HYDRONOMEAS: A WATER RESOURCES PLANNING AND MANAGEMENT SOFTWARE SYSTEM

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What is HYDRONOMEAS?

HYDRONOMEAS is an operational tool for the management of **complex water resource systems**. It is suitable to a wide range of hydrosystems, incorporating numerous physical, operational, administrative and environmental aspects of integrated river basin management. The mathematical framework follows the **parameterisation-simulation-optimisation** scheme; simulation is applied to faithfully represent the system operation, expressed in the form of **parametric rules**, whereas optimisation is applied to derive the **optimal management policy**, which simultaneously minimises the risk and cost in decision-making.

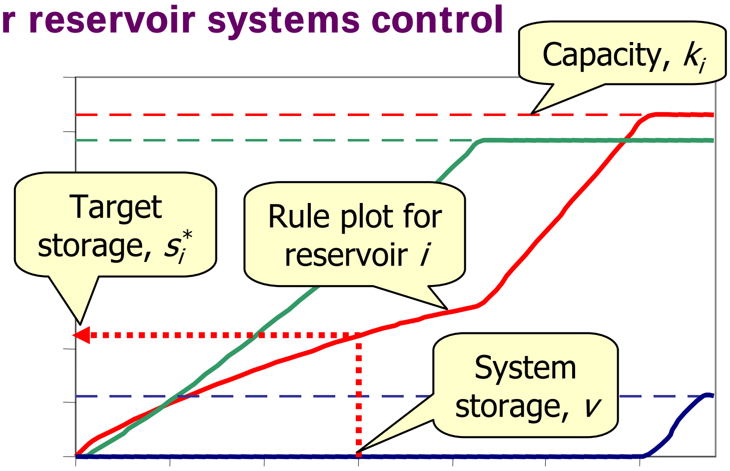
Main modelling issues

- Employing **stochastic simulation** to handle the inherent **uncertainty** of future inflows and evaluate the system performance in **reliability** terms.
- Establishing a **low-dimensional approach** (by means of parametric operation rules), thus enabling an effective and efficient coupling of stochastic simulation within a water resource system optimisation framework.
- Handling all physical and operational constraints though a **network linear optimisation model**, ensuring a faithful representation of system operation and drastically reducing the computational effort of the simulation procedure.

Parametric rules for reservoir systems control

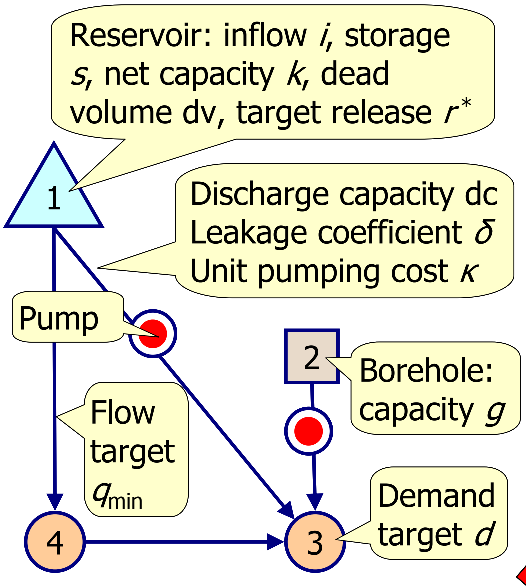
The rules, using two parameters per reservoir *i*, specify the corresponding target storage s_i^* as a function of:

- the actual system storage *v*
- the total system capacity *k*
- the capacity of the specific reservoir k_i (physical constraint)
- the desirable storage fluctuation limits s_i^{min} and s_i^{max} (operational constraint, user defined)



The parametric rules, introduced by *Nalbantis & Koutsoyiannis* (1997), have been generalised for the optimal control of both surface and groundwater resources.

Simulation through a network optimisation model



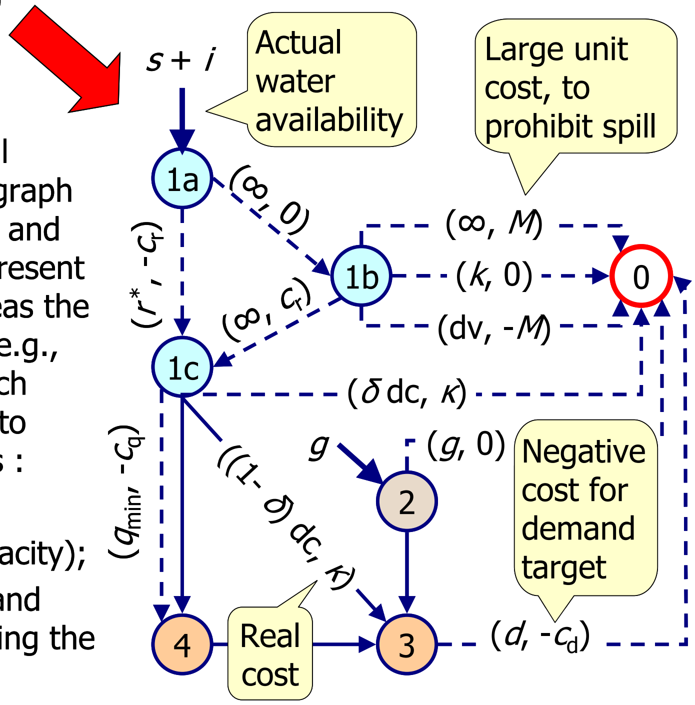
Actual hydrosystem

Assuming that inflows are projected through stochastic simulation, the target releases, as specified by the operation rules, may differ from the real ones, due to at least one of the following reasons:

- insufficient discharge capacity of the downstream aqueduct network;
- existence of alternative flow paths, with different costs (e.g., due to pumping);
- existence of multiple and contradictory water uses and operational constraints;
- insufficient inflows to fulfil demands or insufficient capacity to store flood runoff.

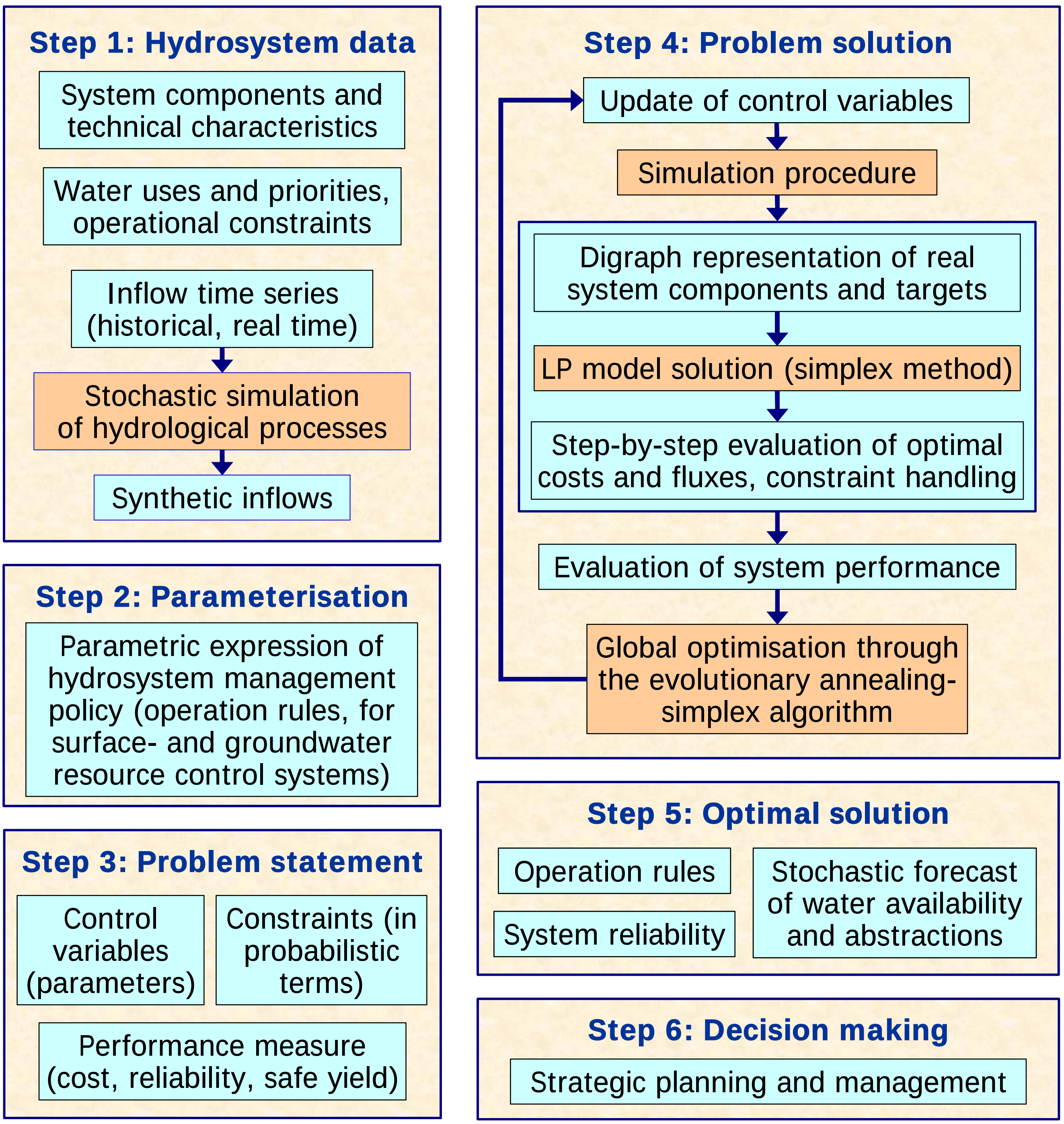
To evaluate the optimal fluxes, real components are transformed to digraph components, and virtual capacities and costs are assigned; the former represent target abstractions or flows, whereas the latter penalise undesirable fluxes (e.g., spill) and preserve priorities. At each time step a LP problem is formed, to achieve the following requirements :

1. strict satisfaction of all physical constraints (storage & flow capacity);
2. satisfaction of demand targets and operational constraints, preserving the user-defined priorities;
3. minimisation of departures between actual and target abstractions;
4. minimisation of transportation costs.



Digraph model representation; dotted lines represent virtual arcs, with capacity and unit cost in parenthesis.

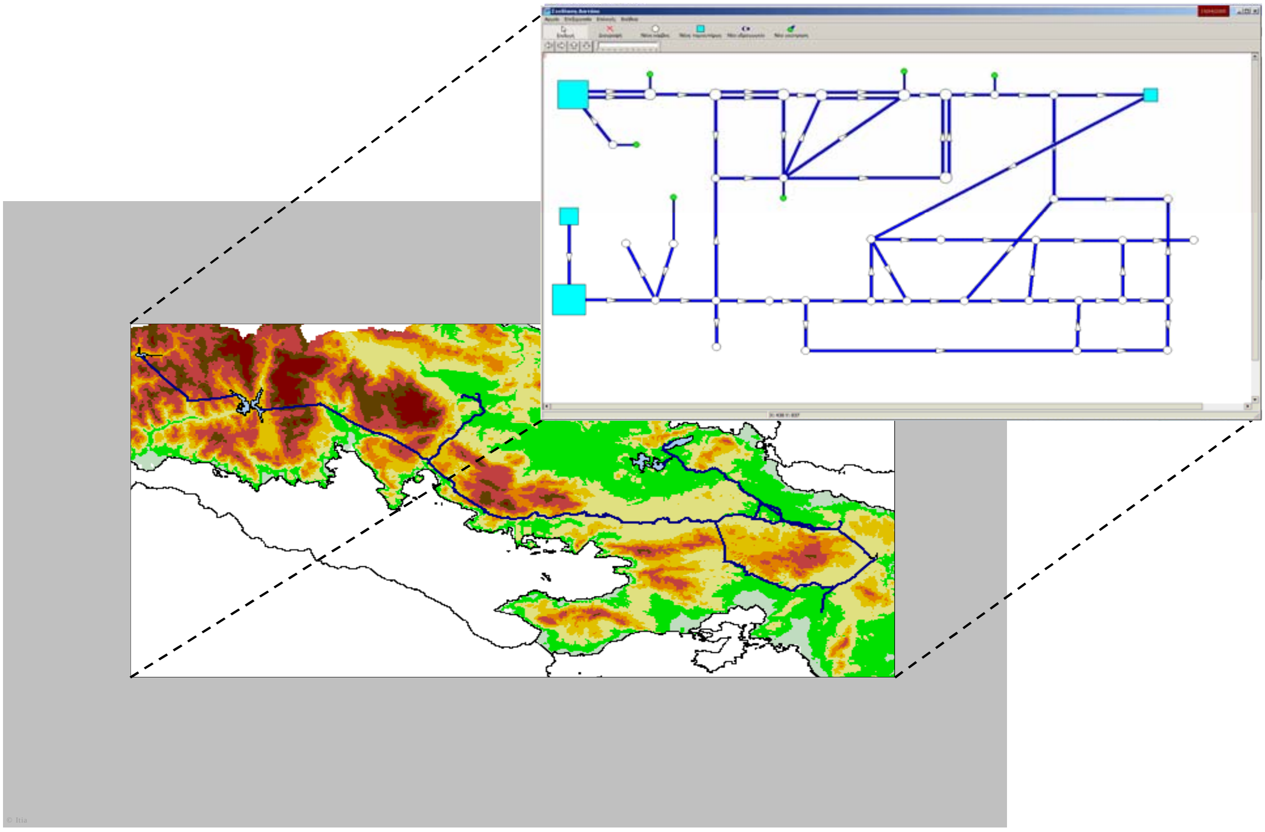
The parameterisation – simulation – optimisation methodological framework



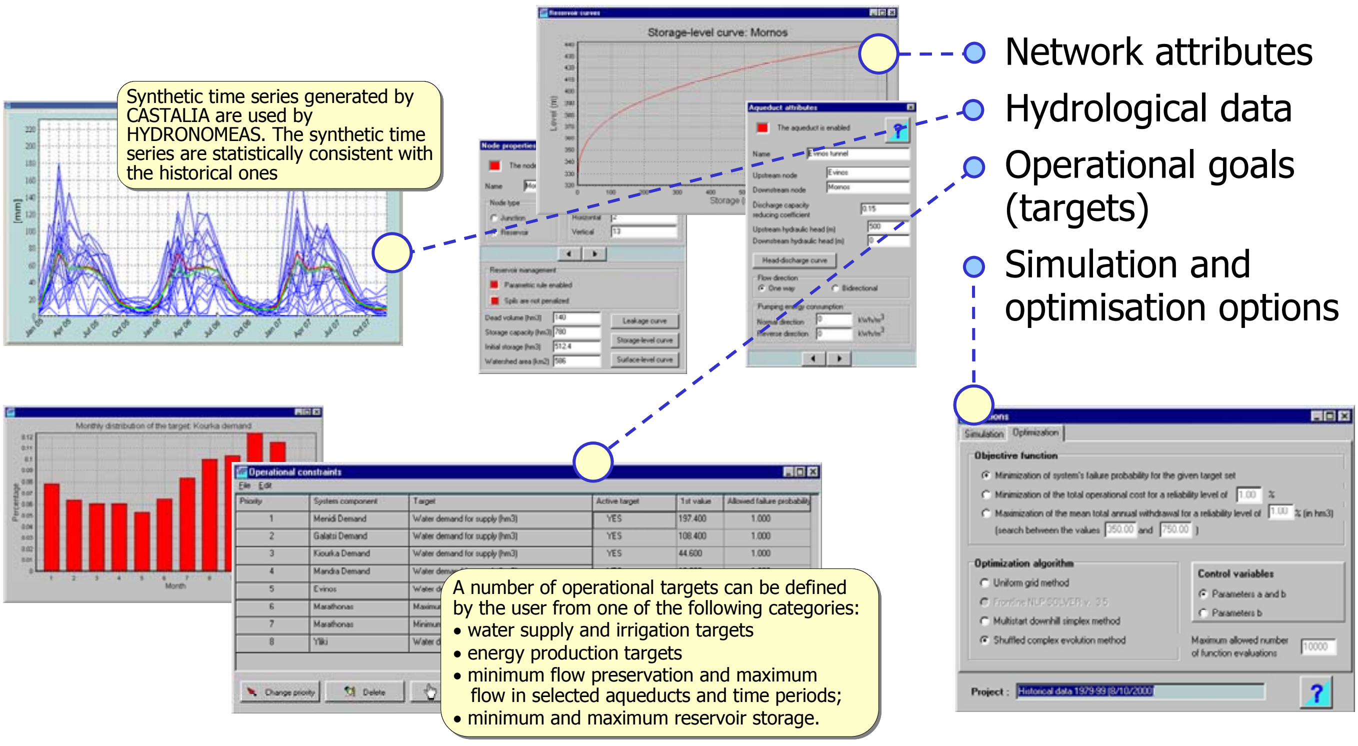
HYDRONOMEAS gives answers to questions such as:

- What is the **maximum total withdrawal** from the hydrosystem, for a given hydrologic regime and a given reliability level?
- What is the **minimum failure probability** in achieving a given set of operational goals, for a given hydrologic regime?
- What is the **minimum cost** to achieve a given set of operational goals, for a given hydrologic regime and a given reliability level?
- What is the **maximum benefit** from energy production?
- Which will be the **water availability** for a short-term time horizon?
- What are the impacts of different **management policies** or **hydroclimatic scenarios**?
- How could the system respond to **special occasions** such as channel damages or an intense increase of water demand for a specific period?
- What are the consequences of specific **modifications** in the hydrosystem (e.g., construction of new projects)?

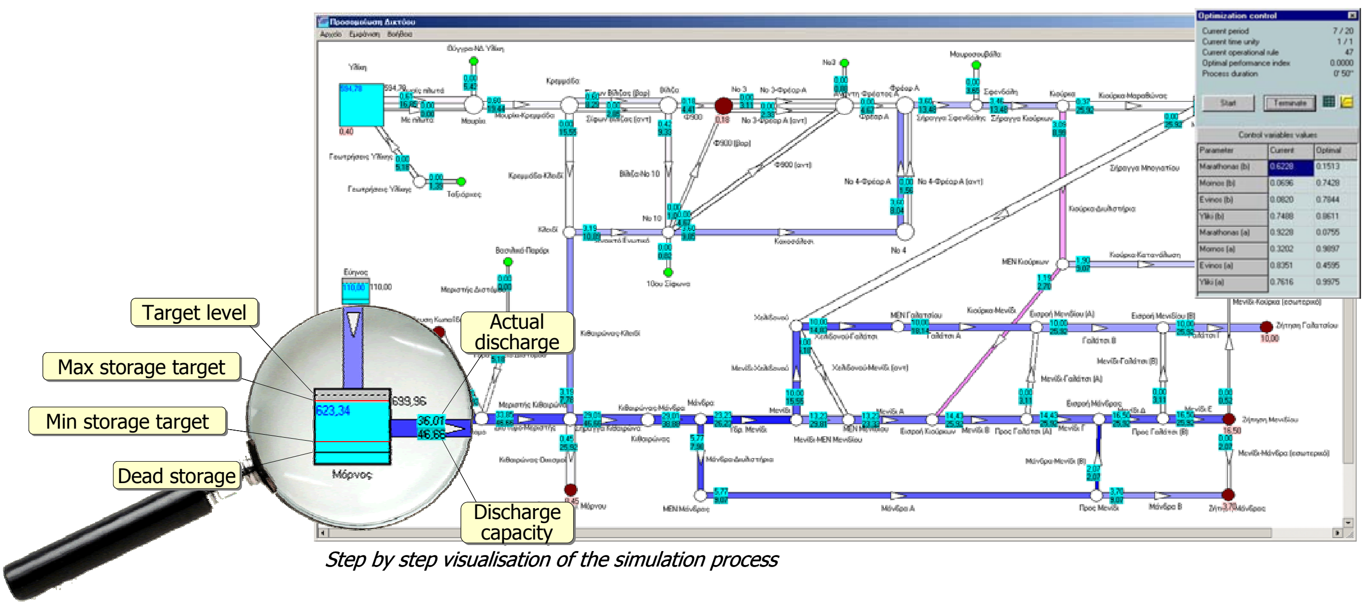
Schematisation



Scenario data

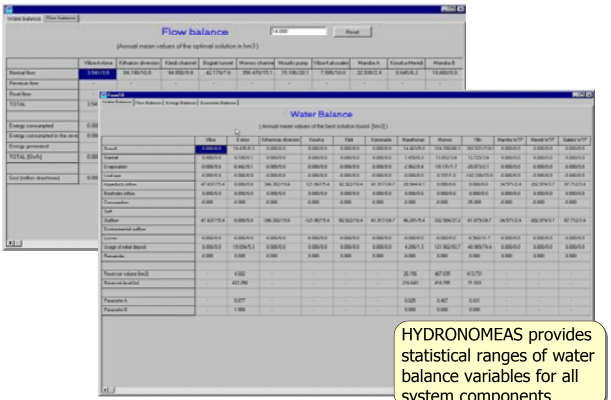


Simulation



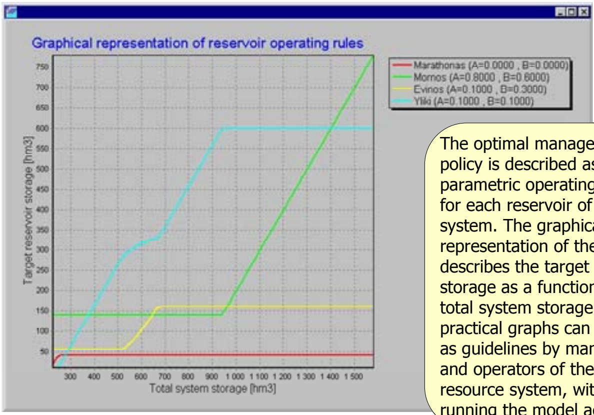
Step by step visualisation of the simulation process

Results



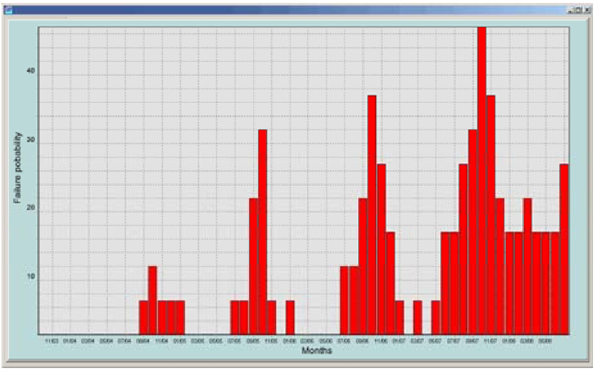
HYDRONOMEAS provides statistical ranges of water balance variables for all system components

Analytical water, flow and energy balance



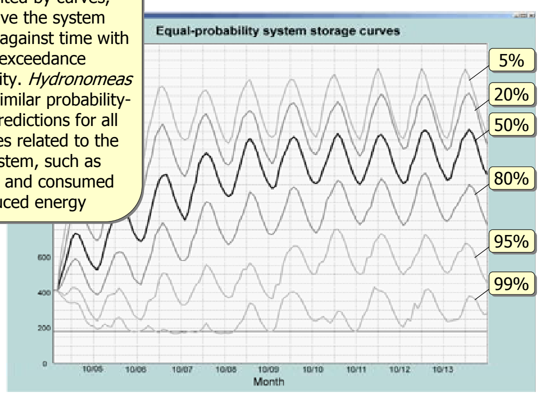
The optimal management policy is described as parametric operating rules for each reservoir of the system. The graphical representation of these rules, describes the target reservoir storage as a function of the total system storage. These practical graphs can be used as guidelines by managers and operators of the water resource system, without running the model again.

Reservoir operating rules (after optimisation)



Distribution of the failure probability for given targets

The prediction is represented by curves, which give the system storage against time with a given exceedance probability. *Hydronomeas* makes similar probability-based predictions for all quantities related to the hydrosystem, such as releases and consumed or produced energy



Surface water resources storage predictions

Documentation and references

1. Efstratiadis, A., D. Koutsoyiannis, and D. Xenos, Minimising water cost in the water resource management of Athens, *Urban Water Journal*, 1(1), 3-15, 2004.
2. Efstratiadis, A., and D. Koutsoyiannis, An evolutionary annealing-simplex algorithm for global optimisation of water resource systems, *Proceedings of the Fifth International Conference on Hydroinformatics*, Cardiff, UK, 1423-1428, International Water Association, 2002.
3. Koutsoyiannis, D., A. Efstratiadis, and G. Karavokiros, A decision support tool for the management of multi-reservoir systems, *Journal of the American Water Resources Association*, 38(4), 945-958, 2002.
4. Koutsoyiannis, D., and A. Economou, Evaluation of the parameterization-simulation-optimization approach for the control of reservoir systems, *Water Resources Research*, 39(6), 1170, 1-17, 2003.
5. Koutsoyiannis, D., G. Karavokiros, A. Efstratiadis, N. Mamassis, A. Koukouvinos, and A. Christofides, A decision support system for the management of the water resource system of Athens, *Physics and Chemistry of the Earth*, 28(14-15), 599-609, 2003.
6. Nalbantis, I., and D. Koutsoyiannis, A parametric rule for planning and management of multiple reservoir systems, *Water Resources Research*, 33(9), 2165-2177, 1997.

HYDRONOMEAS is developed within the project "*ODYSSEUS: Integrated Management of Hydrosystems in Conjunction with an Advanced Information System*".

Project web page: http://www.odysseusproject.gr/

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