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Vulnerability-based evaluation of water supply design under climate change

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Long-lived water supply infrastructures are strategic investments in the developing world, serving the purpose of balancing water deficits compounded by both population growth and socio-economic development. Robust infrastructure design under climate change is compelling, and often addressed by focusing on the outcomes of climate model projections ('scenario-led' planning), or by identifying design options that are less vulnerable to a wide range of plausible futures ('vulnerability-based' planning). Decision-Scaling framework combines these two approaches by first applying a climate stress test on the system to explore vulnerabilities across many traces of the future, and then employing climate projections to inform the decision-making process. In this work, we develop decision scaling's nascent risk management concepts further, directing actions on vulnerabilities identified during the climate stress test. In the process, we present a new way to inform climate vulnerability space using climate projections, and demonstrate the use of multiple decision criteria to guide to a final design recommendation. The concepts are demonstrated for a water supply project in the Mombasa Province of Kenya, planned to provide domestic and irrigation supply. Six storage design capacities (from 40 to 140 million cubic meters) are explored through a stress test, under a large number climate traces representing both natural climate variability and plausible climate changes. Design outcomes are simulated over a 40-year planning period with a coupled hydrologic-water resources systems model and using standard reservoir operation rules. Resulting performance is expressed in terms of water supply reliability and economic efficiency. Ensemble climate projections are used for assigning conditional likelihoods to the climate traces using a statistical distance measure. The final design recommendations are presented and discussed for the decision criteria of expected regret, satisficing, and conditional value-at-risk (CVaR).