

Reliable Urban Water Supply to Intermittent Supply Grid and No-Service Areas by Considering IUWM Principles

by

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ABSTRACT

Future climatic and non-climatic uncertainties are expected to exacerbate issues in the unreliable water supply areas of developing countries. Globally, researchers have advocated an Integrated Urban Water Management (IUWM) approach to managing urban water in the face of escalating water-related challenges. The present research aimed to analyze and optimize the potential of the IUWM approach in providing a reliable urban water supply to regions with intermittent supply and no-service, tested for Bengaluru, India, as a case study. A simulation model named 'Integrated Urban Water Balance Model' (IUWBM) was developed using Source Version 5.10.0.1184, tailored to the site specifics. Reliability of five system configurations developed (by mapping diversified supply sources, i.e., river water, groundwater, harvested stormwater, rooftop rainwater, and recycled wastewater to meet potable and non-potable demand) was studied for Bengaluru. Results show an improvement in average volumetric and time reliability of supply from less than 50% to ~100%. Acknowledging the future uncertainties, the system configurations' robustness (i.e., consistently good performance across future scenarios) is also explored, using robustness metrics representing a spectrum of optimistic to pessimistic risk aversion attitudes of decision makers. Results indicate that incorporating recycled wastewater leads to the most robust integrated urban water system configurations across all scenarios and under a range of risk aversion attitudes. To identify the optimal mix of the water supply options yielding the least total cost and energy consumption, the IUWBM is integrated with the optimization tool Insight Version 5.10.0.11841, utilizing the NSGA-II algorithm for a robust optimal water mix. Three robustness metrics—Laplace's Principle of Insufficient Reasons, Hurwicz Optimistic-Pessimistic Rule, and Signal-to-Noise Ratio—are incorporated into a multi-scenario and objective optimization problem to make the optimal solutions more robust. The cheap robust optimal water mix solutions were those that relied on existing infrastructure (thus minimal capital cost for new infrastructure) but were found to have high energy consumption due to long-distance pumping. Under best future scenario, a narrow range of trade-offs between cost and energy exists, while under worse scenario, the compromise between two objectives is high while choosing a single robust optimal water mix solution. A robust optimal water mix solution with equal preference to both minimum cost and energy objectives contains at least 34% harvested stormwater and 35% recycled wastewater for potable and non-potable water uses, respectively. Overall, the study presented an optimal approach for integrating alternate water sources to achieve robust and reliable water supply services, even under diverse future climatic scenarios.

Keywords: Integrated Urban Water Management, Reliability, Robustness, Future Uncertainties, Urban Water Supply