INTERNATIONAL CONFERENCE
GROUNDWATER, KEY TO THE SUSTAINABLE DEVELOPMENT GOALS
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Numerical groundwater modelling SMART-CONTROL web-based tool applied on MAR system of Bas-Gapeau Alluvial Aquifer (Hyères les Palmiers, France)

SMARTControl

#350

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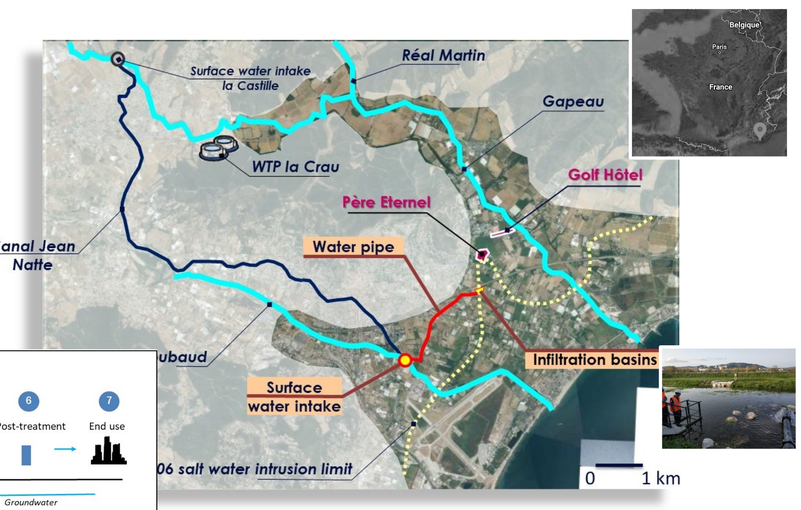
Context

Managed aquifer recharge (MAR) is a widely accepted technique to increase groundwater supply for drinking and mitigate salt water intrusion in coastal aquifers heavily pumped for several usages. This is the case of the Gapeau aquifer located close to Hyères city, South of France, were the full-scale Aquarenova scheme launched in the 2010s by SUEZ mitigates the salt water intrusion by an infiltration of Roubaud River water in the alluvial aquifer through basins and by a pumping strategy controlled by data measurements provided by a monitoring system.

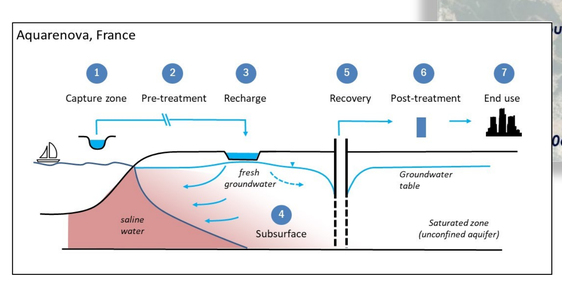
An efficient control of recharge and recovery processes through simulation-based optimization and control incorporating real-time data would allow water operators to optimize the performance of MAR systems.

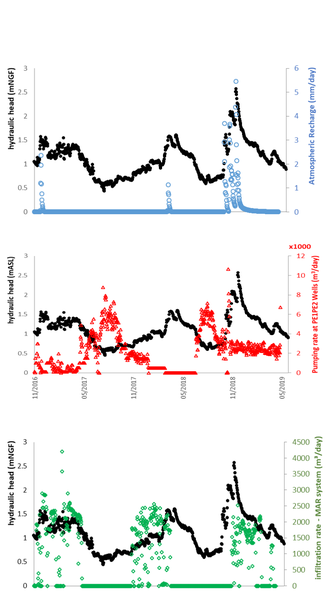
The SMART-Control approach encompasses research, piloting, demonstration, training and technology transfer in one framework. The core of this approach consists of the web-based INOWAS platform, where various analytical and numerical tools for MAR assessment are compiled.

INOWAS – Free web-based groundwater modeling platform



Site overview of the Aquarenova MAR project (SUEZ)



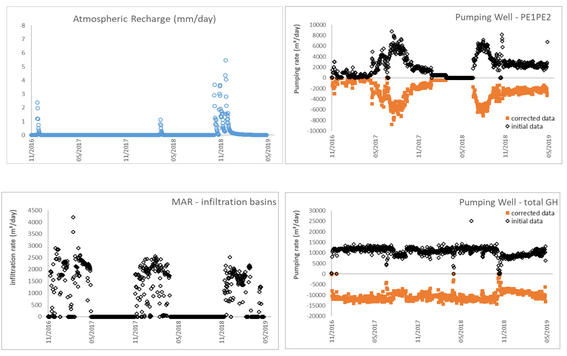


The approach will be tested at the full-scale Aquarenova scheme which ensures that the framework can be applied to improve integrated water resources management techniques.

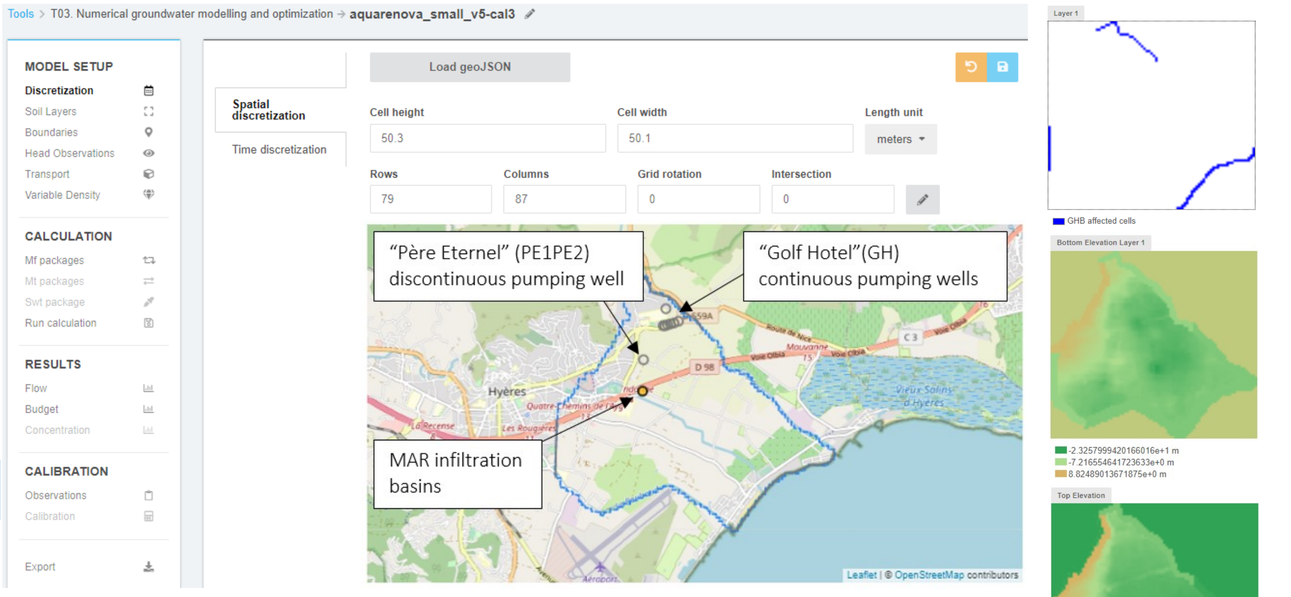
Smart-Control web-based tool T03 – Numerical Groundwater Modelling

The application of the Smart-Control web-based tool T03 – Numerical Groundwater Modelling and Optimization is provided for modelling Bas Gapeau alluvial aquifer and its groundwater management (the MAR solution and the pumping strategy).
A MODFLOW numerical model of the Gapeau aquifer is implemented on the platform for simulating groundwater flow in transient conditions and especially for assessing the impact of the infiltration through basins.

https://dss.smart-control.inowas.com/tools



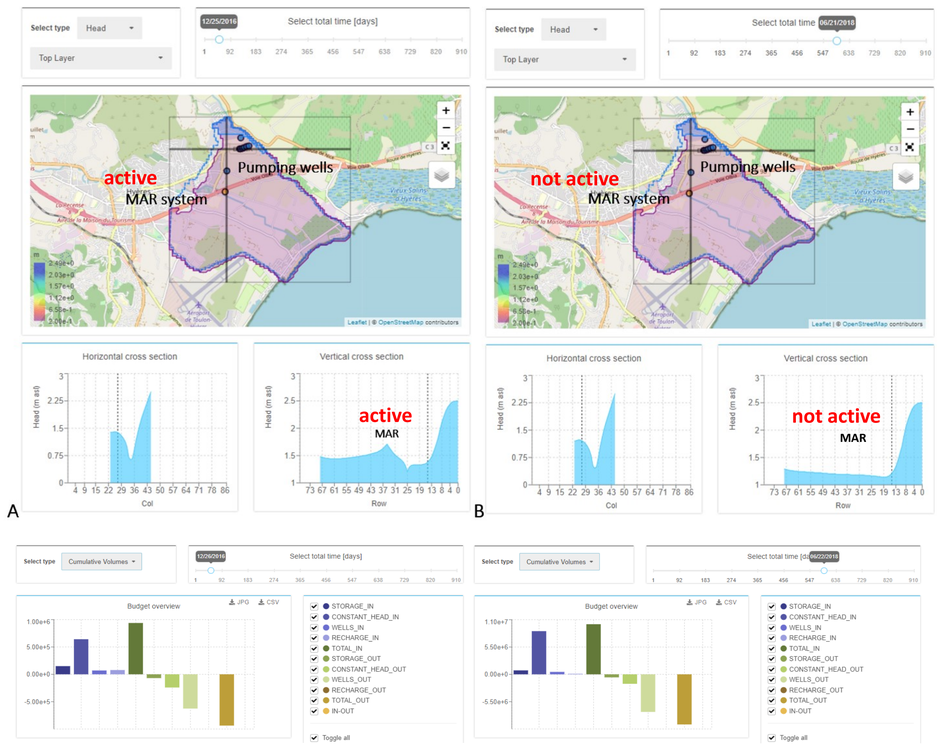
Time dependent boundary values for the 910 stress periods considered in the model



Spatial discretization edition of the alluvial aquifer layer, the top and bottom elevation of the alluvial aquifer layer and of the applied boundary conditions "constant head"

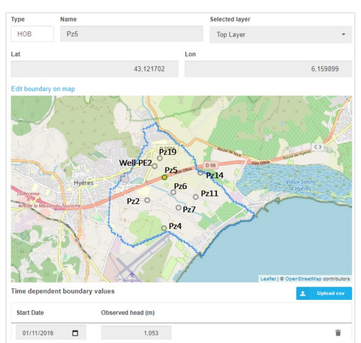
Calibration & results of the reference model results - 2.5 years

Groundwater levels are quite flat over the entire domain at elevations of about +1mASL, except close to the boundaries due to fixed « constant heads » conditions to the north and west around +2 to +2.5mASL and close to the pumping well areas where the groundwater elevation is simulated below +1mASL. The volumes of water inflow through the boundary conditions « Constant heads » imposed to the north and west dominate the flows due to pumping well effects correctly reproduced in this model.



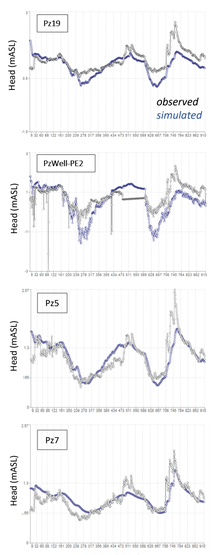
Hydraulic heads (mASL) & water budget (cumulative, m^3) calculated at A) 12/25/2016 (with MAR infiltration), and B) 06/21/2018 (without MAR infiltration)

The inflow trough the boundary conditions (~13000m^3.d-1) is higher than the outflow (~4000m^3.d-1) but these calculated volumes depend on the « Constant heads » fixed values and also on the permeability value selected for the calculation, all driven by pumping. As we do not have detailed information on these two quantities (flow from boundaries and permeability values), only the comparisons between the measured and simulated water levels can inform us if they are correctly evaluated.



9 observation wells

There are discrepancies especially for the piezometers located close to the boundaries and those located near the pumping areas (Pz19 and PzWell-PE2).



The volumes coming from the atmospheric recharge and the infiltrated volumes through the MAR system are low compared to the other terms of the water budget on the modelled period. They represent respectively 5.5% and 4.0% of the volume of inflow in the aquifer while the upstream regional flow represents 81.0% and the pumping volumes represent 73.0% of the total outflow. Finally, the proportion of volume discharged by natural flow (to the sea) is 20% in this model.
Even if the infiltration MAR system seems to be negligible in volumes, it is nevertheless visible locally on the simulated hydraulic head (sea cross section) and certainly also on the observed piezometry. On the latter, it is less obvious because it is often confounded with the increase in level due to winter recharge and the decrease of pumping rate at the PE1PE2 wells occurring at the same periods.

Calculate statistics

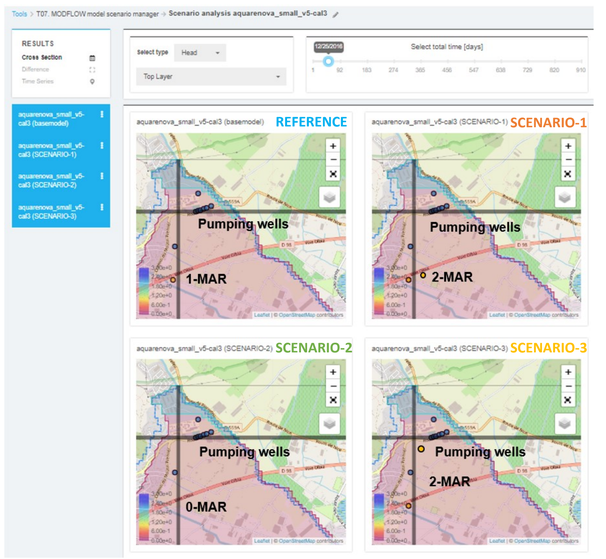
Name	Symbol	Value	Unit
Number of data points	n [-]	7304	-
Maximum Absolute Residual	R_{MAX}	4.263	m
Minimum Absolute Residual	R_{MIN}	0.000	m
Residual Mean	R_{MEAN}	-0.044	m
Absolute residual Mean	$\|R_{MEAN}\|$	-0.044	m
Standard error of estimation	SSE	0.004	-
Root Mean Squared Error	RMSE	0.327	m
Normalized Root Mean Squared Error	NRMSE	0.058	-
Correlation Coefficient Pearson R	R	0.666	-
Coefficient of determination	R^2	0.443	-

Smart-Control web-based tool T07 - Scenario analysis

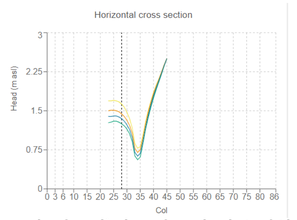
The numerical model developed on the web-platform constitutes at this stage a feasibility demonstration.
Apart the reference scenario, 3 scenarios have been simulated on a 2.5-year duration, based on several assumptions on MAR scheme numbers and location (all other conditions remaining equal):

- SCENARIO-1 : duplicated MAR syst. at the same location
- SCENARIO-2 : no MAR syst.
- SCENARIO-3 : duplicated MAR syst. upstream of the PE1PE2 pumping wells

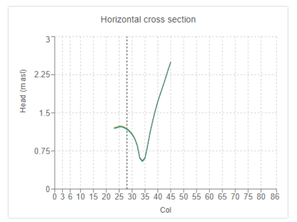
Modeling tool T07 – MODFLOW model scenario manager developed on the web-based SMART-Control platform is applied. Even considering a simplified version of the hydrosystem, it allows the identification of major processes but especially the simulation of the impact on groundwater of alternative groundwater management practices.



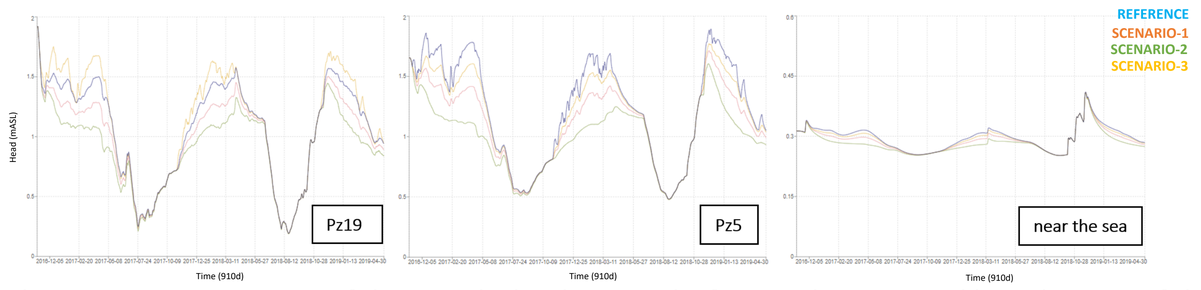
When system is active, the groundwater level increases with the action of the MAR system and the closer to the infiltration system, the greater the variation in the hydraulic head. It is of the order of several tens of centimetres near the basins and only a few centimetres near the sea.
When the system is inactive (06/21/2018), no significant difference is observed on the calculated hydraulic heads between the different simulations, which indicates that the effect of the MAR on groundwater level is not very inertial in this specific case due to the high permeability of the aquifer.
The results of the Scenario-2 (no MAR system) show that the infiltration MAR system is visible on the simulated hydraulic head and explain better the piezometry measured on the observation wells. Indeed, the scenario-2 with no MAR compared to the reference model with MAR system indicate that the increase is not only due to winter recharge and lower PE1PE2 pumping but also to the MAR system.



hydraulic heads calculated the 12/25/2016 (with MAR active)



hydraulic heads calculated the 06/21/2018 (with MAR inactive)



For the moment, no comparison of the water budget between the four simulation is possible at this stage of the platform's development, which does not allow us to identify the impact of the MAR system on the groundwater inflow and outflow through the boundary conditions fixed as « Constant head ».
These simulations do not however indicate anything about water quality and the beneficial effect of MAR systems on groundwater salinity. This model would have to be completed by a calculation of convection and dispersion of solutes (and possibly take into account the associated density phenomena). It is more probable that the effect of MAR on groundwater quality is much more inertial in this aspect.

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