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## Operations Eclipse Sequencing in Multipurpose Dam Planning

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A resurgence of dam planning and construction is under way in several river basins where untapped hydropower potential could meet growing energy demands. In Africa, more than 300 new hydropower projects are under consideration. Yet, hydropower expansion is a contentious issue given the uncertainty in water and energy demand as well as the negative impacts of these infrastructures on other sectors. Despite calls for a more comprehensive evaluation of hydropower projects, most dams continue to be planned with traditional methods that neglect interdependencies between planning and management and the cumulative impacts of multiple new dams. Here, we use the transboundary Zambezi Watercourse in southern Africa to present a novel dam planning approach that integrates sequencing of planned reservoirs with adaptive, multipurpose operations to address increasing and competing demands for water, energy, and food in the region.

Results show how seeking compromise through operations while constructing dams early improves environmental and irrigation objectives by 50% and 80%, with an 8% loss in hydropower compared to an operation and sequencing strategy that singularly maximizes hydropower. Alternatively, seeking compromise only through delayed dam construction yields modest environmental and irrigation improvements of 6% and 9%, respectively, with a 22% loss in hydropower. Our findings indicate that while additional hydropower capacity reduces structural energy deficits, operating policies emerge as the main driver of human-environmental tradeoffs. Consequently, traditional single-objective operating policy selection may lead to erroneous perceptions of tradeoffs across infrastructure options. The robustness of this result is tested under an ensemble of stochastic hydrologic projections where environmental flow and irrigation deficits are found more sensitive to operations than shifts in water availability. The predominance of operating policies is relevant for improving multi-objective dam planning in other river basins already fragmented by dams built in the 20th century.