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Accounting for water management issues within hydrological simulation: Alternative modelling options and a network optimization approach

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In mixed natural and artificialized river basins, many complexities arise due to anthropogenic interventions in the hydrological cycle, including abstractions from surface water bodies, groundwater pumping or recharge and water returns through drainage systems. Typical engineering approaches adopt a multi-stage modelling procedure, with the aim to handle the complexity of process interactions and the lack of measured abstractions. In such context, the entire hydrosystem is separated into natural and artificial sub-systems or components; the natural ones are modelled individually, and their predictions (i.e. hydrological fluxes) are transferred to the artificial components as inputs to a water management scheme. To account for the interactions between the various components, an iterative procedure is essential, whereby the outputs of the artificial sub-systems (i.e. abstractions) become inputs to the natural ones. However, this strategy suffers from multiple shortcomings, since it presupposes that pure natural sub-systems can be located and that sufficient information is available for each sub-system modelled, including suitable, i.e. "unmodified", data for calibrating the hydrological component. In addition, implementing such strategy is ineffective when the entire scheme runs in stochastic simulation mode.

To cope with the above drawbacks, we developed a generalized modelling framework, following a network optimization approach. This originates from the graph theory, which has been successfully implemented within some advanced computer packages for water resource systems analysis. The user formulates a unified system which is comprised of the hydrographical network and the typical components of a water management network (aqueducts, pumps, junctions, demand nodes etc.). Input data for the later include hydraulic properties, constraints, targets, priorities and operation costs. The real-world system is described through a conceptual graph, whose dummy properties are the conveyance capacity and the unit cost of each link. Unit costs are either real or artificial, and positive or negative. Positive costs are set to prohibit undesirable fluxes and negative ones to force fulfilling water demands for various uses. The assignment of costs is based on a recursive algorithm that implements the physical constraints and the user-specified hierarchy for the water uses. Referring to the desired management policy, an optimal allocation is achieved regarding the unknown fluxes within the hydrosystem (flows, abstractions, water losses) by minimizing the total transportation cost through the graph. The mathematical structure of the problem enables use of accurate and exceptionally fast solvers. The proposed methodology is effective, efficient and easy to implement, in order to link on-line multiple modelling components, thus ensuring a comprehensive overview of the process interactions in complex and heavily modified hydrosystems. It is applicable to hydrological simulators of the semi-distributed type, in which it allows integrating groundwater models and flood routing schemes within decision support modules. The methodology is implemented within the HYGROGEIOS computer package, which is illustrated by example applications in modified river basins in Greece.