Linking water quality and simulation models

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Abstract

Júcar river water resources system is located in the East of Spain, a typical Mediterranean basin with very spatial–temporal irregular pluviometry and a high use of the water resources. The area of “La Ribera”, the last part of the river, is where the main part of the use is located. Due to these demands and their returns this area presents several important water quality problems such as low concentration of dissolved oxygen and high concentrations of nitrogen, phosphorous, etc.

This paper explains the link between a water quality model and a simulation model in order to improve the water quality of this part of the river maintaining the guarantees of the demands of the system.

The first step was building a water quality model of the low part of the river with the module QUAL2E. A model of 8 constituents—conductivity, suspended solids, CBOD, dissolved oxygen, ammonium, nitrate, nitrites and phosphorous— was developed, calibrated and tested. By the other side, a simulation model for the entire Júcar basin was available. This model was developed using the SIMGES module. SIMGES is part of the Decision Support System AQUATOOL.

With the goal of improving the water quality on the river, an application has been developed to connect both models. Several wastewater treatment and management alternatives can be combined and tested with the application. The simulation model estimates the flows and returns in the river that can then be used as input for the water quality model. The results of the water quality model represent the efficiency of each alternative. This approach allows us to achieve the best alternative that assures the water quality physical-chemical conditions for aquatic life and the lower impact over the guarantees of the demands.

Keywords: water quality, water management, simulation models, QUAL2E, SIMGES, AQUATOOL, Júcar River.
1 Introduction

One of the main factors of the water quality is the river flow. Generally, water quality models have been calibrated and simulated with low flows, analyzing exclusively the water body in a pessimistic situation. Combining water quality and simulation models allows the estimation of water quality under different situations facing several alternatives of management, allocation, treatment, etc. Historically, water quantity and water quality concerns have been separated, considering both aspects in a common strategy is commonly advocated (Somlyody et al. [11], Arnold and Orlob [4], Strzepek and Garcia [12] and Chapra [8]).

This paper presents a link between water quality and simulation models to analyze different possibilities to improve the water quality in a river. The case of the study is the low part of the Júcar River currently with a high degree of pollution due to urban, industrial and agricultural activities. A river water quality model has been developed with QUAL2E [6] tool. By the other side, there was available a simulation model of the Júcar River Basin, developed with SIMGES program. SIMGES is part of the Decision Support System AQUATOOL (Andreu et al. [1]).

2 Jucar River

Júcar river basin is located in the east of Spain, see figure 1. It has an area near 22,000km², and a length of the main course of approximately 500 km. Annual average precipitation is 510 mm/year. Human water consume is 150 hm³/year supplying a population of 860,000 people. The irrigable surface is about 158,500 ha consuming 1000 hm³/year. It is a much regulated basin, with a reservoir capacity of 2,900 hm³.

![Figure 1: Situation of Júcar River Basin.](image-url)
The river has a good water quality except in the lowest part of the river. This area is affected with the wastewater loads from several urban areas, especially near Alcira village, and the returns from an extensive agricultural area. These two effects produce low concentrations of DO (under 1 mg/l), and high concentrations of CDBO (up to 12 mg/l) and Suspended solids (up to 32 mg/l). Moreover there is an increment of concentrations of nitrates (35 mg/l) and phosphates (up to 1 mg/l) mainly due to the agricultural activity.

An explanatory scheme of the low part of the river can bee seen in figure 2.

Figure 2: Scheme of the low part of the Júcar River.

3 The quality model

The module QUAL2E allows modelling of up to 15 constituents in a river water body.

A one-dimensional hypothesis is considered for modelling the river considering advection and dispersion processes. Several point and diffused loads
can be considered in the model. The QUAL2E model has been the most widely used stream model (Drolc and Koncan [10]). A complete description of the model can be found in Brown and Barnwell [5]. For the case of study a water quality model of 8 constituents: Conductivity, Suspended Solids, Dissolved oxygen, CBOD, N-org, NO₃, NO₂, NO₃, and P_Tot) has been developed. The model is composed of 8 streams with inflows, uptakes, point and diffuse loads, and weirs. In order to calibrate the model 8 measurement points were available with series of data. Figure 3 shows calibration results for several parameters in one point of the river. Figure 4 reflects the simulated versus measured average profile of the stream.

Figure 3: Calibration results for several parameters.

4 Simulation model

Model SIMGES optimizes, using the Oult of Kilter algorithm, a conservative network flow to allocate the resource in the basin. One of the main characteristics of the SIMGES module is the amount of elements available for modelling. Moreover, the importance of the surface and ground water links is incorporated with the possibility of modelling aquifers with different levels of complexity from simple models to distributed ones. The SIMGES module is included inside AQUATOOL (Andreu et al. [1]) Decision Support System. This DSS is a group of modules for modelling planning and managing water resources systems. AQUATOOL includes basically an optimization module, a simulation module, an aquifer module, and several utilities.

For the Júcar case a previous model was available. Several modifications were done to obtain more accurate water flows in the lower part.
Figure 4: Simulated results versus measured average profile of the stream.
5 Simulated scenarios

The simulation model has allowed the estimation of flows, returns, and inflows in all the streams of the river for the different scenarios studied.

The goals of this study were: To evaluate the current situation facing different situations of drought and its implication for water quality, to estimate the effect of the future Alcira Waste Water Treatment Plant, and finally to evaluate the water quality in several medium and large term situations of the water demands of the basin. Each aspect of study has converted into a different scenario. Each scenario has been simulated in the Simulation model for 40 years of inflows in a monthly scale. The river flows estimated by the simulation model have been analyzed and several critical situations of each scenario have been simulated in the water quality module.

6 Results

The results obtained from the simulations of different drought periods show the water quality in the river of the current situation in several critical moments. The results show that while in a normal situation the anoxic length is about 2Km in the drought periods it can be incremented to 10Km. Moreover concentrations of CDBO and Suspended Solids can be over 14 mg/l and 29 mg/l respectively.

The second aspect of study was the effect of the future WWTP. The Alcira Plant will treat around 14000 m³/year with a secondary treatment and an advanced nitrification treatment. With this WWTP the anoxic area would be eliminated, the model estimates a DO concentration over 3 mg/l in all periods studied. However phosphorous concentrations will remain high due to there being no treatment in the WWTP to eliminate it. Table 1 shows the mean values comparing the current situation and the WWTP situation in the critical point of the stream and figure 5 shows the evolution of DO in the river profile in those situations.

<table>
<thead>
<tr>
<th>(mg/l)</th>
<th>DO</th>
<th>CDBO</th>
<th>Suspended solids</th>
<th>NH₄</th>
<th>NO₂</th>
<th>NO₃</th>
<th>P_Tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Situation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With WWTP</td>
<td>6.27</td>
<td>5.37</td>
<td>7.69</td>
<td>0.19</td>
<td>0.19</td>
<td>23.69</td>
<td>0.11</td>
</tr>
<tr>
<td>Without WWTP</td>
<td>4.6</td>
<td>10.86</td>
<td>15.03</td>
<td>1.25</td>
<td>0.89</td>
<td>22.76</td>
<td>0.45</td>
</tr>
<tr>
<td>Low flow Situation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With WWTP</td>
<td>6.34</td>
<td>6.81</td>
<td>16.96</td>
<td>0.58</td>
<td>0.75</td>
<td>19.84</td>
<td>0.69</td>
</tr>
<tr>
<td>Without WWTP</td>
<td>4.42</td>
<td>22.3</td>
<td>32.11</td>
<td>3.20</td>
<td>2.20</td>
<td>17.76</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Finally, several management basin scenarios have been simulated: The former scenario considers only the increment of upstream water demands. The integral model has allowed the estimation of the new flows and the water quality in this
situation. The results show a generalized decrement of water quality, overall the conductivity in the current situation in the critical point has an average of 2.025 µs/cm and in the hypothetical situation it is incremented to 3.650 µs/cm. Another aspect studied has been the current modernization of the irrigation system of the Ribera Alta. Results estimate the water quality of the river as a result of this action. The decrease of nitrates to a maximum of 20mg/l-NO₃ and phosphates to 0.2 mg/l-P is remarkable. Although this measurement will improve the water quality the flows will be lower due to the fall of the returns that are a main part of the flow in the river.

![Figure 5: DO profile in the different scenarios.](image)

7 Conclusions

This paper presents the advantages of considering conjunctive water quality and quantity aspects in the evaluation of basin management alternatives. Interaction between the water quality developed with the QUAL2E program and the simulation model using the SIMGES module has allowed the problem to be dealt with in an integral approach. Its application to the Júcar River has demonstrated the advantages of this approach in different aspects.

References


