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Integration of hydrogeological modelling in decision support systems in Spain: the case of Loma de Ubeda aquifer

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Introduction

This study has been carried out within the framework of the IGME's strategic line related to Artificial Recharge and Integrated Management. It has been made as an expert advice for the Regional Gobernment of Andalusia and the Water Authority of the Guadalquivir river basin. The Loma aquifer has been intensively exploited during last decades in order to meet the increasing agricultural demands of the region (olive trees), wich has led to decreasing groundwater levels.

Previous numerical flow models of Loma de Ubeda aquifer (IGME, 2004a; Heredia, 2012) have been considered to develop a new model to be integrated in the decision support system.

Objectives

• To develop a decision support tool for water management of the exploitation system where the carbonate aquifer of Loma de Ubeda is integrated (Gomez, 2012).

• To analyse different management scenarios in the exploitation system, including current scheme, the incorporation of new projected infrastructure (Siles reservoir), and the implementation of artificial recharge (IGME, 2005) to reach a better regulation of water resources and the recovery of water levels in Loma aquifer.

• To analyse urban water supply schemes in order to improve supply guarantees and water quality by diversification of water sources.

Methodology

The decision support system of Loma de Ubeda has been made using the code AQUATOOLDMA v 1.0 (Solera et al 2008), and specifically its module SIMGES (Andreu et al. 1991).

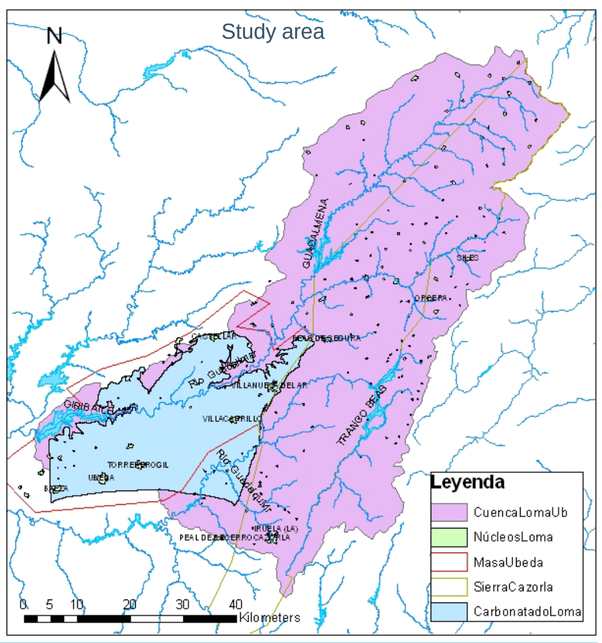
This is a software for integrated management modelling of water resources at a basin scale, appropriate for simulation of the river-aquifer interaction, regulation elements such as reservoirs and aquifers, and many other elements involved in water management such as river flows, demands, return flows, ecological flows, canals and other conections, pumpings and artificial recharge. The simulation uses a monthly time step.

The Loma aquifer has been integrated in the conjunctive use model by means of a flow model made with the code AQUIVAL (Pulido-Velazquez et al. 2007), which simulate transient state groundwater flow by the eigenvalues method (Sahuquillo y Cassiraga, 2010).

The activities carried out in this project can be grouped into two phases:

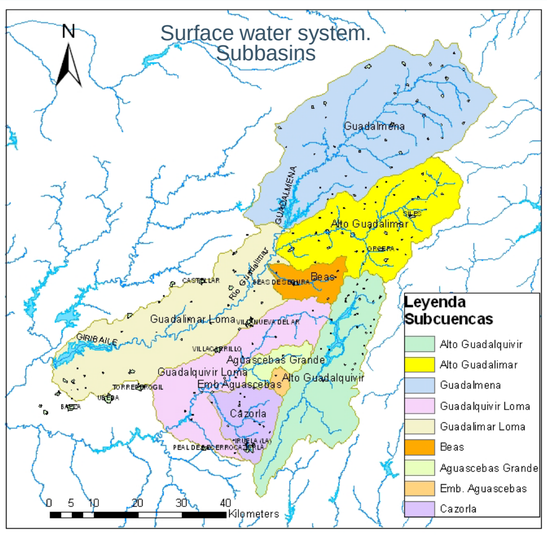
- Characterisation of the hydrological system Loma de Úbeda, setting and describing the different elements to be considered, available resources (surface water and groundwater), demands to be met and current hydraulic infrastructures.

- Simulation of alternative scenarios for integrated management of Loma de Ubeda system, considering current and projected hydraulic infrastructure.



Surface water system

The surface water system has been divided into nine subbasins in order to calculate partial runoffs at a natural state of flow. A rainfall-runoff method (Temez, 1977) has been applied for this purpose.



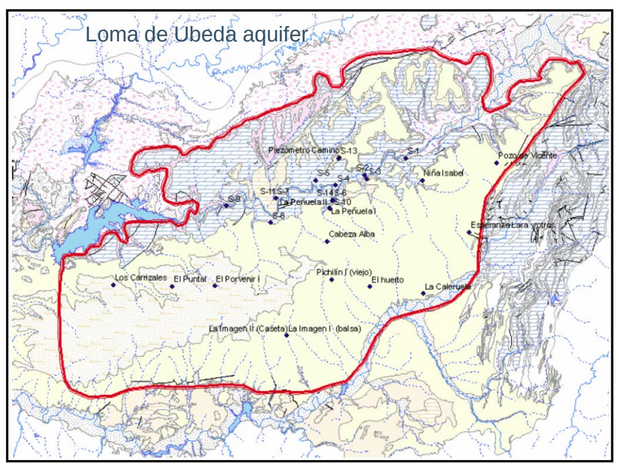
Study area

The study area is located in the province of Jaen, south of Spain, at the upper Guadalquivir basin. The hydrological system has been defined considering the Loma aquifer as the key element to analyse, and its total or partially depending demands. Starting from this central scheme, all the other water sources (surface or groundwater) related to Loma aquifer and its associated demands have been considered.

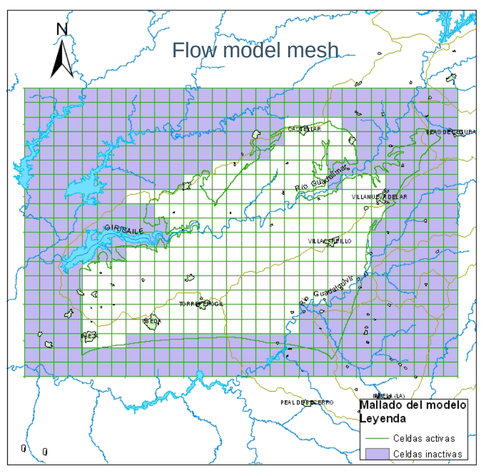
Groundwater system

The Jurasic aquifer of Loma de Ubeda consists of Liasic dolomites (IGME, 2004b). Triasic materials constitute the impermeable base and the northern boundary of the aquifer. It is unconfined at the northern third, and confined under Miocene deposits toward the south.

The river Guadalquivir goes along the SE boundary of the aquifer, over the confining marls. The river Guadalimar goes from NE to SW along 25 km over the unconfined Jurasic dolomites, in close hydraulic conection to the aquifer.

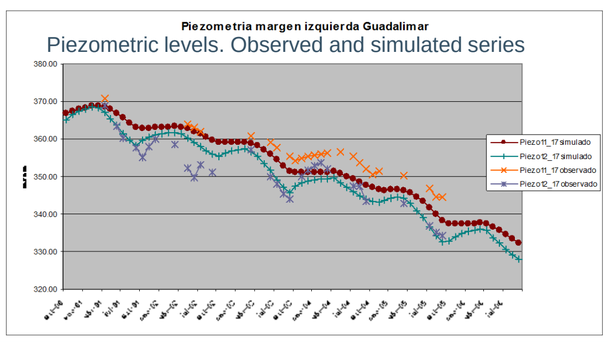


Subbasin	Calculated mean annual runoff (hm3/yr)	
	Period 1960-2006	Period 2000-2006
Guadalmena	142.01	144.90
Alto Guadalimar	157.52	139.76
River Beas	27.34	19.09
Guadalimar Loma	165.43	145.54
Alto Guadalquivir	217.88	100.85
Aguascebas Reservoir	9.61	2.25
Aguascebas Grande	10.75	8.06
River Cazorla	39.41	22.65
Guadalquivir Loma	59.02	77.67
Total	828.97	660.77



Flow model: code Aquival, transient state, 204 active cells, simulation period 2000-2006.

The hydraulic interaction river-aquifer and the piezometric evolution have been analysed with the flow model under diferent management scenarios.



Demands and return flows

Agricultural demands are mainly related to irrigation of olive trees as the predominant crop and key activity for the economy of the region. But there are also urban demands to meet in the Loma area (about 105,000 people).

Ecological flows have also been considered as non consumptive demands, as described in the Guadalquivir River Basin Plan.

Treated urban wastewater from the Loma community has been included as the main return flow element. The mean annual volume of treated wastewater produced in the system is estimated as 8.03 hm³/yr, and the volume reused is estimated as 3.11 hm³/yr, what means 38.7% of wastewater reused (2.13% of the total internal demand for irrigation).

Demand priority	Demand type	No. of demands	No. of intakes	Demand (hm³/yr)
0	Ecological flows	*3*	*3*	*9,568*
	Urban	*1*	*2*	*10,792*
1	Agricultural	*14*	*19*	*145,900*
	External	*3*	*3*	*332,019*
TOTALS		***21***	***27***	***498,279***

Integrated Water Resources Management model

Once the integrated management model was set up with SIMGES, the current scenario has been calibrated and simulated.

Furthermore, 8 different management scenarios has been simulated. They have been set up combining the following elements:

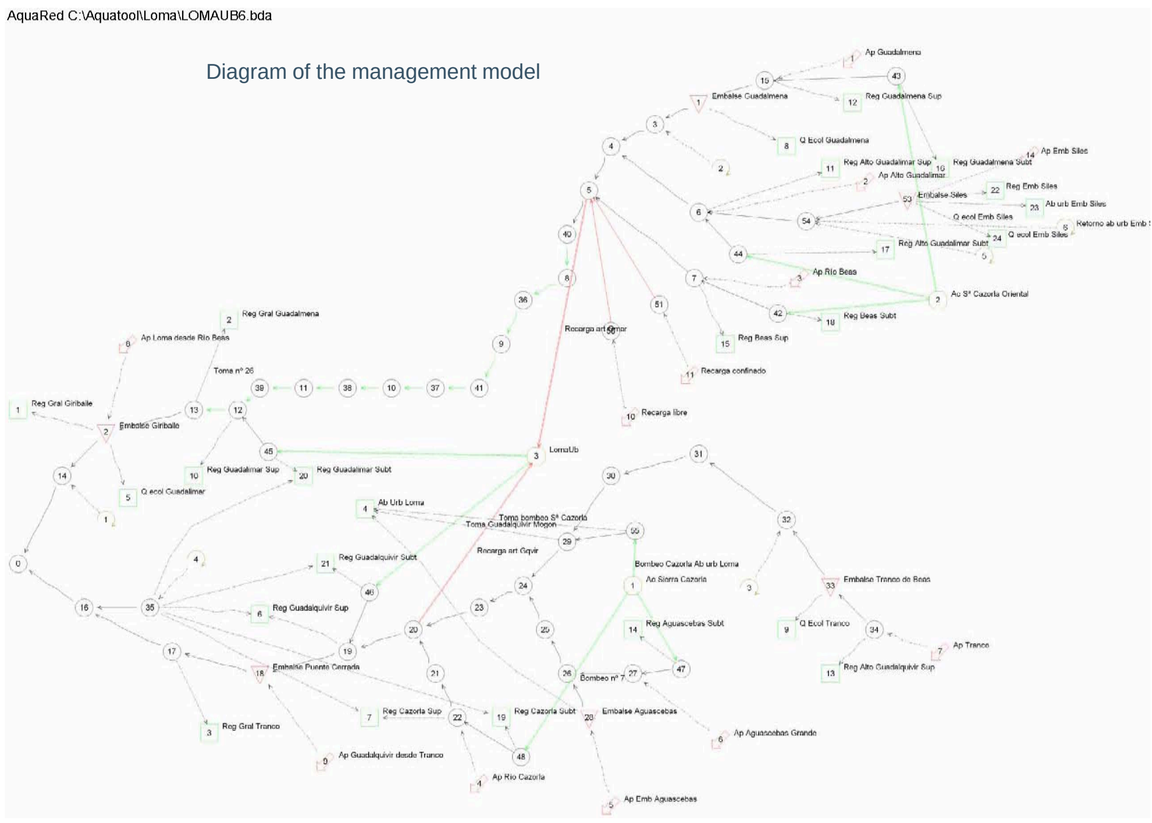
• Put into operation of Siles reservoir;

• Priority of pumping from the Sierra de Cazorla aquifer over surface water intake from the river Guadalquivir for urban supply;

• Artificial recharge in the Loma aquifer with overflows from the rivers Guadalimar and Guadalquivir;

• Increase of agricultural demand.

Simulation 1represents the current management scenario, which is the reference for the alternative scenarios to compare to.



Some conclusions

- The feasibility of artificial recharge in the Loma aquifer has been proved from the point of view of the availability of resources, both from rivers Guadalimar and Guadalquivir. The mean annual water availability has been estimated as 13.84 hm3/yr for the simulation period 2000-2006 (8.47 hm3/yr from the Guadalimar and 5.37 hm3/yr from the Guadalquivir).

-This managed recharge would lead to recover piezometric levels in the most intensively exploited sectors of the aquifer, and would increase the available resources.

- The replacement of the river Guadalquivir's intake at Mogon by pumping wells in Sierra de Cazorla aquifer, in order to complement urban supply to the Loma community, would mean to improve quality of water supplied and to increase supply guarantees, and also more available surface water for agricultural use.

-The reuse rate of wastewater in the system has been estimated as 38,7%. This means the posibility of increasing treated wastewater reuse for farming, and so decreasing water pumping from the aquifer to recover groundwater levels.

- Finally, the developed decision support system has proved to be a useful tool to analyse diferent management scenarios and to help decision making in a complex hydrological system like Loma de Ubeda's.

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