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A Many-Objective Optimization of Supply and Demand Management Options for the Thames Basin

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In this study we link a water resource management simulator and a many-objective evolutionary optimization algorithm to reveal the trade-offs mapped out by the set of Pareto-optimal water supply portfolios. The approach is applied to a case-study involving the water stressed Thames basin in South East England which includes the city of London. Such a many-objective approach could be used by regulators and stakeholders to supplement current water resource system planning which uses single-objective least-cost optimization. We consider both infrastructure additions and demand management options to produce possible water system portfolios that satisfy the future demand trajectory and meet regulatory performance constraints. Possible infrastructure options explored in the case study include a new reservoir, water transfers, conjunctive use of groundwater, wastewater reuse and brackish groundwater desalination. Demand management options include leakage reduction, the introduction of seasonal tariffs with compulsory metering and efficiency improvements. System performance is evaluated using quantitative performance measures that minimize costs and energy use while maximizing engineering and environmental performance, subject to supply reliability constraints set by the local water utility and the Environment Agency regulator. We use many-objective visual analytics to explore the Pareto approximate trade-off surfaces that show the tradeoffs between engineering, cost, social and environmental performance measures and interactively interrogate the impact of the infrastructure portfolios on the performance measures. Using trusted realistic simulators embedded into global optimzers enables the consideration of non-linear and rule-based physical and management processes that are integral to accurately describing real water systems. The Thames basin is modeled using a generalized computationally efficient open-source water resource simulator, the Interactive River-Aquifer Simulation-2010 (IRAS-2010). The IRAS-2010 Thames system model is linked via a C++ wrapper to the Epsilon Dominance Nondominated Sorted Genetic Algorithm-II (ε-NSGAII). Results suggest that considering multiple objectives explicitly in the planning problem can eliminate potential decision bias that occurs with lower dimensional optimization. We discuss how this multi-criteria approach that maps out the trade-offs implied by the best plans could be integrated into water supply planning practices in England and Wales and beyond.