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Socio-hydrologic Modeling to Understand and Mediate the Competition for Water between Humans and Ecosystems: Murrumbidgee River Basin, Australia

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Around the world the demand for water resources is growing in order to satisfy rapidly increasing human populations, leading to competition for water between humans and ecosystems. An entirely new and comprehensive quantitative framework is needed to establish a holistic understanding of that competition, thereby enabling development and evaluation of effective mediation strategies. We present a case study centered on the Murrumbidgee river basin in eastern Australia that illustrates the dynamics of the balance between water extraction and use for food production and efforts to mitigate and reverse consequent degradation of the riparian environment. Interactions between patterns of water resources management and climate driven hydrological variability within the prevailing socio-economic environment have contributed to the emergence of new whole system dynamics over the last 100 years. In particular, data analysis reveals a pendulum swing between an exclusive focus on agricultural development and food production in the initial stages of water resources development and its attendant socio-economic benefits, followed by the gradual realization of the adverse environmental impacts, efforts to mitigate these with the use of remedial measures, and ultimately concerted efforts and externally imposed solutions to restore environmental health and ecosystem services. A quasi-distributed coupled socio-hydrologic system model that explicitly includes the two-way coupling between human and hydrological systems, including evolution of human values/norms relating to water and the environment, is able to mimic broad features of this pendulum swing. The model consists of coupled nonlinear differential equations that include four state variables describing the co-evolution of storage capacity, irrigated area, human population, and ecosystem health, which are all connected by feedback mechanisms. The model is used to generate insights into the dominant controls of the trajectory of co-evolution of the coupled human-water system, to serve as the theoretical framework for more detailed analysis of the system, and to generate organizing principles that may be transferable to other systems in different climatic and socio-economic settings.