Numerical Modelling Tools for Water Crisis Prediction and Management

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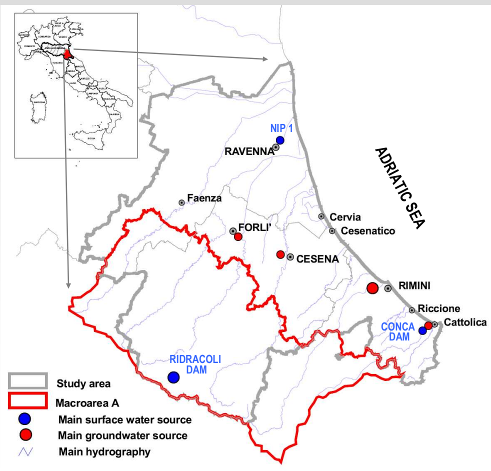
THE STUDY AREA

This work refers to the area of the three Provinces of Ravenna, Forlì-Cesena and Rimini, in the eastern part of Emilia-Romagna Region (North Italy).

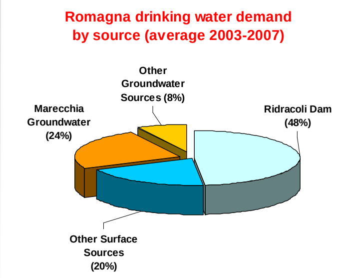
Here, in the last ten years several situations of water crisis (2003, 2007 and 2011) occurred due to prolonged drought periods.



LOCAL DRINKING WATER SOURCES

Local drinking water annual needs, corresponding to more than 100 million m^3, are satisfied by both surface water and groundwater.

The **main surface source** is Ridracoli dam (capacity of 33 million m^3), while the **major groundwater reservoir** is the alluvial fan of the Marecchia River (about 25 million m^3/year withdrawals) located near Rimini. Further sources are distributed on the territory of the three provinces.



AIM OF THE WORK

The amount of water available from all sources may be seriously affected by extended dry periods. Available data on local water consumptions show that in such situations, it is necessary to make a greater use of groundwater sources.

The evaluation of the groundwater quantitative state and of the sustainability of withdrawals become a strategic element in the water crisis management.

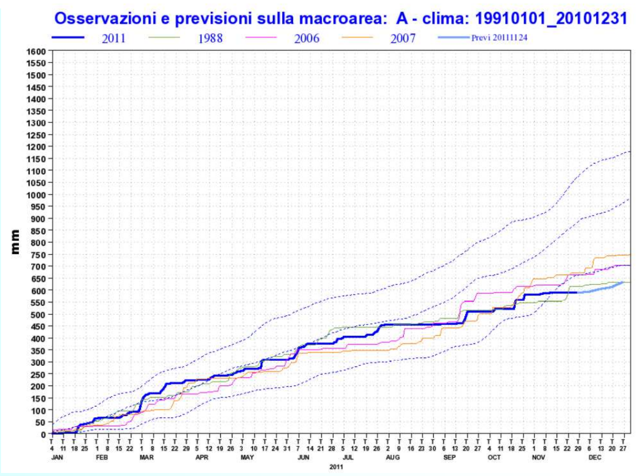
In this context, Arpa Emilia-Romagna has developed modeling tools and assessing procedures in order to predict and then to support the management of a possible water crisis. These tools are constantly made available to the decision makers that have to manage such ordinary and emergency situations.

LONG-RANGE PRECIPITATION FORECASTING

Specific tools for monitoring observed and forecasted aggregated precipitation over different areas of our region have been developed at ARPA-SIMC.

An example of one of these graphical tools is shown. It allows to quickly compare, for a given area, the current accumulated precipitation with climatology distribution or with previous years.

This example refers to the area average rainfall measured over the Romagna mountain region (macroarea A). Colored curves refer to past dry years and the blue one refers to 2011.



Evolution of the total rainfall accumulated from the beginning of each year.

Starting from the last observed value, the blue curve is prolonged with a forecast (cyan curve) resulting from the calibration of the ensemble mean total precipitation from the monthly forecast system of the European Center for Medium-range Weather Forecast (ECMWF, 2012), available twice per week. Dashed lines represent the climatology of the total accumulated rainfall taken as a reference. Upper line is 95° percentile, middle line is the 50° percentile, b ottom line is the 5° percentile of the climatology observed over that area between 1991-2010.

DAM INFLOW PREDICTION

Weeks	Forecast/ Prediction		Climatology values	
	A [mm]	VOL [Mm^3]	A [mm]	VOL [Mm^3]
28/11/11_04/12/11	3	0.1 – 0.3	19	1.9
05/12/11_11/12/11	10	0.2 – 0.5	12	1.4
12/12/11_18/12/11	9	0.2 – 0.6	12	1.4
19/12/11_25/12/11	20	0.4 – 0.9	24	2.2
monthly values	**42**	**0.9 – 2.3**	**67**	**6.8**

Forecasted precipitation and predicted volumes of water inflow into the Ridracoli dam. The examlpe refers to the last very dry autumn (2011) with extremely dry soil and limited run-off compared with climatological values (right columns) based on 1991-2010 climatologies.

The next step of the evaluation tool is the quantitative estimation of the inflow predicted into the Ridracoli dam, given the precipitation forecast 1 month ahead.

The precipitation estimate, resulting from the ensemble mean calculations, is then converted in dam inflow using a monthly statistical regression based on the last 10 years of observed precipitation over the basin and inflow measured at the dam, in order to compute seasonal dependent run-off coefficients. The inflow interval for each week is empirically obtained applying two different run-off coefficient.

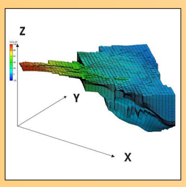
The first one usually corresponds to the current month, while the second one corresponds to the previous month, accounting for uncertainty in the estimate of the water saturation of the ground.

Finally, the predicted monthly inflow volumes are decremented by the monthly expected consumption in order to estimate the future level of the water in the dam.

MARECCHIA ALLUVIAL FAN GROUNDWATER FLOW MODEL

The groundwater quantitative state of Marecchia alluvial fan is monitored through a groundwater flow model that is constantly updated (recharge and withdrawals) and verified on the basis of piezometric level measurements available from a dedicated network.

Groundwater Flow Model

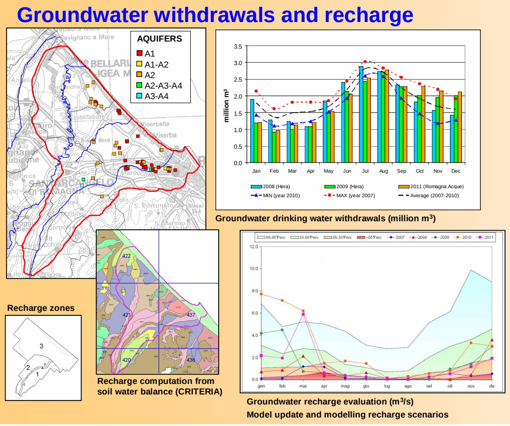


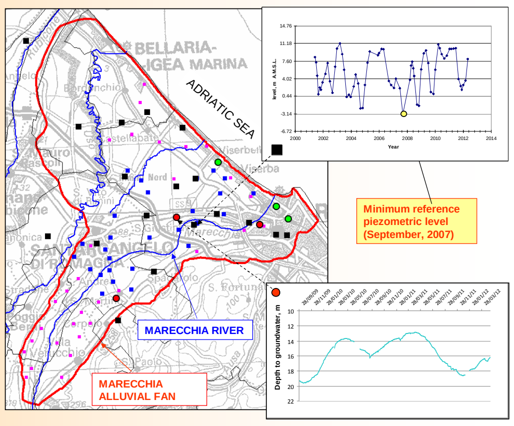
- Modflow 3D groundwater flow model
- Model extensioin: 140 km^2
- Spatial discretization: 48.000 cells / 50 layers
- Transient flow simulation (monthly SP)
- Two-Monthly average time basis model update. Last update: April 2012

Dedicated Monitoring Network

Levels Monitoring Network	Number of wells/piezometers (Annual measurements)
ARPA Regional Monitoring Network	15, manual (2), 3 continuous
Local Monitoring Network (Rimini Administration)	36, manual (6) 36, manual (2)
SGSS monitoring piezometers	3, continuous

Groundwater withdrawals and recharge





GROUNDWATER QUANTITATIVE STATE EVALUATION AND MODELLING SCENARIOS

All evaluations are carried out through model water budget calculations. Variations on storage volumes of water resource within the system are computed and cumulated starting from the reference critical point set equal to the minimum of the piezometric levels of 2007. In this way, a measure of distance from that critical situation is provided.

Six modeling comparative scenarios

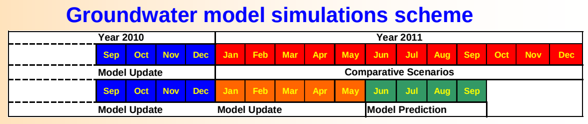
COLORED BANDS: Six model simulation runs are performed combining four different natural recharging possibilities (main percentiles based on historical data) with three levels of system exploitation. Colored bands from orange to blue are associated to a poor or good evolution of groundwater quantitative state.

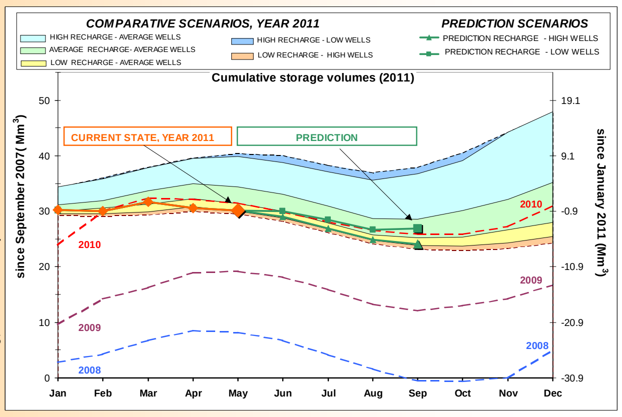
Model update and prediction

ORANGE LINE: the graph allows to evaluate the current state of groundwater availability resulting from the last model update.

GREEN LINES: forward simulation runs allow to predict groundwater quantitative state after 2-4 months, depending on seasonal forecast simulations and on expected drinking water needs for the same period. At the same time, comparison with past year curves (colored lines) could be done.

Groundwater model simulations scheme





CONCLUSIONS

- This work shows how different parts of the hydrologic cycle can be analyzed as a whole resulting in a multi-step operating decision support tool.
- Both monitoring data collection and numerical modelling application can be used for the description of the current state and the temporal evolution of water resource and its availability.
- In the effort to optimize the water resources, with a balanced use of underground water and surface reservoir, we developed forecasting tools based on long-range forecasting products.
- Through a statistical calibration the ECMWF monthly forecast direct model output of precipitation is converted in volume inflow in the Ridracoli dam to estimate the potential recharge a month ahead.
- Also groundwater flow modeling can be part of this multi-step operating support tool in which groundwater quantitative state and groundwater resource availability over time could be evaluated and compared to proper reference levels.
- This methodology could be of great help for decision makers to face water emergency management and prevention.

Acknowledgment

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