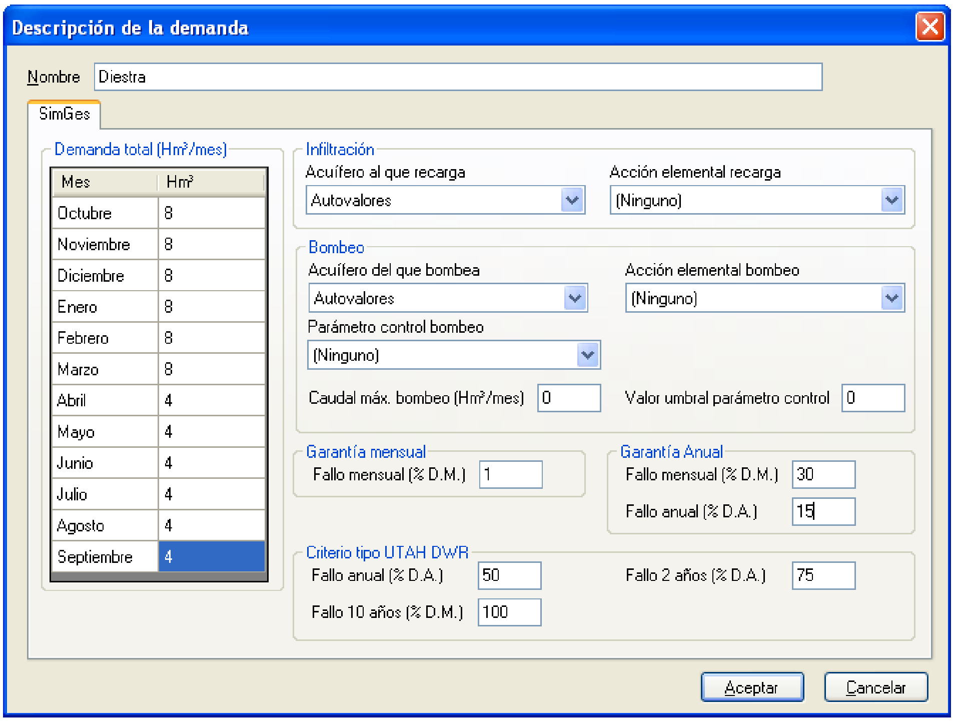


Figure18.- Demand data sheet.

"Total demand": 12 gross monthly water volume values required by the corresponding use.

"Aquifer recharged": This is the aquifer that receives the infiltration of ground water not consumed by the demand (whose magnitude depends on the α and β coefficients defined for the intakes). The "To be determined" option can be chosen provisionally if the aquifer still has not been included in the scheme, but must be changed before executing the model. The "None" option is also available, meaning that the infiltrated water is lost to the system.

"Basic recharge stress": This identifies the basic stress by which an aquifer is recharged. If an aquifer is defined for seepage, the basic stress is required.

"Extraction aquifer": This is the aquifer from which complementary flows are extracted when surface supply cannot satisfy the demand. This is not necessarily the same as the one that receives infiltration. The "None" option is also available.

"Pumping control parameter": This allows a pumping operational rule to be defined so that if this control parameter is below the value defined in **"Control parameter threshold value"** pumping is not permitted for this demand.

“Basic pumping stress”: This identifies the basic stress of the aquifer from which water is extracted. If an aquifer is defined for pumping, the basic stress is required.

“Maximum pumping flow”: This limits the monthly maximum extraction.

The **“Guarantees”** group permits definition of criteria for identifying failures for each of the guarantee criteria calculated by the SIMGES model. For further information on calculating guarantees, see the SIMGES User Manual.

2.7 INTAKE TYPE ELEMENTS.

An intake is an element that supplies water to a demand. A demand may be supplied by various intakes. This gives a certain flexibility by distinguishing between demand priorities, even if the water proceeds from the same point, or by distinguishing between supplies from different subzones within the zone considered.

To include an intake in the scheme, a node or reservoir must have been previously defined within the scheme as the node or reservoir from which the intake is supplied and also a demand which it serves.

Intake data are as follows (Figure 19):

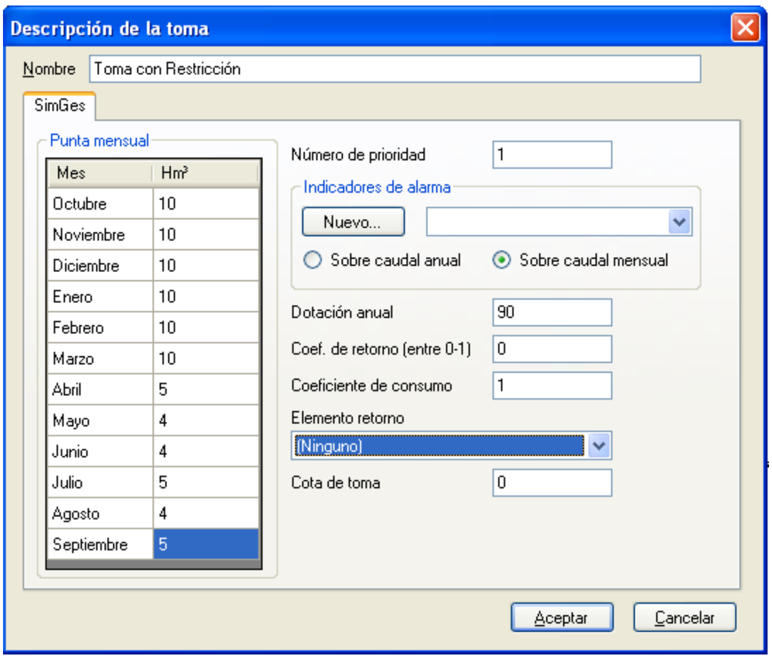


Figure 19.- Data sheet for a demand intake.

“Monthly peak”: This is the maximum volume that can be supplied in a month.

“Return coeff.”: This is a value (between 0 and 1) which determines the percentage of water that returns to the surface system. If this value is other than 0, **“Return element”** must be selected in the corresponding dropdown menu. If the value is 0, select the “`none`” option.

“Coefficient of consumption”: This is a value (between 0 and 1) which defines net consumption (or the part of the supply delivered at the intake which is lost to the system).

“Ground return flow”: This is defined by the difference between supply on the one hand and surface return and consumption on the other. Internally, the SIMGES model calculates ground return flow as: `(1 – return coeff. – coeff. of consumption).` It is considered to take the form of deep infiltration and is added to the recharge of the underlying aquifer, if the aquifer has been established in the destination demand data sheet. The return and consumption coefficients cannot total more than 1.
If pumping is required to meet the demand, the return and consumption coefficient applied to this ground supply is the average of the values defined for the intakes that supply the demand.

“Annual assignment”: The maximum value of the permitted annual supply (in Hm^3).

“Priority number”: The priority number of each intake can be used to establish the relative priority among the system intakes. Water is first supplied to intakes with the lowest priority number.

“Intake elevation”: This only applies to intakes connected to reservoirs. If the value is other than 0, water will only be supplied to the intake when the level of the reservoir is above the elevation of the intake. If the reservoir level is higher than the intake at the start of the month and lower at the end, the volume that can be supplied is calculated by interpolation, subtracting the remaining reservoir releases and spills.

“Alarm indicator”: An operating rule can be defined to reduce monthly or annual intake capacity (according to whether “`on monthly flow`” or “`on annual flow” is selected)` when the water volume stored in a given group of reservoirs is below the threshold values defined by the user. The alarm indicator files are described below.

2.8 SURFACE RETURN TYPE ELEMENTS.

These indicate the entry point on a river of the calculated surface returns from intake type elements. A return can be used by one or more intakes.

In order to include a return in the scheme, the node (or reservoir) to which it is connected must previously have been defined. A return element does not require any further data.

2.9 NON-CONSUMPTIVE DEMAND TYPE ELEMENTS OR HYDROPOWER PLANTS.

Although these elements use water, at the same time they return it to the system without actually consuming any.

To define an element, the intake and return nodes must be previously defined. This type of element requires the data necessary for calculating hydroelectric production and the operating rules described as follows (Figure 20):

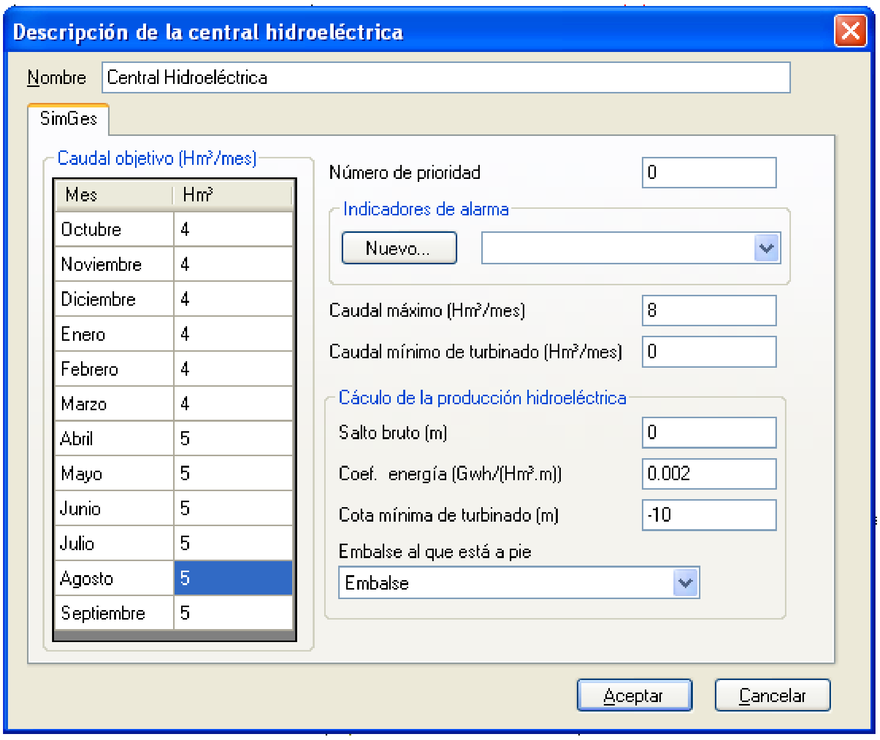


Figure 20.- Hydropower station data sheet.

"Target flow": The model will try to supply the target flow to the turbines as long as this does not mean diverting supplies from other demands with lower priority numbers.

"Reservoir over hydropower plant": If a reservoir is selected, the model uses the average level of the reservoir at the start and end of the month obtained from the reservoir elevation-volume curves to calculate gross head. The calculation is based on the difference between this gross head and the "`Minimum elevation of powerplant`".

"Reservoir over hydro-powerplant": If one is selected, the model uses the average of reservoir levels at the start and end of the month from the reservoir altitude-volume curves to calculate gross head, calculated as the difference between this gross head and the "`Depth base of the powerplant`".

"Priority number": This establishes the priority of the plant relative to other hydropower plants.

"Minimum flow": This is calculated for each month. The model will try to supply this flow above other priorities (as is the case with all minimum flows). This value is usually 0, since, being calculated on a monthly scale, it is likely that one of the regulation elements will allow the volume to be concentrated in a shorter time than one month, so that in this shorter period the turbined flow will be compatible with the plant's instantaneous minimum flow.

"Gross head/ depth base of powerplant": This is used to calculate energy production together with "**Energy Coeff**.". If the plant is at the base of a dam, from the dropdown menu "**Hydropower plant at the base of a dam**" the corresponding reservoir is selected. This reservoir is then assumed to mean "**depth base of powerplant**". In this latter case, the program calculates monthly gross head according to the level of water in the selected reservoir. Otherwise, the head is considered to be constant

"Minimum elevation for energy production": For power plants situated at the base of a dam if the water level is below this elevation the turbines are not operated.

"Minimum water level for power generation": For hydropower plants at the base of a dam, when the water drops below this level electricity generation is halted.

2.10 CHANNEL TYPE ELEMENTS.

When all nodes have been defined, the next step is to define their interconnections.

Channels always go from an "initial node" to a "final node", so that before defining a channel these nodes (or reservoirs) must be previously defined.

There are five types of channels, with the following characteristics:

- Type 1 channels: These connections have no special characteristics.

- Type 2 channels: These have the characteristic of losing water by seepage.
- Type 3 channels: These are used to define connections between an aquifer and a surface system.
- Type 4 channels: For these, a maximum flow can be calculated according to the height difference between the reservoirs at either end.
- Type 5 channels: These are connections via uncontrolled tunnels or pipes in which water can flow in both directions.

Channels type 4 and 5 are not commonly used.

Channel data are given in the following section.

2.10.1 TYPE 1 CHANNELS.

Monthly minimum and maximum flows can be defined for Type 1 channels as well as operating rules for controlling flow (Figure 21). Data are as follows:

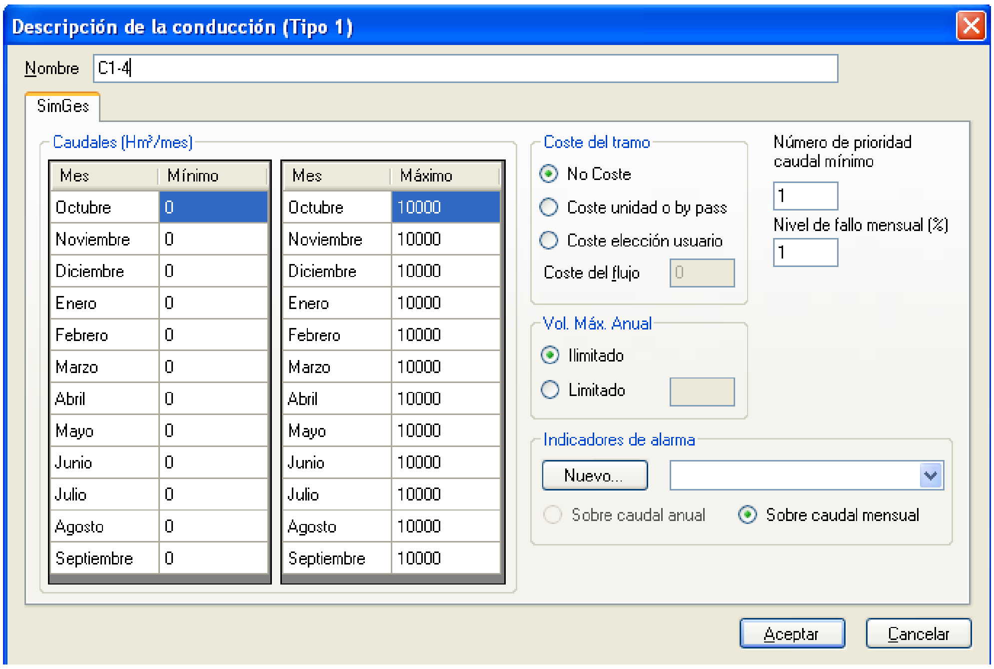


Figure 21.- Type 1 channel data sheet.

"Minimum flow" and **"Maximum flow":** 0 ≤ Qmin ≤ Qmax must be satisfied. The calculation model allows flows smaller than minimum flow but not greater than maximum flow.

"Annual Max. Vol.": This allows an upper limit to be set to the annual volume flowing through the channel. When this volume is reached, the channel will not transfer any more water until the following year.

"**Cost of reach**": This is associated with optimisation of the scheme and permits the cost of sending a unit of water through the channel to be selected. This can be 0, 1 or any other value. In the latter case, the value is entered in the "**Cost of flow**!" field (for the criteria to be used in selecting this value, see the SIMGES User Manual).

"**Monthly failure level (%)":** This is the admissible percentage of failures in minimum flow and is used if a minimum flow is other than 0.

"**Minimum flow priority":** This establishes a relative order of priority for minimum flow.

"Alarm indicators": These allow a channel operating rule to be defined to limit monthly or annual maximum flow as selected by the user. Alarm indicators are described below.

No more than one Type 1 channel can be included with the same initial and final nodes or with these nodes interchanged.

2.10.2 TYPE 2 CHANNELS (WITH SEEPAGE)

The difference between these and Type 1 channels is that no operating rules can be defined for Type 2 channels and data must be defined for the calculation of seepage (Figure 22):

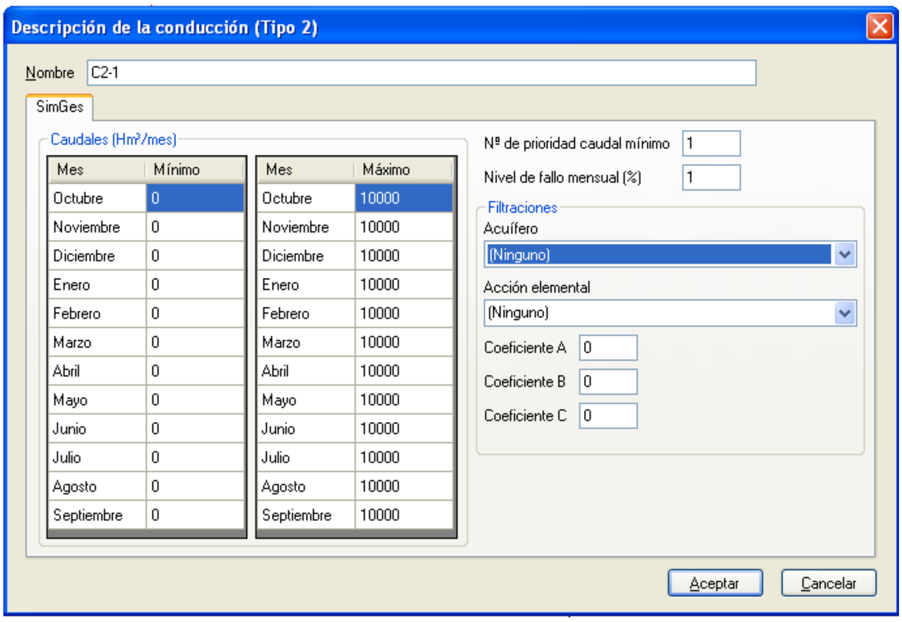


Figure 22.- Type 2 channel data sheet.

"Aquifer": This allows the aquifer to be selected for recharge by water lost to the channel.

"Basic stress": This corresponds to the selected aquifer and must be other than "(None").

"Coefficient A", **"Coefficient B"** and **"Coefficient C":** These are the parameters for calculating seepage losses by the $Filt = A + B \cdot V^{C}$ formula.

2.10.3 TYPE 3 CHANNELS (HYDRAULICALLY CONNECTED TO AQUIFER)

This type of channel exists when a river is hydraulically connected to an aquifer and there is seepage from the bed to the river or vice-versa, according to the relative piezometric levels.

The data required for this type of channel are those that define the aquifer to which it is connected (Figure 23):

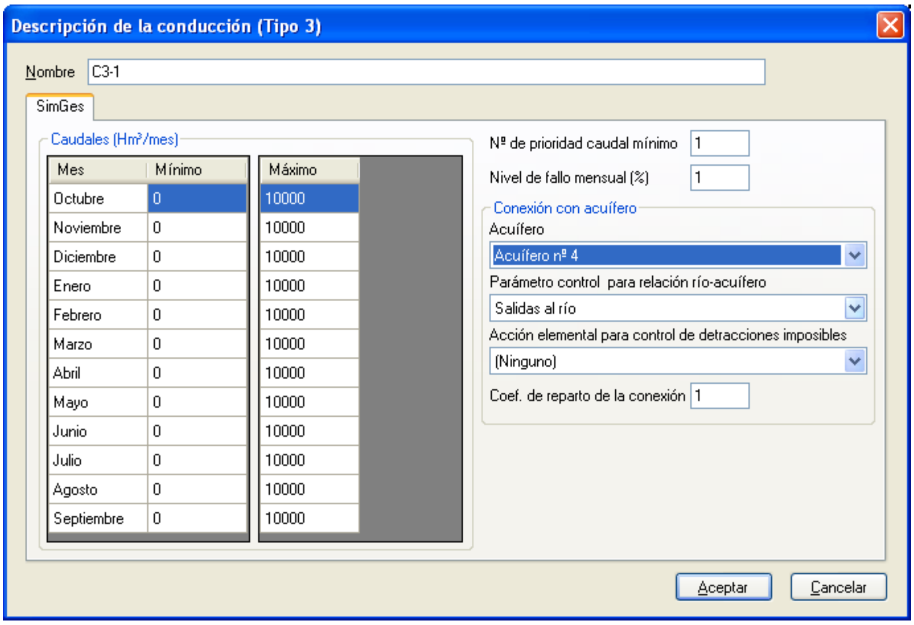


Figure 23.- Type 3 channel data sheet

"Aquifer": This allows the aquifer to which the channel is connected to be selected. The provisional "(To be determined") option can be selected if the aquifer still has not been included in the scheme. If chosen, this option must be modified before model execution.

"Basic stress for control of impossible extractions": This refers to the basic aquifer stress to which impossible extractions will be applied if the river cannot supply the flow required by the aquifer. This information is only necessary for distributed model aquifers as in other types the stress is pre-established by the calculation model.

"Control parameter": This defines the aquifer parameter in which the aquifer model calculates the monthly river connection values. This parameter is given by the SIMGES program for all models except Eigenvalue and three-level types (see SIMGES Manual). For aquifer models in which the parameter is pre-selected, if the selection is incorrect it will be automatically corrected during simulation.

"Coeff. of distribution of the connection": This coefficient makes it possible to distribute an aquifer connection among various Type 3 channels (making sure that the sum of all coefficients in the same control parameter is always equal to 1).

2.10.4 TYPE 4 CHANNELS (WITH LIMITED HYDRAULIC FLOW)

This type of channel has no connection with the aquifer and maximum flow is limited by the height difference between the initial and final nodes. It can reproduce situations such as that of a channel starting from a reservoir, at a certain elevation, in such a way that the maximum flow that can be obtained is limited by the elevation of the water surface. It could be considered as a controllable conduit with no pumping capacity.

2.10.5 TYPE 5 CHANNELS (CONTROLLED ONLY BY HYDRAULIC CONDITIONS)

This type of channel has no connection with the aquifer and flow is defined by the height difference between the extremes. Water can flow in either direction and the channel may join two reservoirs. It is distinguished from Type 4 channels by the fact that water can flow in both directions and it is not controllable.

It also differs in that while in Type 4 the maximum flow value is calculated, the real flow is controlled by the model (the appropriate circulating flow is calculated and if this is below the maximum nothing happens, while if it is higher flow is limited to the maximum value). In Type 5 channels, the circulating flow is calculated for each interval solely according to the height difference without any other factor coming into play.

2.11 AQUIFER TYPE ELEMENTS.

To simulate aquifer behaviour a choice can be made from different mathematical models (Figure 24). These models are explained in the SIMGES

User Manual (Andreu et al., 2007). A brief description of the data of each model is given in the following section.

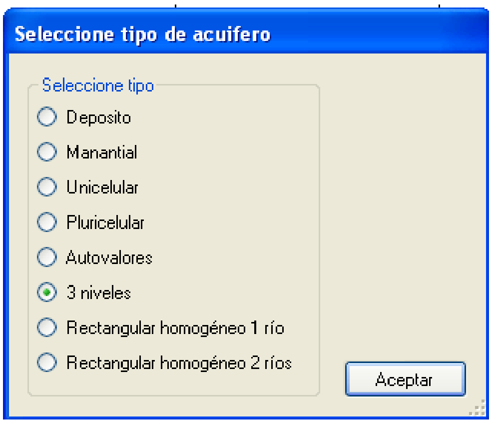


Figure 24.- Aquifer type selection sheet.

2.11.1 TANK MODEL.

In this model the aquifer is not hydraulically connected to the surface system and behaves as an isolated tank.

The data required in the sheet shown in Figure 20 must be filled in.

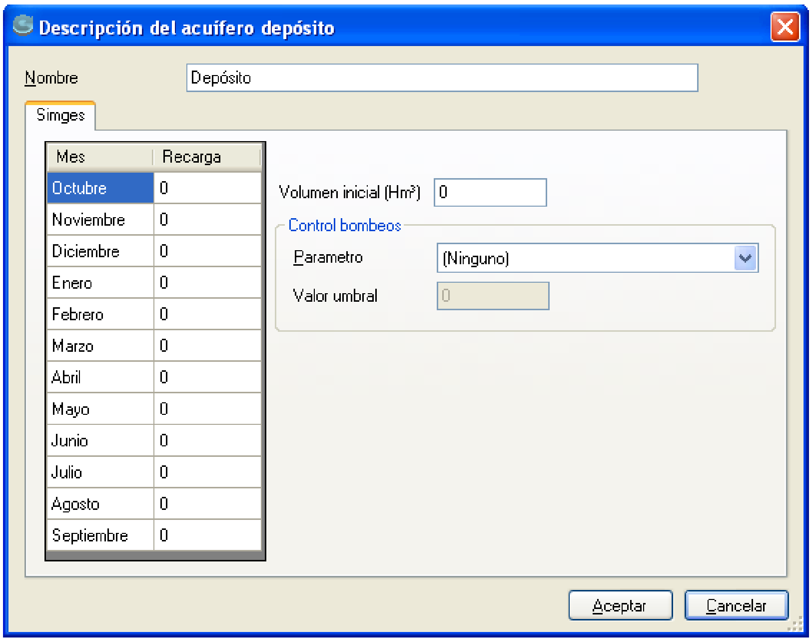


Figure 20.- Data entry sheet for deposit aquifer model

"Recharge": 12 mean monthly recharge values in the natural regime.

"Pumping control": operating rule that prohibits pumping when the **value** of this control parameter is below **"Threshold Value".**

"Initial volume": aquifer volume at start of simulation.

2.11.2 SINGLE-CELL MODEL.

This model requires a single operating parameter, which is the α coefficient that regulates the connection with the river (type 3 channel)[5]. The rest of the data are the same as those described for the deposit model (Figure 25).

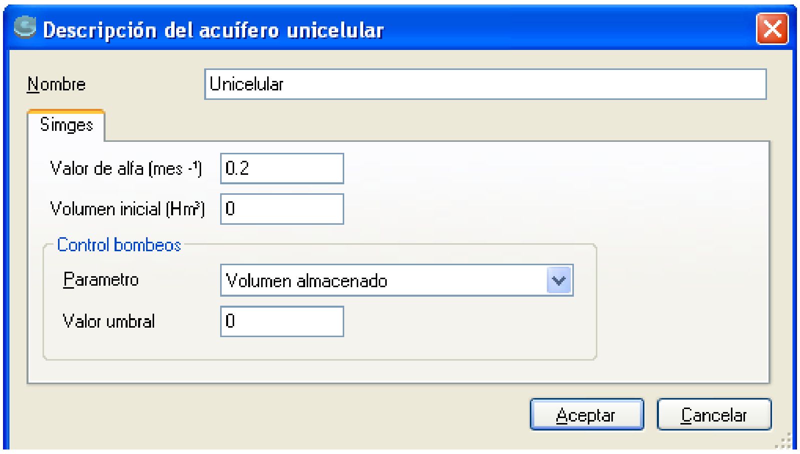


Figure 25.- Single-cell aquifer model data sheet

2.11.3 SPRING MODEL.

The aquifer model is similar to the single-cell model, the difference being that it is modelled by superposition. The user must enter 12 mean outputs from the aquifer through springs in the natural regime (Figure 26). These will be used as the upper limit for the water volume the aquifer can extract from the river.

It also distinguishes two basic stresses - recharge far from aquifer and recharge close to aquifer - as well as two control parameters – volume and flow taken from the river by the spring.

[5] Connection with the surface system is through a type 3 channel to which a connection is made with the control parameter "outlets to river".

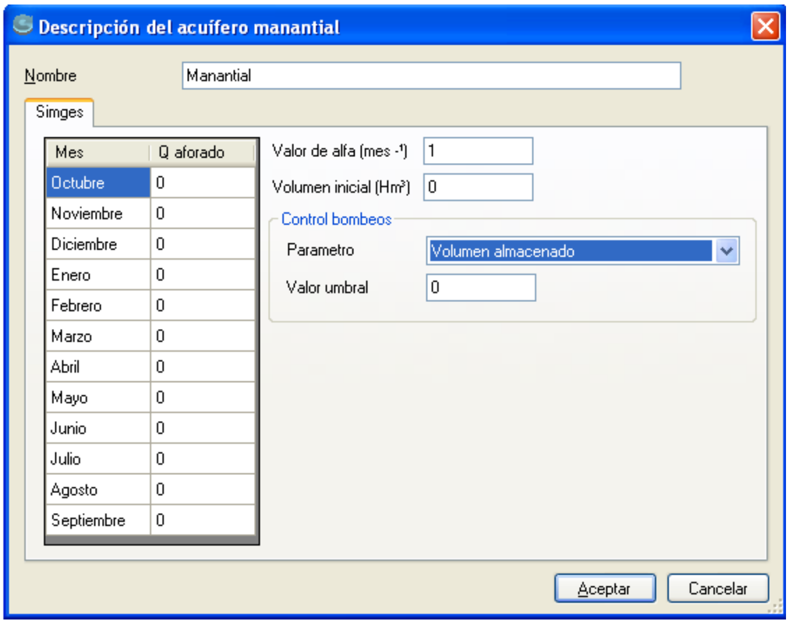


Figure 26.- Spring aquifer model data sheet

2.11.4 MULTICELL MODEL.

This is an extension of the single-cell model with an arbitrary number of cells. It allows different discharge rates into the river to be defined as well as different arbitrary distribution of exterior actions (Figure 27).

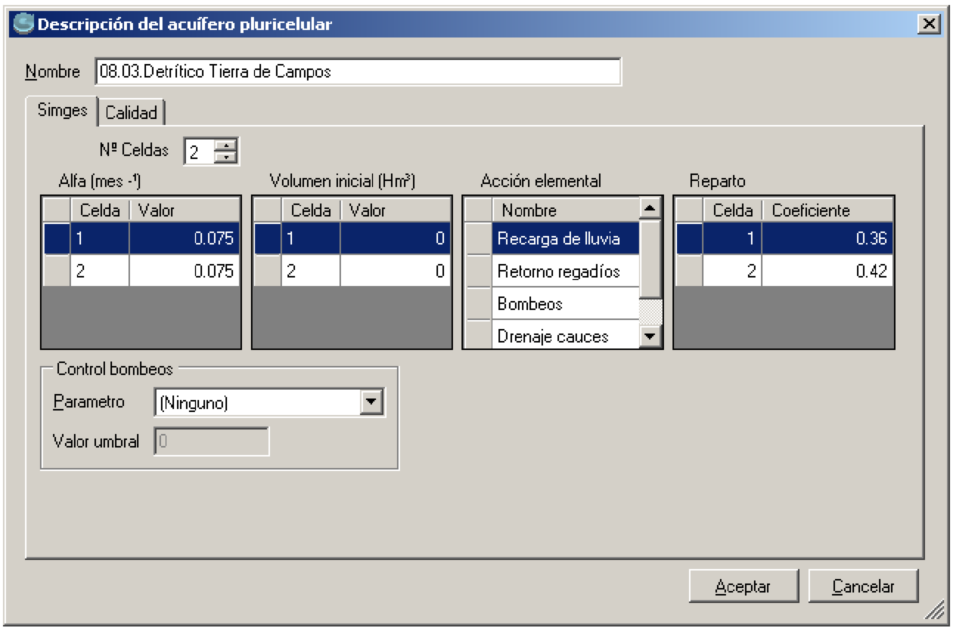


Figure 27.- Multicell aquifer data sheet

2.11.5 EIGENVALUE MODEL.

This is a general distributed model for aquifer simulation and therefore has no restrictions as to topographic conditions or hydrodynamic parameters. To formulate an aquifer model by the Eigenvalue method, previous calibration is necessary. This can be done with the AQUIVAL model (Capilla and Andreu (1996) user manuals in Andreu et al. 2007).

Model data can be edited by the interface[6] (Figure 28), although the normal procedure is to enter the data by means of the file produced by the AQUIVAL model.

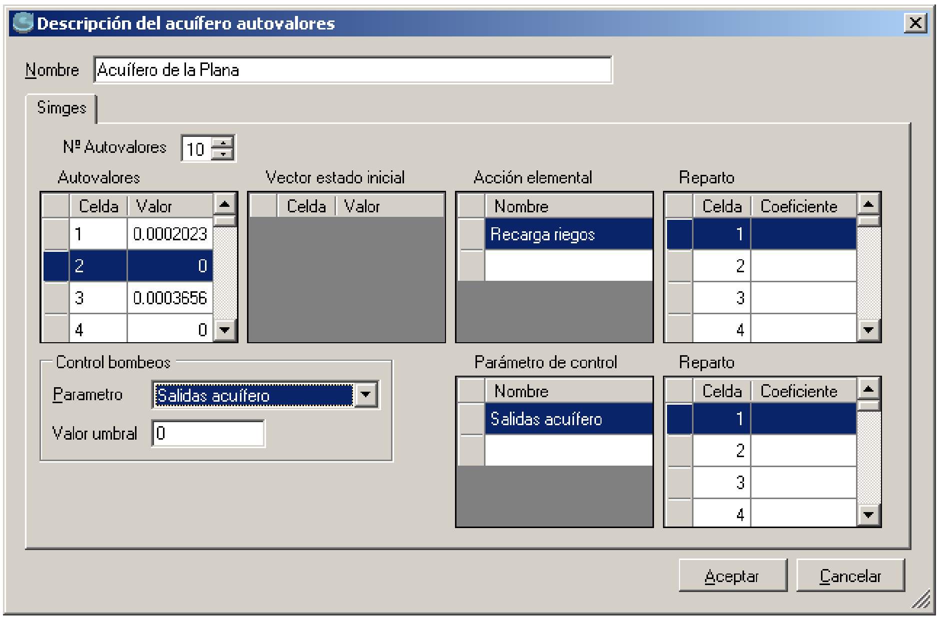


Figure 28.- Eigenvalue aquifer model data sheet.

2.11.6 HOMOGENEOUS RECTANGULAR MODEL (1 RIVER)

This model considers the aquifer to be homogeneous, rectangular and perfectly connected to a river. It also allows stresses on the aquifer to be considered in different locations (Figure 29), so that the deferred effects of the river-aquifer relationship can be studied with greater precision than with the single-cell model.

[6] A detailed description of the data required by the model can be found in in the SIMGES user manual and of the theoretical basis of the Eigenvalue method in the AQUIVAL manual.

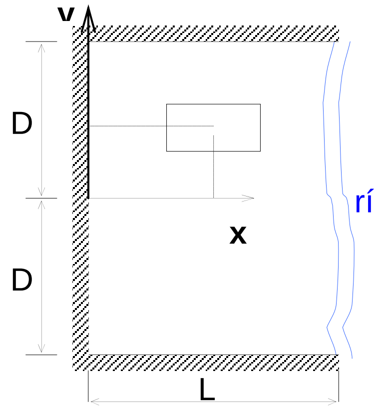


Figure 29.- Scheme of the geometry of a rectangular aquifer connected to a river.

The equations of the model can be consulted in the SIMGES user manual. The data required are those that define the aquifer's geometry, its hydrodynamic properties (Figure 30) and the basic stresses to be considered.

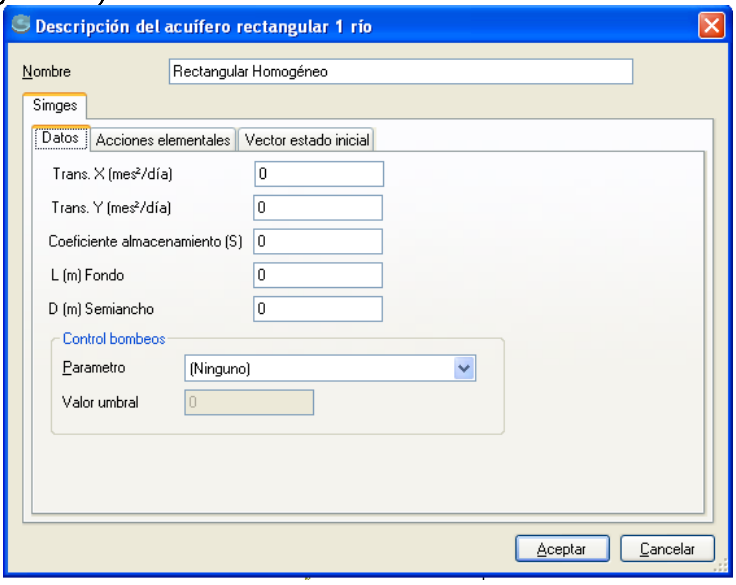


Figure 30.- General data sheet of a rectangular aquifer (1 river)

"Trans. X", **"Trans. Y", "Storage coeff. S"** , **"L"** and **"D"** characterise the aquifer and correspond to the scheme given in Figure 29.

"Basic stresses." There are two types of basic stresses:

- Occasional stresses defined as a set of points for each one according to its location (xk, yk) and weight pk. The sum of the weights of a set of occasional stresses must be 1 and all must be positive.
- A stress distributed within a rectangle whose sides are parallel to the coordinate axes, defined by the coordinates of the centre of the rectangle (XGk,YGk) and the lengths of the sides of the rectangle.

"Initial status vector" consists of 15 values that define the initial status of the aquifer according to the Eigenvalue method.[7] The following cases may occur:

Aquifer simulation is carried out according to a scheme identical to that of the Eigenvalue method described above. The state vector is thus recalculated for each simulation time interval. For the theoretical basis of this model see Sahuquillo (1981).

2.11.7 HOMOGENEOUS RECTANGULAR MODEL (2 RIVERS)

This model is similar to the preceding but is connected to two completely penetrating rivers (Figure 31). The analytical solution was given by Ramos et al. (1983). The description of the required data is practically the same as for the one-river model.

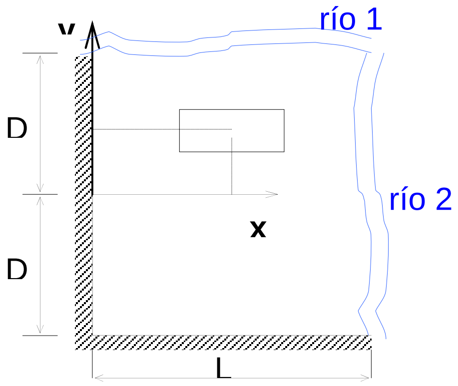


Figure 31.- Scheme of the geometry of a rectangular aquifer connected to two rivers.

[7] The state vector can be calculated from the aquifer piezometric level data (see SIMGES manual or, for greater detail, Sahuquillo, 1981). Another alternative is to leave all values at 0 (or equal to the natural regime if the simulation is by superposition on the natural regime) and simulate a period of heating of the model to obtain an initial state vector corresponding to stationary conditions.

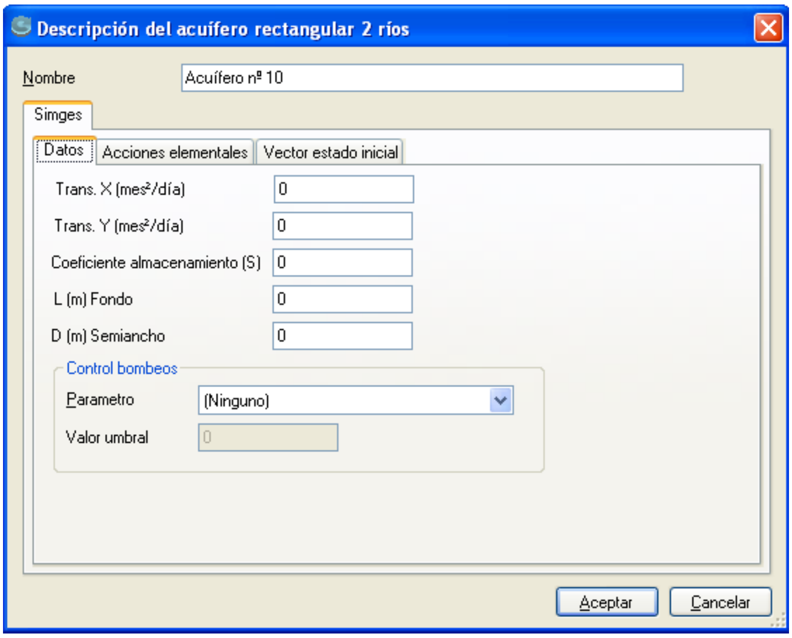


Figure 32.- General data sheet of rectangular aquifer (2 rivers).

It is important to indicate here that, unlike the previous model, this one presents two control parameters to connect with two type 3 river stretches or with one on both sides of the aquifer.

2.11.8 THREE-LEVEL (LUMPED) MODEL

This model was specially designed for the case of the Vega Baja on the Segura river. It is a lumped model that can simulate three outlet levels (Figure 33) that correspond to:

- Aquifer evaporation (the level i close to the surface).
- Water drains out to an irrigation channel network.
- Hydraulic connection of the aquifer with a river.

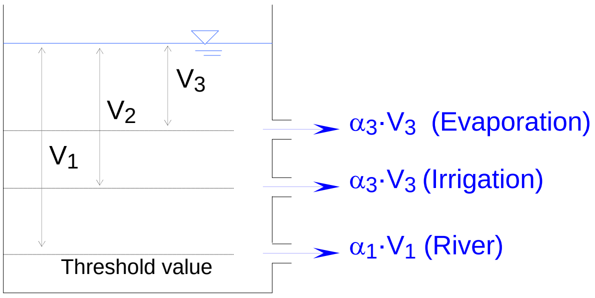


Figure 33: Scheme of a three-level type aquifer.

The data required are, besides the normal for all types of aquifer, are as follows (Figure 33):

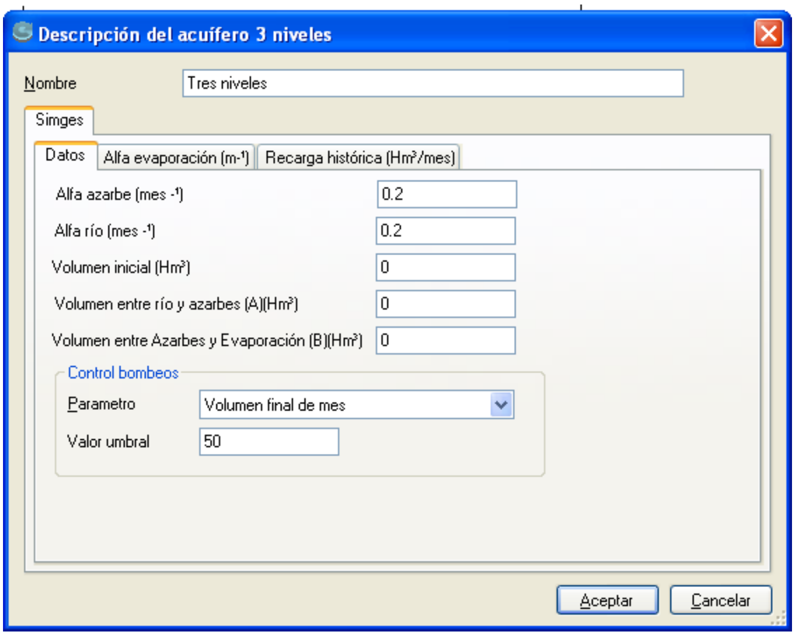


Figure 34.- General data sheet for a three-level aquifer.

"**Alpha irrigation channels**" and "**Alpha river**" coefficients for the calculation of drainage from intermediate and lower levels.

"Alpha evaporation": 12 monthly coefficient values to calculate aquifer evapotranspiration.

"Volumes between river and irrigation channels" and "Volumes between irrigation channels and evaporation": values of (V2-V3) according to Figure 32.

"Historic recharge": 12 mean historic recharge values.

2.12 ADDITIONAL EXTRACTION AND ARTIFICIAL RECHARGE TYPE ELEMENTS.

These elements connect an aquifer with the surface system by pumping water in or out of the aquifer. To add an element of this type, after selecting it on the button bar, first click on the (recharge) node or (extraction) aquifer from which the water is to be taken and then on the aquifer element or destination node.

The related data sheets need the following information (Figure 35):

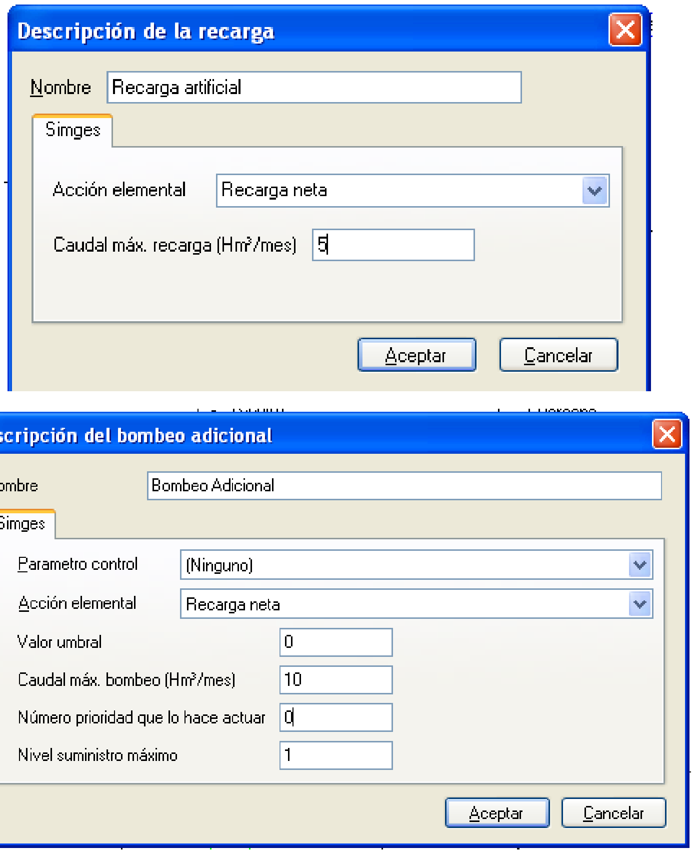


Figure 35: Artificial Recharge and Additional Extraction data sheets.

"Basic Stress" indicates the basic stress acted on.

"Max. recharge flow" and **"Max. extraction flow"** are permitted maximum monthly flow values.

Only additional extractions also require the operating rules to be activated. These are similar to the description of Demand-type elements for extraction from the aquifer, the only difference being that the extraction defined in the demand is only activated to complete the supply that cannot be obtained from surface intakes. Additional Extraction elements also require an "**Activation priority number**", which determines when they will be activated. This will be when a deficit is detected in an intake with a priority number equal to or less than the Activation priority number). They also require the "**Max. supply level**" value that indicates the maximum percentage of total demand that can be supplied from this extraction.

2.13 OPERATION RULES.

In addition to the operation rules that can be defined individually in the data sheets of some elements, the model provides facilities for defining rules for grouped elements.[8]

For creating or editing rules, entry to the editing window is obtained through the `[Edit]→ [Operation Rules]` (Figure 36) and then selecting the operation rules creation/editing data window (Figure 37).

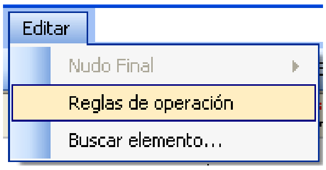


Figure 36: Operation rules editing menu.

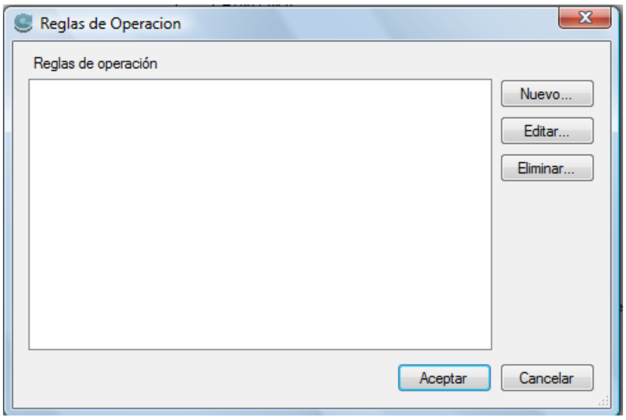


Figure 37: Operating rules creation/editing data window.

To create a new operation rule, access is again by the button to the window shown below.

[8] These operating rules are called “alarm-restriction elements” in the SIMGES user manual and are described in Section 5.1.1.

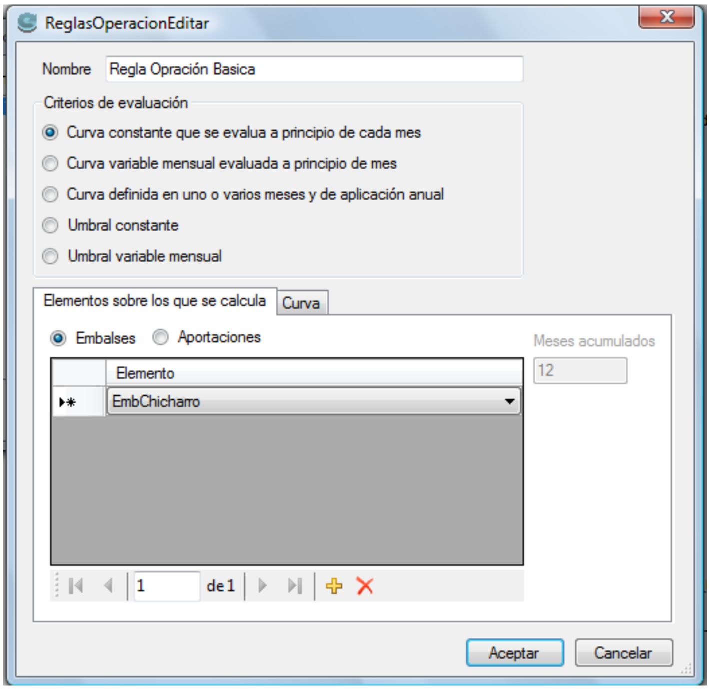


Figure 38: Operating rules definition window.

The definition process is as follows:

1. Choose a name for the new indicator or operation rule.

2. Select a system status evaluation criterion from the five options available:

   a. "`Constant curve evaluated at the start of each month".` The indicator value is calculated at the start of every month and the restriction coefficient is then found by interpolation on the given curve.
   b. `"Monthly variable curve evaluated at the start of each month".` Indicator value is calculated at the start of each month and the restriction coefficient is then found by interpolation on the given curve.
   c. "`Curve defined for one or several months for annual application".` Unlike the preceding curves, the decision is fixed in one or two months, e.g. October (start of the campaign) and May (end of the rainy season) and the calculated restriction is maintained throughout the rest of the months of the year.
   d. "`Constant threshold`". Unlike the preceding curves, this is not calculated at the start of the month but is interpolated on the iterative process so that the release result does not fall below the given threshold. In this case, the values given by the curve do not

   define a continuous but a stepped curve. This operating rule is usually described as "… *reserves will not fall below X hm³ ,…"*

   e. "`Variable monthly threshold`". Same as the preceding curve but needs 12 thresholds, one for each month of the year.

3. Select the reservoir elements or inflows for which the indicator is to be evaluated.

4. Define the indicator value curve(s) → restriction coefficient to calculate the indicator.

2.13.1 DEFINITION OF APPLICATION ELEMENTS

Once the operating rule or rules have been defined to control the system, the elements to which they are to be applied must be selected to put them into effect. These operating rules can be applied to maximum intake flows, maximum type 1 channel flows and target flows in hydropower plants.

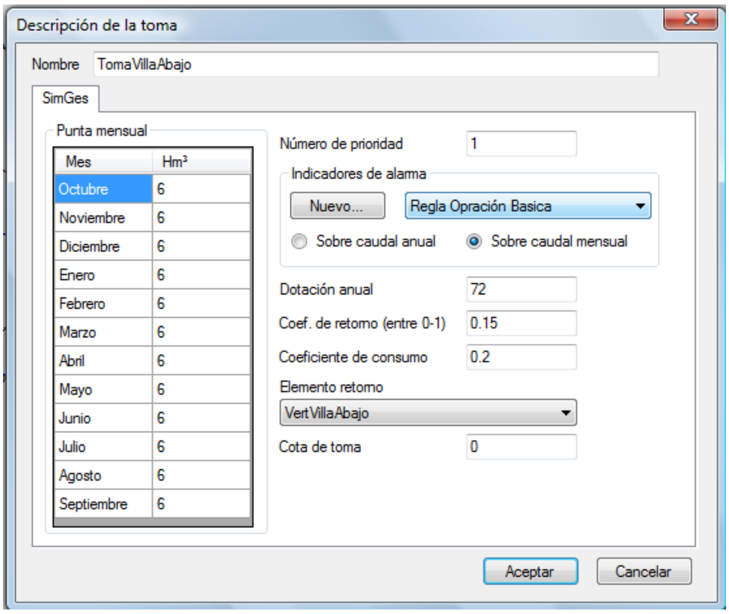


Figure 39: Assigning an operating rule to demand intake.

For application, the selected element is edited and the rule to be applied is selected in the Alarm Indicator option of the dropdown menu (Figure 39).

The calculation program will modify the maximum supply capacity of the elements to which the indicator is assigned according to the monthly calculated coefficient in Point 4 for the elements selected in Point 3 of the definition process

2.14 SIMULATION DATA.

Once the model design is complete, simulation can be initiated on the SIMGES calculation model. Entry is by the `[Models]`→ `[Simges`→ `[Execute Simges]` menu (Figure 40), which gives access to the general simulation data window Figure 2). The "`Inflows file`" will have been previously defined in this window and now suitable headings should be chosen to describe the simulation project and scenario as well as a simulation period for the inflows data file (Initial "`year`" and "`nº of years`")[9]

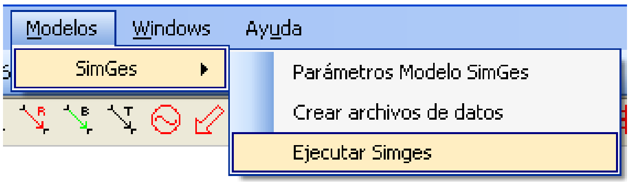


Figure 40: SIMGES model options.

When this window has been accepted, the program will make a check of the general data integrity and if this is satisfactory it will call up the SIMGES simulation model[10] (Figure 41). The SIMGES control window will then appear on the screen for as long as the simulation lasts. This may take from several seconds to a few minutes, depending on the number of years and the size of the system.

[9] It must be understood that these dates refer only to year labels included in the inflows file and should not be interpreted as actual dates, unless the model is calibrated with historic data.
[10] If the SIMGES user manual is consulted, for the use of this model, besides the inflows file, a series of additional data files are also required. These files are defined by default in the data base and are generated by the program. The default names can be changed by editing the "Scenario" and "SimulationFiles" tables.

Figure 41: SIMGES control window.

After the first simulation the results can be analysed, firstly to calibrate the simulation model and secondly to be able to compare different development alternatives, adding any foreseeable alterations or operating rules in the basin in the future.

For further information on the handling of SIMGES results, see Section 5 of this manual.

3 CHOOSING BETWEEN A SIMULATION MODEL AND AN OPTIMISATION MODEL.

The description in the preceding section refers to the data required for running a simulation model with SIMGES. If the optimisation model (OPTIGES) is used, some of these data will not be necessary.

4 DEVELOPMENT OF THE WATER QUALITY SIMULATION MODEL.

The GESCAL model uses the SIMGES model results as input data, so that a simulation should previously have been carried out with this program. AQUATOOLDMA combines SIMGES and GESCAL data editing and creates a single tool from the two models for the integrated management-quality modelling of water resource systems.

This tool can create and edit water-quality simulation models for any water resource system that has previously been subjected to quantitative modelling. The advantage of these models and AQUATOOLDMA is their flexibility in creating models of almost any system.

4.1 INITIATING THE WATER QUALITY SIMULATION MODEL.

When the SIMGES model has been created (or when developing the simulation model for SIMGES) the option of working with the GESCAL model should be activated. This is done by selecting the menu `[Models]`→ `[Project options]` (Figure42) and opening the window for defining basic model parameters (Figure 43). The "`Model GESCAL`" option is then selected to activate data editing for water quality modelling.

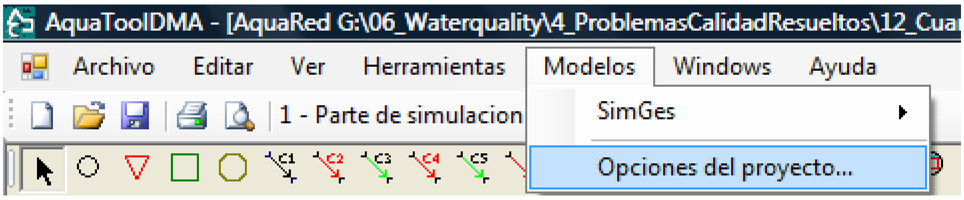


Figure 42: General simulation data editing menu.

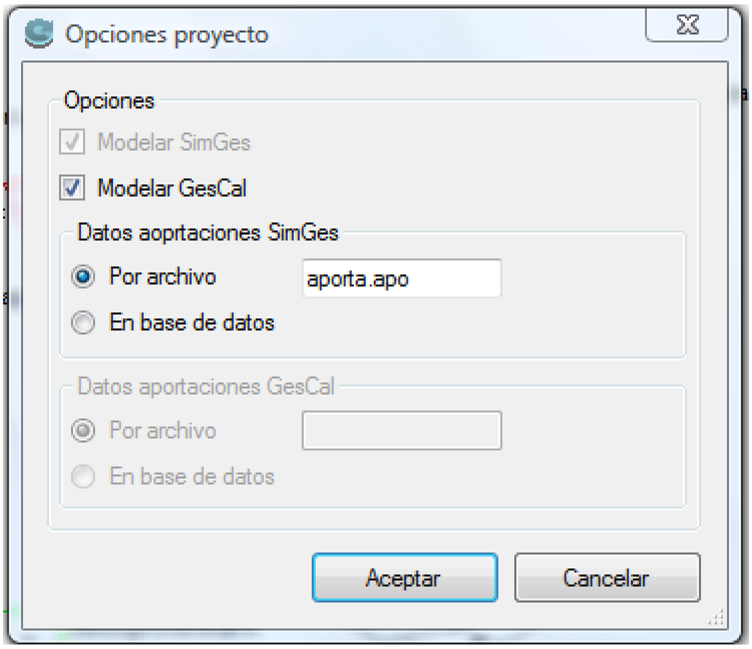


Figure 43. Project options definition window showing the "Model GESCAL" option.

On marking this option and clicking on "Accept" the "Quality Model Parameters" window (Figure 44) will appear on the screen. This window is used to define the basic parameters of GESCAL modelling.

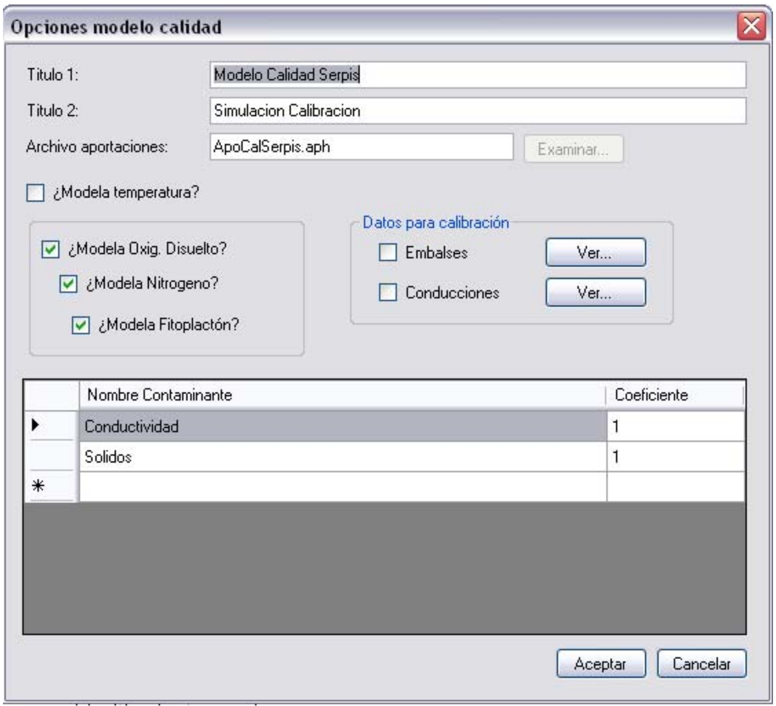


Figure 44. Window for defining GesCal Model parameters.

The following elements must be defined in this window:

- Headings 1 and 2, specified by the user for the model in use.
- Name of the GESCAL inflows file containing the concentrations of the model inflows.
- Modelling options. The options required to be modelled are marked and may include temperature, dissolved oxygen (together with carboniferous organic material), nitrogen cycle and phytoplankton. The last option models a typical eutrophication problem including organic and inorganic phosphorous.
  The nitrogen cycle modelling option is only possible when the dissolved oxygen option has been selected. Similarly, the phytoplankton option is only available when the dissolved oxygen and nitrogen cycle options have been selected.
- A table is also included in which the names of the arbitrary contaminants to be modelled must be specified, including temperature correction coefficients. There are no limits, in principle, to the number of arbitrary contaminants that can be modelled.
- Finally, the program provides the option of specifying whether an "obligatory calibration" is to be used for a reservoir and/or channel and also allows editing of an obligatory calibration data sheet.

When the required options have been selected in this window, pressing the "`Accept`" button returns us to the Project Options window. Here we can choose to send the quality data to a file or to read them on the screen.

AQUATOOLDMA then creates the necessary registers in the data base with all the information to carry out water quality modelling. Default values have been established for each of the elements but these can be changed by the user. This information is edited by simply clicking twice on any of the elements and selecting the "`Quality`" tab in the element's data sheet.

In the course of creating the model the quality modelling parameters can be changed by returning to the quality modelling parameters window through the option `[Models]`→ `[Gescal]`→ `[Gescal model parameters]` (Figure 45).

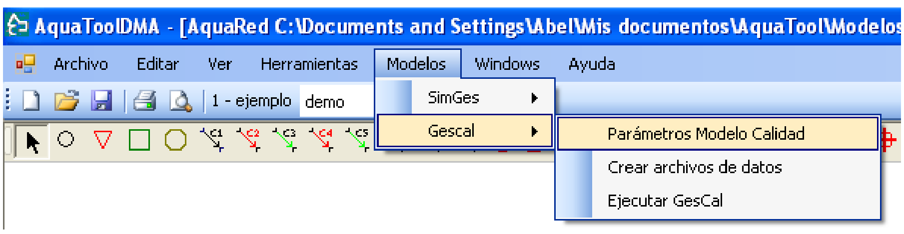


Figure 45: Menu for setting up water quality modelling.

4.2 CHANNEL DATA

Channels are considered to be river stretches or water courses with homogeneous conditions for modelling. The GESCAL model treats all the channel types defined in SIMGES in the same way.

The channel quality sheet can be edited in the `[Quality]` dropdown menu when editing any channel data sheet.

The information on this data sheet is classified by different concepts in the tabs of each data sheet:

- `General data`: General parameters of the behaviour of the river stretch.
- `Temperature`: Temperature simulation data.
- `Dissolved oxygen`: Parameters for modelling dissolved oxygen, the nitrogen cycle and eutrophication.
- `1st order contaminants`: Data on the arbitrary contaminants defined in the general modelling data file.
- `Diffuse contamination`: Data on contaminants entering the stretch from an external source.

The contents of each data type include the following:

4.2.1 GENERAL CHANNEL DATA

The user can define the following variables in the `[General data]` tab:

- Dispersion: the dispersion value in this stretch in cm^2/s.
- Length: length of stretch in metres.
- Spatial step: expresses in metres the distance of the calculation step in this stretch or channel.
- Type of hydraulic calculation: in this case, a value of 1 means that hydraulic calculations are by the Manning method, while 2 means they are done by potential relations. The value of this field affects the following fields:
- Manning/Velocity coefficient: Manning's coefficient or the multiplying coefficient of the expression that relates flow with velocity.
- Section Width/Velocity Exponent: width of stretch section in metres, or the exponent of the potential relationship.
- Channel gradient/Width Coefficient: represents the gradient of the gradient of the river stretch or the multiplying coefficient that relates width and flow.
- Transversal Gradient/Width Exponent: transversal gradient of the section of the river stretch or the exponent of the expression that relates width and flow.
- Initial estuary salinity: salinity at beginning of estuary for automatic

calculation of dispersion. A value of 0 eliminates this calculation.
- Final estuary salinity: salinity at the end of the estuary.

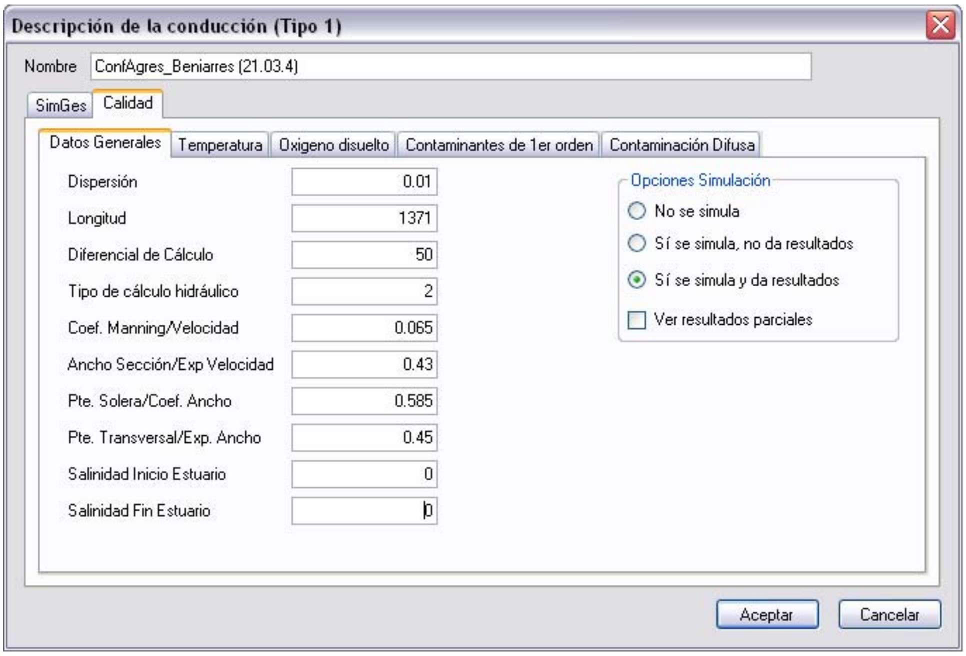


Figure 46. General channel data.

Simulation options for this river reach are also defined in this window and may include:

- No simulation: In this case, GesCal assumes that concentrations at the end of the reach are the same as at the start. With this option, no calculations are carried out within the water mass.[11]
- Simulation with no results: with this option, simulation of water quality is carried out in the reach according to the modelled constituents but the results are not recorded in the output file. These results, for river reaches, represent the concentrations for all the constituents modelled at the end of the reach.

If information is required on the evolution of the constituents in the river reach, the "`See partial results`" option must be marked. In this way, simulation results are obtained for each calculation step established in the channel.[12]

[11] If the channel simulation is not to be carried out, it is not necessary to fill in the general data values or the constants, in which case the program default values will be activated.
[12] The calculation step is important inasmuch as the validity of the results obtained for the reach depends on its relationship with the length of the reach.

4.2.2 CHANNEL TEMPERATURE DATA

On the same data sheet, data must be entered in the `[Temperature]` tab whether or not temperature is to be modelled in the system (Figure 47).

Three data must be entered: base temperature, the heat exchange coefficient and which curve contains the seasonal variation of the base temperature. Base temperature is multiplied by the values on the seasonal curve to obtain this variable throughout the year.

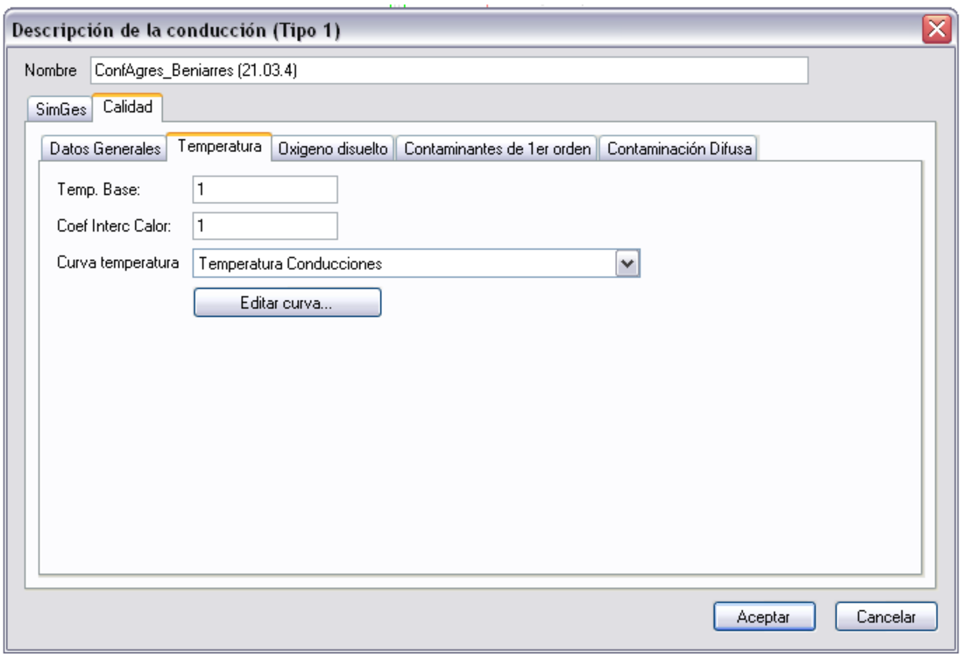


Figure 47. Channel temperature data.

If water temperature is to be modelled, base temperature represents the "equilibrium temperature". This is obtained by multiplying the "Base Temp" value by the corresponding value on the assigned temperature curve. The heat exchange coefficient represents the constant of heat exchange with the atmosphere.

Even if the temperature is not to be modelled, water mass temperature should be entered so as to be able to modify the constants of the different modelling processes. The user should enter an annual temperature variation curve for each simulated year. This can be obtained by multiplying base temperature by the assigned curve.

The program assigns a default base temperature of 20º C and a time curve unity.[13].

If temperature is not modelled, the Heat Exchange Coefficient is not used.

For the different variables subject to variation throughout the course of a year the GesCal model assigns a base value and a time curve, as in the case of the temperature of the different modelled elements. To create or edit these curves, the curve manager can be brought up on screen from any channel or reservoir by the `[Edit Curve]` button. With the time curve manager (Figure 48) we can create, edit and eliminate the different time curves associated with water temperature, radiation, wind speed, dispersion in reservoirs, etc.[14]

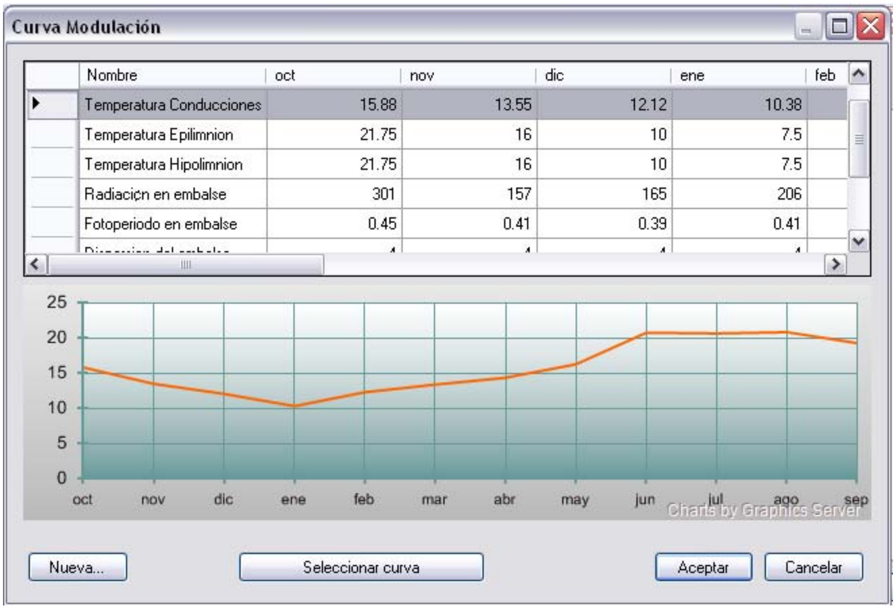


Figure 48. Time curve manager.

The time curve manager contains the available set of stored curves. When a curve is selected, its time evolution graph appears on the screen

To create a new curve, the `[New...]` button brings up the new curves window (Figure 49).

---

[13] A common error is to leave base temperature at 20º C and assign a curve that contains the mean temperature values, so that the product of these values assigns temperatures over 100º to the channel and consequently causes further calculation errors.
To assign a temperature to each of the model elements, it is easier first to create all the time curves and then to assign the corresponding curve to each element.

[14] To speed up data input, it is recommended to first enter all time curves and then assign curves to each of the required variables.

Figure 49. Window for creation of new time curves.

In this window, the curve is given a name and a value is assigned for each month of the year.[15]

To modify an existing curve, the required curve is selected from the curve manager and the values can be obtained by placing the cursor over the values.

To eliminate an existing curve, press the "Delete" key. If the curve has been assigned to an element, the program will show an error warning (Figure 50) indicating that the curve is in use and if it is eliminated the elements to which it has been assigned will be unusable.

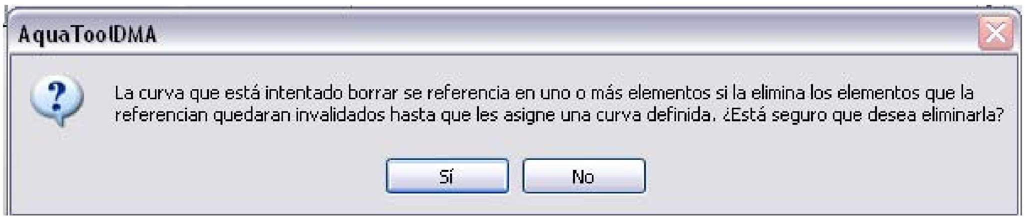


Figure 50. Curve elimination warning.

Finally, any changes made to the curves can be filed or cancelled by the `[Accept]`and `[Cancel]` buttons.

[15] Different elements and variables can share the same time curve, which thus does not need to be newly created each time.

4.2.3 PARAMETERS FOR MODELLING DISSOLVED OXYGEN, NITROGEN CYCLE AND EUTROPHICATION IN CHANNELS.

Basic or advanced modelling of dissolved oxygen can be carried out and the parameters can be accessed through the `[Dissolved oxygen]` tab.

Figure 51 shows the window with a table of values for quality modelling of the parameters for dissolved oxygen and nitrogen cycle and the eutrophication problem. The table gives a description of each parameter, its value and the units in which it must be entered.

The parameters shown in this table are calibrated by the user based on the data available from observations.

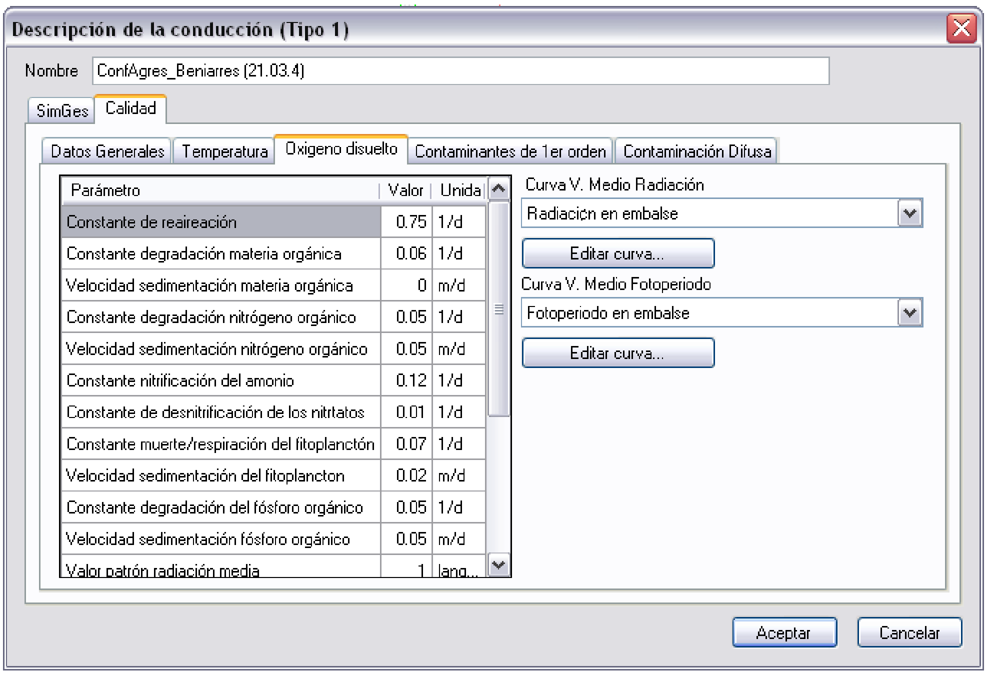


Figure 51. Parameters for modelling dissolved oxygen, nitrogen cycle and phytoplankton.

Whatever the modelling option, all the parameters appear on the screen, however, if the basic option is selected (dissolved oxygen and organic material) the user must enter values for the parameters associated with re-aeration of dissolved oxygen and degradation and sedimentation of organic material. The remaining constants can be left at default values, since they will not be taken into account by the program. If the re-aeration constant is given the value `“-1”,` the program will automatically calculate re-aeration by the Covar method.

If the nitrogen cycle is included, the user must enter the organic nitrogen degradation and sedimentation values, the ammonium nitrification constant and the denitrification constant if conditions are anoxic.

The rest of the parameters in the table are used for the complete modelling option, which includes the parameters connected with phytoplankton and organic and inorganic phosphorus. Some of these variables evolve throughout the year, so that the corresponding time curve should then be entered.

4.2.4 PARAMETERS FOR MODELLING OF FIRST ORDER CONSTITUENTS IN CHANNELS.

The `[1st order contaminants]` tab contains the parameters for modelling contaminants by first order kinetics (Figure 52).

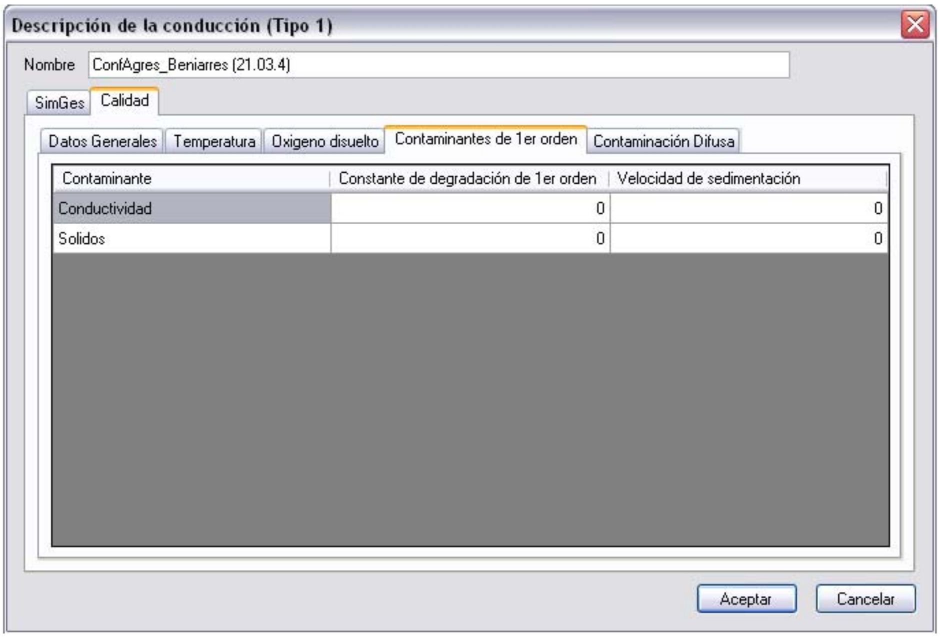


Figure 52. Parameters of first order constituents.

The user will introduce the first-order degradation constant and sedimentation speed values for the different first order constituents to be modelled. These parameters will be based on the type of contaminant modelled and will be calibrated in accordance with the available observed data.

4.2.5 DIFFUSE CONTAMINATION LOADS IN RIVER REACHES.

To include diffuse contamination in river reaches in the simulation, select the `[Diffuse contamination]` tab in the channel data sheet (Figure 53).

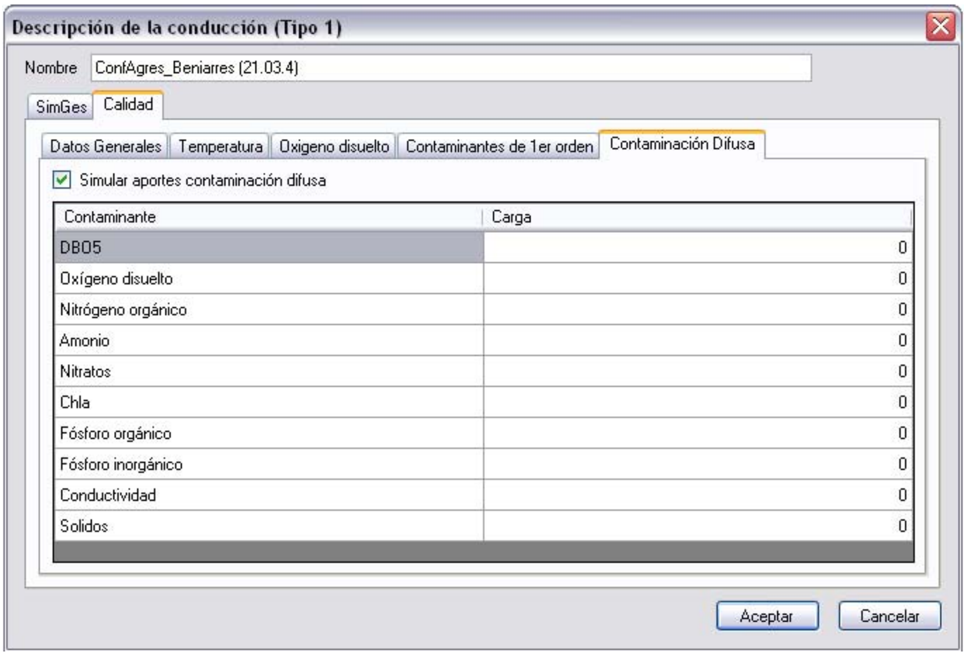


Figure 53. Entering the diffuse contamination load for a river reach.

First, the `[Simulate diffuse contamination inputs]`box is selected, which brings the appropriate table to the screen. Contamination loads are entered in the form of "grams/day". The program shows all the constituents being modelled but it is not necessary to enter values for all of them, only the known values. For example, there is no point in entering diffuse load values for dissolved oxygen or phytoplankton.

4.3 DATA FOR RESERVOIR WATER QUALITY MODELLING.

The reservoir quality sheet can be edited in the `[Quality]` dropdown menu when editing any reservoir data sheet (Figure 54).

The information on this sheet is classified into different concepts with tabs similar to those used for channels but some of the data are different.

4.3.1 GENERAL RESERVOIR DATA.

The general data are first entered. Figure 54 shows this data sheet.

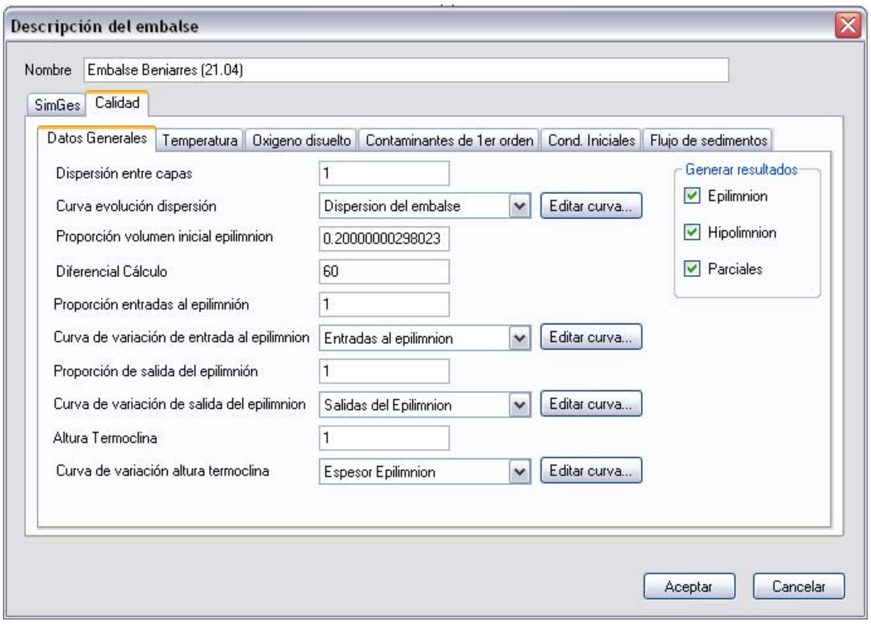


Figure 54 General data for reservoir modelling.

Reservoir modelling can be considered “completely mixed” or in two layers (see the GesCal technical manual for more information on these options).

The fields common to both types are:

- Time step: this value represents the calculation increment which is desired to use, it should be entered for all reservoir modelling and depends mainly on reservoir volumes and the processes modelled. The program establishes a default calculation differential of 30, which is sufficient for most cases. For eutrophication or very low reservoir volumes it may be necessary to increase this differential. The units are the time increments into which the month is divided, so that a value of 30 makes an approximate daily time scale.
- Thermocline height and thermocline variation curve: Thermocline height is the standard value which is multiplied by the assigned time curve. To carry out “completely mixed” reservoir modelling, it is sufficient to give a value of 0 to the thermocline height.
- “Generate results”: The results options are on the top right-hand corner of the sheet. If results are required for a completely mixed model, the “Epilimnion” option should be chosen. If two layers are modelled, the layers for which results are required are selected. In both cases, the program generates results in the global results file. The monthly global results represent the mean concentration of the simulations. The “Partial” option writes a partial results file on the reservoir that enables a more detailed study to be carried out on the evolution of the reservoir water quality. The contents of this file are described in the GesCal technical manual.

For the completely mixed model[16] it is not necessary to enter more data, as the program ignores the data entered in the other boxes of this window. For the two-layer model,[17] the following data should also be entered:

- Dispersion between layers and dispersion evolution curve: dispersion between two layers is entered, in cm^2/s, by a standard value and an evolution time curve. A value of "-1" in this box informs the program that dispersion has been estimated by the Snodgrass method.
- Initial epilimnion volume proportion: This represents the fraction of the epilimnion volume stored in the first simulated month.
- Proportion of epilimnion inflow and epilimnion inflow variation curve: The proportion of epilimnion inflow is entered as a fraction by means of a standard value and a time curve.
- The same operation is carried out with outflows, entering the information in the different fields *Proportion of Epilimnion outflows* and *Epilimnion outflows variation curve.*
- The "Edit curve" buttons bring up the curve manager, whose working is explained in the section on channels.

4.3.2 RESERVOIR TEMPERATURE DATA.

In the same sheet under the `[Temperature]` tab we find the information that must be entered whether system temperature is to be modelled or not (Figure 55).

Three items are entered: base temperature, heat exchange coefficient and and the indication of which curve contains the base temperature seasonal variation. Base temperature is multiplied by the values on the time curve[18] according to the variations throughout the year.

[16] The epilimnion is the reservoir surface layer and the hypolimnion the lower layer. In the case of a completely mixed model, the entire reservoir is considered to be the epilimnion.
[17] The model permits the reservoir to be considered as containing two layers at certain times and at others to be completely mixed. The reader is referred to the GesCal technical manual for further information on this subject.
[18] See the channels section for the management of monthly modulation curves.

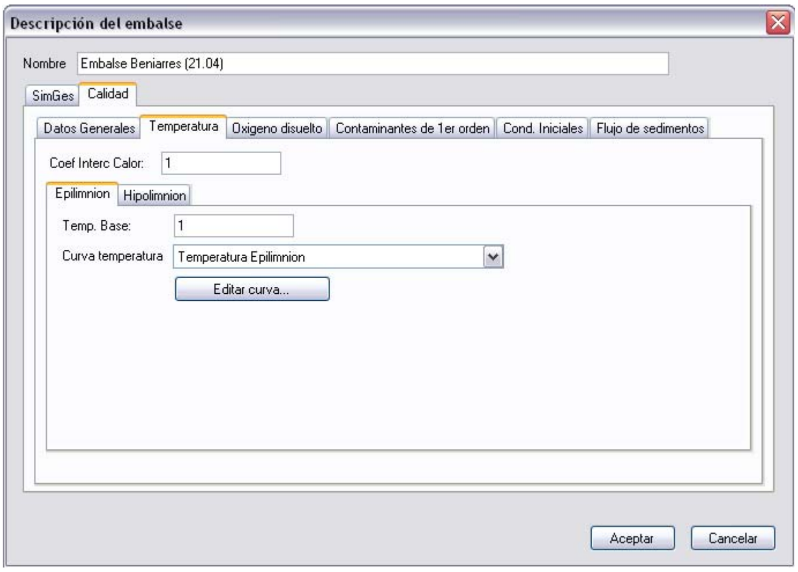


Figure 55. Reservoir temperature data.

If water temperature is to be modelled, the base temperature represents "equilibrium temperature". This is obtained for each month by multiplying the value of "`Base Temp`" by the corresponding value on the assigned temperature curve. The heat exchange coefficient represents the constant of heat exchange with the atmosphere.

If temperature is not modelled, the water mass temperature should be entered to modify the constants of the various modelling processes. The user should enter the annual temperature variation curve for every simulated year. This curve is obtained by multiplying base temperature by the assigned curve.

The program establishes a base temperature of 20º C and a time curve of unity.

If temperature is not modelled, the heat exchange coefficient is not used.

If the reservoir is modelled in two layers, information should be entered both for the epilimnion and the hypolimnion. The data corresponding to the hypolimnion is the radiation that reaches this layer. If the reservoir is completely mixed, it is enough to enter the epilimnion data and leave the default settings for the lower layer.

4.3.3 PARAMETERS FOR MODELLING DISSOLVED OXYGEN, NITROGEN CYCLE, AND EUTROPHICATION IN RESERVOIRS.

This process is very similar to that already described for channels. The modelling parameters can be reached by the `[dissolved oxygen]` tab, whether the modelling is the basic dissolved oxygen or a more advanced process.

Figure 56 shows the appropriate window with the table containing quality modelling parameters for dissolved oxygen, the nitrogen cycle and the eutrophication problem. The table gives a description of the parameter, its value and the units in which it should be entered.

The parameters in this table should be calibrated by the user based on the available historical data.

Regardless of the modelling option chosen all the parameters appear, although if the basic option is selected, the user should enter values of parameters associated with re-aeration of dissolved oxygen and degradation and sedimentation of organic material. The remaining values can be left at the default settings since they are not taken into account by the program. For the program to automatically calculate re-aeration[19] by the Smith method from the wind data, the re-aeration constant should be assigned the value "-1".

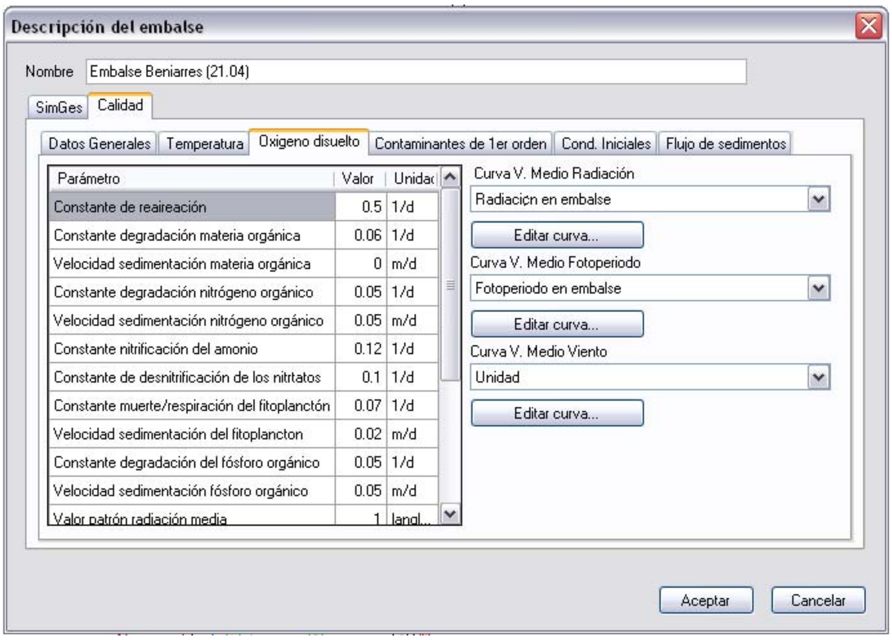


Figure 56. Parameters for modelling dissolved oxygen, the nitrogen cycle and phytoplankton.

If the nitrogen cycle is to be included in the modelling, values should be assigned to the constants for organic nitrogen degradation and sedimentation, ammonium nitrification and, if conditions are anoxic, the denitrification constant.

The remaining parameters in the table are used for the more complex modelling options in which parameters associated with phytoplankton and organic and inorganic phosphorus are considered. Some of these variables evolve throughout the year and if this is the case the appropriate time curve should be entered.

[19] If the option is chosen of internally estimating the re-aeration coefficient, wind values with their time evolution should be used.

4.3.4 Parameters for modelling first order constituents in reservoirs.

The [1st order contaminants] tab contains the parameters associated with contaminant modelling by first-order kinetics (Figure 57).

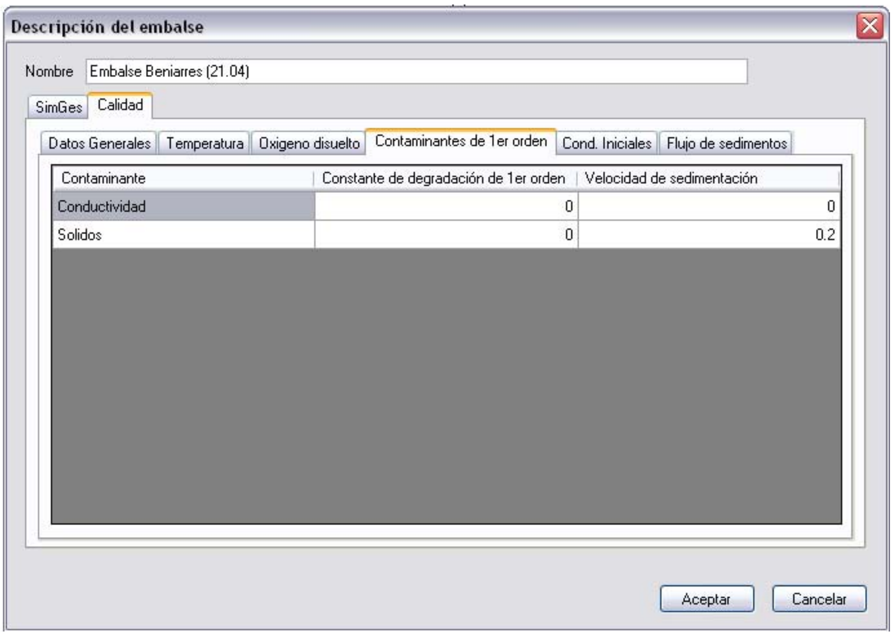


Figure 57. Parameters of the first-order constituents of reservoirs.

The constants are the same as those for channel modelling: first-order degradation constant and sedimentation speed. These parameters will depend on the contaminant type being modelled and calibration of the historical data.

4.3.5 Initial concentrations in reservoirs.

For all the modelled constituents and all reservoirs, initial reservoir concentrations should be entered in the [Initial Conds] tab (Figure 58) at the start of simulation.[20]

If the reservoir is considered as completely mixed, initial hypolimnion concentrations are not taken into account. If considered as two levels, hypolimnion concentrations should also be entered.

[20] Initial concentration units should agree with those entered in the quality inflows file.

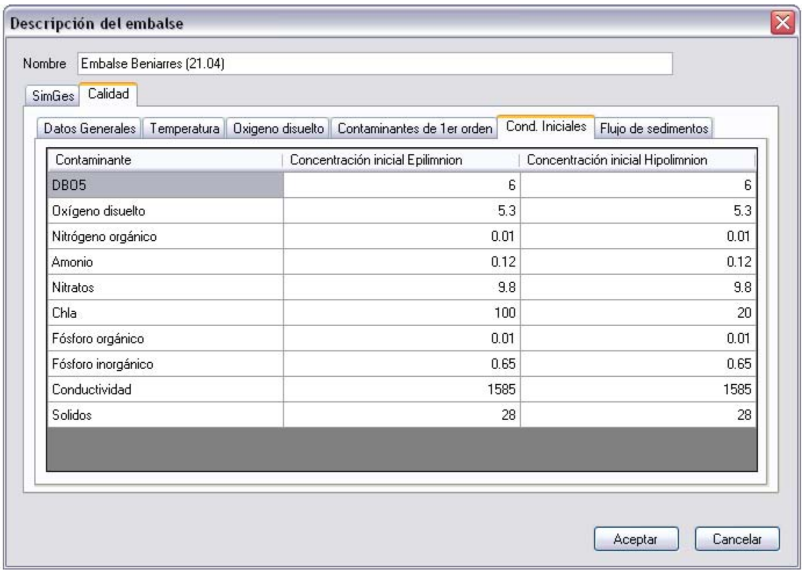


Figure 58. Initial reservoir concentrations.

4.3.6 SEDIMENT FLOWS.

With the GesCal model contaminant flows out of the reservoir can be modelled. Although the model can consider any type of contaminant flow, typical flows are: oxygen requirement from the reservoir and flows of ammonium, phosphorus[21] and nitrates. This information is entered in the [`Sediment flows`] tab of the reservoir file (Figure 59).

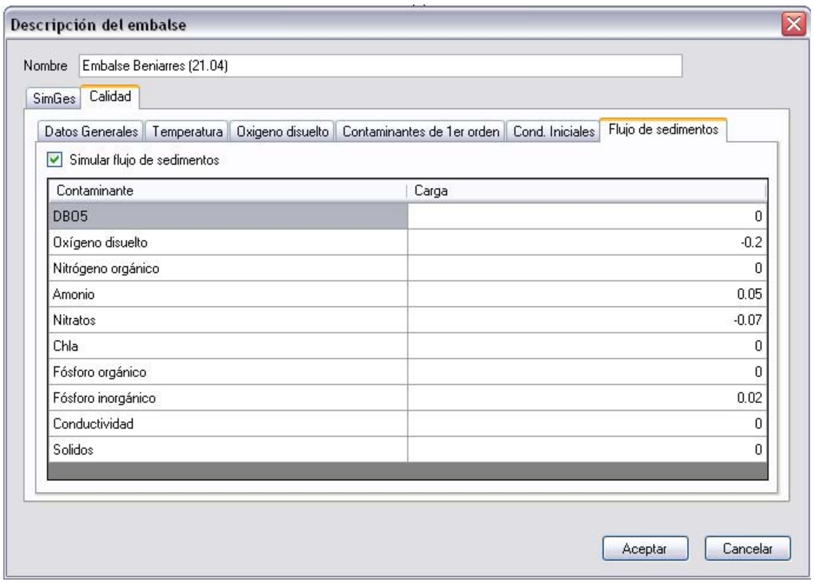


Figure 59. Sediment flows out of reservoirs.

[21] Inorganic ammonium and phosphorus flows only occur in anoxic conditions. The reader is referred to the GesCal technical manual for further information on this subject.

Before entering the data, the “`Simulate sediment flows`” tab should be activated. Flows are entered in units of “gr/m^2/d”.

It is neither usual nor necessary to enter values for all constituents, since flows between sediments and the water column only occur with certain constituents under certain conditions.

4.4 DATA ON CONCENTRATIONS IN AQUIFERS.

Concentrations for each of the constituents modelled should be entered for each aquifer. This information is entered in the `[Quality]` tab of the element’s data sheet (Figure 60).

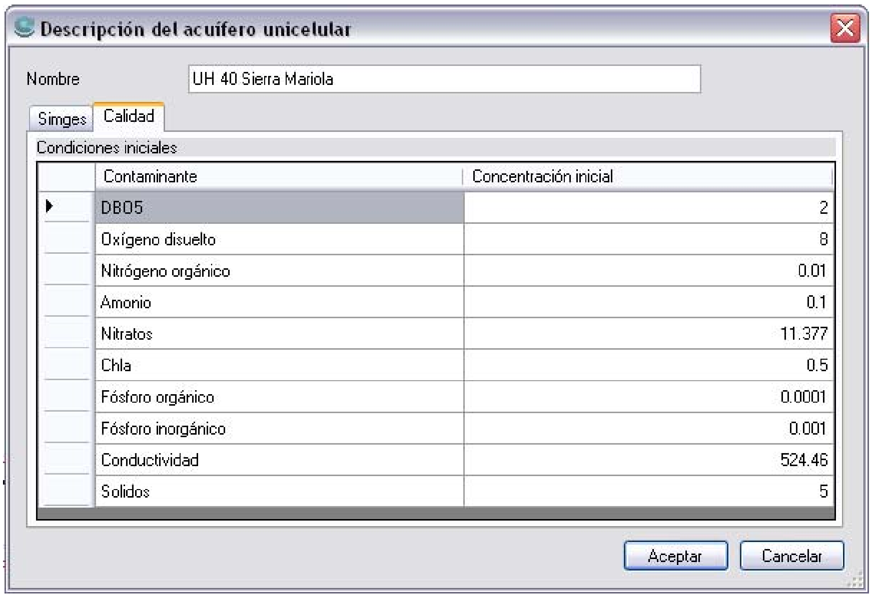


Figure 60. Aquifer concentrations window.

The concentrations of all constituents should be in the same units as those of the quality inflows file.

4.5 DATA ON TREATMENT/CONTAMINATION OF INTAKES AND RETURNS.

If treatment or contamination processes are taking place in an intake or return, the outlet concentrations must be entered for the element.[22]
This is done by simply editing the return element (Figure 61) or the `[Quality]` tab of the intake element (Figure 62).

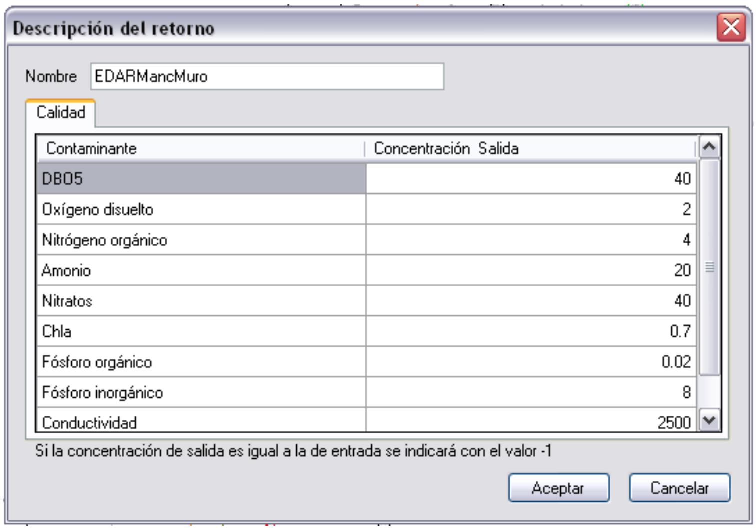


Figure 61. Return outlet concentrations data.

[22] Treatment or contamination in an element does not necessarily affect all the constituents. It is possible to modify the concentrations in certain constituents while the concentrations are calculated for the others.

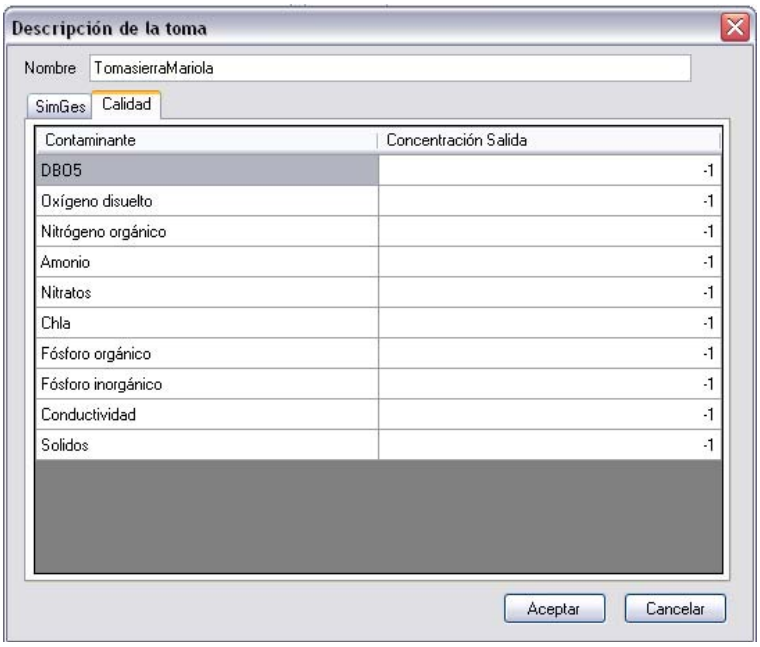


Figure 62. Entering intake outlet concentrations.

The default value `“-1”` for both intakes and returns indicates that the element outlet concentrations are the same as inlet concentrations.

4.6 RUNNING THE MODEL.

When all the necessary data for modelling the quality system have been entered, the model is ready to run. First, go to the `[Models]`→ `[Gescal]`→ `[Run Gescal]` menu (Figure 45), which shows all the Quality Model options (Figure 44). The modelling options should not be changed at this time, since this could cause errors in the subsequent simulation. The GesCal module will start to run when the Accept button is clicked. The GesCal simulation program will appear on screen (Figure 63) and at all times will show the simulation year and month. The process may last several minutes according to the length of the simulation period and the complexity of the project.

Figure 63. GesCal program execution window.

When the simulation has finished, this is indicated on the screen. The window can be closed by clicking on the Accept button.

4.7 CALIBRATION AND SIMULATION PROCESSES.

The first stage in all quality simulation models consists of calibrating all the modelling parameters. The parameters and their values depend on the type of constituent being modelled, so that it is usual to have to run the program many times with different calibration constants to check the fit with historical data.

After the model has been suitably calibrated, the following simulations are carried out to analyse the impact of the different situations the system may find. After modifying the model to deal with these situations, the program is again run to observe their effects.

It should be emphasised that the model processes SIMGES model results, so that there should be complete consistency between the last SIMGES simulation and the one about to be carried out with GESCAL. If the parameter of a constituent is being calibrated, it is therefore not necessary to run the SIMGES model every time, since the quantitative elements will not change. However, if a return coefficient (or any other factor that modifies flow variations in the system) is to be modified, the SIMGES model should first be run again and then the GESCAL model. Special attention should be paid to this point, as otherwise, serious errors could occur in quality simulations if flows are different to those that the user thinks he is dealing with.

SIMGES and GESCAL data handling tools are described in Section 5.

5 HANDLING THE MODEL RESULTS.

To edit simulation results, click on the “File” button (Figure 64) of the tool bar. This will automatically change to “Graph” (Figure 65). Clicking twice on any element will bring its graphic results into view. The same procedure can be used to return to the file editing screen.

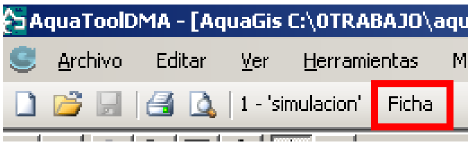


Figure 64: File editing toolbar.

Figure 65: View of toolbar in graph editing mode.

5.1 *AQUATOOL RESULTS VIEWER.*

After selecting the “`Graphs`” option on the toolbar, double clicking on any of the elements will bring the Aquatool GRAFDMA graph viewer onto the screen (Figure 65).

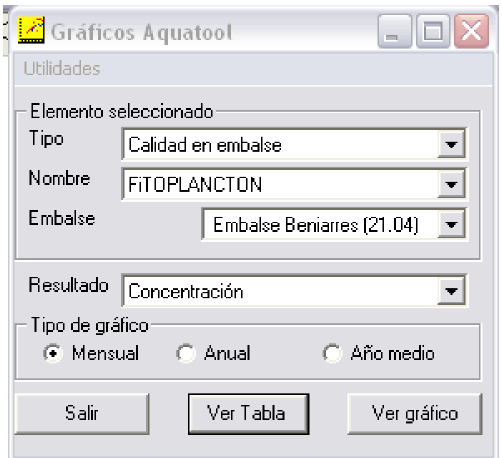


Figure 8. GRAFDMA graph viewer.

SIMGES and GESCAL simulation results, and also water mass results, can be seen with this manager.

The use of this window includes the following items:

- "**Type":** refers to the type of element for which results are sought. Also included as types are: "Basic aquifer stresses", "Reservoir contamination" and "Contamination in river reaches". The drop-down menu only shows the type of results produced by the models.
- **"Name":** name of the element for which graphs are sought. A list of the names of elements of this type included in the model can be obtained by selecting element "Type"
- The third dropdown menu ("Reservoir" in Figure 65) only appears when results are required for types of elements associated with others. Thus, in Fig. 65, "Reservoir contamination" has been selected, which gives a list of all reservoirs in the model. "Name" gives a list of the names of all the simulated contaminants.
  This option is also used for "Demand intakes", "Basic stresses" and "Control parameters" in aquifers, also for "Reservoir contamination" and "Channel contamination".
- **"Result**": allows a choice to be made between all the result types generated for each "Type" of element.
- **"Type of graph":** provides a choice between monthly, annual or average annual results.
- There is also a button to obtain results in table format.

When a graph of any type has been generated, clicking the right-hand mouse button on the graph will copy the data in the Windows clipboard. The data series can then be pasted on a spreadsheet or the graph figure can be pasted onto a text editor.

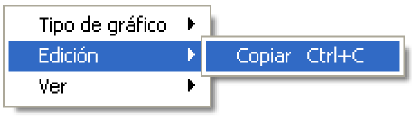


Figure 9: Right-hand mouse button options for a graph.

There is also an upper menu by which part or all of the generated results can be exported to a data base file (Figure 67).

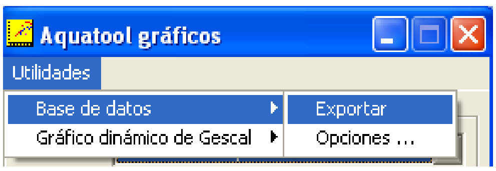


Figure 10: Menu for exporting results to a data base.

5.2 SIMGES MODEL RESULTS.

After running the SIMGES model, the data sheets and generated results can be viewed.[23] Graphs and numerical results tables for the different elements can also be seen using GRAFDMA, as described in the preceding section. The types of results generated by the model are as follows:

1. Reservoirs.
    - Final volume.
    - Inflows by river reaches.
    - Intermediate inflows.
    - Final altitude.
    - Controlled releases.
    - Uncontrolled releases.
    - Evaporation
    - Seepage.
2. Channels.
    - Flow
    - Seepage (in type 2 channels)
    - Connection with aquifer (in type 3 river reaches)
3. Consumptive demands.
    - Total demand.
    - Surface supply
    - Ground supply.
    - Deficit.
    - With numerical results, using any of the above options, the results calculated for guarantees are also provided.
4. Demand intakes.
    - Supply by intake.
5. Returns.
    - Total returns.
6. Non-consumptive demands (hydropower plants).
    - Flow passing through turbines.
    - Gross head.
    - Hydro-electric production (GW.h.)
    - Target flow
7. Intermediate inflows.
    - Inflow data.
8. Aquifers.
    - Net recharge.
    - Total extraction.
9. Control parameters.
    - Individual parameter values.

[23] It is important to ensure that the model has been run immediately before viewing, since the program shows the results that appear in the latest output files produced by SIMGES, otherwise the graph files and tables viewed could belong to a simulation carried out previous to the latest changes introduced in the data.
SIMGES generates different results files, some of which are not referred to here. A complete description of all files is available in the SIMGES model user manual.

10. Basic stresses.
    - Value of each stress.
11. Additional extractions.
    - Value of extraction.
12. Artificial recharge.
    - Value of recharge.
13. Operating rules (alarm-restriction type).
    - Value of indicator.
    - Value of restriction.
14. Contamination in reservoirs and channels.
    - Value of each contaminant.

5.3 GESCAL MODEL RESULTS.

There are two ways of viewing GESCAL module results: one is through the GRAFDMA results viewer, which can show both SIMGES and GESCAL, and the other is through “dynamic graphs” on an Excel spreadsheet. To access either option, after simulation, the graph viewing option is activated as described above.

With the Aquatool results viewer (Figure 65), quality simulation results can be accessed by the dropdown menu `[Type]` in `[Selected element]`. Available options are “Quality in Reservoir”, “Quality in Type 1 Channel”, etc. The parameter for which data are required is selected from the dropdown menu `[Name]` and the element (reservoir or channel) for which results are required is selected from the next menu.

5.3.1 Results by element and contaminant.

After choosing the options, results are presented in the form of a graph (Figure 68) or a table (Figure 69) by clicking on the `[Table]` or `Graph]`buttons.

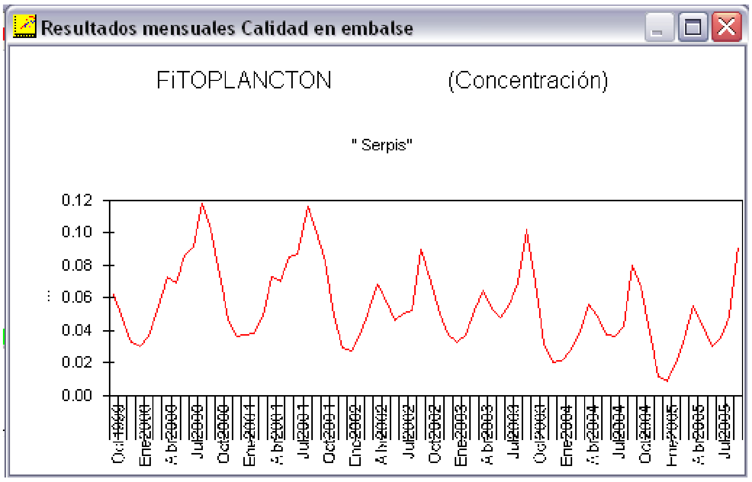


Figure 69. Quality graph obtained from the Aquatool graph manager.

Calidad en embalse: FiTOPLANCTON (Concentración)

	Oct	Nov	Dic	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Total
1999-2000	0.062	0.047	0.033	0.030	0.036	0.052	0.073	0.069	0.086	0.091	0.118	0.102	0.799
2000-2001	0.074	0.047	0.036	0.037	0.038	0.049	0.073	0.070	0.085	0.087	0.116	0.100	0.812
2001-2002	0.082	0.049	0.029	0.027	0.037	0.052	0.068	0.058	0.046	0.050	0.052	0.089	0.639
2002-2003	0.073	0.050	0.037	0.033	0.037	0.052	0.065	0.053	0.048	0.056	0.069	0.102	0.675
2003-2004	0.069	0.032	0.020	0.021	0.028	0.040	0.056	0.049	0.037	0.036	0.042	0.080	0.510
2004-2005	0.066	0.039	0.011	0.009	0.019	0.035	0.055	0.044	0.030	0.035	0.049	0.091	0.483
Promedio	0.071	0.044	0.028	0.026	0.033	0.047	0.065	0.057	0.055	0.059	0.074	0.094	0.653

Figure 70. Quality results obtained in the form of a table.

GRAFDMA provides different services, such as selecting the type of graph, copying graphs in the clipboard or exporting a graph to Excel. A table can also be copied in the clipboard for later pasting onto an Excel spreadsheet. All these options are accessed with the right-hand mouse button.

5.3.2 Results analysis by Excel dynamic graph.

Another means of consulting data, not included in the SIMGES module, is to export them to an Excel spreadsheet in the form of a dynamic graph.

Dynamic graphs and tables are Excel applications that allow large quantities of data to be viewed quickly and easily.

This option is accessed by the graph manager utilities menu. The [Utilities]→ [Dynamic graphs for Gescal results] option allows you to create a [new] dynamic graph or [Update] an existing one (Figure 70).

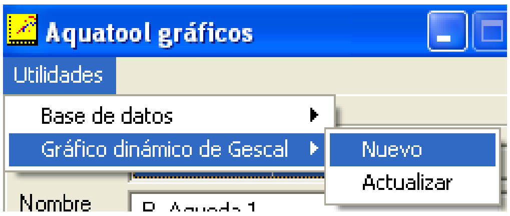


Figure 11. Accessing dynamic graphs by the graph manager.

When you have chosen an option, the program will ask if it is desired to compare the results obtained with an existing historical data file. This data file is given the name "observed.csv" (Figure 71) by default.[24]

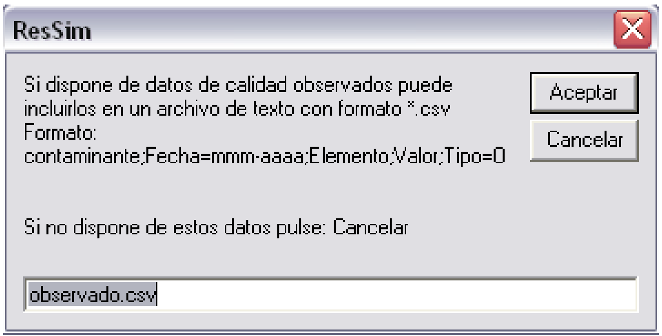
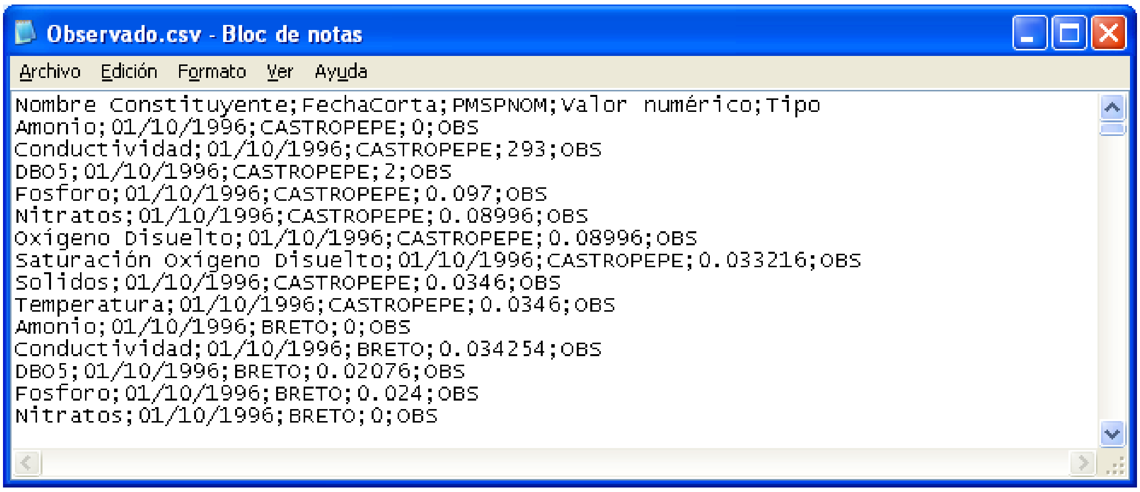


Figure 12. Specifying a historical data file for model calibration.

The program shows us the format the historic data sheet must be in for the comparison to be carried out. The file needs to have five columns and a row for each data value. The contaminant must be specified in the first row and this field must be "exactly" the same as that written by the GESCAL program in the results file. The second column contains the date the "*mmm-aaa*" format must have. The third column must contain the name of the point at which the value was observed. The fourth column represents the value measured in the observation. The fifth should have a label indicating that this value is "observed" and not "simulated". Figure 72 shows a historic data file as seen by a text editor.

[24] ".csv" files are ascii-type files in which the fields are separated by ";". They are very efficient, since a spreadsheet (such as in Microsoft Excel) can open them directly so that none of the advantages of being ascii files are lost. Most of the GESCAL output files are of this type and this format is also required for the historic data file.




```
Nombre Constituyente;FechaCorta;PMSPNOM;Valor numérico;Tipo
Amonio;01/10/1996;CASTROPEPE;0;OBS
Conductividad;01/10/1996;CASTROPEPE;293;OBS
DBO5;01/10/1996;CASTROPEPE;2;OBS
Fosforo;01/10/1996;CASTROPEPE;0.097;OBS
Nitratos;01/10/1996;CASTROPEPE;0.08996;OBS
Oxigeno Disuelto;01/10/1996;CASTROPEPE;0.08996;OBS
Saturación Oxigeno Disuelto;01/10/1996;CASTROPEPE;0.033216;OBS
Solidos;01/10/1996;CASTROPEPE;0.0346;OBS
Temperatura;01/10/1996;CASTROPEPE;0.0346;OBS
Amonio;01/10/1996;BRETO;0;OBS
Conductividad;01/10/1996;BRETO;0.034254;OBS
DBO5;01/10/1996;BRETO;0.02076;OBS
Fosforo;01/10/1996;BRETO;0.024;OBS
Nitratos;01/10/1996;BRETO;0;OBS
```

Figure 13. Example of a historic data file for model calibration.

Should no historic data be available or a comparison not be required, it is enough to click on the `[cancel]` button.

The program will then create a an Excel spreadsheet[25] with a dynamic graph formatted for correct viewing of the results (Figure 73). More information on "dynamic graphs" can be found in the instructions for Microsoft Excel.

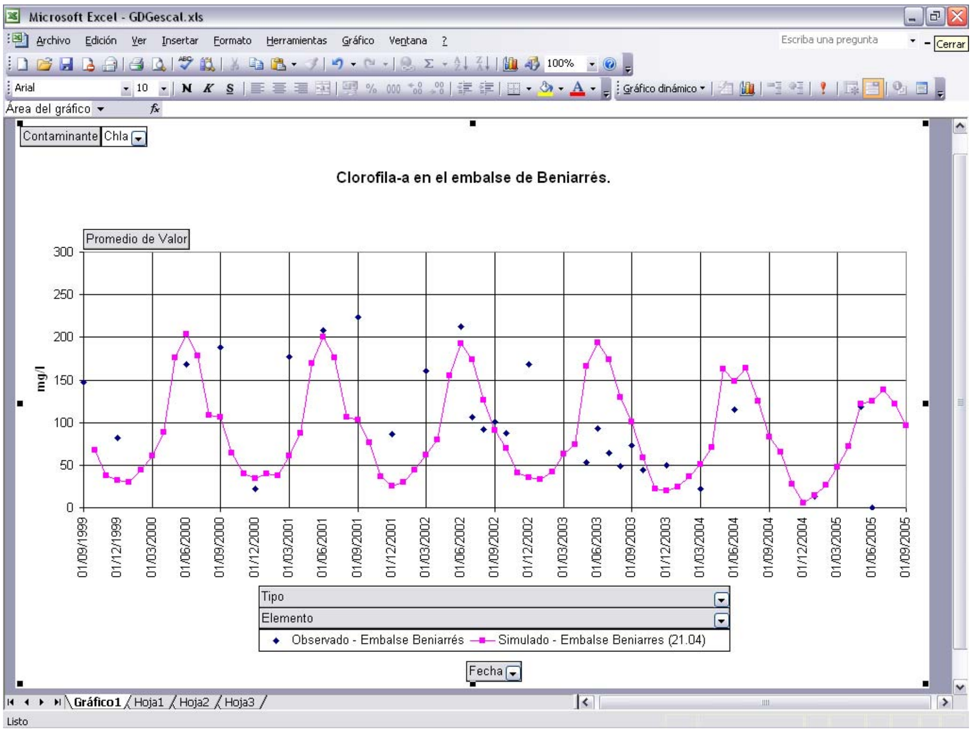


Figura 14. Quality modelling results in an Excel dynamic graph.

[25] Dynamic graphs are associated with a "dynamic table" with the same values as the graph and in which different filtering processes can be carried out.

The dynamic graph consists of four dropdown menus: “Contaminant”, “Type”, “Element” and “Date”. The constituent to be viewed (one only) is chosen from the first. The elements to be viewed and/or observation points are selected from the second. The date menu allows filtering of simulated and observation dates. The type menu presents the options “Simulated” and “Observed” or the label chosen for the fifth column of the historic data file.

The user of this program will soon realise that this tool is easy to use and can be very useful for handling the massive amounts of results obtained from system quality simulations.

If a second simulation is carried out, either because the model is being calibrated or different scenarios are being evaluated, the dynamic graph need not be closed during the set-up and running of the new simulation. The “Update” option is then selected in GRAFDMA and the update button is activated in the dynamic graph toolbar.

5.3.3 PARTIAL RESULTS FILES.

Both reservoir and channel partial results files are “*.csv” type and are directly accessible from Microsoft Excel. The results obtained and types of units are specified for reservoirs and channels in each column.

6 LINKING THE MODEL RESULTS WITH GIS.

One of the original aims of AQUATOOLDMA was to provide hydrological model results on the scale of “Water Masses” as defined by the Hydrographic Confederations (HC) without the need to include every individual water mass in the simulation. Including all water masses involves the disadvantage of having a large number of inflows and arcs for which, firstly, no reliable information is available to generate the data the model needs and, secondly, the handling of the model results can become very complicated for the user.

In this section, an intermediate solution is suggested, which, without overcomplicating the models, allows:

1. Individual results to be obtained for each of the water masses derived from the simulation results.
   These results are calculated by means of simple formulas, such as applying a percentage of the model result.
2. The link to be preserved in the database between each of the individual elements in the HC and the combination of “macroelements” defined in the simulation model.
   For example, from the point of view of river water masses, each water mass would have an assigned channel in the model, and each channel in the model could be linked to one, several or no other water masses.

The user, of course, does not have to follow this suggestion, since the program allows schemes to be defined to any scale of detail. The problem will arise when the data required by all the details have to be generated for the model to provide valid results.

6.1 DOWNLOADING THE GIS INTERFACE.

To access the GIS interface, select the options on the [Windows] → [2 AquaGis ….] menu (Figure 75), which provides access to a GIS files viewer,[26] (Figure 76) which will be used to associate the GIS basin elements and those in the simulation model. The viewer has the basic elements for image handling and for adding or removing layers (shp files).

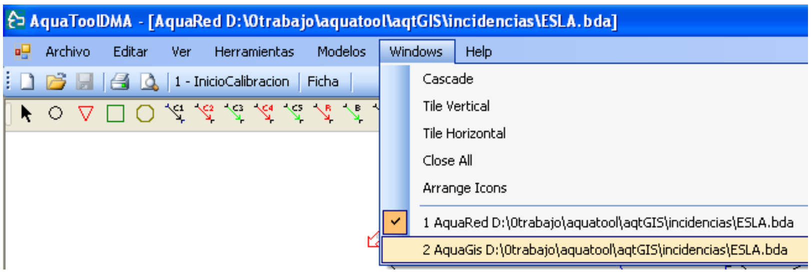


Figure 75: Menu for selecting graph window.

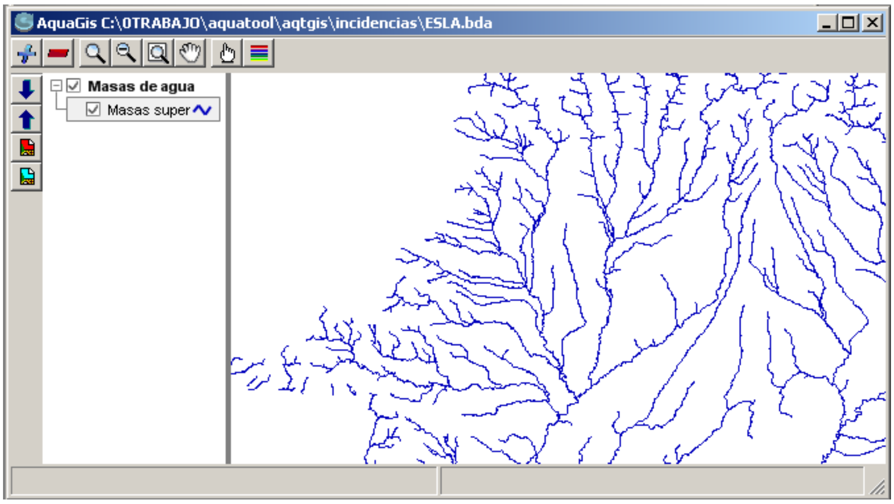
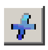


Figure 76: GIS layer viewer in AQUATOOLDMA.

6.2 DOWNLOADING GIS LAYERS.

To add new GIS layers to the viewer, click on the  icon to access the GIS layer interpretation data window (Figure 77). The following information should then be entered:

[26] The GIS viewer can be obtained by means of a library produced by MapwindowGIS (http://www.mapwindow.org)

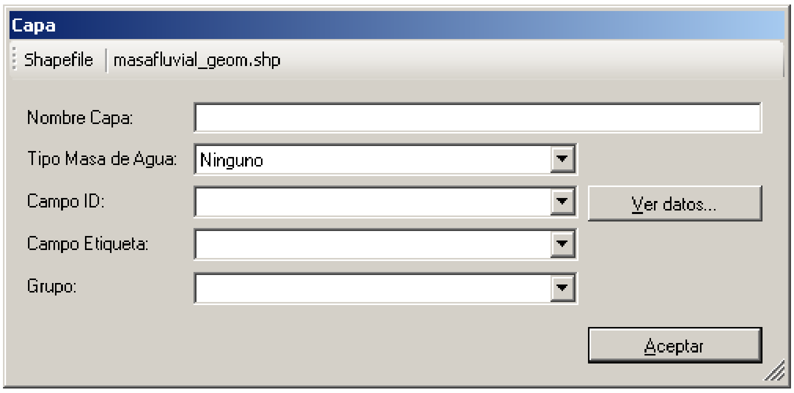


Figure 77: GIS layer definition data window.

1. `Name of layer`: This text will serve as a label to describe the content of the information layer.
2. `Type of water mass`: In this menu a mass type is selected from the list (Figure 78). Each one involves a different treatment of model results to calculate results for the elements in the layer. The options currently available are:

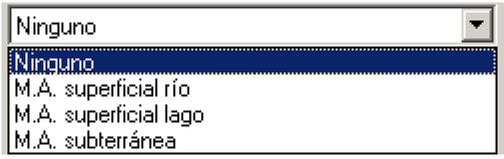


Figure 78: GIS layer description options.

- `W.M. River surface`: This indicates a river reach and therefore the elements in this layer are expected to connect with channel-type elements to obtain results for circulating flow.
- `W.M. Lake surface`: Indicates a reservoir or similar and layer elements are expected to connect with reservoir-type elements to obtain results for stored volume.
- `W.M. Groundwater`: Indicates aquifers connected with similar type elements.
- `None`: Used only for screen presentation with no implications for the model.

3. `Field ID`: Field used as linking code with model elements.

4. `Field label`: Field shown in GIS element identification lists. Must be different to 3.
5. `Group`: Name used in viewer to group the layers. It is useful for classifying layers into groups as required.

6.3 LINKING GIS ELEMENTS WITH AQUATOOLDMA ELEMENTS.

When the GIS layers have been downloaded, a model element should be assigned to each of the active GIS layers. This is done by editing the matching table through the options of the [Tools]→[Gis-Simges]menu (Figure 79). This opens a window (Figure 80) in which a model element, a hydrology data calculation coefficient and a quality data calculation coefficient are assigned to each GIS element.

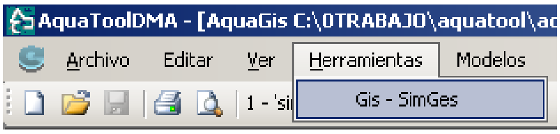


Figure 79: Menu option to match GIS elements with model elements.

Elem. Gis	Elemento	Coef. Hidrol.	Coef. Calidad
01.01	Conducción - Tipo 1 Albacete_por_Pozos	0.65	1.00
01.02	Conducción - Tipo 1 Albacete_por_Pozos	0.30	1.00
02.01	Conducción - Tipo 1 Albaida: Cabecera	0.32	1.00
09.02	Conducción - Tipo 1 Albaida: Cabecera	1.00	1.00
10.07.02.01	Conducción - Tipo 1 Albaida: Rio Barcheta	1.00	1.00
10.05	Conducción - Tipo 1 ATS_Segura	1.00	1.00
15.11	Conducción - Tipo 1 Bco_Poyo	1.00	1.00
10.09	Conducción - Tipo 1 ATS_Segura	1.00	1.00
10.12.01.04.01.02	Conducción - Tipo 1 Albaida: E.Bellus	1.00	1.00
10.12.01.05	Conducción - Tipo 1 Albaida: Rio Cañoles	1.00	1.00

Figure 80: Data window for matching GIS elements with model elements.

6.4 VIEWING RESULTS OF GIS ELEMENTS.

When the model elements have been assigned to GIS elements and the simulation has been run with the models, to see the model results for GIS elements, simply activate the graph editing option and double click on the required element. The GRAFDMA program, described in Section 5.1., is used to edit water mass graphs.

7 WORKING WITH DIFFERENT SCENARIOS IN A SINGLE PROJECT.

AQUATOOLDMA allows different alternatives or scenarios from the same basin to be handled using the same data base. This feature makes it a simple matter to compare alternatives in a single session.

For this, two fields are used as code words to identify an element:

- → “`ScenarioCode`”: Each model or alternative stored in the database is identified by a code for the scenario it belongs to, described in the “`Scenario`” table.
- → “`ElementCode`”: Each element represented in a model has an internal identification code which will be the same for all simulated scenarios.

AQUATOOLDMA includes the option of creating new scenarios copied from a pre-existing one (Figure 81). In this way, an exact copy of the existing scheme is obtained which keeps the element codes but is identified by a different scenario code.

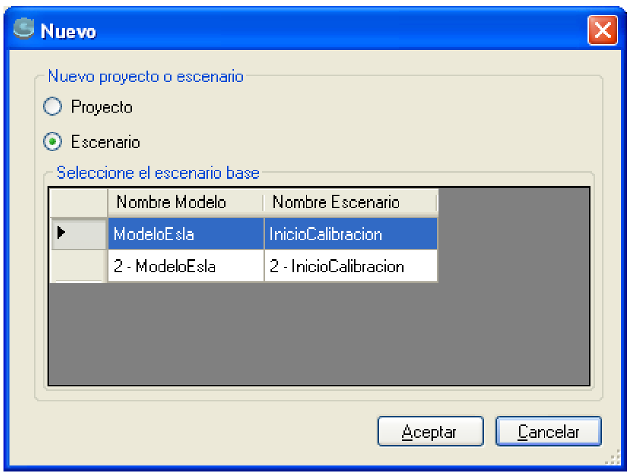


Figure 81: [File]→[New] Menu to create a new scenario.

For this model to work correctly, all the scheme elements should be created with the first scenario developed, since, when an element is added to a new scenario it is no longer represented in the other project scenarios.[27]

[27] It should be noted that this design also enables different models to be kept separately in the database file.

ANNEX 1: IMPORTING PROJECTS FROM SIMWIN.

A module is included to update SIMWIN projects to AQUATOOLDMA projects (Figure 82), activated by the Windows menu `[Start]` → `[Programs]` → `[Aquatool]` → `[Version updater]` (“*ges2dma.exe*” program).

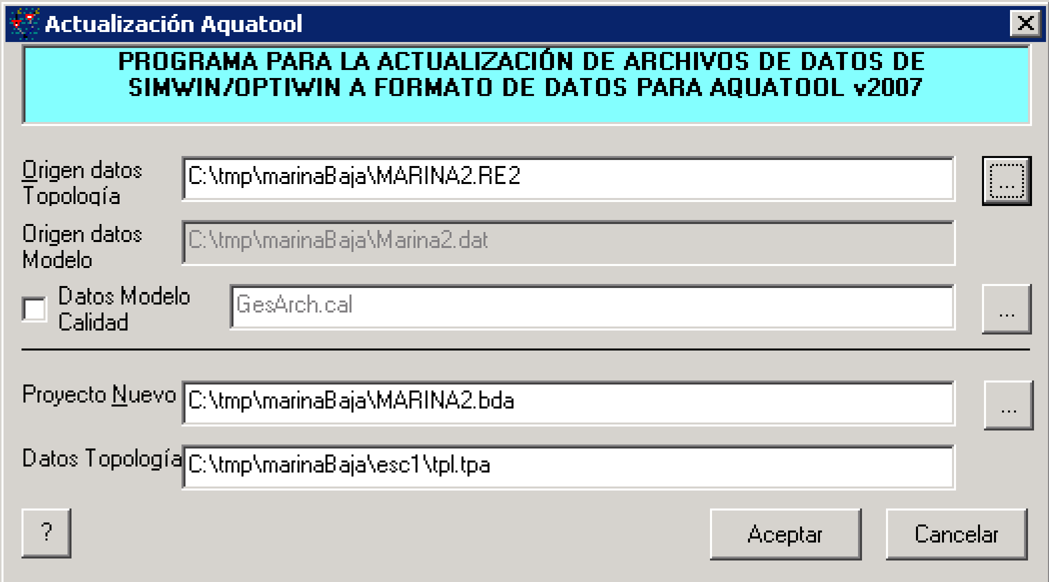


Figure 82: Data window for updating SIMWIN models to AQUATOOLDMA models.

To activate the module, select the original (*.re2) data file and the destination folder and file in AQUATOOLDMA (also the GESCAL general data file, if required). For the latter, two files are defined “`New project`” and “`Topology data`”. The second file should be included in a sub-folder in the first file. (If one does not already exist, it is created automatically.)

Remember that the updating program will read the SIMGES model physical data file, so that if a simulation has not been carried out after the latest changes, the data will not be updated correctly.

For cases in which different copies have been generated from the first SIMWIN model to simulate different scenarios, all the copies can be added to a single AQUATOOLDMA project. Just select the same “New project” when updating each of the copies. When updating is selected, the dialogue window shown in Figure 83 will appear. Selecting the “No” option, the menu shown in Figure 83 is added to Figure 84 and two options are then available.

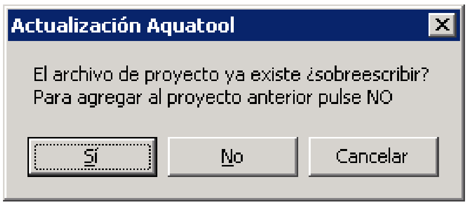


Figure 83: Dialogue window to activate downloading of different SIMWIN models to a single AQUATOOLDMA PROJECT.

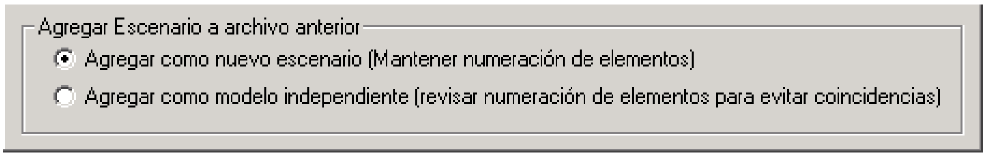


Figure 84: Options to add a scenario to a previous project.

- The first option “`Add as new scenario`” will conserve the internal element numbers. This will permit handling the same reference number for each element in all scenarios in AQUATOOLDMA.
- The second option “`Add as independent model`” can be used to keep various independent schemes in the same project or database file.

ANNEX 2: SUMMARY OF TECHNICAL MANUALS.

The AQUATOOLDMA basin management analysis model environment consists of a set of programs and libraries that interact with each other by exchanging data files and commands.

This annex summarises the programs included and explains the working criterion of each one, with the double aim, firstly, of helping users to solve by themselves any possible problems due to unforeseen circumstances and, secondly, of making it possible for others to develop software to improve the performance of this decision support system.

The following programs and libraries are included in AQUATOOLDMA (Figure 84 shows a scheme of the data flow and how the programs are interrelated) :

- Aquatooldma.exe - General data-editing and program call interface.
- simges.exe - Basin management simulation program including conjoint use.
- gescal.exe - Water quality simulation program for entire basins.
- grafdma.exe - Program for handling the graphic results of SIMGES and GESCAL simulation, also calculates results for water masses.
- ges2dma.exe - Program for updating projects developed on SIMWIN and projects for AQUATOOLDMA.
- AQTValidacionDatos.dll - Model data validation library.
- AQTEscrituraDatos.dll - Library for reading databases and writing data files for simulation.
- AQTVisorTopo.ocx Window for viewing and editing simulation schemes (graphs only, does not handle data).

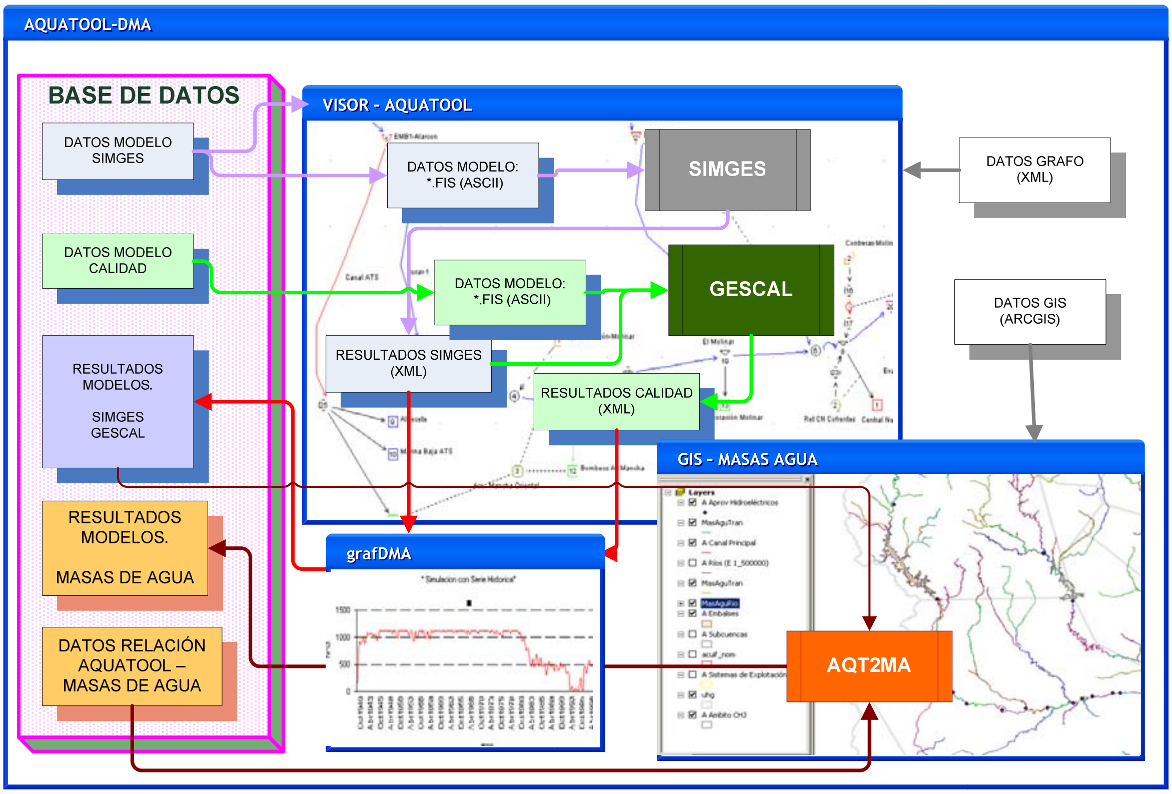


Figure 85: Scheme of resources and programs in the AQUATOOLDMA environment.

Below, we give some technical data on the different libraries designed to be used as references in the development of additional utilities for AQUATOOL.

A2.1. THE DATABASE.

The AQUATOOLDMA database contains multiple data tables whose contents are described in detail in the corresponding document. Here, we describe the principal tables and their functions. Figure 86 shows the basic data structure and below a description is given of the contents.

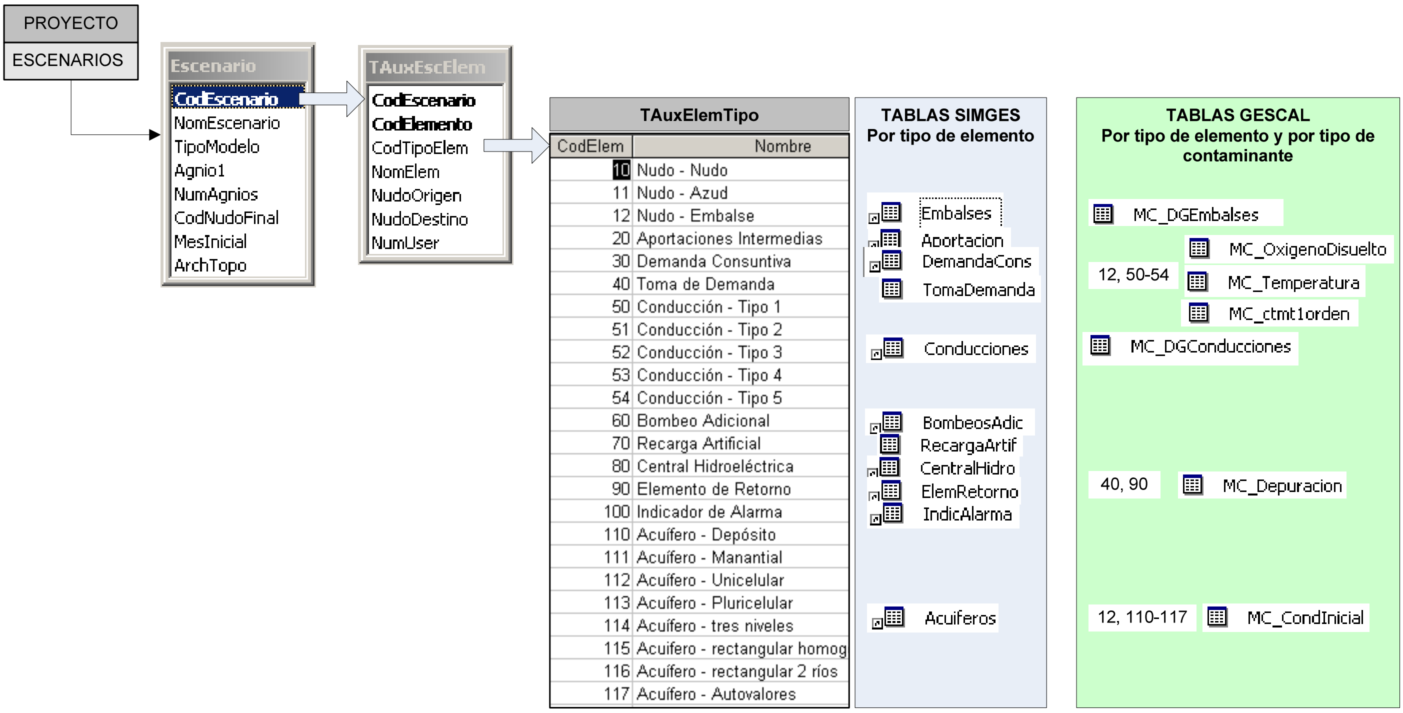


Figure 86: Structure of principal data in the AQUATOOLDMA database.

- The "Scenario" table contains a register for each scenario in the project. The main code of this table is "ScenarioCode", which is repeated in the other tables to identify the registers with the corresponding scenario.
- The "TAuxEscElem" (abbreviation of scenario-elements auxiliary table) contains a register for each element in each scenario. The principal code is formed by the "ScenarioCode" and "ElementCode" fields. Both are repeated in the rest of the tables to identify the data with each of the elements.

  This table also contains data common to all elements as well as those most frequently consulted in the database.
    - "CodTipoElem": This code is used to identify the type of element that it represents. Element-type codes are listed in the table "TAuxElemTipo".

        - "`NomElem`": Name or title used to define the element. Title that appears in the scheme to identify elements.
        - "`NumUser`": Order or "user" number used for numbering within each element type. It may contain gaps, although this is not recommended.
        - "`NudoOrigen`" and "`NudoDestino`": For line type elements or those connected to others. Contains the `CodElemento` of the element it is joined to.
    - The tables listed in the "SIMGES Tables" and GESCAL Tables" groups in Figure 86 are those which contain most of the data for each type of element. Data from the SIMGES hydrological model are separated from data from the GESCAL water quality model.

The links that clearly must exist between related fields in the different tables were deliberately not defined in the database, since when adding or removing information from programs errors are likely to occur due to lack of information. Although certain links can be included without causing problems, it is recommended to do so with caution, because they could later interfere with operations in AQUATOOLDMA. Should this happen, the links can be erased for the model to function correctly.

New tables, registers, consultations, etc. can be added to the database without interfering with the working of the program. This is recommended when massive data editing or consulting is carried out on previous projects. It is also recommended that any change in the structure of the model flow be done through the interface, since there are multiple dependency relationships, including with other data files, that could cause errors in the functioning of the programs.

A2.2. THE SCHEME EDITOR.

The AQUATOOLDMA database file includes all the information necessary to define a simulation model. However, there are other auxiliary data which are used to used to draw the topological scheme of the model and which it was decided to leave out of the database. These include data such as icon screen coordinates, viewing colour, etc.

The AQUATOOLDMA scheme is managed by an application independently of the main program and has been included in the main program in the form of a library (`AQTVisorTopo.ocx`). This library independently manages both the on-screen display of the scheme and the data file used to define the topology of the simulation model.

The structure and content of each of the titles used in the design of the data file are shown in the table below:

Labels	Description
Scheme	
Elements	
Node, Reservoir, Inflow, Demand, Channel1, Channel2, Channel3, Aquifer, Hydropower Plant, Return, Recharge, Pumping, Intake, Channel4, Channel5	Contain data on each type of element.
Element	
gfCodSig	Linking code with the element in the database.
Nombre	Chain of text to be viewed.
Tipo	Index of type of element. (as defined in TAuxElemTipo)
NumUser	User number to be displayed on screen.
posX	X screen coordinate for the element.
posY	Y screen coordinate for the element.
NudoOrigen	gfCodSig of initial element (line type only).
NudoDestino	gfCodSig of destination element (line type only).
NombrePosX	X coordinate of name.
NombrePosY	Y coordinate of name.
VerNombre	0, 1 if name is to be displayed or not.
ColorIcono	Colour code used to view icon.
ColorLinea	Colour code used to view line.
TextoGiro	Turning angle of name.
Line	Defines points on the line (line type elements only). For Hydropower plant type elements there are two line groups.
Point	Defines consecutive points on the line.
X	X coordinate of point.
Y	Y coordinate of point.
NombreTamanyo	Name letter size modification factor.

		Tamanyo	Element size modification factor.
		ConecSec1	gfCodSig of secondary connection destination element. (-1 if this does not exist).
		ConecSec2	gfCodSig of second secondary connection destination element. (-1 if this does not exist).
		NombreMovido	Position of name, in relation to default position.
		NomTamRelativo	If 0, letter size in relation to icon size, if 1, in relation to normal size.
		Valor	
	ImagenFondo		Information on background image to be displayed.
		Archivo	Background image file name.
		X0	X coordinate of upper left corner.
		Y0	Y coordinate of upper left corner.
		LX	Horizontal length of image.
		LY	y/x ratio of image dimensions.
		Oculta	True if image not displayed.

The above table is tabulated in accordance with the file structure.

A2.2. PROJECT SCENARIO MANAGEMENT.

All the scenarios are contained in the database, however, since different programs have to interact with each other during a project, a considerable number of data files are brought into action and these must be carefully organised. For example, each scenario handles at least the following files:

- a topology file (*.tpa) controlled by the scheme viewer "AQTVisorTopo.ocx".
- copy of *.SHP and associated files viewed in the GIS layer window.
- various calculation model working files and results files.

To avoid confusion and keep together all the files belonging to each scenario, the following file scheme was designed (Figure 87):

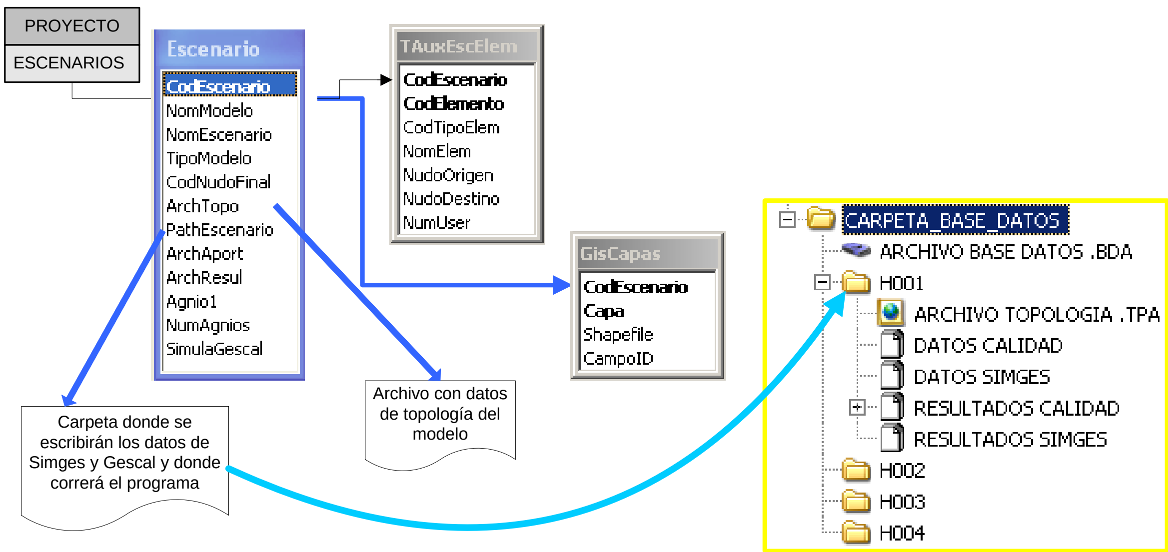


Figure 87: File structure of an AQUATOOLDMA project.

The project database file has the extension `*.BDA` and there can only be one project per file.
Various scenarios from the same model can be kept in a database. Different files are operated with each scenario, all of which are located in the same file. As a control measure, the "`Scenario`" table includes the "`PathEscenario`" field, which contains the path in relation to that of the project database containing all the files activated for each scenario. A scenario file cannot contain more than one scenario. The names of additional scenario files included in the "`Escenario`" table will only have the name of the file but not the path included in "`PathEscenario`".

A2.3. DATA VALIDATION LIBRARY.

A verification system to check that the data contained in the database are consistent with the calculation models was programmed in a library external to the main program, so that it could be compiled in other programs that edit the database. Its design criteria are as follows:

COMPILATION.

Compilation language: Visual basic .NET
File name: `AQTLibValidacionDatosDMA.dll`
Library Name: `AQTLibValidacionDatosDMA.clsValidador`

FUNCTIONS PROVIDED.

Name: **`clsValidador.New`**
Description: On initiating the class, it must be given the project file and the scenario number.
Result: ----
Arguments in the call:
"Nom" > Name of *.BDA project file.
"esce" > Scenario number.

Name: **`clsValidador.Elemento`**
Description: Checks consistency of data elements with the rest of the scheme.
Result: Sends back an error code (SinError=0)
Arguments in the call:
"gfCodSIG" > Element code
"amsg" > (Byref) Should the error code be other than 0, returns error description here.

Name: **`clsValidador.Esquema`**
Description: Checks consistency of data of complete system.
Result: Returns an error code (SinError=0)
Arguments in the call:
"gfCodSIG" > Element code
"amsg" > (Byref) Should the error code be other than 0, returns error description here.

Name: **`TipoResultadoRevision`**
Description: Declaration of numeration for result types of Element and Scheme functions.
Values:
```
SinErrores = 0
Avisos = 1
FaltaDatos = 2
ErroresFatales = 3
ErrorInterno = -1
```

A2.4. DATA WRITING LIBRARIES.

The calculation models were developed in Fortran programming language and work completely independently. They read a series of text files with the data necessary for simulation and also write their results in text files.

Data files for calculation models are written from an external library of the main program so that they can be compiled in other programs used to edit the database. Their design criteria are as follows:

COMPILATION.

Compilation language: Visual Basic .NET
File name: `AQTLibEscrituraDatosDMA.dll`
Library name: `AQTLibEscrituraDatos.simges`
`AQTLibEscrituraDatos.EscrituraGescal`
`AQTLibEscrituraDatos.simrisk`

FUNCTIONS PROVIDED.

Name: **`EscrituraGesCal.GenerarDatosGesCal`**
Description: Data writing order for the GESCAL model.
Result: Text chain with information on the process result. If there have not been incidents, returns an empty chain.
Arguments in the call:
"`NombreBDA`" > *.BDA project file name
"`CodEscenario`" > Scenario number

Name: **`Simges.EscribeSimges`**
Description: Data writing order for the SIMGES model.
Result: Text chain with information on the process result. If there have not been incidents, returns an empty chain.
Arguments in the call:
"`NombreBDA`" > *.BDA project file name
"`CodEscenario`" > Scenario number

Name: **`Simges.EscribeAportaciones`**
Description: Writes inflows file for SIMGES from information in the database. Only writes the period requested for the SIMGES simulation.
Result: True if correct.
Arguments in the call:
"`NombreBDA`" > *.BDA project file name
"`CodEscenario`" > Scenario number

A2.5. GRAPH EDITING PROGRAM.

The use of the GRAFDMA program from the general interface is described in Section 5 of this manual.

The program can also be activated by orders in the command line, defined by labels within cone brackets with criteria established in standard XML. The labels used are the following:

LABEL	CONTENT
<Commands>	**Container of all options**
<Type>	Type of element in graph
<Number>	Element user number
<NombreElemento>	Name of element in graph
<CodElem>	Unique element code (If not given, name is not considered)
<ArchivoProy>	Simulation file (Project database). If not defined, a new DB file is created with simulation results. If it exists, results are added to database.
<ArchivoSimges>	"salanupp.tmp" by default.
<ArchivoGescal>	"calidad.sal" by default.
<Directory>	Project directory.
<HabidoCambios>	0=no; 1 =yes, there have been changes in model after last simulation.
<Model>	Model from which results have been obtained. If GESCAL, the program will read the GESCAL results file and will incorporate it together with the SIMGES file. If SIMRISK, it will look for data for SIMRISK graphs.
<Scenario>	Calculation scenario dode. (Default = 1)
<Version>	Program version number. (If the older version, it is considered to be 1.2) (If not found and is a labelled file, it is considered to be 1.3)
<Action>	By default = "LanzaGrafico" and makes the defined graph to be shown in the rest of the arguments. (This value is not required.) If it appears and takes values such as: * **"GeneraBD"** A graph is not edited and results are transferred to the "ArchivoProy" DB or if not to a new DB "grf.mdb" If quality model results are found, these are also sent to the DGB. If information to generate results for Water Masses has been defined in the DB, this is also sent to the DB. * "**LanzaGraficoMA**" edits the water mass graph window. It should also have access to: <CodElem>, <Escenario>, <Directorio>, <ArchivoSimges>, and optionally: <ArchivoGescal> * "GraficoPorArchivo" If this label appears, the functioning of the program is changing and a graph will be opened with data contained in a text file. The label <Archivo> is also required with the complete route and the name of the file that contains the data to be shown. The format of this file is described below.

Not all the data are essential and those that are essential are not demanded. The graph module will generate results according to the information available in the following order:

0. The directory containing the scheme (essential).
1. Unique element code (with or without scenario).
2. Type and name of element.

Other data will be used if available.

Example of a data Caín:

```
<Comandos><Modelo>GESCAL</Modelo> <Directorio>C:\tmp</Directorio>
<NombreElemento>E. Arenos</NombreElemento><Tipo>12</Tipo></Comandos>
```

This call will open the Stored Volume results graph in the E. Arenos” reservoir contained in the “salanupp.tmp” results file which should be located in the “c:\tmp” directory (the results file is described in the Simges Manual)

WRITING RESULTS IN THE DATABASE.

The GRAFDMA graph editing program can also export all the simulation results to the model DB or to a specific DB for the simulation. The DB is structured as shown in Figure 88:

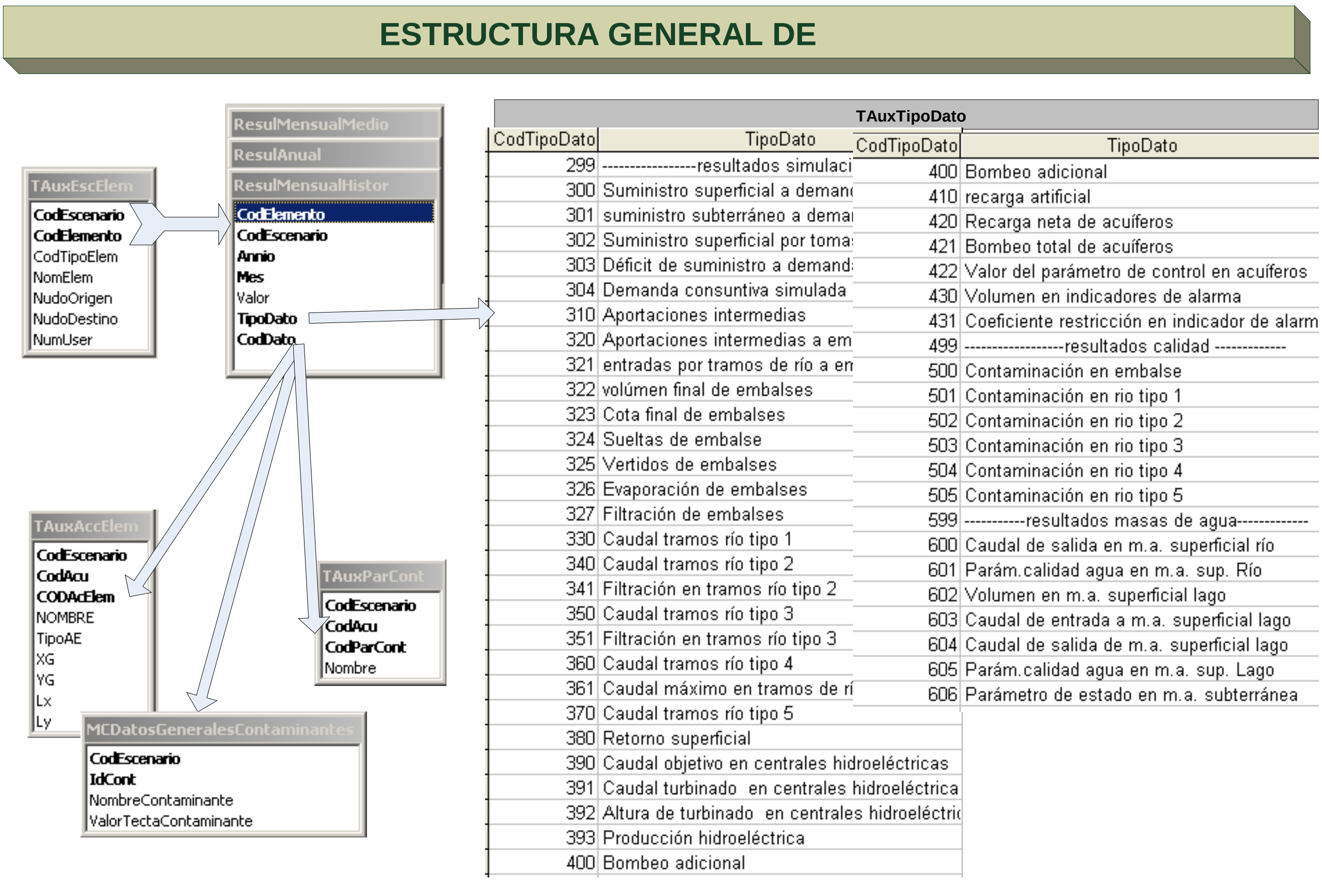


Figure 88: Structure of the simulation results database.

The results are stored in the tables: `ResulAnual`, `ResulMensualMedio` and `ResulMensualHistor`. and include annual, mean monthly and the complete series of results, respectively. The tables are structured with the following fields:

- `CodEscenario` and `CodElemento`: these fields identify the result with the simulation elements.
- `Annio` and `Mes`: define the date. The `ResulAnual` table only includes the `Annio` field and the `ResulMensualMedio` table only `Month`.
- `TipoDato`: is a numerical code that describes the type of result contained in the register. Its meaning can be found in the `TauxTipoDato` table.
- `CodDato`: certain types of result may have different values with different meanings. The different values are identified in this field. They are specifically used to identify the following results:
    * Basic stresses in aquifers: `CodDato` coincides with the value of `CODAcElem` in the table `TAuxAccElem`.
    * Aquifer control parameters: `CodDato` coincides with the value of `CodParCont` in the `TauxParCont` table.
    * Quality simulation results: if GESCAL simulation results are available, these results are also included. `CodDato` coincides with the value of `IdCont` in the `MCDatosGeneralesContaminantes` table.
- `Valor`: numerical value of result.

These results tables can be used for consultations or other functions programmed from on the project's own database.

FORMAT OF FILE WITH GRAPH DATA.

This function was developed to display results graphs for the CALRISK program, used in calculating qualitative state probabilities with the GESCAL module.

If the call to the program contains the label <Action> with the value "**GraficoPorArchivo**", the program will act independently of the simulation program and will show a single graph with the data contained in a text file. Also required is the <File> label with the complete route and the name of the file that contains the data to be displayed. This file is read in labelled text format and the contents are as follows:

*. <SERIES> label. After reading this label on one line, the program will read 2 values on the next line:

1) number of rows (NF) or x-axis values to be displayed on a graph.

2) number of columns (NC) or series available in the y-axis.

And after the second line will read NF lines with NC values each. Each row will contain, firstly, the value to be shown on the x-axis followed by each of the values of the NC curves to be included in the graph.

* <TITULO1> and/or <TITULO2> labels (optional): if one of these labels is used, on the next line the program will read a chain with the title to be shown on the graph.
* <TIPOGRAFICO> label (optional): if used, on the next line the program will read the code of the type of graph to be displayed. By defect, this will be a line graph, although the graph type is editable.

ANNEX 3: INSTALLING THE PROGRAM.

The program should be run with the Microsoft Windows NT or Vista operating systems

The installation requires 30 Mb of hard disc. As simulations can generate sizeable files on the hard disc (over 100 Mb), it is recommended to take special care with the results output options.

The installation is run on the "Instalador.exe" program, which opens a dialogue window with a description of the installation process, which includes:

- First, the interface installation, which contains a complete copy of the software.
- An updating function for components and licensed programs; licensed use of the program requires a copy of the SIMGES.EXE and/or GESCAL.EXE programs. If these programs are available, answer “yes” to the question “Do you have personalised programs?”. The installer will then ask for the location of SIMGES.EXE and/or GESCAL.EXE and will automatically include them in the installation.

The program also needs to have the following items installed:

- Compiled program execution environment in .NET Framework 2.0. During AQUATOOLDMA installation, the installer will check if an Internet connection is available and if not will install it automatically.
- Microsoft libraries for XML support for MSXML applications.
- ODBC and OLE DB controllers for access to Microsoft MDAC data.

Licensed users must also have the WIBU-KEY (support web: wibu.com) license control service.

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